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Financial efficiency of Mexican WUOs: A DEA approach

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***Abstract**: This study focuses on the financial evaluation of 32 municipal WUOs in Mexico during 2019 and 2021, applying the DEA. Thus, it seeks to answer the question: What is the financial efficiency of municipal WUOs in Mexico in 2019 and 2021, and what can be improved? The hypothesis presented in this study is that there are significant differences in the financial efficiency of municipal WUOs in Mexico. Its objective is to evaluate the financial performance of WUOs. To do this, DEA methodologies are used with the CCR and BCC models to measure technical efficiency and are applied to WUOs in terms of their evolution in average efficiency. In general, most WUOs show increasing returns to scale. Finally, WUOs must generate strategies that optimize their operational and financial efficiency, improve revenue management and adopt good practices.*

***Keywords**: Data envelopment analysis, Benchmarking, Efficiency, Performance to Scale*

Finansijska efikasnost meksičkih organizacija korisnika voda: DEA pristup

***Apstrakt**: Ova studija se fokusira na finansijsku procenu 32 opštinskih organizacija korisnika voda u Meksiku tokom 2019. i 2021. godine, primenom*

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DEA. Dakle, pokušava da odgovori na pitanje: Kolika je bila finansijska efikasnost opštinskih organizacija korisnika voda u Meksiku 2019. i 2021. godine i šta se može poboljšati? Hipoteza predstavljena u ovoj studiji glasi da postoje značajne razlike u finansijskoj efikasnosti opštinskih organizacija korisnika voda u Meksiku. Cilj rada je da proceni finansijski učinak organizacija korisnika voda. Da bi se to uradilo, korišćena je DEA metodologija sa CCR i BCC modelima za merenje tehničke efikasnosti i primenjuju se na organizacije korisnika voda u smislu njihove evolucije u prosečnoj efikasnosti. Uopšteno govoreći, većina organizacija pokazuje sve veći prinos na obim. Konačno, organizacije korisnika voda moraju generisati strategije koje optimizuju njihovu operativnu i finansijsku efikasnost, poboljšavaju upravljanje prihodima i usvajaju dobre prakse.

***Ključne reči**: Analiza obuhvata podataka, benčmarking, efikasnost, Efikasnost u odnosu na obim*

1. Introduction

Responsible use of water sources is a strategic management need. Several authors have pointed out that efficient water resource management becomes important in the water sector where there is high demand but limited availability of such resources (Molinos-Senante and Maziotis, 2018, 2019, 2020, 2021a, 2021b). In this sense, Water Utility Organizations (WUOs) are key institutions to guarantee sustainable access to drinking water and sanitation.

The Mexican Institute for Competitiveness (IMCO) report (2023) describes the presence of a serious water crisis in Mexico, characterized by the overexploitation of aquifers (which supply water to around 60% of the population), which has reduced the availability of water per capita from 18,035 m3 in 1950 to 3,821 m3 in 2020. Added to this is poor water management, since 35% of water is lost in leaks and only 30% of wastewater is treated. Unequal access to drinking water and sanitation services and the lack of investment in infrastructure (only 6% of federal spending is allocated to this) limit the response capacity of WUO. Another impediment is the poorly managed financial aspect of collecting 64% of revenue from water services, which makes it difficult to implement any solution.

Data Envelopment Analysis (DEA) has been a very useful tool in assessing the efficiency of water utilities at a global level (Abbott and Cohen, 2009; Berg and Lin, 2008; Brettenny and Sharp, 2018; Corton and Berg, 2009; García-Sánchez, 2006). This approach does not require establishing any a priori distribution and allows comparing the relative efficiency of a group of

productive units, in this case, the WUOs. Although useful in many aspects, research focused on using DEA to measure the financial performance of municipal WUOs in Mexico is still scarce.

This article analyzes the financial performance of 32 Mexican municipal water utilities based on data from 2019 and 2021. Based on the analysis, the DEA improves the understanding of the sector's performance and seeks to find areas for improvement in the management of financial resources. The findings of this study will help make rational decisions that will help improve the efficiency and sustainability of water supply services in Mexico.

2. Literature review

This study aims to fill this gap by investigating an analysis of the financial efficiency of Mexican municipal water services, thereby understanding the performance of the sector and identifying some possible improvements. Basically, the study will apply the DEA for the evaluation of the financial performance of 32 Mexican municipal water services in 2019 and 2021. The result of this study would be fundamental to guide rational decisions that would result in an improvement in the efficiency and sustainability of water supply services in Mexico. Efficient water resource management becomes indispensable in a water sector facing increased demand coupled with limited availability. There is a considerable literature on efficient water use within the global economy that has addressed many issues, ranging from performance and efficiency determinants to the effects of regulations and public policies.

