Industrial water demand in Mexico : Econometric analysis and implications for "water management policy".

Hilda Guerrero Garcia Rojas

UNIVERSITE DE TOULOUSE 1 - SCIENCES SOCIALES

INDUSTRIAL WATER DEMAND IN MEXICO: ECONOMETRIC ANALYSIS AND IMPLICATIONS FOR WATER MANAGEMENT POLICY

THESE

Pour le Doctorat en Sciences Economiques
Sous la direction d'Alain ALCOUFFE
et Jean-Pierre AMIGUES
Présentée et soutenue le 14 février 2005 par

Hilda GUERRERO GARCIA ROJAS

Membres du Jury

Alain ALCOUFFE, Professeur, Université de Toulouse 1.
Jean-Pierre AMIGUES, Directeur de Recherche INRA, Université de Toulouse 1
Patrick POINT, Directeur de Recherche CNRS, Université Bordeaux IV, rapporteur
Steven RENZETTI, Professor at Brock University, Canada, rapporteur
Alban THOMAS, Directeur de Recherche INRA, Université de Toulouse 1

L’Université de Toulouse 1 - Sciences Sociales n’entend donner aucune approbation ni improbation aux opinions émises dans cette thèse: ces opinions doivent être considérées comme propre à leur auteur.

Contents

3 Manufacturing Water Demand in Mexico

4. Experiments on water for industrial use in Mexico

Annex A

List of Figures

List of Tables

Acknowledgements

I would like to express my thanks to the Consejo Nacional de Ciencia y Tecnología (Conacyt) from Mexico for the scholarship which allowed me to do my PhD Program.

I wish to express my sincere gratitude to Professor Alain Alcouffe for accepting me under its direction, as well as to my co-director Professor Jean-Pierre AMIGUES.

My gratitude to Professor Patrick POINT and Professor Steven RENZETTI for agreeing on evaluating my thesis research as examiners.

I also express my gratitude to Professor Michel Moreaux for giving me his support and confidence to pursue my doctoral program.

All my gratitude and reconnaissance to Professor Alban THOMAS for his support, patience and advice all the way through my thesis work.

This research project would not be achieved without confident data. For the opportunity and the accessibility to Mexican data I am thankful to the Instituto Nacional de Estadística, Geografía e Informática (INEGI) and to the Instituto Mexicano de Tecnología del Agua (IMTA), both from Mexico, I specifically appreciate the support given by Pilar Hernández Valladares from INEGI as well as by Ramón Piña Sánchez and Ramón López Hernández, both from IMTA.

I gratefully acknowledge Charles Howe and Ariel Dinar for their continuous sustain to go after this non easy road that a PhD involves.

I thank Christine Garcia-Carro, Sylvie Billout and Aude Schloesing for their constant aid in my stage at the Manufacture de Tabac

My gratitude to Chantal Hornero for her friendship, for our long talks and for encouraging me during my adverse moments in Toulouse.

My special thanks to Gloria Gutierrez for sharing her tight time checking over the whole document in an extremely short schedule.

To all my friends here in Toulouse, in Spain, in Holland, in Mexico, or where they could be around the world, many thanks for being there, next to me, cheering me up on difficult moments and sharing the good ones.

DEDICATORIA

Esta tesis es para ti mamá, para ti papá, para ustedes hermanas (Ruth, Gloria, Verónica y Nora), y hermanos (Miguel, César, Sergio, Alejandro, Jorge y Marco), para ustedes sobrinas y sobrinos quienes ahora forman una nueva generación con aspiraciones, ilusiones y valores como los que me enseñaron sus abuelos . Todos ustedes, mi familia, me han dado su apoyo, su confianza, su cariño incondicional. Gracias por hacerme saber cada uno a su manera que siempre estan conmigo.

Mami, papi una vez mas les agradezco, ya que son ustedes quienes me han impulsado y dado la inspiración para seguir adelante, quienes me han enseñado la satisfacción que da luchar por un ideal y poner la vida al servicio de un ideal.

Esta tesis es la muestra de un triunfo más del espíritu de lucha de nuestra numerosa y querida FAMILIA.

Introduction

It is well documented that water is becoming a resource with increasing scarcity for a large number of countries, principally semiarid ones. In order to promote efficient water management, policymakers are trying to find the best way to allocate existing water reserves and persuade users to adopt conservation practices. In the search of mechanisms to support that, around the world, different economic instruments have been used to promote an efficient water use. The most used are taxes, charges, subsidies, levies and quotas. But the effectiveness of the results that any of them could generate is in function of the economical and political context where they are applied.

The price of water has been utilized as an economic tool to enforce water users to become more efficient, since a commodity price is seen as a measure of its scarcity. But also, water has ecological, recreational and social values that need to be reflected in the pricing system. Hence, a charging system should encourage a reasonable use of the environment. Meaning that, a price is supposed to be a sign of the right and the whole social costs for supplying water, including resource depletion.

Dinar and Subramanian (1997) document experiences, through several countries, on water pricing, and identify water pricing as a key to improve water allocation and encourage conservation. For this reason, reforms on water pricing have come to play an important role to encourage the use of water efficient. Dinar (2000) addresses this topic and presents a framework to compare water pricing reforms, as well as selected experiences of reforms in different sectors and countries.

In Mexico, like in many other countries, modern water management rests on a delicate balance between governmental regulation and market mechanisms. The country's legal and institutional reforms implemented in the early 90’s have the objective to achieve this balance.

Mexico's approach of pricing water has been pragmatic in nature. Thus, rather than going into a complicated scheme of calculating, if possible, opportunity costs or long term marginal costs, it has take into account the political resistance associated with the introduction of new fiscal burden. That is why, the introduction of water charge in 1986 considers less important to assign the "right" price than introducing the concept of water as an economic good with a specific value. Nevertheless, the initial water charges introduced by law consider some principles of proportionality, capacity to pay and actual water availability in every region.

The basis for developing and consolidating Mexico's Water Financing System is established by a system of charges for both water use and wastewater discharge. Besides providing an incentive to increase water use efficiency, which is already measurable, the collection of charges, for water use as well as for water discharge, have resulted in the generation of financial resources to carry out water programs and activities.

Mexico has a long hydraulic tradition, which goes back to Pre-Hispanic times, where the relation with water was not just for religious purposes, but it was associated with economic development. Water has influenced different aspects of the country social and economic development. For the past 80 years, the increasing water use in cities, industries and irrigation for agriculture have based its growth in the expansion of hydraulic infrastructure, as well as on the accomplishment of different policies to guarantee a proper water management. In 1989, The National Water Commission in Mexico (Comisión Nacional del Agua - CNA, by its acronym in

Spanish), was established and declared as the administrative agency responsible for the national water.

Mexican economy is the 10th largest in the world (WB-WDI 2003); no matter that it has not grow as fast as the ideal due to a series of economic crises and a rapid population growth. But there also exist some geographic limits that affect the economical development as nation's irregular terrain in addition to limited farmland. The number of conflicts for water demand has already increased as a consequence of the continued population growth and urbanization. These conflicts occur between urban and rural users, among neighboring cities, and, more commonly, between neighboring states and regions.

The problems requesting a new approach to water management have been diverse, among others it can be recognized an inefficient water use practices, poorer quality in water bodies; increasing differences between those who have access to water services and those who have not; reduction in water services as a consequence of inadequate maintenance as well as a feeble organization capacity for providing these services. In addition, water was, and still is, seriously under-priced carrying out inefficiencies in the resource allocation to its most beneficial use, as well as disturbing the quantity and quality of water services expected by the population and their economic activities.

Surrounded by this environment, at the beginning of 1990s, the Mexican Government started a number of structural reforms concerning the water sector and the management of national water resources. Legal and institutional modification took place and a series of strategies were implemented with a view of reverting negative trends. These transformations had a significant impact upon water consumers.

Considering that industrial water consumption comes, principally, from self-supplied water, its exploitation is under a concession – that is, water right - or license authorized by the National Water Commission, and the industry is under obligation to pay for a federal fiscal right for the use of water and also for wastewater discharge on national streams. These are unique (once and for all) payments. In addition, self-supplied industrial water users have to pay quarterly abstraction charges per cubic meter, depending on their geographical location, which is determined according to relative water scarcity. For effluent emission discharge, industrials also have to pay for contaminants as well as for the volumes discharged. On the subject of the abstraction charge payment, there are some subsidies. Additionally, some municipalities are also compensated for a given proportion of their water charges, resulting in an implicit subsidy scheme. The amount of all these payments are set up in the Federal Law Act (Ley Federal de Derechos en Materia de Agua), and they are updated each semester.

In this thesis, our goal is not to determine whether water price in Mexico already represents the relevant value for water. Instead, this research work deals with the effects water pricing reform in Mexico has produced inside Mexican manufacturing sector. Therefore, we try to answer the following questions: Is water price working as a good economical tool to support the efficient use of water within Mexican manufacturing sector? If this is the case, then what is the level of responsiveness of the demand of water by Mexican industry? What is the mapping of manufacturing sector in Mexico? And finally, what is the water demand constraint that allows us to identify the technical shutdown point of the firm?

This research work is the first effort, to our knowledge, of this kind of approach, in which we estimate the elasticities of substitution between water and other productive inputs for the aggregate Mexican manufacturing and mining sectors.

The outline of the thesis is as follows. Chapter 1 starts with a general description of the Mexican hydrological situation and in a worldwide context. The purpose of this chapter is to develop a framework of water management in Mexico and the evolution of its institutions and water legislation. In addition, we analyze the water pricing system actually used in Mexico as well as the principal water uses.

The literature concerning industrial water demands econometric estimation is quite concise regarding other water uses. Renzetti's works are the first documented studies in which water use is analyzed, not just as a one more input for industrial together with capital, labor and other inputs, but considering the different uses water may have within industrial production processes. That is, he takes account of different production steps implying water from a technical point of view: intake water, recirculation, water treatment prior to use and water treatment prior to discharges (Renzetti 1988); or intake and recirculation (Dupont and Renzetti 2001).

In the empirical literature, the production technology of the firm is usually characterized either by the Profit Maximization Problem -PMP (primal approach) or by the Cost Minimization Problem -CMP (dual approach). Input demand levels are derived from the result of one of the following approaches: profit maximization or cost minimization. Under the dual approach, it is not essential to identify the exact amounts of the input used. We only need information of input prices and final output levels. It holds because cost function is conformed by the conditional demand of factors, which are conditioned to a specific production level. The dual approach is privileged given that it is easier to reach reliable data with reference to input prices in an industry than the quantity of these inputs used by the firm.

Thus to characterize the technology of the Mexican industrial sector, we adopt the dual approach. Then we will consider a cost function which relates the (short-run) variable cost of production to input prices and to the output level. Translog functional form has become the most popular tool for estimating industrial input demand, due to the advantages it offers, like the capability to model production relationships with numerous inputs without imposing rigorous conditions on the elasticity of substitution.

As many other empirical studies, we will use the Translog Cost function to model Mexican industry cost structure.

In Chapter 2 we present a survey on industrial water demand and the microeconomic foundations we use to characterize the technology of the Mexican industrial sector. We also describe the Translog cost function we are going to apply to Mexican data of the manufacturing sector.

The conflicts between water users in Mexico have a long history. Then and now, industrial users have played an important role. We begin Chapter 3, Section 3.1, giving an overview of what has been the evolution of industrial sector in Mexico and its relationship with water.

Next, in Section 3.2, we give a general description of the participation of industrial activity in the Mexican economy, and we briefly describe some of the most relevant characteristics for the 8 major water demanded industries.

In Section 3.3 we present the data of Mexican industry. Data is for the aggregate Mexican manufacturing and mining sector. Even if, strictly speaking, mining is not a manufacturing industry, we include this sector in this thesis work because mining is considered one of the principal water users in Mexico. The 8 industrial sectors we use in this research are: mining, food, sugar, beverage, textile, paper, chemistry, and steel, which are representative of the major water demanded industries. The total amount of observations is 500 (single cross section of firms). In this Section we explain the source of the data and the way different variables are constructed.

In Section 3.4 we present preliminary variables analysis and we describe the correlation between them. Then, using the data of the 500 firms of eight industrial sectors, the industrial water demand is estimated, using a Translog cost system, by Seemingly Unrelated Regression (SUR) procedure.

In Section 3.5 we present the empirical results of the water demand for the Mexican industry, as well as the elasticities that the cost estimates allows us to obtain. We find that industrial water demand is inelastic and not very responsive to changes in water price (elasticity -0.2976). Water is found to be a substitute for both labor and materials in the sense of Morishima Elasticity of Substitution.

In Chapter 4, Section 4.1 we conduct an experiment whose objective is to evaluate the consistency of the industrial firm distribution regarding water availability zones. Presumably, if a firm faces the same market conditions, and if input prices for labour and materials are uniform throughout regions, then the firm will be better off by operating in the region where water is cheapest. If, on the other hand, a firm with intensive water use is located in a zone with a high price for water, this would indicate that profit differentials with other water availability zones depend on other factors such as those mentioned above. This experiment reports that 44.4% of firms are consistently located regarding the water availability zones.

In Section 4.2 we compare the water zones from our database against the availability water zones in year 2003. We got that 45.8% of our original database water zones are still in the same zone in the year 2003.

In Section 4.3 we perform a short experiment without subsidy on water price, where we, principally, make a brief data analysis to compare water price with subsidy and without it. In this Section we first give a note on the legal framework of subsidies on water price in Mexico. We carry out this experiment exclusively for those industrial sectors which benefit from a subsidy on water price. That is, the mining sector with a subsidy of 75%, sugar with a 50% subsidy and finally, those firms placed in Zone 7, 8 or 9 from paper sector that have a 20% subsidy on water price.

In Section 4.4 we perform an experiment to analyze the effect that elasticity on water price has on the volumes of water demanded by firms. First, we construct the elasticity for each of the 8 industrial sectors by availability water zone. Then, using these elasticities, we define 7 scenarios to analyze the water demand response against subsidy elimination. In the last experiment achieved we identify a water demand constraint to define the technical shutdown point of the firm.

Chapter 1

Water in Mexico

Introduction

Mexico has a long hydraulic tradition, which goes back to Pre-Hispanic times, where the relation with water was not just for religious purposes, but was associated with economic development. The hydraulic structure consisted of irrigation systems, aqueducts, chinampas (floating gardens of Xochimilco), and the hydraulic system of the Gran Tenochtitlan for both flood control and navigation (Guerrero, 1995).

The hydraulic structures from the Conquest times were followed by the Viceroyalty era. In the 18th and 19th centuries dams were built, some of which are still operating. The tradition to legislate water in the Mexico post-independence era has its origins with the Ley General de Vias Generales de Comunicacion (General Law of general communication routes) in 1888. It was followed in 1910 by the Ley de Aprovechamientos de Aguas de Jurisdicción Federal (Law of water use from Federal jurisdiction origin). The former already classified supply sources, regulated water uses and formalized concession regimes (Ortiz, 2001).

In 1926, the Law over Irrigation using Federal Water (Ley sobre Irrigación con Aguas Federales) was established, giving origin to the National Irrigation Commission (Comisión Nacional de Irrigación - CNI, by its acronym in Spanish). In

1947, the creation of the Secretaria de Recursos Hidraulicos provides a greater impulse to the development of the hydraulic infrastructure. Laws and Institutions were developed, and improved to respond to the requirements of the society. In 1960, different sector and regional Plans were promulgated with the goal to improve the use of the hydraulic resources. In 1975, the Plan Nacional Hidraulico was settled. And in 1989, The National Water Commission in Mexico (Comisión Nacional del Agua - CNA, by its acronym in Spanish), was established and declared as the administrative agency responsible for the national water.

Water has influenced different aspects of the country's social and economic development. For the past 80 years, the increasing water use in cities, industries and irrigation for agriculture has based its growth in the expansion of hydraulic infrastructure, as well as on the accomplishment of different policies to assure a proper water management.

Mexico's territory encloses an area of 1,964,375 Km^2 (CNA, 2003a) with a population of 100.9 million inhabitants (INEGI, 2000). In Latin America, only Brazil with 172 million inhabitants (WB-WDI, 2003) has a larger population than Mexico. In the Continent of America, Mexico is the fifth largest country. Mexico City, the nation's capital, is by some calculations the largest city in the world.

Mexican economy is the 10th largest in the world (WB-WDI 2003); no matter that it has not grow as fast as the ideal due to a series of economic crises and a rapid population growth. But there are also some geographic limits that affect the economical development as nation's irregular terrain in addition to limited farmland. The number of conflicts for water demand has already increased as a consequence of the continued population growth and urbanization. These conflicts occur between urban and rural users, among neighboring cities, and, more commonly, among neighboring states and regions.

The problems requesting a new approach to water management have been diverse, among others it can be recognized inefficient water use practices, poorer quality in water bodies; increasing differences between those who have access to water services and those who have not; reduction in water services as consequences of inadequate maintenance as well as a feeble organization capacity for providing these services. In addition, water was, and still is, seriously under-priced carrying out inefficiencies in the resource allocation to its most beneficial use, as well as disturbing the quantity and quality of water services expected by the population and their economic activities.

Surrounded by this environment, at the beginning of 1990s, the Mexican Government started a number of structural reforms concerning the water sector and the management of the national water resources. Legal and institutional modification took place and a series of strategies were implemented with a view of reverting negative trends. These transformations produced a significant impact on water consumers.

The purpose of this chapter is to develop a framework for water management in Mexico and the evolution of its institutions and water legislation. In addition, we analyze the water pricing system actually used in Mexico as well as the principal water uses. This chapter starts with a general description of the Mexican hydrological situation and in the worldwide context.

1.1 Water statistics in Mexico and in the world

Mexico is a Federal Republic, consisting of 31 federal entities and one federal district (DF), which are composed of 2430 municipalities and 16 political delegations in the DF. The territorial extension of the country is 1,964,375 km^2. Mexico is bordered in the north by the United States, in the south by Guatemala and Belize, in the east by the Gulf of Mexico and the Caribbean Sea, and in the west by the Pacific

Ocean. The Tropic of Cancer cuts almost by half the country, giving a specific climatic characteristic with arid climates in the north, warm-humid and sub-humid in the south and temperate or cold in regions with greater elevation.

Mexico has a vast diversity in its territory, making it a country with heterogeneous topographical characteristics. It also has a wide variety of natural resources. Therefore, the country has a wide range of climates. Two-thirds of the territory is arid or semi-arid, and the rest ranges from very humid to moderate.

Historic mean annual rainfall (1941-2001) is of 772 mm which results in a mean surface annual runoff of 394 Km^3 and 75 Km^3 of mean renewable groundwater (aquifers recharge), giving a mean natural water availability of 469 km^3 (CNA, 2003a). Rainfall varies widely both by location and season. 67% of the rainfall occurs in only 4 months, which is an attribute of countries with tropical influence, like Mexico. The country is regularly subject to hurricanes and it is continually influenced by drought periods. The climate during the summer is excessive in the occurrence of important rainstorms and for the rest of the year with an almost complete absence of precipitation.

The topographic characteristics and climatic conditions have an important role in the country, since they affect agricultural, livestock, forestry, industrial activities and human communities, and in that sense they affect social and economic activities. The estimated Gross Domestic Product (GDP) is of 6,512 thousand million Mexican pesos -current price of 2003. (INEGI, 2003). The estimated population for 2003 is 104.2 million inhabitants (CONAPO, 2002). Comparing these numbers with other countries (table 1.1), Mexico is the 10^{th} largest economy in the world and the eleventh most populated (WB - WDI, 2003).

Table 1.1 GDP and Population 2002.

Ranking for Economy		GDP (millions USD)	Population (thousands)	Ranking Population
1	United States	10 416 818	288 369	3
2	Japan	3 978 782	127 144	10
3	Germany	1 976 240	82 495	12
4	United Kingdom	1 552 437	58 858	21
5	France (a)	1 409 604	59 442	20
6	China	1 237 145	1 280 975	1
7	Italy	1 180 921	57 919	22
8	Canada	715 692	31 414	34
9	Spain	649 792	41 180	29
10	Mexico	637 205	100 921	11
11	India	515 012	1 048 279	2
12	Korea, Rep.	476 690	47 640	26
13	Brazil	452 387	174 485	5
14	Netherlands	413 741	16 144	57
15	Australia	410 590	19 581	50

Source: WB-WDI (2003). (a) Data include the French overseas departments of French Guiana, Guadeloupe, Martinique, and Réunion.

Considering water availability and precipitation in the world, the performance of Mexico is reported in table 1.2. The Mexican per-capita water accessibility is around 4,685 m^3/hab/year. According to the World Bank and United Nations, it is considered that a per-capita water availability lower than 1,000 m^3/year is a signal of a huge scarcity water problem, while less of 2,000 m^3 means a significant water stress level, principally under years of low precipitation (CNA, 2001).

Then, for the sample of countries reported in table 1.2, Mexico seems to be a country far from having water problems. And it would be true if the water availability were homogeneous throughout the territory, but less than a third of total runoff occurs within 75% of the national territory, where most of the country's largest cities, industrial facilities and irrigated land are located.

Table 1.2 Precipitations and Water Availability.

Country	Precipitation (mm/year)	water availability (km^3/year)	per-capita water availability (m^3/hab/year)	Ranking per-capita
Brazil	1 758	5 418	32 256	2
Canada	493	2 740	91 567	1
China	648	2 812	2 257	9
Egypt, Arab Rep.	18	2	930	10
Spain	684	112	2 844	8
United States	685	2 460	8 906	4
France	870	180	3 258	6
Indonesia	2 700	2 838	13 709	3
Mexico	772	469	4 685	5
Turkey	647	196	3 162	7

Source: CNA (2003a).

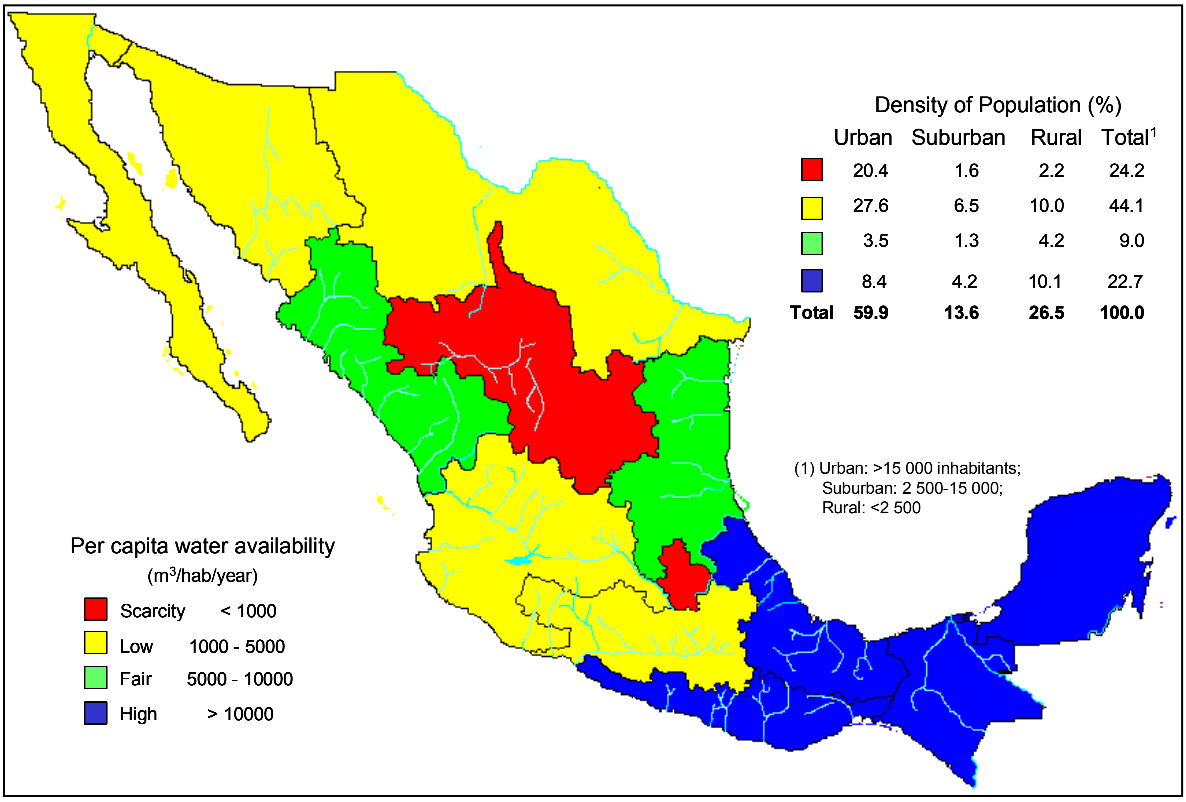

Figure 1.1 Regional Water Availability (Source: IMTA, 1999).

Figure 1.1 depicts this irregular per-capita water availability along the country. It can be seen that in two of the 13 hydrologic regions, fresh water resources fall below the 1000 m^3 per person per year, revealing a persistent scarcity situation. Five other hydrologic regions fall between 1,000 and 5,000 m^3 per person per year, which indicates periodic and regular water stress.

As it was already pointed out, the climatic and topographic characteristics in Mexico are heterogeneous and these have an influence on the economic activity. Figure 1.2 highlights how both population and economic activity are inversely related to water availability in Mexico, since 32% of the runoff occurs where 77% of the population reside and 86% of the GDP is generated (Guerrero, 2002).

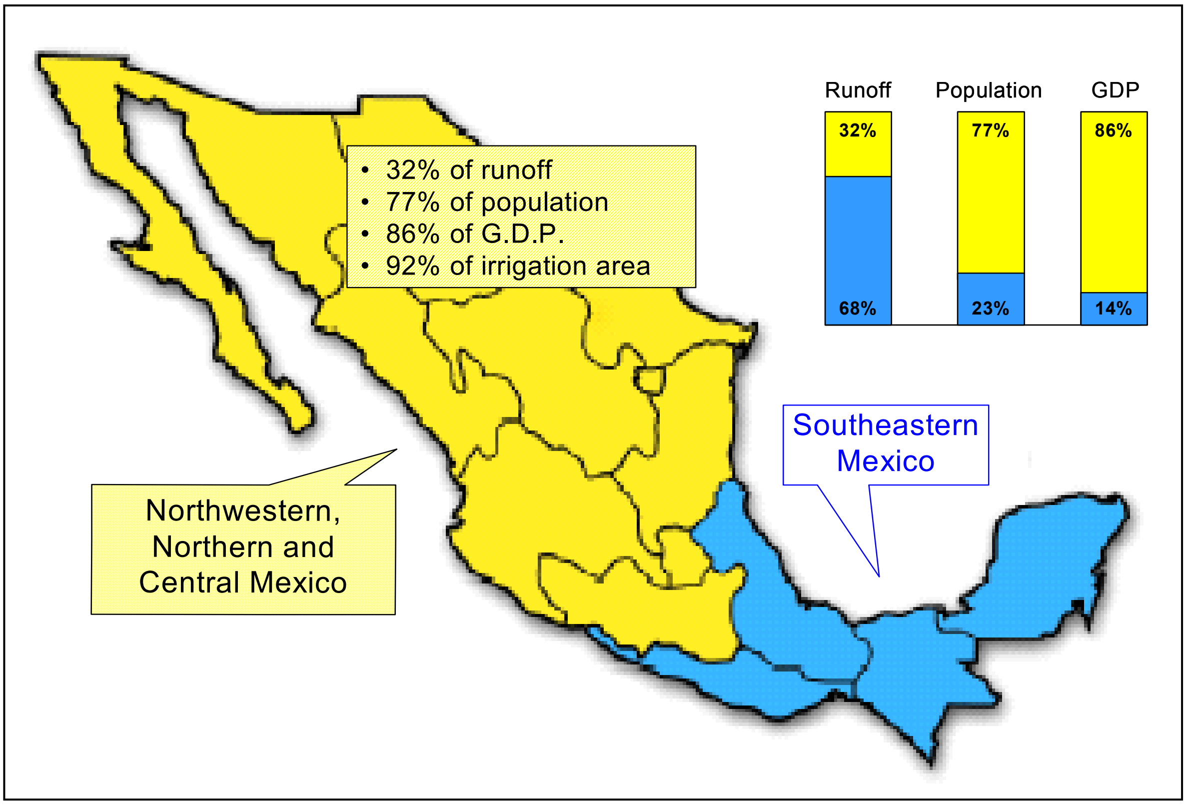

Figure 1.2 Water Availability and Economic Activity (Source: Guerrero, 2002).

That is, population concentration and economic activity in the country take place in areas where water is right now scarce. Or maybe it obeys to the phenomenon that, on one hand, historically the population in Mexico has been concentrated in the central regions of the country, with development moving northward along central plateau; and on the other hand, the climatic aspect already mentioned, both facts have resulted in water availability problems.

Today, the population in Mexico is concentrated in large urban centers and is also scattered in smaller towns. Metropolitan cities like Mexico, Guadalajara and Monterrey concentrate more than 25% of total population of the country.

Consequently, surface runoff and ground water are less and less sufficient to sustain the population elevated growth rates and economic activity, resulting in over-pumped aquifers and in some cases a need to transfer water between river basins. Additionally, for some water bodies their potential use has been affected by pollution. Then, conflicts for the use of water have increased causing important political and social effects.

Most groundwater use takes place in the arid and semi-arid areas of central, northwestern and northern Mexico where the pumping/recharge balances are negative, with the consequent over-exploitation of numerous aquifers. Total annual abstraction of groundwater is around 27.4 km^3, but there are already 97 aquifers over drafted. From them, 13 have additionally an intrusion salinity problem. The majority of these aquifers are located mainly in the northwestern and northern states, as well as in the Lerma-Balsas river basin in the central plateau. This river basin can be located in figure 1.3 as Region VIII Lerma-Santiago Pacífico. Figure 1.3 illustrates the hydrologic administrative regions that the National Water Commission in Mexico uses for water management.

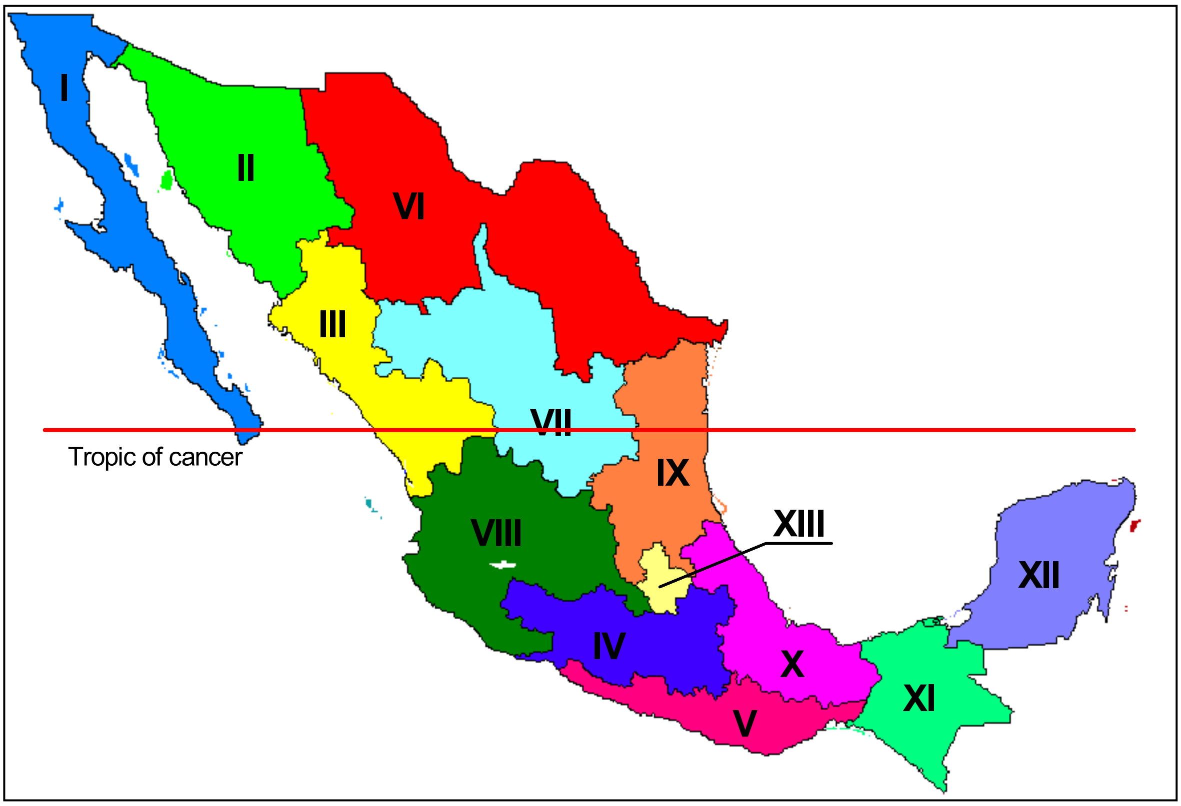

Figure 1.3 Hydrologic-Administrative Regions (CNA 1999) (Source: IMTA, 1999)

Therefore, groundwater has become fundamental for the Mexican economy and sustainable development. It represents the major or even the single source of water in the arid and semi-arid regions of the country. Table 1.3 summarizes water volume withdrawals for origin source, surface water and underground, and for type of water uses.

Table 1.3 Consumptive water uses in Mexico for 2001.

Water Use	Surface water		Groundwater		Total	
	km^3	%	km^3	%	km^3	%
Agricultural	36.8	82	19.6	71	56.4	78
Urban (domestic)	3.3	7	6.2	23	9.5	13
Industry (self-supplied)	5.0	11	1.6	6	6.6	9
Total	45.1		27.4		72.5	

Source: CNA (2003a).

In 2001, 72.5 km^3 of water were used in the country for different consumptive uses. Irrigation uses 78%, 13% goes for urban uses and only 9% is for industrial activities. From this national total extraction, 62% has a surface water derivation and 38% groundwater source. That is, more than one third of total water use (agricultural, municipal/domestic, and industrial) comes from groundwater utilization. Groundwater reliance is even higher in urban/domestic demand, which rises 65% above of their water requirements from this source. Around 75 million people depend on groundwater for their water supply. An important part of the renewable resources are left more or less untouched in the less developed southern regions where technical and natural barriers restrain the development of irrigated agriculture.

Table 1.4 shows the consumptive water use for each hydrologic administrative region by its origin source, surface water or groundwater, and for kind of use.

Table 1.4 Water extractions by region, source and type of use for 2001.

	Administrative Region	Agricultural		Urban (domestic)		Industry (self-supplied)	
		Surface water km^3	Groundwater km^3	Surface water km^3	Groundwater km^3	Surface water km^3	Groundwater km^3
I	Península de Baja California	1.896	1.839	0.102	0.231	0.004	0.213
II	Noroeste	2.991	2.032	0.607	0.351	0	0.032
III	Pacífico Norte	7.002	0.615	0.144	0.334	0.047	0.021
IV	Balsas	4.579	0.624	0.251	0.468	3.264	0.142
V	Pacífico Sur	1.131	0.072	0.124	0.133	0.005	0.008
VI	Río Bravo	1.940	4.183	0.185	0.486	0.061	0.216
VII	Cuencas Centrales del Norte	2.920	2.953	0.008	0.334	0.001	0.105
VIII	Lerma-Santiago-Pacífico	7.318	4.274	0.512	1.381	0.074	0.257
IX	Golfo Norte	2.831	0.757	0.238	0.157	0.156	0.047
X	Golfo Centro	1.294	0.266	0.470	0.257	1.356	0.090
XI	Frontera Sur	0.814	0.255	0.277	0.123	0.016	0.068
XII	Península de Yucatán	0.031	1.201	0	0.454	0	0.152
XIII	Valle de México	2.083	0.482	0.388	1.547	0.044	0.240
	Total	36.830	19.553	3.306	6.256	5.028	1.591

Source: CNA (2003a).

Table 1.5 displays total values corresponding to Table 1.4 by kind of user as well as the per capita extraction in cubic meters regarding total withdrawal by administrative region. In Table 1.5 we note that the major per capita extractions are realized in the regions with lower per capita water availability. Figure 1.1 shows that Region VII Cuencas Centrales del Norte is in fact characterized as a region with scarcity water problems, since its per capita water availability is inferior to 1000 m^3/inhab/year. Therefore its per capita extractions (1650m^3) are grater than its per capita water availability.

Table 1.5 Per capita extractions in cubic meters by region for 2001.

Administrative Region		km^3				Population (millions)	per capita m^3
		Agricultural	Urban	Industry	Total		
I	Península de Baja California	3.7	0.3	0.2	4.3	3.06	1400.3
II	Noroeste	5.0	1.0	0.0	6.0	2.40	2505.4
III	Pacífico Norte	7.6	0.5	0.1	8.2	3.88	2103.9
IV	Balsas	5.2	0.7	3.4	9.3	10.26	909.2
V	Pacífico Sur	1.2	0.3	0.0	1.5	4.02	366.4
VI	Río Bravo	6.1	0.7	0.3	7.1	9.73	726.7
VII	Cuencas Centrales del Norte	5.9	0.3	0.1	6.3	3.83	1650.4
VIII	Lerma-Santiago-Pacífico	11.6	1.9	0.3	13.8	19.42	711.4
IX	Golfo Norte	3.6	0.4	0.2	4.2	4.79	873.9
X	Golfo Centro	1.6	0.7	1.4	3.7	9.30	401.4
XI	Frontera Sur	1.1	0.4	0.1	1.6	6.03	257.5
XII	Península de Yucatán	1.2	0.4	0.2	1.8	3.35	532.5
XIII	Valle de México	2.6	1.9	0.3	4.8	20.07	238.4
Total		56.4	9.5	6.6	72.5	100.14	724.1

Source: CNA (2003a)

Even though the watercourse uses, for example hydroelectric power generation, it does not reduce the amount of the water available for other uses, they do engage large amounts of water, 145 km^3 for year 2001 (CNA, 2003a).

Comparing values from table 1.4 with the hydrologic regions from figure 1.3, we see that for Region XII, underground water is the principal source for all its uses, since only 0.031km^3 come from surface derivation for agricultural use. Region VII supplies water for urban and industry uses just from groundwater. The same behavior is shared by Regions I and II regarding their industrial use. And from figure

1.3 it is clear that those regions placed above Tropic of Cancer are the principal underground water users. Excepting Region XII, where their specific soil characteristics move them to take water, mainly, from their underground resources.

Agricultural users are supplied principally from surface source (65%). From the total national water used by industry, Region IV –Balsas, takes 52%, from which 96% comes from surface origin. Taking out this Region, the origin source for industry is pretty similar, 1.77km^3 from surface water, 1.45km^3 from groundwater. The larger urban water users are Region VIII and XIII. Mexico City is placed in the former. These two regions take 47% of total urban water from underground origin.

Due to over extraction, groundwater non-renewable reserve is being mined at a rate of approximately 8 km^3 per year. Accelerated dropping of underground water tables increases the costs of extraction. Similarly, excessive exploitation has caused seawater intrusion problems in coastal aquifers.

Table 1.6 Principal Water Use (consumptive use).

Country	Total Water Extraction (km^3)	Use (%)		
		Agricultural	Urban	Industry
Brazil	55	61	21	18
Canada	45	9	11	80
China	526	77	5	18
Egypt, Arab Rep.	55	86	6	8
Spain	36	69	13	18
United States	448	27	8	65
France	41	12	15	73
Indonesia	74	93	6	1
Mexico	73	78	13	9
Turkey	36	73	16	11

Source: CNA (2003a).

Following with the type of water users, Table 1.6 presents the principal uses for 10 different countries. Canada, France and United States, the industrialized ones, present an inverse behavior regarding the others countries, since they are the solely where the industry takes more than 65% of total water withdrawal. In the other countries, irrigation for agriculture is the principal user.

The previous water balance in Mexico does not reflect the problems that affect an important number of aquifers and river basins. An important fact to mention is that the average water use efficiency in irrigation is around 46%, and from total water withdrawn to public water supply, conduction losses varies between 30 and 50% (CNA, 2000). Presently, regional water balances in over half of the territory show considerable deficits (see figure 1.1). But certainly, growing water pollution has decreased the possible exploitation of several rivers and water bodies. From total surface water bodies, in December 2001, just 26% were classified as non-polluted or with acceptable quality level. 51% were considered poorly contaminated, 16% polluted and 6% with a high pollution level. The remaining water bodies have toxic presence (CNA, 2003a)

The major reason of pollution is the discharge of solid wastes and residual water emission not collected by sanitation systems. Most of the aquifers with pollution problems are located near major urban population centers. Main water bodies have been polluted because of untreated municipal and industrial wastewater emissions. The nearly 200 thousand geographically dispersed rural communities throughout the country have become a technical problem to provide water and sanitation to rural population.

In the last decade nearly 19.7 million people were added to public water supply systems and 20 million to sanitation systems --compared with a population growth of 15 million people in the same period of time,-- almost 12% of the population still do not have access to safe drinking water and 24% to adequate sanitation (CNA, 1999b). The present use patterns and withdrawals may not be sustainable, and water scarcity can become the limiting factor to economic growth.

Table 1.7 presents these values compared with the covering of potable water and sewerage system in the same 10 countries before analyzed. From this sample of countries, Indonesia has the lowest level for potable water (69%), while the other countries supply more than 80% potable water. With respect to sewerage system, China is the one with critical sanitation problems since only cover 21% of the population, followed by Indonesia with 54%.

Table 1.7 Potable Water and Sewerage System.

Country	Potable Water (%)	Sewerage System (%)
Brazil	82	67
Canada	99	95
China	90	21
Egypt, Arab Rep.	94	87
Spain	99	100
United States	100	100
France	100	79
Indonesia	69	54
Mexico	88	76
Turkey	80	87

Source: CNA (2003a).

Of course it is well known that growth and concentration of population and economic activity are definite factors generating water unbalances, but it is also irrefutable that water deficits have a direct consequence of a series of inefficiencies accumulated over the last decades. But also, a water price which does not reflect the correct value of the resource will lead to inefficiencies in the allocation of the resource, as well as affect the quantity and quality of the water services.

