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REGULATION, ORGANIZATION, AND INCENTIVES: THE POLITICAL ECONOMY OF POTABLE WATER SERVICES IN MEXICO

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1 Introduction

By the end of the 1980s, the provision of potable water and sewage and wastewater treatment services in Mexico came to the forefront as a major social problem. For example, in 1990, 16.7 million people lacked potable water and 28.8 million did not have any sewage services. Moreover, an analysis by the Comisión Nacional del Agua (1995) of data available for 1990 revealed that the level of provision of potable water and sewage services is biased towards larger and richer cities. Additionally, of the 250 cubic meters per second provided to the population in 1990, 160 cubic meters per second returned to the environment as wastewater and of this total only 10% was treated.

At the same time, it was also realized that the majority of the water utilities operating in Mexico had severe financial, technical, organization, and institutional problems. In fact, the majority of the water utilities were seriously deteriorated due to the lack of funds to carry out maintenance programs and to expand their services. The lack of funds was a result of very low water and sewage tariffs and of poor revenue collection systems. The resulting consequence was a "low quality level" equilibrium in which the services provided by water utilities were of poor quality and, as a consequence, water users refused to pay more for poor water services.

Responding to the challenge, the Mexican federal government undertook three major policy avenues: (a) expansion of the existing potable water and sewage infrastructure, (b) implementation of measures aimed at improving water use efficiencies, and (c) reduction of water pollution. The fundamental principles underlying this new water policy focus were:

- the use of integrated planning to make good use of scarce water;
- the strengthening of the regulatory capacity of the central water authority;
- the introduction of market mechanisms such as water pricing and incentives to induce the efficient use of water and to control pollution;
- the strengthening of institutional coordination at all government levels:
- the effective decentralization of tasks and responsibilities;
- the modernization of federal and state water laws; and
- the participation of water user in decisions relating to water use and water pollution.

Additionally, in 1990 the *Programa Nacional de Agua Potable, Alcantarillado y Saneamiento* came into being to respond to increased potable water, sewage service, and wastewater treatment needs (Comisión Nacional del Agua, 1994).

The objective of this study is to examine how institutional changes in Mexico's potable water sector influence public and private investment, incentives, efficient water use, and administrative capacities in the sector. Given the institutional structure of Mexico’s water utilities, the study will formulate and test hypotheses relating to institutional changes that have occurred in the sector and to the regulation, organization, and efficiency of the sector. The study seeks to provide policy recommendations aimed at improving the services provided by this sector.

The relevance of this study can be summarized in two main points. First, over the last eight decades, and in particular the last two, Mexico has moved towards the separation of normative and operative functions of its state and municipal water utilities and in some cases even towards privatization. Thus, it is illuminating to compare the performance of water utilities operating under different organizational structures (*i.e.*, directly administered (combined normative and operative functions) at the state level, autonomous (separated normative and operative functions) at the state level, directly administered at the municipal level, and autonomous at the municipal level). Some of the lessons that can be learned from this comparison relate to how the organizational structure of the water utilities influences their efficiency and to the role played by the state in bringing about institutional changes designed to promote efficiency in the sector.[1]

Second, Mexico's federal government is currently promoting the updating of the potable water and sewage laws of each Mexican State. Here too, it would be revealing to compare the performance of water utilities with different organizational structures under different legislative regimes. From this comparison one may infer how water legislation influences the efficiency of the sector.

It should be noted that over the last 5 years Mexico's federal government has encouraged the privatization of its public water utilities through its water utility concession model. To date, four water utilities have been privatized or partly privatized. Although it would be instructive to examine and compare the performance of privatized water utilities to the performance of public water utilities, or to explore the incentive structure of water utility concession contracts, this will not be done in this study since no data was available for the privatized water utilities.

The rest of the study is organized as follows. In the next section, a chronological review of the institutional reforms that have been undertaken in Mexico's potable water sector are presented. Section 3 presents a succinct overview of the status of the sector. In section 4, efficiency and scale effects of four types of water utilities operating in Mexico are econometrically examined using a 1995 sample of Mexican water utilities. Concluding comments are provided in section 5.

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[1] In Mexico, the sparation of normative and operative functions is called "decentralización" independent of any change from state to municipal levels.

2 Institutional Reform

Up to 1946, the administration of Mexico’s potable water and sewage sector was highly centralized at the federal level. However, in 1947, the Mexican government created the *Secretaría de Recursos Hidráulicos*, under which the *Juntas Federales de Agua Potable y Alcantariado* (Potable Water and Sanitation Federal Boards) were created. These Federal Boards were Mexico’s first attempt to decentralize the administration of this sector (Palma, 1996). Additionally, in 1956 the “*Ley de Cooperación Para la Dotación de Agua Potable a los Municipios*” water law was enacted and it enabled the creation of the *Sistemas de Administracion Directa* (Direct Administration Systems) and the *Comités Municipales de Agua Potable* (Potable Water Municipal Committees). The creation of these administrative systems as well as the Federal Boards gave this sector a certain degree of decentralization and they stimulated the participation of the citizenry in the decision making process (Sahab, 1993).

