CIDE

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DESIGNING NATURAL GAS DISTRIBUTION CONCESSIONS IN A MEGACITY: THE CASE OF MEXICO CITY

Abstract

This paper presents the elements considered in the design of the natural gas distribution franchises for the Mexico City Metropolitan Area (ZMCM). Fostering efficient development of the natural gas distribution system involves trade-offs between economies of scale and information disclosure. On one hand, if the complete area of a megalopolis such as the ZMCM is granted to a single firm, scale economies may be realized but the regulation of such a large concession would be difficult. On the other hand, if the area is subdivided, economies of scale may decrease but information for comparative regulation increases. Unit cost is the main variable analyzed relative to scale of production. Since natural gas distribution presents certain characteristics of a natural monopoly, this variable should reach lower values the larger the size of the distribution franchise zone. Beyond considering economies of scale and information, technical characteristics of the geographic area, and potential for competition in related services were also considered. Likewise, the larger the number of distribution franchise zones the greater the scope for competition and the speed of development of distribution systems. However these same factors pose greater risk and uncertainty to the investor because the impact of unexpected events and from losing industrial consumers may be higher. Other factors considered were the previously existent distribution infrastructure in the ZMCM as well technical risk since the ZMCM is located in a seismic region. The result of the study is that the optimal partition for the ZMCM is two distribution franchise zones where one distribution franchise zone is the Federal District and the other is formed by suburban municipalities. Market players endorsed this proposal in public hearings.

Resumen

Este documento presenta los elementos considerados en el diseño de franquicias de distribución de gas natural para el área metropolitana de la ciudad de México. El impulso de un desarrollo eficiente del sistema de distribución del gas natural implica un *trade-off* entre economías de escala y el acceso a la información relevante. Por un lado, si se le otorga a una sola empresa la concesión del espacio completo de una megalopolis, como el que abarca el área metropolitana de la ciudad de México, las economías de escala se pueden alcanzar, pero la regulación de una concesión tan grande sería complicada. Por otro lado, si el área se subdivide las economías de escala podrían decrecer pero la información pertinente para la regulación comparativa aumentaría. La variable principal analizada en relación con el nivel de producción es el costo unitario. Debido a que la distribución del gas natural presenta algunas de las características de un monopolio natural, esta variable debe disminuir conforme aumente el tamaño de la zona de distribución asignado a la franquicia. Asimismo, no sólo se debe tener en cuenta las economías de escala y la información relevante, sino también las características técnicas del área geográfica y el potencial para competir en servicios relacionados con la distribución del gas natural. Así, mientras mayor sea el número de zonas de distribución asignadas mayor será la competencia entre las franquicias; con ello aumentaría la velocidad en que se desarrollan estos sistemas de distribución. Sin embargo, los mismos factores inciden en el riesgo y la incertidumbre para el inversionista debido a eventos inesperados que se pueden presentar y a una posible mayor pérdida de consumidores industriales. Otros factores que se consideraron fueron la infraestructura instalada de distribución en el área metropolitana de la ciudad de México, así como el riesgo técnico que implica la ubicación de la ciudad en un área sísmica. El resultado del estudio es que la división óptima del área metropolitana de la ciudad de México constaría de dos zonas de distribución: una el Distrito Federal y otra los municipios conurbados. Los participantes de este mercado respaldaron esta propuesta en audiencias públicas.

Introduction

In 1995 Mexico's government initiated structural reform for the natural gas sector—reform that permitted private investment in transportation, storage, distribution, and marketing while maintaining a state monopoly in production. It prepared a detailed regulatory framework to implement the sector liberalization, including an element to develop distribution systems through concessions in each geographic area (Rosellón and Halpern 2000). The concessions are bid and the winner is permitted physical exclusivity for 12 years in gas distribution but not in gas marketing.[1] In each concession award process a distribution geographical area is defined and minimum consumer coverage targets are established. Bidders present their proposals with technical and economic information on the project, including a market demand study. The winning project must have high technical quality and the lowest average revenue for the first five-year period.[2]

Densely populated geographic areas pose a problem for exclusivity in distribution. If the concession is granted to a single firm, scale economics might be very attractive, but regulating a "mega-monopoly" would be difficult. If the distribution area is subdivided, economies of scale decrease while information for benchmark regulation increases. These and such elements as technical characteristics of the geographic area and potential for competition in related services were considered when designing natural gas distribution franchises for the Mexico City Metropolitan Area (ZMCM).

Unit cost is the main variable related to scale of production. Since natural gas distribution has natural monopoly characteristics, unit costs should fall as distribution franchise zones get bigger. An assessment was made as to how the partition of the ZMCM would affect the amount of information available to the regulator, the nature and magnitude of financial risk borne by the distributor, the scope for promoting competition in activities related to natural gas distribution, and the pace of build-out of the network. As the number of distribution franchise zones increases, so will competition and the speed of developing distribution systems—along with risk and uncertainty. Another element considered in the partition decision was the configuration of the existing distribution infrastructure in the ZMCM and the areas with technical risk.

[1] The Energy Regulatory Commission regulates distribution tariffs through an average revenue regulation. In general, gas marketing inside the distribution area is not regulated because this activity is contestable. The distributor's marketing subsidiary competes with other marketeers. When there is not enough competition either from marketeers or substitute fuels, the final price to the distributor's captive gas buyers is regulated through an acquisition price methodology. See Rosellón (1998 a).

[2] Distributors that had a distribution concession prior to April 1995 are also incorporated to the permit regime.

Theoretical Framework

Intuitively, more distribution franchise zones provide more information to regulate regional monopolies; fewer distribution franchise zones permit greater economies of scale. The optimal number of distribution franchise zones should reach an equilibrium between adequate information (to permit the regulator to optimize social welfare) and unit cost minimization.

A fundamental problem for the regulator is lack of information on technological characteristics (and hence costs) of regulated firms. The firm can use this private information to increase strategic market power. Learning potential and the amount of the information available to the regulator grow as the number of distributors grows, because the regulator can compare the performance of each company (yardstick regulation). This comparison permits prices to reflect competitive costs and implies greater pressure for firms to behave efficiently (box 1).

Box 1

Using Yardstick Regulation to Set Price Caps

Yardstick regulation can be used to set a firm's price cap as a function of the cost performance of another firm. Armstrong and others (1994) present a model of firms i and j that operate in independent markets and produce the same product. The authors assume that demand for the product is inelastic, and costs depend on information known only to the firm. But the regulator knows that the cost parameters of each firm are correlated. The regulator uses yardstick regulation to set a price cap for each firm so that the price of firm i is a function of the costs of firm j, because these costs reveal information on the effort level of firm i.

The model finds that yardstick regulation works whenever there is a positive correlation between the cost uncertainty parameters of both firms. Only in this case is it sensible to make the price and effort of one firm depend on the costs of the other. If this result is applied to the case of partition of a distribution area, we see a correlation among the firms' costs. It is therefore advisable to set the regulated price of one firm as a function of the performance of others. The greater information yielded by an increase in distribution franchise zones permits more efficiency in incentive regulation. The effort levels of regional monopolies are optimized because they depend on the performance of the other distribution franchise zones.

Artificial yardsticks, or benchmarks, can also be constructed through cost models that control the behavior of certain variables. Models of this type have been used to compare gas delivery costs for different urbanization levels.

Productive Efficiency: Unit Cost Analysis

A natural monopoly has high sunk costs and a subadditive cost function. That is, a single firm faces lower costs than do multiple firms serving the same market. In such network industries as natural gas distribution, spatial dimensions depend on the number and density of consumers and the size of the geographic area.

