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Articles

Determinants of financial self-sufficiency of Mexican water utilities

Determinantes de la autosuficiencia financiera de los organismos operadores de agua mexicanos

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Abstract

This article aims to explore the variables that impact the financial self-sufficiency of water utilities in Mexico. A panel database is built with the public information available from 31 agencies in big cities, which serve a third of the country's urban population during the years 2017 to 2019, referring to financial self-sufficiency, domestic, commercial and industrial tariffs, cross-subsidy level, physical efficiency, commercial efficiency, collection efficiency, global efficiency and a dichotomous variable that is activated when the utility is from a state in southeastern Mexico. It is found that there is a significant positive relationship between self-sufficiency and the variables domestic tariff, physical efficiency, commercial efficiency and global efficiency. Likewise, a strong significant negative relationship is found between self-sufficiency and that the organization belongs to a state in the Mexican southeast. It is concluded that the public financial information of the organizations is very limited, that an adequate tariff, as well as efficiency in management, increases financial self-sufficiency; and that the southeastern states, where there is a lot of water, decrease incentives to improve the efficiency of water utilities.

Keywords: Tariff, urban water, physical efficiency, commercial efficiency, global efficiency, water utilities

Resumen

El objetivo de este artículo es explorar las variables que impactan en la autosuficiencia financiera de los organismos operadores de agua en México. Para lo anterior, se construye una base de datos de panel con la información pública disponible de 31 organismos de grandes ciudades que atienden a una tercera parte de la población urbana del país durante los años 2017 a 2019 referente a autosuficiencia financiera, tarifa doméstica, comercial e industrial, nivel de subsidio cruzado, eficiencia física, eficiencia comercial, eficiencia de cobro, eficiencia global y una variable dicotómica que se activa cuando el organismo es de un estado del sureste mexicano. Se encuentra que hay una relación significativa positiva entre la autosuficiencia, y las variables tarifa doméstica, eficiencia física, eficiencia comercial y eficiencia global. Asimismo, hay una fuerte relación significativa negativa entre la autosuficiencia y que el organismo pertenezca a un estado en el sureste mexicano. Se concluye que la información financiera pública de los organismos es muy limitada y que una adecuada tarifa, así como la eficiencia en la gestión, incrementan la autosuficiencia financiera; asimismo, los estados del sureste, donde hay mucha agua, carecen de incentivos para mejorar la eficiencia de los organismos operadores de agua.

Palabras clave: tarifa, agua para uso urbano, eficiencia física, eficiencia comercial, eficiencia global, organismos operadores de agua

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Introduction

Given the growing urbanization processes in cities, as well as the problems of water scarcity that exist in some population centers, it is essential to study the entities in charge of managing the resource in cities. In the case of Mexico, these entities are commonly called water operating agencies (*Organismos Operadores de Agua* or OOAs, in Spanish). Derived from the reform to article 115 of the Constitution in 1983, the municipality is the body empowered to manage water. However, since some municipalities lack economic or institutional capacities, the state can take over this important task. Likewise, there are some cities in which the drinking water service is administered, at least in some functions, by private companies. Due to the above, in Mexico there are municipal and state operating organizations with private participation in the administration. The vast majority of these are decentralized municipal public bodies.

The performance of water utilities, henceforth OOAs, has traditionally been studied with Data Envelopment Analysis (DEA) methodology, in which inputs and outputs allow observation of which agencies achieve greater efficiency. However, there is a lack of studies that analyze the financial performance of water utilities, which is also very important because it allows them to cover their operating expenses and to meet the infrastructure needs to provide water to citizens.

The objective of this article is to explore the factors that are associated with the adequate financial management of water utilities (measured through financial self-sufficiency), as well as their impact.

In the following sections, a review of the literature is carried out on the factors that impact the performance of water utility agencies and a management evaluation approach based on financial self-sufficiency is proposed. The construction of a database is explained and different econometric models are analyzed. Finally, conclusions regarding the main factors that influence the financial self-sufficiency of the OOAs in Mexico are given.

Studies on the performance of water utilities (OOAs)

In this section, a review of the literature is carried out on the main studies that address the performance of OOAs at the international level; these agencies are called *water utilities* in the English language. For the above, a search was carried out in the "title of the article" field of the search engine of the *Scopus*. Search keywords included "water utilities", with the possibility of additionally using the word "performance", "non revenue water", "unaccounted for water, "efficiency", "UFW" or "unaccounted-for water"; with the limitation of only articles and *journals*. Papers with these specific terms in the title, abstract, or keywords were considered to meet the study requirements. In addition, it covered the period from 2017 to 2022. The complete search code is shown in Table 1.

Table 1. Search syntax on the performance of water utilities (OOAs).

Database	Syntax	Results
Scopus	TITLE ("water utilities " AND ("performance" OR "non revenue water" OR "Unaccounted for Water" OR "efficiency" OR "UFW" OR "Unaccounted-for Water")) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) AND (LIMIT-TO (DOCTYPE, "ar ")) AND (LIMIT-TO (SRCTYPE, "j"))	32

Source: *Scopus*.