1.2 Water management reforms in Mexico

Practically all people involved with the analysis of water resources has pointed out that water is less available every day. Conflicts among water consumers increase since each time there exist more users, mainly because of population growth, and for different reasons there is less water (quality diminution, aquifers over-exploited, low efficiency allocation etc.). Since water, each time is scarcer in quantity but also in quality around the world, then, managing water has become not only an activity for monitoring both demand and supply of water. Countries like Kuwait, Qatar, and Jordan manage the small quantity of water they have in a very strict sense to be efficient, since the access to alternative sources of water is gradually more complicated. For example, around the world, these three countries are the ones with greater percentage (from 20 to 30) of reclamation water with reference to their respective withdrawn water (Segui, 2004). Understanding reclamation water as the activity where that water already used in previous activities is treated and reused again. That is, reclamation water is the wastewater treated that satisfy the quality to be used again (Segui, 2004).

The purpose of water resources management is not simply to provide water in the quantity and quality desired. Water also has ecological, recreational and social values that need to be taken into consideration.

In Mexico, since 1946, water management has been under a sole authority. But, the modern water policies in Mexico have their roots in the 1917 Constitution's fundamental declaration that the resource is a national property which can only be used through proper authorization by the corresponding Federal Authority. But in chronological order, the first important legal water text was the 1910 Water Law (Saade, 2003).

1.2.1 Institutional framework

In this thesis work, water institution is considered not just as a fixed organization. It is considered in a wider sense, in the same sense Saleth and Dinar (2000) conceptualized it, “as an entity defined interactively by its three main analytical components, i.e., water law, water policy, and water administration”.

Water policies and management in Mexico have traditionally been "top-down" and centralized government activities coming from Mexico City[1]. A series of laws, regulations and institutions have arisen over the last ninety years to define the scope of Government intervention, as well as the rights and obligations of individuals and organizations, public or private, that wish to use the national water.

Different reforms to manage water have been taken. Summarizing, in 1926 the Law for Irrigation with Federal Water is decreed giving origin to the National Irrigation Commission (CNI, in Spanish). In 1934 and 1936 the Law of Water of National Property and its bylaw were decreed. In 1946 the Ministry of Water Resource took the place of the National Irrigation Commission. Between 1940 and 1960 Sector and Regional Plans were made to improve the use of water. In 1956 and 1958 the Law and its bylaw of exploitation of subsoil water (groundwater) were established, beginning to regulate the extraction and use from this source (Ortiz, 2001). In 1971 Environmental regulations were implemented.

A Federal Law of Waters was approved in 1972 which comes to support the legal framework for water management by creating a centralized system of permits and concessions for water use. It defines a set of regulations and controls for water use, including water allocation priorities. This law was the basis of the first National Water Plan in 1975 (Saade, 2003). This Plan was made in a unified vision sense.

[1] The political administration in Mexico is organized, at the top, by Federal Government, next the States Government (31), and last, the Municipal Government (The number of municipalities varies from one state to other).

In 1980 a project to fix quotas for water was formulated. Since 1983 municipalities are in charge of the services of public water supply and both wastewater collection and subsequently treatment. Since then, the creation of water utilities has been promoted, in order to separate these activities from others that are carried out by the municipalities.

The creation and consolidation of water utilities support a greater participation of local authorities in water management and on the other hand separates water budget from general municipal finances. In most of the cases water utilities have a poor performance and need to be greatly improved to achieve technical and economical sufficiency.

The States Government role in the water sector is, principally, restricted to regulate public water supply and sanitation services, and in some cases to support the municipalities with low technical and economical performance. State legislation, which regulates social and private sector participation in the water industry, establishes the basis for the creation of water utilities and sets the rules to fix water tariffs. The Federal Government has promoted variation in state laws to encourage the participation of State Governments in all water sector activities and not only in public water supply and sanitation services; however, only a few states have changed their laws.

In 1982 the Federal Law of Water Rights was established. It was updated in 1985 and reformulated in 1986. Since 1989 with the National Water Commission (CNA) creation, it is adjusted annually to respond to the new requirements of the sector.

An important break-point was made in 1989 when the National Water Commission (CNA) was created, by Presidential Decree, as an autonomous agency attached to the Ministry of Agriculture and Water Resources, to become the sole federal authority dealing with water management, thus responding to growing institutional problems and to the need of reinforcing water policies and strategies. In 1994, the National Water Commission was functionally re-allocated within the then newly created Ministry of Environment, Natural Resources and Fisheries (SEMARNAP), nowadays Ministry of Environment and Natural Resources (SEMARNAT).

CNA is the federal agency in charge of defining water policy, granting permits to withdraw water and to discharge wastewater, establishing national standards for the use of water, and integrating national and regional master water plans.

The responsibilities of the Commission include:

- Define the country's water policies, and formulate, update and monitor the implementation of the National Water Plan, as well as the associated regional water plans.
- Measure water quantity and quality, and regulate water use.
- Preserve and upgrade water quality in the national rivers and water bodies.
- Allocate water rights to users, and grant the corresponding concessions and permits.
- Plan, design and construct the waterworks carried out by Federal Government in the water sector, excepting those under Federal Power Commission responsibility.
- Regulate and control river flows, and guarantee the safety of major hydraulic infrastructure.
- Provide technical assistance to users and promote the efficient use of water, in quantity and quality.
- Define and, if necessary, implement the financial mechanisms to support water development and the provision of water services.

As early as 1990, the necessary studies were carried out to design a new legal instrument. The National Water Law, authorized in December of 1992, provided a modern regulatory framework for water management. It reinforced the institutional setting for water management, by strengthening the role of the National Water Commission as the country's sole Water Authority, in charge of managing the resource, both in quantity and quality.

The bylaw of the National Water Law was approved in January of 1994.

It is worth mentioning that the National Water Law explicitly declares sustainable development as its primary objective. The Law promotes decentralization, stakeholder participation, more control of water withdrawals and wastewater discharges, efficient use of water, greater private sector participation, and establishment of economic instruments and fiscal policies related to the collection of water levies for both water use and water pollution control.

Mexico's new structure for the conceding and allocating of water rights lies in the combined use of regulatory and economic instruments or incentives, which are embodied in the National Water Law and other water related fiscal laws. According to the new legal framework derived from the National Water Law, water management now rests on two basic principles: First, a license or concession is needed for everyone, public or private, to use the Nation's waters, and a subsequent permit is required for discharging waste water into the Nation's rivers or injecting them into the ground. And second, those who benefit from water abstraction or those using the water courses to dispose of waste waters have to contribute to resource management and development, and to water quality restoration and improvement, in proportion to their water consumption or to the amount and characteristics of the waste waters they discharge.

So, in that way, conceding water rights (water use concessions) and allocating discharge permits are clearly regulated, since legal rights and obligations are well defined. Transmission of water rights are also allowed and regulated.

A Public Registry of Water Rights is established to ensure legal confidence of the water rights, to solve problems associated with third party effects, and to provide the flow of information needed for "regulated water markets" to operate. The National Water Commission, on the other hand, is empowered to act as an arbiter and conciliator in the resolution of conflicts, to establish water reserves, and to allocate the resource through the request of water rights. In 2001 there was an estimate of 437 thousand water users (CNA, 2003a). Major efforts have been dedicated to the registration of all of them and the amount of water they withdraw, through the Public Registry of Water Rights (REPDA – Registro Público de Derechos de Agua). The Public Registry of Water Rights is already operational and most existing users, water withdrawals and pollutant dischargers have been regularized. 97.5% of water users have been registered up to December 2001.

The National Water Law allows the transfer of water rights from one user to other. Nevertheless, the fact that some users are not registered has delayed the operation of water markets. Most water right transactions are performed in a year-to-year basis. Preliminary works for the enforcement of the new system of water rights through concessions and discharge permits were completed in 1994, although the process of recognizing existing water rights is still in process.

Agricultural Sector deserves a special consideration, since agriculture has been a traditional activity in Mexico. Lately, it has suffered a variety of essential changes along with them, the use of water. The Agricultural sector administration has varied widely. The *ejido*, or communally farmed plot, emerged as the unique Mexican form of redistributing large landholdings. Originally, the state retained title to the land but granted the villagers, now known as *ejidatarios*, the right to farm the land, either in a collective manner or through the designation of individual *parcelas* (plots). *Ejidatarios* could not sell or mortgage their land but could pass usufruct rights to their heirs. *Ejidatarios* had to work their land regularly in order to maintain their rights over it.

Mexican administration has changed extensively in the importance accorded to the *ejido*. During the 1920s and early 1930s the *ejido* was viewed as a transitional system that would lead to small private farms nationwide. From the 1940s through the 1970s, the government favored large-scale commercial agriculture at the expense of the *ejido*.

Confronted with the dysfunctional character of much of Mexican agriculture, the government in 1992 radically changed the *ejido* land tenure system, codifying some existing actions that were against the law but widely practiced and introducing new characteristics. Under the new law, an *ejido* can grant its members individual titles to the land, not merely usufruct rights to their plots. *Ejidatarios* can, in turn, choose to rent, sell, or mortgage their properties. The *ejidatarios* do not need to work their land to maintain ownership over them. They also may enter into partnerships with private entrepreneurs. Finally, the processing and resolution of land disputes are decentralized.

Currently, the concession of water rights in the agricultural sector may adopt one of next four forms:

i) Water rights settled through concessions to single individuals for the use and exploitation of the water resources for farming purposes, or to enterprises for the administration and operation of irrigation systems or the shared use and exploitation of common water sources for agricultural purposes.
ii) Water rights settled to ejidos and rural communities in coordination with legal dispositions deriving from the new Agrarian Law.
iii) Water rights settled to irrigation units, as defined by the previous water law.
iv) Water rights settled to public irrigation systems.

Since 1989 the Federal Government started the transference of operation and maintenance activities of Irrigation Districts to User Associations. The Irrigation Management Transfer Program (Programa de Transferencia de los Distritos de

Riego) establishes new forms of organization and user representation. The Water User Associations, WUA, are organizations whose main function is the operation, maintenance, and management of the irrigation infrastructure. They can be established as civil associations and granted certain fiscal privileges. The Board of Directors of these associations is selected by the Assembly comprised of water users of the irrigation modules in the irrigation districts or units.

The National Water Commission concedes volume water rights to the irrigation districts. In those irrigation districts where management has been transferred to users, the concession that allocates water rights is accompanied by a concession to administer the corresponding public infrastructure. Water users are organized in water user associations, one for each irrigation module, as defined by the National Water Commission.

The water concession (water rights) granted by the government to the irrigation districts is part of the general agreement between the government and each module. As such, water users do not have individual water rights but instead each association has a proportional right (the proportion is based on area) to the supply of water (normally the estimated surface supply) available to the district for any given season. In the same sense, members of a module have the right to use a proportion of the volume allocated to it and according to their registered area. Concessions are granted for a fixed time frame, 5 to 50 years, and can be taken away if an association does not fulfill his agreement with the government. Concessions are not for a fixed volume of water but are for the use of a proportion of the available water supply. Therefore, the associations do not have a fixed, volumetric water right.

The National Water Commission has the necessary authority to resolve any conflict that may originate concerning individual water rights, or volume water rights allocated to the modules. Water rights may be transferred within each module according to the regulations approved by the Commission. Transfer of water rights among modules is subject to the regulations established for the irrigation district as a whole. Transfer of water rights outside the irrigation district can only be transferred previously authorized by the National Water Commission.

Out of the 84 Irrigation Districts (3.4 millions hectares) that exist in Mexico, 78 have been fully transferred and 4 partially, covering 99% of the total irrigated area in Irrigation Districts (CNA, 2004). The transfer of irrigation districts to the Water User Associations (WUA) ensures a greater participation of agricultural users in water management and gradually reduces the economic subsidies from the government to this sector. This program is a novelty and it has been taken as a reference worldwide (Johnson III, 1997).

1.2.2 River Basin Councils

Organizing water management from a basin approach obeys to the logic of taking into account the natural characteristics that water flows follow, which do not respect administrative boundaries. In Mexico, water was managed using ‘political’ boundaries up to the year 1998. It is pointed out ‘political’ since the administrative National Water Commission offices were delimited by the Mexican political division, i.e., by states. Figure 1.4 shows the six regional offices that in 1989 the National Water Commission used to manage water.

These boundaries were changed in May 1998. A new number, location and limits of the National Water Commission (CNA) regional offices were published, and updated in January 1999 (CNA, 1999a). The new limits were defined by hydrologic criteria, giving place to a new water management organization in Mexico. The country is divided into 13 hydrographic administrative regions and a CNA office has been established for each of the regions. It is important to note that the CNA regional offices work under a watershed approach, where each one of the regions is composed by one or more basins. (See figure 1.3). National Water Commission regional offices are responsible of most water management duties while its central offices will be responsible of establishing general guidelines and standards.

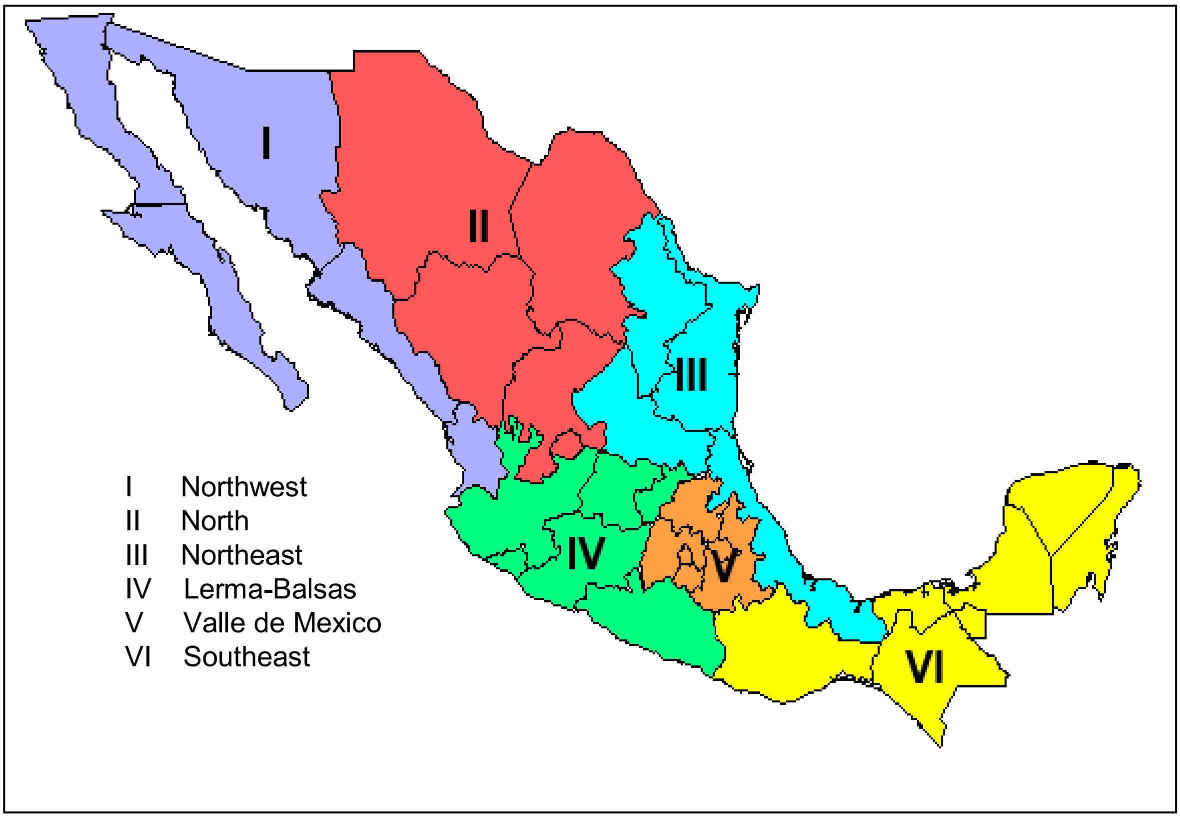

Figure 1.4 Regional offices in 1989 (CNA) (Source: CNA, 2002).

The promotion of stakeholder participation in the water sector is visualized in the Law with the creation of River Basin Councils, which are forums where Federal, State and Municipal governments, the water users and other stakeholders can share the responsibility of planning and managing the basin's water resources. River basin planning and coordination is guaranteed with the new organization of the National Water Commission. This new organization allows for a better interaction with local stakeholders and facilitates coordination with river basin councils.

The National Water Law commands the establishment of the River Basin Council, in order to facilitate the coordination of hydraulic programs and policies with the three governmental levels existing in Mexico: Federal, State and Municipal. But also, to propitiate the arrangement of strategies, policies, programs, and actions, between the federal water authority and water users and diverse society organizations (NGO's). Figure 1.5 shows a River Basin Council general structure for year 1999.

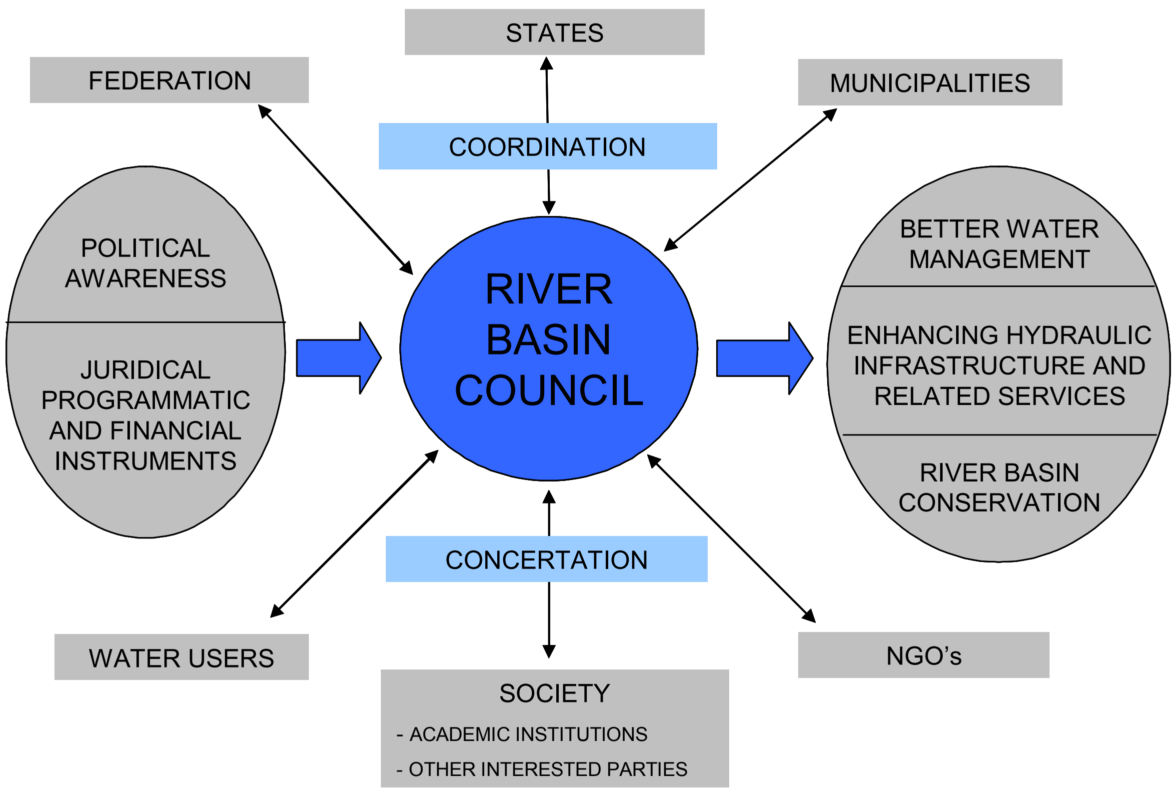

Figure 1.5. River Basin Council (general structure 1999) (Source: CNA, 1999b).

Article 15 of the bylaw of National Water Law defines the way River Basin Council should be integrated and their responsibilities. Briefly they are: (i) The General Director of the National Water Commission, who should be the president of the Council and will have definitive vow in case of tie. (ii) The governmental board members who are the State Governors from the states in the basin. They have voice and vow. (iii) One representative (agent) for each kind of water user in the basin (agriculture, industry, supplier of potable water services, etc.). They should be, at least, in the same number that those governmental board members. They have voice and vow. (iv) There would be guests that should have voice but not right to vote. They are NGO's, Universities, Institutes, Municipal President, various organisms, and institutions from the public sector but also could be from the private sector. And finally, (v) the structure of the river basin council incorporates a Technical Secretariat, who is a representative of the National Water Commission and appointed by its titular. The Basin Secretary should supply the technical information needed by the Council. The Secretary has voice but not a right to vote.

The principal target of River Basin Councils is to guarantee the sustainable development of the resource under an integrated water resources management criterion.

The River Basin Council has auxiliary organizations that work at different levels, from the hydrologic point of view: sub-basin, micro-basin, and aquifer. Respectively, the organizations are called Basin Commission, Basin Committee, and Technical Committee of Groundwater (COTAS – Comités Técnicos de Aguas Subterráneas, in Spanish), for those aquifers over-exploited or under risk of being over-exploited. All of them are subordinated to the River Basin Council and supported on the allowance that Law gives to the National Water Commission, to promote users organization for region, states, basins and aquifers to participate in the hydraulic programs.

River Basin Councils, once created, have authority to sanction regional water plans and constitute the forum to negotiate specific responsibilities for plan execution and financing.

The influence area of the River Basin Council is a basin of first order or macro-basin. The Basin Commission considers user participation in a basin of second order or sub-basin. Then, the organizations can be associated as it is shown in Table 1.8.

The numbers between parentheses in the organization column are the total Councils, Commissions or Committees established up to November 2002 (CNA, 2003a).

Table 1.8 River Basin Auxiliary Organizations.

Organization	Hydrographic Level
• River Basin Council (26)	• Macro-Basin
• Basin Commission (7)	• Sub-Basin
• Basin Committee (7)	• Micro-Basin
• Technical Committee of Groundwater (57)	• Aquifer

The organization and participation of the society in Councils, Commissions and Committees of Basin is under general objectives which obey to problems and goals associated to water. The objectives are: (a) Arrange the different uses of water. In this forum the ways to conciliate, inside each basin, water availability against water demand, are analyzed. But also, it is analyzed the way to prevent and control water pollution. (b) Sanitation of the basins and water receptor bodies to prevent contamination. (c) Promote the acknowledgment of economical, environmental and social value of water. (d) River Basin conservation (water and soil). And, (e) Efficient water use.

In this sense, the role of the River Basin Council is to improve the management of water, the development of hydraulic infrastructure and the preservation of the source within the basin, though the river basin councils and their auxiliary organizations have variable performance.

In essence, River Basin Councils were created to solve conflicts among users based on technical analysis and stakeholders' participation. These bodies were already envisaged in the national water plans formulated in 1975 and 1982. Those plans acknowledge two main facts: (i) River Basin should be the basic territorial unit to do the integrated water resources management; and (ii) decentralization and water management improvement should be done through the River Basin Council.

In December 2003 a bill was submitted, to the Congress to promote, among other issues, the strengthening of the River Basin Councils. In particular, there are two key project proposals regarding river basin water management: (a) a new body - River Basins Organism - will be created; and (b) new assignments will be conferring to the River Basin Councils. The bill has been passed on April 29^{th}, 2004 (DOF, 2004).

National Water Commission used to formulate the water policy and plans in centralized way. Consequently, in this reformulated National Water Law it is recommended that National Water Commission organizes its activities in two levels: (i) national level; and (ii) hydrologic-administrative regional level, through their River Basin Organism.

1.2.3 River Basin Organism

River Basin Organism will be a decentralized organism attached to the National Water Commission, expressly to its General Director. This new governmental organism is going to be the water authority and will be in charge of the integrated water resources management. Its sphere of influence is that of the hydrologic river basin, hydrologic regions, as well as hydrologic-administrative regions. The National Water Commission is in charge of drawing up the boundaries of the geographic frontiers.

Article 12 of this reformulated National Water Law defines what should be a River Basin Organism, the manner it should be fitted and its responsibilities. The structure, organization, functions and limits of the River Basin Organism are going to be established in the bylaw of the National Water Law. Article 12 BIS 6 describes the attribution of the River Basin Organism. In a few words, we rescue some of them:

- Formulate and propose to the National Water Commission the regional water policy, as well as the water programs for hydrographic river basin or aquifer, update and follow-up their achievement.
- Plan, design, construct, operate and maintain the federal waterworks.
- Take the necessary actions for an integral efficient water use.
- Regulate and control water as well as the preservation of its quantity and quality.
- Grant the concessions and permits for discharging.
- Manage the Public Water Registry –REPDA, inside its geographic limits of action.
- Propose the appropriate amounts to charge water rights and river basin tariffs, including withdrawal charges, wastewater discharge charges and environmental services related to water and its management.
- River Basin Organism has the authority to act as arbiter and conciliator in the resolution of conflicts, related to water and its administration, as a request of whichever River Basin Councils water users.
- Regulate the transfer of water rights among users.
- Manage the water rights payment mechanism.

River Basin Organism will sanction, in congruence with the national water policy, the regional water policy for each one of its hydrologic river basins

In summary, through the reformulated National Water Law and its bylaw (in process), National Water Commission is transferring a lot of their responsibilities and activities to this new governmental figure, the River Basin Organism, in a way that water resources can be managed from a real decentralized hydrological context.

National Water Commission is responsible for establishing and fitting River Basin Organisms in addition to their geographic confines. To do that, CNA has 18 months; therefore by October 2005 all River Basin Organisms should be operating.

National Water Commission also is in charge to establish the River Basin Councils. Article 13 in the reformulated National Water Law defines the River Basin Councils attributions. They maintain their autonomy and they neither are subordinated to River Basin Organisms nor to the National Water Commission; as well as to any of the River Basin Council auxiliary organizations (see Table 1.8).

One thing is clear, the consequence that these reforms, in their functions and responsibilities, of the National Water Commission and River Basin Councils, in addition to the effects that River Basin Organism are, all of them, to have in the water resources management is still uncertain. The reforms on National Water Law have some gaps that are expected to be covered through its bylaw and by their internal guidelines of these three institutional figures to manage water resources: National Water Commission, River Basin Organism and River Basin Councils. But the scope of these measures is going to take time to be known.

1.3 Economic framework

Around the world, different economic instruments have been used to promote an efficient water use. The most commonly used are taxes, charges, subsidies, levies and quotas. But the effectiveness of the results that any of them could generate is in function of the economical and political context where they are applied.

The price of water has been utilized as an economic tool to enforce water users to become more efficient, since a commodity price is seen as a measure of its scarcity. But also, water has ecological, recreational and social values that need to be reflected in the pricing system. Then, a charging system should encourage a reasonable use of the environment. Meaning that, a price is supposed to be a sign of the right and of the whole social costs for supplying water, including resource depletion.

Rather than going into a complicated scheme of calculating, if possible, opportunity costs or long term marginal costs, Mexico's approach of pricing water has been pragmatic in nature, considering the political resistance associated with the introduction of any kind of new fiscal burden. That is why, the introduction of water charges in 1986 considered less important to assign the "right" price than introducing the concept of water as an economic good with a specific value. Nevertheless, the initial water charges introduced by law consider some principles of proportionality, capacity to pay and actual water availability in every region.

The basis for developing and consolidating Mexico's Water Financing System is established by a system of charges for water use and wastewater discharge. Besides providing an incentive to increase water use efficiency, which is already measurable, the collection of both kinds of charges, for water use as well as for water discharge, have resulted in the generation of financial resources to perform water programs and activities.

Like in many other countries, in Mexico modern water management lies on a fragile balance between governmental regulation and market mechanisms. The country's legal and institutional reforms implemented in the early 90’s have the objective to reach this balance.

1.3.1 Water charge framework

Water use charges and wastewater effluent charges are considered in Mexican Legislation. In agreement with the legal framework, those who benefit from water use or those using the water courses to dispose of waste waters, have to pay towards: (a) the management and development of the resource, and (b) the restoration and improvement of water quality, in proportion, respectively, to their water consumption or to the amount and characteristics of the waste waters they discharge.

Taking into consideration that industrial water consumption comes, principally, from a self-supplied water, surface water as well as underground sources, its exploitation is under a concession – that is, water right - or license granted by the National Water Commission, and the industry is under obligation to pay for a federal fiscal right for the use of water and also for wastewater discharge on national streams. These are unique (once and for all) payments. In addition, self-supplied industrial water users have to pay quarterly abstraction charges per cubic meter, depending on their geographical location, which is determined according to relative water scarcity. For effluent emission discharge, industrials also have to pay for contaminants as well as for the volumes discharged. Regarding the abstraction charges payment, there are some subsidies. For example in 1993, sugar sector was allowed to pay only 60% of the amount set up per cubic meter in function of the availability water zone where the factory is located. For the first quarter of 2003 this amount was set to 50%. Additionally, some municipalities are also compensated for a given proportion of their water charges, resulting in an implicit subsidy scheme. The amount of all these payments are set up in the Federal Law Act (Ley Federal de Derechos en Materia de Agua), and are brought up to date each year.

For the first semester 2003 (CNA, 2003b), self-supplied industrial water users have to pay abstraction charges from US$0.1041to US$1.3265 per cubic meter, depending on the geographical situation, which is grouped according to relative water scarcity. And urban water utilities have to pay extraction charge that goes from US$0.0030 to US$0.0263 per cubic meter. Average exchange rate used is 10.6358 Mex$/USD (Banco de México, 2003). See Annex A.1 for values en Mexican pesos.

Since water tariffs and commercial efficiency of water utilities are very low, federal, state and municipal governments provide financial support. Actual fees are not enough to cover water utilities operation and maintenance costs. Tariffs would have to be increased at least a 100% in order to promote self-financing water utilities.

This situation is critical in rural areas where state and federal subsidies have to cover all the service costs.

Regarding the agricultural sector, presently, users of water for irrigation pay no abstraction charges. This policy has been the cause of intense discussions since irrigated agriculture accounts for most of water abstraction (not considering hydropower) and water consumption. Pro and con argumentation goes beyond economic rationality; it has to do with social and political considerations. Nevertheless, governmental policies have been adopted to introduce efficiency in water use for irrigation through the Irrigation Management Transfer Program.

Transferring the management of the irrigation districts to the users was foreseen as the proper strategy to create a different relationship between the government and the water users. The Irrigation Management Transfer program carried in Mexico was designed primarily to ensure that Water User Associations had adequate financial resources to be self-sufficient, this meant that the irrigation fees or water tariffs had to reach a level where the cost of operation, administration, and maintenance (O&M) at the module level were covered. In addition, the water tariffs have to be sufficient to meet the module's share of the costs of operation, administration and maintenance at the main canal and water source level as well.

In line with the policy of making irrigation districts more financially sustainable, it was recognized that users would have to pay the real O&M costs for the irrigation district. The general idea was to eliminate bureaucracy, reduce costs and make those costs to be paid by the users in proportion to the benefits they receive. Irrigation districts would, under this strategy, advance rapidly toward financial self-sufficiency. In fact in the core of the negotiations between the National Water Commission and the water users was the pre-requisite of bringing service tariffs up to self-sufficiency – at least, to fully recover operation and maintenance (O&M) costs.

Consequently, irrigation water charges went up in a majority of irrigation districts. As financial self-sufficiency was attained, the transfer of management keeps on. Water charges are determined for each module by the respective water user association (WUA).

Probably the most relevant issue on water pricing reform within the agricultural sector is connected with the charging of abstraction rates and in some extent to the establishment of pollution rates (non-point pollution rates). Under existing fiscal laws, no user is exempt from paying abstraction charges, including the agricultural water users. At present the corresponding tariff for agricultural water users is set at zero. This is important, since no major legal modifications are required. The National Congress sets water abstraction charges annually, and it is in this field where the issue will have to be discussed and resolved.

Tariffs need to be significantly increased. In order to achieve this, it is necessary to design and apply tariffs that are efficient, equitable and sustainable. The correct design and application of tariffs is still a priority and a challenge.

1.3.2 Water price structure

Before 1986, when the Water Law was modified substantially, the pricing system employed the same fixed price per cubic meter throughout the country. The water pricing system in Mexico incorporates two kinds of tariffs: one of them is a fixed price per cubic meter of water used, differing by water supply zone. The other system is an increasing block rate structure. Actually, the water tariffs are determined as a function of the water availability.

Then and now, the idea has been that the water price needs to be quantified by the magnitude of its four components: Right, Services, Use, and Preservation (Guerrero 1995).

Right: represents the associated cost of disposable water regionally and locally.

Service: represents the tariffs of the user connected to the water supply system. It includes both irrigation water and potable water.

Use: represents the charges to cover the management cost and operating and maintenance costs.

Preservation: represents the wastewater treatment cost.

The quotas were established taking into account the regional heterogeneity of the water availability. Up to 1996, four types of zones were defined from the hydrological point of view: Zone 1, where water is now scarce relative to demand; Zone 2, where supply and demand are in balance but only for the short term; Zone 3, where supply is enough to satisfy demand for the intermediate term; and Zone 4, where water is in abundance for the indefinite future. Pricing weights are assigned to each zone.

Four principal water uses were also established: irrigation, hydroelectric generation, urban (potable), and industrial. For each kind of user a pricing weight is assigned. The industrial sector get the highest weight; in second place is the water for urban use (potable); in third is the water for irrigation; and the water for hydroelectric generation is assigned the lowest weight. The criterion for assigning these weights has not been made explicit, but it clearly includes considerations of return flow and ability to pay. The weights (given in 1980) are exhibited in Table 1.9.

Table 1.9 Weight by zone and use.

Water zone	Weight	Water use	Weight
1	1.0	Industrial	1.00
2	0.5	Potable	0.80
3	0.15	Irrigation	0.013
4	0.05	Hydroelectric	0.001

Source:CPNH (1980).

The methods used to fix the prices *appear* to combine both the water availability weights and the sector weights, probably plus some political considerations. As noted above, there are four water supply zones. Thus, we can describe at least 16 different tariffs for the use of water. In fact, each municipality has the option of defining their own pricing steps beyond the first block. Regarding the kind of use, the industrial sectors have the highest cost; in second place is the water for urban use (potable); then in third is the water for irrigation; and the water for hydroelectricity is the cheapest. In Table 1.10 examples of the resulting first blocks prices are shown (1993 data).

Table 1.10 Cost of water by type of use.

Water zone	Characteristics	Industrial (N$/m^3)	Urban (N$/m^3)
1	Scarce	1.30	0.060
2	Equilibrium	.90	0.028
3	Enough	.32	0.014
4	Abundance	.24	0.007

Source: Guerrero, H. and Ch. Howe (2000). Quotas are from "Ley Federal de Derechos en Materia de Agua". Comision Nacional del Agua, 1993.

Table 1.10 displays in the last two columns, as an example, the cost of water per cubic meter that consumers had to pay in 1993, for industrial and potable water. We see that zone 1, where water is scarce, has the highest price.

In the same way, using the four availability zones, the tariffs for wastewater discharge were established. Each group of four different tariffs is determined by the cubic meter discharge, and also by the sort and percentage of pollutants discharged (BOD, TSS, DO and other pollutants). Then, on the discharge side, we also have at least 20 different tariffs. Thus, the tariffs depend on both the regional hydrological characteristics for water use and the sort of pollutants discharged.

Then, a specific zone will have different tariffs: one for water use, and may have more than one for discharges, which depends, principally, on the industrial activity that the zone has. Also, there are quotas for special cases and other uses as: commercial and services, livestock, irrigation for sporting fields, and aquariums. But they are few and do not have incidence in the cost, because they comprise approximately 1% of the water withdrawal.

Water has more value as it becomes less available, that is, as its scarcity rises. So, the water tariffs are determined as a function of the water availability. "The principal objective to fix a price for water is: efficiency for all the users and equity in the cost that each one has to pay. Because of this, domestic water user has to pay the minimum given its low productivity, and the industrial user has to pay more due to the aggregate value of the product generated from the water use and its productivity" (CPNH, 1980). But those prices do not have to be so small since wasting water is feasible at a low water price.

The industrial water users have suffered the biggest impact. Many industries tap their water supply by themselves and the National Water Commission applies the respective tariffs for the right to use water, according to the availability zone weights. As the industries tap their own water from groundwater that is a common source for other urban users, thus, industries contribute to the overexploitation of the aquifers. In addition, industries also have to pay for the discharge of wastewater. Inside the manufacturing sector, the industries of cellulose and paper, mining and metallurgy, chemical and petroleum, and beverage, food and sugar are claiming that the actual charges are too high and it is affecting their competitiveness.

Regarding the other two main customers, irrigation and urban use, in most of the cities, water is being charged in a block structure with increasing prices that try to recover operating and maintenance (O&M) costs. The farmers pay the cost of O&M in terms of the irrigated area based on the water consumption of the crop being raised. The irrigation districts have been transferred to the customers, and a recent change in the water law allows for the transfer of water rights.

This mechanism attempts to generate an efficient use of the water in scarcity zones. The objective of the payment is to compensate the system cost, which includes both the investment in hydraulic structures (dams, canals, etc.), and the O&M costs. The amount of the fee depends on the regional hydrological characteristics. And it tries to reduce the subsidy on the water, attempting to eliminate it altogether.

Water scarcity has increased in the last ten years in the majority of the hydrological regions in Mexico. This tendency has been the result of growing demand due to population growth, but also there have been greater levels of water pollution, which deteriorates water quality and so, the water supply capacity has decreased.

Since 1989, and due to the National Water Commission policy on implementing an efficient use of the water that is becoming scarce, the water tariffs have risen substantially. Looking to induce a rational water use and efficient allocation the water law has undergone transformations. This has produced a considerable fee collection increment.

In 1992, the federal fee collection increased again because the discharges of wastewater on streams or sewerage were taxed strongly, where the policy "who pollutes must to pay" is applied. The fees for discharge of wastewater are also defined considering the water availability zone. These fees augmentations have generated a more efficient water use, as well as a source of capital for the sector.

In 1997, the National Water Commission changes the number of availability zones -which were previously defined from the hydrological point of view- based on administrative concerns. Table 1.11 displays water quotas defined for year 2003. See Annex A.1 for supplementary information.

Table 1.11 Water quotas first semester 2003.

Water zone		Industry ($/m^3)	Urban ($/m^3)
1	Scarce	14.1086	0.2795
2		11.2865	✓
3		9.4053	✓
4		7.7596	✓
5		6.1133	✓
6		5.5251	✓
7	Equilibrium	4.1587	0.1302
8	Enough	1.4776	0.0650
9	Abundance	1.1073	0.0324

Quotas in current terms. Source: CNA (2003b).

The principal change is that zone 1 - the scarcity one - was extended up to 6 zones, due to a number of practical difficulties handling water rights payment mechanisms Problems like the application of subsidies, permissions and exceptions for some industrial use or municipalities. Nevertheless, zones 1 to zone 6 are still considered as scarcity zones. The other zones -7 to 9 - retain the conditions as they were defined in 1986. Therefore, Zone 7 is equivalent to zone 2 (equilibrium), zone 8 is equivalent to zone 3 (enough) and zone 9 is equivalent to zone 4 (abundance).

Each year National Water Commission updates water charges each user should pay as well as the catalog of the municipality's localization by water availability zone. In some circumstances, the municipality should changes its water availability zone, for example, some of them could move from zone 9 to zone 8 or zone 7, and so on. These updates are published in the Federal Law Act (Ley Federal de Derechos en Materia de Agua).

The way that the Mexican water law has determined water prices per cubic meter, as a function of the availability zone is excellent: the highest price for the scarcity zone and the cheapest for the abundant water zone. It really is responding to the theoretical principle that a commodity price is seen as a measure of its scarcity.

And also, there exists the difference between water users, which respond to the knowledge that no matter that water is an input for industrial process, water also is a good of first necessity and in that sense, the use of water has different value for industry or irrigation, and consequently for other uses.

The increasing block tariff structure applied in Mexico is efficient in discouraging water wasters. But beyond that, the problem becomes knowing how the prices were determined and what do they represent.

The management of water in Mexico is carried out in a more efficient way than 15 years ago through water prices that appear to reflect water scarcity, return flows and the cost of each unit delivery. Potential improvements would include the certainty that appropriate pricing policies should be followed, that is, policies that motivate efficient water allocation in the short run and efficient patterns of development in the long run.

1.4 Conclusion

In this chapter we set up a general panorama about the evolution of water management reforms in Mexico. We began the chapter with a broad report of some water statistics in Mexico and in the world.

We described the development of the water institution since the first legal water text, the 1910 Water Law. Considering water institution not just as a fixed organization but as a 'body' conformed by the interaction of three components: law of water, policy of water, and administration of water. We call attention to the relevant role National Water Commission has come to play since its creation in 1989, becoming the sole federal authority dealing with water management. And as a result of this change, it is in 1998 that water management began to be made by hydrologic criteria, through its 13 hydrographic administrative regions that the National Water Commission has around the country.

The present chapter also explains the water charges currently applied in Mexico, as well as the structure of water prices. It is highlighted that the manner water price per cubic meter is determined is excellent, since it is determined as a function of the availability water zone, as well as taking into account the kind of user. It really responds to the theoretical principle that a commodity price should be seen as a measure of its scarcity.

We conclude that water reforms carried out in the last years have allowed managing water in a more efficient way, but as expected, they must be improved.

Chapter 2

Industrial water demand

Introduction

The literature concerning industrial water demands econometric estimation is quite concise with respect to other water uses. Renzetti (2002) in the Economics of Industrial Water Use's introduction already mentions that in an ECONLIT search for "Industrial Water" for the period 1982-1998, there were only five titles while for "Residential/Urban Water" were returned 63 citations and for "Agriculture/Irrigation Water" 105 references existed.

Renzetti's works are the first documented studies where water use is analyzed, not just as one more input for industrial production together with capital, labor and other inputs, but considering the different uses water may have within industrial production processes. That is, he takes into account different production steps considering water from a technical point of view: intake water, recirculation, water treatment prior to use and water treatment prior to discharges (Renzetti 1988); or intake and recirculation (Dupont and Renzetti 2001). Reynaud (2003) considers the origin of water source translated into three water inputs: water bought to the water utility (network), autonomous water (self-supplied) and water treated before use. Apart from these studies, all the others only consider plain intake water.

Translog functional form has become the most popular tool for estimating industrial input demand, due to the advantages it offers, like the capability to model production relationships with numerous inputs without imposing restrictive conditions on the elasticities of substitution.