Economies of scale are not infinite. If consumer density is too high, economies of scale will disappear as administrative costs rise. If economies of scale were never exhausted, the minimum pipeline delivery cost would be achieved by having a single distributor supply the whole market, regardless of the size of the geographic area.

Distribution Costs. The costs of a natural gas distribution firm are such that:

- Connection costs can decrease as the urban network develops but may increase with network congestion.
- It is cheaper to provide the distribution service to industrial consumers than residential consumers, because the capacity utilization of industrial consumers is greater and more uniform over time.
- The unit cost of connecting a consumer to the network increases with greater distance from the network.

Therefore, the cost function of the distribution firm will be determined by input prices, volume throughput, and the number of consumers and their geographic dispersion and consumption levels. Estimates of distribution costs for alternative partitions of the ZMCM were calculated using coefficients of a translog cost function[3] for the natural gas distribution market in the United States.

The U.S. natural gas market was chosen as a cost and demand benchmark because of its abundance of relevant and reliable data on natural gas distribution systems in the country. Since the Mexican market is part of the North American market,[4] the U.S. local distribution companies are a relevant target model for Mexican local distribution companies in network development, service standards, and cost efficiency. And because the U.S. gas market is more mature than Mexico's, the behavior of local distribution companies in the United States may foreshadow the behavior of those in Mexico. Thus the least unit cost analysis for the ZMCM was supposed to be valid in 2010, assuming that the resulting partition was also optimal in 1998. In other words, the proportion among unit costs in distinct distribution franchise zones was assumed to remain constant for 12 years.

[3] The translog functional form has been widely used in studies on determining cost functions. It does not impose a priori restrictions on substitution possibilities among factors of production. It allows for variation in scale economies at different production levels, which is essential for the unit cost function to be U-shaped. And due to its generality it has been shown to be superior to other functional forms used in applied research. See Christensen, Jorgensen, and Lau (1973).

[4] The price of natural gas in Mexico is determined through a regulatory formula based on the prices in south Texas (see Brito and Rosellón 1998). Moreover, the Mexican pipeline system is physically linked to the North American one also in south Texas.

The unit cost analysis also required estimating demand to 2010. The demand projections were then plugged into the cost function, and the effects on unit costs of different partitions of the ZMCM were studied.

Demand for Natural Gas. There are two ways to analyze demand for energy products. *Consumer theory* is applied for residential users and small firms that do not use energy as an input in production. Demand depends on the price of the product as well as on prices of substitute and complementary products. The *theory of production* is applied for consumers that use energy as a production factor (industry, commercial). Demand depends on the price of natural gas and other potentially competing fuels and the prices of other inputs that can substitute for energy, such as capital and labor.

Both approaches were used for Mexico. Demand was assumed to depend on prices of relevant variables, a set of variables that measure purchasing power, and another set of variables that measure market conditions. As in the cost function, a translog demand function was used. This translog functional form was then modified to estimate future natural gas demand in Mexico.

Coefficients of a translog demand function in the natural gas distribution market of the United States were estimated. The data from the resulting demand functions were then included in the estimations for the cost function of different partitions of the ZMCM. Likewise, different economic scenarios were assumed in order to provide different values for demand and, consequently, different results for the unit costs associated with distinct partition options.

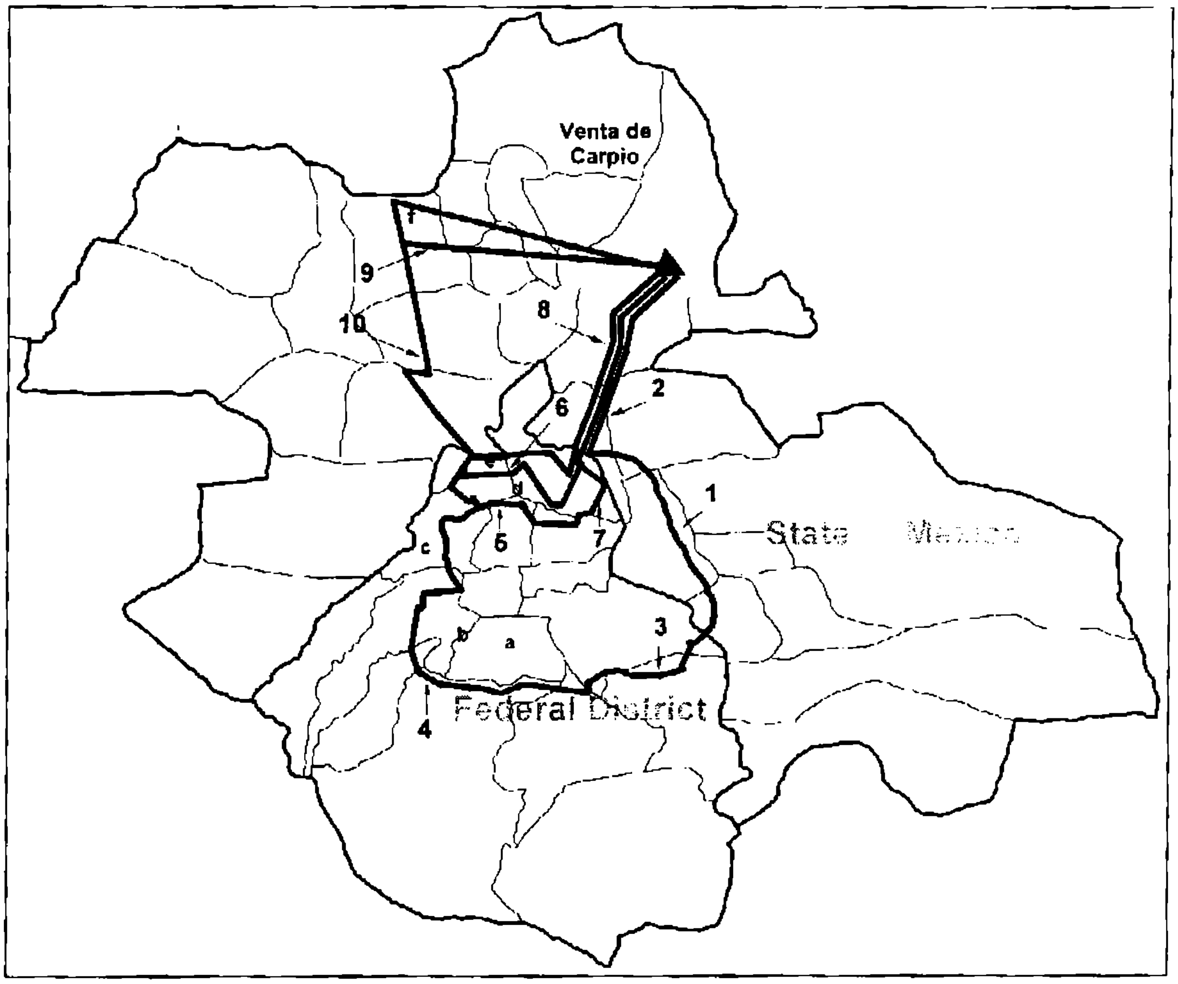
Technical Efficiency The decision to segment a distribution geographic area is affected by the technical characteristics of the natural gas distribution franchise zone. In the ZMCM, a distribution infrastructure already existed. The ZMCM is also an earthquake area.