Financial efficiency is the ability of the enterprise to generate maximum performance with the available funds. It optimizes resources, minimizes costs, and maximizes profits (Chen et al., 2020). In the case of WUOs, financial efficiency is necessary to ensure service sustainability, infrastructure investment, and water quality (Zhang et al., 2018). This is even more pressing in developing or water-stressed countries, where resource efficiency demands optimal resource management.

DEA has become a standard tool in assessing the financial efficiency of water utilities (Zhiyong and Xiuhui, 2010). Through DEA, the efficiency of utilities can be compared based on their inputs (financial costs, assets) and outputs (revenues, profits). From this, the performance of the utilities can be inferred and areas for improvement can be identified for those with inefficiencies (Chen et al., 2020). DEA can also reveal determinants of financial efficiency, such as ownership, size, and resource management, which are valuable elements for decision making and policy design.

Several studies have addressed the efficiency of water utilities using DEA (Marques et al., 2014; Molinos-Senante and Maziotis, 2018, 2019, 2020, 2021a, 2021b; Ngobeni and Breitenbach, 2021; Tupper and Resende, 2004; Vilarinho et al, 2023a, 2023b; Villegas et al., 2019; Walker et al., 2019, 2020, 2021). DEA provides techniques to compare a set of companies in terms of their relative efficiency ranking, best practices, and areas for improvement. Other systems such as stochastic frontier analysis (SFA) and the Malmquist Productivity Index (MPI) have also been used to analyze performance and productivity trends (Brettenny and Sharp, 2018; Cheng et al., 2022; Maziotis et al., 2023; Mocholi-Arce et al., 2021a, 2021b; Molinos-Senante and Maziotis, 2019, 2020).

In the literature review, different factors have been found that have an effect on the efficiency of water companies, such as:

- Operational factors: Supplier size (Amaral et al., 2023), staff allocation (Amaral et al., 2023), water losses (Amaral et al., 2023; Marques et al., 2014; Molinos-senante and Maziotis, 2018; Robles-Velasco et al., 2022; Villegas et al., 2019), infrastructure (García-Sánchez, 2006; Bennich et al., 2023) and management practices (Vilarinho et al., 2023b).

- Environmental factors: Population density (Molinos-Senante and Maziotis, 2018, 2020; Villegas et al., 2019; Walker et al., 2019), Type of water source (Walker et al., 2019) and Climatic conditions (Molinos-Senante and Maziotis, 2018, 2020; Senante and Maziotis, 2019).

- Institutional factors: Ownership structure (Corton and Berg, 2009; Lambert et al., 1993; Lannier and Porcher, 2014; Molinos-Senante and Maziotis, 2020; Romano et al., 2018), Regulation (Aubert and Reynaud, 2005; Molinos Senante and Maziotis, 2019, 2020; Nyathikala et al., 2023; Nyathikala et al., 2017) and Governance (Estache and Kouassi, 2002; Nyathikala et al., 2023; Romano et al., 2018).

Several studies have examined the effect of regulation and public policies on water industry performance. It has been shown that regulation can affect cost efficiency (Aubert and Reynaud, 2005), influence innovation (Molinos-Senante and Maziotis, 2019) and also affect productivity (Molinos-Senante and Maziotis, 2020). Benchmarking policies (Brettenny and Sharp, 2018) and the grouping of small suppliers (Amaral et al., 2023) have been found as ways to improve efficiency.

The relationship between efficiency and sustainability in the water sector has also been examined in the literature. Among others, the need to incorporate sustainability measures, such as water losses (Amaral et al., 2023; Robles-Velasco et al., 2022) and greenhouse gas (GHG) emissions (Sala-Garrido et

al., 2021), into performance evaluation has been emphasized. Furthermore, it is also argued that the two objectives of efficiency and effectiveness should be pursued in a complementary manner (Lo Storto, 2018; Walker et al., 2021).

The literature identifies challenges in measuring efficiency, such as data availability and reliability (Camanho et al., 2024; Molinos-Senante and Maziotis, 2021c). Opportunities for future research are also pointed out, such as the analysis of the impact of environmental management (Abbott and Cohen, 2009) and the incorporation of service quality in performance evaluation (Mocholi-Arce et al., 2021a; Sala-Garrido et al., 2022).