In this chapter we present a survey on industrial water demand and the microeconomic foundations we use to characterize the technology of the Mexican industrial sector. We also describe the Translog cost function we are going to apply to Mexican data of the manufacturing sector.

2.1 Brief survey on industrial water demand

Table 2.1 highlights the main features and results of the so far documented econometric studies to estimate the demand for water in industry.

Table 2.1 Econometrics Applications to Analyze Industrial Water Demand.

Authors / Country (*)	**Functional Form (Method) / Inputs**	**Main Results (**) (price elasticities)**
(1) Rees (1969) / England (Southeast)	Variety of forms (OLS) / Intake water	Chemical (-0.958); food (3.28); drink (1.3); non-metallic (2.5); paper (1.44) at lowest price.
(2) Turnovsky (1969) / USA (Massachusetts Towns) (n = 19, years 1962 & 1965)	Linear equation (OLS) / Industrial and Domestic	From (-0.473) to (-0.836)
(3) De Roy (1974) / USA (New Jersey) (n = 30, year 1965)	Cobb-Douglas (OLS) / Water Intake for chemical industry	Cooling (-0.894); Processing (-0.354); Steam Generation (-0.590)
(4) Grebenstein and Field (1979) / USA (year 1973)	Translog (SUR) / K, L and Water Intake	AWWA series (-0.326) MM series (-0.801). L & W substitutes; K & W complements
(5) Babin, Willis and Allen (1982) /USA (year 1973)	Translog (SUR) / K, L and Water Intake	Pooled (-0.56): food (0.14) to paper (-0.66). Labour substitutes for K and W.

Authors / Country (*)	Functional Form (Method) / Inputs	Main Results (**) (price elasticities)
(6) Ziegler and Bell (1984) / USA (Arkansas) (n = 23)	Cobb-Douglas (OLS) paper and chemical / Intake water	Average cost better estimates than marginal cost
(7) Renzetti (1988) / Canada (British Columbia) (n = 372; year 1981)	Cobb-Douglas (2SLS) / Intake water; Treatment prior use; Recirculation; Discharge	Intake: petrochemical (-0.12) to light industry (-0.54). Intake & discharge complement. Intake & Recirculation substitutes
(8) Renzetti (1992) / Canada (n = 1068, year 1985)	Translog (I3SLS) / Intake water; Treatment prior use; Recirculation; Discharge	Intake manufacturing (-0.3817): plastic (-0.1534) to paper (-0.5885). Recirculation substitute for Intake & Discharge.
(9) Renzetti (1993) / Canada (n = 1068, year 1985)	Probit and Regression Model (ML) / public and private supply. External and internal water price	Intake External: self (-0.308) public (-0.755). Internal: self (-0.090) public (-0.068). So, public supply intake more sensitive to external price.
(10) Dupont and Renzetti (2001) / Canada (n=58 for each year 1981, 1986 & 1991)	Translog (SUR) / Intake and Recirculation and KLEM	Elasticity (-0.7752). Intake and Recirculation Subs. Intake substitute for K, L & E, but complement to M. Recirculation substitute to L
(11) Wang and Lall (2002) / China (n=2000, year 1993)	Translog Production (SUR) / KLEM and Water Intake	Elasticity (-1.0) Mean Marginal Productivity 2.5 yuan/m^3.
(12) Reynaud (2003) / France (n=51 for each year from 1994 to 1996)	Translog (SUR & FGLS)/ Water Network; Autonomous and treated prior use	Network (-0.29): alcohol (-0.10) to (0.79) for various. Treated (-1.42): alcohol (-0.9) to (-2.21) for chemical. Autonomous & Treatment Complements. Network & Treatment substitutes.
(13) Renzetti and Dupont (2003) / Canada (n=58 for each year 1981, 1986 & 1991)	Translog (SUR) / Recirculation, Treatment and KLEM. Intake quasi-fixed	Intake: elasticity (-0.1308) and Shadow value 0.046CAN$/$m^3$.
(14) Féres and Reynaud (2004) / Brazil (n=404 for year 1999)	Translog (SUR) / KLEMW and plants effluents discharges	Elasticity for water (-1.085), for effluent discharge (-0.16), and for production (0.91). Water substitute to K, L & E, complement to M.

Regarding table 2.1 the meaning of symbols used is: (*) Data base information (n= number of observations and year) when available. (**) K, L, E, M, W stand for Capital, Labor, Energy, Materials and Water, respectively. Regarding the methods used OLS stands for Ordinary Least Square; SUR for Seemingly Unrelated Regression; 2SLS for Two-Stage Least Square; I3SLS for Iterate Three-Stage Least Square; FGLS for Feasible Generalized Least Square; and ML stands for Maximum Likelihood.

The main features of these studies are briefly described below.

(1) Rees (1969) analyzes the different way industrial groups use water as well as the different source to satisfy water demand. Her data set consist of manufacturing firms in southeastern England. She takes into account, among others, the price of water bought and extraction costs to explain some of the differences in the water demand at the inter- and intra-industry level. She mentions that almost all firms in every industry group use water for staff hygiene but that it is unknown if this use is important regarding quantity of water demanded by group. Contrary to this, she finds wide differences in the proportion of firms using water for cooling. While for the food group 65% of its firms use water for cooling, for the non-metallic minerals group less than 27% of its firms demand water for this use, and no firms in the clothing and leather industry require water for cooling. According to Rees data, almost all firms from drink industry demand water for each one of the different uses where water is utilized for industrial purpose.

Regarding the variation in the sources of water supplied she finds that surface water is the principal source in terms of quantity, despite that the number of wells and bores from where water is taken is more important. But she points out that rarely a firm use its groundwater extraction for staff hygiene purposes. Paper and chemical industries are the biggest water users. All industry groups purchase water from local enterprises at least in small volumes.

Rees uses a variety of functional forms to study intake demand equations. She uses Ordinary Least Square (OLS). She estimates price elasticities of water intake for different industry groups. For all industry groups where price elasticity of water is estimated, it shows to be elastic except for chemical firms at its lowest observed price, where water price elasticity is inelastic at value (-0.958) but it becomes elastic when price is increased. For food group the price elasticity at all observed prices is shown to be elastic (3.28). The price elasticity for drink firms is also elastic at value (1.3) at its lowest observed price. Regarding paper group its water price elasticity is 1.44 under same condition. Non-metallic minerals group has elasticity equal to 2.5 and it increases as price increases.

(2) Turnovsky (1969) estimates a demand equation for water under circumstances where supplies are known to be stochastic. The sample data covers the beginning (1962) and the end (1965) of the New England drought, then two cross-sections are estimated, one for each year. He uses a sample from 19 Massachusetts towns and he estimates by Ordinary Least Square (OLS) separately a linear equation for households and a linear equation for industrial demand.

Regarding industrial demand, both average price and index of per-capita industrial production in town as a proxy for output are the explanatory variables together with the variance of supply in town. He found that per-capita industrial water demand is independent of production level of the industry. The demand for water is basically constant and it oscillates through price and variance discrepancy. He estimates elasticity which is calculated at the mean value of the variables. The industrial price elasticity goes from -0.473 for year 1962 to -0.836 for year 1965.

(3) De Roy (1974) uses a Cobb-Douglas form to estimate industrial water demand through Ordinary Least Square (OLS). His data source is from New Jersey 30 chemical plants, for year 1965. The firm outputs are composed of a quite heterogeneous list of products from paints to gases to toiletries. De Roy points out two aspects, first that his model is incomplete since it does not explain the behavior of the firms regarding the introduction of substitutes for water withdrawals, such as recycled effluent emissions. And secondly, the fact that many firms do not recycle effluent emissions indicates either water is still very cheap or that industrialists do not known the saving that could be realized by using other factors.

He estimates separate demand equations for cooling, processing, steam generation and sanitation. The price of water intake and price of water circulation both, through a weighted average, form the price of water for the model. These together with plant output and a technology index are the explanatory variables. The estimated price elasticities for each water application are: cooling (-0.894), processing (-0.745) and steam generation (-0.741).

(4) Grebenstein and Field (1979) estimate the elasticities of substitution between water and other productive inputs for the aggregate U.S. manufacturing sector. Their data is for year 1973. Water is considered as input. The analysis is made for two different series in what concern price of water. One constructed by the American Water Work Association (AWWA) whereas the other was created by Montanary and Mattern (MM). They use these two series to construct the cost of water, multiplying these prices by the quantities of withdrawals.

The cost share of water is 1.2% for AWWA series and 1.9% for MM series. They note that water prices of these two series represent a very high degree of aggregation since they assume that these rates reflect the water cost to all industrial sectors within each state. They use a Translog cost function to estimate the empirical elasticities. And they assume the drawback it implies of using a single production function for the entire US manufacturing sector.

The price elasticity of demand for water for AWWA series is -0.326 and -0.801 for the MM series. Finally, they found that water and capital inputs show to be complements, not substitutes (as “normal neoclassical expectations”) and that labor and water are substitutes in production.

(5) Babin, Willis and Allen (1982) followed between others Grebenstein and Field work; they examine water use for different U.S. manufacturing industries. They estimate by Seemingly Unrelated Regression (SUR) procedure the parameters in the share equations. Their results show significant differences in the parameter estimates between the individual industry groups and the pooled data set. Whereas water price elasticity for the pooled data is -0.56 it varies from positive values (0.14) for food sector as well as for machinery industries, to an inelastic value (-0.66) for paper industry.

Regarding the relationship between factors and sectors, the differences are remarkable. For pooled data water and capital are complements as well as in other 3 sectors: paper, stone and machinery. But these two factors are shown to be substitutes in other three sectors analyzed: food, metal and electric. From their results, changes in the price of water will have little effect in other inputs use but the reverse is not true since, for example, cross price elasticity between capital and water is -0.16 while cross price elasticity for energy and capital is -0.71 both for paper sector. Capital and labor are substitutes in all industries analyzed.

(6) Ziegler and Bell (1984) test the hypothesis that there are no significant differences in the estimates of industrial water demand using either average cost of intake water or marginal costs. They estimate the intake water demand using a Cobb-Douglas functional form for self-supplied industries. They employ a cross

section data collected from a sample of 23 high-volume water-using firms (paper and chemical) in Arkansas, USA. They found that the use of average cost results in a different and better estimate of the water use for self-supplied industries.

(7) Renzetti (1988) considers the industrial water demand for 4 different aspects: water intake, treatment prior to use, recirculation and treatment prior to discharge. In that way, with the introduction of these aspects, he considers the mode water is used inside production process. Renzetti estimates, through a Two Stage Least Square (2SLS) procedure, the input demand from a Cobb-Douglas cost function assuming weak separability in the water inputs. He considers 4 manufacturing subgroups: petrochemicals, heavy industry, forest industry and light industry. The data set is from a survey of water use by Canadian manufacturing firms conducted in 1981. He uses 372 observations of British Columbia, Canada.

Renzetti results show that intake price elasticities range from -0.1186 in petrochemical industry to -0.5368 in light industry. He points out that the relative magnitude of these elasticities correspond to previous expectations such that the cost share of water is smallest in the petrochemical industry as well as in heavy industry, whereas water's cost share is largest in the light industry. And the absolute size of the respective elasticity for intake water follows the same behavior. Regarding the cross price elasticity the results show that for all industries water intake and water discharge are complements; while water intake and recirculation are substitutes.

(8) Renzetti (1992) models industrial water use considering the same four components from Renzetti (1988), which are: water intake, treatment prior to use, recirculation and treatment prior to discharge. The difference is that here each one of the four components is treated as a separate input and the four demands are estimated as a system of interrelated equations from a water-use cost function. He uses the Translog functional form to estimate the cost function by means of an Iterative Three Stage Least Square (3SLS) procedure.

Data is from Canadian manufacturing firms (Industrial Water Use Survey and Survey of Municipal Water Prices), for 1985 including 1068 firms. The estimation results show that industrial water use is sensitive to economic factors. Intake and recirculation are substitutes. Water intake price elasticity varies from -0.1534 (plastic) to -0.5885 (paper). Recirculation and Discharge are also substitutes. These results point out the potential for using economic incentive to reduce industrial water pollution.

(9) Renzetti (1993) estimation procedure in this study proceeds in two stages. One for estimating a Probit model with the firms' selection of either public or private supply stands for dependent variable. And in the second step a regression is applied to derive Maximum Likelihood (ML) estimates of publicly and self-supplied industrial water demands. He utilizes the same source data set used in Renzetti (1992), a cross-sectional survey of Canadian manufacturing firm's water consumption and expenditures for year 1985.

His estimation considers two types of water price: (1) external price, which is the price of water intake either public or self-supplied; and (2) internal price of water, calculated as the sum of the marginal estimated of water treatment, recirculation and discharge. He applies all these to the six industry sub-groups and a pooled data set for the manufacturing firms. Elasticities of the intake pooling data with respect to external price are for self-supplied firms -0.3086 and for publicly supplied -0.7555. The related elasticities for internal prices are for self-supplied -0.0904 and -0.0686 for publicly supplied. So, he shows that publicly supplied firms' water intake demand is more sensitive to external prices. It holds for all industrial sub-groups except for paper firms where, in this case, publicly supplied intake water demand is more sensitive to internal price.

(10) Dupont and Renzetti (2001) model first water intake and water recirculation as variable factors of production to insert them into an econometric KLEM model of manufacturing Canada industry. The data set is from a three cross-sectional survey of water use for 1981, 1986 and 1991. They estimate a Translog cost function, by Seemingly Unrelated Regression (SUR) procedure, for a total of 58 cross-sectional observations for each year under study.

The own-price elasticity for intake water is -0.7752 and for recirculation is -0.6901, but the latter is not significant. Their results show that water intake and water recirculation are substitutes. Intake is substitute for capital, labor and energy; and complement to materials. Recirculation is only substitute to labor. Regarding the input demand elasticity in relation to the level of output, they found that a manufacturing output growth in 1% will produce an augmentation of both water intake and recirculation by approximately 0.7%, while other inputs will rise at the same proportion of output, that is by 1%.

(11) Wang and Lall (2002) examine the value of water for industry by estimating, via Seemingly Unrelated Regression (SUR) procedure, a Translog production function with data for about 2000 Chinese industrial firms for 1993. Water is treated as an input in the production process along with capital, labor, energy and raw materials. They develop a model of price elasticity of water demand associated with the marginal productivity approach, which is estimated assuming the price being set equal to marginal cost of water use. Their results show that the average price elasticity of water for the whole Chinese industry is about -1.0. The marginal productivity of water for industry varies among sectors in China with an industry average of 2.5 yuan/m^3.

(12) Reynaud (2003) studies the structure of industrial water in France. His model of industrial water use considers three components: quantity of water bought to a water utility, network water quantity of autonomous water and quantity of water

treated prior use. Each one is treated as a separate input. He estimates all as a system of simultaneous equations. He uses a sample of 51 industries in the Gironde district observed from 1994 to 1996 using Seemingly Unrelated Regression (SUR) and Feasible Generalized Least Square (FGLS) in a Translog cost function.

His results show that industrials are sensitive to water price inputs. Elasticity for network water is -0.290; it varies from -0.095 for Alcohol industry to -0.787 for various industries. Treated water elasticity is -1.262; it goes from -0.899 for Alcohol industry to -2.173 for Chemical one. Autonomous water price elasticity is not significant. Network and treated water are substitute's production inputs, while autonomous water is a complement for both network water and treated water. In his analysis, by type of industry, network water and autonomous water are complements, excepting commercial and services. Finally, network water and treated water are substitutes in all the industries included. So, an increase in the price of network water will result in an increase of treated water. This work represents the first econometric estimation of industrial water demand in France.

(13) Renzetti and Dupont (2003) examine the value of water in manufacturing processes, by estimating firms' own valuation of their water use. They combine information on water and non-water inputs to estimate a restricted cost function (Translog) for Canadian manufacturing by Seemingly Unrelated Regression (SUR) procedure. Their inputs are internal water recirculation, water treatment, Capital, Labor Energy and Materials (KLEM). Intake water is taken as a quasi-fixed factor. They use the same source data set used in Dupont and Renzetti (2001).

Their results show that the elasticity of cost in relation to the quantity of intake water is -0.1308, and the mean shadow value of intake water is 0.046 $/m3 (1991 CAN$). This value, although positive, is inferior to those in previous studies. Authors claim that an important factor to explain this result could be the environmental regulation controlling manufacturing water use, such that in most provinces, self-supplied water intake is available at almost zero external cost.

(14) Féres and Reynaud (2004) characterize Brazilian manufacturing plants water demand by estimating a multi-product Translog cost function by Seemingly Unrelated Regression (SUR) procedure. They made a special emphasis on the structure of cost and on pollution. Their database contains information on 404 industrial plants in the State of São Paulo, Brazil, for year 1999. Their cost function includes five inputs: Capital, Labor, Energy, Materials and Water. And the multi-output cost function includes two different outputs: a measure of production, Y_1, and a measure of plants effluents, Y_2, which is interpreted as an index of effluent discharge.

Their results show that the cost elasticity for the production Y_1 is 0.91%, then a 1% increase of the production Y_1 results in a 0.91% rise in costs. Regarding the cost elasticity for the effluent discharge index, Y_2, it is equal to -0.16 which imply that a minor reduction of industrial effluents can be realized without a huge cost increment. They found that Brazilian industry displays a significant price elasticity since its value is -1.085 at the sample mean. Water is shown to be substitute to capital, labor and energy; and complement to materials. Regarding the effluent discharge analysis, they found that more polluting plants have a tendency to be more material-intensive. For the other inputs, they note that capital-intensive plants appear to produce lower effluent discharge, similar for labor-intensive plants. The sanctioned firms are inclined to have lower capital share than those firms fulfilling environmental standards, revealing that capital investment may be a way of reducing effluent discharges.

Finally, they simulate changes in production cost, input cost share and water demand produced by different water price increases. They find that a 100% increment in the price of water produces less than 0.5% rises in total cost, since the cost share of water is low. As the water price elasticity is high (-1.085) a 10% increase in water price leads to a 9.33% reduction in water extraction. But on the contrary, reducing effluent discharge will result in an important change in total cost. Total cost rises by 11.24% when the effluent discharge index diminishes by 50%, but this reduction level in the index of the effluent discharge also generates an augmentation of 44% in water extraction. Then, they suggest a combined water policy where in addition to reduce the effluent discharge index, water price is increased through an extraction tax. They demonstrate that a 20% decline of the effluent index jointly with a 12.5% increase in the water price will cause water extraction to remain at the same level. They conclude that effluent rules and water charge should be considered more complementary tools than substitutes.

From this brief survey on industrial water demand, we see that Renzetti's works are the first documented studies in which water use is analyzed, not just as a one more input for the industry together with capital, labor and other inputs, but considering the different uses water may have within industrial production processes. That is, he remarks different production steps taking into consideration water from a technical point of view: intake water, recirculation, water treatment prior to use and water treatment prior to discharges (Renzetti 1988); or intake and recirculation (Dupont and Renzetti 2001). Reynaud (2003) considers the origin of water source, that is, he considers three water inputs: water bought to the water utility (network), autonomous water (self-supplied) and water treated before use. Apart from these studies, all the others only consider intake water.

In general, these studies deal with the problem of defining the price of water. The authors propose different methods and techniques to address this issue, but it is often stressed that working with non-market natural resources, like water, is problematic. As an example, Halvorsen and Smith (1986) use a restricted cost function (Translog) to estimate by Iterative Three Stage Least Square (I3SLS) procedure, substitution possibilities for unpriced natural resources. They use an annual time series data for the Canadian metal mining industry (metallic ore) for year 1954 through 1974. They found that the elasticity of substitution between reproducible inputs and the natural resources is equal to unity. Water is treated as a quasi-fixed input.

There are also other econometric studies where water is viewed as an output.

Teeples and Glyer (1987) present a production function model of water delivery which is estimated from a multi-product dual cost function (Translog) by Seemingly Unrelated Regression (SUR) procedure. They measure the price of purchased water as an average cost (the sum of amounts paid by a firm to its suppliers divided by total units received). Data are for year 1980 in Southern California for 119 water delivery firms. Their results show that purchased and own-water inputs are strong direct substitutes (elasticity of substitution equal to 4.14), but the interaction of each one with other inputs is different. Own-water is substitute with the capital-materials input and complementary uses with energy. Purchased water has these two relationships reversed.

Garcia and Thomas (2001) model the structure of production for municipal water utilities with two outputs: water sold to final customer and water network losses. They estimate the cost structure of water utilities via a Generalized Method of Moments procedure with a Translog cost function and panel data, using 55 water utilities (53 privately operated) located in the Bordeaux region (France) for the years 1995 to 1997. They compute economies of density, scale and scope in the water industry. Concerning substitution elasticities, they found that all inputs (Labor, Electricity and Materials) are significant substitutes in the Morishima sense.

A Mexican study (IMTA, 1998) and its associated paper (Guerrero et all, 1998) assumes a given price elasticity, which strongly argues that water tariffs in Mexico can achieve water savings without lowering the industries' profitability for some of the industries considered in this present research work. In the former, water price elasticity was not the target but how increment in water tariff affects industry benefits.

An interesting fact that comes out from this literature review is that Translog functional form has become the most popular tool for estimating industrial input demand, due to the advantages it offers, like the capability to model production relationships with numerous inputs using a flexible form. Hence, restrictions from production theory can easily be imposed and tested, while elasticities of substitution are left unrestricted.

2.2 Microeconomic foundations

In the empirical literature, the firm production technology is typically represented either by the Profit Maximization Problem -PMP (primal approach) or by the Cost Minimization Problem -CMP (dual approach). Input demand levels are derived from the result of one of the following approaches: profit maximization or cost minimization. Under the dual approach, it is not necessary to know the specific amounts of the input used. We only need information on input prices and final output levels. It holds because cost function is composed of the conditional demand of factors, which are conditioned to a predetermined production level. The dual approach is often preferred since it is easier to achieve reliable information about input prices in an industry than the levels of these inputs used by the firm. Furthermore, working with the primal approach with more than 2 inputs is often cumbersome.

Thus to characterize the technology of the Mexican industrial sector, we adopt the dual approach. Then we will consider a cost function which relates the (short-run) variable cost of production to input prices and to the output level. As many other empirical studies, we will use the Translog Cost function to model Mexican industry cost structure, since it offers different advantages that will be explained in this chapter.

2.2.1 The model: the dual approach

We start by assuming that there is a relationship among inputs and outputs that can be represented in a mathematical form. Then, it is assumed that there is a function

$$Y(y,x) = 0\,, \tag{2.1}$$

where *x* is a n-dimensional vector of nonnegative inputs and *y* is an m-dimensional vector of nonnegative outputs as in Chamber (1988).

For the single-output case, *y* can be treated as a scalar and expression (2.1) can be represented as

$$y = f(x)\,, \tag{2.2}$$

where *y* is the amount of output and *x* is still an n-dimensional vector.

Let us assume that the industry technology associates a single output to a four-input production scheme. Then, equation (2.1) can be represented as

$$Y(Q; K, L, W, M) = 0\,, \tag{2.3}$$

where *Q* represents the homogenous output of the firm; *K, L, W*, and *M*, represent capital, labor, water and other inputs, respectively. In terms of expression (2.2), the production function for *Q,* can be written as

$$Q = Q(K, L,\ W, M)\,, \tag{2.4}$$

where, the inputs are used to produce Q.

Let us define, in general terms, the Cost Minimization Problem as:

$$c(w, y) = \min_{x \geq 0} \{wx : x \in V(y)\}, \tag{2.5}$$

where *w* is an (*1xn*) vector of strictly positive input prices, *V(y)* is the input requirement set

$$V(y) = \left\{x \in \Re^n_+ : \forall y \in \Re^m_+ \ , Y(y, x) \leq 0\right\},$$

i.e., all input combination capable of producing the output level *y*, and *wx* is the inner product ($\sum_{i=1}^{n} w_i x_i$). That is, the cost function displays the minimum cost of producing a given output level *y* in terms of input prices and proportional to that level of output (Chamber, 1988). Expression (2.5) assumes that input prices are exogenous to the producer.

The basic assumption of production theory is that firm's manager maximizes profits, which equal total revenues minus total economic costs. Thus, maximizing profits implies minimizing the production cost for every single output level that the manager could choose to sell in the market. That is, the cost minimizing problem is equivalent to finding the efficient combination of input such that the firm saves at maximum its limited resources. Consequently, the restrictions and limitations of the production function in terms of technology are translated into the cost function.

Thus, we will face the challenge of describing the technology of the firm in terms of the cost function.

As Chambers (1988) points out, "The implication of being able to use the cost function to describe accurately the technology is that the specification of a well-behaved cost function is equivalent to the specification of a well-behaved production function" (p. 82).

In the single-output and four-inputs case, and assuming that firm minimizes the long-run production costs (*C*) for any given production level and exogenous levels of the input prices, there is a restricted cost function which is the dual of equation (2.4) that can be written as,

$$C = C(Q, P_K, P_{L,} P_{W,} P_M), \tag{2.6}$$

where $P_K, P_{L,} P_{W,} P_M$ are the prices of capital, labor, water and other inputs; respectively. Thus, the cost function for the single-output and four-inputs case, can be written as,

$$C(P_K, P_L, P_W, P_M, Q) = \underset{(K,L,W,M)\geq 0}{Min} \{P_K K + P_L L + P_W W + P_M : (K, L, W, M) \in V(Q)\} \tag{2.7}$$

where $V(Q) = \{(K, L, W, M) \in \Re_+^4 : \forall Q \in \Re_+ , Q \geq Q(K, L, W, M)\}$

The theory of duality requires that *C* be monotonic in *Q* and linear homogenous and concave in input prices.

In the previous equations, it is implicit that the firm tries to solve an optimization program regarding all the inputs, implying that the production factors levels could be fitted at once. But, it is well-known that the capital stock is an input that in the short-term does not change in considerable amounts, because any modification in the interim period is either not viable or extremely costly. In that sense, we can consider the capital as a quasi-fixed input and construct a short-run cost function from the minimization of the variable cost that is conditional to *K* (Garcia and Thomas, 2001). That is, the short-run cost model is converted from the long-run model by dropping the assumption of the perfect flexibility of all inputs. Usually capital cannot quickly adjust to changes, so in our short-run cost model, capital is specified as quasi-fixed.

The short-run cost function in our case can be built as:

$$C_{SR}(P_K, P_L, P_W, P_M, Q; K) = VC(Q, P_L, P_W, P_M) + P_K\overline{K}$$
$$= \underset{(L,W,M)\geq 0}{Min}\left\{P_L L + P_W W + P_M \;:\; (L,W,M) \in V(Q,\overline{K})\right\} + P_K\overline{K}$$

where $V(Q,\overline{K}) = \left\{(L,W,M) \in \Re_+^3 : \forall Q \in \Re_+ \; and \; \forall \overline{K} \in \Re_+ ,\; Q \geq Q(\overline{K}, L, W, M)\right\}$

and *VC* is the variable cost and $P_K\overline{K}$ represents the fixed costs (*FC*). From now on, we consider the variable cost function, "as it contains the same information as the original production process" (Garcia and Thomas, 2001), since the production technology is the same.

The dual approach is quite more used than the primal one for estimating the production parameters since the former has several advantages (Binswanger, 1974):

(1) It is not necessary to impose homogeneity of degree one on the production process to achieve the estimation equations. Cost functions are homogeneous in prices despite of the homogeneity properties of the production function, e.g., multiply by two all prices will double costs but will not change factor ratios.

(2) The estimation equations have the factor prices as independent variables instead of the factor quantities, which are not appropriate exogenous variables. Managers make decisions about the use of production factors in terms of exogenous prices, which imply that the factor levels are endogenous decision variables, since firm has a price taking behavior.

(3) To estimate the elasticities of substitution between factors, when a production function procedure has been used, requires the estimated matrix of the production function coefficients to be inverted. It will generate without any doubt estimation errors. When a cost function is used, no inversion is necessary.

The theory of duality implicates that specified some regularity conditions of the cost function (non-negativity, non-decreasing in prices (P) and outputs (Q), concave and continuous in P, linearly homogeneous in P, and no fixed costs) there exist cost and production functions that are dual to each other. Consequently, the production technology configuration can be evaluated by means of a production function or a cost function; the option is supposed to be prepared on statistical arguments. Production function estimation is appropriate under the assumptions of profit maximization and endogenous output levels, whereas cost function estimation is preferred under the assumptions of exogenous outputs and input prices (Segal, 2003).

Since the manufacturing industry is assumed competitive, where every firm attempts to maximize its profits, both outputs and input prices are exogenous to the firms. Additionally, the firms' competitiveness imply that firms compete for their inputs (capital, materials and labor), and as a result, input prices are exogenous too. It follows then that is reasonable to estimate a cost function rather than a production function. Furthermore, it is easier to achieve reliable information about input prices in an industry, than the levels of these inputs used by the firm.

These are some of the reasons we have decided to use the dual approach (cost function procedure) to estimate our parameters. The dual approach is preferred when information on prices is available, whereas a primal approach (production function procedure) is more appropriate to single-product firms with information on quantities.

2.2.2 Translog cost function, flexible form – short run

Taking the logarithm of $C(w, y)$ and applying a Taylor expansion of second degree we get the Translog cost function (See expression 2.8).

$$\begin{aligned} \ln C(w, y) = \alpha_0 + \alpha_y \ln(y) + \sum_{i=1}^{N} \alpha_i \ln(w_i) + \sum_{i=1}^{N} \alpha_{yi} \ln(y) \ln(w_i) \\ + .5\alpha_{yy} \ln(y)^2 + .5\sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{ij} \ln(w_i) \ln(w_j). \end{aligned} \quad (2.8)$$

Berndt (1991) signals that a cost function well behaved must be homogeneous of degree 1 in prices, given *y*, which implies the following restrictions on equation 2.8:

$$\sum_{i=1}^{N} \alpha_i = 1, \quad \sum_{i=1}^{N} \alpha_{ij} = \sum_{j=1}^{N} \alpha_{ji} = \sum_{i=1}^{N} \alpha_{iy} = 0$$

He also remarks that for the Translog cost function it is necessary and sufficient that $\alpha_{iy} = 0 \quad \forall i = 1, \dots n$ to be homothetic. And if in addition to the homotheticity restrictions, we have that $\alpha_{yy} = 0,$ then homogeneity of a constant degree in output occurs. If additionally to these homotheticity and homogeneity restrictions, we have that $\alpha_y = 1,$ then constant returns to scale of the dual function take place.

Christensen et al (1971) point out that, in particular, the Constant Elasticity of Substitution (C.E.S.) and the Cobb-Douglas functions, as well as other lesser known varieties, are special cases of the "Trans-Log" function.

Berndt (1991) shows that from expression 2.8 we could arrive to the constant-return-to-scale Cobb-Douglas function when, in addition to all the above restrictions, each of the $\alpha_{ij} = 0, \quad i, j = 1, \cdots n$. Thus, following our notation in expression 2.8, it can be expressed as,

$$\ln C(w, y) = \alpha_0 + \alpha_y \ln(y) + \sum_{i=1}^{N} \alpha_i \ln(w_i)$$

This equation highlights the linearity and empirical simplicity of the Cobb-Douglas cost function equation (see Berndt 1991, p.70). The advantage of a Cobb-Douglas cost function is that the parameters can be without difficulty estimated and meaningfully interpreted. But it imposes some limits on the production process, mainly, constant returns to scale and a unity elasticity of input substitution. That is, under the Cobb-Douglas model, it is unlikely to evaluate correlation between factors and their prices for the reason that the restriction of the Cobb-Douglas model connoted that all elasticities of factor substitution are equal to 1 (Segal, 2003).

Like the Cobb-Douglas function, the Constant Elasticity of Substitution (C.E.S) function also constraints the elasticity of substitution to be constant, but it does not constraint it to be equal to one (Berndt, 1991). The Cobb-Douglas function is a limiting form of the CES specification.

Contrary to these two previous functions, the Translog flexible form offers several advantages like the easiness to model production relationships with more than a few inputs without restrictive assumptions about the elasticities of substitution. Mongkolporn and Yin (2004) point out that, translog representations are extensively applied in econometrics since they permit for second-order conditions without the limitations of unity elasticities of substitution and constant return to scale. "The Transcendental Logarithmic (Translog) cost function was developed by Christensen, Jorgenson and Lau [1971] to overcome the restrictions of the Cobb-Douglas function. Since then, it has become an essential tool for the production analysis and many researchers have investigated and applied the translog cost function" (Mongkolporn and Yin, 2004).

The three-input model used in this study includes labor (*L*), Water (*W*) and other Materials (*M*). We take the capital as a quasi-fixed input and, in that sense; the Translog represents a short-run cost function with the minimization of the variable cost, conditional to *Q* and to a fix and a given *K*. From now on, we will refer to the variable cost function.

Following Berndt (1991), the non-homothetic Translog cost function in our case reads

$$\begin{aligned}\ln VC = {} & \alpha_0 + \alpha_L \ln P_L + \alpha_W \ln P_W + \alpha_M \ln P_M + \alpha_Q \ln Q \\ & + \frac{1}{2}\beta_{LL}(\ln P_L)^2 + \frac{1}{2}\beta_{WW}(\ln P_W)^2 + \frac{1}{2}\beta_{MM}(\ln P_M)^2 + \frac{1}{2}\beta_{QQ}(\ln Q)^2 \\ & + \beta_{LW} \ln P_L \ln P_W + \beta_{WM} \ln P_W \ln P_M + \beta_{LM} \ln P_L \ln P_M \\ & + \beta_{LQ} \ln P_L \ln Q + \beta_{WQ} \ln P_W \ln Q + \beta_{MQ} \ln P_M \ln Q\end{aligned} \quad (2.9)$$

where *VC* is the total variable cost, *Q* is the output, P_i symbolizes the input prices (excluding capital); α_i, α_Q, β_{ij}, β_{QQ}, and β_{iQ} are the parameters to be estimated for $i, j = L, W, M$. Each one of the variables is divided by its sample mean. The restriction of symmetry is imposed, i.e., $\beta_{ij} = \beta_{ji} \; for \;\; i \neq j$.

Early, it was noted that the cost function, for our case expression (2.9), is well behaved if it is positive and homogeneous of degree one regarding input prices, which implies the following restrictions on the parameters of expression (2.9).

$$\sum_i \alpha_i = 1, \quad \sum_i \beta_{ij} = \sum_j \beta_{ij} = \sum_i \beta_{iq} = 0; \quad for\ i, j = L, W, M$$

Berndt (1991) points out that efficiency can be gained by estimating the conditional input demand equations applying Shephard's lemma.

Defining the cost share as

$$S_i \equiv \frac{P_i X_i}{VC} = \frac{\partial \ln VC}{\partial \ln P_i}; \qquad \text{where } VC = \sum_{i=1}^{n} P_i X_i .$$

It follows that $\sum_{i=1}^{n} S_i = 1$. So, the cost share can be written, for our specification as,

$$S_i = \alpha_i + \Sigma_j \beta_{ij} \ln P_j + \beta_{iQ} \ln Q \quad i = L, W, M \tag{2.10}$$

Assuming cost minimizing behavior and exogeneity in prices, Shephard's lemma $-\frac{\partial C}{\partial P_i} = X_i$, where X_i is the *ith* cost minimizing input demand, implies expression (2.10), where S_i is the cost share of the *ith* input in production cost.

Symmetry and homogeneity of degree one in factor prices are imposed through parameter constraints. Simultaneous equations estimation of the cost function (2.9) and input share equations (2.10) can be performed by iterating the Zellner's two-step procedure for estimating Seemingly Unrelated Regressions (SUR).

As factor share equations sum up to 1, then one of the cost share equations is dropped to obtain a nonsingular covariance matrix.

2.2.3 Elasticities

One of the purposes of this thesis work is to determine Labor, Water, and Materials substitution possibilities using model (2.9). In particular, we focus first on price elasticity of input demands. The elasticities for the Translog cost function are expressed following Berndt (1991), and own and cross-price elasticities of factor demand are calculated as:

$$\varepsilon_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i}\,;\ i = L, W, M \quad \text{and}$$

(2.11)

$$\varepsilon_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i}\,;\ i, j = L, W, M;\ but\ i \neq j$$

Thus, ε_{ij} is the percentage change in the quantity of the *ith* input resulting from a one percent change in the price of the *jth* input, output being constant. With cross price elasticity there is an important distinction between substitute products and complementary goods. Substitutes mean that for an increase in the price of one good will lead to an increase in demand for the rival product. Cross price elasticity for two substitutes will be positive. In contrast, the cross price elasticity of demand for two complements is negative. The stronger the relationship between two products, the higher is the co-efficient of cross-price elasticity of demand. That is, for two very close substitutes the cross-price elasticity will be strongly positive. Consequently, when there is a strong complementary relationship between two products, the cross-price elasticity will be highly negative. For Unrelated products the cross-price elasticity of demand is zero.

The Allen Elasticities of Substitution (AES) are:

$$\sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2}\,;\ i = L, W, M \quad \text{and}$$

(2.12)

$$\sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j} = 1 + \frac{\beta_{ij}}{S_i S_j}\,;\ i, j = L, W, M;\ but\ i \neq j$$

Allen Elasticities of Substitution turns out to be a simple function of the cross-price elasticities, ε_{ij} and factor shares, S_j. Positive σ_{ij}'s indicates that factor inputs *i* and *j* are substitutes, negative that such factors are complements.

An alternative measure of elasticity of substitution in the multi-input case was proposed by Morishima known as the Morishima Elasticity of Substitution (MES). See Blackorby and Russell (1989). It is defined as:

$$MES\,(M_{ij}) = \varepsilon_{ji} - \varepsilon_{ii} \quad \text{and}$$

$$MES(M_{ji}) = \varepsilon_{ij} - \varepsilon_{jj} \tag{2.13}$$

Morishima elasticities measure relative input adjustments to a single-factor price change. Thus, asymmetry of partial elasticities of substitution is natural. Blackorby and Russell (1989) showed that Allen Elasticities of Substitution is an appropriate measure of substitution only in specific cases and provide no additional information relative to the cross-price elasticities and the factor shares. They showed that the Morishima Elasticities of Substitution has several advantages over the Allen Elasticities of Substitution, concluding that Morishima Elasticities of Substitution is the more natural extension to the multi-input case.

Following Stiroh (1999), a comparative analysis of the results given by both elasticities of substitution, the Allen Elasticities of Substitution and the Morishima Elasticities of Substitution, can be performed.

2.3 Summary

First, in this chapter, in the survey on industrial water demand econometric estimation we brought to light the lack of researchers and research on this subject regarding the other principal water demanding users: irrigation and urban.

Second, we present the microeconomic foundations we use to characterize the technology of the Mexican industrial sector. We pointed out that the dual approach is preferred since it is easier to achieve reliable information about input prices in an industry than the levels of these inputs used by the firm.

Third, we introduce the Translog cost function, which will form the basis of our parameter estimation, since it offers several advantages like the facility to model production relationships with more than a few inputs without restrictive assumptions about the elasticities of substitution.

Finally, we present the tools we are going to use to estimate the substitution possibilities between water and other productive inputs for the aggregate Mexican manufacturing sector.

Chapter 3

Manufacturing water demand in Mexico

Introduction

The conflicts between water users in Mexico have a long history. Then and now, industrial users have played an important role. We begin this chapter, section 3.1, giving an overview of what has the evolution of industry in Mexico been and its relationship with water. Next, in section 3.2, we give a general description of the participation of industrial activity in the Mexican economy, finding that industry in Mexico has grown by 24% in average, since year 1993.

In section 3.3 we present the data of Mexican industry. Data is for the aggregate Mexican manufacturing and mining sector. Even if, strictly speaking, mining is not a manufacturing industry, we include this sector in this thesis work because mining is considered one of the principal water users in Mexico. The 8 industrial sectors we use in this research are: mining, food, sugar, beverage, textile, paper, chemistry, and steel, which are representative of the major water demanding industries. The total number of observations is 500 (single cross section of firms). In this section we explain the source of the data and the way different variables are constructed.

In section 3.4 we present preliminary variables analysis and we describe the correlation between them. Then, using the data of the 500 firms in the eight industrial sectors, the industrial water demand is estimated, using a Translog cost system, by Seemingly Unrelated Regression (SUR) procedure.

In section 3.5 we present the empirical results of the water demand for Mexican industry, as well as the elasticities that the cost estimates allows us to obtain. We find that industrial water demand is inelastic and not very responsive to change in water price (elasticity -0.2976). Water is found to be a substitute for both labor and materials in the sense of Morishima Elasticity of Substitution.

3.1 Overview of the industry and water in Mexico

Conflicts for the uses of water in Mexico are not recent. Since the beginning of the Colonial times, Spaniards developed different activities that required important volumes of water, like mining, wheat milling and tannery; in addition to the water needed for irrigation. Since then it has existed an intense battle for water control. Conquers gave a great impulse to the use of water as moving energy. The industry of transformation was built then, next to the watercourses. Principally, in those where the hydraulic resources were present in abundance.

In 1525, the Mexico City local government conferred the permission to take water from Tacubaya River to be used for moving the wheels of the first millers (Suarez, 1997). That river turned out to be, for a long time, the principal source of energy for industry in the colonial time. Millers were an important activity for the economy of the New Spain (Nueva España). Those millers were grand water users. Water derived to millers restrains water to other users, like water for urban use or for irrigation. Since then, that competition engendered in a large conflict between water consumers.

Together with the millers, “batanes”, paper factories and “haciendas de beneficio”, the Spanish started other activities which demand water in abundance, like tannery. All these industries dependent on water were fragile, since the lack of water in drought times and the maintenance of the hydraulic infrastructure used to move machines, making the industry an activity with high risk level. During the independence war a lot of that infrastructure (hydraulic and industrial) were destroyed or damaged from abandonment.

Toward the beginning of the independence period, Mexican government was concern for taking the country out of the chaos that war had brought. It was made through to restore mining industry and agriculture, but one of the strategic favoritism was to impulse textile industry. Through the first half of XIX century the biggest and most modern factories made use of hydraulic force to be in motion. For that, they were also established peripherals to rivers. Industrialists bought the old millers and transformed them in factories of paper or spinning mill and textile cotton.