Distribution Infrastructure. Before bidding began in April 1998 to grant exclusive distribution service in the ZMCM, the network was operated by a Petróleos Mexicanos (Pemex) subsidiary—Pemex Gas y Petroquímica Básica (PGPB)—and by Diganamex. PGPB's network was 237 kilometers long, with branches 195 kilometers long and diameters of 10–36 inches. This network covered 312 industrial consumers and had two segments. The first connected producing fields to the city gate using three pipelines with a capacity of 300 million cubic feet a day.[5] The second connected the city gate to the rest of the consumers inside the ZMCM. This second segment was designed as a series of interconnected rings to provide flexibility in distribution (figure 1). Four rings in the north supplied industrial consumers; one ring in the south served residential consumers. The system operated at pressures of 13–24 kilograms per square centimeter. Its capacity was 190 million cubic feet a day, and distribution loads varied between 113 million cubic feet a day and 138 million cubic feet a day. Available capacity was 52–77 million cubic feet a day—enough to serve 900,000 consumers.

[5] See the first three pipes in the PGPB chart of figure 1.

Figure 1

The PGPB and Diganamex Distribution Network



PGPB			
Pipe	Diameter (inches)	Length (km)	Route
1	24	51	Venta de Carpio–Chalco
	14	29	
2	24	51	Venta de Carpio–Nonoalco
3	?	?	Venta de Carpio–Chalco (cont.)
4	22	76	Venta de Carpio–Camarones–San Pedro–Cuemanco–Chalco
	14		
	10		
5	14	3	Nonoalco–Camarones
6	24	14	Altavilla–San Pablo
7	14	29	Venta de Carpio–Nonoalco (cont.)
8	22	76	Venta de Carpio–Camarones–San Pedro–Cuemanco–Chalco (cont.)
9	20	26	Venta de Carpio–Barrientos
10	20	38	Venta de Carpio–Guanos–Romana–San Pablo I
	12		
	14		

Diganamex	
a)	Jardines de Coapa Villa Coapa Alianza Pop. Rev Culhuacán Villa Quietud
b)	Pedregal de Carrasco Copilco Universidad Villa Olímpica
c)	Lomas de Plateros Lomas Sotelo
d)	Camarones Tlatelolco
e)	Rosario Vallejo Ceylan Acueducto de Guadalupe
f)	Reyes Iztacala Cuautitlán Izcalli

Before 1998, Diganamex had the concession to operate 1,015 kilometers of distribution pipelines with diameters of 0.5 and 12 inches. It served 135,517 mostly residential consumers.

Risk Areas. The urban growth of the ZMCM has taken place in the absence of a comprehensive urban land use plan and has harmed forests, soil, and the atmosphere. Moreover, the growth of human settlements on the city's periphery, where there are adverse geological and hydrological conditions, increases risks. The main risks in the ZMCM are earthquakes, volcanic activity (the Popocatépetl and the Federal District's southern transversal volcanic range), landslides of sedimentary material from hills, and areas that might flood.[6] Any distribution project must consider Mexico City's susceptibility to earthquakes and other forms of geological instability.

Other Elements: Financial Risk, Competition in Related Services, and Speed of Development

Large distribution franchise zones—with an adequate mix of consumers—decrease the financial risks of operating distribution systems. If the number of distribution franchise zones that subdivide a distribution area decreases financial risks will also decrease. As the number of distribution franchise zones increases, so does the financial impact of losing industrial consumers. If the regulatory commission defined a large number of distribution franchise zones in the distribution area, so

[6] See Rosellón (1998b), annex 2, for a detailed description of the main risk distribution franchise zones in the ZMCM.

that every distributor only had a reduced number of industrial consumers, demand in one of the distribution franchise zones may abruptly decrease when a large consumer goes bankrupt.

The possibility of reaching an adequate balance in the coverage of different types of consumers increases when the distribution franchise zones are large. A relatively extensive service region provides the companies more growth options. And the larger the service region, the lower the risk that unforeseeable or uncontrolled events (such as earthquakes and the discovery of archaeological sites) will decrease the distributor's profits. These events will have less impact on financial performance if they affect a small part of the total operations of the company.

The way the ZMCM is partitioned would also influence the promotion of competition in segments related to natural gas distribution, such as gas marketing and connecting new consumers to the distribution network. Competition is also feasible in reconversion services of equipment for the use of natural gas, maintenance and repair of equipment, and consultation for the energy administration. Even though entry to these markets is open, distributors have experience in offering an ample variety of gas services and could extend distribution to these related markets. Since a distributor can efficiently offer these services, competition in these markets is promoted as the number of distributors increases and, consequently, when the number of distribution franchise zones is higher.

Finally, since each potential distributor has a short-run coverage objective to generate profits, more area will be covered in less time as more distributors participate. In other words, the more distribution franchises there are, the faster the network will develop.

Other Partition Experience

Buenos Aires, Argentina, provides an example of how to grant infrastructure services concessions to the private sector. The distribution area was segmented before the network was privatized. The following criteria were employed:

- Cost minimization—the criterion was to minimize the cost of separating the systems. The mix of consumers and growth potential of resulting distribution franchise zones were not considered.
- Integrated network—to maintain system integrity and to be able to have more than one firm in the network, the methodology considered the pipeline systems as a single network.
- Number of distributors—macroeconomic and commercial objectives were considered, as well as operational restrictions.

The macroeconomic and commercial objectives were:

- Access to gas production.
- Access to markets.
- Distribution pipeline conditions.

- Size of the distribution system (a comparison with U.S. local distribution companies was performed).
- Information flows for the regulator (benchmarking).
- Maximization of the potential value of each distribution subsystem (in terms of age of assets, physical expansion, and potential market growth).

The only alternatives considered were two or three business units. Four or more units were shown to be unattractive because of operational restrictions and a small potential value of each distribution segment. Buenos Aires was divided into two concessions—the north, with 871,000 consumers and a development potential based on industrial consumers and growth of suburban areas; and the south, with 1.7 million consumers in the federal capital city and the rest of the metropolitan area. Its development potential is based on industrial and commercial clients, heating and air-conditioning systems, and auxiliary power plants.

Unit Cost Analysis of the ZMCM

To demarcate the natural gas distribution area of Mexico City—in which one or more distribution franchises would be permitted to operate—physical characteristics and economic, political, and social transformation processes were considered.[7] Three demarcation options—Megalopolis, the Valley of Mexico, the ZMCM—were considered, and they all had the same distribution infrastructure (table 1).

[7] These criteria are described in Programa General de Desarrollo Urbano del Distrito Federal; Plan de Desarrollo del Estado de México 1993–1999; Programas Delegacionales de Desarrollo Urbano; Planes de los Centros de Población Estratégico de los Municipios del Estado de México; Propuestas de Divisiones del Área Metropolitana de la Ciudad de México (Secretaria de Desarrollo Social, Instituto Nacional de Estadística, Geografía e Informática); and Planes y Programas Gubernamentales.

