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Designing Natural Gas Distribution Concessions in a Megacity:

Tradeoffs between Scale Economies and Information Disclosure in Mexico City

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Introduction

In 1995 the Mexican government initiated structural reform of the natural gas sector—reform that permitted private investment in transportation, storage, distribution, trade 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 specific geographic areas (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 technical and financial proposals, including a market demand study. The winning proposal must be technically sound and offer 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 economies 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 comparative 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 operation. 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 existing distribution infrastructure in the ZMCM and the areas with technical risk.

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* Several sections of this paper draw on and update the analysis contained in Juan Rosellon, editor, *División Óptima de la Zona Metropolitana de la Ciudad de México para Fines de Dristribución de Gas Natural,* Documento de Trabajo 121, CIDE, México.

[1] The Energy Regulatory Commission regulates distribution tariffs through average revenue yield price caps. 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 natural gas distribution 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 to residential consumers, because 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, 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 unit cost analysis for the ZMCM was presumed to be valid up to 2010. In other words, the proportion among unit costs in distinct distribution franchise zones was assumed to remain constant for 12 years.

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[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 through 2010. The demand projections were then plugged into the cost function, and the effects on unit costs of different partitions of the ZMCM were evaluated.

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, services). 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 the above mentioned 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. The translog functional form was then modified to estimate future natural gas demand in Mexico.

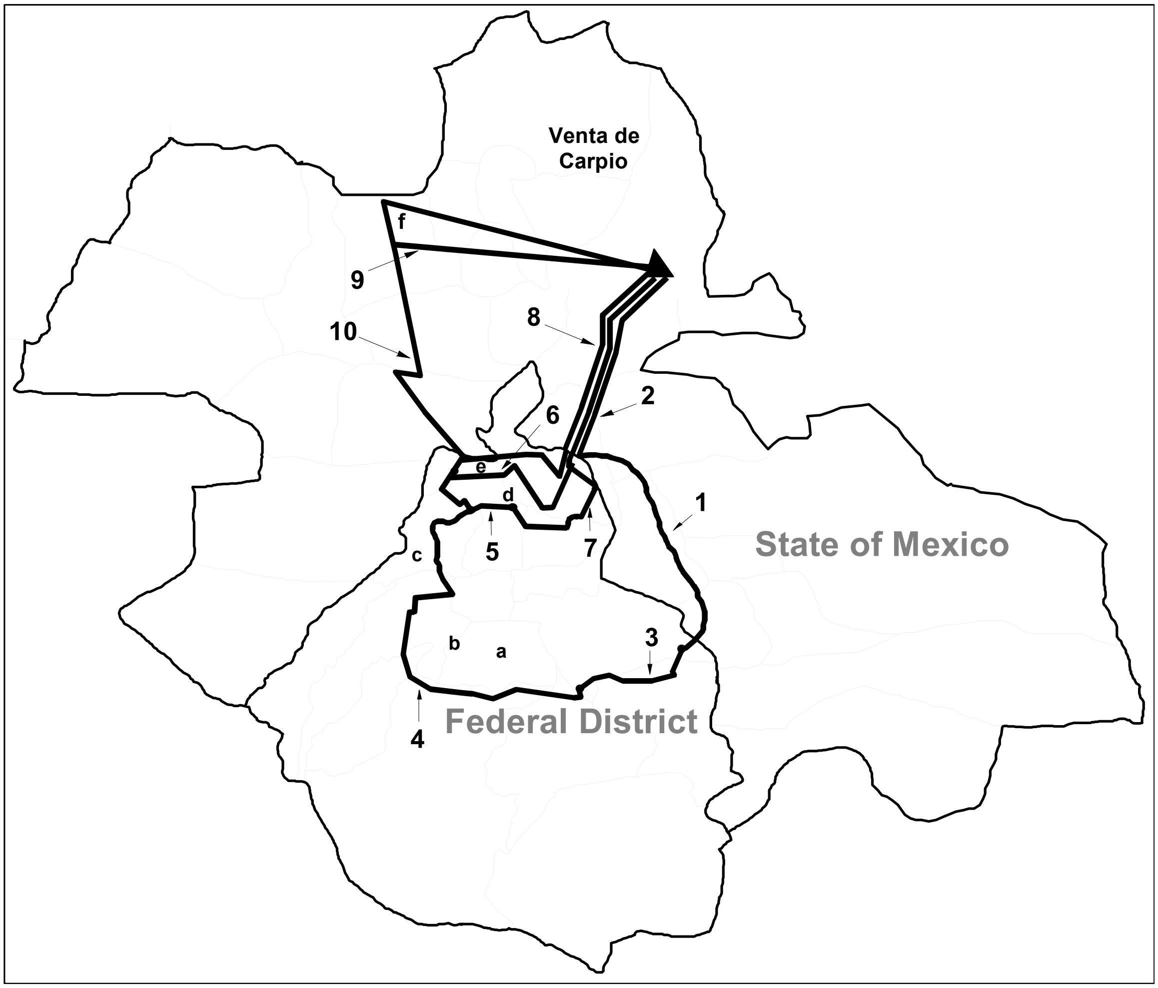
Coefficients of a translog demand function in the natural gas distribution market of the United States were estimated. The data from the resulting demand functions were then included in the estimations for the cost function of different partitions of the ZMCM. Likewise, several economic scenarios were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

