Policies for Meeting Future Water Needs in Mexican Cities

Alejandro Salazar-Adams[1] and Nicolás Pineda-Pablos[2]

Abstract

The aim of this paper is to evaluate the impact of water management policies on the future demand for water in major Mexican cities. Scenarios of water demand and proposed management policies were projected to the year 2030 for a sample of 21 cities with population greater than 500,000. According to these scenarios it is concluded that without any improvement in management policies, by 2030 most of these cities would face water shortages; however, if all proposed measures were carried out, only 4 cities would require additional sources of water.

Key words: sustainable water management, demand projections, price elasticity of water, income elasticity of water, public policy scenarios.

Introduction

During the last decade, population growth has increased the water needs of Mexican cities and water shortages have occurred in cities as important as Mexico City. As the population of Mexican cities grows in the future, a greater pressure will be put on water resources and shortages will probably be more frequent. However, population growth is probably not the main cause of these shortages, but rather the poor management of urban water in most Mexican cities: the current average price is below water production costs, revenue collection efficiency is low and unaccounted for water (mainly due to leakages) levels are high. Instead of improving management policies, local governments usually search for solutions based on increasing the supply of water by means of

[1] El Colegio de Sonora, email: asalazar@colson.edu.mx
[2] El Colegio de Sonora, email: npineda@colson.edu.mx

additional sources. However, this approach is rather expensive and unsustainable. In contrast, a demand management approach is proposed by increasing the average water price and revenue collection efficiency, in order to induce a reduction in the per capita quantity of water demanded and to reduce the unaccounted for water levels.

In order to evaluate policies to improve water management in Mexican cities, in this paper a demand function was estimated in order to obtain income and price elasticities, then, projections were made in order to determine the total quantity of water demanded by each city under five scenarios. This paper is divided in sections: in the *Water in Mexican Cities* section, an overview of the demand and management in Mexican cities is presented; in the *Methods and Procedures* section, the estimation and projection approaches are described; in the *Results and Discussion* section, the estimation of elasticities and the projection of scenarios are presented; and finally in the *Conclusions* section the main findings of this study are summarized.

Water in Mexican Cities

Urban water in Mexico is managed mainly by local governments. These local governments face the challenge of providing water to an ever increasing population. Not only cities are growing, but also, the cities with greater growth are located in the north of the country, which is the most arid region in the country (Pineda and Salazar, 2009). In spite of population growth and ever harder to obtain water supplies, water managers have not addressed the problem posed by the high levels of water loss. A good indicator of this is the Water Use Efficiency (WUE), which is calculated as follows:

$$WUE = \frac{Total\ Water\ Billed}{Total\ Water\ Produced} \qquad (1)$$

Table 1 shows that, on average, WUE in major Mexican cities is about 59%. That is, only 59 liters out of every 100 liters of water produced are actually consumed by customers. The rest of the water (41%) is lost due to leakages in the water distribution networks. On average, per capita production of water in Mexico is 310 liters per day, but once we take into account water losses, the effective (net) per capita consumption is only 182 liters per day. Table 1 also shows that WUE differs from one city to another. Mexicali, for instance, has the highest WUE (83%) while Merida has the lowest (36%).

Table1. Cities with population greater than 500,000

City	Population with water services	Per capita Water Production	Water Use Eficiency (WUE)	Net per cápita Consumption	Collection Eficiency (CE)
Acapulco	593,078	366	38%	139	87%
Aguascalientes	659,701	340	56%	191	91%
Cancún	567,963	283	79%	224	66%
MexicoCity	8,277,960	334	59%	197	78%
Chihuahua	716,781	460	53%	244	89%
Ciudad Juárez	1,310,302	413	59%	244	79%
Culiacán	613,144	288	67%	194	88%
*Guadalajara**	3,408,488	231	68%	157	n.a.
Hermosillo	688,112	400	47%	187	74%
León	1,086,298	205	57%	117	70%
Mérida	795,146	346	36%	125	92%
Mexicali	718,516	325	83%	270	61%
*Monterrey**	3,459,121	275	70%	193	99%
Morelia	587,823	452	40%	181	56%
Puebla	1,733,393	183	68%	124	70%
Querétaro	612,156	310	51%	158	100%
Reynosa	536,587	294	64%	189	65%
Saltillo	597,584	221	55%	221	n.a.
San Luis Potosí	921,958	291	51%	150	88%
Tijuana	1,486,800	191	81%	155	70%
Torreón	557,203	307	51%	158	86%
** metropolitan zone*					
Maximum	8,277,960	460	83%	270	100%
Mínimum	536,587	183	36%	117	56%
Average	1,425,148	310	59%	182	79%
Median	716,781	307	57%	187	79%