Table 1

Demarcation Options for Mexico City's Natural Gas Distribution

Option	Approximate population (millions)	Degree of connectivity between the Federal District and other states	Number of jurisdictions
Megalopolis	23	Very low—due to distance	16 "delegations"—Federal District. Metropolitan areas of Toluca, Cuernavaca, Puebla Tlaxcala, and Pachuca 91 municipalities—State of Mexico 16 municipalities—Morelos 29 municipalities—Puebla 37 municipalities—Tlaxcala 16 municipalities—Hidalgo 7 Isolated urban centres (Atlacomulco; Tepeapulco; Jilotepec-Tepeji-Tula; Tepozotlan-Huehuetoca-Zumpango; Piramides-Nopaltepec; Texcoco and Chalco-Amecameca)
The Valley of Mexico	18.5	Low—due to distance	16 "delegations"—Federal District 57 municipalities—State of Mexico 1 municipality—Hidalgo
The ZMCM	16	High—due to economic links and physical links (roads)	16 "delegations"—Federal District (Mexico City) 28 municipalities—State of Mexico

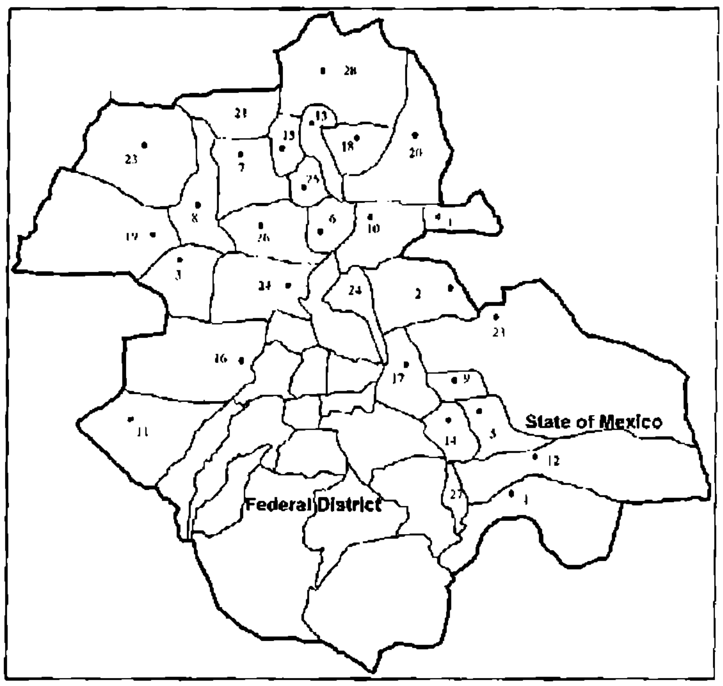
The Megalopolis alternative was deemed too extensive and had insufficient economic links among towns and subregions. Population had more than doubled in the Valley of Mexico in 1970–95, posing a challenge for sewerage, drainage, electric power, and transportation systems. Diverse interests, local sovereignty, and the political characteristics of coordination among different jurisdictions have made the existence of two public administrations running the city (the Federal District and the State of Mexico) an obstacle to efficient urban development. The Valley of Mexico was considered too heterogeneous—economically, politically, and socially—to be a viable distribution area.

The ZMCM covers 471,383 hectares and comprises 16 delegations of the Federal District (148,331 hectares) and 28 suburban municipalities of the State of Mexico (323,052 hectares) (figure 2). In 1995 the ZMCM had about 16 million inhabitants—55 percent live in the Federal District, 45 percent in the State of

Mexico. Demographics shifted between 1980 and 1990 as the relative participation of people in the Federal District decreased and relative participation of people in the State of Mexico increased. The ZMCM has historically been economically, culturally, and socially homogeneous. Moreover, common streets, roads, and highways connect all of its regions. So, despite the lack of a common public administration, the ZMCM was considered the best alternative for a natural gas distribution area.

Figure 2

The ZMCM



Suburban municipalities of the State of Mexico

1. Acolman	8. Cuautitlán Izcalli	15. Melchor Ocampo	22. Tepotzotlán
2. Atenco	9. Chimalhuacán	16. Naucalpan	23. Texcoco
3. Atizapán de Zaragoza	10. Ecatepec	17. Nezahualcóyotl	24. Tlalnepantla
4. Chalco	11. Huixquilucan	18. Nextlalpan	25. Tultepec
5. Chicoloapan	12. Ixtapaluca	19. Nicolás Romero	26. Tultitlán
6. Coacalco	13. Jaltenco	20. Tecamac	27. Valle de Chalco Solidaridad
7. Cuautitlán	14. La Paz	21. Teoloyucan	28. Zumpango

Estimation of Unit Costs

After selecting the ZMCM as the distribution area, a unit cost analysis for the U.S. natural gas distribution market was conducted as a proxy for estimating the unit costs of distribution in the ZMCM. Since the distribution market in the ZMCM is not as mature as the market in the United States, the partition for the ZMCM should be optimal for 2010. But it was also valid for 1998, assuming a stable evolution of the unit cost proportion in the different distribution franchise zones.

The unit cost analysis for the ZMCM required demand projections for 2010, which could be derived from demand estimates for the U.S. natural gas distribution market. The unit cost analysis had four phases:

1. A cost function was estimated for the U.S. natural gas distribution market.
2. A demand function was estimated for the U.S. natural gas distribution market.
3. Coefficients of the demand function were used to forecast both number of consumers and volume of demand in the natural gas distribution market of the ZMCM in the year 2010. Demand projections were also made based on technical and market characteristics of the ZMCM.
4. Coefficients of the cost function were used to forecast unit costs for a given demand and for several alternative partitions of the ZMCM.

Phase one was carried out using a general translog cost function (Rosellón 1998b). Explanatory variables for unit costs included price of labor, price of capital, price of other inputs, volume demanded, number of consumers, area of service, and time tendency (table A1).

Phase two was carried out using a translog demand function for each type of consumer (residential, commercial, and industrial). For each group demand was estimated according to the number of users with natural gas delivery service (access demand) and consumed volume. Since there are three types of consumers and two types of demand, a total of six equations were estimated (Rosellón 1998b). In all these equations explanatory variables included wholesale natural gas prices for each type of consumer, price of electricity, and price of hydrocarbon substitutes. Prices of labor and capital were also included in the industrial demand equations.[8]

The results of estimating demand in the U.S. distribution market show that:[9]

- The number of families is the variable that explains demand for access from residential and commercial consumers.
- Demand for heating does not explain demand for access from residential consumers but it does explain demand for volume.

[8] Other variables were number of families and personal income (measuring purchasing power), number of days a year when heating is required (measuring demand-induced by weather), and such qualitative variables as environmental policies that promote the use of natural gas, presence of energy intensive industry, and distance from gas fields and pipelines serving the area. A time linear trend variable was also included to reflect long-term energy demand and the impact of relevant market variables that were not explicitly included in the analysis.

[9] There is no table for demand from industrial consumers because the results were not statistically significant.

- Commercial volume demand is more elastic than residential volume demand.
- Industrial volume demand is more elastic than residential and commercial volume demands.
- There is an effect of substitution of capital and labor for energy in the industrial volume demand (tables A2–A6).

Before the parameters estimated in phase two were used to estimate the number of consumers and volume of delivered gas in the ZMCM for 2010, the specification of variables used in the demand model pertinent to Mexico City were verified. All such variables were deemed appropriate with one exception. At the residential and commercial levels the principal substitute for natural gas in the United States is distillate fuel; in Mexico it is liquid petroleum gas.

Projections were needed for explanatory variables of demand for natural gas. Projections were made for temperatures, fuel oil, energy prices, house incomes, urban territory, population and houses, and prices of capital and labor. Forecasts for these variables were performed by using reference projections from the United States, long-run trends for Mexico, or distinct scenarios based on recent experiences (Rosellón 1998b).

Once projections for the explanatory variables were obtained, demand for the natural gas distribution market of the ZMCM was estimated for 2010. Thirteen scenarios were run; each controlled for variations in population and economic growth, energy prices, and capital costs (table 2).