In 1976, the administration of the sector was assigned to the *Secretaría de Asentamientos Humanos y Obras Públicas* (Human Settlement and Pubic Works Secretary) and, in 1980, this *Secretaría* relinquished the operation of the water utilities to the state governments. The states, in turn, reserved a normative role for themselves and established various administrative schemes. The schemes ranged from the establishment of independent statewide or municipal water utilities to de-concentration and fiduciary administrative schemes. Because of the diversity of schemes, water tariff increases could be approved by either the state government, the governor, or by local councils. Additionally, in 1983, new reforms and additions to Article 115 of Mexico’s constitution established that potable water and sewage services were the responsibility of the municipalities. However, the States ignored these reforms and opted (during most of the 1980s) to create autonomous state water utilities instead of decentralized municipal water utilities (Palma, 1996).

During the 1980s, the autonomous state water utilities ran into difficulties. First, they were not generating enough revenue for water supply expansions or maintenance requirements. Second, the utilities were being de-capitalized as scant water utility revenues were being devoted to other state government uses. In many cases, the de-capitalization of the water utilities led to a demand for subsidies not only for maintenance and additional infrastructure but also for the mere operation of the water utility itself. Political factors also tended to weaken the authority of water utilities, especially with respect to the setting of tariffs (Navarrete, 1996). Furthermore, state laws also hampered the autonomy and administrative options water utilities had at their disposal.

Consequently, in 1989, the federal government created the *Comisión Nacional de Agua* (National Water Commission). The Commission was charged, among other things, with the task of defining policies and strategies aimed at re-enforcing the technical, administrative, and financial autonomy of state and municipal water utilities. The Commission's major effort with respect to the potable water and sewage sector has been the creation of the *Programa Nacional de Agua Potable, Alcantarillado, Saneamiento y Consolidación de Organismos Operadores* (National Potable Water, Drainage, Sewage and Water Utility Consolidation Program). This program was designed to respond to a series of deficiencies encountered in the potable water and sewage sector. Two of its basic objectives are to further the decentralization of Mexico's water utilities at the municipal level and to assure the adequacy of state water legislative efforts (Palma, 1996).

Since 1992, Mexico's National Water Commission has also been promoting throughout the nation modern legislative recommendations. In essence, the National Water Commission has developed a "model state water law" which is based on the water law enacted by the state of Sonora. To date, only four states have adopted this model state water law and another seven have adopted some modified version of it. The law is aimed at promoting the autonomy of water utilities, the ability to suspend water services, and private sector participation, among other things.

In summary, two underlying themes can be gleaned from this overview of the institutional reforms that have occurred in Mexico's potable water and sewage sector. The first theme indicates that Mexico has heavily promoted the separation of normative from operative functions of its water utilities. At first, Mexico promoted this separation at the state level, but now promotes it at the municipal level. Mexico believes that by making the water utilities autonomous it would make the water utilities more efficient since they had to respond to local concerns and were more in touch with water users. The second theme indicates that since 1992, Mexico's National Water Commission has been promoting its "model state water law." The rationale behind the promotion of this model law is that its adaptation will also promote efficiency within the potable water and sewage sector. However, a shortcoming inherent to this model law is that it law still maintains a centralized administrative scheme and, in some cases, requires that tariffs be set by congress. This might prevent the gains in efficiency that are its goal.

3 Current Status of the Sector

3.1 Coverage

Over the last two decades, the provision of potable water in Mexico has experienced an enormous amount of expansion. Up to the beginning of the 1980s, the level of potable water coverage was low. According to Noriega (1990), the percentage of population with access to potable water services was 50% in 1980. Nevertheless by the end of the 1980s, the level of coverage increased to 78.2% and by 1994 to almost 85% (see Table 1).

Although this increase in the provision of potable water was substantial, Table 2 indicates that there are still serious problems in the sector. Table 2 contains a breakdown for 1994 of the level of potable water services by size of locality. The table shows that there are still great potable water needs in localities with population of less than 2,500 inhabitants. These localities represent about 28% of the population of Mexico. In localities with 1-99 inhabitants the level of potable water coverage is 38%, in localities with 100-499 inhabitants the level of coverage is 48.1% and in localities with 500-2,500 inhabitants the level is 65.8%. This is in sharp contrast with the level of potable water coverage found in localities with more than 2,500 inhabitants. The larger localities have coverage levels that range from 77.8% to 94.7%.