For all the articles found in this search, the method and main findings were analyzed. The most used methodology to analyze the performance of water utilities is Data Envelopment Analysis or DEA (Cetrulo, Ferreira, Marques, & Malheiros, 2020; Gidion *et al*., 2019b; Güngör-Demirci, Lee, & Keck, 2017; Ngobeni & Breitenbach, 2021; Robles-Velasco, Rodríguez-Palero, Muñuzuri, & Onieva, 2022; Romano, Molinos-Senante, & Guerrini, 2017; Romano, Salvati, & Guerrini, 2018); with stochastic frontier analysis or SFA, as a complement to DEA (Molinos-

Senante, Maziotis, & Sala-Garrido, 2021). Some authors draw attention to the limitations of DEA and SFA; and the importance of characterizing the context of the OOAs sector (Estruch-Juan, Cabrera, Molinos-Senante, & Maziotis, 2020), as well as presenting a more holistic vision (Akimov & Simshauser, 2020). Cetrulo *et al*. (2020) mention that in DEA, the investment to achieve universal coverage may penalize efficiency results, though this is something positive for the agency. Due to the above, it may not be the best tool to measure the performance of OOAs.

To a lesser extent, other methods are used, such as non-parametric stochastic data envelopment or StoNED (Molinos-Senante *et al*., 2021); network DEA, which seeks to make comparative analyzes between organizations from different segments ((Gidion, Hong, Adams, & Khoveyni, 2019a); two-stage DEA ((Güngör-Demirci, Lee, & Keck, 2018a); double *bootstrap* DEA, in order to characterize groups according to contextual variables ((Nithammer, Mahabir, & Dikgang, 2022; Salazar-Adams, 2021); *bootstrap* combined with a truncated regression, also with the purpose of including context variables (Ablanedo-Rosas, Campanur, Olivares-Benitez, Sánchez-García, & Nuñez-Ríos, 2020); panel data regression analysis ((Angeles-Castro, Arriola-Barcenas, & Baeza-Almaraz, 2018; Güngör-Demirci, Lee, Keck, Guzzetta, & Yang, 2018b; Li, 2018); multiple regressions and artificial neural networks (Nafi & Brans, 2018); and panel data with dynamic factors (Zirogiannis & Tripodis, 2018).

Some articles propose different methodologies to assess agencies. Tskhai (2020) proposes evaluating OOAs according to a matrix that combines external and internal resources against external and internal results, concluding that it is important to consider the characteristics of the region where the agency is located. D'Inverno, Carosi and Romano (2021) point out the importance of generating more global performance indicators that integrate financial, economic, environmental, and service quality aspects in order to evaluate the agency from a broader vision. Berg (2020) emphasizes the relevance of generating accurate, reliable, and relevant information that allows building key performance indicators (*KPIs*) to measure management and improve it in the long term. Pinto, Costa, Figueira and Marques (2017) deem it pertinent to define indicators to determine service quality categories.

There are also other types of studies that address different important aspects to consider in agencies. For example, underlining the importance of OOAs fulfilling their mandate to supply water to all citizens, including those with limited resources (Kemendi & Tutusaus, 2018). Guerrini, Molinos-Senante and Romano (2018) point out the need to generate incentives to save costs and improve productivity, as well as improve investment in agencies. Kayaga, Kingdom and Jalakam (2018) talk about the importance of having an organizational design that clarifies the roles and responsibilities of the actors within the agency to achieve better performance. Da Silveira and Mata-Lima (2021), as well as Walker, Williams and Styles (2020) underline the need to improve efficiency in the use of energy in providing water service in the OOAs. Tskhai (2022) suggests that agency performance can be measured through external (consumer characteristics) and internal (company characteristics) indicators. And Santos, Cardoso and Galvão (2022) recommend that water systems have a performance assessment framework to detect vulnerabilities to flooding to anticipate investments in rehabilitation.

Regarding the main findings of the aforementioned studies, the variables that positively influence the performance of OOAs, in general, are ratio of connections with measurement over those without measurement ((Nithammer *et al*., 2022), agency size ((D'Inverno *et al*., 2021; Ngobeni & Breitenbach, 2021), agencies with several functions or multiple agencies ((D'Inverno *et al*., 2021), private agencies (Li, 2018; Salazar-Adams, 2021), cutting off service for users who are behind in payments (Salazar-Adams, 2021), the number of connections per unit volume of water lost (Ablanedo-Rosas *et al*., 2020), billing, collection and profitability (Angeles-Castro *et al*., 2018)), network length and operating revenue (Güngör-Demirci *et al*., 2018b), number of directors, and directors with political connections (Romano *et al*., 2018), and public companies when quality is excluded, but companies with private participation when the quality of the service is considered (Romano *et al*., 2017).

Regarding the variables that negatively impact performance, water leaks stand out (Güngör-Demirci *et al*., 2018b; Molinos-Senante *et al*., 2021), non-graduate board members or medium-sized companies (Romano *et al*., 2018), and the number of connections as well as precipitation (Güngör-Demirci *et al*., 2017).