Diverse aspects exert influence about where to situate factories. Obviously, one of the most important was the availability of water. No matter that there were water sources almost from side to side of the country; factories were placed principally in the central zone. As an example, we have that in 1843, Mexico City and the State of Mexico already concentrated 29% of textile factories, while in Puebla State were localized 36%. This State is located in the central region of the country too. This incidence also obeys to the availability of raw materials and workers and the proximity to the principal markets (Suarez, 1997).

Water in the Colonial period was under the ownership (property) of Spanish monarchy. There existed public and private water users but the private use was only allowed through concession (“merced”), given by the king. Water legislation from the Colonial period was still applied in the first half of XIX Century. Since the Colonial time, it becomes common that a way of getting water concession, without paying for it, was to finance hydraulic construction or to improve them as a source to public use (like fountains or small font). The productive units (mills, factories, tannery, etc.) got the major quantity of water inside of the cities. As an example, in Puebla City the "merced" of potable water supplied only 2% of all the houses, the rest of the population got water from public fountains. In 1854, Mexico City had 806 fountains where 764 were private property (Suarez, 1997). The lack of order with respect to water concession was a constant through all this period, principally because of the absence of a clear legislation. There were also developed different economical activities using the same hydraulic resource.

The uneven water distribution and the battle for this resource prevailed throughout XIX century. In the first half of XX century, the allocation of potable water to cities generated strong political and social tensions and the federal government was the only instance able to solve those by monetary contributions to build hydraulic infrastructure. This result in the fact that both municipal and state government, lost power on water administration.

The period between 1921 and 1929 was one of (post revolution construction, which was restrained by the 1929's world crisis. At the end of this crisis, the federal government increased its participation in the national economy through public expenditure. Starting from the decade of 30's the public expenditure for infrastructure works like roads, irrigation works, and supply of potable water, increased.

During the Second World War period a protectionist policy prevailed and the State augmented its role as ruler of the economy. After the war, the accumulation of capital gave place to an industrial growth, displacing, amongst others, agricultural development.

The modernization project made between 1930 and 1950 has as a priority to solve the problems that blocked the economical development and in general, the country modernization. This project consisted of a transformation policy where the rural economy left its place to one of industrial type. One of the principal factors that work in favor of industrial development was the huge uncertainty that agrarian policy created inside the investment group. The investment that traditionally was given to agricultural sector moved to industrial one (Birrichiaga, 1997).

Up to 1960 the Mexican industrial development was made, principally, under the modality of import substitution of non lasting goods. That policy generated a high-protected structure. In 1960 the highest custom duty protection was given to the non-durable industrial goods. But, in 1970 these custom duties levels were reduced, but not for other industrial goods as machinery and chemistry which were increased. The import substitution model followed in Mexico had a positive effect in its early stages. Between 1950 and 1952 the manufacturer imported goods represented 18% of the domestic manufacturing production, while from 1967 to 1969 this value dropped to 11% (Hernandez, 1985). Starting 1970, the industrial development model began to show a gradual diminution in its growth. The period 1970-1978 has the characteristic of recession time followed by expansion ones but of short duration.

As the import substitution model was oriented towards the substitution of those manufactured goods which did not require a high technology level or huge amount of investment, it generated a dependence of the importation of intermediate goods and capital goods needed for the industrial investment. Also, as a result of the high custom duty protection, industry grows free of exterior rivalry. For that, industrial productivity and efficiency were far from those levels needed to be in condition to compete in the international markets. In that way, domestic industry growth carried out the advantage of saving foreign currency for all the manufactured goods which were not imported. But it had the disadvantage of becoming an industry restricted to the availability of currency to achieve the importation of those goods that allow an increase in the production capacity. Then, industry relied on the currency generated in other sectors.

Consequently, the industry growing path is limited because of the low currency availability and so; the government went into a greater external debt. But, it is until

1980-1982 that this problem becomes stronger. We have that Mexico has to buy from the exterior 90% of its entire technological requirement (Olivares, 1995). And in addition, we have the fact that the country has a lack of scientific-technological infrastructure and it also exists isolation between research and technology development done by the Institutes of Superior Education.

In summary, the industrial strategy followed was based on import-substitution process. However, as the industrialization was done without modification in the import parameters - through technological changes - the foreign purchase increased considerably, producing at the beginning of the 80's a crisis in the payment balance, because of unstable exportation infrastructure that might give a financial support to the importation growth. For the last 25 years, the renovation process has not been easy, principally for those enterprises of a small and medium size. In general, the productive plants have not a Research and Development (R&D) area. Then, the renovation activity has consisted in a process to try to fit technologies developed outside.

3.2 Industrial water use

Industry in Mexico considers mining and manufacturing sectors. According to the XV Industrial Census (INEGI, 1999), mining sector provides work to 108,810 employees, and manufacturing sector generates 4,232,322 direct employment. Mining reports 4.63% employment annual growth rate compared to year 1993 and manufacturing sector rises by 5.72% in the same period. The Aggregate Gross Value for mining sector is 8.62% regarding national value. For industrial sector, the total gross product grew, relating year 1994, by 2.18% for mining and by 4.21% for manufacturing sector, both in real values (INEGI, 1994; INEGI, 1999).

The principal manufacturing industries, taking into account the number of workers, are the "maquiladoras" - clothing industry, which employs 453,414 workers, followed by Electric Equipment industry with 294,452 laborers, and in third place, the Electronic industry with 225,905 labor force (IMTA, 2000). Other manufacturing industries relevant by number of workers are: automobile, plastic, editorials and printer, textile, and production of timber furniture.

Taking into account the level of total gross product for manufacturing sector, in figure 3.1 is displayed the participation administrative region.

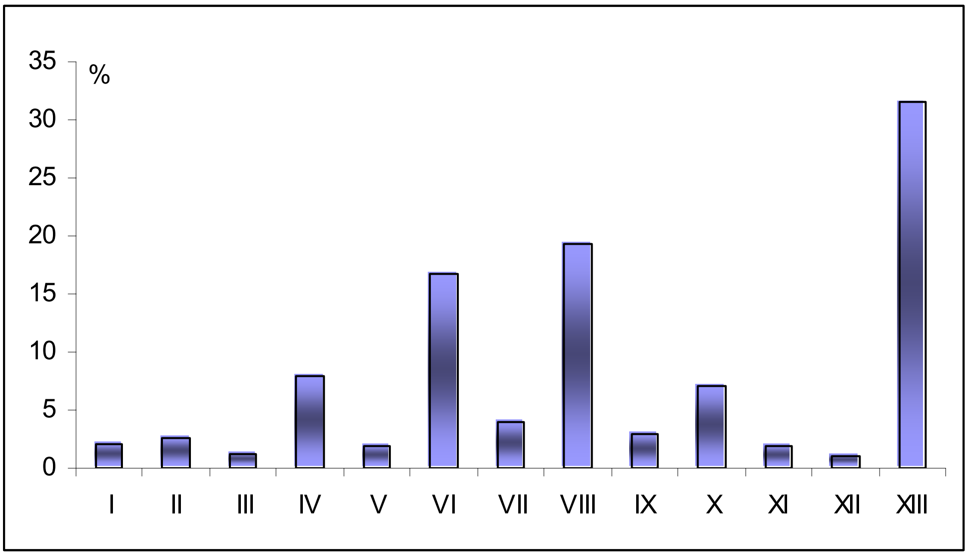

Figure 3.1 Manufacturing Gross Product (%) by Administrative Region (Source: IMTA 2000).

In this figure we see that Region XIII Valle de Mexico has the greatest participation in manufacturing gross production, followed by Region VIII Lerma-Santiago-Pacifico, both of these regions are placed in Central Mexico. In third place we have Region VI Rio Bravo. This last is located in the North of the country, along the frontier with the United States. Region VI has the characteristic that it is the greatest of all 13 administrative regions in the country. It is constituted by the federal states of Chihuahua (51%), Coahuila (30%), Nuevo Leon (13%), Tamaulipas (5%) and Durango (1%) (IMTA, 2000). The relevance of Region VI Rio Bravo participation in manufacturing sector production is due to the fact that, principally there, together with Region I Peninsula de Baja California, and Region II Noroeste, are installed the majority of “maquiladoras” (clothing factories). Figure 3.2 presents the distribution, through administrative regions, of workers by economic unit (IMTA, 2000). Understanding by Economic Unit as the statistic observation unit over which information is obtained during the Census, like production plants or factories.

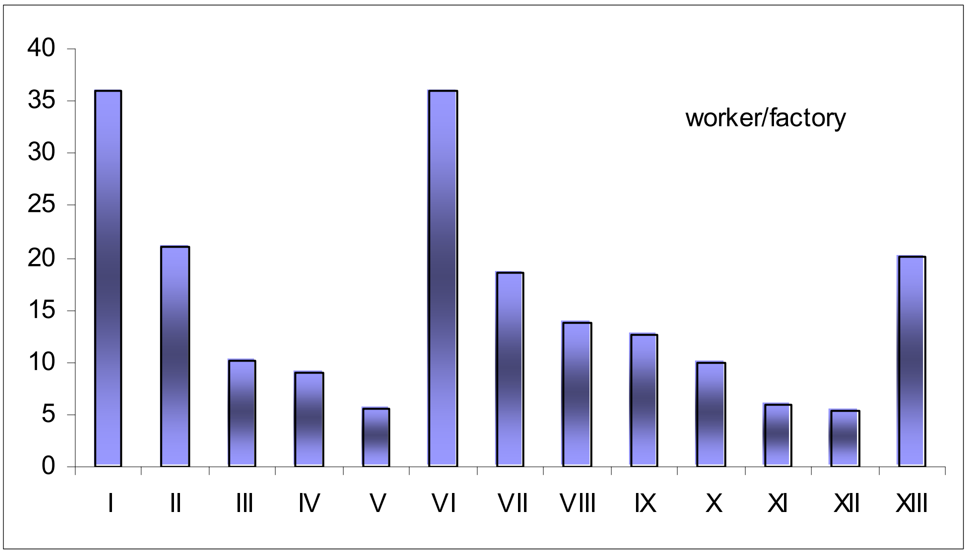

Figure 3.2 Workers / Economic Unit by Administrative Region (Source: IMTA, 2000).

In figure 3.2 we see that the three administrative regions, which cover the Mexican north frontier, have the greatest average number of workers by installed production plant. We are talking of Region VI Rio Bravo, Region I Peninsula de Baja California, and Region II Noroeste, respectively by its participation.

Concerning to water use, the industries previously mentioned as those with major number of employees are not huge water consumers, since they use water, principally, for services and green areas irrigation.

The use of water in Mexico for the self-supplied industry is over 6.6 km^3 of water per year. It represents 9% of the consumptive water uses (see table 1.3 from Chapter 1). It corresponds to about 70% of total industrial water use. The other 30% comes from municipal network. Table 3.1 gives us the volumes of water for the self-supplied industry in 2001, for each one of the 13 National Water Commission administrative regions. The principal origin source for industry is surface water (76%).

Table 3.1 Water extractions by region and source for 2001.

	Administrative Region	Industry (self-supplied) Surface water km^3	Groundwater km^3	Total
I	Península de Baja California	0.004	0.213	0.217
II	Noroeste	0	0.032	0.032
III	Pacífico Norte	0.047	0.021	0.068
IV	Balsas	3.264	0.142	3.406
V	Pacífico Sur	0.005	0.008	0.013
VI	Río Bravo	0.061	0.216	0.277
VII	Cuencas Centrales del Norte	0.001	0.105	0.106
VIII	Lerma-Santiago-Pacífico	0.074	0.257	0.331
IX	Golfo Norte	0.156	0.047	0.203
X	Golfo Centro	1.356	0.090	1.446
XI	Frontera Sur	0.016	0.068	0.084
XII	Península de Yucatán	0	0.152	0.152
XIII	Valle de México	0.044	0.240	0.284
	Total	5.028	1.591	6.619

Source: CNA (2003a).

The industrial sector altogether discharges 5.36 km^3 (170 m^3/s) of wastewater per year. It turns into more than 6 millions of tons of BOD. This quantity exceeds by 140% the charges of contaminants generated by all the country population (CNA, 2000). There are 1485 treatment plants for industrial discharges, from them 1405 are in operation. Consistent with the National Water Commission statistics reported for year 2004, the treatment volume is 76% (26.2m^3/s) of the treatment plants installed capacity.

Table 3.2 shows total treatment plants installed and in operation for each administrative region. It also displays the installed capacity and treatment volume. In average, from all treatment plants 95% are in operation and they utilize 76% of their installed capacity.

Table 3.2 Treatment Plants for Industrial Wastewater (December 2002).

	Administrative Region	Instaled Plants	Plants in Operation	Instaled Capacity (L/s)	Treated Volume (L/s)
I	Península de Baja California	191	164	1 189.8	1 102.1
II	Noroeste	20	18	303.6	83.6
III	Pacífico Norte	30	26	685.6	468.7
IV	Balsas	226	206	2 933.8	2 058.0
V	Pacífico Sur	15	14	228.8	225.0
VI	Río Bravo	99	97	5 008.2	3 293.1
VII	Cuencas Centrales del Norte	92	92	1 201.4	824.0
VIII	Lerma-Santiago-Pacífico	348	344	3 905.7	2 730.8
IX	Golfo Norte	62	61	2 080.3	1 391.0
X	Golfo Centro	190	186	13 628.7	11 698.7
XI	Frontera Sur	79	77	1 116.6	1 070.5
XII	Península de Yucatán	120	108	217.0	119.9
XIII	Valle de México	55	55	1 804.1	1 166.2
	Total	1 527	1 448	34 303.6	26 231.6

Source: CNA (2004).

From 1996 to 2001 the treatment of industrial residual discharges has increased by 18.32%. In figure 3.3 we show this evolution. Data is m^3/s (CNA, 2004).

Ortiz (2001) points out that 92% of the wastewater discharge from industrial origin ($80m^3/s$) is made by those major industrial water users. In table 3.3 is displayed the participation of the principal industries on wastewater discharge as well as for principal kind of pollutants.

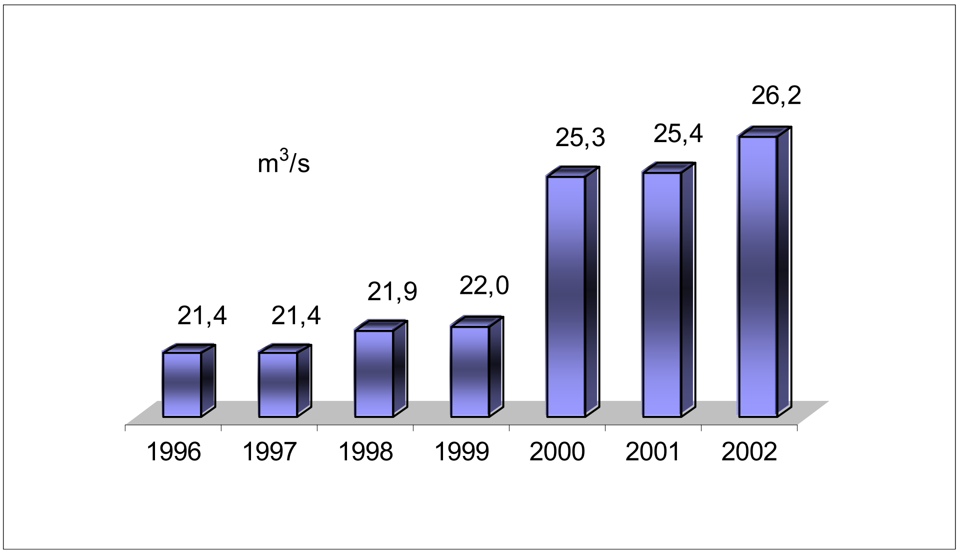

Figure 3.3 Treated volume of industrial wastewater 1996 – 2002 (Source: CNA, 2004).

Table 3.3 Wastewater discharge by industry (%)

Industry	Discharges %	BOD %	DO %	TSS %
Sugar	30.8	40.4	24.1	36.8
Food	15.3	20.2	21.5	24.6
Steel	12.9	1.9	2.4	2.4
Beverage	10.8	22.2	29.0	13.3
Oil (refinery)	6.4	1.4	2.1	1.8
Paper	6.2	5.7	6.4	13.8
Agro-Chemistry	5.8	3.1	4.0	0.6
Mining	2.9	0.7	2.3	1.5
Inorganic Chemistry	2.3	0.8	1.6	0.6
Organic Chemistry	2.2	1.0	1.2	1.0
Textile	2.1	1.0	3.3	1.3
Resin and similar	1.4	0.7	0.8	1.9
Petro-chemistry	0.9	1.0	1.4	0.3

BOD = Bio-chemical Oxygen Demand (organic matters); DO = Oxygen Demand; TSS =Total Suspended Solid. Source: IMTA (2001).

Sugar industry is the one that made maximum wastewater discharge, 30.8%, the double of food industry, which is the second wastewater discharger (15.3%). 70% of wastewater discharge is made by just four industrial sectors: sugar, food, steel and beverage. About 40% of the total water reuse by industry is used in process, 55% into cooling systems and 5% in cleaning services (CNA, 2000).

From total extraction, 86% is carried out by 8 categories of industries, principally sugar, chemistry, mining, paper, steel, textile, food, and beverage (CNA, 2000). Table 3.4 shows extraction and consumption for those industrial sectors identified as the most important water demanding.

Table 3.4 Water consumption by Industry (Mm^3/y).

Industry	Extraction Mm^3/y	Consumption Mm^3/y	Discharges Mm^3/y
Sugar	459	86	372
Paper	283	208	75
Food	214	29	185
Steel	198	42	156
Beverage	192	61	131
Agro-Chemistry	127	57	70
Oil (refinery)	93	15	77
Organic Chemistry	72	45	27
Mining	64	30	35
Inorganic Chemistry	38	10	28
Petro-chemistry	35	24	11
Textile	30	5	25
Resin and similar	21	4	17
TOTAL	1 826	616	1 209

Mm^3/y = Million of cubic meters per year. Source: IMTA (2001).

In figure 3.4 we note that sugar sector is the greater water demanding, but table 3.4 shows clearly that paper industry is the major water consumer.

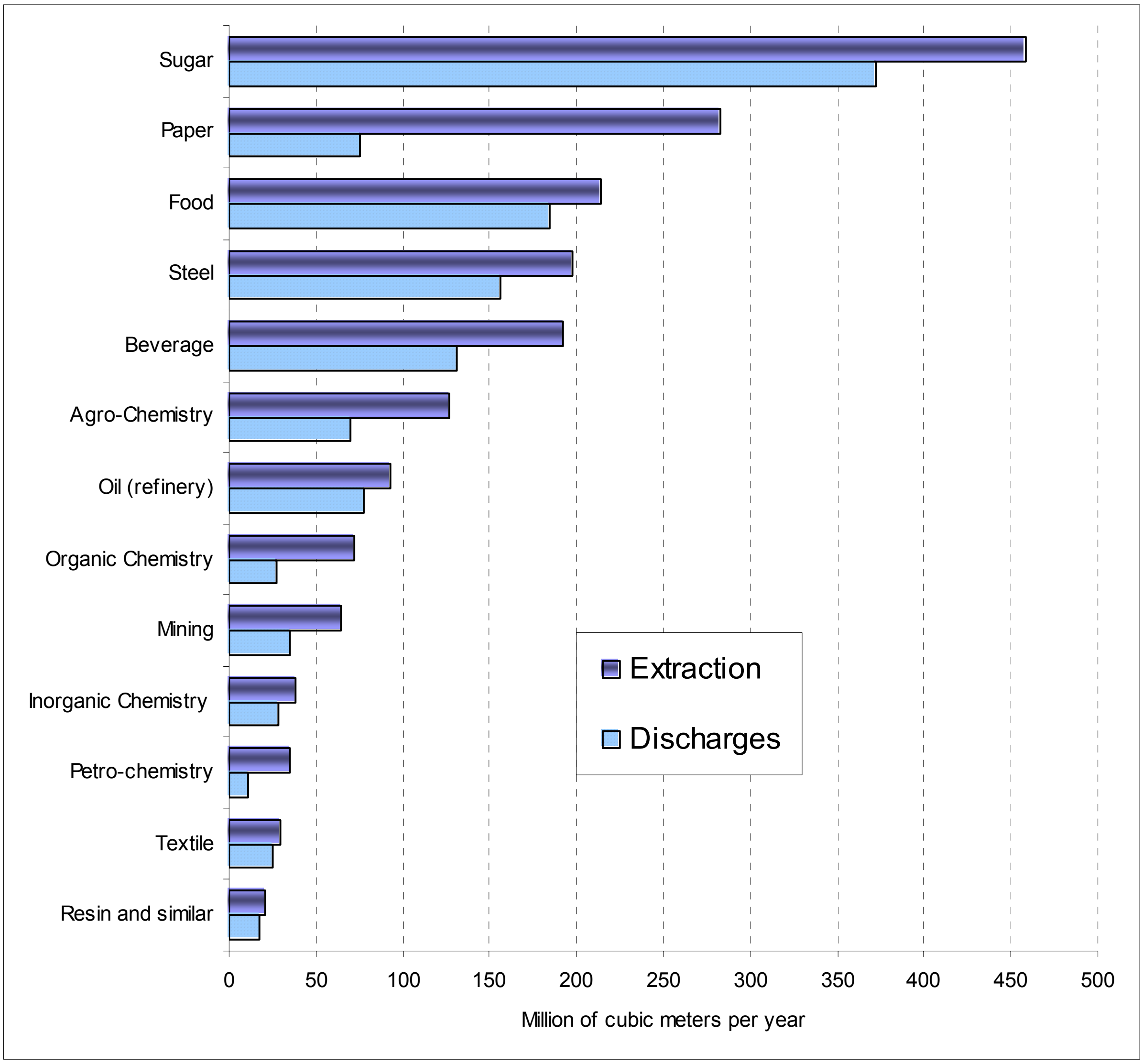

Figure 3.4 Extraction and discharge by major water consumer industries (Source: IMTA, 2001).

Manufacturing industrial sector participates, in 2001, with 19.6% of the Gross Domestic Product (GDP) and generates 4.23 millions of direct employment. In the interior of manufacturing sector, beverage, sugar and food contribute with 28% of the GDP (INEGI, 2001). Next, we briefly describe some of the most relevant characteristics of the 8 major water demanding industries.

Mining sector participates, in 2001, with 1.36% of the gross domestic product and generates 108,810 direct employments, which grow in an annual rate of 4.63% in comparison to year 1993 (INEGI, 1994). The total gross product of mining grew by 2.18% for the same period. This is an important activity in the Region VI Rio Bravo, participating with 3.25% of production. Regarding water use, mining has an important level of water recirculation, 62.5%, concerning its water needs, and discharges 48% in relation to its water withdrawal. Specifically, in Region VI Rio Bravo, the mining water demand is 55.844 Mm^3/y (millions of cubic meters per year), from them, they extract 20.963 Mm^3/y and discharge 10.062Mm^3/y (IMTA, 2000).

Mining is an activity developed principally in 4 federal states: Sonora, Zacatecas, Durango and Veracruz. Table 3.5 displays, by water availability zone, volumes of extraction and discharges made by mining industry.

Table 3.5 Water extractions by Availability Zone in Mining Industry.

Water Availability Zone	Groundwater m^3/y	Surface water m^3/y	Extraction m^3/y	Discharges m^3/y
2	13 966 257	*	13 966 257	1 666 085
3	4 126 170	*	4 126 170	*
4	22 476 255	39 244	22 514 819	721 879
5	7 554 653	399 255	7 914 898	3 216 283
6	11 441 091	678 393	12 119 484	428 255
7	6 682 852	16 769 351	23 452 203	2 393 425
8	1 604 595	1 198 033	2 802 628	311 883
9	1 284 110	1 100 436	2 384 546	149 905
Total	69 135 983	20 184 712	89 281 005	8 887 716

Source: CNA-IMTA (2001c). * Data not available.

The aggregate gross value of mining sector is 8.62% compared to national value.

Food sector is distributed around the country, but it is mainly intense in Region VIII Lerma-Santiago-Pacifico. In accordance with INEGI (1999), aggregate gross value of food industry corresponds to 68.43% regarding 'Food, Beverage and Tobacco' division, 14.32% of manufacturing sector, and 5.4% to national level. This sector employs almost 80% regarding 'Food, Beverage and Tobacco' division.

The principal water source for food industry is groundwater, 88%, and a small quantity of surface origin, 12%. Food industry extracts 57.167Mm^3/y and discharges 7.724Mm^3/y (IMTA 2001). In table 3.6 we see, for each one of the different types of industries which compose the food sector, the quantity of water they obtain, either by groundwater source or by surface origin. This table also shows water discharge volumes.

Table 3.6 Water extraction for type of Food industry.

Type of Food Industry	Groundwater m^3/y	Surface water m^3/y	Extraction m^3/y	Discharges m^3/y
Meat industry	7 634 913	619 264	8 254 177	382 596
Milk products	7 766 012	1 591 930	9 357 942	1 059 758
Food conserves	7 513 331	2 650 185	10 163 516	2 267 538
Cereals and similar	9 242 180	851 716	10 093 896	1 297 982
Bakery products	2 158 651	2 400	2 161 051	355 565
Edible Oil and similar	3 933 411	30 192	3 963 603	1 270 414
Chocolate and similar	506 478	*	506 478	212 458
Other food products	11 789 813	876 726	12 666 538	877 701
Total	50 544 791	6 622 414	57 167 203	7 724 012

Source: CNA-IMTA (2001a). * Data not available.

Food conserves industry is the one which made the greatest water extraction from surface origin, and it is also the industry with major discharge volumes.

Sugar sector counts with a total of 60 “ingenios”(sugar mill) (factories to process sugar cane) within the country. 37% of its factories are placed in Veracruz State. The principal problem inside this sector is that the factories still use an old production process which demands a lot of water and generates a large quantity of pollutants in their wastewater discharge. There is an estimate that 20m^3 of water are used to process one ton of sugar cane (CNA, 2000).

The aggregate gross value of sugar industry is 4.67% within ‘Food, Beverage and Tobacco’ division, 0.98% regarding manufacturing sector and 0.37% at national level.

Table 3.7 Sugar industry water extraction by administrative region.

	Administrative Region	Groundwater m^3/y	Surface water m^3/y	Extraction m^3/y	Discharges m^3/y
III	Pacífico Norte	*	104 396	104 396	*
IV	Balsas	332 146	10 627 664	10 959 810	4 650 774
VIII	Lerma-Santiago-Pacífico	4 370 704	7 653 617	12 024 321	160 633
IX	Golfo Norte	359 383	22 470 086	22 829 469	14 775 724
X	Golfo Centro	5 420 108	37 580 397	43 000 505	64 435 393
XI	Frontera Sur	360 070	433 724	793 794	1 683 993
XII	Península de Yucatán	933 590	*	933 590	450 000
	Total	11 776 001	78 869 884	90 645 884	86 156 517

Source: CNA-IMTA (2001b). * Data not available.

In table 3.7 we see that Region X Golfo Centro is the major groundwater user. In addition, this region discharges major volumes. This region apparently discharges greater volumes than those it extracts. It can be explained because in some regions with water in abundance, like Region X, there are dams to control excessive floods, but also to stock surplus for industrial process and in some cases to promote water recirculation. Then, that is the reason for discharges to be higher than the extraction volumes.

Beverage sector, according to the XV Industrial Census, has an important role in the national economy. The aggregate gross value of this industry corresponds to 26.90% regarding 'Food, Beverage and Tobacco' division, 5.63% of manufacturing sector and 2.12% of national level. Beverage sector consists of beer industry, soft carbonated beverage and water purification, and alcoholic beverage. The soft carbonated and non alcoholic beverage industry generates 131,788 direct employments.

The principal water source for beverage industry is from groundwater, 94.77%, and only 5.23% comes from surface origin. The soft carbonated beverages and non alcoholic drinks production industry discharges less than 7% regarding its total extractions, meaning that more than 93% of water is consumed in production processes (See table 3.8). And it is explained because water turns to be a principal input for products generated by this industry.

Table 3.8 Water use for soft carbonated and no alcoholic drink production.

	Administrative Region	Groundwater m^3/y	Surface water m^3/y	Extraction m^3/y	Discharges m^3/y
I	Península de Baja California	345 315	*	345 315	53 208
II	Noroeste	549 503	*	549 503	70 482
III	Pacífico Norte	1 508 419	234 422	1 742 841	677
IV	Balsas	4 687 042	24 888	4 711 930	185 826
V	Pacífico Sur	1 714 526	*	1 714 526	27 917
VI	Río Bravo	4 811 645	*	4 811 645	1 840
VII	Cuencas Centrales del Norte	1 907 922	*	1 907 922	*
VIII	Lerma-Santiago-Pacífico	10 378 782	17 949	10 396 731	128 421
IX	Golfo Norte	1 647 199	154 039	1 801 238	164 450
X	Golfo Centro	2 753 024	89 814	2 842 839	1 179 556
XI	Frontera Sur	1 304 235	*	1 304 235	321 644
XII	Península de Yucatán	3 656 862	*	3 656 862	894 117
XIII	Valle de México	10 320 299	*	10 320 299	*
	Total	45 584 773	521 112	46 105 885	3 028 138

Source: CNA-IMTA (1999). * Data not available.

In table 3.8 we observe that the administrative Region VIII Lerma-Santiago-Pacifico is the one which made the main water extraction but its volumes are no so far from those of Region XIII Valle de Mexico. Concerning wastewater discharge, Region X Golfo Centro discharges the most important volumes than others.

Textile. The aggregate gross value of textile industry represents 8.51% of manufacturing sector and 3.21% of national value. Consistent with the XV Industrial Census (INEGI 1999), textile sector, including all its activities, generates 894,005 direct employment. This is a sector placed around the country but there are four federal states where it is a predominant activity, by order of importance we have: Distrito Federal, Estado de Mexico, Puebla and Guanajuato. All of them are located at the central part of the country. For that, textile sector dominates in the Administrative Region XIII Valle de Mexico and Region VIII Lerma-Santiago-Pacifico (IMTA, 1998c).

Concerning the use of water, in table 3.9 we see that the principal water source for textile industry is groundwater (97.12%).

Table 3.9 Textile industry water use.

	Administrative Region	Groundwater m^3/y	Surface water m^3/y	Extraction m^3/y	Discharges m^3/y
I	Península de Baja California	8 202	300	8 502	8 502
II	Noroeste	17 919	323 108	341 027	18 387
III	Pacífico Norte	800	*	800	229 330
IV	Balsas	3 333 846	451 672	3 785 518	4 242 625
VI	Río Bravo	216 490	*	216 490	216 490
VII	Cuencas Centrales del Norte	834 666	*	834 666	837 546
VIII	Lerma-Santiago-Pacífico	1 889 307	*	1 889 307	3 007 840
IX	Golfo Norte	18 107 724	*	18 107 724	18 107 724
X	Golfo Centro	22 547	*	22 547	39 971
XIII	Valle de México	1 976 658	6 693	1 983 351	2 234 242
	Total	26 408 159	781 773	27 189 932	28 952 424

Source: CNA-IMTA (1998c). * Data not available.

Region IX Golfo Norte extracts all its water from groundwater source. The water quantity this region extracts represents 69% regarding total groundwater withdrawal for textile industries, 67% of total extraction. Also, in this administrative region occurs 63% of wastewater discharges.

Paper industry encloses the production of cellulose, paper and other paper products, like carton. Paper industry represents 1.98% of national aggregate gross value and 5.24% regarding manufacturing sector. The industries of paper generate 222,609 direct employments (INEGI, 1999); its annual growth rate is 2.73% regarding employment created by this sector in 1993.

In table 3.10 we observe that 64% of water that this sector uses comes from groundwater source. And it discharges 17% of its water extraction.

Table 3.10 Paper industry water use.

Administrative Region		Groundwater m^3/y	Surface water m^3/y	Extraction m^3/y	Discharges m^3/y
I	Península de Baja California	*	410 147	410 147	221 675
II	Noroeste	351 655	*	351 655	3 992
III	Pacífico Norte	17 710 052	44 313	17 754 364	15 097 138
IV	Balsas	5 758 650	1 480 116	7 238 766	3 792 785
VI	Río Bravo	26 098 995	*	26 098 995	608 493
VII	Cuencas Centrales del Norte	940 900	*	940 900	14 361
VIII	Lerma-Santiago-Pacífico	10 526 630	18 715 384	29 242 014	2 813 730
IX	Golfo Norte	14 969 494	*	14 969 494	405 032
X	Golfo Centro	10 929 177	31 718 960	42 648 137	2 115 300
XI	Frontera Sur	44 713	*	44 713	24 774
XII	Península de Yucatán	4 117	*	4 117	1 151
XIII	Valle de México	7 364 971	1 235 960	8 600 931	26 234
Total		94 699 354	53 604 880	148 304 234	25 124 664

Source: CNA-IMTA (1998a). * Data not available.

Region X Golfo Centro makes the most important water extraction, but it is Region III Pacifico Norte were major discharge occurs.

Chemistry sector has 10,751 factories around the country, but they are principally established in the states of Distrito Federal, Estado de Mexico, Jalisco, Nuevo Leon, Queretaro and Veracruz. This sector has 479,855 employees (INEGI, 1999). Chemistry aggregate gross value is 19.4% regarding manufacturing sector and 7.32% at national level.

Table 3.11 displays water consumption made by the type of industries which assemble chemistry sector.

Table 3.11 Water consumption by chemistry industry (Mm^3/y).

Industry	Extraction Mm^3/y	Consumption Mm^3/y	Discharges Mm^3/y
Agro-Chemistry	127	57	70
Oil (refinery)	93	15	78
Organic Chemistry	72	45	27
Inorganic Chemistry	38	10	28
Petro-chemistry	35	24	11
Resin and similar	21	4	17
TOTAL	386	155	231

Mm^3/y = Million of cubic meters per year. Source: IMTA (2001).

In table 3.11 we perceive that the average water consumption is 40% of their total water supplied. The production of agro-chemistry; like fertilizers, is the industry which made principal water extractions, 127 Mm^3/y, however it is oil (refinery) industry that makes minor water consumption regarding its own extraction level, 16%. The greater water consumer relating its own extraction is the petrochemical industry, 69%. Figure 3.5 displays water extraction and water discharge by the industries considered as part of chemistry sector.

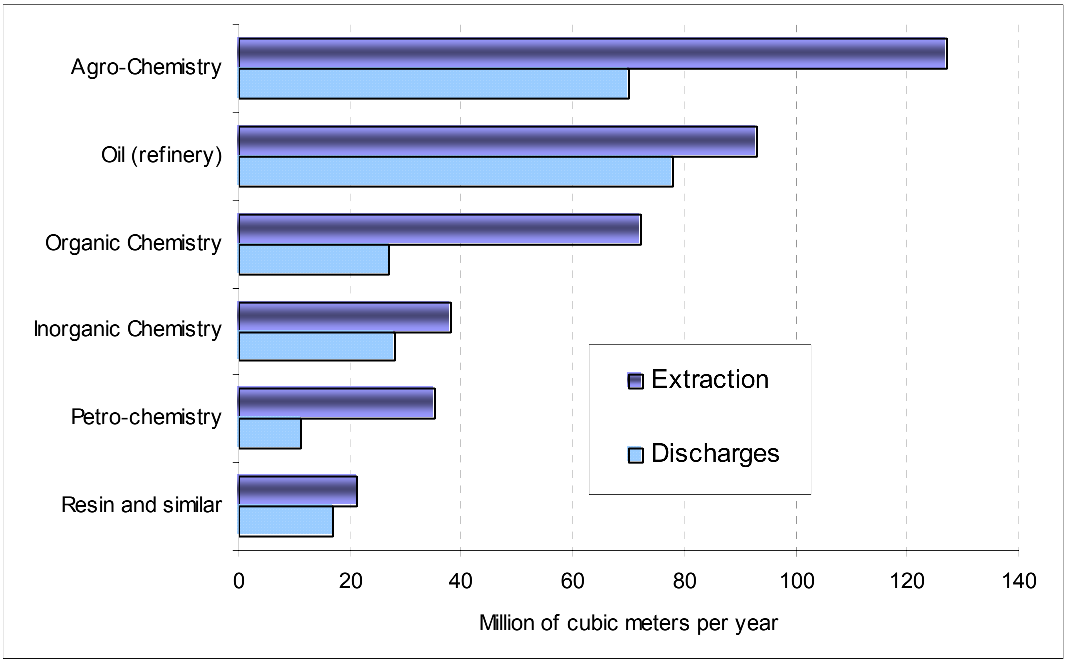

Figure 3.5 Extraction and discharge by chemistry industry (Source: IMTA, 2001).

Steel industry is an important activity in the federal states of Michoacan, Nuevo Leon, Coahuila, Veracruz, Guanajuato and Puebla. Consistent with the XV Industrial Census, steel industry produces an aggregate gross value equivalent to 1.88% concerning nation value and 5% regarding manufacturing sector. Steel industry generates 44,981 direct employments.

For the type of production process, this industry demands an important quantity of water for cooling processes. 46% of total extraction is oriented to this step process. According to table 3.12 Region VI Rio Bravo is the main water user, but Region IV Balsas reports greater discharge volumes, 96% of total steel industry discharges.

Obviously, the volume discharges in Region IV Balsas grab our attention, principally because of the huge difference regarding extraction. In this administrative region, two of the most important steel industries in the country are placed and both are in the municipality of Lazaro Cardenas at Michoacan State. This municipality gets the benefits of subsidies on water price and water extraction, among others. As a result, both industries report cero extraction volume (CNA-REDA, 1996).

Table 3.12 Steel industry water use.

	Administrative Region	Extraction m^3/y	Discharges m^3/y
IV	Balsas	173 915	6 006 591
VI	Río Bravo	21 687 700	5 877
VII	Cuencas Centrales del Norte	1 526 040	8 434
VIII	Lerma-Santiago-Pacífico	147 036	197 464
IX	Golfo Norte	301 264	4 200
X	Golfo Centro	5 308 366	12 243
XIII	Valle de México	479 397	6 147
	Total	29 623 718	6 240 956

Source: CNA-IMTA (1998b).

Summary

Mining and manufacturing industries in Mexico grow by 2.18 and 4.21%, respectively from year 1994 to 1999. The industries which generate greater number of employments are not those which make greater water use (see figures 3.2 and 3.4). And regarding participation in the national gross product; industries are concentrated in the central region of the country (see figure 3.1).

Relating to the treatment of industrial residual discharge, it has increased by 18% between years 1996 – 2002 (see figure 3.3). According to official water information, sugar sector makes greater water extraction followed by paper and food industries, where both ensembles extract almost the same quantity as sugar.

About economical activity participation we see that the aggregate gross value of chemistry industry has the highest level of participation inside manufacturing sector; followed by food industry which by its side has the highest participation in the ‘Food, Beverage and Tobacco' division. Chemistry participation to national aggregate gross value is close to mining sector, 7.32% and 8.62%, in that order. Sugar industry is the one with smaller participation in the manufacturing sector. After sugar, we have steel, paper and beverage with a similar participation in manufacturing area, 5%, 5.24% and 5.63%, respectively. And textile industry which participates with 8.51% has the third place in importance in the manufacturing sector.

3.3 Industrial data description

For this research, data refers to the aggregate Mexican manufacturing and mining sector. Even if, strictly speaking, mining is not a manufacturing industry, we include this sector in this work because mining is considered one of the principal water users in Mexico (Ortiz, 2001). The 8 industrial sectors we use in this research are: mining, food, sugar, beverage, textile, paper, chemistry, and steel, which are representative of the major water demanding industries.

Our principal data source is the National Institute of Statistics, Geography and Informatics (INEGI - Instituto Nacional de Estadistica, Geografia e Informatica). The source for water data is the Mexican Institute of Water Technology (IMTA - Instituto Mexicano de Tecnologia del Agua). Water information allows us to compute the quantity of pesos per cubic meter paid by each industry. The total number of observations is 500 (single cross section of firms). The dataset initially is made of 14 variables for the year 1994. From them, 8 are related to production factors and output. The other 6 are associated to reference codes which allow us to classify the sample by availability water zones, administrative regions as well as by type of industry.

With the first 8 variables, output supply level and input prices (Q, PL, PW and PM) are computed. Table 3.13 gives us the detail of each one of the variables used. In this table we can see the description and source, as well as the variable unit. It is important to note that the unit $ refers to Mexican Pesos for 1994 and only for water expenses (bill) it refers to1996 Mexican pesos. These last were deflated in the way to have equivalent units for the same year. Additionally, water price stays constant for those years. Therefore they can be taken as good instruments for year 1994.

Table 3.13 Data description.

Variable	Unit		Description
Q	Ton	(***)	Physical production
L	Workers	(*)	Labor
CL	Thousand $	(*)	Labor expenditure
PL	$/worker		Price of labor
W	m^3	(**)	Water consumption
CW	Thousand $	(**)	Water expenses
Pw	$/m^3		Price of water
M	Thousand $	(*)	Total expenses in inputs
Pm	$/output		Price of materials

Source: (*) INEGI (1994). (**) IMTA (1996). (***) INEGI (2003a).

Inputs

- **Labor (L):** Labor (L) is defined as the average of total number of workers in equivalent full-time. Labor expenditure (CL) represents the total remuneration to workers. The unit price of labor (PL) is obtained by dividing CL by the number of workers.

- **Water (W):** Almost all authors who work with applied cases have noted that achieve water data is a complex task, and that in Mexico, it is not an exception. Previously, in Chapter 1, it has been pointed out that the industrialist in Mexico is under obligation to pay for the use of water. The amount of pesos per cubic meter each industrialist should pay is determined according to the water availability zone where the exploitation is made. There are 9 tariff zones: Zone 1 is defined as the zone with serious water problem, and zone 9 is the zone where water is in abundance. Consequently, in zone 1 water users should pay the highest amount of pesos per cubic meter of water and zone 9 is the cheapest one. For further details refer to table 1.10 from Chapter 1.

The source for the other variables employed in this project is from 1994. The most complete and accurate source for water data is from 1996 and taking into account that industrial process does not change so much in 2 years, we take as valid these data sources. The unit water price (PW) is obtained by dividing the annual water expenses-bill of an industry (CW) by its annual water consumption (W). It represents exclusively water intake.