Table 1
Level of Coverage of Potable Water and Sewage Services, 1990-1994

Year	Total Population (Millions)	Population Served (Millions)	Level of Coverage (%)
		Potable Water	
1989	80.7	63.1	78.2
1990	82.5	65.8	79.8
1991	84.1	67.8	80.6
1992	85.7	71.3	83.2
1993	87.3	73.7	84.4
1994	88.9	75.5	84.9
		Sewage	
1990	82.5	53.7	65.1
1991	84.1	55.4	65.9
1992	85.7	58.5	68.3
1993	87.3	60.8	69.6
1994	88.9	62.6	70.4

Source: Comisión Nacional del Agua, 1995.

An examination of the data relating to sewage services reveal that the level of coverage of sewage services has also increased in the last 5 years. Table 1 shows that the level of coverage of sewage services increased from 65% in 1990 to 70% in 1994. Compared to potable water the coverage level of sewage services has lagged behind that of potable water. Table 2 also indicates that the localities with populations of less than 5,000 also have severe problems with the level of coverage of sewage services.

Table 2
Level of Coverage of Potable Water and Sewage Services by Size of Locality, 1994

Size of Locality (Population)	Total Population (Millions)	Population Served (Millions)	Level of Coverage (%)
		Potable Water	
1–99	2.2	0.8	38.0
100–499	7.9	3.8	48.1
500–2,499	14.6	9.6	65.8
2,500–4,999	5.3	4.1	77.8
5,000–49,999	14.6	12.9	88.4
50,000–79,990	2.5	2.2	89.7
80,000 or more	41.8	39.6	94.7
Total	88.9	75.5	84.9
		Sewage	
1–99	2.2	0.6	25.8
100–499	7.9	2.1	26.1
500–2,499	14.6	5.3	36.1
2,500–4,999	5.3	2.7	51.5
5,000–49,999	14.6	11.1	76.0
50,000–79,990	2.5	2.1	83.8
80,000 or more	41.8	38.8	92.8
Total	88.9	62.6	70.5

Source: Comisión Nacional del Agua, 1995.

3.2 Water Treatment

Mexico’s wastewater treatment capacity is very low. For example, in 1994 there was only an installed capacity of 42,788 liters/second available to treat the 160,000 liters/second of wastewater that was generated in that year. This implies that in 1994 only about 27% of the wastewater that was generated was adequately treated. Further, for this same year, there existed 196 wastewater treatment plants with a capacity to treat 4,090 liters/second that were out of operation. As of 1994, the following states still had severe wastewater treatment problems: Baja California Sur (treats 28%), Chihuahua (treats 7%), Hidalgo (treats 1%), Mexico (treats 54%), Michoacan (treats 8%), Oaxaca (treats 0%), San Luis Potosi (treats 28%),Veracruz (treats 44%), and Zacatecas (treats 46%).

Private investment in the wastewater treatment sector has become very evident recently. For example, between the last months of 1992 and December of 1994, 32 plants with a combined wastewater treatment capacity of 23,344 liters/second and a total investment figure of 179.3 million dollars were put up for bid.[2] These wastewater treatment plants will be operated under private participation schemes of finance, construction and operation. In these schemes, the investor will finance, construct, and operate the wastewater treatment system and the water utility will pay for this service based on a price per cubic meter turned over to the system. The private investor will not be involved in charging the users.

3.3 Tariff Structure, Unaccounted Water, and Revenue Collection

Water tariffs in Mexico vary substantially across water utilities. In 1993 the domestic water tariff ranged from \$0.05 per cubic meter in the state of Tabasco to \$4.16 per cubic meter in the state of Zacatecas. At the same time, the commercial and industrial tariffs ranged from \$0.17 per cubic meter in the state of Sonora to \$7.22 per cubic meter in the State of Tlaxcala. In 1994, the ranges were (\$0.10-\$9.80), (\$0.15-\$7.33), and (\$0.16-\$3.18) for the domestic, commercial, and industrial sectors.

During 1994, tariffs were modified in 24 states. Most states increased their tariffs by about 10%. However, some cities increased their tariffs substantially more. For example, Aguascalientes increased its tariffs by more than 100%, La Paz by 40% and Pachuca by 30% in the commercial and industrial sectors (Comisión Nacional del Agua, 1995). Overall the majority of the tariffs in Mexico are insufficient to cover the costs incurred by the water utilities.

Unaccounted water as a percentage of total production is defined as the share of volume of water produced by the water utility that is not billed. Unaccounted water represents a serious problem in Mexico. Applying this measure to 71 localities throughout Mexico in 1993 and 86 localities in 1994 yield an average measure of 48% and 43%, respectively. This implies that in Mexico at least 45% of the water is unaccounted for. Table 3 provides an overview of the distribution of unaccounted water for the localities examined in 1993 and 1994. The range covering 51-60% of unaccounted water has the greatest number of localities.