Table 2

Demand Scenarios for the ZMCM in 2010

[See query in "Volume" heading.]	Number of consumers	Percentage change from base scenario	Volume (millions—annual CF) [???]	Percentage change from base scenario
1. Base scenario	1,965,526		6,980	
2. Fast population growth[a]	2,635,320	34.1	7,131	2.2
3. Fast economic growth[b]	1,965,526	0.0	7,415	6.2
4. Economic stagnation[c]	1,965,526	0.0	6,437	–7.8
5. 20 percent decrease in national gas prices	1,992,651	1.4	7,890	13.0
6. 20 percent decrease in liquid petroleum gas prices	1,917,140	–2.5	6,932	–0.7
7. 20 percent decrease in electric tariffs	1,894,425	–3.6	6,379	–8.6
8. 20 percent increase in natural gas prices	1,939,496	–1.3	6.230	–10.7
9. 20 percent increase in liquid petroleum gas prices	2,008,602	2.2	7,025	0.6
10. 20 percent increase in electric tariffs	2,051,169	4.4	7,617	9.1
11. Constant fuel oil prices	1,965,526	0.0	5,691	18.5
12. Moderate increase in fuel oil prices[d]	1,965,526	0.0	6.357	8.9
13. Convergence of Mexican and U.S. capital prices	1,965,526	0.0	6,134	12.1

a. 25 percent more than in the base scenario.

b. 1 percent more than in the base scenario.

c. Zero growth rate.

d. Increase in fuel oil prices that reduces natural gasconsumption in 40 percent (as opposed to 80 percent of the base case).

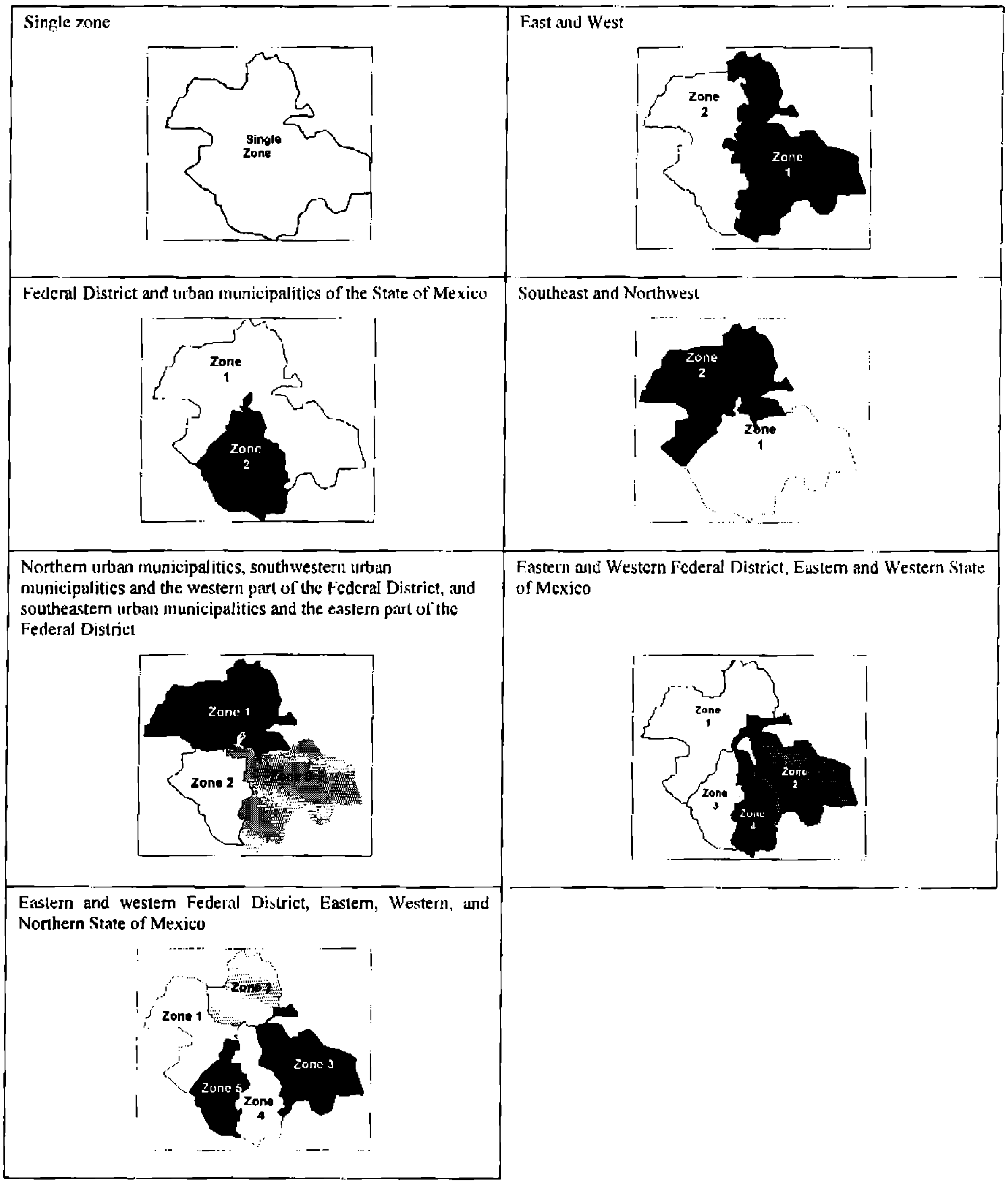
This comparative analysis indicated that the demand model provided a reasonable explanation of natural gas demand in Mexico. Furthermore, the base scenario could be used with confidence because the inelastic behavior of demand suggests that results from the demand equation are not so sensitive to measurement precision in the explanatory variables.

In parallel, demand was estimated using criteria for the technical and market evolution conditions of the ZMCM. This scenario was named the optimistic scenario; the base scenario was named the conservative scenario. The optimistic scenario predicts higher average daily consumption, more consumers, and lower average costs for the ZMCM (tables A7 and A8). The discrepancy comes from the conservative scenario's assumption that a certain proportion of residential consumers can opt to use liquid petroleum gas instead of natural gas. Likewise, the average consumption of 1.85 cubic meters a day in the conservative scenario is obtained from the ratio of total volume to consumers. The optimistic scenario projects the number of residential consumers first according to demographic and engineering data, and proposes an expected consumption of 2.0 cubic meters a day. This is multiplied by the number of consumers to calculate total volume.

Once demand was calculated for each type of consumer, the calculation was used to estimate natural gas distribution costs for several hypothetical symmetric and nonsymmetric partitions of the ZMCM. In the symmetric case the ZMCM was divided into five symmetric distribution franchise zones with the same number of clients, the same volume of delivered gas, and the same amount of urban territory. But this is unrealistic because it assumes that consumers and all other variables are uniformly distributed. The next step was to account for heterogeneity in population density by using nonsymmetric partitions with a roughly balanced distribution of different types of consumers in each zone (figure 3).

Figure 3

Nonsymmetric Partition Options for Distribution Franchise Zones in the ZMCM

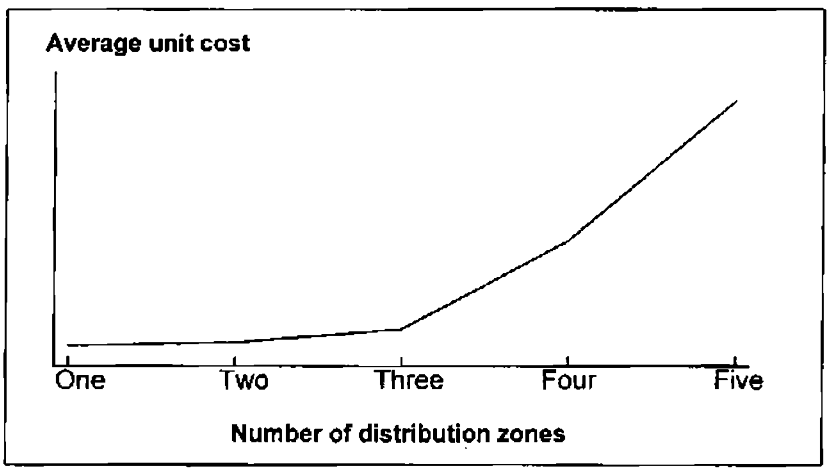


The lowest unit cost is obtained when the complete ZMCM is a single distribution franchise zone. In the case of two perfectly symmetric distribution franchise zones there is a cost 3–6 percent higher than that of a single distribution franchise zone. With five symmetric distribution franchise zones there is an additional cost of approximately 27–37 percent. That is, each additional distribution franchise zone increases unit costs exponentially as the scale of operations shrinks. The symmetric partition confirms that the average cost of production progressively increases as the number of distribution franchise zones increases.