Various perspectives have been adopted to assess financial efficiency in the water sector, adopting different methodologies and approaches. Zhang et al. (2018) assessed the cost efficiency of WUOs in China, while Ashton (2000) analysed the cost efficiency of water and sewerage companies in the UK, and Brooks and Harris (2008) examined resource allocation efficiency, focusing on efficiency gains in water markets in Australia.

Inefficiency in water management can have serious consequences, as documented in several works. For example, lack of investment in infrastructure and poor management of water resources have led to the consequence of chronic shortages in water supply in South Africa, with an emphasis on rural areas (Ngobeni and Breitenbach, 2021). In India, for example, inefficient urban water services have resulted in a decline in quality and intermittent water supply, with an impact on public health and the productive economy (Nyathikala and Kulshrestha, 2017). In Latin America, inefficiency in the water and sanitation sector results in water pollution and unequal access to services, adding vulnerability to diseases in this population (Ferro et al., 2011). It highlights the need to efficiently manage water and encompass public health, economic development and environmental sustainability.

There are abundant sources on efficiency in the water sector and, more importantly, across a wide range of issues. This study seeks to build on the existing evidence by conducting an analysis of the financial efficiency of Mexican municipal water utilities, understanding the performance of the sector as well as identifying possible improvements.

3. Research metodology

Proposed by Charnes, Cooper and Rhodes (1978), DEA determines the efficiency of an organization by the ratio of inputs used to outputs produced

before making a comparison with other organizations in the sample. This allows finding the most productive suppliers with the least waste in resources consumed (Abbott and Cohen, 2009). According to Farrell (1957), technical efficiency is used to improve products with given inputs while economic efficiency measures the lowest cost of using available production technologies (Coelli et al., 2005). After determining the envelope of the efficient frontier, it is important to perform returns to scale analysis (decreasing, constant or increasing) to formulate strategies aimed at improving those units that are still inefficient.

The DEA analysis uses two models: the CCR model (Charnes et al., 1978) which assumes constant returns to scale (CRS), is suitable for measuring overall efficiency in sectors with uniform operations (Gadžo et al., 2024; Zhiyong and Xiuhui, 2010) and the BCC model (Banker et al., 1984) which allows for variable returns to scale (VRS), is appropriate for situations with different decision-making units (DMUs) not operating at optimal scale (Zhiyong and Xiuhui, 2010).

In the context of the CRS model, a proportional increase in inputs produces the same proportional increase in output. Increasing returns to scale (IRS) refers to an increase that is more than proportional, while decreasing returns to scale (DRS) is the reverse. The difference between the efficiency measures in the VRS model and the CRS model is called scale efficiency.

In this study, the DEA was oriented towards production inputs because it becomes significantly important for the technical efficiency analysis of WUOs when it comes to the minimization of resources, especially water or energy or chemicals, during the production of drinking water, but without reduction of water produced or quality of service. As water is a vital and scarce resource, WUOs face the challenge of using it efficiently in areas that are under some kind of water stress. Focusing the analysis on inputs allows identifying strategies for more sustainable and efficient management of water resources, as well as for improving water productivity. (Abbott, M., and Cohen, B. (2009), Goldar, B., et al. (2004), Hernández, AB, (2023), Mugisha, S. (2008), Ngobeni, V., and Breitenbach, MC (2021), Robles-Velasco, A., et al (2022), Worthington, AC, and Dollery, B. (2014) and Xu, S., Zhang, et al (2020))

Benchmarking in DEA uses "peers", which are DMUs that are considered efficient compared to other peers, in which case they limit the results and help identify and leverage best practices to maximize efficiency.

More than 100 million inhabitants in Mexico are supplied with water by 672 formal WUO’s; however, not all of them send their data to CONAGUA (UNESCO, 2023). This study assesses the financial efficiency of 32 Mexican municipal WUO according to the information available through their websites

in the transparency section. Convenience sampling was used to select these OUs, and only those having an excess of 200,000 inhabitants and matching organizational structure were analyzed: decentralized municipal, paramunicipal, and one local, excluding remaining modalities (National Water Commission [CONAGUA], 2015).