The total amount of revenue collected during 1993 by the 730 water utilities that provide information to Mexico's National Water Commission amounted to \$1,556 million dollars. In 1994 this amount increased to \$1,634 million dollars. A comparison of the revenue collected for 1993 and 1994 reveals that not all states increased their revenues in 1994. For example, the states of Guerrero, Morelos,

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[2] In this study all dollar figures are in 1995 dollars.

Sonora, Veracruz and Oaxaca had decreases of 44%, 67%, 41%, 34%, and 44%. There is still much to do with respect to revenue collection in Mexico.

Table 3
Ranges of Unaccounted Water for a Sample of Localities Throughout Mexico, 1993-1994

% of Unaccounted Water	Number of Localities 1993	Number of Localities 1994
20-30	4	11
31-40	11	18
41-50	18	21
51-60	28	23
60-70	8	10
> 70	2	3

Source: Comisión Nacional del Agua: 1994, 1995.

3.4 Investment

Financial resources for the potable water, sewage and wastewater treatment sectors of Mexico come from a wide range of sources including: (a) federal government, (b) state governments, (c) international banks, (d) social groups, (e) private sector, and (f) from water utilities themselves. To guarantee a more effective use of the scarce funds in this sector, the government of Mexico has developed an investment profile structure that specifies how investments in the sector will be undertaken. The investment profile for 1994 for cities with a population of more than 80,000 is presented in Table 4. Compared to previous years, this investment profile allocates 100% of these funds to the drainage sectors and none to the potable water sector. Notice also that the secondary wastewater treatment investment is 100% from the private sector. This indicates that public funds are going to drainage and primary wastewater treatment and that secondary wastewater treatment investment will be forthcoming only to the degree that the private sector can be attracted to it. This implies that Mexico wants (1) the potable water sector to pay for itself, (2) the private sector to invest in secondary wastewater treatment and to recover its investment through charging potable water, and (3) for drainage to get a pure fiscal transfer.

The amount of investment that has occurred in the potable water and sewage and wastewater treatment sectors in 1993 was $1,090 million dollars and in 1994, $741 million dollars. As can be observed, investment in this sector decreased by 26% in 1994 as compared to 1993 (Comisión Nacional del Agua, 1995). Table 5 presents a breakdown of the 1994 investment level. Of the total amount invested in this sector 40% went to the three biggest cities, 40% to all the other urban cities, and only 10% to rural areas. Additionally, there is no private investment in rural areas. Also credit and private funds make up only 21% of the funds invested in this sector (Comisión Nacional del Agua, 1995).

Table 4
Investment Profile for Cities with Populations of More than 80,000, 1994

Item	Credit	Fiscal Funds	Private Investment
Potable Water	100%	0	0
Drainage	0	100%	0
Wastewater Treatment			
Primary	100%	0	0
Secondary	0	0	100%

Source: Comisión Nacional del Agua: 1994, 1995.
Note: Credit also contains funds generated from the water utility itself and Fiscal Funds are 50% federal and 50% state.

Table 5
Investment in the Potable Water, Sewage, and Wastewater Treatment, 1994
(Millions of dollars)

Area	Federal	State/Local	Credit	Private	TOTAL
Mexico City	143				143
Monterrey	82		19	20	121
Guadalajara	12		4	11	27
Other Cities	106	86	88	9	289
Rural Areas	111	50			161
TOTAL	454	136	111	40	741

Source: Comisión Nacional del Agua: 1994, 1995.
Note: Private also contains funds generated from the water utility itself.

Since 1993, the private sector has jointly participated with the Mexican government at all three levels in the financial and administrative processes of some water utilities. This participation has been made possible because of the implementation of a new financial framework that has well established and transparent rules (Comisión Nacional del Agua, 1995). This new financial framework has given private investors more security with respect to its investment. Additionally, Mexico’s recently modified National Water Law promotes the participation of private citizens in the potable water and sewage and wastewater treatment sector through various arrangements as outlined in the next section.

4 Econometric Analysis

Sections 2 and 3 provided a review of institutional, regulatory, and organizational changes that have occurred in Mexico's potable water sector. In essence, the review presented in Section 2 indicates that Mexico is promoting (1) the separation of the normative and operative functions of its water utilities, (2) the municipal management of its water utilities, and (3) the adoption of a model state water law aimed at improving the efficiency of the potable water sector. Alternatively, the overview provided in Section 3 indicates that Mexico needs to provide more potable water services to localities with populations of less than 5,000 habitants, treat more of its wastewater, improve its tariff structure, and attract more private sector participation in Mexico's potable water sector.

The descriptive analysis provided in Sections 2 and 3 suggests several hypotheses that need to be address or tested. First, does autonomy (in terms of separate normative and operative functions) increase water utility efficiency? Second, does greater autonomy in state systems have a greater impact on performance for large systems than for small systems? Third, do autonomous municipal systems have a greater impact on performance for large systems than for small systems? Fourth, are water utilities that set their own tariffs more efficient than those whose tariffs are set by congress? Fifth, does the adoption of the National Water Commission’s model state water law promote efficiency?