In the case of nonsymmetric partitions, the lowest costs per volume were empirically obtained under the optimistic scenario (Rosellón 1998b). There is a direct relation between unit cost and the number of distribution franchise zones defined for the ZMCM. That is, fewer distribution franchise zones mean a lower unit cost in each zone (figure 4).

Figure 4

Variation in Average Unit Cost as Number of Distribution Zones Rises



So, the data show that even with similar estimated volumes of operations, unit costs vary considerably with more distribution franchise zones. And the design of distribution franchise zones is an important factor for the unit costs of operation. Of the options considered, the one that corresponds to the Federal District and urban municipalities shows the lowest cost differences compared with other options, the lowest difference with respect to the single-distribution franchise zone option, and the lowest difference with respect to the symmetric case.[10]

[10] These results might have been influenced by the difficulty of defining homogeneous distribution franchise zones with respect to the three principal variables that determine the unit cost: volume in the system, coverage area, and mix of consumers.

Synthesis of Decision Criteria

The different options for partioning the ZMCM were evaluated according to four criteria:

- Economic efficiency.
- Promotion of competition—speed of development of the system, scope for benchmarking among distributors, and competition in related services.
- Technical efficiency.
- Financial risks to the operator.

The first two criteria imply lower total operating costs and thus lower tariffs for consumers. Promotion of competition implies a fast start in providing the distribution service and several alternatives in such related services as connection, metering, reconversion, maintenance and repair of equipment, gas marketing, and consulting for the energy administration. Creating geographic distribution franchise zones requires balancing these criteria with the financial risk criterion.

With respect to promoting competition, more distribution franchise zones means more information for comparative regulation and competition in related services, and faster development of the distribution network. Taken together, these considerations militated for partitioning the ZMCM into more than one distribution franchise zone.

Concerning technical efficiency, restrictions on the use of the existing distribution network influence the partition decision. The ZMCM's distribution infrastructure is composed of two main rings (one for the Federal District, one for urban municipalities) and remains valuable as long as the design of the rings is maintained. The ring design preserves the integrity of the system, increases security of supply, and eases design and operation of the new pipeline network. The options that preserved the configuration of the existing network were those that responded to the Federal District and urban municipalities, and to the Northwest and Southeast. The other alternatives would have required breaking the integrity of the infrastructure, diminishing its value.[11]

Financial risks to the operator increase as the number of distribution franchise zones increases. The effects of losing large (anchor) consumers and of unforeseeable events are greater when the distribution franchise zones are smaller and more numerous. Likewise, the company can better manage growth in demand in large zones because a mix of residential, commercial, and industrial consumers tends to be more balanced. Thus:

- A single distribution franchise zone implies a maximum value for the economic and technical efficiency criteria. It also reduces financial risk but is weaker on promotion of competition.

[11] Formally speaking, the unit cost analysis should also consider the effects of the configuration of the preexisting distribution network.

- Two distribution franchise zones incorporate competition criteria, imply a marginal increase in unit costs and financial risk, and can maximize the value of existing infrastructure.
- Three or more distribution franchise zones considerably increase unit costs and financial risk, lead to unbalanced distribution of the different types of consumers, complicate the transfer of infrastructure, but introduce more competition elements.
- In the Federal District and urban municipalities option, unit costs of operation for each distribution franchise zone are near their minimum value, implying the lowest tariffs for consumers.
- In this option and the East-West option, the geographic distribution franchise zones are defined homogeneously by mixture of consumers (residential, commercial, and industrial) as in potential operating volume. This would permit each distribution franchise zone to realize economies of scale and scope that attract investor interest.
- In the Federal District–urban municipalities and Northwest-Southeast options, it is technically feasible to define distribution assets that will be transferred to each private distributor.
- In the Federal District–urban municipalities option, the selection of distribution franchise zone coincides with political jurisdictions.

This analysis suggested that the Federal District–urban municipalities option was the best. This was supported by consultations with interested public and private parties.[12] Consultations centered on three issues: the viability of each partition option, the necessity of promoting competition in related services, and the best option to make use of the existing distribution infrastructure. The consultations revealed that the two distribution franchise zones presented different conditions. The Federal District has less potential for growth and greater development complexity. But it has greater population concentration and potential to generate positive net cash flows in the short term. The urban municipalities of the State of Mexico have better potential for expansion, pose less difficulties for construction, and cover a larger area. It was also stressed that special interconnection agreements should be negotiated when part of the infrastructure that is relevant for one distributor is in the area of the other distributor.

Results to Date

Unlike in other privatizations in Mexico, in the natural gas distribution bids the government only establishes the number of consumers that must be covered at the

[12] Assistants to the consultations included Asociación Mexicana de Gas Natural (AMGN), Controladora Comercial e Industrial, Gaz de France, Gaz Metropolitain, Gobierno del Distrito Federal, Gobierno del Estado de México, Gutsa-Noram-Transcanada Pipelines, Pacific Enterprises International, Pemex Gas y Petroquímica Básica, Repsol México, and Tribasa.

end of the first five years. When applicable, it sets the value of the preexisting distribution pipelines to be acquired by the winning bidder. It also requires that two-thirds of total investment must be capital owned by the firm; one-third can be debt. These features, together with the specifics of the regulatory framework (such as the average revenue methodology used to regulate distribution tariffs) and the technical characteristics of the project, define the allocation of risk for distribution projects and how they can be financed (Rosellón 2000). The terms and conditions, operation and maintenance obligations, service standards, and other obligations are set by the Energy Regulatory Commission (CRE) at the outset of the tender process. The market study presented by the winning bidder defines the coverage goals, tariffs, volumes, and investment commitments. Service standards are defined in official Mexican standards (NOMs) and relevant international standards. The final price to consumers is regulated by the acquisition price methodology (Rosellón 2000).

Because the minimum number of consumers to be served at the end of the first five years of operation is a principal award criterion, the local distribution companies have an incentive to expand the network to connect as many consumers as possible.[13] This implies constructing the distribution network quickly despite the inconvenience to the public. The bidding procedure then provides incentives to start the building of the network in high-density areas—as opposed to a looped network that could grow in a less disruptive fashion—to meet minimum consumer coverage obligations.

The bidding package for the ZMCM distribution projects contained the minimum coverage required by the regulator: 350,000 consumers in the Federal District and 300,000 in the State of Mexico at the end of five years. The CRE was also expecting $1 billion in investments (CRE 1998). The winning bids ended up with coverage commitments of almost 440,000 consumers in the Federal District and 370,000 in the State of Mexico after five years, and $0.5 billion in investment after 10 years.

The winners in the bidding were Comercializadora Metrogas (Metrogas) for the Federal District and Consorcio Maxi-Gas (Maxigas) for the State of Mexico. They received their permits on September 14, 1998. Metrogas was originally a consortium formed by Grupo Diavaz (15 percent), Lone Star Gas International (70 percent), and Controladora Comercial e Industrial (15 percent).[14] Maxigas is a consortium of Gaz de France (75 percent) and Buffete Industrial (25 percent).