Studies have been carried out in various countries around the world such as Spain (Robles-Velasco *et al*., 2022); South Africa (Ngobeni & Breitenbach, 2021; Nithammer *et al*., 2022); Italy (D'Inverno *et al*., 2021; Guerrini *et al*., 2018; Romano *et al*., 2018); Mexico (Ablanedo-Rosas *et al*., 2020; Angeles-Castro *et al*., 2018; Salazar-Adams, 2021); Brazil (Cetrulo *et al*., 2020); Russia (Tskhai, 2020); Tanzania (Gidion *et* *al*., 2019b); China (Li, 2018), and the United States (California) (Güngör-Demirci *et al*., 2017; Güngör-Demirci et al., 2018a; Güngör-Demirci *et al*., 2018b).

Since the present study concerns OOAs in Mexico, it is considered relevant to return to the findings of the most important studies in recent years. Angeles-Castro *et al*. (2018) carry out a data panel analysis of 368 OOAs during the period 2010 to 2014, to explain the total efficiency (volume of water billed divided by that produced), finding that small companies are more efficient, and that billing, collection and profitability are very relevant factors to improve efficiency. Ablanedo-Rosas *et al*. (2020) carry out a two-stage method combining Bootstrap DEA and a truncated regression analysis, generating evidence that the number of connections per unit of volume lost has a significant positive impact on the operational efficiency of OOAs in Mexico. Salazar-Adams (2021) through a double Bootstrap DEA, and with information from 359 agencies, suggests that the few existing private OOAs are more efficient than the public ones. He also points out that cutting off water service in the event of non-payment has a positive relationship with efficiency (Salazar-Adams, 2021).

As previously seen, research focused on the performance of OOAs both in Mexico and in the world centers on calculating technical efficiency through the different types of DEA, and to a lesser extent on seeking contextual explanations that may have a positive or negative relationship with said efficiency. In recent years, it appears that the only Mexican research focused on studying the total or global efficiency (volume of water billed divided by volume produced), instead of calculating the technical efficiency generated by DEA is that by Angeles-Castro *et al*. (2018).

The present study focuses on the financial performance of the operating agency. Specifically, it seeks to calculate the factors that are associated with its financial self-sufficiency based on variables such as tariffs, and physical, commercial, and global efficiencies. No studies similar to the one proposed were detected, which is limited by the little information published by the OOAs in Mexico, considering that there may be an effect of the different macro and micro measurement coverage that gives rise to part of the published data.

Previous studies such as that of Briseño and Sánchez (2018) indicate that municipalities were assigned a responsibility to manage water for urban use, but they have needed to develop the resources and institutional capacities necessary for this. It is very important that they have adequate metering, billing, and collection to have healthy finances to face operating costs and infrastructure needs. Briseño (2018) mentions that the water rate must be determined with technical criteria and be accompanied with efficiency in the operation of the agency, since it is useless to increase revenue if it is not used properly. It is important to note that when the population perceives that the authority performs well, there is a greater willingness to pay for the service (Briseño & Macedo, 2021).

The following section describes the construction of a database on OOAs in Mexico with information on financial self-sufficiency, tariffs, and efficiencies, with the purpose of analyzing, through econometric models, the factors that impact the agency's having a better revenue/expense ratio.

Database and methodology

In order to find the main variables that impact financial self-sufficiency of OOAs in Mexico, a database is carried out with the information available from agencies in different cities during the years 2017, 2018 and 2019. The criterion to define what the observations would be was that the agency in question had at least information on its domestic tariff, since it is a fundamental variable to explain the revenue, and an indicator of financial self-sufficiency. Specifically, the domestic, industrial, and commercial rates were obtained from the website of the National Water Information System (SINA) of the National Water Commission (CONAGUA). With the rates, an indicator is proposed that we call cross-subsidy level (CSL), which is the average of the commercial and industrial rates divided by the domestic rate. Cross-subsidizing, in essence, is charging a significantly higher tariff to commercial and industrial users in order to subsidize domestic users by charging them a lower tariff. The number of OOAs from which the information was obtained is 31, which serve a quarter of the country's total population and a third of the urban population according to the National Urban System (SUN).

The financial self-sufficiency variable (variable to be explained or dependent) was obtained from the "Information system to encourage water collection-payment", an initiative of the Gonzalo Río Arronte Foundation in conjunction with the Mexican Institute of Water Technology (IMTA). This initiative seeks to encourage best practices in water management among the OOAs and irrigation districts. From this same system, other variables were obtained that are extremely relevant to evaluate the correct administration of the OOAs, such as: physical efficiency, commercial efficiency, collection efficiency and global efficiency. Physical efficiency is a percentage obtained by dividing billed water by produced water (both in cubic meters); commercial efficiency is the division of the paid water by billed water (measured in cubic meters); the collection efficiency is the percentage of water paid over billed water (measured in pesos); and global efficiency is the paid water divided between the water produced (in cubic meters), or the product of physical efficiency and commercial efficiency ((Río Arronte & IMTA, 2021).

To measure the impact of areas with high water availability, a dichotomous variable was constructed that takes the value of one when the agency belongs to a state in the southeast of the country and zero otherwise. The underlying idea with this variable is that the areas of the Mexican southeast have fewer incentives to be efficient in water management, since they do not have the problem of scarcity of this resource to the extent found in states in the center and north of the country. Table 2 shows the variables, their source, their description, and their descriptive statistics.