The research consisted of three stages in which financial data were analyzed in 2019 and 2021:

- Efficiency identified: DEA models (CCR and BCC) were applied to inputs to find WUO that minimized operating costs (input-oriented).
- Scale efficiency analysis: It was evaluated whether the WUO worked under increasing economies of scale, decreasing economies of scale or constant economies of scale.
- Benchmarking: Peers with the same efficient WUO line were identified to create a benchmark that would facilitate performance comparison.

Table 1. Indicators of efficiency and productivity of the WUO

Indicator	Description
Personal services	Remuneration of permanent or temporary staff, additional special benefits, and other social and economic benefits, among others.
Materials and supplies	Administrative materials, issuance of documents, official articles, food, utensils, construction and repair articles, chemical products, pharmaceuticals, laboratory products, fuels, lubricants, additives, clothing, linens, protective clothing, sporting goods, tools, spare parts, minor accessories, among others.
General services	Basic services, leasing, professional, scientific, technical, financial, banking, commercial, installation, repair, maintenance, conservation, social communication, advertising, transfer, travel, official and other general services.
Management income	Rights for the provision of services.

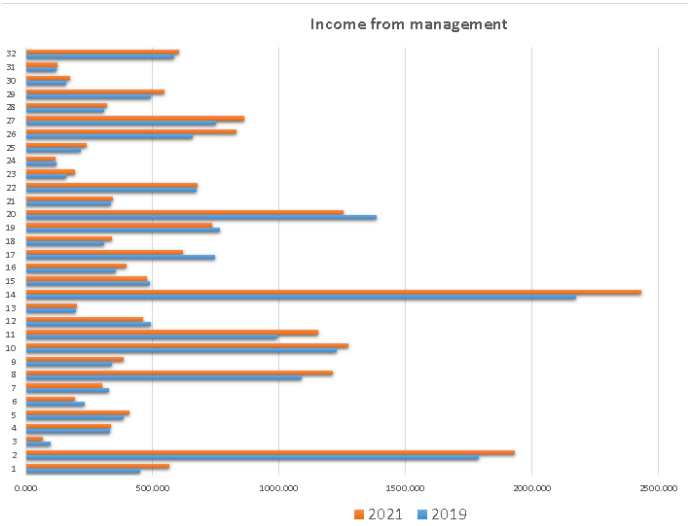
Source: Prepared by the authors using data from the websites (transparency section) of each WUO

The choice of inputs and products for the DEA was resolved based on a review of the literature on WUO efficiency. The result of the selective element distribution is indicated by the indicators performed, listed in Table 1, which provides for the inclusion of output in management revenues, and three operating expenses (personal services, materials and supplies, general services) as production costs (input). The study was proposed as a structured quantitative design, using mathematical models for the DEA analysis. Finally, the calculations of the DEA analysis were performed with Tim Coelli's DEAP 2.1 software, which is a specific computational tool for efficiency analysis.

4. Results and discussion

Fig. 1 provides panel data on the "Management Revenue" (Operating Revenue, in monetary units) of 32 WUOs in the water sector in 2019 and 2021. In 2019, the average revenue was 599.63, with a range from 98.14 to 2173.51. In 2021, the average revenue amounted to 633.67, with a range from 67.01 to 2431.50. This average increase of 34.05 units per DMU masks considerable heterogeneity: 23 WUOs (71.9%) increased their revenue; and 9 (28.1%) decreased it. The year-over-year variation by DMU ranged from a maximum decrease of -128.70 (DMU 17) to a maximum increase of 257.99 (DMU 14), highlighting the diversity of individual financial trends and providing a quantitative basis for comparative analyses and efficiency reviews over the period studied.

Figure 1. Management Revenues for 32 WUO, 2019 and 2021.

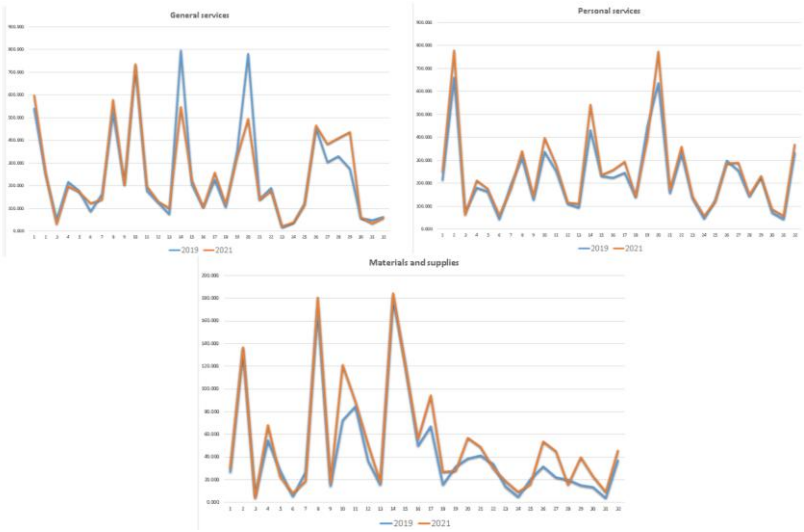


Source: Prepared by the authors using data from the websites (transparency section) of WUO