Metrogas's average revenue cap of $2.42 per gigacalorie is higher than the national average of $1.49. Maxigas's average revenue cap is lower than the average, and its typical monthly bill for a residential consumer ($74.58) also is below the national average. In fact, Maxigas maintained the same tariffs for existing and new industrial consumers. Metrogas's existing industrial consumers pay more than new ones, partly because the Metrogas project network has higher and lower conducted

[13] The other criterion is the lowest average revenue.

[14] In March 2000 the Metrogas consortium was reconstituted. It now comprises Grupo Diavaz (14.7 percent) and the Spanish companies Grupo Cantábrico (42.65 percent) and Gas Natural de México (42.65 percent).

volume than the Maxigas project. Nevertheless, Metrogas paid about $72 million for the existing PGPB/Diganamex pipeline infrastructure; Maxigas paid about $94 million.

Gas Contracts

Gas supply contracts for Metrogas and Maxigas are arranged according to Pemex's general terms and conditions for firsthand sales and CRE's recently published directive on firsthand sales (CRE 2000; Rosellón and Halpern 2000). Pemex offers different kinds of supply gas contracts at the processing plant and the delivery point, as well as long-term contracts and forward or futures contracts. Regulated by the CRE, these contracts include firm, interruptible, spot, tunnel, and volumetric modalities.

Investors' Perceptions after Two Years

In the two years since the distribution franchises were granted, unforeseen institutional problems have hindered network development. Managers of the ZMCM local distribution companies report that the CRE's forecasts of demand growth and economic growth were too optimistic, and that market size and consumption levels are lower than predicted. The managers also believe that the value of the PGPB/Diganamex system was overestimated given the condition of pipelines, and that security and safety measures need to be stricter than those indicated by regulations and NOMs

Managers of the ZMCM local distribution companies also report that acquisition price regulation has been unable to control cross subsidies by distributors. This assertion can be analyzed in more detail since regulators have approved prices for imported gas in such northern distribution systems as Mexicali, which imports gas from western North America basin; Ciudad Juárez, which imports gas from New Mexico (Permian Basin). A typical monthly bill in Mexicali ($84.42) is less than Mexico's national average ($107.68), and the gas price in Ciudad Juárez is above the national average. This provides some evidence that the acquisition price methodology, which the CRE has applied through national benchmarks, has been able to moderate cross subsidies.

Several unanticipated operational problems have also emerged. Authorities in the Federal District and the State of Mexico require that excavations for pipeline installation be performed with "directional drilling" to minimize inconvenience to city dwellers and traffic. This is impossible in the ZMCM because there are no maps of the underground water and cables systems in the distribution franchise zone. So, the only feasible solution is the "open trench" method, which, according to the ZMCM local distribution companies, local people dislike . Both distribution companies report that a March agreement between the CRE and the Federal District states that pipes will be installed through open trenches, with the exception of important streets and avenues where directional drilling will be used .

Additionally, liquid petroleum gas–related explosions in Guadalajara in 1992 and Mexico City in 1985 have made Mexicans wary of gas pipelines. Both Metrogas and Maxigas are struggling to educate users about the benefits of natural gas.

Local distribution companies in the ZMCM also see a lack of coordination among the CRE, the Federal Competition Commission, and the Federal Consumer Agency regarding cross subsidies between industrial and residential consumers. There are also problems in the coordination among government agencies in implementing regulation:

- Pemex interferes with the granting of rights of way to private distribution pipes that pass near their oil pipelines. This is being handled through meetings among the Ministry of Energy, the CRE, and Pemex legal offices. If they do not resolve the problem, the next step is an executive decree.
- Two entities of the Ministry of Environment—the National Ecology Institute and the Water Commission—are working on an arrangement with the CRE to simplify the requirements and procedures that local distribution companies must meet. The Water Commission already has an agreement to facilitate pipeline crossings with rivers and waterlines. The Ministry of Transportation will also participate in these arrangements.
- The existence of specific local regulations has required coordination of the federal regulatory authorities and the local authorities. The Ministry of Energy, Ministry of Environment, Ministry of Transportation, Ministry of Social Development, and the CRE are working to establish unique agreements of coordination with the states and municipalities. The purpose of these agreements is to simplify regulatory procedures and educate the public on the natural gas industry.

Future Issues

The first tariff review for the ZMCM is scheduled for 2003. A basic concern is how Maxigas and Metrogas can renegotiate the low tariffs upon which the concessions were awarded. The CRE is preparing for the first tariff review by constructing national and international benchmarks.

Appendix. Table A1

Results of the Estimation of the Translog Cost Function for the U.S. Natural Gas Distribution Market

Explanatory variable	Estimated coefficient	Standard deviation	T statistic	Explicative variable	Estimated coefficient	Standard deviation	T statistic
PL	0.251	0.004	71.43	PON	0.040	0.009	4.58
PLPL	0.012	0.011	1.06	POA	0.009	0.002	4.25
PLPK	–0.011	0.012	–0.95	POT	0.003	0.001	3.73
PLPO	–0.012	0.011	–1.06	V	0.60	0.039	1.55
PLV	–0.053	0.010	–5.20	VV	0.021	0.112	0.19
PLN	0.048	0.010	5.08	VN	0.124	0.105	–1.19
PLA	0.000	0.002	0.12	VA	0.018	0.024	0.77
PLT	–0.001	0.009	–1.12	VT	–0.012	0.003	–3.72
PK	0.596	0.005	115.48	N	0.800	0.079	10.13
PKPK	–0.088	0.016	5.60	NN	0.386	0.124	3.10
PKPO	0.099	0.010	9.94	NA	0.011	0.032	0.34
PKV	0.098	0.015	6.55	NT	0.007	0.004	1.81
PKN	–0.088	0.014	–6.30	A	0.029	0.024	1.23
PKA	–0.009	0.003	–2.78	AA	0.028	0.012	2.22
PKT	–0.002	0.001	–1.55	AT	–0.001	0.001	–0.82
PO	0.153	0.003	47.60	T	–0.003	0.002	–1.39
POPO	-0.098	0.013	–7.70	TT	0.001	0.001	2.40
POV	–0.045	0.009	–4.83	Constant	12.164	0.067	180.24

Variables: PL = price of labor, PK = price of capital, PO = price of other inputs, V = volume, N = number of consumers, A = area of the service territory (squared miles), T = time tendency.

Each parameter value can be interpreted as the percentage change in unit costs due to a 1 percent increase of each explicative variable, when the value of rest of the variables remains constant. Confidence level: 95 percent.

SOURCE: Energy Regulatory Commission.

Table A2

Residential Consumers of Natural Gas, Results of the Translog Regression, 1980–93

Explanatory variable	Estimated coefficient	T statistic	Explicative variable	Estimated coefficient	T statistic
Constant	–0.094	–1.42	PO	0.108	2.24
H	1.236	6.30	POPO	0.061	0.31
HH	0.084	0.60	POPE	0.179	1.12
HPG	-0.057	–1.32	POZ	0.145	2.33
HPO	0.086	2.33	POT	0.027	2.73
HPE	0.057	0.91	PE	0.144	1.93
HZ	0.089	1.20	PEPE	0.328	1.66
HT	–0.001	–0.43	PEZ	0.071	0.49
PG	–0.060	–1.02	PET	–0.019	–2.01
PGPG	–0.042	–0.20	Z	0.099	1.18
PGPO	0.157	0.90	ZZ	0.135	1.45
PGPE	–0.179	–1.17	ZT	0.010	2.61
PGZ	0.053	0.54	T	0.002	0.53
PGT	0.015	1.63	TT	0.003	3.43

Variables: H = number of families, PG = price of natural gas, PO = price of fuel oil, PE = price of electricity, Z = days of demand for heating, T = time tendency.

Each parameter value can be interpreted as the percentage change in unit costs due to a 1 percent increase of each explicative variable, when the value of the rest of the variables remains constant. Confidence level: 95 percent.