Table 2. Variables, source, and descriptive statistics.

Variable	Description	Source	Obs.	Mean	Median	Standard deviation	Minimum	Maximum
FINS (%)	Revenue from the sale of water between discharges reported by the OOA	Río Arronte and IMTA (2021)	90	65.17	67.19	29.69	5.33	175.1
DRATE	Tariff for a domestic consumption of 30 m^3 per month	National Water Information System (SINA) of the National Water Commission (Conagua) (2022)	147	16.36	14.92	8.85	1.02	68.33
CRATE	Rate for commercial consumption of 30 m3 per month		148	29.42	25.56	16.50	3.95	76.58
IRATE	Rate for an industrial consumption of 30 m^3 per month		142	33.51	29.20	18.99	4.62	97.36
CSL	Division of the commercial and industrial rate average by the domestic rate	Authors with data from (Conagua) (2022)	142	2.16	1.81	1.28	0.86	8.68
PHYSICAL (%)	Volume invoiced by volume produced in cubic meters	Río Arronte and IMTA (2021)	96	56.88	56.71	13.05	25.14	84.44
COMMERCIAL (%)	Volume collected by volume invoiced in cubic meters. Also called efficiency in volumetric collection		81	75.60	78.03	17.56	34.21	114.5
COLLECTION (%)	Revenue from the sale of water divided by expected revenue of billed water		93	78.10	81.54	17.06	35.81	114.5
GLOBAL (%)	Volume collected divided by volume produced in cubic meters		82	44.22	150.6	114.5	114.5	76.78
SOUTHEAST	Organization in the states of Yucatán, Quintana Roo, Campeche, Tabasco, Chiapas, Veracruz or Oaxaca = 1; In another case = 0	Map of the Mexican Republic	159	0.17	0.00	0.38	0	1

To observe the degree of association between the variables, a correlation matrix is carried out, which is seen in Table 3. We can observe that the variables that have the highest correlation with financial self-sufficiency are collection efficiency (0.63), commercial efficiency (0.47) and global efficiency (0.47). Regarding the relationships between the possible explanatory variables of financial self-sufficiency, it is observed that the highest degrees of association are found between the different types of tariffs, and between the pairs of variables physical efficiency and global efficiency (0.76), commercial efficiency and collection efficiency (0.63), and commercial efficiency with global efficiency (0.78).

Table 3. Correlation matrix.

	FINS	DRATE	CRATE	IRATE	CSL	PHYSICAL	COMMERCIAL	COLLECTION	GLOBAL
FINS	1								
DRATE	0.31	1							
CRATE	0.23	0.63	1						
IRATE	0.13	0.59	0.88	1					
CSL	-0.22	-0.33	0.28	0.36	1				
PHYSICAL	0.19	-0.09	0.16	0.21	0.36	1			
COMMERCIAL	0.47	0.08	0.17	0.23	-0.01	0.23	1		
COLLECTION	0.63	0.14	0.21	0.22	0.00	0.15	0.63	1	
GLOBAL	0.47	-0.00	0.25	0.29	0.25	0.76	0.78	0.48	1

With the previously mentioned and analyzed database, various panel econometric models are carried out intending to identify the variables that best explain the financial self-sufficiency of the OOAs. The following section describes the different models, as well as their respective validation tests.

Models and results

Given the nature of the information in the database in which there are measurement units (OOAs) and time units (years 2017, 2018 and 2019), panel data regressions are carried out. It was found that, to comply with the correct specification validation test, the dependent variable had to be at level and most of the explanatory variables, except for some cases, at logarithm. The models with the best fit, as well as their validation tests, are shown in Table 4. It is important to note that the panel models are of the *Pooled* type. Fixed and random effects are not reported because the variables showed coefficients contrary to those expected in most cases.

Table 4. Panel regression models to explain financial self-sufficiency (FINS).

Concept	(Model 1)	(Model 2*)	(Model 3*)	(Model 4)
	FINS	FINS	FINS	FINS
Constant	−28.7576 (0.1876)	−41.1077 (0.2049)	−187.894 (0.0045)	−113.467 (0.0075)
DRATE			0.768049 (0.0302)	
l_DRATE	8.31395 (0.0118)			
l_CRATE		8.33014 (0.0642)		
l_CSL		−10.8304 (0.0096)		
l_PHYSICAL			27.7403 (0.0359)	27.4261 (0.0027)
l_COMMERCIAL			28.9707 (0.0836)	15.7876 (0.0475)
l_GLOBAL	18.7594 (0.0003)	22.8665 (0.0015)		
SOUTHEAST	−23.2960 (0.0100)	−20.9793 (0.0152)		−36.5681 (0.0000)
Observations / Utilities	74/31	72/31	74/30	78/30
R^2	0.49	0.50	0.35	0.46
R^2 adjust	0.47	0.47	0.33	0.43
P value normality test	0.31	0.15	0.14	0.10
P value Ramsey Reset test	0.58	0.77	0.29	0.80
P value White test	0.06	0.04	0.04	0.09
VIF DRATE			1.019	
VIF l_DRATE	1.427			
VIF l_CRATE		1.504		
VIF l_CSL		1.163		
VIF l_PHYSICAL			1.046	1.054
VIF l_COMMERCIAL			1.052	1.108
VIF l_GLOBAL	1.082	1.153		
VIF SOUTHEAST	1.524	1.565		1.079

Notes: *p*-value in parentheses.