At this point it is important to note two issues. First, the value of Cw is the payment done for water rights use. Second, we did not take the quotas fixed in the Federal Law Act (Ley Federal de Derechos en Materia de Agua - LFDMA), by water availability zone for each firm as price of water because we consider that firms' water expenses represent in a better way the payment firms already made for water used. It is not an average price of water since the firm pays per cubic meter extracted and it is not a block tariff.

- **Material (M):** Materials (M) are defined as the total expenses in other inputs. A proxy for the unit price of materials (PM) is obtained by dividing total expenses in inputs by the value of output as a proxy of the value in pesos per unit of output in monetary unit ($/output).

Output

Production (Q): The level of production Q corresponds to a physical measure of output (ton is the unit). It is obtained by dividing the gross product (Y) by the market price of output (PY). The latter has a unit of one thousand pesos per ton. In the case of beverage, the original unit is in thousand pesos per cubic meter, but since the beverage output are principally soft carbonated drinks and a few non alcoholic drinks, and as the density of this kind of liquid is almost the same as water[1], then we can say that one cubic meter of beverage output is equal to one ton. Consequently, from now on the unit for Q is in tons for all kinds of industrial production and its price (PY) is in thousand pesos per ton.

Cost

The firm total cost is the sum of labor expenditures (CL), water expenses (CW) and total expenses in other inputs - materials (M). Therefore, Cost = CL + CW + M. The cost unit is in thousand Mexican pesos.

Table 3.14 presents descriptive statistics for variables used.

Table 3.14 Sample Descriptive Statistics.

Variable	Unit	Mean	Standard Deviation	Minimum	Maximum
L	Workers	678.956	1 123.89	1	14 268
W	m^3	446 316.66	1 510 814.56	90	19 908 882
CL	1000 pesos	17 642.45	31 200.34	4.2	289 229.80
CW	1000 pesos	816.01	2 156.12	0.062	20 656.33
M	1000 pesos	89 255.32	163 970.18	1.1	1 496 532.50
PL	Pesos / worker	22 045.98	14 149.61	247.05882	94 438.37
PW	Pesos / m^3	2.56892	2.03216	0.03369	14.40149
PM	Pesos / output	0.67867	0.52688	0.05851	10.44851
Q	Ton	100 169.87	373 627.12	0.20452	6 370 717.03
Cost	1000 pesos	107 713.77	191 524.73	10.924	1 586 639.16
SL	___	0.20668	0.12381	0.00701	0.87880
SW	___	0.02174	0.07981	0.00002	0.95499
SM	___	0.77157	0.14585	0.03665	0.98746

[1] Water has a density of one g/mL. The density for the 6 principal kind of sodas produced in Mexico goes from 0.978 g/mL to 1.017 which gives an average of 0.9997 g/mL. Source: Mrs Aker (2003).

It is important to make clear that all the variables are scaled to their respective average observation point. At the mean of the sample, material cost share is equal to 77.2%, labor cost share is equal to 20.6%, and for water the mean cost share is scarcely 2.2%.

3.4. Preliminary data analysis

The sample consists of 500 firms throughout the country, which are concentrated in 8 industrial sectors for the year 1994. The characteristics of the variables allow us to make the analysis in 3 different ways: by industry, by availability water zone and by administrative region.

Table 3.15 shows the number of firms by industrial sector. Steel is the sector with the lowest number of observations (less than 1%). Beverage and food industries jointly concentrate 55% of total observations.

Table 3.15 Average Water Productivity by Industry.

Industry	Firms	% Water Used	Mean Water Price ($/m^3)	WaterAv.Prod (Th. $/m^3)
Mining	43	15.90%	0.81760	0.10735
Food	126	5.86%	2.76578	0.93519
Sugar	21	5.27%	0.45756	0.25587
Beverage	151	18.74%	2.29228	0.48660
Textile	59	5.14%	3.61129	0.80299
Paper	64	37.29%	3.19733	0.13976
Chemistry	32	7.67%	3.56662	0.28709
Steel	4	4.13%	3.31115	0.22861
TOTAL	500		2.56892	0.30138

This table also displays, by type of industry, water average productivity (i.e., the value of output divided by water consumption). For the whole sample, the average productivity of water is about 300 pesos per cubic meter of water. By type of industry, food has the highest water average productivity, 935 pesos per cubic meter of water used.

Mining represents the lowest water average productivity, with 107 pesos per m^3. Regarding quantity of water used, paper industry is the largest user (37.29%) followed by beverage (18.74%) but this latter with a three times higher water average productivity. Mining is the third water user (15.9%). These three industries use 72% of water and cover 51.6% of the total sample.

Apparently, mean water price is not correlated to water average productivity (correlation coefficient of 0.3432) when we analyze them just for kind of industry, but a more realistic relationship can be established regardingthe availability water zones. Table 3.16 shows water average productivity by availability water zone as well as its mean water price.

Table 3.16 Average Water Productivity by Zone.

Availability Zones	Firms	% Water Used	Mean Water Price ($/m^3)	WaterAv.Prod (Th. $/m^3)
Zone 1	53	6.15%	6.40007	0.86799
Zone 2	47	6.15%	5.02263	0.70036
Zone 3	26	4.15%	3.91111	0.39519
Zone 4	25	3.39%	3.33233	0.64383
Zone 5	116	22.29%	2.31898	0.34361
Zone 6	45	8.32%	2.05528	0.22726
Zone 7	51	14.08%	1.81489	0.13017
Zone 8	66	18.93%	0.57940	0.14123
Zone 9	71	16.54%	0.44937	0.15776

Consistently with the characteristics of availability water zones, water in zone 1 (the zone with scarcity water problems) has the highest average productivity (868 pesos per m^3) and also the highest average water price (6.40 $\$/m^3$). In this table we see that as the zone goes from the most expensive to the cheapest one, both mean water price and water average productivity decrease. This behavior is corroborated by the high correlation coefficient among them, which is 0.9284. The exception is the zone 3 that drops off in productivity in an unexpected value.

That could be explained because almost 20% of the firms placed in Zone 3 are from paper sector, which has the second lower water average productivity (139 $\$/m^3$). On the contrary, in Zone 4, 32% of the firms located there, are from food sector, the one with the highest water average productivity (935 $\$/m^3$).

Continuing the analysis inside availability water zones, the correlation coefficient between the percentage of water used and the percentage concentration of industry is equal to 0.8842, this being due to the fact that the number of industries is almost equally distributed throughout zones, except for zone 5 which concentrates the greater number of industries (23%) as well as the greater water use (22.29%).

These two high correlations allow us to conclude that water prices, as they are so far defined by availability water zone, have already affected the productivity of the firms, at least regarding water consumption. As a reference of the amount of pesos per cubic meter industrial user should pay in the first semester 2003 per zone, table 1.10 from Chapter 1, shows these quotas.

Figure 3.6 shows the 9 availability water zones in 1999. It helps us to have a clear idea of how water availability zones are distributed all over the country. In this figure, we can see that the cheapest water zones are included in the southwest and the scarce (expensive) water zones are in the north, where the climatic characteristics are arid and semiarid. In the Central area of the country, excluding Distrito Federal, where Mexico City is sited with its 23 million inhabitants, we found more of zones 6 to 9 than the others

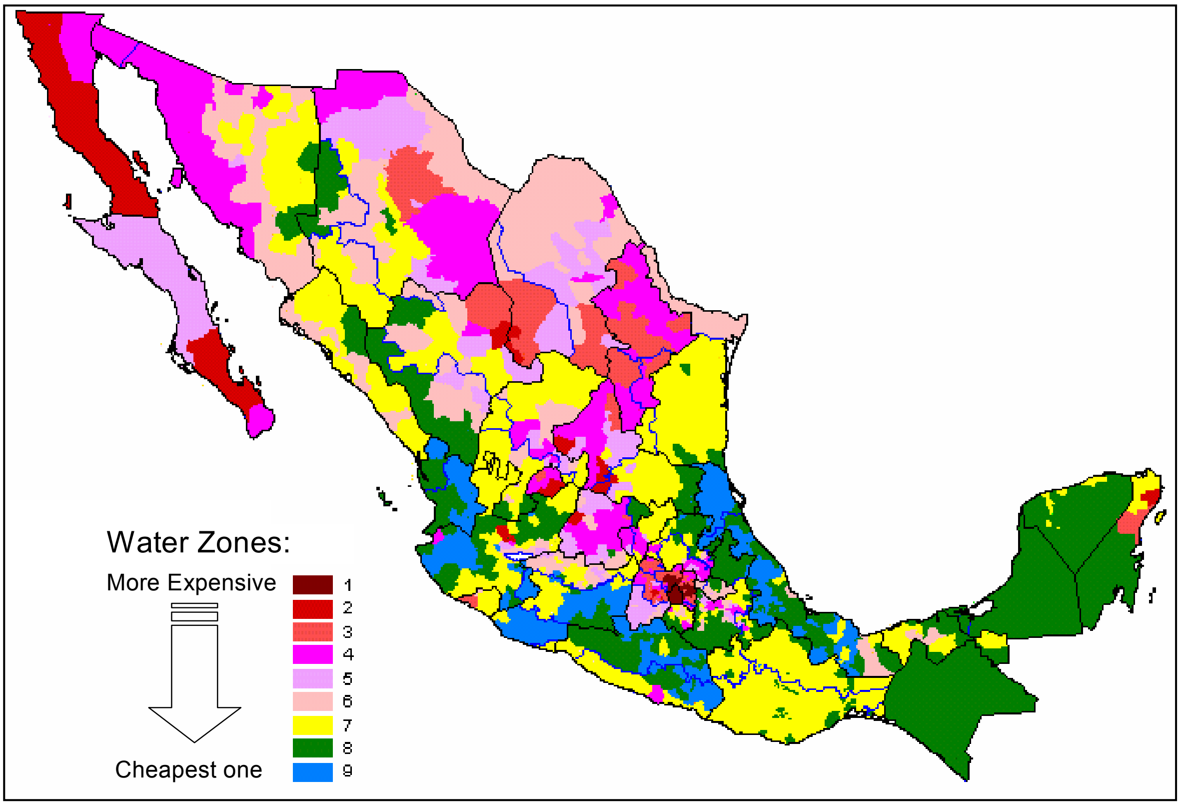

Figure 3.6 Availability Water Zones (Source: IMTA, 2002).

Figure 1.3 from Chapter 1, shows the 13 administrative regions. In the north of Mexico are regions I, II, III, VI, VII, and IX. Central Mexico contains regions IV, VIII, XIII and the north part of region X. Finally, in the southwest we found regions V, X, XI and XII. In table 3.17 we can observe the performance of water average productivity by administrative regions and total water used.

Analyzing table 3.17 we notice that Region I has the highest water productivity. This region is located in the Northwest of Mexico where the climatic characteristic is of a desert zone. Mexico City is located in region XIII, and if we compare with figure 3.6 we see that in this region, the four more expensive water zones are placed. So, in that way, it explains that the highest mean water price is in region XIII, followed by region I where high-priced water zones are also located (see figure 3.6).

Table 3.17 Average Water Productivity by Administrative Region.

Administrative Region	Firms	% Water Used	Mean Water Price ($/m^3)	WaterAv.Prod (Th. $/m^3)
Region I	10	0.21%	4.36761	2.18595
Region II	19	6.22%	2.23574	0.13088
Region III	24	3.68%	1.33074	0.24035
Region IV	64	7.22%	1.78686	0.42215
Region V	9	0.34%	1.78382	0.92367
Region VI	63	18.20%	2.94010	0.25546
Region VII	25	6.57%	2.46687	0.24948
Region VIII	114	19.71%	2.79716	0.32498
Region IX	26	7.72%	1.44043	0.21302
Region X	51	20.59%	0.96602	0.16281
Region XI	19	0.81%	1.01644	0.46464
Region XII	16	1.50%	1.31728	0.33857
Region XIII	60	7.23%	5.71786	0.83572

In the administrative regions we also detect significant correlations. Firstly between industry concentration and water use (0.7943) (remember that the respective correlation regarding water zones is 0.8842), and secondly, among water average productivity and mean water price (0.5746).

This can be explained by the fact that the regions number-names were assigned from northwest to southeast. In consequence, it captures the climatic characteristic from arid and semiarid to tropic humid, and logically the water available more expensive zones are located in the north and the cheapest zones in the south (regions X, XI and XII). But these correlations are lower than those in water zones since the relationship of water price inside administrative regions is not so much linear.

In agreement with this analysis, it could be so risky to conclude that, so far, industries are concentrated where water does not represent a real constraint to production. But certainly it is possible to conclude that water price is pushing industry owners to do an efficient use of water.

We say that it is so risky to assume that industrial plants are well located because there are already zones with real water accessibility problems. Ortiz (2001) points out that, regions XIII Valle de Mexico, VIII Lerma-Santiago-Pacifico, VII Cuencas Cerradas del Norte and Region I Baja California, nowadays extract more water than their availability allow. Just Valle de Mexico extracts 71% more than its availability. In these 4 regions, more than 65% of the national industrial product is generated and roughly 50% of total population of the country lives in those regions.

The 2003 National Water Commission's report on water statistics in Mexico mentions that, inside administrative regions, there exists a significant disparity in the source (surface or groundwater) from where the self-supplied industry obtains water. In table 3.1 we can see that, for example in year 2001, industries in regions II and XII withdraw 100% from groundwater. And region VII get only one of its 106 hm^3 of water used from surface source. On the contrary, Region IV and Region X use less than 10% from groundwater source. Only 5 of the 13 regions extract more of 35% from surface source.

Figure 3.7 give us a panorama of the disparity between water sources origin.

Finally, taking into consideration industry category, in tables 3.18 and 3.19 we distinguish the way that our 500 sample of firms are distributed, throughout the country, by availability water zone and by administrative region, respectively.

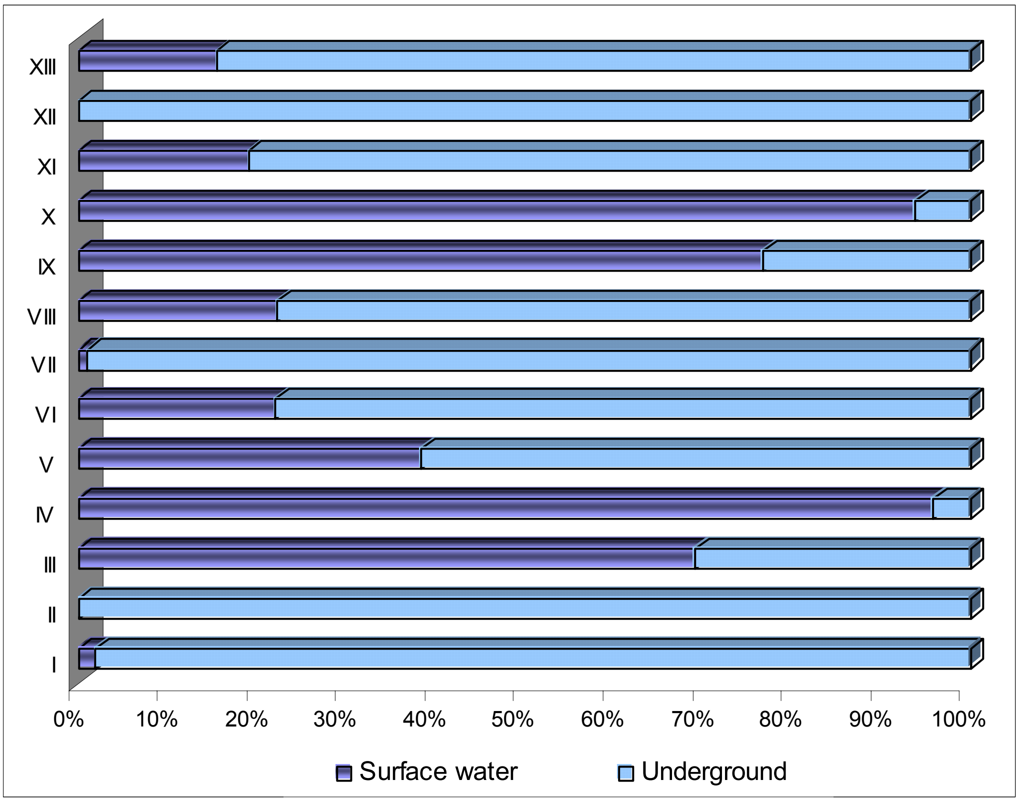

Figure 3.7 Water source for self supplied Industry (Source: CNA, 2003a).

Table 3.18 Firms by Water Availability Zone.

Industry	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	TOTAL
Mining	1	1	1	3	13	8	4	8	4	43
Food	10	12	7	8	36	10	19	13	11	126
Sugar						2	3	6	10	21
Beverage	15	9	7	6	22	12	15	28	37	151
Textile	10	8	3	3	22	8	2	3		59
Paper	11	12	5	3	11	2	5	7	8	64
Chemistry	5	4	3	2	10	3	3	1	1	32
Steel	1	1			2					4
TOTAL	53	47	26	25	116	45	51	66	71	500

In table 3.18 we see that 28% of the food industry is located in Zone 5. Other 25% is in Zones 7 and 8. Considering just Zone 5, the one with greater concentration of firms (23%), we have that 50%, as a group, is composed of textile (22 observations) and food (36 observations) industries.

An important fact that comes out is that nearly 53% of the beverage industry, a high water user (19%, see table 3.15), is placed in the three more economical zones, from 7 to 9. Regarding paper industry, the highest water user in relation to table 3.15, almost 50% of their factories are placed in the four more expensive zones. In zone 1, 28% of observations are from the beverage industry. Finally, 27% of our sample firms are located in cheaper zones, 13% in zone 8 and 14% in zone 9.

Table 3.19 Firms by Administrative Regions.

Industry \ Region	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	TOTAL
Mining	1	4	7	4		10	8	6	1	1			1	43
Food	4	6	7	7	2	15	6	41	11	7	4	6	10	126
Sugar				3				4	2	8	3	1		21
Beverage	2	5	7	18	7	17	6	27	5	24	10	8	15	151
Textile	2	3		18		4	2	12	4	1			13	59
Paper	1	1	2	7		8	1	18	1	7	2	1	15	64
Chemistry			1	6		8	1	6	2	3			5	32
Steel				1		1	1						1	4
TOTAL	10	19	24	64	9	63	25	114	26	51	19	16	60	500

Note: In columns are the number for each one of the 13 National Water Commission Administrative Regions.

In table 3.19 we have the industrial distribution through the National Water Commission administrative regions. Region VIII Lerma-Santiago-Pacifico accumulates almost 23% of total firms. Within this Region, 36% corresponds to food industry, which also represents, just on the side of food industry, 32.5% of their total firms. On Region VIII Lerma-Santiago-Pacifico, the major number (28%) of paper firms are also placed. 30.5% of textile firms are located in Region IV Balsas.

Tables 3.18 and 3.19 give us a general mapping of the way Mexican industry is located around the country. If it is seen by region, excluding Region VI Rio Bravo (13% of the sample), which is placed in the North, the greater part of firms, 47.6%, are positioned in the central part of the country, that is associated to Regions IV Balsas, VIII Lerma-Santiago-Pacifico and XIII Valle de Mexico. If it is seen by water zone, excepting Zone 5, 27% of firms are placed in the two cheapest zones.

Summary

The data analysis reports that average water productivity is 0.3013 thousand pesos per cubic meter. Water average productivity is highly and positively correlated (0.9284) with water price by availability water zone.

This correlation however, although still positive, changes considerably when we pay attention to different types of industry (0.3432). It allows us to claim that water price as so far defined by scarcity zones is pushing industrialists toward an efficient use of water.

Most of the firms are placed in water availability Zone 5 and for the side of administrative region, are in Region VIII Lerma-Santiago-Pacifico where the most important number of firms of our sample data are located.

3.5 Estimation of industrial water demand in Mexico: Empirical results for manufacturing sector

In Chapter 2 we already introduce the dual approach specifications and in the previous sections 3.3 and 3.4, we describe the database for the aggregate Mexican manufacturing and mining sector. Then, using the data of the 500 firms of eight industrial sectors, we estimate the industrial water demand for the Mexican industry, using a Translog cost system already exposed in Chapter 2, by Seemingly Unrelated Regression (SUR) procedure. The Translog cost function is calculated by the SAS econometric program version 8e.

The system of Translog Cost function and cost share equations we estimated is presented in expression 3.1.

$$
\begin{aligned}
\ln C = {} & \alpha_0 + \alpha_l \ln P_l + \alpha_w \ln P_w + \alpha_m \ln P_m + \alpha_q \ln Q \\
& + \frac{1}{2}\beta_{ll}(\ln P_l)^2 + \frac{1}{2}\beta_{ww}(\ln P_w)^2 + \frac{1}{2}\beta_{mm}(\ln P_m)^2 + \frac{1}{2}\beta_{qq}(\ln Q)^2 \\
& + \beta_{lw} \ln P_l \ln P_w + \beta_{wm} \ln P_w \ln P_m + \beta_{lm} \ln P_l \ln P_m \\
& + \beta_{lq} \ln P_l \ln Q + \beta_{wq} \ln P_w \ln Q + \beta_{mq} \ln P_m \ln Q \\
S_l = {} & \alpha_l + \beta_{ll} \ln P_l + \beta_{lw} \ln P_w + \beta_{lm} \ln P_m + \beta_{lq} \ln Q \\
S_m = {} & \alpha_m + \beta_{ml} \ln P_l + \beta_{mw} \ln P_w + \beta_{mm} \ln P_m + \beta_{mq} \ln Q
\end{aligned}
\tag{3.1}
$$

where, L stands for labor, W for water, M for other materials, and Q for output.

Remember that as factor shares sum to 1, then one of the cost share equation should be dropped to obtain a nonsingular covariance matrix. We dropped the cost share equation of water (S_w).

Table 3.20 shows parameter estimates for the Translog system. Overall, the model fits the data well since the R^2 statistics of the cost functions is nearly 0.8 and share equations range between 0.03 and 0.06. All the parameters are significatively different from zero, except for two (see table 3.20). Estimated input cost shares are given by the intercept terms (α_i) (Grebenstein and Field, 1979). The estimated share of labor is 21.46% and the estimated share of water is 2.65%, these two moves up regarding the actual ones. The estimated for other input materials share is 75.89% (variables P_L, P_W and P_M, respectively in table 3.20).

Table 3.20 Translog Cost Function Estimation Results for Mexican Industry.

Parameter	Variable	Estimate	Std Error	t Value
α_0	Intercept	0.1645	0.06130	2.69 (*)
α pl	P_L	0.2146	0.00661	32.45 (*)
α pw	P_W	0.0265	0.00469	5.65 (*)
α pm	P_M	0.7589	0.00822	92.38 (*)
α q	Q	0.6957	0.03380	20.58 (*)
β plpl	$P_L * P_L$	0.0413	0.00783	5.28 (*)
β pwpw	$P_W * P_W$	0.0146	0.00442	3.30 (*)
β pmpm	$P_M * P_M$	0.0417	0.01100	3.78 (*)
β qq	Q * Q	0.0086	0.00858	1.00
β plpw	$P_L * P_W$	-0.0071	0.00421	-1.69 (**)
β pwpm	$P_W * P_M$	-0.0075	0.00555	-1.35
β plpm	$P_L * P_M$	-0.0342	0.00833	-4.11 (*)
β plq	P_L * Q	0	0	.
β pwq	P_W * Q	0	0	.
β pmq	P_M * Q	0	0	.

(*) t value significant at 1 percent.

"The monotonicity requirement is met if the predicted cost shares are positive for all inputs" (Teeples and Glyer, 1987). From table 3.20 it can be seen that monotonicity condition holds such that all α_i (α *pl,* α *pw and* α *pm*) are positive and significative different from zero.

All t-values for the imposed restrictions are significant at least at 5% excepting restriction (*β plpl+β plpw+β plpm=0*), then we fail to reject the null hypothesis. We test for homotheticity by imposing that the parameters associated with cross-products between input prices and output are zero ($P_L Q = 0; P_W Q = 0; P_M Q = 0$)

We test for the exogeneity of water price. The reason for testing exogeneity of water price is because we have an observed price of water, denoted P_{wi}, which represents the cost of raw water (quota or fee), but we do not take into consideration the other cost industrialist implements to get water like extraction cost, pumping cost, denoted φ_i. That is, the true unit cost R_{wi} to get water is represented by:

$$R_{wi} = P_{wi}(1+\varphi_i) = P_{wi} + \varsigma_{wi} \;, \quad where \quad \varsigma_{wi} = P_{wi}\varphi_i \;; \tag{3.2}$$

where P_{wi} represents fees or quota and ς_{wi} represents other cost relating to extraction and pumping costs, principally.

We know that pumping cost are greater in zones with low water availability, that is in scarcity water zones, as it is the case of Zone 1, which rises extraction costs. Then, we include in the Translog Cost function the true water price $R_{wi} = P_{wi}(1+\varphi_i)$.

The Translog is now expressed as:

$$\begin{aligned} \ln C = {} & \alpha_0 + \alpha_l \ln P_l + \alpha_w \ln R_w + \alpha_m \ln P_m + \alpha_q \ln Q \\ & + \frac{1}{2}\beta_{ll}(\ln P_l)^2 + \frac{1}{2}\beta_{ww}(\ln R_w)^2 + \frac{1}{2}\beta_{mm}(\ln P_m)^2 + \frac{1}{2}\beta_{qq}(\ln Q)^2 \\ & + \beta_{lw}\ln P_l \ln R_w + \beta_{wm}\ln R_w \ln P_m + \beta_{lm}\ln P_l \ln P_m \\ & + \beta_{lq}\ln P_l \ln Q + \beta_{wq}\ln R_w \ln Q + \beta_{mq}\ln P_m \ln Q \end{aligned} \tag{3.3}$$

Then we test for the exogeneity of water price replacing P_{w_i} by the estimated price of water which is a function of the regions and kind of industry, that is, $\hat{P}_{w_i} = f(region,\ industry)$. The procedure we follow in this test is to run a regression of water price against industries and regions. The equation we consider is:

$$\ln p_w = \sum_{i=1}^{7} \gamma_i Industry_i + \sum_{j=1}^{12} \gamma_j\, region_j \tag{3.4}$$

Where *i* stands for 7 of the 8 industries and *j* stands for 12 of the 13 regions we have in our data base, since they are dummy variables.

Then we use the residuals from this regression; call it $resid \ln P_w$ as data source to estimate, by Seemingly Unrelated Regression (SUR), the same system from expression 3.1 including the water price residuals to check if these residuals are significantly affecting.

The system we estimate is:

$$\begin{aligned}
\ln C = {} & \alpha_0 + \alpha_l \ln P_l + \alpha_w \ln P_w + \alpha_m \ln P_m + \alpha_q \ln Q \\
& + \frac{1}{2}\beta_{ll}(\ln P_l)^2 + \frac{1}{2}\beta_{ww}(\ln P_w)^2 + \frac{1}{2}\beta_{mm}(\ln P_m)^2 + \frac{1}{2}\beta_{qq}(\ln Q)^2 \\
& + \beta_{lw}\ln P_l \ln P_w + \beta_{wm}\ln P_w \ln P_m + \beta_{lm}\ln P_l \ln P_m \\
& + \beta_{lq}\ln P_l \ln Q + \beta_{wq}\ln P_w \ln Q + \beta_{mq}\ln P_m \ln Q + \gamma_{uc} resid \ln P_w \\
S_l = {} & \alpha_l + \beta_{ll}\ln P_l + \beta_{lw}\ln P_w + \beta_{lm}\ln P_m + \beta_{lq}\ln Q + \gamma_{ul} resid \ln P_w \\
S_m = {} & \alpha_m + \beta_{ml}\ln P_l + \beta_{mw}\ln P_w + \beta_{mm}\ln P_m + \beta_{mq}\ln Q + \gamma_{um} resid \ln P_w
\end{aligned} \tag{3.5}$$

Table 3.21 displays these results, where we can see that the residuals are highly statistically significant in the cost function (γ_{uc}) as well as in the cost share equation (γ_{um}), indicating endogeneity of water price.

Table 3.21 Translog Cost Function: Homogeneity Test.

Parameter	Estimate	Std Error	t Value
α_0	0.1255	0.06130	2.05 (*)
α pl	0.2146	0.00707	30.34 (*)
α pw	0.0284	0.00474	5.98 (*)
α pm	0.7571	0.00753	100.54 (*)
α q	0.6797	0.03380	20.10 (*)
β plpl	0.0377	0.00857	4.40 (*)
β pwpw	0.0258	0.00550	4.70 (*)
β pmpm	0.0498	0.01060	4.68 (*)
β qq	0.0083	0.00852	0.97
β plpw	-0.0069	0.00478	-1.44
β pwpm	-0.0190	0.00602	-3.15 (*)
β plpm	-0.0309	0.00835	-3.70 (*)
β plq	0	0	.
β pwq	0	0	.
β pmq	0	0	.
γ uC	0.2342	0.0720	3.25 (*)
γ uL	-0.0093	0.0115	-0.81
γ uM	0.0325	0.0126	2.59 (*)

(*) t value significant at 1 percent.

In the way to check for an alternative option, we run the same exogeneity test by just considering the cost share equation system, that is, we now estimate expression 3.6 in place of the previous one, expression 3.5.

$$S_i = \alpha_i + \Sigma_j \beta_{ij} \ln P_j + \beta_{iQ} \ln Q + \gamma_{ui} resid \ln P_w \qquad i, j = L, W, M \tag{3.6}$$

Under this alternative option, we got that for the three share equations the residuals are not statistically significant. The t-value for residuals with respect to labor (γ_{uL}) is 0.13, the t-value for residuals relating water (γ_{uw}) is -1.67, and finally, the residuals regarding other material (γ_{um}) has a t-value of 1.18; none of them are statistically significant. Then, we fail to reject the null hypothesis, therefore price of water is not endogenous and we can say that the price of water is proportional to true price.

The difference in the results generated on one side from those of expression 3.5 and on the other, from those from expression 3.6 can be explained for the fact that in expression 3.5 all the direct, square and cross effects of R_{w_i} are captured in $\ln C$.

For example the effects in the component relating $\alpha_w \ln R_w = \alpha_w \ln[P_w(1+\varphi_i)]$, or $\frac{1}{2}\beta_{ww}(\ln R_w)^2 = \frac{1}{2}\beta_{ww}[\ln(P_w(1+\varphi_i))]^2 = \frac{1}{2}\beta_{ww}[\ln P_w + \ln \varsigma_{wi}]^2$, or the cross effect in $\beta_{wq} \ln P_w(1+\varphi_i)\ln q_i$, and so on. These elements are not included in expression 3.6, the system of cost share equation.

Then due to the fact that with expression 3.6 water price is not endogenous, as well as the fact that under this we get better estimators and statistic behave better than those from expression 3.5, we decide to use the three cost share equations system. Then, in our case the system equation is represented as:

$$
\begin{aligned}
S_l &= \alpha_l + \beta_{ll}\ln P_l + \beta_{lw}\ln P_w + \beta_{lm}\ln P_m + \beta_{lq}\ln Q \\
S_w &= \alpha_w + \beta_{wl}\ln P_l + \beta_{ww}\ln P_w + \beta_{wm}\ln P_m + \beta_{wq}\ln Q \\
S_m &= \alpha_m + \beta_{ml}\ln P_l + \beta_{mw}\ln P_w + \beta_{mm}\ln P_m + \beta_{mq}\ln Q
\end{aligned}
\tag{3.7}
$$

We impose symmetry restriction assuming $\beta_{lw} = \beta_{wl}$; $\beta_{lm} = \beta_{ml}$; $\beta_{mw} = \beta_{wm}$; where L stands for labor, W for water, M for other materials, and Q for output.

Table 3.22 displays parameter estimates. In general, the model fits well, with a R^2 statistic of 0.4050; 0.1077 and 0.4302, for the share equations of labour, water and materials, respectively.

All parameters in table 3.22 are significantly different from zero, except two (α *pw*) the coefficient on water price level, and (α *plpw*) the cross effect of labor and water.

Table 3.22 Cost Share Equation System Estimation: Results for Mexican Industry.

Parameter	Variable	Estimate	Std Error	t Value
α pl	P_L	0.1519	0.00577	26.32 (*)
α pw	P_W	0.0062	0.00452	1.38
α pm	P_M	0.8426	0.00632	133.41 (*)
β plpl	$P_L * P_L$	0.0938	0.00647	14.50 (*)
β pwpw	$P_W * P_W$	0.0148	0.00337	4.39 (*)
β pmpm	$P_M * P_M$	0.1212	0.00809	14.98 (*)
β plpw	$P_L * P_W$	0.0003	0.00333	0.08
β pwpm	$P_W * P_M$	-0.0154	0.00396	-3.90 (*)
β plpm	$P_L * P_M$	-0.0962	0.00607	-15.86 (*)
β plq	$P_L * Q$	-0.0298	0.00186	-16.07 (*)
β pwq	$P_W * Q$	-0.0087	0.00133	-6.53 (*)
β pmq	$P_M * Q$	0.0387	0.00199	19.44 (*)

(*) t value significant at 1 percent.

Estimated input cost shares are given by the intercept terms α_i (Grebenstein and Field, 1979). The estimated share of labor is 15.19% and the estimated share of water is 0.62%, these two decrease significantly regarding the actual ones. The estimated share for the materials input share is 84.26% (variables P_L, P_W and P_M, respectively in table 3.22).

Table 3.23 presents the Allen Elasticities of Substitution obtained by means of expression (2.12) from Chapter 2. It is a lower triangular matrix, because, by definition, the Allen Elasticities of Substitution (AES) are symmetric.

Table 3.24 contains the own and cross price elasticities of input demand estimated through expression (2.11) from Chapter 2, together with their respective t-value. Each element in the table is the elasticity of demand for the input in the row after a price change of the input in the column.

Table 3.23 Allen Elasticities of Substitution (AES) = σ_{ij}

	Labor	Water	Material
Labor	-1.6415 (-10.83)		
Water	1.0617 (1.43)	-13.6890 (-1.92)	
Material	0.3965 (10.41)	0.0801 (0.33)	-0.0924 (-6.80)

t-statistics are in parentheses.

Table 3.24 Own and Cross-Price Elasticities of Demand = ε_{ij}

	Labor	Water	Material
Labor	-0.3392 (-10.83)	0.0230 (1.43)	0.3059 (10.41)
Water	0.2194 (1.43)	-0.2976 (-1.92)	0.0618 (0.33)
Material	0.0819 (10.41)	0.0017 (0.33)	-0.0713 (-6.80)

t-statistics are in parentheses.

Berndt (1991) points out that the estimated Translog cost function should be checked to ensure that it is monotonically increasing and strictly quasi-concave in input prices, as it is required by theory. Teeples and Glyer, (1987) signal that "The monotonicity requirement is met if the predicted cost shares are positive for all inputs". From table 3.22 it can be seen that the monotonicity condition holds since all α_i (α *pl,* α *pw* and α *pm*) are positive and significantly different from zero.

Regarding concavity, Bergström and Panas (1992) explain that concavity requires that the own elasticities of substitution be negative. From table 3.24 it can be seen that this condition is met. Substitution elasticity is highly statistically significant for labor and materials, but for water input, it is different from zero 0 at 5% level.

Here, it is important to note out that elasticities have been calculated at the mean of the actual input cost shares shown in table 3.14 (*SL, SW* and *SM*, respectively for Labor, Water and Materials). It was made following Anderson and Thursby (1986). And standard errors were estimated through expression (3.8), following Binswanger (1974).

$$SE(\varepsilon_{ij}) = \frac{SE(\beta_{ij})}{S_i} \quad and \quad SE(\sigma_{ij}) = \frac{SE(\beta_{ij})}{S_i S_j} \tag{3.8}$$

Table 3.25 reports the Morishima Elasticity of Substitution (MES) gotten from expression (2.13) from Chapter 2. This table excludes the diagonal because Morishima Elasticity of Substitution is defined as a logarithmic derivative of the optimal input quantity ratio in relation to the input price ratio, and the diagonal contains no information. In the sense of Morishima Elasticities of Substitution all inputs are well significantly substitutes excepting the pair material/water.

Table 3.25 Morishima Elasticities of Substitution (MES) = M_{ij}

	Labor	Water	Material
Labor		0.5587 (3.40)	0.4212 (11.17)
Water	0.3207 (2.00)		0.2993 (1.89)
Material	0.3772 (10.02)	0.1331 (0.70)	

t-statistics are in parentheses.

All own price elasticities (Table 3.24) have the expected value, that is, input responds negatively to its own price. As price elasticity of water is -0.2976, we can conclude that industrial water demand for Mexican manufacturing is inelastic (less than one in absolute value). Also, water demand is not very responsive to changes in water prices, with clearly significant own-price elasticity. Hence, our estimates suggest that a one-percent change in the price of water (all else hold constant) will result in roughly 0.30% change (reduction) in the quantity of water consumed for Mexican industry.

Continuing on table 3.24, estimated elasticities (own and cross) for labor and materials are statistical significant at 1%, as well as the own one for water, the others are significant at 15%, excepting both cross-price elasticities between water and materials, which are no significantly different from zero.

Both cross-price elasticities between labor and water have the same signs (0.0230 and 0.2194) but lower value than those for Morishima (0.5587 and 0.3207). That means that an increment in water price leads to an increment in the use of labor and conversely, but at the same time water input use become more intense at such a rate that the ratio water/labor rises. But, for cross-price, elasticities are not significant.

Morishima elasticities measure relative input adjustment to a single-factor price changes. So, from table 3.25, the first row shows how labor/water and labor/materials ratios responded to a change in the price of labor. Then, for the second row, under a change of water price the ratio water/labor changes in a 0.3207 and the ratio water/materials changes in a 0.2993. The largest degree of substitution is generated for changes in the price of labor in relation to water. And its value is half of that in the Allen Elasticities of Substitution in table 3.23, but this latter is not statistically significant. The main difference between the Allen Elasticities of Substitution and the Morishima Elasticity of Substitution concerns the relationship between materials and water, in that these inputs appear as substitute according to AES (0.0801), but not at all significant. Hence, the Allen Elasticities of Substitution underestimates the water/materials elasticity of substitution, particularly in response to a change in the price of water, such that in table 3.25 we see that the pair water/material is significant at 5%.

Something important to notice is that in principle, water price does not seem to have a strong impact on labor. We see that water is a high substitutable input for labor (1.0617 in table 3.23), and in table 3.24 for the pairs labor/water (0.0230) and water/labor (0.2194); all of them are not statistically significant. On the contrary, in table 3.25 we see that water and labor show to be also substitutes, in the sense of Morishima and statistically well significant for both pairs and it reports the highest elasticities of all the Morishima Elasticity of Substitution (0.5587) for the pair labor/water.

Regarding the relationship between water and other materials, for all the cases they are substitutes and not significantly different from zero. The Morishima Elasticity of Substitution pair of water/materials has the highest elasticity (0.2993) and is roughly significant (1.89).

Regarding labor and other materials, those inputs are statistically significant substitutes, and Allen Elasticities of Substitution and Morishima Elasticity of Substitution elasticities are nearly the same.

Confirmed what it was already pointed out in Chapter 2, that Morishima Elasticities of Substitution is more natural extension to the multi-input case, for our analysis Morishima Elasticity of Substitution appears to be a better tool to determine the effects that water price changes may have on the other production inputs.

As the water input only represents a small share of the total cost in the estimation (less than one percent), it is unlikely that variation in water input price would have a significant impact on output price. Hence in our case, the constant output price elasticity of input demand for water may not be a poor elasticity approximation.

The value of the price elasticity of demand for water in Mexico (-0.2976) is not very far from those reported in previous studies (see table 2.1 in Chapter 2). First, most previous elasticity estimates are also pretty low. Grebenstein and Field (1979) obtain -0.326 for the AWWA series. Renzetti reports a water price elasticity of -0.3817 for intake manufacturing (1992) and -0.308 for price of water intake (1993). Reynaud (2003) obtains -0.29 for network water. Babin et all (1982) for pooled data get -0.56. The lowest elasticity (in absolute value) for intake water (-0.1308) is reported in the last published study of Renzetti and Dupont (2003). Féres and Reynaud (2004) report the highest water price elasticity, -1.085 (in absolute value).

Regarding the relationship of water to other inputs we found that water is substitute for both labor and other materials. Babin et all (1982), Grebenstein and Field (1979), and Dupont and Renzetti (2001), all of them find that water is substitute to labor. But complementarity of water in relation to materials is reported by Dupont and Renzetti (2001). Concerning these results, it is important to keep in mind that we use Morishima Elasticities of Substitution and those reported in table 2.1 in Chapter 2 use the traditional cross-price elasticity.

Summary

In this chapter we first estimate a production cost system using data on 500 firms from eight industries for the year 1994. Cost estimates allow us to compute price and (Morishima) substitution elasticities, which are necessary tools for determining whether industries are indeed responsive to water prices.

From our estimation results, we can conclude that industrial water demand is not very responsive to changes in water price given that average value for the price elasticity of industrial water demand for Mexican manufacturing is inelastic (-0.2976).

Water is found to be a substitute for both labor and materials in the sense of Morishima Elasticity of Substitution.

We also find that industrial price elasticity of demand for water is not far from the values reported in previous research previously mentioned in Chapter 2 (See table 2.1). Excluding the value reported by Féres and Reynaud.

Chapter 4

Experiments on water for industrial use in Mexico

Introduction

In chapter 3 we described the database for the aggregate Mexican manufacturing and mining sector. Then, using the data of the 500 firms of eight industrial sectors, the industrial water demand is estimated, using a Translog cost system, by Seemingly Unrelated Regression (SUR) procedure. We presented the empirical results of the water demand for Mexican industry, as well as the elasticities that the cost estimates allow us to get. We found that industrial water demand is inelastic and not very responsive to change in water price (elasticity -0.2976). Water is found to be a substitute for both labor and materials in the sense of Morishima Elasticity of Substitution.

Using the results from the previous chapter, in this chapter we perform a series of experiments under different scenarios. The first experiment, in section 4.1, is related to water zones location. Here we find that 44.4% of firms are consistently located regarding the water availability zones. As a second step, in section 4.2, we compare our water zones' database against water zone in 2003, resulting that 45.8% of the water zone from our database are still in the same water zone in the year 2003. In section 4.3 we perform a short experiment with no subsidy on water price, where we, principally, make a brief data analysis to compare water price with subsidy and without it. In this section we first give a note on the legal framework of subsidies on water price in Mexico.