In this section, we build an econometric model that is capable of addressing the above questions and hypotheses. We begin by specifying a theoretical model which describes how water utilities in each type of organizational structure choose inputs such that they minimize the variable costs of producing a given level of water. Next, we describe the data that will be used to estimate the model. Finally, we estimate the model and discuss the econometric results and draw implications.

4.1 Model Specification

Following the studies of Atkinson and Halvorsen (1984), Bhattacharyya, Parker, and Raffiee (1994), and Koh, Berg, and Kenny (1996), we use an actual variable cost function that exhibits the regular characteristics of the neoclassical variable cost function. We assume that the water utilities produce water (Q) using labor (L), energy (E), and a quasi-fixed capital stock (K). To account for the influence of institutional factors, input shadow prices $(P_i^*, i = L, E)$ are assumed to differ from observed market prices (P_i). As in Atkinson and Halvorsen (1984) and Koh, Berg, and Kenny (1996), shadow prices are related to observed market prices through a proportionality factor (k_i) that is input specific and depends on institutional factors (*i.e.*, $P_i^* = k_i P_i$).

Following Atkinson and Halvorsen (1984), we assume that water utilities choose inputs so as to minimize the shadow variable costs, $\sum_i (k_i P_i) X_i$, of the chosen level of output. *P* and *X* represent the observed input market prices and quantities. The water utility's shadow variable cost function is defined as $VC^S \equiv VC^S(kP, K, Q)$ where *kP* is a vector of input specific shadow prices that depend on institutional factors and *K* and *Q* are as defined above. Actual input demand functions can be derived from the shadow variable cost function by applying Shephard's Lemma, $\partial VC^S / \partial(k_i P_i) = X_i$. Thus, the water utility's actual variable cost function can be written as $VC^A = \sum_i P_i X_i = \sum_i P_i[\partial VC^S / \partial(k_i P_i)]$. By specifying an appropriate functional form for the shadow variable cost function, we can derive a parametric expression for the water utility's actual variable costs.

To simplify notation, define M_i^S as the shadow variable cost share of input *i*, that is

$$M_i^S \equiv \frac{k_i P_i X_i}{VC^S}. \qquad [1]$$

From [1] we have that

$$X_i = M_i^S (VC^S)(k_i P_i)^{-1}$$

which, when substituted in the actual variable cost function yields

$$VC^A = (VC^S)\sum_i k_i^{-1} M_i^S .$$

Taking logarithms we have that

$$\ln(VC^A) = \ln(VC^S) + \ln \sum_i k_i^{-1} M_i^S . \qquad [2]$$

For purposes of estimation, the logarithmic shadow variable cost function, $\ln(VC^S)$, is specified as a translog function

$$\ln(VC^S) = \alpha_0 + \alpha_K \ln(K) + \alpha_Q \ln(Q) + \sum_i \alpha_i \ln(k_i P_i) + \tfrac{1}{2}\sum_i \sum_j \beta_{ij} \ln(k_i P_i)\ln(k_j P_j) + \tfrac{1}{2}\beta_{KK}[\ln(Q)]^2 +$$
$$\sum_i \beta_{ik} \ln(k_i P_i)\ln(K) + \tfrac{1}{2}\beta_{QQ}[\ln(Q)]^2 + \sum_i \beta_{iQ} \ln(k_i P_i)\ln(Q) \qquad i, j = L, E \qquad [3]$$

where $(\beta_{ij} = \beta_{ji})$. Linear homogeneity of the shadow variable cost function in shadow prices implies the following relationships among the parameters

$$\alpha_L + \alpha_E = 1,$$
$$\beta_{LL} + \beta_{EL} = 0,$$
$$\beta_{LE} + \beta_{EE} = 0,$$
$$\beta_{LK} + \beta_{EK} = 0, \text{ and}$$
$$\beta_{LQ} + \beta_{EQ} = 0.$$

Logarithmic differentiation of equation [3] yields parametric expressions for the shadow variable cost shares specified in equation [1],

$$\frac{\partial \ln(VC^S)}{\partial \ln(k_i P_i)} = \frac{k_i P_i}{VC^S} \frac{\partial (VC^S)}{\partial (k_i P_i)} = \frac{k_i P_i X_i}{VC^S}$$

$$= M_i^S = \alpha_i + \sum\nolimits_j \beta_{ij} \ln(k_i p_j) + \beta_{iK} \ln(K) + \beta_{iQ} \ln(Q) \qquad i, j = L, E \qquad [4]$$