*Robust standard deviations to correct for heteroscedasticity.

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In model 1, the variables domestic tariff (DRATE) and global efficiency (GLOBAL) were used as explanatory variables for financial self-sufficiency (FINS) in logarithmic functional form, as well as the dichotomous variable SOUTHEAST. In this model, the observation of Ensenada for the year 2018 was eliminated since it was considered atypical data for having a residue greater than 2.5 deviations around the mean. In this model, the variable l_GLOBAL is positive at one percent and the variable l_DRATE at five percent. Likewise, the SOUTHEAST variable is significantly negative at five percent. The R^2 of 0.49 indicates that 49 % of the variability in the dependent variable financial self-sufficiency (FINS) is explained by changes in the independent variables used in the model. Since the variance inflation factors (VIF) are less than 10 and the correlation between the variables involved in the model are less than 0.5, it is assumed that there is no multicollinearity. The model has normality in errors, correct specification, and homoscedasticity.

Regarding model 2, the commercial tariff (CRATE), the cross-subsidy level (CSL) and global efficiency (GLOBAL) are used as explanatory variables, all in logarithmic functional form. In addition, the dichotomous variable SOUTHEAST is introduced. It is significantly positive at one percent l_GLOBAL, and at ten percent l_CRATE. On the other hand, SOUTHEAST is significantly negative at five percent and l_CSL at one percent. The goodness of fit measured through R^2 is 0.50. It is assumed that there is no multicollinearity since the variance inflation factors (VIF) are less than 10 and the correlations between pairs of variables included in the model are less than 0.5. The model has normality in errors and correct specification. Since it does not comply with homoscedasticity, robust standard deviations were used.

Model 3 includes the domestic tariff (DRATE) without logarithm as explanatory variables; and PHYSICAL and COMMERCIAL efficiency in logarithmic functional form. The DRATE and l_PHYSICAL variables are significantly positive at five percent; and l_COMMERCIAL at ten percent. The coefficient R^2 is 0.35. It is assumed that there is no multicollinearity since the VIFs are less than 10 and the correlation between pairs of variables is less than 0.5. The model complies with normality and correct specification. Robust standard deviations were used in the presence of heteroscedasticity.

In model 4, the PHYSICAL and COMMERCIAL variables are used with logarithmic functional form. The SOUTHEAST dichotomous variable is also added. The variable l_PHYSICAL is significantly positive at one percent and l_COMMERCIAL at five percent. SOUTHEAST is negatively significant at one percent. The coefficient R^2 is 0.46. It is assumed that there is no multicollinearity because the VIFs are less than 10 and the correlation between pairs of variables is less than 0.5. The model complies with normality, correct specification, and homoscedasticity.

Table 5 shows the correlation matrix of the transformed variables as they were used in the regression models. As previously noted, there is not a high correlation (greater than 0.5) between the variables used in each of the models.

Table 5. Correlation matrix of the variables used in the model.

	FINS	DRATE	l_DRATE	l_CRATE	l_CSL	l_PHYSICAL	l_COMMERCIAL	l_GLOBAL
FINS	1							
DRATE	0.31	1						
l_DRATE	0.42	0.88	1					
l_CRATE	0.33	0.67	0.77	1				
l_CSL	-0.27	-0.34	-0.40	0.24	1			
l_PHYSICAL	0.22	-0.06	-0.13	0.04	0.31	1		
l_COMMERCIAL	0.46	0.10	0.23	0.23	0.01	0.21	1	
l_GLOBAL	0.46	0.04	0.08	0.21	0.21	0.73	0.81	1

Regarding the interpretation of the coefficients, it is important to pay attention to the functional form in which the dependent variable and each of the independent variables are found. In this order of ideas, and to facilitate the understanding of the results, some conversions were made so that the coefficients can be interpreted as elasticities. The type of model according to the functional form, the coefficients, the elasticity and its interpretation are observed in Table 6. It should be noted that increases or decreases in the explanatory variables are bounded, so it is important to consider the maximum and minimum values indicated in the descriptive statistics.

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Table 6. Interpretation of the results (FINS explanatory variables).