Figure 2 shows the operating expenses of the 32 DMUs for 2019 and 2021 (in millions of pesos), broken down into “Personal Services” (PS), “Materials and Supplies” (MS), and “General Services” (GS). On average, total operating expenditure per monetary unit increased by 68.02, from 595.91 in 2019 to 663.93 in 2021. This average increase was recorded across all three items, with an average increase of 26.93 in PS (from an average of 243.38 to

270.31), 8.51 in MS (i.e., from 48.92 to 57.43), and 32.58 in GS (from 303.61 to 336.19). In contrast to these aggregate trends, the table shows substantial heterogeneity in expenditure levels and their variations across units of measurement (e.g., ranges in 2021: PS [60.03 - 778.84], MS [4.22 - 184.43], GS [22.41 - 735.14]), providing room for scrutiny of individual cost structures and their evolution.

Figure 2. Evolution of Operating Expenses for 32 DMUs (2019 and 2021)



Source: Prepared by the authors using data from the websites (transparency section) of WUO

The document presents the average operating income and expenses of 32 WUO in Mexico for the years 2019 and 2021. In 2019 and 2021, the WUO with the most income were León, Guanajuato (2,268.85 million pesos) and Celaya, Guanajuato (1,925.39 million pesos). In both years, the WUO with the least collected income were Chilpancingo, Guerrero (66.78 million pesos) and Tehuacán, Puebla (114.85 million pesos).

Regarding operating expenses, the WUOs with the highest total expenditure in both years were León, Guanajuato (3,599.80 million pesos) and Celaya, Guanajuato (3,070.92 million pesos). The WUOs with the lowest total expenditure in both years were Nicolás Romero, Mexico (218.75 million

pesos) and Chilpancingo, Guerrero (164.03 million pesos). In general, management income did not show any significant change from 2019 to 2021.

To summarize the information illustrated in Table 2, the percentage change in the average of both models (CCR and BCC) was determined and the variability in both years was analyzed. Table 2 illustrates the descriptive statistics of the efficiency results for the years 2019 and 2021, stratified into the CCR and BCC models.

Average:

- In 2019, the average efficiency of both models was comparable, with 0.72 for CCR and 0.79 for BCC.
- The average efficiency of both models decreased significantly in 2021, standing at 0.47 for CCR and 0.63 for BCC. This shows a drop in the performance of WUOs as a whole in 2021.
- The percentage change based on average figures from 2019 to 2021 was – 34.72% for CCR, and – 20.25% for BCC.

This finding means that, on average, the WUO of municipalities in Mexico, for the most part, presented a lower capacity to more efficiently manage their financial resources through the use of their spending in 2021.

Standard Deviation:

- The standard deviation in both models was 0.20 in 2019.
- In 2021, the standard deviation increased to 0.25 for CCR and 0.28 for BCC indicating a greater dispersion of efficiency results in 2021.

Table 2 provides a clear representation of the decrease in the average efficiency of Mexican municipal WUO from 2019 to 2021 and the increase in the dispersion of results.

Table 2. Descriptive statistics of efficiency results by year and model

Year	Model	Average	DevSt	CoefVar	Minimum	Median	Maximum
2019	CCR	0.72	0.20	0.28	0.41	0.71	1.00
	BCC	0.79	0.20	0.25	0.43	0.79	1.00
2021	CCR	0.47	0.25	0.54	0.20	0.36	1.00
	BCC	0.63	0.28	0.45	0.24	0.52	1.00

Source: Prepared by the authors using data from the websites of the WUOs in the transparency section