Another common problem of water management in Mexico is collection. Not only are water prices low (8.3 pesos or 0.68 US dollars per m^3 on average), but collection is also rarely enforced, so customers have not incentives to reduce their consumption. The indicator used for measuring Collection Efficiency (CE) is calculated as follows:

$$CE = \frac{Total\ Collection}{Total\ \ Billing} \qquad (2)$$

Table 1 shows that average CE in Mexico is about 79%, which means that 79 out of every 100 pesos billed for water services are actually collected by local utilities. By having a low collection, utilities usually face financial constraints: acording to Conagua data (2008) revenue amounts to only 73% of the expenses of water utilities. Therefore, utilities have no financial resources to improve the service and reduce of leakages. In addition, when collection is not enforced, people are less likely to reduce consumption, so the whole city requires more water sources to provide the population.

Despite these inefficiencies, Mexican water managers have barely focused on improving these indicators. Instead, they usually propose new sources of water for the cities, which have to be financed by the federal or state government because utilities cannot afford them as a result of their low revenue collection levels. If they cannot get these additional sources, then the daily number of hours of water service is reduced. However, reducing the hours of water provision induces a high variation on the water pressure of the network, which in turn causes the pipes to deteriorate, increasing the number of leakages and thus reducing WUE. Thus, utilities around the world have realized the importance of planning urban water resources on the basis of water demand management rather than supply of additional water, but in spite of some exceptional cases, Mexican utilities are still focusing on additional sources or reduction of hours of service. In the next section, we propose policies based on improving efficiency indicators and a method for assessing their future impact.

Methods and Procedures

This study comprises two phases. First, the estimation of elasticities and second, the projection of scenarios. Due to information availability, two different sets of data were used for each phase. In the first phase (estimation) a panel of 134 cities for the period 1996-2001 was used because after this year, data quality and quantity went down.

For the second phase, more recent data was required, thus, a sample of 21 cities with population greater than 500,000 and information available for the 2004-2007 period was used. By using these cities for projection, it is also possible to focus on the policy effects for mayor cities, and also on those cities with a greatest population growth.

Estimation

In order to construct prospective scenarios, price and income elasticities were obtained by means of fitting a demand function. Per capita water consumption in Mexican cities was modeled as a function of income, price and sociodemographic and climate variables that act as demand shifters. Thus, water demand in a city would be given by:

$$Q = f(Y, P, HSIZE, TMAX, PRECIP) \qquad (3)$$

Where

Q is the per capita water quantity demanded

Y is per capita income

P is the average water Price (Mexican pesos/m3)

HSIZE is the household size

TMAX is the average maximum temperature

PRECIP average annual precipitation

Regression parameters were estimated by three different methods. First, ordinary least squares (OLS) method was applied. However, this method might not be appropriate, since most Mexican cities apply an increasing rate tariff scheme, therefore, the price of water is affected by quantity of water demanded, so this variable is correlated to the error term. For that reason, a second model was obtained through the instrumental variables (IV) approach. In this model, in the first stage the endogenous Price (P) variable was estimated through the instrumental variables Population (POP), Proportion of the population with water services (PPW) and Proportion of rented houses (PRH). These variables were selected based on the study by Nauges and Thomas (2000).