Finally, in section 4.4 we get the elasticities relating industrial sector and water zone, and perform the experiment to observe the change in the demand of water, using water price elasticity, under different subsidy participation scenarios. In this last experiment we look to find the subsidy level industrial sector should have before reaching the technical shutdown point.

4.1. Water zone location experiment

In this section, we conduct an experiment whose objective is to evaluate the consistency of the industrial firm distribution regarding water availability zones. Presumably, if a firm faces the same market conditions, and if input prices for labour and materials are uniform across regions, then the firm will be better off by operating in the region where water is the cheapest. If, on the other hand, a firm with intensive water use is located in a zone with a high price for water, this would indicate that profit differentials with other water availability zones depend on other factors such as those mentioned above.

In our empirical application, parameter estimates and data on cost shares and output levels allow us to compute average costs for firms in all industries and water availability zones. Given the Translog specification for the cost function, this cost will depend on input prices that are likely to differ across zones but also across industries. Firms with a higher value-added may require more skilled workers or materials, and local labour market conditions and transportation infrastructures may influence labour cost.

The experiment proceeds as follows. We first compute average input prices by water availability zone and by industry, to control for observed heterogeneity in these cost factors. We then use our cost estimates to construct average cost measures for each firm in the sample, assuming a) same output level; b) no additional investment, *when it faces prices in other zones*. For instance, a firm in the beverage industry located in zone 1, when "moving" to zone 2, will now pay the average labour, materials and water unit prices that firms in the beverage industry already face in zone 2.

In terms of the Translog we have:

$$\begin{aligned}(\ln C_i - \ln C_1) &= \beta_L(\ln P_L - \ln P_{L1}) + \beta_w(\ln P_w - \ln P_{w1}) + \beta_m(\ln P_m - \ln P_{m1}) \\ &+ \frac{1}{2}\beta_{LL}\left[(\ln P_L)^2 - (\ln P_{L1})^2\right] + \frac{1}{2}\beta_{ww}\left[(\ln P_w)^2 - (\ln P_{w1})^2)\right] \\ &+ \frac{1}{2}\beta_{mm}\left[(\ln P_m)^2 - (\ln P_{m1})^2)\right] \\ &+ \beta_{Lw}\left[(\ln P_L \ln P_w) - (\ln P_{L1} \ln P_{w1})\right] \\ &+ \beta_{wm}\left[(\ln P_w \ln P_m) - (\ln P_{w1} \ln P_{m1})\right] \\ &+ \beta_{Lm}\left[(\ln P_L \ln P_m) - (\ln P_{L1} \ln P_{m1})\right] \\ &+ \beta_{Lq}(\ln P_L - \ln P_{L1})\ln Q + \beta_{wq}(\ln P_w - \ln P_{w1})\ln Q \\ &+ \beta_{mq}(\ln P_m - \ln P_{m1})\ln Q\end{aligned} \tag{4.1}$$

Where the β's are the parameters estimated from the Translog cost function in Section 3.5, $(\ln C_i - \ln C_1)$ represents the cost in which the firm drops for moving from its actual zone (i) to zone 1, call it Cost1, thus $Cost1 = (\ln C_i - \ln C_1)$, $Cost2 = (\ln C_i - \ln C_2)$, and so on. Then,

$$\exp(Cost1) = \frac{C_i}{C_1} = \frac{\text{actual cost}}{\text{new cost}}$$

where the *new cost* (C_1, C_2 ...C_9) is the cost constructed by the average input prices, and the *actual cost* (C_i) is the cost obtained from the observed input prices.

Finally, we compute for each firm, the relative average-cost differential for being in other zone and denote this cost differential by

$$DC_i = \left[\frac{actual\ cost}{new\ cost} - 1 \right] \tag{4.2}$$

where *i* represents the index of the zone. That is, DC_i is the relative average-cost differential, where the new cost is the average cost computed by using input prices from zone *i* .

For example, for all 15 beverage firms located in zone 1, *DC1* will be equal to zero (as all those 53 firms actually placed in zone 1, see table 3.18 in Chapter 3), but *DC2* could be either greater or lesser than zero. In the first situation, if, its actual cost is greater than that in zone 2, this firm would be better off by moving to zone 2. On the contrary, when *DC2<0*, then we would say that this firm is well located given its actual cost and it will be worse if it moves to zone 2.

In conjunction with the sign of the cost differential estimate, we also need to check for the significance of the differential DC_i. This is done by computing a simple Student test statistic for the significance of the empirical mean in the DC_i measures for each zone and each industry. What should be expected is that, as we move to cheaper water zones, we find positive and possibly higher average cost differentials, meaning that being located in expensive zones for industrial water use is not efficient. Also, we could expect that, as we try to move firms from zone 9 (the cheapest zone), the cost gap is not significantly different from 0, or becomes negative and statistically significant.

The results of this water zone experiment are in table 4.1. Each water zone is examined from 1 to 9 (from the most expensive to the cheapest) in column, for firms in the 8 industries (in row). The firms with $DC_i = 0$ are obviously excluded, which leaves 8 zones in each case. Table 4.1 reports average cost differentials in the form of ratios,

$$\frac{C_i}{C_1} - 1, \frac{C_i}{C_2} - 1, \ldots, \text{etc.}$$

and significance level indicators associated with these relative cost differences.

Table 4.1 Water zone location experiment

DC 1 = 0 - Firms in ZONE 1 moving to zone *i*, $i \neq 1$

	DC2	DC3	DC4	DC5	DC6	DC7	DC8	DC9
Mining	-0.93	-0.79	-0.59	-0.81	-0.75	-0.68	-0.77	-0.83
Food	0.26	0.03	0.16	0.33 **	0.13	0.43 **	0.61 **	0.47 **
Sugar								
Beverage	-0.14	-0.09	-0.25 **	-0.03	-0.08	0.05	0.28 **	0.29 **
Textile	0.16 *	0.12	0.04	0.10	0.18 *	0.72 **	0.14 *	
Paper	0.03	-0.18 **	-0.16 **	0.12	0.32 **	-0.32 **	-0.21 **	-0.13 *
Chemistry	0.07	0.56 **	0.02	-0.22 **	-0.14 **	0.52 **	0.31 **	-0.57 **
Steel	2.49			-0.45				

DC 2 = 0 - Firms in ZONE 2 moving to zone *i*, $i \neq 2$

	DC1	DC3	DC4	DC5	DC6	DC7	DC8	DC9
Mining	2.36	1.02	1.65	0.47	0.56	0.86	0.48	0.25
Food	-0.23 **	-0.18 *	-0.08	0.06	-0.10	0.15	0.29 *	0.18
Sugar								
Beverage	0.11	0.04	-0.15 *	0.09	0.04	0.18 *	0.41 **	0.42 **
Textile	-0.15 **	-0.02	-0.10 **	0	0.03	0.55 **	0.03	
Paper	-0.11 *	-0.27 **	-0.25 **	0.01	0.19 **	-0.39 **	-0.28 **	-0.20 **
Chemistry	-0.11	0.40	-0.09	-0.30 *	-0.23	0.36	0.17	-0.62 **
Steel	-0.72			-0.84				

Table 4.1 Water zone location experiment (Cont'd).

DC 3 = 0 - Firms in ZONE 3 moving to zone *i*, $i \neq 3$

	DC1	DC2	DC4	DC5	DC6	DC7	DC8	DC9
Mining	0.41	-0.47	0.23	-0.30	-0.27	-0.15	-0.31	-0.41
Food	-0.05	0.23 **	0.13	0.30 **	0.11	0.41 **	0.58 **	0.44 **
Sugar								
Beverage	0.07	-0.06	-0.18 *	0.06	0.01	0.15	0.41 **	0.42 **
Textile	-0.16	-0.01	-0.11	-0.01	0.01	0.53	0.02	
Paper	0.21 **	0.26 **	0.03	0.36 **	0.61 **	-0.17 **	-0.03	0.06
Chemistry	-0.39 **	-0.34 **	-0.38 **	-0.52 **	-0.47 **	-0.06	-0.17	-0.74 **
Steel								

DC 4 = 0 - Firms in ZONE 4 moving to zone *i*, $i \neq 4$

	DC1	DC2	DC3	DC5	DC6	DC7	DC8	DC9
Mining	0.62 **	-0.73 **	-0.36 **	-0.5 **	-0.42 **	-0.28 *	-0.45 **	-0.56 **
Food	-0.17 *	0.09	-0.11	0.16	-0.02	0.25 *	0.41 **	0.29 **
Sugar								
Beverage	0.27	0.12	0.19	0.25	0.19	0.36 *	0.64 **	0.65 **
Textile	-0.03	0.13	0.10	0.09	0.15	0.7 **	0.13	
Paper	0.17	0.19 **	-0.03	0.30 **	0.55 **	-0.20 **	-0.08	0
Chemistry	-0.02	0.06	0.53	-0.23	-0.16	0.49	0.28	-0.58 **
Steel								

DC 5 = 0 - Firms in ZONE 5 moving to zone *i*, $i \neq 5$

	DC1	DC2	DC3	DC4	DC6	DC7	DC8	DC9
Mining	1.92 **	-0.40 **	0.34 **	0.94 **	0.14	0.40 **	0.08	-0.12 *
Food	-0.29 **	-0.07	-0.24 **	-0.15 **	-0.16 **	0.08	0.22 **	0.11
Sugar								
Beverage	-0.01	-0.14 **	-0.08	-0.24 **	-0.07	0.07	0.31 **	0.32 **
Textile	-0.24 **	-0.10	-0.12 *	-0.18 **	-0.07	0.43 **	-0.05	
Paper	-0.15	-0.10	-0.29 **	-0.27 **	0.14	-0.41 **	-0.32 **	-0.24 **
Chemistry	0.25 **	0.36 **	0.96 **	0.28 **	0.08	0.91 **	0.64 **	-0.46 **
Steel	0.86 **	4.63 **						

Table 4.1 Water zone location experiment (Cont'd).

DC 6 = 0 - Firms in ZONE 6 moving to zone *i*, $i \neq 6$

	DC1	DC2	DC3	DC4	DC5	DC7	DC8	DC9
Mining	1.21 **	-0.50 **	0.08	0.52 **	-0.19 **	0.09	-0.15 *	-0.30 **
Food	-0.16	0.10	-0.10	0.01	0.17	0.26	0.42 **	0.30 *
Sugar						-0.35 **	-0.22 **	-0.34 **
Beverage	0.01	-0.11	-0.05	-0.22 **	0.01	0.10	0.35 **	0.36 **
Textile	-0.17 **	-0.02	-0.05	-0.12	-0.02	0.52 **	0.01	
Paper	-0.28	-0.22	-0.41	-0.39	-0.17	-0.50 *	-0.41	-0.34
Chemistry	0.14	0.24 *	0.86 **	0.18	-0.10	0.78 **	0.58 **	-0.50 **
Steel								

DC 7 = 0 - Firms in ZONE 7 moving to zone *i*, $i \neq 7$

	DC1	DC2	DC3	DC4	DC5	DC6	DC8	DC9
Mining	1.00 **	-0.57 **	-0.06	0.34	-0.29	-0.21	-0.25	-0.39 *
Food	-0.36 **	-0.16	-0.32 **	-0.23 *	-0.10	-0.23 *	0.12	0.02
Sugar						0.52 *	0.18	0
Beverage	-0.12	-0.23 **	-0.18	-0.33 **	-0.12	-0.16	0.19	0.20
Textile	-0.52	-0.43	-0.43	-0.47	-0.36	-0.40	-0.35	
Paper	0.45	0.50	0.20	0.23	0.62	0.92	0.15	0.26
Chemistry	-0.37	-0.31	0.04	-0.35	-0.50 **	-0.45 **	-0.11	-0.72 **
Steel								

DC 8 = 0 - Firms in ZONE 8 moving to zone *i*, $i \neq 8$

	DC1	DC2	DC3	DC4	DC5	DC6	DC7	DC9
Mining	1.84 **	-0.49 **	0.16	0.75 **	-0.10	0.03	0.28	-0.22
Food	-0.44 **	-0.26 **	-0.40 **	-0.32 **	-0.20 *	-0.32 **	-0.12	-0.09
Sugar						0.28 **	-0.16 *	-0.16 *
Beverage	-0.33 **	-0.41 **	-0.37 **	-0.49 **	-0.32 **	-0.36 **	-0.26 **	-0.05
Textile	-0.13	0.02	-0.01	-0.09	-0.02	0.04	0.53 **	
Paper	0.25	0.29	0.04	0.07	0.40	0.66 *	-0.14	0.08
Chemistry	-0.30	-0.23	0.16	-0.27	-0.44	-0.39	0.11	-0.69
Steel								

Table 4.1 Water zone location experiment (Cont'd).

DC 9 = 0 - Firms in ZONE 9 moving to zone *i*, $i \neq 9$

	DC1	DC2	DC3	DC4	DC5	DC6	DC7	DC8
Mining	2.54 **	-0.34	0.49	1.21 *	0.15	0.31	0.61	0.23
Food	-0.41 **	-0.21	-0.36 *	-0.27	-0.13	-0.26	-0.04	0.11
Sugar						0.51 **	-0.01	0.18
Beverage	-0.30 **	-0.39 **	-0.35 **	-0.47 **	-0.30 **	-0.33 **	-0.23 **	-0.04
Textile								
Paper	0.09	0.17	-0.09	-0.07	0.25	0.47	-0.24	-0.11
Chemistry	1.33	1.51	2.56	1.38	0.81	1.00	2.50	1.92
Steel								

(*) and (**) respectively indicate a relative, average-cost differential significantly different from 0 at the 10% and 5% level.

In the beverage industry, for firms already in zone 9, their *DCs* for being in any of the other zones are significantly different from zero except for zone 8, but all of them are negative, meaning that all the 37 firms are actually well located in zone 9 and they will be worse off in any other water pricing zone. We have the same result for beverage firms located in zone 8, with a negative and significant DC for zones 1 to 7, and a cost differential not significant for zone 9. By inspecting further zones 6 to 1 upward for the beverage industry, we see that it confirms perfectly the prediction regarding water input cost: when the firm moves to a zone with cheaper industrial water (to the "right" of its actual location in table 4.1), the relative cost differential is either not significant or is positive and significant.

On the other hand, the relative cost ratio is either not significant or negative and significant when the firm in beverage industry moves to zones with higher water price (to the "left" of the actual location). For all firms in this industry and located from zone 1 to zone 6, the cost differential with cheaper water zones 8 and 9 is always positive and significant. This positive and encouraging result can be explained by the fact that this sector is the second water user with a rather limited water average productivity (see table 3.15 in Chapter 3). Hence, in the beverage industry, 61% of the firms are adequately located, while the other 39% will be significantly better off in zones 8 or 9.

According to our water statistics, paper is the largest water user (37.29%) with the second lowest water average productivity (see table 3.15 on Chapter 3). This industry seems to be well located in expensive water zones, as *DCs* are not significantly different from zero for all firms located from zones 6 to 9, and are negative and significant for firms in zone 5. With the exception of firms actually located in zones 1 and 2, we find a behavior according to that of the firm (minimize cost), where paper firms would be better in zone 6. Concerning zones 3 and 4, firms will be better located in zone 5 or 6, but also in zone 1 and 2, which are more expensive zones. Consequently, 51.5% of paper firms are well located, 12.5% reports an unexpected behavior (those in zones 3 and 4), and 36% will have lower average costs if they move to zone 6.

Zone 7 seems to be the best option for textile industry because it reports a positive *DC* which is significantly different from zero for all the costs (except *DC3*), even those placed in zone 8. The few others which are significantly different from zero are negative, indicating a worse situation.

43.7% of food firms are adequately located (firms in zone 2, 7, 8 and 9). Those located in zone 5 and 6 (36.5%) will be better in zone 8. Firms in zones 1 and 4 will improve if they move to any of the zones 7 to 9. In contrast, firms in zone 3 would be better off in zone 2, a more expensive one, but also in cheaper zones (7 to 9).

Chemistry sector displays an unusual behavior for firms placed in zone 5 and 6 (40.6%), because it appears they would improve by moving to any other zone, still for expensive ones (zones 1 to 4), and worsen if they go to the cheapest zone. Firms in zone 1 will make better in zones 3, 7 or 8. The other firms seem well situated. A possible explanation is that unit cost of inputs other than water (labour and materials), are cheaper for chemical plants in precisely the very same zones where water is cheaper.

Sugar firms in our sample are only located in zones 6 to 9. The best water availability zone for this sector looks to be zone 6, since relative cost differentials are positive and significantly different from zero for being in this zone instead of any other.

If we remove the 43 mining firms which by definition cannot be moved from their actual geographical zone to another, as well as the four steel firms, this leaves 453 firms out of the original 500. From these, 44.4% are consistently located regarding the water availability zones. 19 of the 21 firms in the sugar industry will be better off in more expensive zones. Identical performance showed 13 chemistry firms, 7 for food, 3 for textile, and 8 in paper sector. Hence, 50 firms (11%) have an unexpected behavior regarding water price, leaving 44.6% of firms that will achieve lower production cost in cheaper water availability zones. As pointed out above, this may simply mean that water cost is not a limiting factor for these firms, and that other input cost or different market conditions are more important determinants of the actual firm location.

Zones 1 to 5 involve 53.9% of firms, from which 14.3% are adequately located, 6% have an unexpected performance, and the rest (almost 80%) will be better in cheaper zones regarding industrial water. For the other firms located in zones 6 to 9, 85% are well located. An important fact that comes out from this analysis is that 64% of paper firms, the biggest water user, are suitably located, as well as for beverage sector (61%) which is the second water user. Indeed, in our sample, these two industries together consume about 56% of total industrial water. (See table 3.15 in Chapter 3).

4.2 Changes of water zones analysis

We want to remind that water availability zones are determined as a function of water balance National Water Commission perform each year, and as a result of this evaluation, each of the 2436 municipalities around the country are assigned to one water zone. In Chapter 1, we already explain that so far there exist 9 different water availability zones. Where Zone 1 is the one with major water problems: scarcity, quality, availability, accessibility to water sources, principally. The reason why Zone 1 is the expensive one. Obviously, Zone 9 is the cheapest of all zones, since it has minor accessibility water problems.

Taking that into account, we carry out a data analysis to check what has been the behavior of water zones, i.e., how they have moved through the years. Therefore, we take our 500 database sample and we observe municipality location at that time and we compare it against municipality position in the year 2003. That is, which was its water zone then and which is its water zone in year 2003. We analyze if the water zones change or nor, and if they are either better or worse, since then.

This analysis was made considering kind of industry. In table 4.2 we have the results of this experiment. Source data for water zones for year 2003 is IMTA (2003).

One important thing to keep in mind is that we analyze the change of municipality in relation to the water zone where the firm is placed; and it is not the firm which moves. It is the municipality which each year is assigned to, because of its water balance, a water availability zone. Then, when we say that 38% of the firms in sugar industry keep the same zone, we really are meaning that 38% of the municipalities where sugar firms are placed have not changed of water availability zone.

In table 4.2 in the first column, when we say that changes of zone gain in 6, it means that, if for instance one firm was placed in Zone 3 and it has moved to Zone 9 for the year 2003, then this firm gained in 6 zones since Zone 9 is cheaper than Zone

3. On the contrary, a firm losses in 5 when, for example, if this firm was located in Zone 9 in our original database and if that same firm is placed in Zone 4 in the year 2003, subsequently, in relation to water price rights, now this firm has to pay more.

Table 4.2 Changes of water zone relating to year 2003.

Change of zones	Firms	% from total	Mining	Food	Sugar	Beverage	Textile	Paper	Chemistry	Steel
Loss in 5	5	1.0%	1	1		3				
Loss in 4	5	1.0%	1	1		2		1		
Loss in 3	22	4.4%		7	2	8	2	2	1	
Loss in 2	52	10.4%		14	3	16	3	12	4	
Loss in 1	124	24.8%	8	40	6	35	14	14	6	1
Same zone	229	45.8%	26	49	8	68	34	27	14	3
Gain in 1	22	4.4%	5	4	1	6	2	2	2	
Gain in 2	15	3.0%	1	3		5	2	3	1	
Gain in 3	14	2.8%	1	4	1	4		1	3	
Gain in 4	8	1.6%		1		2	2	2	1	
Gain in 5	2	0.4%		1		1				
Gain in 6	2	0.4%		1		1				
Total	500		43	126	21	151	59	64	32	4
percentage of firms in the same zone			60%	39%	38%	45%	58%	42%	44%	75%

Only one percent of our sample is in the last situation, losing in 5 zones, the worse condition of our analysis. And 0.4% gain in 6 zones. An important item that comes out is that 45.8% of our 500 firms are still in the same zone. In consequence, we may well conclude that, so far, hydrologic water balance is not revealing a clear evidence of water accessibility problems. And this conclusion is corroborated by the fact that if we consider those firms that lose in one and gain in one, all together with firms which maintain the same zone, we get that 75% of firms are included; meaning that 75% of the municipalities already keep their hydrologic situation. Given that moving by one zone, up or down, does not imply a huge change, respecting neither the availability of water nor the water price.

Analyzing by kind of industry, 58% of textile firms keep the same zone. Followed by beverage firms, where 45% of them maintain the zone. Recall that beverage industry is the second water user (18.74%) of our sample (see table 3.15 in Chapter 3). In paper industry, which is the major water consumer (see table 3.15 in Chapter 3), 42% of their firms keep the same zone. And sugar firms are the ones which move more since only 38% of them are in the same zone. Anyhow, analyzing in the bounds of industries, at least one third of their firms maintain the same zones.

Contrasting our two previous experiments from the relative average-cost differential analysis reported in table 4.1 we came to the conclusion that 44.4% of the firms are consistently located regarding the water availability zones and that 44.6% of firms will achieve lower production costs in cheaper water availability zones. From the changes of water zones analysis in table 4.2 we get that 45.8% of firms are still in the same water zone, i.e., they keep their hydrologic situation.

Therefore, from these two experiments we conclude that water cost is not a limiting factor for these firms and that other input costs or different market conditions are more important determinants of the actual firm location. But also, that the accessibility to water has not represented a real problem for firms, since almost 46% of the municipalities are still in the same hydrological condition without meaning they could not be under a stressed water situation.

The previous results could be confirmed by examining table 4.3, which shows all those 229 firms (see table 4.2), that are already located in the same water zones.

Analyzing table 4.3 we notice that 63% of paper firms are placed between Zone 1 and Zone 2, which is important, since this industry is the major water consumer according to table 3.15 from Chapter 3. In contrast, 47% of beverage firms are placed in the three cheapest water zones (7 to 9) and only 28% are placed in expensive zones (1 and 2). It is relevant to notice, because beverage industry is the one with the major number of firms (30%) that have maintained the same water zone (see table 4.2), but also it is the second water user (See table 3.15 in Chapter 3).

Table 4.3 Firms in the same water zone relating to year 2003.

	Firms	% from total	Mining	Food	Sugar	Beverage	Textile	Paper	Chemistry	Steel
Zone 1	46	20.1%	0	7	0	12	10	11	5	1
Zone 2	26	11.4%	0	7	0	7	4	6	1	1
Zone 3	10	4.4%	0	3	0	2	1	2	2	0
Zone 4	6	2.6%	2	2	0	1	1	0	0	0
Zone 5	31	13.5%	7	7	0	5	7	2	2	1
Zone 6	37	16.2%	6	9	1	9	8	2	2	0
Zone 7	18	7.9%	4	6	2	5	1	0	0	0
Zone 8	30	13.1%	4	5	2	14	2	2	1	0
Zone 9	25	10.9%	3	3	3	13	0	2	1	0
Total	229		26	49	8	68	34	27	14	3

Continuing with table 4.3 we observe that 35.8% of the firms are located in Zone 1, Zone 2 and Zone 3, all of them, are zones with real stressed water problems. So, no matter that 45.8% of firms do not move of water zone (see table 4.2), more of one third of them are placed under strained availability water zones.

Summary

In this first part of the chapter, sections 4.1 and 4.2 we conduct two experiments. First, we perform an experiment whose objective was to evaluate the consistency of the industrial firm distribution regarding water availability zones. From the relative average-cost differential analysis, we reached the conclusion that 44.4% of the firms are consistently located regarding the water availability zones.

Secondly, we carry out an experiment to analyze the changes of water zones, where we got that 45.8% of firms are still in the same water zone, meaning that they keep their hydrologic situation. But it comes out that despite the fact that 45.8% of firms do not change of water zone, more than one third of them are placed in availability water zones exposed to a stressed water situation.

Consequently, we could conclude that water cost is not a limiting factor for firms and that other input cost or different market conditions are more important determinants of the actual firm location. But also, that accessibility to water has not represented a real problem for the firms, since almost 46% of the municipalities are still in the same hydrological condition without meaning they could not be under a stressed water situation.

An associated empirical question is the fact that water price, as defined by scarcity zones, is pushing or not the firm managers towards an efficient use of water.

We come to an important fact within the Mexican manufacturing sector: water price is acting as a good economic tool to support the efficient use of water, although the responsiveness level of water demand against change in water price is not very strong. That is, water price as so far defined by water availability zones is a good economic tool, but it has not have a significant impact inside industry behavior, since they (industrial owners) have not moved to another cheaper water zone. For our data analysis we get that water price participation in total cost is very low, 2.2%. And for the side of the hydrologic water balance, the accessibility to water does not represent a real problem. Then, the question that remains unanswered is how far has to go water price to force on industrialist to take into account water scarcity and do an efficient water use? Therefore, water pricing reforms have to improve on the insertion of economic tools to achieve efficiency in the use of water.

4.3 Experiments without subsidy on water price

In this section, considering as a framework the previous results in section 3.4, we give a note on the legal framework of subsidies on water price in Mexico and we also do a brief data analysis of water price without subsidies.

4.3.1 Legal framework

We already explained in previous chapters (Chapter 1 and 3), that each year water quotas are updated through the Ley Federal de Derechos en Materia de Agua (LFDMA). This updating takes into account economical elements, like inflation rate, but it also considers political aspects. Among the political elements we have that some industries exert enormous pressure on water sector. Those political stresses result, in some cases, in a subsidy on water quotas.

In the Ley Federal de Derechos en Materia de Agua for year 1996 (see Annex A.2) in its Article 223 the quotas for the right to use water for each one of the 9 availability water zones are characterized. The quotas are defined for industrial user (in cubic meters) and for all other users (in thousand cubic meters), as potable, hydroelectric generation, recreation parks, among others.

But also at the Ley Federal de Derechos en Materia de Agua 1996 we found some transitory dispositions with deadline of one year. In the Article Twentieth of the temporary dispositions of the Ley Federal de Derechos en Materia de Agua 1996 fixed the subsidy to be applied for some industrial sectors is fixed.

For mining industry, they pay 25% of the quota per cubic meter relating to the water availability zone where mining factory is positioned.

For sugar industry, it was disposed for them to pay 50% of the quota per cubic meter in correspondence of the availability water zone where the factory is placed.

For paper industry it was established that factories placed in zones 7, 8 and 9, should pay 80% of the respective quota.

There are also some municipalities which get the benefits of some subsidy, but it is specified that this subsidy is only applied for water from surface origin. In this situation we have, first, two municipalities from Veracruz State, Coatzacoalcos and Minatitlan. These two municipalities paid the quota of water zone 7. Secondly, we have the municipality of Lazaro Cardenas in Michoacan State, as well as the municipality of Hueyapan de Ocampo in Veracruz State; both of them were designed to pay the quota of water zone 9. It is important to note that it does not matter if any of these municipalities is located as a result of hydrologic balance reasons, in other water availability zone.

From all these subsidies applied in 1996 (some of them are still applied in year 2004), the only one that could have some logic in relation to the purpose of doing an efficient use of water, is the one applied to paper industrial sector, since it could produce some pressure to move or to establish new factories from this sector in any of the zones 7, 8 or 9, which is an important water user sector. In our sample, the greatest water consumer, 37.3% (see table 3.15 in Chapter 3).

Regarding sugar sector, it is true that this sector is a ‘poor’ one since in general they still use a very old technical production process, but also they form a strong political force which makes a lot of demands on government to get subsidies in water and in other economic issues. In our sample data all factories from this sector are already placed in the cheapest water zones, 6 to 9, and from them, the majority, 47.6%, is established in zone 9. (See tables 3.18 in Chapter 3). And additionally, this industrial sector gets a 50% of subsidy in its water quotas.

This kind of subsidy carries out two problems. One, it produces an inefficient water use since water is already cheap. And second, factory owner does not have any 'real' motivation to improve technical production process, at least in what corresponds to the use of water, because water cost is not an important share of its total cost. The cost share of water in sugar sector is equal to 0.20% with subsidy on water quotas.

In the way to analyze in a more efficient way the behavior of the manufacturing sector in Mexico, we perform an experiment which consists in taking out all the subsidies previously explained from our original data base. And we make an analysis of the water price without subsidy and compare these results against those from original data base (with subsidy on water price).

4.3.2 Data analysis

We present, in table 4.4 the mean water price for the three industrial sectors where subsidy was removed.

Table 4.4 Mean Water Price without subsidy by industry.

Industry	Firms	Original Mean Water Price ($\$/m^3$)	No Subsidy Mean Water Price ($\$/m^3$)	% Δ Pw
Mining	43	0.81760	3.27040	300%
Sugar	21	0.45756	0.91511	100%
Paper	64	3.19733	3.25924	1.94%
Paper fims in zones 7 to 9	20	0.79230	0.99040	25%

The third column in table 4.4 corresponds to the fourth column in table 3.15 from Chapter 3, excepting the last row. The other columns from table 3.15 were not considered since they do not change when we remove subsidy on water price.

Remember that water average productivity is the value of output divided by water consumption, then for the level of our analysis it is not affected by water price. Of course if the price of water increased in a considerable amount it could affect the water quantity consumed, theoretically decrease water consumption (determined by the elasticity of water demand), and in that way the productivity of water should change.

The growth rate of the mean price of water is given by expression 4.3, where *i* denotes the industrial sector and $Pwns_i$ is the price of water without subsidy.

$$g_i = \left[\frac{Pwns_i - Pw_i}{Pw_i} \right] \tag{4.3}$$

Last row in table 4.4 shows data only for the 20 firms of paper sector placed in zones 7, 8 and 9, the ones which get the benefits of the subsidy. These 20 firms represent 31.25% of paper industry. Analyzing all 64 paper firms together we see that the mean price of water changes in less than 2%.

The correlation coefficient for kind of industry is already small in the original data base, 0.3432 (See Chapter 3), it decreases even more when we take out subsidies on water price (0.05195). But considering water availability zones, the correlation coefficient between mean water price without subsidy and water average productivity is important, 0.9286, which is very close to the value we get when we consider subsidy on water price, 0.9284 (See Chapter 3).

In table 4.5 we display mean water price without subsidy, by availability water zone. This table in its third column includes the mean water price from original data base (see table 3.16). We see in table 4.5 that zones 6 to 9 report the greater percentage changes in the mean water price from original data. It is due to the fact that, first, all sugar firms are placed between zones 6 to 9. Secondly, 56% of mining factories are located also in these water availability zones (See table 3.18 in Chapter 3). And finally, regarding paper sector, the factories which get the benefits of subsidy on water price are those placed in zones 7, 8 and 9.

Table 4.5 Mean Water Price without subsidy by water zone.

Availability Zones	Firms	Original Mean Water Price ($/m^3)	No Subsidy Mean Water Price ($/m^3)	% Δ Pw
Zone 1	53	6.40007	6.75774	6%
Zone 2	47	5.02263	5.12298	2%
Zone 3	26	3.91111	4.03489	3%
Zone 4	25	3.33233	3.71866	12%
Zone 5	116	2.31898	2.56553	11%
Zone 6	45	2.05528	2.45004	19%
Zone 7	51	1.81489	2.14562	18%
Zone 8	66	0.57940	0.74106	28%
Zone 9	71	0.44937	0.57038	27%

Comparing the mean water price without subsidy (fourth column in table 4.5) by availability water zone against those quotas fixed in the Ley Federal de Derechos en Materia de Agua 1996 (See Annex A), we can check that the values we get from our sample draw near to the quotas established for the second semester of 1996. Note that those in zone 7 to 9 have gone slightly up of those in the Ley Federal de Derechos en Materia de Agua 1996.

So, in that sense we can be sure that the way we define the unit water price in Chapter 3 is correct and it fixes the real quotas defined in the Ley Federal de Derechos en Materia de Agua 1996.

4.4 Experiment with water price elasticity

In this section, considering the preceding results in section 3.5 and those in section 4.3, we perform an experiment to analyze the effect that elasticity on water price has upon the volumes of water demanded by firms. To do that, we first construct the elasticity for each one of the 8 industrial sectors by availability water zone. Then, using these elasticities, we define 7 scenarios to analyze the water demand response against subsidy elimination. In the last experiment achieved we identify a water demand constraint to define the technical shutdown point of the firm.

We carry out these two experiments exclusively for those industrial sectors which benefit from a subsidy on water price. That is, the mining sector with a subsidy of 75%, sugar with a 50% subsidy and finally, those firms placed in Zone 7, 8 or 9 from paper sector that have a 20% subsidy on water price.

4.4.1 Elasticity by industry and water zone

In the way to get the own-price elasticity for water, ε_{ww} (see expression 2.11 in Chapter 2), for each one of the 8 industrial sectors, we use the β_{ww} estimated (expression 2.9 in Chapter 2), or its equivalent the α_{ww} estimated from the share equation system in expression 3.7 in Chapter 3, as well as the cost share of water predicted from expression 3.7. That is, we estimate the elasticity for each industry according to the following expression.

$$\varepsilon_{ww_{ij}} = \frac{\hat{\alpha}_{ww}}{\hat{\hat{S}}w_{ij}} + \hat{\hat{S}}w_{ij} - 1 \quad where\ i = industry;\ j = water\ zone \tag{4.4}$$

Remember that we already use the mean cost share to estimate elasticities. Here, we use for each industrial sector its mean predicted cost share of water for each water zone, $\hat{\bar{S}}w_{ij}$.

Then, in that way the elasticity for every industrial sector captures the cost shares for each water availability zone, which initially should be different since getting access to water in Zone 1 should cost more, for the reason that accessibility or extraction cost are greater than for example in Zone 9, where water is normally in abundance. So, we assume that for a specific industrial sector, all their firms placed in the same water zone have, in average, the same cost share. Thus, using expression 4.4 we get the elasticity for each industry in each water availability zone. Table 4.6 presents these elasticities.

The first thing to notice, in table 4.6, is that 87% of the elasticities are significantly different from zero at the 10% or 5% level. Second, for cases where the elasticity was positive due to a very small cost share of water, we use the mean elasticity of the respective sector. In these cases the t-value is not meaningful.

Analyzing table 4.6 we observe that for food sector all elasticities are statistically well significant, and that they are pretty similar, they range from -0.3086 in Zone 6 to -0.5451 in Zone 1. An analogous behavior is found in textile sector, but here the elasticity values are greater, from -0.3943 in Zone 4 to -0.7245 in Zone 7.

In chemistry sector 40% of the firms, those placed in Zone 4, 5 and 8 (see table 3.18 in Chapter 3), have a very small cost share of water, which is the reason why we take the mean elasticity of the sector for these cases (-0.5678). Regarding the other zones, the elasticities are statistically significant (excluding that in zone 6) and they range from -0.2506 to -1.5642 in Zone 6 and Zone 9, respectively.

Table 4.6 Elasticity by industry and water zone ($\varepsilon_{ww_{ij}}$).

Industry	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Mining	-0.7567	-2.8279	-1.4739	-0.6003	-0.8875	-0.8875	-0.1102	-0.0519	-0.3913
	(-27.48)	(-6.82)	(-14.7)	(-7.35)	(n.a.)	(n.a.)	(-0.55)	(-0.24)	(-2.94)
Food	-0.5451	-0.4837	-0.3494	-0.4815	-0.5021	-0.3086	-0.5080	-0.4351	-0.4884
	(-5.70)	(-4.37)	(-2.44)	(-4.33)	(-4.73)	(-2.02)	(-4.85)	(-3.55)	(-4.45)
Sugar						-7.2464	-1.9603	-1.6373	-1.5428
						(-5.09)	(-9.11)	(-11.72)	(-13.18)
Beverage	-0.4686	-0.0238	-0.2945	-0.2192	-0.0544	-0.0987	-0.3892	-0.2055	-0.2192
	(-4.09)	(-0.10)	(-1.89)	(n.a.)	(-0.25)	(-0.48)	(-2.91)	(-1.16)	(n.a.)
Textile	-0.4999	-0.6175	-0.6519	-0.3943	-0.6172	-0.5504	-0.7245	-0.5794	
	(-4.68)	(-8.00)	(-9.58)	(-2.98)	(-7.98)	(-5.84)	(-15.72)	(n.a.)	
Paper	-0.5174	-0.5201	-0.3110	-0.0430	-0.3419	-0.6427	-1.4359	-7.6754	-1.4359
	(-5.05)	(-5.11)	(-2.04)	(-0.20)	(-2.36)	(-9.12)	(n.a.)	(-5.05)	(n.a.)
Chemistry	-0.3917	-0.2600	-0.3954	-0.5678	-0.5678	-0.2506	-0.5694	-0.5678	-1.5342
	(-2.95)	(-1.63)	(-2.99)	(n.a.)	(n.a.)	(-1.50)	(-6.36)	(n.a.)	(-13.34)
Steel	-0.6900	-0.6948			-1.7965				
	(-12.06)	(-12.46)			(-10.14)				

Note: between parenthesis t-values. (n.a.) not applying.

Beverage sector, in relation to other sectors, reports the lowest elasticities values but all of them are not statistically different from zero. 25% of the firms in this industrial sector have a low cost share; then we replaced their original positive elasticity by the mean elasticity of the sector, which is -0.2191. These industries are the ones placed in Zone 9 (see table 3.18 in Chapter 3). Zone 1 has the higher elasticity -0.4999 with high t-value.

The mean elasticity for mining sector is -0.8875, value that we use to replace in Zone 5 and 6 since the cost share of water for these firms is insignificant. Remember that this sector, mining, is the one which benefits from the greater amount of subsidy on water price (75%), since they pay only 25% of the quota established in the Ley

Federal de Derechos en Materia de Agua (see chapter 4.3). The elasticities in this sector go from -0.0519 in Zone 8 with a t-value indicating that this estimate is not significantly different from zero; to -2.8279 in Zone 2 with high t-value.

Paper sector in Zone 8 has a high elasticity, -7.6754, with high t-value. The elasticity for Zones 7 and 9 is the mean of the sector, -1.4359. The other elasticities, those between Zone 1 to 6 go from -0.3419 to -0.6427. In section 4.3 we pointed out that those firms from paper sector placed in Zone 7, 8 and 9 pay 80% of the water quota, so they have 20% of subsidy, and it is in these zones where water price elasticity reports the higher values. A similar behavior is found in the sugar industries. All their elasticities are greater than one and they are statistically significant different from zero. In Zone 6 elasticity is -7.2464. Recall that sugar sector also has a subsidy on water price of 50%. Then in a first instance we could conclude that if we remove subsidy on water price for sugar and paper sectors, the demand of water will be significantly affected. The same is valid for mining sector, principally for firms placed between Zone 1 and Zone 6 were their elasticities are around or greater than one.

Doing a brief analysis of the elasticities by zone, we found that all the elasticities from Zone 1, the more expensive zone, to Zone 3 are well significantly different from zero, excepting one in beverage sector, and their mean value is around -0.55, meaning that for one-percent change in the price of water (all else hold constant) will result in more or less 0.55% change (reduction) in the quantity of the water consumed in these three water availability zones. Finally, it is starting from Zone 4 where we find results with small water cost share with reference to total cost, giving as a consequence that we use the mean elasticity of the respective sector, in place of those positive events.

4.4.2 Scenarios on water demand changes due to subsidy elimination

In section 4.3 we introduce the legal framework of subsidy in water price that manufacturing sector in Mexico has. Three industrial sectors benefit from the subsidies on water price: mining 75% of subsidy, sugar 50%, and for paper firms located in Zones 7, 8 and 9, 20% of subsidy. From now on, we denote subsidy on water price as τ.

The own-price water demand elasticity ε_{ww} is calculated as a ratio of the percentage change in the quantity demanded of water (%ΔQw) to the percentage change in the price of water (%ΔPw):

$$\varepsilon_{WW} = \frac{\%\Delta Q_W}{\%\Delta P_W} \tag{4.5}$$

Using the elasticity by industry and by water zone ($\varepsilon_{ww_{ij}}$), we perform an experiment with different subsidy scenarios, to see how water demand behaves.

Mining sector pays just 25% of the water quota established in the Ley Federal de Derechos en Materia de Agua. If we take out the 75% subsidy on water price they have, then the price of water in mining sector will increase by 300%. Doing the same for sugar and paper sector, the respective water price grows by 100% and 25% (see table 4.4).

The experiment, we perform here, consists in defining one first scenario where we eliminate just 15% of τ, the subsidy level for each sector. The percentage change in water price is a function of the subsidy level. For example, if we take out 15% of the subsidy, for mining sector water price changes by 12.67%, for sugar sector price of water raises by 8.1% and for paper the price of water increases by 3.1%. Following this idea we define 7 scenarios where we remove subsidy beginning with 15% and at the end removing the entire subsidy on water price.

First scenario takes out 15%; scenario 2 removes 30%; scenario 3, 45%; scenario 4, 60%; scenario 5 eliminates 75%; scenario 6, 90% and scenario 7 removes 100%, that is under scenario 7 we have that $\tau = 0$.

In table 4.7 we present the percentage change in water price for each scenario by industrial sector. The last column in table 4.7 shows the extreme situation when we take out all subsidy in the price of water. That was already analyzed in table 4.4, also in its last column.

Table 4.7 Change in water price due to subsidy elimination: scenarios.