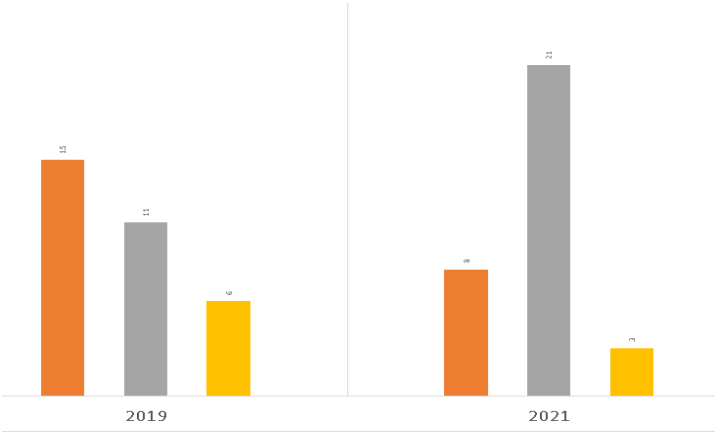
Statistical evidence has clearly indicated that there was a marked drop in the average efficiency scores of Mexican municipal WUOs between 2019 and 2021. Apparently, the mean efficiency score for the CCR model fell from 0.72

to 0.47 and for the BCC model; it also dropped from 0.79 to 0.63. This decline shows that OOAs have become less capable of effectively managing their financial resources.

Additionally, there was standard deviation in efficiency score across WUOs. From 0.20 in 2019 to 0.25, the standard deviation in 2021 rose for CCR statistic and to 0.28 for BCC models. A paired t-test has confirmed that the mean differences in the average efficiency scores of the two years is statistically significant ($p<0.05$). This highlights the need for WUOs to develop improvement strategies through optimization of operational scales as well as imposition of best practices, which will lead to better financial performance and sustainable water services.

The analysis of WUO returns to scale (ROS), illustrated in Figure 2, shows intra-annual changes in their distribution. However, it is evident that there is a majority of WUOs with IRS (50%) and those with DRS (36%). It is noteworthy that in 2021, the majority of WUOs show IRS, indicating the presence of room for operational efficiencies for organizations that have not yet scaled to their optimal size.

Figure 2. Returns to scale by year



Source: Prepared by the authors using data from WUO websites in the transparency section

Table 3 details the financial efficiency of 32 WUOs in Mexico from 2019 to 2021 through two DEA models (CCR and BCC). In addition, the type of Average Scale Return (SSR) for each WUO considered for the year 2021 is presented.

Table 3 shows that there are considerable variations in the financial efficiency of WUOs across Mexican municipalities. Coacalco and Xalapa are known for their consistent efficiency, but other WUOs show some fluctuations in their efficiency over time. Most WUOs are of increasing scale, implying that there is room for improvement in the use of their resources.

Table 3. Efficiencies and returns to scale in finance

City of the WUO	2019			2021		
	CCR	BCC	RDE	CCR	BCC	RDE
Atizapan, Mexico	0.41	0.57	DRS	0.2	0.24	IRS
Celaya Guanajuato	1	1	CTE	0.94	1	DRS
Chilpancingo, Guerrero	0.57	0.79	IRS	0.31	1	IRS
Obregon City, Sonora	0.41	0.43	IRS	1	1	CTE
Ciudad Victoria, Tamaulipas	0.61	0.62	DRS	0.35	0.41	IRS
Coacalco, México	1	1	CTE	1	1	CTE
Cuernavaca, Morelos	0.53	0.53	IRS	0.32	0.41	IRS
Culiacán Sinaloa	0.7	0.72	DRS	0.33	0.54	DRS
Durango, Durango	0.58	0.65	DRS	0.29	0.43	IRS
Hermosillo, Sonora	0.69	0.99	DRS	0.27	0.51	DRS
H. Matamoros, Tamaulipas	1	1	CTE	0.83	0.91	DRS
Irapuato, Guanajuato	1	1	CTE	0.53	0.6	IRS
Ixtapaluca, Mexico	0.64	0.7	IRS	0.29	0.52	IRS
Leon, Guanajuato	0.98	1	DRS	0.66	1	DRS
Los Cabos, BCS	0.51	0.53	IRS	0.31	0.34	IRS
Los Mochis, Sinaloa	0.54	0.61	IRS	0.49	0.51	IRS
Mazatlan, Sinaloa	0.76	0.79	DRS	0.35	0.36	IRS
Monclova, Coahuila	0.78	0.79	DRS	0.42	0.51	IRS
Morelia, Michoacan	0.72	0.81	DRS	0.35	0.35	IRS
Naucalpan, Mexico	0.86	1	DRS	0.38	1	DRS
Nogales, Sonora	0.54	0.57	IRS	0.36	0.44	IRS
Reynosa, Tamaulipas	0.86	0.92	DRS	0.55	0.55	IRS
Tapachula, Chiapas	1	1	CTE	0.86	1	IRS
Tehuacan, Puebla	0.9	1	IRS	0.41	0.97	IRS
Tepic, Nayarit	0.48	0.51	IRS	0.31	0.49	IRS
Toluca, Mexico	0.53	0.7	DRS	0.28	0.28	DRS
Torreon Coahuila	0.89	1	DRS	0.34	0.36	DRS
Tultitlan, Mexico	0.41	0.49	DRS	0.21	0.41	IRS
Tuxtla Gutierrez, Chiapas	0.78	0.87	DRS	0.2	0.26	IRS
Uruapan, Michoacan	0.64	0.77	IRS	0.4	0.68	IRS
V. Nicolas Romero, Mexico	0.86	1	IRS	0.49	1	IRS
Xalapa, Veracruz	1	1	CTE	1	1	CTE