SOURCE: Energy Regulatory Commission.

Table A3

Natural Gas Residential Volume,
Results of the Translog Regression, 1980–93

Explantaroy variable	Estimated coefficient	T statistic	Explicative variable	Estimated coefficient	T statistic
Constant	0.028	0.63	PGPO	0.055	0.45
N	0.193	1.57	PGPE	0.263	2.79
NN	–0.528	–6.00	PGZ	0.123	1.96
NI	0.380	4.46	PGT	0.008	1.19
NPG	–0.122	–2.83	PO	0.070	2.06
NPO	0.047	1.19	POPO	0.024	0.20
NPE	0.078	1.35	POPE	–0.085	–0.85
NZ	0.004	0.07	POZ	0.069	1.78
NT	–0.007	–2.44	POT	0.004	0.64
I	0.528	5.07	PE	0.027	0.49
II	–0.321	–2.98	PEPE	–0.201	–1.61
IPG	0.149	2.82	PEZ	–0.181	–1.96
IPO	–0.030	0.65	PET	–0.001	–0.17
IPE	0.173	2.20	Z	0.646	12.64
IZ	0.002	0.04	ZZ	0.243	4.05
IT	0.011	3.19	ZT	0.008	3.22
PG	–0.157	–3.97	T	–0.003	–1.13
PGPG	–0.431	–2.71	TT	0.002	2.14

Variables: N = number of consumers, I = total revenue, PG = price of natural gas, PO = price of fuel oil, PE = price of electricity, Z = days of demand for heating, T = Time tendency.

Each parameter value can be interpreted as the percentage change in unit costs due to a 1 percent increase of each explicative variable, when the value of rest of the variables remains constant. Confidence level: 95 percent.

SOURCE: Energy Regulatory Commission.

Table A4

Commercial Consumers of Natural Gas, Results of the Translog Regression, 1980–93

Explanatory variable	Estimated coefficient	T statistic	Explicative variable	Estimated coefficient	T statistic
Constant	–0.013	–0.11	PO	0.130	1.90
H	1.159	3.14	POPO	–0.194	–0.59
HH	–0.609	–2.36	POPE	–0.151	0.58
HPG	–0.030	–0.36	POZ	0.002	0.02
HPO	0.060	1.12	POT	0.002	0.09
HPE	–0.025	–1.18	PE	0.151	0.91
HZ	0.028	0.20	PEPE	1.141	2.77
HT	0.000	–0.02	PEZ	0.445	1.63
PG	–0.162	–1.48	PET	–0.037	–2.06
PGPG	–0.209	–0.49	Z	0.181	1.16
PGPO	0.470	1.65	ZZ	0.093	0.55
PGPE	–0.316	–1.00	ZT	0.011	1.61
PGZ	–0.186	–1.04	T	0.020	3.28
PGT	0.071	3.41	TT	–0.005	–2.86

Variables: H = number of families, PG = price of natural gas, PO = price of fuel oil, PE = price of electricity, Z = days of demand for heating, T = time tendency.

Each parameter value can be interpreted as the percentage change in unit costs due to a 1 percent increase of each explicative variable, when the value of rest of the variables remains constant. Confidence level: 95 percent.

SOURCE: Energy Regulatory Commission.

Table A5

**Natural Gas Commercial Volume,
Results of the Translog Regression, 1980–93**

Explicative variable	Estimated coefficient	T statistic	Explicative variable	Estimated coefficient	T statistic
Constant	–0.184	–1.35	PGPO	–0.005	–0.02
N	0.714	2.85	PGPE	–0.321	–1.01
NN	0.584	2.79	PGZ	0.013	0.07
NI	–0.444	–1.83	PGT	–0.077	–2.91
NPG	0.634	3.57	PO	0.157	2.07
NPO	0.095	0.87	POPO	0.453	1.35
NPE	–1.189	–4.70	POPE	–0.050	–0.19
NZ	–0.398	–2.26	POZ	0.161	1.80
NT	–0.036	–4.44	POT	–0.001	–0.06
I	–0.398	–1.36	PE	0.206	1.22
II	–0.395	1.42	PEPE	0.175	0.36
IPG	–0.550	–2.76	PEZ	–0.044	–0.15
IPO	–0.049	–0.43	PET	0.027	1.32
IPE	1.099	3.63	Z	0.775	4.80
IZ	0.209	1.04	ZZ	0.620	3.19
IT	0.034	3.76	ZT	0.012	1.72
PG	–0.537	–4.64	T	0.016	1.92
PGPG	1.133	1.98	TT	–0.001	–0.24

Variables: N = number of consumers, I = total revenue, PG = price of natural gas, PO = price of fuel oil, PE = price of electricity, Z = days of demand for heating, T = time tendency.

Each parameter value can be interpreted as the percentage change in unit costs due to a 1 percent increase of each explicative variable, when the value of rest of the variables remains constant. Confidence level: 95 percent.

SOURCE: Energy Regulatory Commission.

Table A6

Natural Gas Industrial Volume, Results of the Translog Regression, 1980–93

Explanatory variable	Estimated coefficient	T statistic	Explicative variable	Estimated coefficient	T statistic
Constant	0.079	1.16	POPE	0.143	0.60
N	0.119	2.23	POW	0.528	0.84
NN	−0.074	−2.42	POK	0.163	0.26
NPG	−0.064	−1.14	POT	−0.094	−2.06
NPO	−0.054	−1.33	PE	0.500	3.04
NPE	0.177	2.56	PEPE	0.432	1.57
NW	0.513	1.55	PEW	−0.363	−0.33
NK	0.166	2.45	PEK	0.210	0.61
NT	−0.033	−2.44	PET	0.061	1.26
PG	−0.549	−4.40	W	4.097	1.79
PGPG	−0.533	−2.73	WW	10.095	1.72
PGPO	0.257	0.89	WK	−0.391	−0.38
PGPE	0.324	1.22	WT	−0.389	−1.62
PGW	−1.738	1.94	K	0.308	1.46
PGK	−0.434	−1.33	KK	0.943	0.42
PGT	0.144	3.31	KT	0.026	0.38
PO	0.234	2.47	T	0.150	−1.60
POPO	0.159	0.32	TT	0.028	2.44

Variables: N = number of consumers, PG = price of natural gas, PO = price of fuel oil, PE = price of electricity, Z = days of demand for heating, T = time tendency.

Each parameter value can be interpreted as the percentage change in unit costs due to a 1 percent increase of each explicative variable, when the value of rest of the variables remains constant. Confidence level: 95 percent.

SOURCE: Energy Regulatory Commission.

Table A7

Natural Demand in 2010

	Volume (CM/day) [cubic meters a day]		Number of users		Average consumption (CM [cubic meters a day]daily/ user)	
	Conservative	Optimistic	Conservative	Optimistic	Conservative	Optimistic
Residential	3,323,906	5,307,775	1,754,949	2,653,888	1.89	2.00
Commercial	1,396,554	1,576,064	195,577	78,803	7.14	20.00
Industrial	14,403,696	26,799,751	15,000	31,716	960.25	844.99
Total	19,124,157	33,683,590	1,965,526	2,764,407	9.73	12.18

Table A8

Annual Average Costs of Distribution in Symmetric Zones

Number of zones	Volume (US$/CM[cubic meters?])		Per user (US$)	
	Conservative	Optimistic	Conservative	Optimistic
1	82.51	66.29	293.04	294.81
2	87.46	68.09	310.59	302.84
3	95.54	73.04	339.28	324.82
4	104.22	78.65	370.13	349.78
5	113.06	84.46	401.52	375.64

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