Variables X's	Functional form	Coefficients β's	Elasticity	Interpretation
DRATE	Level – level	0.768049	$\beta\left(\frac{X}{Y}\right)^{*}=0.768\left(\frac{17.62}{62.50}\right)=0.2165$	In terms of a level – level model, an increase of one peso in the domestic rate increases financial self-sufficiency by 0.77 percent. In terms of elasticity, a one percent increase in the domestic rate increases financial self-sufficiency between 0.14 and 0.22 percent
l_DRATE	Level – log	8.31395	$\beta\left(\frac{1}{Y}\right)^{*}=8.314\left(\frac{1}{61.50}\right)=0.1352$	
l_CRATE	Level – log	8.33014	$\beta\left(\frac{1}{Y}\right)^{*}=8.330\left(\frac{1}{62.29}\right)=0.1337$	A one percent increase in the commercial tariff increases financial self-sufficiency by 0.13 percent
l_CSL	Level – log	−10.8304	$\beta\left(\frac{1}{Y}\right)^{*}=-10.83\left(\frac{1}{62.29}\right)=-0.1739$	A one percent increase in the level of cross-subsidy decreases financial self-sufficiency by 0.17 percent
l_PHYSICAL	Level – log	27.4261 to 27.7403	$\beta\left(\frac{1}{Y}\right)^{*}=27.43\left(\frac{1}{61.97}\right)$ to $27.74\left(\frac{1}{62.50}\right)$	A one percent increase in physical efficiency increases financial self-sufficiency by 0.44 percent
l_COMMERCIAL	Level – log	15.7876 to 28.9707	$\beta\left(\frac{1}{Y}\right)^{*}=15.79\left(\frac{1}{61.97}\right)$ to $28.97\left(\frac{1}{62.50}\right)$	A one percent increase in commercial efficiency increases financial self-sufficiency between 0.25 and 0.46 percent
l_GLOBAL	Level – log	18.7594 to 22.8665	$\beta\left(\frac{1}{Y}\right)^{*}=18.76\left(\frac{1}{61.50}\right)$ to $22.87\left(\frac{1}{62.29}\right)$	A one percent increase in global efficiency increases financial self-sufficiency by between 0.31 and 0.37 percent
SOUTHEAST	Level – D	−20.9793 to −36.5681	Not applicable	When the organization belongs to a state in the Mexican southeast, financial self-sufficiency decreases between 21 and 37 percentage units

*According to Gujarati and Porter (2010) elasticities can be measured using averages of *X* and *Y*.

Source: authors based on Gujarati and Porter (2010).

As previously indicated, and given what is shown in Table 6, it can be seen that increases in tariffs (domestic and commercial) and in efficiencies (physical, commercial and global) generate increases in financial self-sufficiency, and vice versa. Conversely, increases in the cross-subsidy decrease financial self-sufficiency. Likewise, belonging to a state in the southeast also causes the FINS variable to decrease.

Regarding Table 6, it is important to consider that the changes in the dependent variable correspond to changes around the average values of the explanatory variables. Considering changes in the explanatory variables that would cause them to stray far from the point of average values can lead to erroneous predictions of changes in the dependent variable.

In order to exemplify the practical utility of the exposed models, the average values of the descriptive statistics were substituted in the model 3 equation, yielding a financial self-sufficiency of 62.08 percent, very close to the 65.17 percent observed. The following section offers some conclusions on the findings of this research.

Conclusions

This article carries out a review of the literature on the factors that affect the performance of OOAs. A gap is found in the literature on the exploration of the determinants of financial performance in OOAs and a study on water management for urban use in Mexico is proposed from the point of view of financial self-sufficiency.

An econometric model is carried out in which the dependent variable is financial self-sufficiency (revenue divided by expenses), and the explanatory variables with a positive sign are the tariff (domestic and/or commercial) and efficiency (physical, commercial and/or global). On the other hand, the independent variables with a negative relationship with financial self-sufficiency are the level of cross-subsidy and being located in the Mexican southeast.

It should be noted that there are other variables that can impact financial self-sufficiency of the OOAs, which are not included in the models but are susceptible to reflection. Examples of these are clandestine tapping, political decisions when setting the tariff, and protection of the vulnerable population.

Regarding tariffs, it is important that they be sufficient to cover the cost of the service and rehabilitate the distribution networks, as well as to improve the existing infrastructure. Rates must be technically determined and not based on political criteria. An adequate rate scheme, in addition to improving the finances of the organization, discourages water consumption. Therefore, it is highly recommended to create councils independent of the OOA that can make decisions on the rate structure with technical reasoning, leaving aside strictly political incentives. It should be noted that at all times it is very important to protect the economically vulnerable population.

It is very common in Mexico for commercial and industrial rates to be significantly higher than domestic rates. This phenomenon is called cross-subsidy. In the present study, an indicator called the cross-subsidy level was obtained, which is the division of the average of the industrial and commercial tariffs by the domestic tariff. The relationship with financial self-sufficiency was negative. This indicates that having very high commercial and industrial rates compared to the domestic rate can be counterproductive. On the one hand, it can generate a financial dependence on fewer users (commercial and industrial) and, on the other hand, encourage irresponsible water consumption in domestic users by not valuing the service, thus increasing production costs.

This study shows evidence that efficiency in the organization, measured as a percentage of billing over production (physical efficiency), as volume paid divided by volume invoicing (commercial efficiency) and as collection divided between volume production (global efficiency), has a significant positive impact on the financial self-sufficiency of the OOA. It is therefore important to strengthen the agency's billing level through the detection and repair of leaks, placement and calibration of meters for different types of users, and identification of clandestine outlets. Additionally, it is convenient to increase payment collection from users, always protecting the economically vulnerable population, in order to discourage excessive consumption of the resource and improve the finances of the organization.