Industry	% Δ Pw: Scenario (percentage of subsidy removed)						
	1 (15%)	2 (30%)	3 (45%)	4 (60%)	5 (75%)	6 (90%)	7 (100%)
Mining	12.7%	29.0%	50.9%	81.8%	128.6%	207.7%	300.0%
Sugar	8.1%	17.6%	29.0%	42.9%	60.0%	81.8%	100.0%
Paper	3.1%	6.4%	9.9%	13.6%	17.6%	22.0%	25.0%

From expression 4.5 we obtain the percentage change in water demand for each one of the scenarios (see expression 4.6).

$$\%\Delta Q_w = \varepsilon_{ww} * \%\Delta P_w \qquad (4.6)$$

Then, through expression 4.6, and using the elasticities from table 4.6 as well as the percentage change on water price reported in table 4.7, we are able to obtain the percentage change in the demand of water by sector. But also we could get these scenarios by water zone, since firms of these three industrial sectors are positioned in different availability water zones.

Figure 4.1 displays, for the 9 water availability zones, the percentage change in quantity of water demanded as the level of subsidy decreases, that is, per scenario. If we take out 100% of the subsidy, that is $\tau = 0$, then price of water reaches its maximum level, producing the greater percentage change in the demand of water.

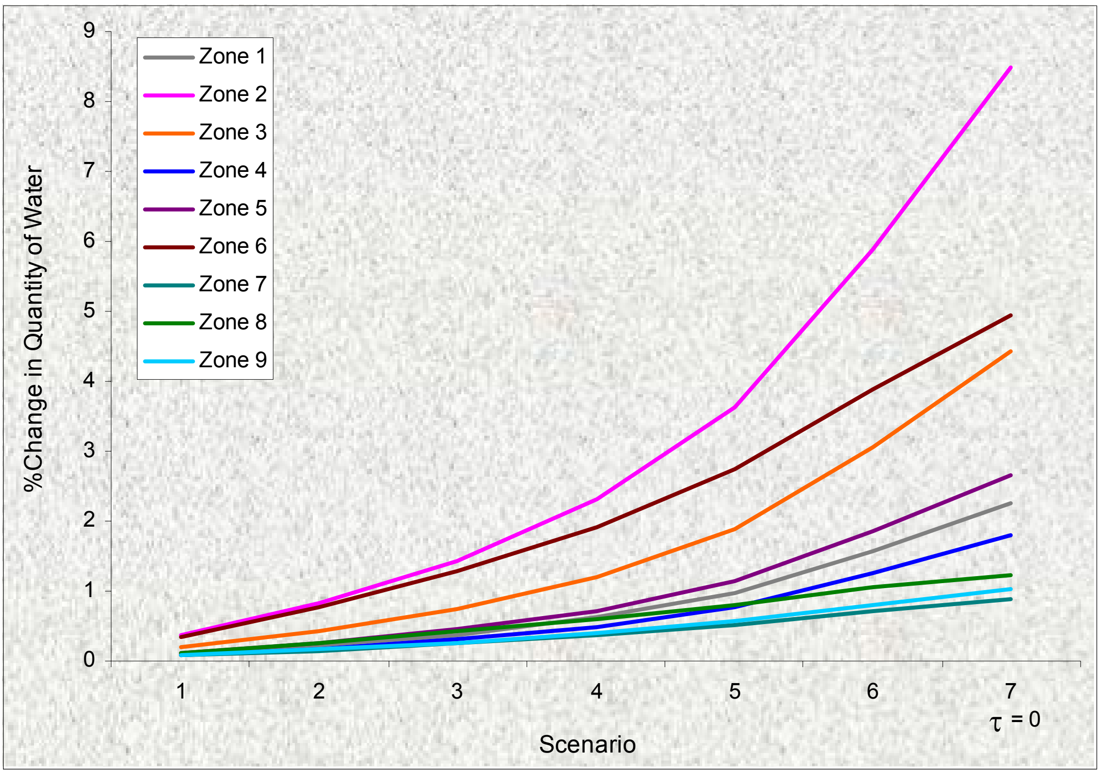

Figure 4.1 Percentage change in quantity of water due to subsidy elimination

Analyzing figure 4.1 we see that Zone 2 has the major reaction against subsidy elimination, since its demand of water decreases around 8.5% when we remove the totality of subsidy on water price. It is followed by Zone 6 which diminishes the quantity of water by almost 5%. Zone 3 reacts also in the same level than Zone 6. The percentage change (reduction) in water demanded in Zone 3 is 4.5%. Zones 2, 6 and 3 are the zones, in that order, that reports major reaction while eliminating subsidy on water price.

Contrary to what was expected, Zone 1, the most expensive zone, does not report a huge response since the percentage change in water demand is just higher than 2.25%. Whereas other cheaper zones report more important reactions against changes in the subsidy level allowed in our scenarios.

Figure 4.2 allows us to see clearly the different reactions in the demand of water by water zone, according to our scenarios.

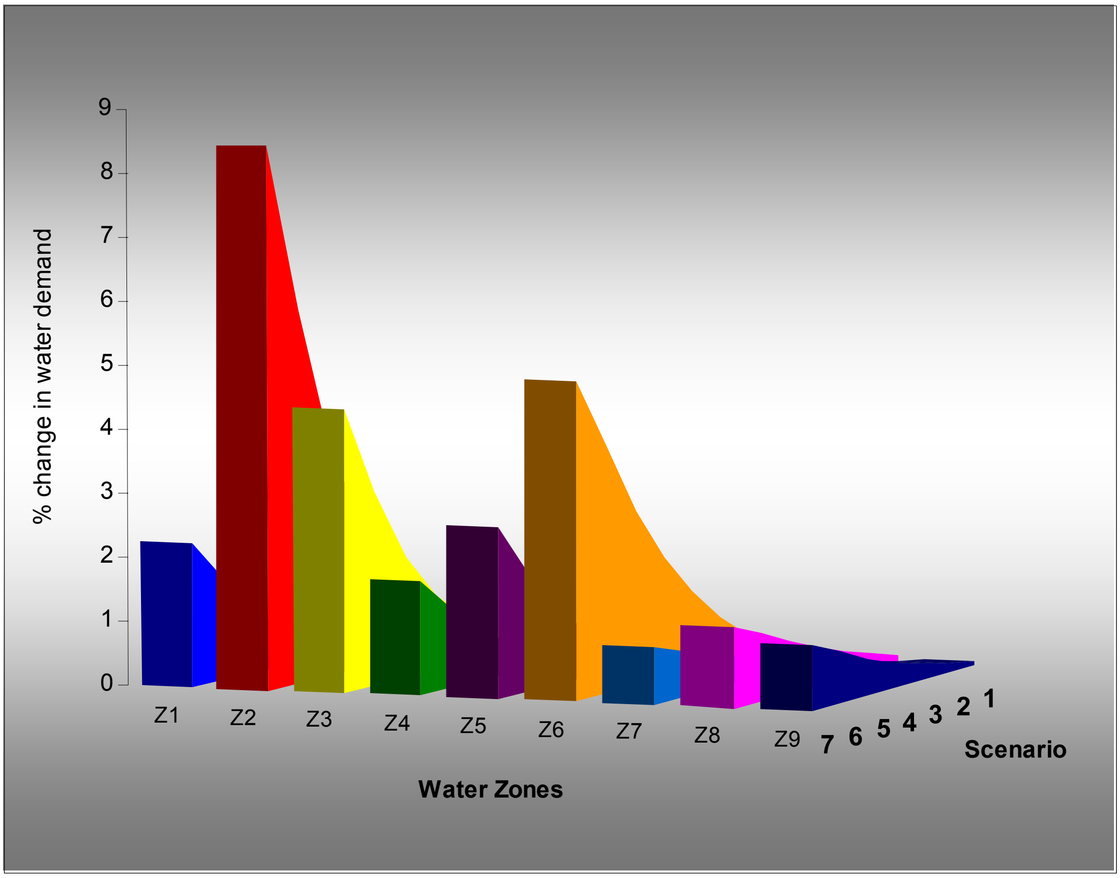

Figure 4.2 Water demand percentage change due to subsidy elimination

The volumes of water that this percentage diminution on water demand represents are in table 4.8 for the three industrial sectors that have subsidy on water price. Table 4.9 displays these volumes by water availability zone. Values are given for each one of the scenarios previously described.

Table 4.8 Water demand decreases due to subsidy elimination: Scenario by industry.

Industry	Scenario (thousand cubic meter)						
	1	2	3	4	5	6	7
Mining	-3 818	-8 745	-15 344	-24 644	-38 726	-62 558	-90 361
Sugar	-1 809	-3 937	-6 476	-9 560	-13 384	-18 251	-22 307
Paper	-8 272	-17 072	-26 452	-36 472	-47 200	-58 712	-66 866
Total	-13 899	-29 753	-48 273	-70 676	-99 310	-139 521	-179 534

In table 4.8 we see, that even though paper industry has subsidy only for firms placed within the three cheapest water zones (7, 8 and 9), this is the sector which reports in almost all the scenarios, the maximum percentage diminution in water demand.

Regarding the total water not consumed by the three industrial sectors, due to subsidy elimination, sugar sector keeps the same percentage level, around 13%, but paper industry reports major reaction in the first scenario than in the last: 60% in scenario 1, 57% scenario 2, 55% scenario 3 and so on up to reporting 37% in scenario 7. Meaning that this sector, paper, reacts more against small subsidy reduction (15% or 30% subsidy reduction), than when removing the entire subsidy on water price.

Concerning mining sector, it diminishes water consumption as the subsidy amount decreases. Figure 4.3 shows, graphically, the values presented in table 4.8 where we see that mining sector is the one that has major reactions against subsidy elimination.

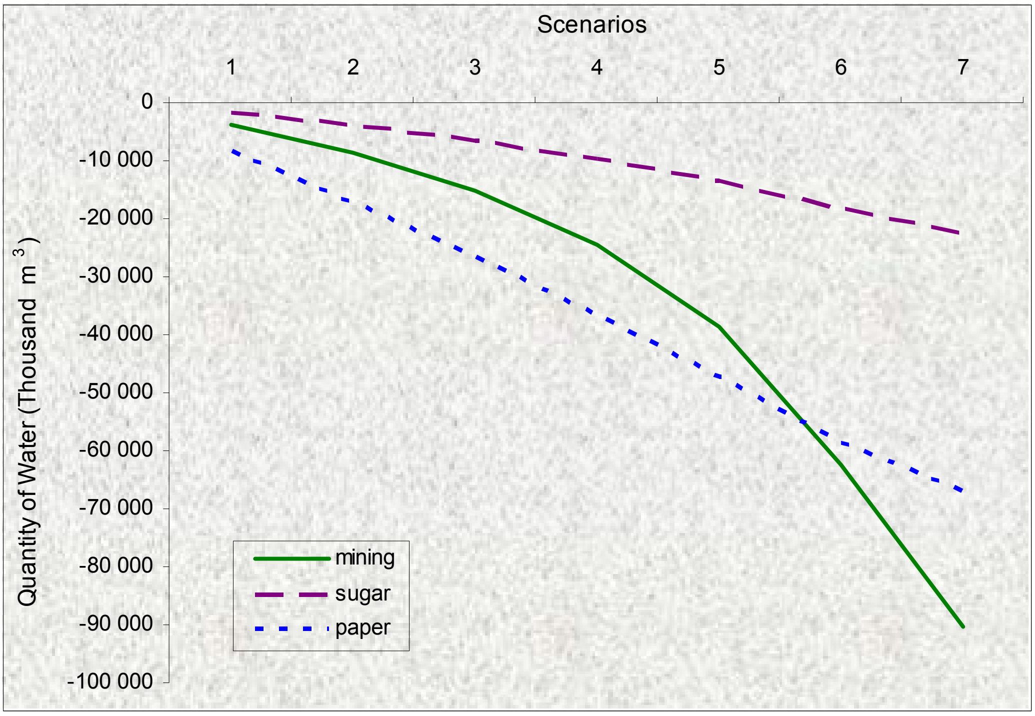

Figure 4.3 Water demand decrease due to subsidy elimination

Looking at table 4.9 we observe that firms placed in Zone 8 have greater reaction to subsidy elimination. They report major water volumes diminution in all the scenarios simulated in relation to the total water not consumed. Firms in Zone 8 diminish water consumption around 50% when we remove subsidy between 15% and 60%. After this point the percentage of water not consumed decreases down to 36% in scenario 7.

Removing the totality of subsidy (last column in table 4.9), the water zones 8, 5 and 6 are the zones with greater response level, diminishing water consumption by 36%, 28% and 19%, respectively, regarding the total volumes of water not consumed in all water zones.

Table 4.9 Water demand decrease due to subsidy elimination: Scenario by water zone.

Water Zone	Scenario (thousand cubic meter)						
	1	2	3	4	5	6	7
Zone 1	-0.015	-0.035	-0.062	-0.099	-0.156	-0.251	-0.363
Zone 2	-190	-435	-764	-1 226	-1 927	-3 113	-4 497
Zone 3	-140	-321	-564	-906	-1 423	-2 299	-3 321
Zone 4	-66	-152	-267	-429	-673	-1 088	-1 571
Zone 5	-2 094	-4 796	-8 416	-13 517	-21 240	-34 311	-49 561
Zone 6	-1 590	-3 607	-6 258	-9 910	-15 301	-24 157	-34 220
Zone 7	-1 326	-2 767	-4 344	-6 083	-8 027	-10 236	-11 909
Zone 8	-7 431	-15 433	-24 093	-33 523	-43 876	-55 372	-63 838
Zone 9	-1 061	-2 241	-3 568	-5 082	-6 842	-8 943	-10 616
Total	-13 899	-29 753	-48 273	-70 676	-99 310	-139 521	-179 534

Table 4.10 exhibits the percentage of water not consumed in relation to the total water consumption of the respective industrial sector. Table 4.11 also shows the percentage of water not consumed related to the total water consumption but it is regarding water availability zone.

Table 4.10 Percentage of water not consumed by industry: scenarios.

Industry	Scenarios: % of water not consumed with respect to own sector						
	1	2	3	4	5	6	7
Mining	11%	25%	43%	69%	109%	176%	255%
Sugar	15%	33%	55%	81%	114%	155%	190%
Paper	13%	26%	40%	55%	72%	89%	102%

Table 4.11 Percentage of water not consumed by water zone: scenarios.

Industry	Scenarios: % of water not consumed with respect to own water zone						
	1	2	3	4	5	6	7
Zone 1	0.0001%	0.0003%	0.0004%	0.0007%	0.0011%	0.0018%	0.0026%
Zone 2	1%	3%	6%	9%	14%	23%	33%
Zone 3	2%	3%	6%	10%	15%	25%	36%
Zone 4	1%	2%	4%	6%	9%	14%	21%
Zone 5	4%	10%	17%	27%	43%	69%	100%
Zone 6	9%	19%	34%	53%	82%	130%	184%
Zone 7	4%	9%	14%	19%	26%	33%	38%
Zone 8	18%	37%	57%	79%	104%	131%	151%
Zone 9	3%	6%	10%	14%	19%	24%	29%

In table 4.11 we observe that for 3 water zones (5, 6 and 8) under scenario 7, the total subsidy elimination produce the effect that water demand diminishes further than the current consumption.

4.4.3 Scenarios under water demand constraint

So far we have analyzed the way firms respond against reduction in the subsidy on water price, using the own-price water elasticity, and we have determined the amount of water not consumed due to increments on water price. But one thing we have not taken into account up to now, is that firms have a minimum requirement of water to produce. So, if we increase arbitrarily the price of water, as a result of diminishing subsidy level, the firm in a first step is going to reduce water consumption, but it is going to arrive to the point were water demand becomes inelastic since the firm will not be able to produce with a smaller amount of water.

That is, considering the water price elasticity as a tool to analyze the demand of water for any industry, if we increase the price of water to reduce the demand of the good, it would be possible that the firm before reaching its shutdown point due to increments on water price, the firm would achieve a technical shutdown point, because the technical process requires a minimum quantity of water to produce. But it does not mean that water has to be used in an inefficient way. It is represented graphically in figure 4.4.

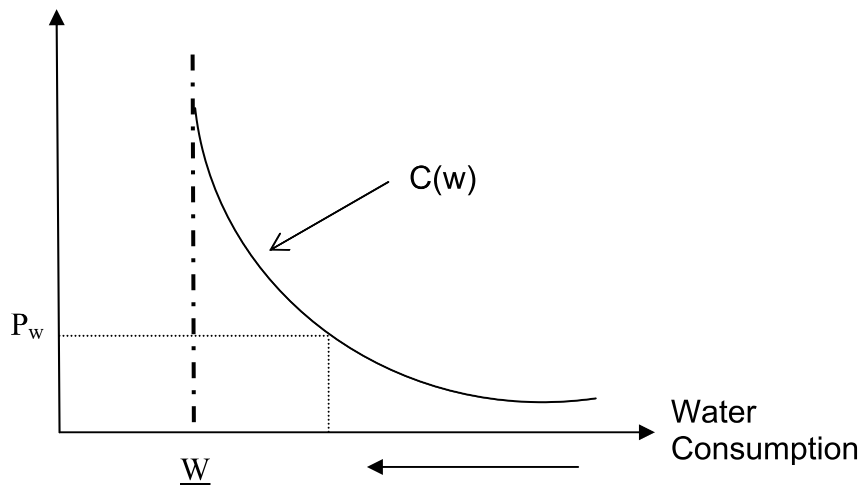

Figure 4.4 Water demand constraint

C(w) is the unit cost of water, and *W* is the minimum amount of water necessary to get one unit of product. So, water consumption cannot decrease after this point, no matter how much water price increases. Then, water demand has a constraint given by the "best" technological production process used by the industry. "Best" has to be understood as the production process which has the most efficient water management (Guerrero, 2000).

Then, concerning our analysis, the situation previously exposed can be clearly analyzed from figure 4.5 where we plot, for mining, sugar and paper industries, the quantity of water (in thousand cubic meters) not consumed in response to water price growth due to subsidy elimination. But also we have plotted the minimum quantity of water (the equivalent to W) the industrial unit needs to produce. We take as minimum volume of water needed to produce, the actual water consumption, since it is with such quantity of water they actually produce.

Figure 4.5 is the mirror in the positive axis of figure 4.3, so it is important to keep in mind that the water volumes plotted represent in fact, the quantity of water not consumed. We decide to present the plot in this way to be able to draw the water demand constraint (W), for each sector.

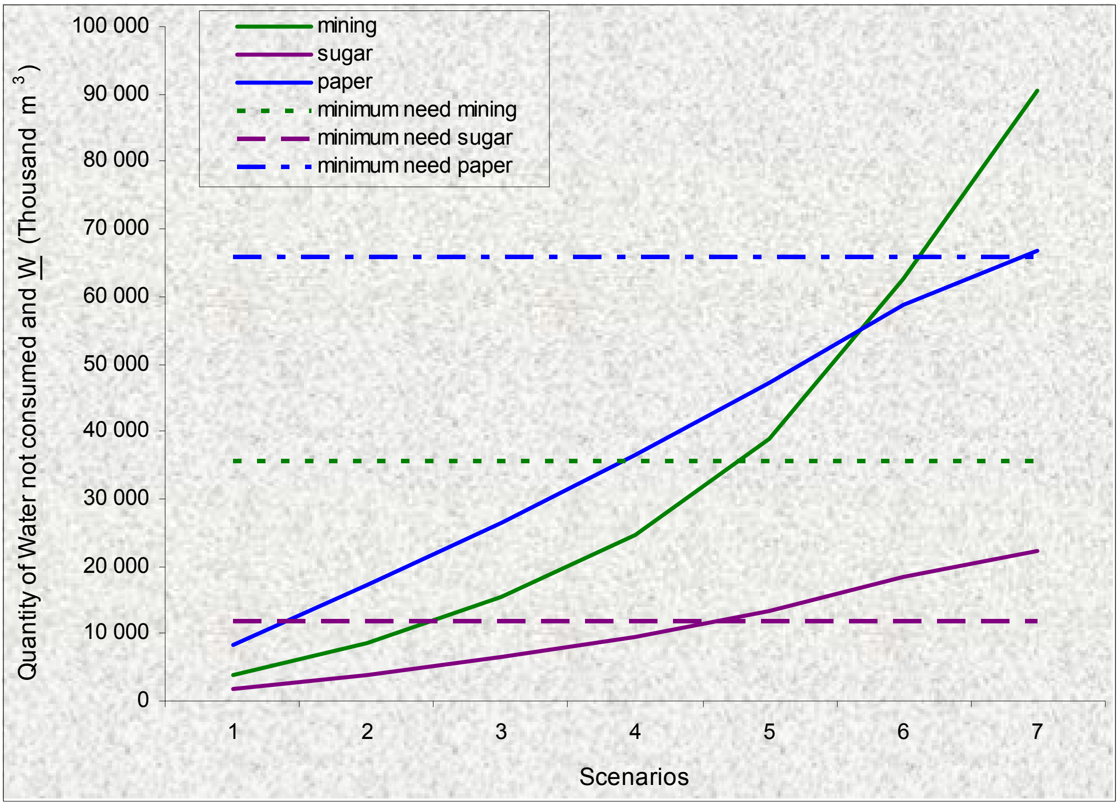

Figure 4.5 Water not consumed and water constraint (W)

The interpretation of figure 4.5 is the following. At the point zero where lines cross, in the horizontal axis we have the minimum price of water therefore the totality of subsidy level. As we move to the right we eliminate subsidy just to reach the point where we have taken out all subsidy ($\tau = 0$), consequently water price reaches its maximum level. In the vertical axis we have the volumes of water not consumed in thousand m³. Then, as we eliminate subsidy, price increases then industrialist sacrifices quantity of water consumed. But firm cannot sacrifice any further to that minimum level necessary to produce. Otherwise the firm reaches its technical shutdown point. That is, for example for mining industry, as water price increases the firm renounces to consume some volumes of water (in function of its elasticity), but mining industrial sector cannot give up more water than 35500 thousand cubic meters, which is the minimum quantity of water that mining industry needs to produce. This is assuming that the actual production level does not change and that there is not a substitute for water.

Figure 4.6 shows the case of mining industry. In that graph we plot what we consider should be the real water consumption behavior of mining firms under subsidy elimination situation.

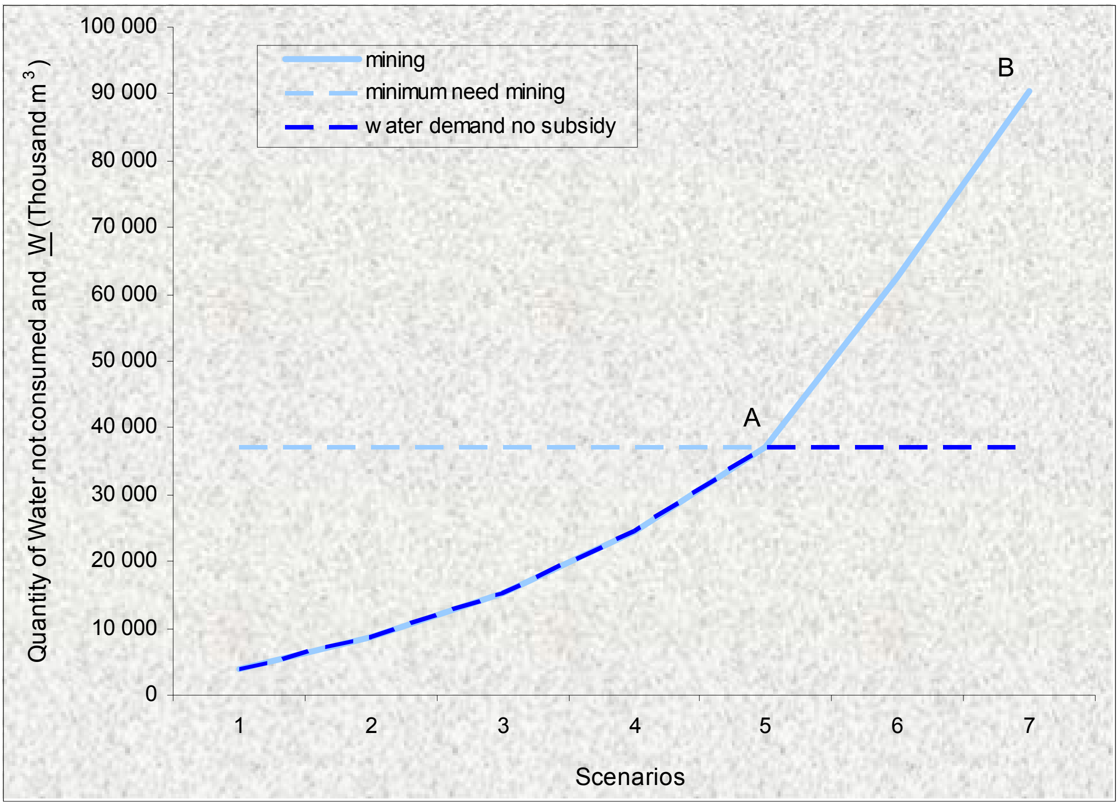

Figure 4.6 Mining: water not consumed and water constraint

Figure 4.6 displays different lines, first, a continuous upward line-curve which represents the behavior of the water demand for mining firms when water prices increase as a result of subsidy elimination. Second, a discontinuous horizontal line (around 36000 thousand m^3), which denotes the minimum quantity of water needed to produce. Third, an irregular darker line which is curved up to point *A* then it becomes horizontal. That is, we have that at the beginning both curve-lines come parallel up to the point *A* where subsidy elimination reaches the level where water demand becomes inelastic in the way to satisfy the minimum volumes of water needed to produce. Section A-B corresponds to the volumes of water not consumed by the firms due to water price increments. But this section indicates the volumes of water that are lower than those needed to produce. Then, the point *A* represents the technical shutdown point for mining industry.

Looking at figure 4.5 we see that sugar behavior is pretty similar to that of mining sector, where both industrial sectors arrive to their technical shutdown point at the same subsidy elimination level, 60%, which does not mean that water quota is the same.

Remember that we take out 60% of the subsidy on water price that both industrial sectors currently have, $\tau = 75\%$ in mining and $\tau = 50\%$ in sugar. This can also be seen in table 4.10, where for both sectors under scenario 5; the percentage of water not consumed is greater than 100%, meaning that they have reached their shutdown point. So, for them it is still technically possible to produce as far as in scenario 4, with 60% of subsidy elimination.

Contrary to these two previous industries, paper firms have different behavior, since this industry arrives to its 'technical' shutdown point when we eliminate almost 100% of the subsidy on water price. Figure 4.7 shows it.

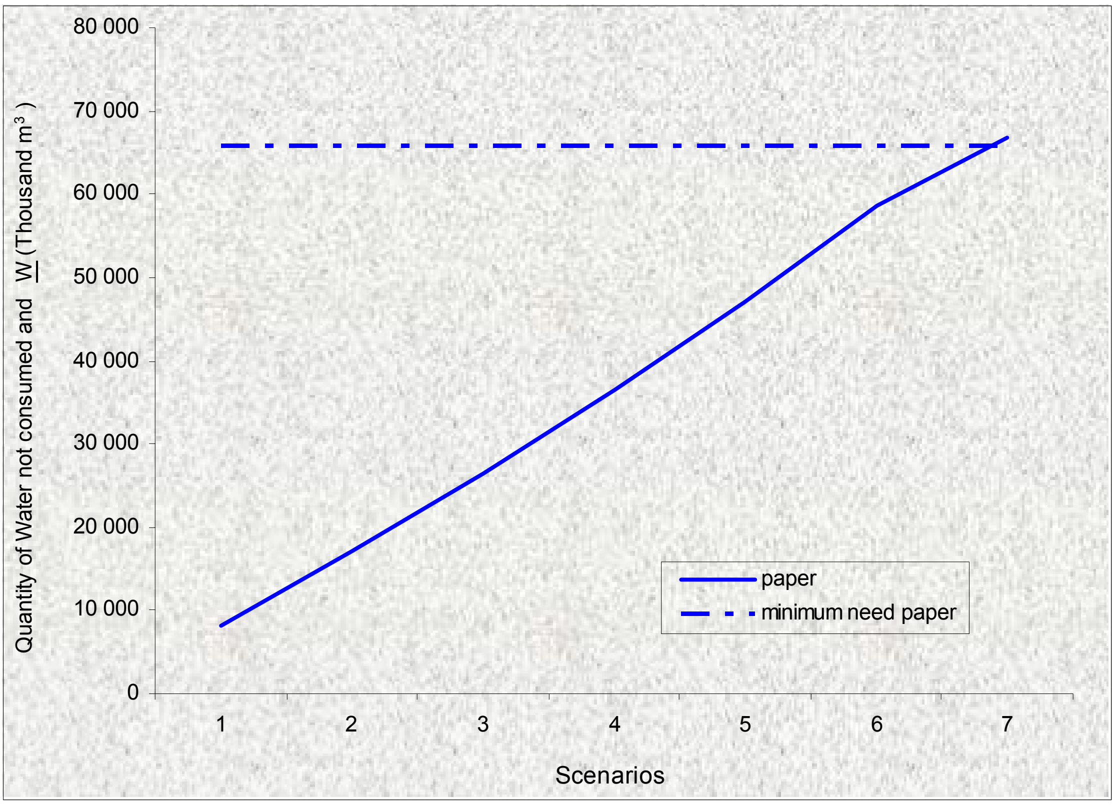

Figure 4.7 Paper: water not consumed and water constraint

Figure 4.7 displays only the effect that subsidy elimination produces in the water zones involved, that is, it shows the water volumes not consumed due to subsidy elimination for paper firms in Zones 7, 8 and 9. But if we consider the effect of that water volumes not consumed in the totality of water zones, the behavior is pretty different. In figure 4.8 we plot what should be the paper industry behavior if the subsidy effect on water demand is considered in the whole water zones.

According to figure 4.8 if the mean of water not consumed is considered to all water zones, the technical shutdown point will be achieved around 50% subsidy elimination. The reason of that is because water consumed for paper firms placed in Zones 7, 8 and 9 represents 79% related to total paper industrial sector.

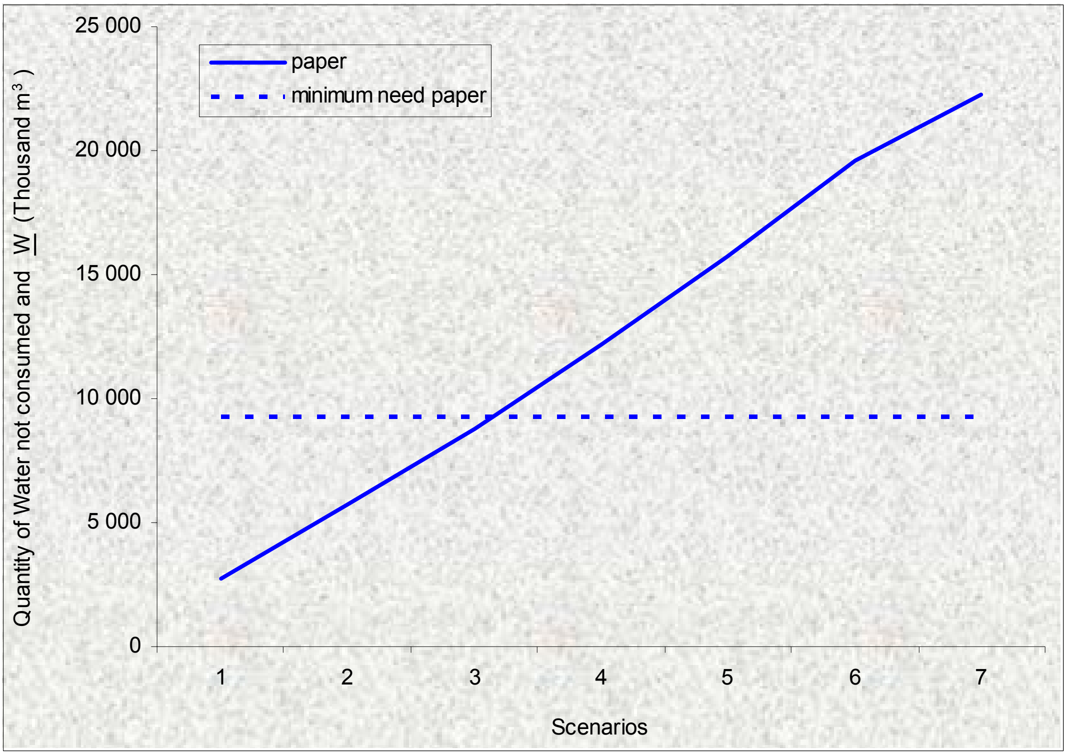

Figure 4.8 Paper (total): water not consumed and water constraint

From figure 4.7 we can conclude that the elimination of subsidy does not affect the real quantity of water needed to produce, since this industrial sector does not arrive to its 'technical' shutdown point before 90% subsidy elimination. But it helps to improve the efficiency in the use of water, since from table 4.8 we have that paper sector renounce to consume important volumes of water due to subsidy elimination.

Summary

In this part of the chapter we first got the own water price elasticity for the 8 industrial sectors by water zone. The mean elasticities by sector are: mining -0.8875; food -0.4557; sugar -3.0967; beverage -0.2192; textile -0.5794; paper -1.4359; chemistry -0.5678; and finally -1.0604 is the mean elasticity for steel sector. Analyzing elasticities by zone, the mean from Zone 1 to Zone 3 is around -0.55

where, excepting one, all are well significantly different from zero. Starting from Zone 4 we found situations with pretty small water cost share in relation to total cost of the firm, resulting in a positive elasticity. In those cases we replace that positive elasticity by the mean elasticity of the respective sector.

Second, we define 7 scenarios to analyze the water demand reply against the elimination of the subsidy on water price. Under the first scenario we take out 15% of the subsidy, in the last scenario we remove the entire subsidy. Regarding the percentage change in the quantity of water, the zones which react stronger against subsidy elimination are Zone 2 followed by Zone 6 and Zone 3. Regarding the volumes of water not consumed by the three industrial sectors, as a result of subsidy elimination, paper industry reports, in almost all scenarios, the maximum percentage of water no consumed related to the ones reported by mining and sugar industries. Continuing with water volumes renounced as a reaction of subsidy elimination, Zone 8 shows up the major volumes related to total water not consumed. Taking out the totality of subsidy, scenario 7, mining sector sacrifices major water volumes (50%) and by the zone side, zones 8, 5 and 6 are the ones with greater reply level, diminishing water consumption by 36%, 28% and 19%, respectively; all these are in relation to the total volumes of water not consumed.

Finally, we define the 'technical' shutdown point as that level where water demand becomes inelastic since beyond that point industrialist can not consume smaller volumes of water, because it will be lower than the minimum quantity of water necessary to produce. Then, from the technical point of view, the firm would not be able to produce with smaller amounts of water, since there exists a water constraint, $\underline{W}$, and no matter that water price could rise arbitrarily, in our case as a result of subsidy elimination.

Following this idea we found, graphically, the technical shutdown point due to subsidy elimination. Mining and sugar industries arrive at their technical shutdown point if we remove 60% of the subsidy level they have, $\tau = 75\%$ in mining and $\tau = 50\%$ in sugar. Regarding paper sector, its technical shutdown point is found after 90% subsidy elimination.

From all these previous results we could conclude that subsidy on water price is a tool which promotes inefficiency in the use of water.

Conclusion

In the introduction of this thesis work we established the following questions we were interested to address throughout the research: Is water price working as a good economic tool to support the efficient use of water within Mexican manufacturing sector? If this is the case, then what is the level of responsiveness of the demand of water by Mexican industry? What is the mapping of manufacturing sector in Mexico? And finally, what is the water demand constraint that allows us to identify the technical shutdown point of the firm.

Through the research we focused on answering them, for that, first, in Chapter 1 we set up a general panorama about the evolution of water management in Mexico and the water charge system currently applied in the country. Then in Chapter 2, we made a literature review on industrial water demand and established the microeconomic foundation we use to characterize the technology of the Mexican industrial sector. Thus, with the intention of dealing with the questions previously formulated, in Chapter 3 we estimated a Translog cost system, by the Seemingly Unrelated Regression (SUR) procedure, using data from 500 firms of eight industrial sectors for year 1994. Cost estimates allow us obtain price elasticities and Morishima Elasticities of Substitution. We find that industrial water demand is inelastic and not very responsive to change in water price (elasticity -0.2976). And in the sense of MES, water is a substitute for labor and material. The data analysis reports that average water productivity is 0.3013 thousand pesos/m^3. Water average productivity is highly and positively correlated (0.9084) with water price by availability water zone. This correlation however, although still positive, changes considerably when we pay attention to different types of industry (O.3432). It allows us to claim that water price, as so far defined by scarcity zones, is pushing industrialists toward an efficient use of water. Using these information and in order to analyze and go into detail to the previous questions, in Chapter 4 we perform different experiments: (*i*) to evaluate the consistency of the industrial firm distribution regarding availability water zones; (*ii*) to analyze the effect that elasticity on water price has on the volumes of water demanded by firms; and finally (*iii*) to identify a water demand constraint to define the technical shutdown point of the firm.

Next, we summarize the principal results and conclusion, as well as the responses to the initial questions.

We began Chapter 1 with a broad report of some water statistics in Mexico and in the world. In this Chapter we set up a general panorama about the evolution of water management reforms in Mexico.

We described the way water institution has developed since the first legal water text, the 1910 Water Law. Considering water institution not just as a fixed organization but as a 'body' conformed by the interaction of three components: law of water, policy of water, and administration of water. We call attention to the relevant role National Water Commission has come to play since its creation in 1989, becoming the sole federal authority dealing with water management. And as a result of this change, it is in 1998 that water management began to be made by hydrologic criteria, through the 13 hydrographic administrative regions that National Water Commission has around the country.

In Chapter 1 we also explain the water charges system that actually is applied in Mexico, as well as the structure of water prices. It is highlighted that the manner water price per cubic meter is determined is excellent, since it is established as a function of the availability water zone, as well as taking into account the kind of user.

It really responds to the theoretical principle that a commodity’s price should be seen as a measure of its scarcity.

We conclude that water reforms carried out in the last years have allowed managing water in a more efficient way, but as expected, they must be improved.

The objective of Chapter 2 was to present the literature review regarding industrial water demand econometric estimation; in a way to be able to situate our work regarding the existed literature. This Chapter also has the purpose to present the economic and econometric specification we employ in Chapter 3 and 4. Thus, we present the microeconomic foundations we use to characterize the technology of the Mexican industrial sector. We pointed out that the dual approach is preferred since it is easier to achieve reliable information about input prices in an industry than the levels of these inputs used by the firm.

Third, we introduce the Translog cost function, which will form the basis of our parameter estimation, since it offers several advantages like the facility to model production relationships with more than a few inputs without restrictive assumptions about the elasticities of substitution.

In Chapter 3 we first give an overview of the industry evolution and its relationship with water in Mexico. Secondly, we offer a general description of the actual participation of industrial activity in the Mexican economy, finding that mining and manufacturing industries in Mexico have grown, in average, by 24% since year 1993. We note that the industries which generate greater number of employments are not those which make greater water use. And regarding participation in the national gross product; industries are concentrated in the central part of the country.

Regarding the use of water, the self-supplied industry in Mexico exploits 6.6 km^3 per year, 5 km^3 from surface source and 1.6 km^3 from groundwater source. Industry withdraws 9% of total extraction (72.5 km^3). From the total extraction figures, 86% is from 7 industries, mainly sugar, chemistry, mining, paper, steel, textile, and food and beverage. The industrial sector participates with 22% of GDP and generates 3.2 million of direct employment.

In Chapter 3, Sections 3.3 and 3.4, we focus to data analysis. It reports that average water productivity is 0.3013 thousand pesos per cubic meter. Water average productivity is highly and positively correlated (0.9284) with water price by availability water zone. This correlation however, although still positive, changes considerably when we pay attention to different types of industry (0.3432). It allows us to claim that water price as so far defined by scarcity zones is pushing industrialists toward an efficient use of water.

Most of firms are placed in availability water zone 5 and on the side of administrative region; it is in Region VIII Lerma-Santiago-Pacifico where the most important number of firms of our sample data are located.

The results reported in these two Sections help us to get a first idea of the mapping of the manufacturing sector in Mexico

In Section 3.5 we first estimate a production cost system using data on 500 firms from eight industries for the year 1994. Cost estimates allow us to compute price and (Morishima) substitution elasticities, which are necessary tools for determining whether industries are indeed responsive to water prices.

From our estimation results, we can conclude that industrial water demand is not very responsive to changes in water price given that average value for the price elasticity of industrial water demand for Mexican manufacturing is inelastic (-0.2976).

According to these results, up to this point we concluded that water prices, as they are so far defined by scarcity water zones, have already affected the productivity of industries, at least concerning water consumption. We conclude that apparently industries are concentrated in regions where water does not represent a real constraint to production. This first conclusion might be a premature one, but certainly it is possible to conclude two things: first, water price is pushing industrialists towards an efficient use of water. And second, more than 60% of the firms from the two greater industrial water users (paper and beverage) are well located as far as availability water zones are concerned.

We find that the Allen Elasticity of Substitution gives a misleading picture of the substitution behavior between inputs and the Morishima elasticity turns out to be a better tool for determining the effects that changes in industrial water price could have on other production inputs. Water is found to be a substitute for both labour and materials in the sense of Morishima Elasticity of Substitution.

We also find that industrial price elasticity of water demand is not far from the values reported in the overview of the research mentioned in Chapter 2.

In Chapter 4 we perform different experiments using estimation results from Chapter 3. The experiments here realized were focused to analyze firm's behavior under diverse scenarios.

First, we perform an experiment whose objective was to evaluate the consistency of the industrial firm distribution regarding water availability zones. Thus, we compute average input prices by availability water zone and by industry to control for observed heterogeneity in these cost factors. We use the cost estimates to construct average cost measures for each firm in the sample, assuming (a) same output level; (b) no additional investment, when it faces prices in other zones. Finally, we compute for each firm its cost differential, which is the relative average-cost differential for being in other zone.

From this experiment we found that 44.4% firms are consistently located with respect to the availability water zones. 19 of the 21 firms in the sugar industry would be better off in more expensive zones. Identical performance is showed by 13 chemistry firms, 7 for food, 3 for textile, and 8 in paper sector. Hence, 50 firms (11%) have an unexpected behavior regarding water price, leaving 44.6% of firms that will achieve lower production costs in cheaper water availability zones. As pointed out above, this may simply mean that water cost is not a limiting factor for these firms, and that other input cost or different market conditions are more important determinants of the actual firm location.