Substituting in equation [2] for $\ln(VC^S)$ from equation [3] and for M_i^S from equation [4] yields the actual variable cost function

$$\ln(VC^A) = \alpha_0 + \sum\nolimits_i \alpha_i \ln(k_i P_i) + \alpha_K \ln(K) + \alpha_Q \ln(Q) + \tfrac{1}{2} \sum\nolimits_i \sum\nolimits_i \beta_{ij} \ln(k_i P_i) \ln(k_j P_j) + \tfrac{1}{2} \beta_{KK} [\ln(Q)]^2 +$$
$$\sum\nolimits_i \beta_{ik} \ln(k_i P_i) \ln(K) + \tfrac{1}{2} \beta_{QQ} [\ln(Q)]^2 + \sum\nolimits_i \beta_{iQ} \ln(k_i P_i) \ln(Q) +$$
$$\ln\left\{ \sum\nolimits_i k_i^{-1} \left[\alpha_i + \sum\nolimits_j \beta_{ij} \ln(k_j p_j) + \beta_{iK} \ln(K) + \beta_{iQ} \ln(Q) \right] \right\} \qquad i, j = L, E \qquad [5]$$

If in equation [5], $k_i = k_j$ for all *i*, *j*, the water utility's actual variable cost function, [5], reduces to its shadow variable cost function, [3], which in turn is equivalent under these conditions to the neoclassical variable cost function.

The actual variable cost share of input *i* (*i* = *L*, *E*) is defined as

$$M_i^A \equiv \frac{P_i X_i}{VC^A}. \qquad [6]$$

Substituting for X_i and VC^A yields

$$M_i^A = \frac{M_i^S k_i^{-1}}{\sum\nolimits_i M_i^S k_i^{-1}}$$

and substituting for M_i^S from equation [4] results in

$$M_i^A = \frac{\left[\alpha_i + \sum\nolimits_j \beta_{ij} \ln(k_j p_j) + \beta_{iK} \ln(K) + \beta_{iQ} \ln Q \right] k_i^{-1}}{\sum\nolimits_i \left[\alpha_i + \sum\nolimits_j \beta_{ij} \ln(k_j p_j) + \beta_{iK} \ln(K) + \beta_{iQ} \ln Q \right] k_i^{-1}} \qquad i, j = L, E. \qquad [7]$$

After imposing symmetry and homogeneity restrictions on the actual variable cost equation [5], it along with the actual cost share equation [7] will be jointly estimated. Since the sum of the actual variable cost shares is equal to one, the energy cost share equation is dropped during the estimation process.

To address the questions raised at the beginning of this section, the translog actual variable cost function intercept (a_0) and the linear terms in output (a_Q) and in shadow prices $(\alpha_i, i = L, E)$ are expanded as

$$\alpha_0 = a_0 + b_0 Z_1 + c_0 Z_2 + d_0 Z_3 + e_0 Z_4 + f_0 Z_5$$

$$\alpha_Q = a_Q + b_Q Z_1 + c_Q Z_2 + d_Q Z_3 + e_Q Z_4 + f_Q Z_5$$

$$\alpha_i = a_i + b_i Z_1 + c_i Z_2 + d_i Z_3 + e_i Z_4 + f_i Z_5 \qquad [8]$$

where

$$Z_1 = \begin{cases} 1 & \text{if water utility is managed by the municipality} \\ 0 & \text{if water utility is managed by the state} \end{cases}$$

$$Z_2 = \begin{cases} 1 & \text{if water utility is directly administered} \\ 0 & \text{if water utility is autonomous} \end{cases}$$

$$Z_3 = \text{percentage of connections with continuous service}$$

$$Z_4 = \begin{cases} 1 & \text{if the state adopted the model water law} \\ 0 & \text{otherwise} \end{cases}$$

$$Z_5 = \begin{cases} 1 & \text{if the water utility is located in a water abundant area} \\ 0 & \text{otherwise} \end{cases}$$

It is through these Z variables that we will be able to test the hypotheses or questions posed at the beginning of this section. For example, the sign of the coefficient associated with variable Z_1 could tell us whether water utilities managed by municipalities are more efficient (have lower variable cost) than water utilities managed by states and also whether this is true at higher output levels (Q) and lower input costs (P_i). If the coefficient is negative it will imply that municipal water utilities are more efficient than state water utilities. Likewise, if the sign of the coefficient associated with variable Z_2 is negative it will indicate that directly administered water utilities which have combined normative and operative functions are more efficient than autonomous water utilities whose normative and operative functions are separated. The sign of the coefficients on Z_1 and Z_2 could be examined jointly to rank (in terms of efficiency) the various types of water utilities (*i.e.*, directly administered at the state level, autonomous at the state level, directly administered at the municipal level, and autonomous at the municipal level).

The variable Z_3 was introduced because it is expected that water utilities that have a greater percentage of connections with continuous service will have higher variable costs than those with a lower percentage of connections with continuous service. It is expected that the sign of the coefficient associated with Z_3 will be positive.