Another interesting finding of this study relates to the lower financial performance of OOAs located in the southeastern states. This is because there is no prevailing need for efficiency since water is not a scarce resource compared to the central and northern states of the country. Therefore, it is important for populations and authorities in cities with a real problem of water scarcity to promote the efficiency of the OOAs in order to avoid a future lack of this precious liquid.

Finally, it is considered relevant to encourage the OOAs to generate and publish information that allows authorities, scholars, and civil society to know their performance in terms of water management and availability, to anticipate possible future problems in this matter, and to improve resilience of cities in the face of climate change.

References

Ablanedo-Rosas, J. H., Campanur, A. G., Olivares-Benitez, E., Sánchez-García, J. Y., & Nuñez-Ríos, J. E. (2020). Operational efficiency of Mexican water utilities: Results of a double-bootstrap data envelopment analysis. *Water (Switzerland)*, 12(2). Recovered from https://doi.org/10.3390/w12020553

Akimov, A., & Simshauser, P. (2020). Performance measurement in Australian water utilities. Current state and future directions. *Australian Journal of Public Administration*, 79(1), 111-142. Recovered from https://doi.org/10.1111/1467-8500.12376

Angeles-Castro, G., Arriola-Barcenas, L. J., & Baeza-Almaraz, C. B. (2018). Determinants of total efficiency in water utilities in Mexico. *Applied Economics Letters*, 25(21), 1531-1534. Recovered from https://doi.org/10.1080/13504851.2018.1430324

Berg, S. V. (2020). Performance assessment using key performance indicators (KPIs) for water utilities: A primer. *Water Economics and Policy*, 6(2). Recovered from https://doi.org/10.1142/S2382624X20500010

Briseño, H. (2018). Water pricing models in Mexico according to social criteria (Modelos tarifarios de agua en México según criterios sociales). *Tecnologia y ciencias del agua*, 9(6), 173-192. Recovered from https://doi.org/10.24850/j-tyca-2018-06-08

Briseño, H., & Macedo, E. (2021). Willingness to pay to improve water quality in Zapopan (Disposición a pagar para mejorar la calidad del agua en Zapopan). *Tecnologia y ciencias del agua*, 12(1), 1-21. Recovered from https://doi.org/10.24850/ j-tyca-2021-01-10

Briseño, H., & Sánchez, A. (2018). Decentralization, consolidation, and crisis of urban water management in Mexico. *Tecnologia y ciencias del agua*, 9(4), 25-47. Recovered from https://doi.org/10.24850/j-tyca-2018-04-02

Cetrulo, T. B., Ferreira, D. F. C., Marques, R. C., & Malheiros, T. F. (2020). Water utilities performance analysis in developing countries: On an adequate model for universal access. *Journal of Environmental Management*, 268. Recovered from https://doi.org/10.1016/j.jenvman.2020.110662

Conagua, Comisión Nacional del Agua. (2022). *Sistema Nacionald e Información del Agua (SINA)*. Recovered from http://sina.conagua.gob.mx/sina/tema.php?tema=tarifas&ver=reporte&o=1&n=nacional

D'Inverno, G., Carosi, L., & Romano, G. (2021). Environmental sustainability and service quality beyond economic and financial indicators: A performance evaluation of Italian water utilities. *Socio-Economic Planning Sciences*, 75(February 2020), 100852. Recovered from https://doi.org/10.1016/j.seps.2020.100852

Da Silveira, A. P. P., & Mata-Lima, H. (2021). Assessing energy efficiency in water utilities using long-term data analysis. *Water Resources Management*, 35(9), 2763-2779. Recovered from https://doi.org/10.1007/s11269-021-02866-8

Estruch-Juan, E., Cabrera, E., Molinos-Senante, M., & Maziotis, A. (2020). Are frontier efficiency methods adequate to compare the efficiency of water utilities for regulatory purposes? *Water (Switzerland)*, 12(4). Recovered from https://doi.org/10.3390/W12041046

Gidion, D. K., Hong, J., Adams, M. Z. A., & Khoveyni, M. (2019a). Network DEA models for assessing urban water utility efficiency. *Utilities Policy*, 57, 48-58. Recovered from https://doi.org/10.1016/j.jup.2019.02.001

Gidion, D. K., Hong, J., Hou, B., Shillamkwese, S. S., Adams, M. Z. A., & Khoveyni, M. (2019b). Consistency in efficiency benchmarking: Urban water utility regulation with performance improvement. *Water Science and Technology: Water Supply*, 19(7), 1955-1964. Recovered from https://doi.org/10.2166/ws.2019.072

Guerrini, A., Molinos-Senante, M., & Romano, G. (2018). Italian regulatory reform and water utility performance: An impact analysis. *Utilities Policy*, *52*, 95-102. Recovered from https://doi.org/10.1016/j.jup.2018.03.005

Gujarati, D., & Porter, D. (2010). *Econometría*. New York, EUA: McGraw Hill.