Zones 1 to 5 involve 53.9% of firms, from which 14.3% are adequately located, 6% have an unexpected performance, and the rest (almost 80%) will be better in cheaper zones regarding industrial water. For the other firms placed in zones 6 to 9, 85% are well located. An important fact that comes out from this analysis is that 64% of paper firms, the largest water user, are suitably located, as well as for beverage sector (61%) which is the second water user. Indeed, in our sample, these two industries together consume about 56% of total industrial water.

In the second experiment in Chapter 4, we compare the water zones' database against water zone in year 2003. We carry out a data analysis to check what has been the behavior of water zones, i.e. how they have move through the years. We analyze either they change of water zone or nor, and if they are better or worse since then.

From this experiment we found that only one percent of our sample lost in 5 zones, the worse condition of our analysis. And 0.4% gained in 6 zones. An important item that comes out is that 45.8% of our 500 firms are still in the same zone. In consequence, we may well conclude that, so far, hydrologic water balance has not revealed a clear evidence of water accessibility problems. And this conclusion is corroborated by the fact that if we consider those firms that lose in one and gain in one, all of them in ensemble with firms in same zone, we get that 75% of firms are included; meaning that 75% of the municipalities already keep their hydrologic situation. Given that moving by one zone, up or down, does not imply a huge change, respecting neither the availability of water nor the water price. But one thing that comes out was that no matter that 45.8% of firms do not move of water zone, more of one third of them is placed under a strained availability water zones.

Therefore, from these two experiments, we conclude that water cost is not a limiting factor for firms and that other input cost or different market conditions are more important determinants of the actual firm location. But also, that accessibility to water has not represented a real problem to firms, since almost 46% of the municipalities are still in the same hydrological condition without meaning they could not be under a stressed water situation. These experiments facilitate us to complete the mapping of the manufacturing sector in Mexico

An associated empirical question is the fact that water price, as defined by scarcity zones, is pushing or not industrialists towards an efficient use of water.

The third experiment highlights the legal framework of the subsidy on water price in Mexico. The subsidy on water price is applied to three industrial sectors. Mining pays 25% of the quota, sugar 50% and paper 80% for the quota for firms placed in Zones 7, 8 and 9. Then the respective subsidy is 75%, 50% and 20%.

This kind of subsidy carries out two problems. One, it produces an inefficient water use since water is already cheap. And second, factory owner does not have any ‘real’ motivation to improve technical production process, at least in what correspond to the use of water, because water cost is not an important share of its total cost. The cost share of water in sugar sector is equal to 0.20% with subsidy on water quotas.

From this analysis when we compare the mean water price with no subsidy by water zone against the quotas fixed in the Ley Federal de Derechos en Materia de Agua 1996, we found that the ones we get from our sample draw near to the quotas established for the second semester of 1996.

In the way to respond the question concerning the level of responsiveness of the water demand by Mexican industry, we perform an experiment to analyze the effect of water price changes on water demand. First we get the own water price elasticity for the 8 industries by the 9 water zone. Food industry has its highest elasticity (in absolute value) in Zone 1, -0.5451, and the lowest is -0.3086 in Zone 6. The mean elasticity of food sector is -0.4557. Beverage presents the minimum (in absolute value) mean elasticity, -0.2192, regarding the other sectors. Sugar has a mean elasticity of -3.0967, the greater regarding other industries. The mean elasticities by sector are: mining -0.8875; food -0.4557; sugar -3.0967; beverage -0.2192; textile -0.5794; paper -1.4359; chemistry -0.5678; and finally -1.0604 is the mean elasticity for steel sector. Analyzing elasticities by zone, the mean from Zone 1 to Zone 3 is around -0.55 where, excepting one, all are well significantly different from zero. Starting from Zone 4 we found situations with pretty small water cost share regarding total cost of the firm, resulting in a positive elasticity. In those cases we replaced that positive elasticity by the mean elasticity of the respective sector.

Next, with the elasticities obtained, we analyze the firm water demand response against increments in water price as a result of subsidy elimination. We consider, for this analysis, mining, sugar and paper sector, since they are the sole industries with subsidy on water price. For this experiment we define 7 scenarios. In the first scenario we take out 15% of the subsidy level industrial sector has. In the last scenario we remove the totality of the subsidy. Regarding the percentage change in the quantity of water, the zones which react stronger against subsidy elimination are Zone 2 followed by Zone 6 and Zone 3. Concerning water volumes not consumed by the three industrial sectors, due to subsidy elimination, paper reports, for almost all scenarios, the maximum percentage with respect to mining and sugar industries. That is, under these scenarios paper sector is the one which sacrifices the major water volumes with respect to the other two sectors. Continuing with water volumes give up as a reaction of subsidy elimination, Zone 8 shows up the major volumes with regarding total water not consumed.

Finally, trying to find the answer for the last question, regarding water demand constraint, we define the 'technical' shutdown point as the level where water demand becomes inelastic since further of that point industrialist can not consume smaller volumes of water, because it will be lower than the minimum quantity of water necessary to produce. Then, from the technical point of view, the firm would not be able to produce with smaller amounts of water, since there exists a water constraint, $\underline{W}$, and no matter that water price could rise arbitrarily, in our case as a result of subsidy elimination. Following this idea we found, graphically, the technical shutdown point due to subsidy elimination. Paper industry is the one which achieve its technical shutdown point further, after 90% subsidy elimination, while mining and sugar arrive to their technical shutdown point when we take out 60% of their respective subsidy level.

Peter Rogers (2003) points out that "in developing countries, water supply and prices are emerging as one of the major constraints in growth of industries". Considering the case of Mexico, it does not seem to hold for Mexican industry given that, according to our empirical analysis, no matter what effect water price appears to have in pushing industrial firms to use water efficiently, the cost of water does only represent a very moderate share of industrial variable cost. It is therefore unlikely that variation in water input price will have a major impact on output price, but in our case, for industrial water use, the constant output price elasticity of input demand might not be a bad approximation for elasticity.

The results here exposed could bring to conclude that water price is working well as an economic tool but not as stronger as one could expect since the water cost share regarding total cost is still small. And the “small” effect water price does, is offset by the pernicious effect that subsidy in water price produces.

Summarizing: We arrive to an important fact within the Mexican manufacturing sector: water price is working as a good economic tool to support the efficient use of water, although the responsiveness level of water demand against change in water price is not very strong. That is, water price as so far defined by availability water zones is a good economic tool, but it has not have a significant impact inside industry behavior, since they (industrial owners) have not move to another water cheaper zone. We conclude that water cost is not a limiting factor for firms and that other input cost or different market conditions are more important determinants of the actual firm location. From our data analysis we get that water price participation in total cost is very low, 2.2%. And on the side of the hydrologic water balance, the accessibility to water does not represent a real problem. Then, the question that remains unanswered is ¿ How far does water price have to go to force industrialist to take into account water price and make an efficient water use? Therefore, water pricing reforms have to improve on the insertion of economic tools to achieve efficiency in the use of water.

Annex A.1

LEY FEDERAL DE DERECHOS PRIMER SEMESTRE DE 2003.

CAPÍTULO VIII

A g u a

ARTÍCULO 222. Están obligadas al pago del derecho sobre agua, las personas físicas y las morales que usen, exploten o aprovechen aguas nacionales, bien sea de hecho o al amparo de títulos de asignación, concesión, autorización o permiso, otorgados por el Gobierno Federal, de acuerdo con la zona de disponibilidad de agua en que se efectúe su extracción de conformidad a la división territorial contenida en el artículo 231 de esta Ley.

ARTÍCULO 223. Por la explotación, uso o aprovechamiento de aguas nacionales a que se refiere este Capítulo, se pagará el derecho sobre agua, de conformidad con la zona de disponibilidad de agua en que se efectúe su extracción y de acuerdo con las siguientes cuotas:

A.- Por las aguas provenientes de fuentes superficiales o extraídas del subsuelo, a excepción de las del mar, por cada metro cúbico:

I. Zona de disponibilidad 1.. 14.1086

II. Zona de disponibilidad 2... 11.2865

III. Zona de disponibilidad 3... 9.4053

IV. Zona de disponibilidad 4... 7.7596

V. Zona de disponibilidad 5.. 6.1133

VI. Zona de disponibilidad 6... 5.5251

VII. Zona de disponibilidad 7.. 4.1587

VIII. Zona de disponibilidad 8... 1.4776

IX. Zona de disponibilidad 9... 1.1073

Las empresas públicas y privadas que tengan asignación o concesión para explotar, usar o aprovechar aguas nacionales y suministren volúmenes de agua para consumo doméstico a centros o núcleos de población, cubrirán el derecho respecto de los volúmenes de agua suministrada, con las cuotas establecidas en el Apartado B, fracción I, de este artículo; para tales efectos, deberán contar con medidor que contabilice exclusivamente el volumen de agua que proporcionen para el citado uso.

De los ingresos que se obtengan por la recaudación de los derechos por la explotación, uso o aprovechamiento de aguas nacionales por usuarios distintos de los municipales y organismos operadores de los mismos, 200 millones de pesos tendrán destino específico para el Fondo Forestal Mexicano para el desarrollo y operación de Programas de Pago por Servicios Ambientales. Estos recursos ampliarán el presupuesto que se asigne a la Comisión Nacional Forestal.

B.- Por las aguas provenientes de fuentes superficiales o extraídas del subsuelo, a excepción de las del mar, se pagará el derecho sobre agua por cada mil metros cúbicos, destinadas a:

I. Uso de agua potable:

Zona de disponibilidad 1 a 6...	$ 279.50
Zona de disponibilidad 7...	$ 130.16
Zona de disponibilidad 8...	$ 65.00
Zona de disponibilidad 9...	$ 32.37

a). Asignada a Entidades Federativas, Municipios, organismos paraestatales, paramunicipales.

b). Concesionadas a empresas que presten el servicio de agua potable o alcantarillado y que mediante autorización o concesión, presten el servicio en sustitución de las personas morales a que se refiere el inciso a).

c). Concesionada a colonias constituidas como personas morales que por concesión de las personas morales a que se refiere el inciso a), presten el servicio de suministro de agua potable de uso doméstico.

Para los efectos del uso de agua potable, se considerará:

Los ingresos que se obtengan por la recaudación de los derechos por la explotación, uso o aprovechamiento de aguas nacionales a que se refiere esta fracción, que paguen los municipios, se destinarán a la Comisión Nacional del Agua para obras de infraestructura hidráulica.

Las tarifas a que se refiere esta fracción, serán aplicables a los sujetos que en las mismas se señalan cuando el consumo de agua en el periodo sea inferior o igua l a un volumen equivalente a los 300 litros por habitante al día, de acuerdo con la población indicada en los resultados definitivos del ejercicio inmediato anterior, referidos exclusivamente a población, provenientes del último Censo General de Población y Vivienda publicado por el Instituto Nacional de Estadística, Geografía e

Informática, actualizado con las proyecciones de población publicadas por el Consejo Nacional de Población.

En aquellos casos en que el consumo no exceda de los volúmenes a que se refiere el párrafo anterior, se aplicarán las siguientes tarifas:

Zona de disponibilidad 1 a 6	$ 279.50
Zona de disponibilidad 7	$ 130.16
Zona de disponibilidad 8	$ 65.00
Zona de disponibilidad 9	$ 32.37

En aquellos casos en que el consumo sea superior a los volúmenes que se mencionan en el párrafo anterior, se aplicarán las siguientes tarifas sobre el volumen de consumo excedente:

Zona de disponibilidad 1 a 6	$ 559.00
Zona de disponibilidad 7	$ 260.32
Zona de disponibilidad 8	$ 130.00
Zona de disponibilidad 9	$ 64.74

II. Generación hidroeléctrica...	$ 2.9658

III. Acuacultura:

Zona de disponibilidad 1 a 6	$ 2.3038
Zona de disponibilidad 7	$ 1.1346
Zona de disponibilidad 8..	$ 0.5336
Zona de disponibilidad 9	$ 0.2534

IV. Balnearios y centros recreativos:

Zona de disponibilidad 1 a 6 .... $ 8.0251
Zona de disponibilidad 7 .... $ 3.9538
Zona de disponibilidad 8.. $ 1.8614
Zona de disponibilidad 9 .... $ 0.8851

Lo dispuesto en esta fracción no es aplicable a hoteles, centros recreativos de acceso exclusivo o privado y campos de golf.

C.- Por las aguas provenientes de fuentes superficiales o extraídas del subsuelo, a excepción de las del mar, destinadas a uso agropecuario, se pagará el derecho sobre agua por cada metro cúbico que exceda el volumen concesionado a cada distrito de riego o por cada metro cúbico que exceda el volumen concesionado a los usuarios agropecuarios restantes, conforme a las siguientes cuotas:

Zona de disponibilidad 1 a 9 .... $ 0.10

El derecho a que se refiere este Apartado, se pagará mensualmente mediante declaración que se presentará en las oficinas autorizadas por el Servicio de Administración Tributaria, dentro de los primeros 17 días del mes inmediato posterior a aquél por el que corresponda el pago.

Los ingresos que se obtengan por la recaudación del derecho a que se refiere este Apartado, se destinarán a la Comisión Nacional del Agua para la instalación de dispositivos de medición y tecnificación del propio sector agropecuario.

TRANSITORIOS

VI. Para los efectos de lo dispuesto en el artículo 223, Apartado A, de la Ley Federal de Derechos, en el pago de los derechos por la explotación, uso o aprovechamiento de aguas nacionales que se utilicen en los ingenios azucareros, se efectuará conforme al 50% de las cuotas por metro cúbico, que corresponda a las zonas de disponibilidad a que se refiere el artículo 231 de la citada Ley.

VII. Por la explotación, uso o aprovechamiento de aguas nacionales superficiales que se extraigan y utilicen en los municipios de Coatzacoalcos y Minatitlán del Estado de Veracruz, se cobrará la cuota que corresponda a la zona de disponibilidad 7 a que se refiere el artículo 223 de la Ley Federal de Derechos.

VIII. Por la explotación, uso o aprovechamiento de aguas nacionales superficiales que se utilicen en los municipios de Lázaro Cárdenas del Estado de Michoacán y Hueyapan de Ocampo en el Estado de Veracruz, se cobrará la cuota que corresponda a la zona de disponibilidad 9 a que se refiere el artículo 223 de la Ley Federal de Derechos.

XIII. Para los efectos de lo dispuesto en el artículo 223, Apartado A, de la Ley Federal de Derechos, la explotación, uso o aprovechamiento de aguas nacionales que se utilicen en la industria de la celulosa y el papel, pagará el 80% de las cuotas por metro cúbico, que corresponda a las zonas de disponibilidad a que se refiere el artículo 231 de la citada Ley, salvo que se encuentren en las zonas de disponibilidad I, II o III y que cuenten con oferta local de aguas residuales tratadas en volumen suficiente y calidad adecuada conforme a la norma NOM-ECOL-001. Si en este caso, los usuarios consumen dichas aguas hasta el límite técnico de su proceso o se agota dicha fuente alterna, los volúmenes complementarios de aguas nacionales se pagarán al 80% de la cuota correspondiente.

XIV. Para los efectos de lo dispuesto en el artículo 223, Apartado A, de la Ley Federal de Derechos, la explotación, uso o aprovechamiento de aguas nacionales que se utilicen en los procesos de exploración, extracción, molienda, separación, lixiviación y concentración de minerales, hasta antes del beneficio secundario, por lo que se exceptúan los procesos de fundición y refinación de minerales, durante el año 2003 pagarán el 25% de las cuotas por metro cúbico que corresponda a la zona de disponibilidad a que se refiere el artículo 231 de la citada Ley.

No obstante lo anterior, el usuario podrá optar someterse al siguiente régimen de pago:

Para los efectos de lo dispuesto en el artículo 223, Apartado A, de la Ley Federal de Derechos, la explotación, uso o aprovechamiento de aguas nacionales que se utilicen en los procesos de exploración, extracción, molienda, separación, lixiviación y concentración de minerales, hasta antes del beneficio secundario, por lo que se exceptúan los procesos de fundición y refinación de minerales durante el año 2003 se pagará el 40% de las cuotas por metro cúbico que corresponda a la zona de disponibilidad a que se refiere el artículo 231 de la citada Ley. Durante el año de 2004 se pagará el 45% de dichas cuotas por metro cúbico; para el 2005, el 50% y para el 2006 el 60%.

Todos los usuarios que se encuentren en los supuestos de explotación, uso o aprovechamiento de aguas nacionales mencionados en el párrafo anterior, hasta antes del beneficio secundario, que pongan a disposición de un municipio, estado o entidad pública, o bien que descarguen el agua en condiciones equivalentes a su extracción a un cuerpo receptor de agua, podrán compensar en la misma proporción el pago del derecho establecido en el párrafo anterior, en la cantidad igual de metros cúbicos entregados o descargados y en el mismo periodo de pago, o en su caso, podrán vender el agua correspondiente a cualquier persona pública o privada.

Annex A.2

LEY FEDERAL DE DERECHOS EN MATERIA DE AGUA 1996.

ARTÍCULO 223.- Por el uso o aprovechamiento de aguas nacionales a que se refiere este Capítulo, se pagará el derecho sobre agua, de conformidad con la zona de disponibilidad de agua en que se efectúe su extracción y de acuerdo con las siguientes cuotas:

A.- Por las aguas provenientes de fuentes superficiales o extraídas del subsuelo, a excepción de las del mar, **por cada metro cúbico**:

		Vigencia 1er. Sem.	Vigencia 2do. Sem.
I.-	Zona de disponibilidad 1	$ 6.0000	$ 7.0290
II.-	Zona de disponibilidad 2	$ 4.8000	$ 5.6232
III.-	Zona de disponibilidad 3	$ 4.0000	$ 4.6860
IV.-	Zona de disponibilidad 4	$ 3.3000	$ 3.8659
V.-	Zona de disponibilidad 5	$ 2.6000	$ 3.0459
VI.-	Zona de disponibilidad 6	$ 2.3500	$ 2.7530
VII.-	Zona de disponibilidad 7	$ 1.7690	$ 2.0723
VIII.-	Zona de disponibilidad 8	$ 0.6287	$ 0.7365
IX.-	Zona de disponibilidad 9	$ 0.4713	$ 0.5521

Las empresas públicas y privadas que tengan concesión para usar o aprovechar aguas nacionales y suministren volúmenes de agua para consumo doméstico a centros o núcleos de población, cubrirán el derecho respecto de los volúmenes de agua suministrada, con las cuotas establecidas en el Apartado B, fracción I, de este artículo; para tales efectos deberán contar con medidor que contabilice exclusivamente el volumen de agua que proporcionen para el citado uso.

B.- Por las aguas provenientes de fuentes superficiales o extraídas del subsuelo, se pagará el derecho sobre agua **por cada mil metros cúbicos, destinadas a:**

I.- Uso de agua potable asignada a entidades federativas, municipios, organismos paraestatales, pararnunicipales o empresas concesionarias que presten el servicio público de agua potable y alcantarillado en sustitución de las anteriores o a colonias populares constituidas como personas morales que por concesión de aquéllos presten el servicio de suministro de agua potable de uso doméstico.

	Vigencia 1er. Sem.	Vigencia 2do. Sem.
Zona de disponibilidad 1 a 6	$ 103.53	$ 121.29
Zona de disponibilidad 7	$ 48.23	$ 56,50
Zona de disponibilidad 8	$ 24,11	$ 28.24
Zona de disponibilidad 9	$ 12,02	$ 14.08
II.- Generación hidroeléctrica	$ 1.00	$ 1.17

III.- (Derogada). Acuacultura, centros recreativos y balnearios:

Zona de disponibilidad 1	$ 0.184
Zona de disponibilidad 2	$ 0.092
Zona de disponibilidad 3	$ 0.046
Zona de disponibilidad 4	$ 0.023

IV .-Acuacultura, balnearios y centros recreativos:

	Vigencia 1er. Sem.	Vigencia 2do. Sem.
Zona de disponibilidad 1 a 6	$ 0.9388	$ 1.0998
Zona de disponibilidad 7	$ 0.4626	$ 0.5419
Zona de disponibilidad 8	$ 0.2179	$ 0.2552
Zona de disponibilidad 9	$ 0.1037	$ 0.1214

Lo dispuesto en esta fracción no es aplicable a hoteles, centros recreativos de acceso exclusivo o privado y campos de golf .

DISPOSICIONES TRANSITORIAS DE LA LEY FEDERAL DE DERECHOS

ARTICULO VIGESIMO.- Durante el año de 1996, se aplicarán en materia de derechos las siguientes disposiciones:

I. -No se incrementarán en el mes de enero en los términos del cuarto párrafo del artículo 1o. de la Ley Federal de Derechos, las cuotas de los derechos establecidos en los artículos 19-G, 19-H, 29-D, 29-E, 29-F, 29-H, 29-J, 32, fracción I. inciso g), 33, fracción I, inciso a), subincisos 1 a 4 y 6, inciso b), fracción II, inciso a), fracción III, inciso a), subinciso 1 e inciso b) y fracción V, 33- A. fracciones III y IV. 86-E, 87. 88, 89, 195-G. 223 Apartado A, fracciones I a VI y Apartado B, fracción II, 232 fracción VIII inciso c), 278, 279 y 280 de la Ley mencionada.

II.-Las cuotas de los derechos establecidos en el capítulo" del Título I de la ley Federal de Derechos, se ajustarán a partir del día 1o. De enero de 1996, a múltiplos de $5.00. Para efectuar este ajuste, las cuotas aumentarán o disminuirán, según sea el caso, a la unidad de ajuste más próxima. Cuando la cuota se encuentre a la misma distancia de dos unidades de ajuste se disminuirá a la baja.

III.-Para los efectos de lo dispuesto en el artículo 223. Apartado A, de la Ley Federal de Derechos, el pago de los derechos por el uso o aprovechamiento de aguas nacionales que se utilicen en la industria minera se efectuará conforme al 25% de las cuotas por metro cúbico. que corresponda a las zonas de disponibilidad a que se refiere el articulo 231 de la Ley.

IV.-Para los efectos de lo dispuesto en el artículo 223, Apartado A, de la Ley Federal de Derechos, el pago de los derechos por el uso o aprovechamiento de aguas nacionales que se utilicen en los ingenios azucareros, se efectuará conforme al 50% de las cuotas por metro cúbico que corresponda a las zonas de disponibilidad a que se refiere el artículo 231 de la Ley.

V.-Para los efectos de lo dispuesto en el artículo 223. Apartado A, de la Ley Federal de Derechos, el pago de los derechos por el uso o aprovechamiento de aguas nacionales que se utilicen en la industria de la celulosa y el papel, corresponderá al 80% de las cuotas establecidas en las zonas 7, 8 y 9 de dicho Apartado.

VI.-Por el uso o aprovechamiento de aguas nacionales superficiales que se utilicen en los municipios de Coatzacoalcos y Minatitlán del Estado de Veracruz, se cobrará la cuota que corresponda a la zona de disponibilidad 7 a que se refiere el artículo 231 de la Ley Federal de Derechos.

VII.-Por el uso o aprovechamiento de las aguas nacionales superficiales que se utilicen en los municipios de Lázaro Cárdenas del Estado de Michoacán y Hueyapan de Ocampo en el Estado de Veracruz, se cobrará la cuota que corresponda a la zona de disponibilidad 9 a que se refiere el artículo 231 de la Ley Federal de Derechos.

References

Aker, Mrs. (2002), 'The Relationship between Sugar and Soda Density' October 7th, 2002; Periods 1, 2, 5, 6. (http://www.fwsd.wednet.edu/staff/laker/downloads/sodareportmrsaker.pdf).

Anderson, R.G. and J.G. Thursby (1986), 'Confidence Intervals for Elasticity Estimators in Translog Models.' *The Review of Economics and Statistics,* January 1986, 647-656.

Babin, F., C.E. Willis, and P.G Allen (1982), 'Estimation of Substitution Possibilities between Water and Other Production Inputs' *American Journal of Agricultural Economics* Vol. **64** (1), 149-152. In *The Economics of Industrial Water Use*, edited by Steven Renzetti, The management of water resources; 4. Edward Elgar Publishing, 2002.

Banco de Mexico (2003), 'Estadisticas de Tipo de Cambio: Octubre 2003'. (http:\\www.banxico.mx).

Bergström, V. and E. Panas (1992), 'Notes: How Robust is the Capital-Skill Complementarity Hypothesis?' *The Review of Economics and Statistics*, p. 540-546.

Berndt, E.R. (1991), *The Practice of Econometrics, Classic and Temporary*. Chapter 9 'Modeling the Interrelated Demands for Factors of Production: Estimation and Inference in Equation Systems'. Addison-Wesley Publishing Company.

Berndt, E.R. and D.O. Wood (1979), 'Engineering and Econometric Interpretations of Energy-Capital Complementarity.' *American Economic Review*, **69**:3, June, 342-354

Binswanger, H.P. (1974), 'A Cost Function Approach to the Measurements of Elasticities of Factor Demand and Elasticities of Substitution.' *American Journal of Agricultural Economics* **56** (1), 377-386.

Birrichiaga, D. (1997), 'El abasto de agua en Leon y San Luis Potosi'. *Dos estudios sobre usos del agua en México (siglos XIX y XX)*. IMTA y CIESAS. Mexico.

Blackorby, C. and R.R. Russell (1989), 'Will the Real Elasticity of Substitution Please Stand Up? (A Comparison of the Allen/Uzawa and Morishima Elasticities)' *American Economic Review* **79**(4), 882-888.

Chambers, R.G. (1988), *Applied Production Analysis. A Dual Approach*. Cambridge University Press.

Christensen, L.R., D.W. Jorgenson, and L.J. Lau (1971), "Conjugate Duality and the Transcendental Logarithmic Function", *Econometrica*, **39**, no. 4 (July 1971) 255-256 (abstract).

CNA (1993), *Ley Federal de Derechos en Materia de Agua1993*. Comision Nacional del Agua, Febrero. Mexico.

CNA (1999a), *Compendio Basico del Agua en Mexico*. Comision Nacional del Agua. Mexico. September. Mexico

CNA (1999b), 'Regional Vision North America (Mexico)'. World Water Vision. Comision Nacional del Agua. December. Mexico

CNA (2000), *El Agua en Mexico: Retos y avances*. Comision Nacional del Agua. Mexico. October. Mexico

CNA (2001), *Programa Nacional Hidraulico 2001-2006*. Resumen Ejecutivo, 2ª. ed. Comision Nacional del Agua. Mexico.

CNA (2002), 'Banco de datos e imagenes del Servicio Meteorologico Nacional'. Comision Nacional del Agua, Mexico.

CNA (2003a), *Estadisticas del agua en Mexico, 2003*. Comision Nacional del Agua, Mexico. (http:\\www.cna.gob.mx).

CNA (2003b), 'Ley Federal de Derechos en Materia de Agua: Primer Semestre 2003'. Comision Nacional del Agua, Mexico.

CNA (2004), 'Estadisticas del agua en Mexico, 2004'. Comision Nacional del Agua, Mexico. (http:\\www.cna.gob.mx).

CNA-IMTA (1998a), 'Parámetros de consumo de agua en la industria. Industria de Celulosa y Papel'. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-IMTA (1998b), 'Parámetros de consumo de agua en la industria. Industria Siderurgica'. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-IMTA (1998c), ‘Parámetros de consumo de agua en la industria. Industria Textil’. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-IMTA (1999), ‘Indicadores industriales en el uso del agua. Industria de Bebidas’. Project Head: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-IMTA (2001a), ‘Indicadores industriales en el uso del agua. Industria Alimenticia’. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-IMTA (2001b), ‘Indicadores industriales en el uso del agua. Industria Azucarera’. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-IMTA (2001c), ‘Indicadores industriales en el uso del agua. Industria de la Mineria’. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

CNA-REDA (1996), ’Sistema de Recaudacion Red de Agua’ Comision Nacional del Agua. Mexico.

CONAPO (2002), ’Proyecciones de la Población de México, 2000-2030’. Consejo Nacional de Poblacion, Mexico.

CPNH (1980), ’El Sistema del Precio del Agua’. Comision del Plan Nacional Hidraulico, SARH, April. Mexico.

De Rooy, J. (1974), ’Price Responsiveness of the Industrial Demand for Water’ Chapter 5 in *The Economics of Industrial Water Use* edited by Steven Renzetti an Edward Elgar Reference Collection 2002.

Dinar, A. and A; Subramanian (1997). “Water Pricing Experiences: An International Perspective”. *Technical paper* no. **386**. Washington, D.C., World Bank.

Dinar, A. (2000). *The Political Economy of Water Pricing Reforms*. Oxford University Press.

DOF (2004), ’Decreto por el que se reforman, adicionan y derogan diversas disposiciones de la Ley de Aguas Nacionales’. Diario Oficial de la Federacion, publicado el 29 de abril de 2004. Mexico.

Dupont, D. and S. Renzetti (2001), ‘The Role of Water in Manufacturing’ *Environmental and Resource Economics*, **18** (4): 411-432.

Féres, J. and A. Reynaud (2004), ‘Assessing the Impact of Environmental Regulation on Industrial Water Use: Evidence from Brazil’. LERNA Internal Report, Université de Toulouse I. July 2004, France. Forthcoming in *Land Economics*.

Garcia, S. and A. Thomas. (2001), 'The Structure of Municipal Water Supply Costs: Application to a Panel of French Local Communities.' *Journal of Productivity Analysis* **16**, 5-29.

Grebenstein, C.R. and B.C. Field (1979), 'Substituting for Water Inputs in U.S. Manufacturing.' *Water Resources Research* **15** (2), 228-232.

Guerrero, H. (1995), 'Water Pricing in Mexico in Principles and in Practice: the Case of Mexico'. MA. Thesis, Department of Economics, University of Colorado, Boulder.

Guerrero, H., Alonso, P. and Ortiz, G. (1998). "Derechos de agua para uso industrial: El cierre de empresas",. XV National Hydraulic Meeting. Oaxaca, Mexico. October.

Guerrero, H. and Ch. W. Howe (2000), 'Water Pricing in Mexico: Principles and Reality'. Tenth Annual Conference, EAERE2000 (European Association of Environmental and Resources Economists). University of Crete. June 29 – July 2. Greece.

Guerrero, H. (2000), 'Applying Water Price as a Mechanism to Manage Water Demand: Case for Industrial Use in Mexico'. Memoire DEA-ERNEA, University of Toulouse I. June. France.

Guerrero, H. (2002), 'Irrigation Water Pricing: The case of Mexico'. Presentation at the International conference "Irrigation Water Policies: Micro and Macro Considerations Meeting'. Agadir, June 15-17. (http:\\www.worldbank.org/agadirconference). Morocco.

Halvorsen, R. and T. Smith, (1986) 'Substitution Possibilities for Unpriced Natural Resources: Restricted Cost Functions for the Canadian Metal Mining Industry'. *The Review of Economics and Statistics* **68** (3): 398-405.

Hernandez, E. (1985), *La productividad y el desarrollo industrial en Mexico*. Ed. FCE.

IMTA (1996), 'Sisefa - Red de Agua'. Banco de Datos de la Subcoordinación de Tecnología Económica y Financiera del Agua. Responsable: Ramon Piña. Instituto Mexicano de Tecnologia del Agua, Mexico.

IMTA (1998). "Aplicacion de Instrumentos de Mercado como mecanismo para regular la demanda de agua para uso industrial" Internal Report No. DP-9728. Instituto Mexicano de Tecnologia del Agua - Mexico.

IMTA (1999), 'Prospectiva del uso del agua y disponibilidad del agua al año 2020'. Internal Report DP-9904. Instituto Mexicano de Tecnologia del Agua, Mexico.

IMTA (2000), 'Uso Regional del Agua en la Industria: Region Administrativa Rio Bravo (VI), Region Administrativa Lerma Santiago Pacifico (VIII)'. Internal Project DP-2013. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

IMTA (2001), 'Uso Regional del Agua en la Industria: Region Administrativa Balsas (IV), Region Administrativa Golfo Centro (X)'. Internal Project DP-0111-4. Responsable: Ramon Lopez H. Jiutepec, Morelos, Mexico.

IMTA (2002), Banco de Datos de la Subcoordinación de Tecnología Económica y Financiera del Agua. Responsable: Ramon Piña. Instituto Mexicano de Tecnologia del Agua, Mexico.

IMTA (2003), 'Zonas de Disponibilidad según la Ley Federal de Derechos en materia de Agua'. Banco de Datos de la Subcoordinación de Tecnología Económica y Financiera del Agua. Responsable: Ramon Piña. Instituto Mexicano de Tecnologia del Agua, Mexico.

INEGI (1994), 'XIV Censo Industrial 1994' Instituto Nacional de Estadistica, Geografia e Informatica – Mexico.

INEGI (1999), 'Censo Economicos 1999' Instituto Nacional de Estadistica, Geografia e Informatica – Mexico.

INEGI (2000), 'XII Censo General de Poblacion y Viviendea, 2000'. Instituto Nacional de Estadistica, Geografia e Informatica - Mexico. (http:\\www.inegi.gob.mx).

INEGI (2001), 'Sistema de Cuentas Nacionales de Mexico. en Cuentas de Bienes y Servicios'. Instituto Nacional de Estadistica, Geografia e Informatica - Mexico. (http://www.inegi.gob.mx).

INEGI (2003a), 'Encuesta Industrial Mensual, 2003'. Instituto Nacional de Estadistica, Geografia e Informatica – Mexico. (http://www.inegi.gob.mx).

INEGI (2003b), 'Sistema de Cuentas Nacionales de Mexico, preliminar information'. Instituto Nacional de Estadistica, Geografia e Informatica - Mexico. (http:\\www.inegi.gob.mx).

Johnson III, S.H. (1997). 'Irrigation Management Transfer in Mexico: A Strategy to Achieve Irrigation District Sustainability'. **16** Research Report, International Irrigation Management Institute. Colombo, Sri Lanka.

Mongkolporn, Veerasak and Xiangkang Yin, (2004), "Did the Introduction of Competition Improve Cost Efficiency? The Case of a State-Owned Telecommunication Company", Department of Economics and Finances, La Trobe University, Melbourne, Victoria, Australia.

Olivares, E. (1995), *Cambio Tecnologico y Modernizacion Industrial en Mexico*. Ed. Nuestro Tiempo, S.A. Mexico.

Ortiz, G. (2001), *Administracion del agua*. Instituto Mexicano de Tecnologia del Agua – Jiutepec, Mexico, Nov.

Renzetti, S. (1988), 'An Econometric Study of Industrial Water Demands in British Columbia, Canada.' *Water Resources Research*, Vol. **24** (10), p.1569-1573. October.

Renzetti, S. (1992), 'Estimating the Structure of Industrial Water Demands: The Case of Canadian Manufacturing' *Land Economics* **68** (4): 396-404.

Renzetti, S. (1993), 'Examining the Differences in Self- and Publicly Supplied Firms' Water Demands' *Land Economics* May 1993, **69** (2): 181-88.

Renzetti, S. (2002), 'Introduction' in *The Economics of Industrial Water Use*. Edward Elgar Publishing, Inc., UK

Renzetti, S. and D. Dupont (2003), 'The Value of Water in Manufacturing' CSERGE Working Paper ECM 03-03.

Reynaud, A. (2003), 'An Econometric Estimation of Industrial Water Demand in France"..*Environmental and Resource Economics*, June 2003, vol. **25** (2), 213-232(20) Kluwer Academic Publishers

Ress, J.A. (1969), 'Inter-industry variation in the Demand for Water", Chapter 3 in *The Economics of Industrial Water Use* edited by Steven Renzetti an Edward Elgar Reference Collection 2002.

Rogers, P. (2003), 'Should there be an Industrial Water Policy?' Harvard University. (www.uwin.siu.edu/ucowr/updates/pdf/V111_A7.pdf) August 08, 2003.

Saade, L. and H. Saade (2003), 'Country Case: Mexico in Water Charge Instruments for Environmental Management in Latin America: from Theoretical to Practical Issues", Inter American Development Bank, II Meeting: The Application of Economic Instruments in Water and Solid Waste Management. Washington, D.C., February 25 - 26, 2003.

Saleth, R.M. and A. Dinar (2000), 'Institution-Performance Interaction within Water Sector: Empirical Results with Cross-Country Data'. Tenth Annual Conference, EAERE2000 (European Association of Environmental and Resources Economists), University of Crete. June 29 – July 2. Greece.

Segal, Dan, (2003). " A Multi-product Cost Study of the U.S. Life Insurance Industry," Review of Quantitative Finance and Accounting, Kluwer Academic Publishers, vol. **20** (2), pages 169-86, March.

Segui, L. (2004), 'Sistemas de Regeneración y Reutilización de Aguas Residuales. Metodología para el Análisis Técnico - Económico y Casos'. PhD Thesis. Departamento de Ingeniería Agroalimentaria y Biotecnología. Universidad Politécnica de Cataluña. Spain. (www.tdx. cesca.es).

Stiroh, K.J. (1999), 'Measuring Input Substitution in Thrifts: Morishima, Allen-Uzawa, and Cross-Price Elasticities' *Journal of Economics and Business*, **51**:145-157.

Suarez, B. (1997), 'Industria y Agua en el Centro de México (1835-1850)'. *Dos estudios sobre usos del agua en México (siglos XIX y XX)*. IMTA y CIESAS. Mexico.

Teeples, R. and D. Glyer (1987), 'Production Function for Water Delivery Systems: Analysis and Estimation Using Dual Cost Function and Implicit Price Specification' *Water Resources Research*, Vol. **23** (5) 765-773. May.

Turnovsky, S.J. (1969), 'The Demand for Water: Some Empirical Evidence on Consumers' Response to a Commodity Uncertain in Supply' Chapter 4 in *The Economics of Industrial Water Use* edited by Steven Renzetti an Edward Elgar Reference Collection 2002.

WB - WDI (2003), 'World Bank Group - World Development Indicators Database", World Bank, Washington DC, July.

Ziegler, J.A. and S.E. Bell (1984), 'Estimating Demand for Intake Water by Self-Supplied Firms'. Chapter 6 in *The Economics of Industrial Water Use* edited by Steven Renzetti an Edward Elgar Reference Collection 2002.

RESUMEN

Demanda del Agua de la Industria en México: Análisis Econométrico y sus Implicaciones en la Política de Administración del Agua.

El presente trabajo de investigación se enfoca a analizar los efectos que las reformas en el precio del agua en México han producido dentro del sector manufacturero mexicano. Este ofrece perspectivas para la regulación del uso del agua en un contexto de políticas orientadas a encontrar la manera más eficiente de asignar las reservas existentes de agua, así como de persuadir a los usuarios para adoptar las prácticas de conservación apropiadas. Conformada por cuatro capítulos, esta tesis presenta un panorama general de la evolución de la administración del agua en México, su sistema de precios actual y una revisión bibliográfica sobre la demanda industrial del agua. Describe la situación hidrológica mexicana y en un contexto global. Introduce la base microeconómica utilizada para caracterizar la tecnología del sector industrial mexicano. Esta es especificada por medio de una función de costo Translog, la cual es estimada utilizando datos de 500 empresas de ocho sectores industriales en 1994. Los resultados indican que la demanda industrial del agua es poco elástica (elasticidad -0.2976) y que el agua es un substituto del trabajo y de los materiales. En la última parte del trabajo, se realizan diferentes experimentos: uno, para evaluar la consistencia de la distribución de empresas industriales en relación a las zonas de disponibilidad de agua; dos, para analizar el efecto que la elasticidad sobre el precio del agua tiene en los volúmenes de agua demandados por las empresas; y finalmente, para identificar una restricción en la demanda de agua para definir el punto de cierre ‘técnico’ de la empresa. Los resultados permiten inferir que el precio del agua, como actualmente esta definido por zonas de disponibilidad, esta impulsando a la industria hacia un uso eficiente del recurso.

ABSTRACT

Industrial Water Demand in Mexico: Econometric analysis and implications for water management policy.

This research work deals with the effects the water pricing reform in Mexico has produced within the Mexican manufacturing sector. It offers perspectives for the regulation of water use, in the context of conservation policies aimed at finding the most efficient way to allocate existing water resources and providing incentives to users to adopt relevant conservation practices. The outline of this thesis starts with a general description of some components of Mexico's water management as well as the current pricing system. It depicts the Mexican hydrological situation and in a worldwide context. Composed of four chapters, this study presents a general panorama of the evolution of water management in Mexico and a literature review on the very few studies of industrial water demand. It introduces the microeconomic foundation used to characterize the technology of the Mexican manufacturing sector. A Translog cost system is estimated by the Seemingly Unrelated Regression (SUR) procedure, using data from 500 firms of eight industrial sectors in 1994. Cost estimates allow obtaining price elasticities and Morishima Elasticities of Substitution (MES). The result was that industrial water demand is poorly elastic and slightly reactive to change in water price (elasticity -0.2976). And in the sense of MES, water is a substitute for labor and material. The exercise is completed with the analysis of the water price changes occurred between 1994 and 2003. Finally, different experiments are performed: to evaluate the consistency of the industrial firm distribution regarding availability water zones; to analyze the effect that elasticity on water price has on the volumes of water demanded by firms; and to identify a water demand constraint to define the technical shutdown point of the firm. The results allow one to infer that water price, when defined by scarcity zone, is pushing industrialists toward an efficient use of water.

RESUME

La demande en eau industrielle au Mexique; analyse économétrique et implications pour la politique de l'usage de l'eau.

Analysant la meilleure manière d´allouer les ressources en eau existantes et d'inciter les usagers à adopter des pratiques adaptées á la conservation, ce travail de recherche traite des effets que la reforme de l´eau a produits dans le secteur manufacturier au Mexique, et offre des perspectives pour la régulation de l´usage de l´eau. Composée de quatre chapitres cette étude présente un panorama général de l'évolution de l'usage au Mexique ainsi que les fondements microéconomiques utilisés pour caractériser la technologie du secteur industriel mexicain. Cette dernière est spécifiée au moyen d'une fonction de coût Translog, qui est estimée en utilisant des données de 500 firmes, de huit secteurs industriels en 1994. Les résultats indiquent que la demande industrielle de l'eau est peu élastique (-0.2976), et que le facteur eau est substitut au travail et au matériel. La dernière partie de la thèse présente des exercices de simulation permettant d'évaluer l'impact que le prix de l'eau a sur la localisation des entreprises industrielles.