The variable Z_4 was included in the model to determine whether the adoption of the National Water Commission's model state water law influences the performance of water utilities. It is expected that water utilities located in states, which have adopted the model law, will have lower variable costs since the law promotes the efficient use of water. Therefore, it is expected that the sign of the coefficient associated with this variable should be negative.

Variable Z_5 was included to examine whether water scarcity influences the variable cost of the water utilities. It is expected that the sign of the coefficient of this variable will be negative, implying that variable costs are lower for water utilities located in water abundant areas. This is so because water utilities located in water scarce areas will have to transport water from water abundant areas and this will lead to increased costs.

To complete the model we specified the factors of proportionality as $k_i = \gamma_i + \omega_i Z_1$. This specification implies that differences in price efficiency between municipal and state managed water utilities are reflected in the k_i coefficient. Since the actual variable cost function and the actual share equations are homogenous of degree zero in the k_i 's, we incorporate one normalization on the k_i (Diewert, 1974). Thus, k_E is normalized to one by setting γ_E equal to one and ω_E equal to zero.

4.1 Data

The data for this study were obtained from the *Unidad de Programs Rurales y Participación Social* branch of Mexico's National Water Commission. The data are from 1995 and represent a sample of 146 water utilities throughout Mexico, excluding Mexico City. The data come from the questionnaire that the water utilities fill out and submit to the National Water Commission. The questionnaire is divided into five sections: (a) general information, (b) the operational system, (c) the commercial system, (d) the administrative system, and (e) the financial system.

Due to missing data, the initial sample of 146 water utilities decreased to 115 water utilities. Using these data, the following variables were constructed. Total output (Q) was calculated as the total quantity of water produced and delivered in millions of liters per year. The output price was computed as total revenue divided by billed water in millions of liters. Variable cost was constructed as the sum of observed total expenditures on labor and energy. Observed labor costs per worker was obtained by dividing total annual costs of labor by the number of employees and is expressed in thousand dollars per year. It was not possible to obtain observed energy cost per kilowatt since the questionnaire did not contain any information on the amount of energy the water utility consumed per year. To circumvent this problem, we obtained the price of energy per kilowatt for 1995 for each state from the annual statistics published by INEGI and assigned this price to each water utility based on the state it was located in.

The capital stock was estimated, following Moroney and Trapani (1981), as the residual of revenue less variable cost divided by the opportunity cost of capital. The rate of cost of capital was obtained from *Banobras* and includes an average depreciation rate. The monetary data is expressed in 1995 US dollars, the exchange rate used to convert 1995 pesos to dollars was $ 6.6 pesos/dollar.

The Z variables were obtained as follows. Variables Z_1 and Z_2 were obtained from data in the *Unidad de Programs Rurales y Participación Social* of the National Water Commission. Variables Z_3 and Z_4 were coded from the information contained in the water utility questionnaires. Variable Z_5 was obtained from information contained in *the Ley Federal de Derechos en Materia de Agua* (Comisión Nacional del Agua).

4.2 Estimation and Results

The econometric model, which consist of equations [5], [7] and [8], was estimated using an iterative nonlinear seemingly unrelated regression, which in convergence approximates maximum likelihood estimation. To facilitate the interpretation and estimation process the variable cost, output quantity and input price data were divided by their respective mean value. The model was first estimated as specified in equation [5], [7], and [8] but the results were not reasonable. Many of the estimated values were insignificant or had the wrong sign. The model was subsequently estimated after deleting some of the Z variables that were insignificant. The parameter estimates and associated t-statistics are presented in Table 6. The overall R-squared value for the model was 0.82. We checked the estimated model for concavity, monotonicity, and nonnegative conditions and found that the conditions were all satisfactorily met.

It is interesting to note that the variable (Z_4) which indicates whether the state where the water utility is located has adopted the model law being advanced by the National Water Commission was insignificant, and subsequently was excluded from the final model. This implies that the adoption of the National Water Commission's model state law does not influence the performance (in terms of lower variable cost) of water utilities, at least not for the utilities included in the data. This could be the case because few water utilities in the sample data were located in states that had adopted the law or because the existence of the law, by itself, has no impact on water utility efficiency.

Another point to note is that the variable (Z_5), which indicates whether the water utility is located in a water abundant area or not had the appropriate sign (negative) but was insignificant, and therefore was excluded from the final model. This implies that water abundance does not influence the variable cost function of water utilities.

As can be observed in Table 6, the intercept in the variable cost function was specified as being dependent on the municipal/state dummy variable, autonomous/directly administered variable, and on the percentage of connections with continuous service. Of these variables only the municipal/state dummy variable is significant, with a negative coefficient. Holding all else constant this implies that water utilities managed at the municipal level are relatively more efficient than water utilities managed at the state level. The insignificance of the autonomous/directly administered dummy variable implies that neither type of organizational structure (autonomous or directly administered) statistically influence the relative efficiency of water utilities. These results indicate that if Mexico wants more efficient water utilities that it needs to focus more on managing water utilities at the municipal rather than focusing on the separation of normative and operative functions.