Güngör-Demirci, G., Lee, J., & Keck, J. (2017). Measuring water utility performance using nonparametric linear programming. *Civil Engineering and Environmental Systems*, 34(3-4), 206-220. Recovered from https://doi.org/10.1080/10286608.2018.1425403

Güngör-Demirci, G., Lee, J., & Keck, J. (2018a). Assessing the performance of a California water utility using two-stage data envelopment analysis. *Journal of Water Resources Planning and Management*, 144(4). Recovered from https://doi.org/10.1061/(ASCE)WR.1943-5452.0000921

Güngör-Demirci, G., Lee, J., Keck, J., Guzzetta, R., & Yang, P. (2018b). Determinants of non-revenue water for a water utility in California. *Journal of Water Supply: Research and Technology-AQUA*, 67(3), 270-278. Recovered from https://doi.org/10.2166/aqua.2018.152

Kayaga, S. M., Kingdom, W., & Jalakam, A. (2018). Organisational design for improved performance of urban water utilities in developing countries. *Utilities Policy*, 50, 49-59. Recovered from https://doi.org/10.1016/j.jup.2017.10.001

Kemendi, T. J., & Tutusaus, M. (2018). The impact of pro-poor interventions on the performance indicators of a water utility: Case studies of nakuru and kisumu. *Journal of Water Sanitation and Hygiene for Development*, 8(2), 208-216. Recovered from https://doi.org/10.2166/washdev.2018.088

Li, L. (2018). Private sector participation and performance of county water utilities in China. *China Economic Review*, 52, 30-53. Recovered from https://doi.org/10.1016/j.chieco.2018.06.001

Molinos-Senante, M., Maziotis, A., & Sala-Garrido, R. (2021). Benchmarking the economic and environmental performance of water utilities: A comparison of frontier techniques. *Benchmarking*. Recovered from https://doi.org/10.1108/BIJ-08-2021-0481

Nafi, A., & Brans, J. (2018). Prediction of water utility performance: The case of the water efficiency rate. *Water (Switzerland)*, 10(10). Recovered from https://doi.org/10.3390/w10101443

Ngobeni, V., & Breitenbach, M. C. (2021). Production and scale efficiency of South African water utilities: The case of water boards. *Water Policy*, 23(4), 862-879. Recovered from https://doi.org/10.2166/wp.2021.055

Nithammer, C. M., Mahabir, J., & Dikgang, J. (2022). Efficiency of South African water utilities: A double bootstrap DEA analysis. *Applied Economics*, 54(26), 3055-3073. Recovered from https://doi.org/10.1080/00036846.2021.2002802

Pinto, F. S., Costa, A. S., Figueira, J. R., & Marques, R. C. (2017). The quality of service: An overall performance assessment for water utilities. *Omega (United Kingdom)*, 69, 115-125. Recovered from https://doi.org/10.1016/j.omega.2016.08.006

Río Arronte, & IMTA, Fundación Gonzalo Río Arronte & Instituto Mexicano de Tecnología del Agua. (2021). *Sistema de información para incentivar el cobro-pago del agua*. Recovered from http://www.fgra-cobro-pago.org.mx/

Robles-Velasco, A., Rodríguez-Palero, M., Muñuzuri, J., & Onieva, L. (2022). Sustainable Development and efficiency analysis of the major urban water utilities in Spain. *Water (Switzerland)*, *14*(9). Recovered from https://doi.org/10.3390/w14091519

Romano, G., Molinos-Senante, M., & Guerrini, A. (2017). Water utility efficiency assessment in Italy by accounting for service quality: An empirical investigation. *Utilities Policy*, 45, 97-108. Recovered from https://doi.org/10.1016/j.jup.2017.02.006

Romano, G., Salvati, N., & Guerrini, A. (2018). Governance, strategy and efficiency of water utilities: The Italian case. *Water Policy*, 20(1), 109-126. Recovered from https://doi.org/10.2166/wp.2017.172

Salazar-Adams, A. (2021). The efficiency of post-reform water utilities in Mexico. *Utilities Policy*, 68. Recovered from https://doi.org/10.1016/j.jup.2020.101153

Santos, L. F., Cardoso, M. A., & Galvão, A. F. (2022). Storm water systems' performance: Assessment framework application to Portuguese water utilities. *International Journal of Water Resources Development*. Recovered from https://doi.org/10.1080/07900627.2021.2004882

Tskhai, A. (2020). Model for evaluating the efficiency of Russian water utilities. *Utilities Policy*, 62. Recovered from https://doi.org/10.1016/j.jup.2019.100986

Tskhai, A. (2022). The impact of increasing environmental requirements on the efficiency of water utilities: Russian case. *Clean Technologies and Environmental Policy*, 24(2), 633-644. Recovered from https://doi.org/10.1007/s10098-021-02133-9

Walker, N. L., Williams, A. P., & Styles, D. (2020). Key performance indicators to explain energy & economic efficiency across water utilities, and identifying suitable proxies. *Journal of Environmental Management*, 269. Recovered from https://doi.org/10.1016/j.jenvman.2020.110810

Zirogiannis, N., & Tripodis, Y. (2018). Dynamic factor analysis for short panels: Estimating performance trajectories for water utilities. *Statistical Methods and Applications*, 27(1), 131-150. Recovered from https://doi.org/10.1007/s10260-017-0394-y