The data for this estimation comprises information on 134 cities with a population greater than 30,000 in the year 2001. Various sources of information were used: data on price and water consumption was obtained from Conagua publications for the period 1996-2001, however since not all cities are included every year, the data has an unbalanced panel structure with an average of 5.8 years per city. The population of these cities amounts to 26.7 million, which was about one fourth of the Mexican Population at that time. Data for precipitation and temperature were obtained from IMTA (2006). Average price (P) was obtained by dividing collection by the total quantity of water billed. The quantity consumed was obtained dividing the total billed quantity by the population of a city with water services. Municipal per capita GDP (Conapo, 2001) was used as a proxy of income (Y). The variables HSIZE and the variables used as instruments were obtained from census data (INEGI, 2009).

Projection

Based on the elasticities obtained, water demand scenarios were projected for a sample of cities. Cities with a population greater than 500,000 and information available from 2004 to 2007 were selected. These cities are the ones shown on table 1.

In order to project demand scenarios the average price (P) of water is assumed as the price billed (PB) times the Collection Efficiency (CE):

$$P = PB \times CE \qquad (4)$$

Thus, any increase in the Collection Efficiency (CE) would increase average price (P), and thus, it would reduce average per capita demand. This relationship is important because it means that utilities can induce reductions in per capita demand just by measuring and collecting from customers that are not paying their bills. It also implies that any increase in the price for water would only work as an incentive for the reduction of water consumption only as long as collection is effectively enforced. Since the total water consumption in a city depends also on population growth, projections to the year 2030 made by Conapo (2009) were used. Income growth was projected based on the observed trends for the state GDP for the period 1993-2006 (INEGI, 2009). The projected scenarios were:

i. Business as Usual. (Current WUE and CE levels)
ii. Water Use Efficiency (WUE) increased to at least 80% in every city.
iii. Same as (ii) plus Collection Efficiency (CE) increased to 95%
iv. Same as (iii) plus a 50% price (P) increase
v. Same as (iv) plus a 100% price (P) increase

Results and discussion

Estimation

In order to estimate the regression parameters a double logarithmic (log-log) functional form was applied. Regression results are shown in table 2

Table 2. Regression Parameters

Variable	*OLS*	*IV*	*GLS*
P	-0.6731 (***) (-27.97)	-0.3325 (***) (-4.18)	-0.3396 (***) (-3.02)
Y	0.3147 (***) (5.54)	0.2222 (***) (3.27)	0.1924 (*) (1.79)
PRECIP	-0.5256 (***) (-5.54)	-0.2955 (***) (-6.00)	-0.2075 (***) (-3.88)
HSIZE	-1.996 (***) (-7.35)	-1.541 (***) (-4.74)	-1.7718 (***) (-3.43)
TMAX	-0.1504 (***) (-3.16)	-.1944 (-1.51)	-0.2751204 (-0.87)
Intercept	8.2204 (***) (8.17)	7.5036 (***) (6.48)	8.0998 (***) (4.38)
Adj. R^2.	0.5723(***)	0.4449(***)	0.5188(***)

t statistics in parenthesis, significance at 10%, 5% and 1% are indicated by (*), (**) and (***) respectively

The three models show significant a fit, but elasticities are lower when instrumental variables are used. In the OLS model, Price elasticity is -0.67, whereas in the instrumental variables approach the elasticity is -0.33. Income elasticity in the elasticity obtained through OLS is 0.31, while IV is 0.22. The GLS model results are not very different from IV so elasticities in both models are very alike. As it has been explained, the IV estimates are more adequate because of the pricing scheme, therefore, the IV model elasticities were used for the projection

Projection

The projected scenarios are shown in table 3.