Of the estimated coefficients associated with the linear terms in output, only b_Q is significant. The positive and significant b_Q coefficient implies that as output increases, water utilities that are managed by municipalities become relatively less efficient. Note also that the negative b_0 coefficient and the positive b_Q imply that water utilities managed by municipalities are more efficient than water utilities managed by the state at low output levels and are less efficient at high output levels. Alternatively, there is no evidence that the effect of output differs if the water utility is autonomous or not since the coefficients c_0 and c_Q are not significant.

As expected, the estimated values of α_L and α_E are positive. Six of the base coefficients (a_L, b_L, d_L and a_E, b_E, d_E) are significant. We find no differences between autonomous and directly administered water utilities in the effect of shadow prices on cost: the coefficients c_L and c_E are not significant. Alternatively, the negative b_L and b_E coefficients indicates that labor and energy prices have a lower impact on costs for municipally managed water utilities than state managed water utilities.

Table 6

Generalized Variable Cost Function Estimates

				Municipal/ State		*Autonomous/ Dir. Administered*		*% Connections With Cont. Serv.*
Intercept								
a_0	a_0	-0.299	b_0	-0.390*	c_0	0.102	d_0	0.072
		(-0.64)		(-2.54)		(1.07)		(0.43)
Shadow Price Coefficients								
a_L	a_L	0.439*	b_L	-0.177*	c_L	0.037	d_L	0.151*
		(2.02)		(-1.69)		(1.25)		(2.88)
a_E	a_E	0.561*	b_E	-0.124*	c_E	0.015	d_E	0.097*
		(2.59)		(-1.69)		(1.25)		(2.88)
b_{LL}		-0.126*						
		(-7.31)						
b_{LE}		0.126*						
		(7.31)						
b_{EE}		-0.126*						
		(-7.31)						
Shadow/Market Price Ratios								
k_L	γ_L	0.881*	ω_L	-0.322				
		(3.81)		(-1.35)				
k_E	γ_E	1.000	ω_E	0.000				
Output Coefficients								
a_Q	a_Q	1.145	b_Q	0.204*	c_Q	-0.078	d_Q	0.112
		(1.36)		(2.42)		(-0.85)		(0.72)
b_{QQ}		-0.034						
		(-0.04)						
b_{LQ}		0.196						
		(1.03)						
b_{EQ}		-0.196						
		(-1.03)						
b_{KQ}		0.006						
		(0.40)						
Capital Coefficients								
a_K	a_K	-0.002	b_K	0.001	c_K	0.001	d_K	-0.001
		(-0.12)		(0.73)		(0.30)		(-0.19)
b_{KK}		0.003						
		(0.47)						
b_{LK}		0.008						
		(1.65)*						
b_{EK}		-0.008						
		(-1.65)*						

Notes: t-statistics in parenthesis; $a_E = 1 - a_L$; $b_{LE} = - b_{LL}$; $b_{EK} = - b_{LK}$; $b_{EQ} = - b_{LQ}$; $b_{EE} = b_{LL}$

* Significant at 5 percent level (one-tailed test)

As noted above, the shadow price/market price ratio for energy (k_E) has been normalized to one. However, we allowed the shadow price/market price ratio for labor to vary with the municipio/state dummy variable. As can be observed in Table 6, there is no evidence that constraints imposed by a water utility's regulatory environment at the municipal or state level distorts their factor prices: the coefficient ω_L is insignificant. Furthermore, with the normalization of $k_E = 1$ imposed, the restriction for relative price efficiency with respect to all inputs becomes $k_L = 1$. This restriction was not rejected at the .05 level, indicating that that the water utilities do minimize costs subject to market prices (*i.e.*, they are relatively price efficient). This implies that shadow prices are equal to market prices.

6 Conclusions

The goal of this study was to examine how organizational structures and legislative regimes, under which Mexico's water utilities operate, influence the efficiency of the potable water and sewage service sector. Overall, it was found that the institutional endowment of the sector significantly influences Mexico's potable water and sewage sector. Specific findings of the study are:

- The adoption of the National Water Commission's model state law does not influence the performance of the potable water and sewage sector.
- Water utilities managed at the municipal level are relatively more efficient (have lower variable costs) than water utilities managed at the state level.
- The separation of a water utilities' normative and operative function does not influence its relative efficiency.
- At low output levels, water utilities managed at the municipal level are more efficient than water utilities managed at the state level but the reverse occurs at high output levels.
- There is no evidence that constraints imposed by the regulatory environment in which a water utility operates distorts their factor prices.
- Mexico's water utilities are relatively price efficient.
- The location of water utilities in a water abundant area does not influence the variable cost function of water utilities.

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