Source: Prepared by the authors using data from OOA websites in the transparency section

Efficiency:

- The best performing WUOs, demonstrating effectiveness in both models and throughout the period, are Coacalco (State of Mexico) and Xalapa (Veracruz).
- Other relatively more efficient WUOs are Tapachula (Chiapas), Villa Nicolás Romero (State of Mexico), Chilpancingo (Guerrero), León (Guanajuato) and Celaya (Guanajuato).
- Most efficient OOAs are decentralized.
- Several OOAs show a reduction in their efficiency in 2021 compared to 2019.

Below is the efficiency analysis of the OOA of each state:

- Baja California Sur: OOMSAPAS in Los Cabos has been inefficient over the years but has a scale efficiency index for 2021 that shows there is room for improvement.
- Chiapas: In 2021, SMAPA's efficiency fell while COAPATAP maintained a good level of efficiency within the BCC model. Both WUOs exhibited IRS in 2021.
- Coahuila: SIMAS de Torreón showed a DRS in 2021, while SIMAS de Monclova had an IRS so there are opportunities for improvement.
- Durango: Aguas del Municipio de Durango (AMD) reduces its efficiency in 2021 but qualifies with an 'IRS' and can therefore improve its performance.
- State of Mexico: Despite the constant efficiency of SAPASAC, the other WUOs evaluated (SAPASA, ODAPAS, OAPAS, AyST, APAST and SAPASNIR) have some gaps.
- Guanajuato: JAPAMI and SAPAL hit rock bottom in 2021, but JUMAPA remained very efficient in the BCC model.
- Guerrero: CAPACH's efficiency index shows an IRS, so it can be said that CAPACH has a lucrative entrepreneurial area, as does OOAPAS in Michoacán, whose efficiency fell in 2021.
- Morelos: SAPAC has a poor performance and has an efficiency index called IRS that still shows room for improvement.
- Nayarit: On the other hand, SIAPA was not efficient in all the years measured; however, it has an IRS in 2021, which means it can improve.

- Sinaloa: JAPAC, JUMAPAM and JAPAMA show very low efficiency, which implies the need for a process evaluation to improve their management.
- Sonora: Agua de Hermosillo and OOMAPAS de Nogales have shown a declining performance, while OOMAPAS de Cajeme has had a good performance in 2021.
- Tamaulipas: COMAPA-Reynosa and COMAPA-Victoria, an IRS has room for improvement, while JAD Matamoros experiences a slight drop in its efficiency.
- Puebla: OOSAPAT exhibits fluctuating performance levels with respect to IRS, which shows room for improvement.
- Veracruz: CMAS maintains a stable level of efficiency within the reviewed period.

In general terms, the evaluation establishes that OOAs must design strategies to improve the efficiency and effectiveness of communication and in these cases use best peer practices and decision-making techniques such as DEA.

5. Conclusions

This article analyzed the financial performance of 32 municipal water utilities in Mexico from 2019 to 2021. Using the DEA, the study aimed to measure the sector's performance to suggest ways to improve water resource management.