Table 3. Scenario Projections

	Population 2030	Current	1.Business as Usual	2. WUE Increase	3. WUE and CE Increase	4. WUE, CE and 50%Price increase	5. WUE, CE and 100%Price increase
Acapulco	473,499	79	70	33	32	28	23
Aguascalientes	905,944	82	130	91	90	77	62
Cancún	1,186,633	59	130	128	116	108	88
Mexico City	8,575,089	1008	1161	856	808	722	588
Chihuahua	977,517	120	210	139	136	117	95
Culiacán	635,294	64	75	63	62	53	43
Guadalajara	4,191,210	287	398	338	n.a.	285	232
Hermosillo	966,821	100	175	102	95	86	70
Ciudad Juárez	1,787,710	198	345	254	241	214	174
León	1,703,109	81	162	116	106	98	79
Mérida	955,433	100	141	64	63	54	44
Mexicali	972,975	85	155	155	137	130	106
Monterrey	4,317,876	347	534	467	473	394	321
Morelia	732,664	97	148	74	64	62	51
Puebla	1,832,038	116	147	125	114	105	86
Querétaro	849,737	69	123	78	79	66	54
Reynosa	904,901	58	119	95	86	80	65
Saltillo	908,601	48	93	64	n.a.	54	44
San Luis Potosí	839,084	98	110	71	69	60	49
Tijuana	2,483,777	104	232	232	213	196	159
Torreón	673,286	63	96	61	60	52	42
Maximum	8,575,089	1,008	1,161	856	808	722	588
Minimum	473,499	48	70	33	32	28	23
Average	1,755,867	155	226	172	160	145	118
Median	966,821	97	147	102	95	86	70
Cities without shortages			**1**	**6**	**9**	**13**	**17**

In the first column (**Population 2003**), the projected population to 2030 is shown. It can be seen that the median size of the cities would grow from 716 thousand (table 1) to 966 thousand in 2030, an increase of 35%. In the second column (**Current**) the current (as for 2007) consumption of water in millions of m^3 for every city is shown. In the rest of the columns, the consumption for every scenario is shown. The shadowed figures indicate that there is a water shortage in that city according to the projection.

It can be seen that in the Business as Usual scenario (i), all but one city (Acapulco) face water shortages. However it is only because Acapulco is the only city in the sample whose population is expected to decrease. The average water consumption would increase from 155 million m^3 to 226 million m^3, which implies that cities would on average require about 50% more water to meet their needs if current management practices are maintained.

Scenario (ii) shows that increasing WUE to at least 80% would allow 5 more cities (Mexico City, Culiacan, Mérida, San Luis Potosí and Torreón) to cover their water needs with the current water production. Average water consumption would only increase to 172 million m^3, only 10% more from current consumption.

Scenario (iii) shows that in addition to increasing WUE, increasing CE would allow three more cities (Hermosillo, Morelia and Puebla) to avoid shortages with the current water production. Thus, just by increasing these two efficiency indicators, 9 out of 21 cities would not need additional water sources.

As for the price, scenario (iv) shows that in addition to the improvement of efficiencies, increasing the price by 50% would allow 4 more cities (Aguascalientes, Chihuahua, Guadalajara, and Querétaro) to avoid shortages, so a total of 13 out of 21 cities would cover their water needs without any additional resources.

Finally, scenario (v) shows that in addition to the improvement of efficiencies, increasing the price by 100% would allow a total of 17 cities to avoid shortages, with only 4 cities requiring additional water sources. These 4 cities are the ones with the highest annual population growth rate in the sample (more than 1.6%): one of these cities (Cancún) is the most important beach tourism destination in Mexico and 3 of them (Monterrey, Tijuana and Reynosa) are some of the most important industrial cities located in the north of the country. The city with greater consumption growth would be Tijuana, since it would require an additional 54 million m^3 of water. It must be noted that Tijuana already has an important WUE level (81%) so only collection efficiency only and price increases would allow the city to reduce consumption, but it would still require additional sources.

Conclusions

According to these scenarios it is concluded that without any improvement in management policies, by 2030 current water production would meet only about 65% of Mexican cities water demand on average; however, if unaccounted for water levels are reduced from an average 40% to 20%, then 6 out of the 21 cities in the study would not have water shortages at all, if the natural water availability remains at its current level. Finally, if all proposed measures were carried out, only 4 cities with a projected average annual population growth greater than 1.6% would require additional sources of water.

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