The results of the study showed a drop in the average performance of the WUOs during the period analyzed, probably as a consequence of the effects of the COVID-19 pandemic. Olivares (2020) argues that WUO s are a sector already characterized by structural weaknesses such as financial instability due to tariff levels below real costs and low efficiency in revenue collection, which have historically covered only a fraction of their operating costs. The pandemic intensified these vulnerabilities by increasing residential demand for water due to hygiene measures and lockdowns, while commercial and industrial demands plummeted due to economic shutdowns (Campos, 2020). Despite the increase in domestic use, many WUO s suffered revenue losses due to lower contributions from non-residential users (with higher tariffs) as some authorities established moratoriums on tariffs and payments as economic relief for households (Campos, 2020). At the same time, operating costs have increased due to the new need for strict hygiene protocols, extensions of water supply via tanker trucks, and a potential increase in

energy consumption, further exacerbating an already existing financial burden (Olivares, 2020).

The pandemic has shown that these models are quite fragile in terms of funding for WUO s, as well as their resilience to external shocks. These are the conclusions of Campos (2020). While always beneficial, provisioning by the federal government through a series of existing programs and other crisis-specific anti-COVID measures initiated by CONAGUA, international assistance from the Inter-American Development Bank, and the North American Development Bank, exceeded their limits. Several WUO s faced liquidity strains. Indeed, trends such as rising overdue accounts were evident, but varied observations had to accommodate regional differences. Potential long-term ramifications include revenue issues, increased indebtedness, and deferred maintenance. The recommendations envision future viability, which would include tariff reform to reflect real costs, guidelines to improve operational efficiency (Olivares, 2020), diversifying financing sources with climate finance options, strengthening governance, and maintaining government support as a key element.

In fact, it has been shown that most of the WUOs have the capacity to increase their efficiency by increasing the size of their operations, indicating increasing returns to scale. The analysis also reveals a significant heterogeneity in financial performance between the different WUOs included in this analysis, with decentralized organizations being more efficient. Finally, the study recognizes areas for improvement, such as optimal scales of operation and the adoption of best practices, for the provision of more efficient services in the water sector.

The DEA analysis proved to be an effective tool for assessing the financial performance of Mexican WUOs. The results of these studies highlight the critical importance of water use efficiency not only in a context of increasing demand but also in conditions of scarcity. In the case of Mexico, key strategies should include the promotion of efficient services and the achievement of an optimal scale of operation for all WUOs as prerequisites for sustainability in water service provision.

The study has some limitations that should be taken into account. First, the sample for the analysis was relatively small and comprised 32 WUOs, which might not be representative of the entire sector in Mexico. The second point is that this analysis has been limited to financial efficiency, so other aspects of performance such as water quality and customer satisfaction have not been considered. In addition, the analysis covered the COVID-19 pandemic, which could have affected the financial results of the WUOs. Finally, even though the DEA is a very good instrument in measuring efficiency, it still has its

inherent limitations in its methodology and does not consider all the variables that can affect the performance of drinking water companies.

To improve their financial efficiency, WUOs should consider the following recommendations: optimize the scale of operations to achieve greater efficiency, either by increasing or decreasing their size as necessary. Implement financial management best practices, including the adoption of strategic management, budget control and accountability. Strengthen revenue management through improvements in collection, tariff review and mitigation of late payments. Streamline management of operating expenses through cost rationalization, reduction of non-revenue water and adoption of energy-efficient technologies. Finally, design and implement performance monitoring and evaluation systems to establish areas for improvement and ensure the sustainability of water services.

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Annex 1. List of the location of the OOA

DMU	City of WUO
1	Atizapan, Estado de Mexico
2	Celaya Guanajuato
3	Chilpancingo, Guerrero
4	Ciudad Obregon, Sonora
5	Ciudad Victoria, Tamaulipas
6	Coacalco, Estado de Mexico
7	Cuernavaca, Morelos
8	Culiacan Sinaloa
9	Durango, Durango
10	Hermosillo, Sonora
11	Heroica Matamoros, Tamaulipas
12	Irapuato, Guanajuato
13	Ixtapaluca, Estado de Mexico
14	Leon, Guanajuato
15	Los Cabos, BCS
16	Los Mochis, Sinaloa
17	Mazatlan, Sinaloa
18	Monclova, Coahuila
19	Morelia, Michoacan
20	Naucalpan, Estado de Mexico
21	Nogales, Sonora
22	Reynosa, Tamaulipas
23	Tapachula, Chiapas
24	Tehuacán, Puebla
25	Tepic, Nayarit
26	Toluca, Estado de Mexico
27	Torreon Coahuila
28	Tultitlan, Estado de Mexico
29	Tuxtla Gutierrez, Chiapas
30	Uruapan, Michoacan
31	V. Nicolas Romero, Edo de Mexico
32	Xalapa, Veracruz