Dimensioning a distribution geographic area also needs to consider the technical characteristics of the natural gas distribution franchise zone. In the ZMCM, some distribution infrastructure already existed. The ZMCM is also an earthquake area.

Pre-existing 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 pipelines 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 prone to flooding.[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. As the number of distribution franchise zones that subdivide a distribution area decreases, financial risks may also decrease. As the number of distribution franchise zones increases, so does the financial impact of losing industrial consumers. If every distributor only had very few industrial consumers, demand in one of the distribution franchise zones may abruptly decrease if a large consumer went bankrupt or exited the market for other reasons.

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 distribution companies with more growth options. And the larger the service region, the lower the risk that unforeseeable or uncontrolled events (such as land subsidence 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 energy management services. 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.

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

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—economic and commercial criteria were considered, as well as operational restrictions.

The economic and commercial criteria were:

- Access to gas production.

- Access to markets.

- Condition of existing distribution infrastructure .

- 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).

Table 1. Demarcation Options for the Mexico City Natural Gas Distribution Area

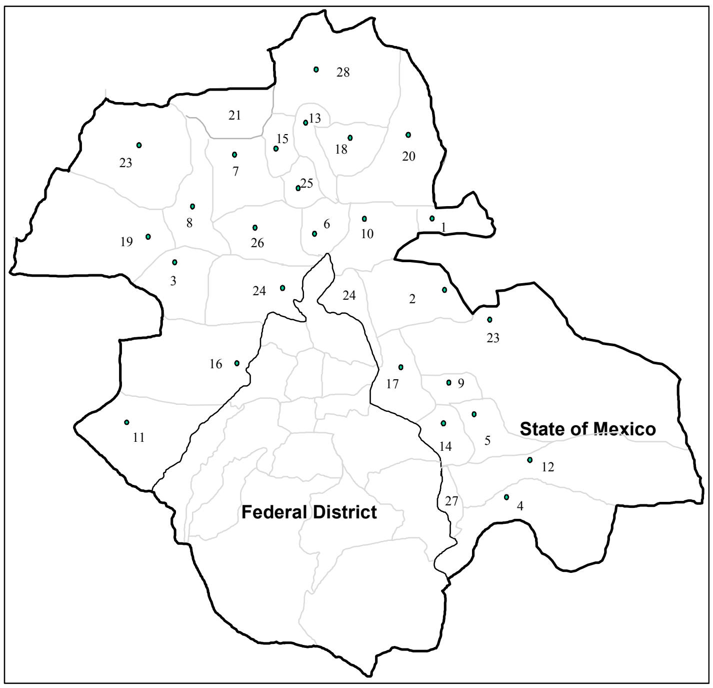
Option	Approximate population (millions)	Degree of connectivity between the Federal District and other states	Number of jurisdictions
Megalopolis	23	Very low—due to distance	16 "delegations"—Federal District. Metropolitan areas of Toluca, Cuernavaca, Puebla Tlaxcala, and Pachuca 91 municipalities—State 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.

[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 (Secretaría de Desarrollo Social, Instituto Nacional de Estadística, Geografía e Informática);* and *Planes y Programas Gubernamentales.*

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, 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 was to be optimized for the year 2010. 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 elements:

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.

The first element used 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 a time trend variable (table A1).

The second 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 explains demand for access from residential and commercial consumers.

[8] Other variables employed included number of families and personal income (measuring purchasing power), number of days a year when heating is required (measuring seasonal demand), 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 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] Results for industrial demand are not presented because they were not statistically significant.

- Demand for heating does not explain demand for access from residential consumers but it does explain demand for volume.

- 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 industrial volume demand (tables A2–A6).

Before the parameters estimated in the first two steps 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 consumption, energy prices, household income, urban territory, population and housing infrastructure, 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, and 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

	Number of consumers	% change from base scenario	Volume (MMCMY)	% 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	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.

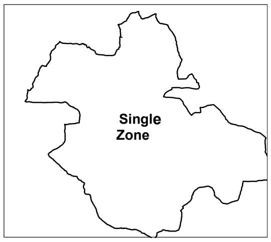
This comparative analysis indicated that the demand model provided a reasonable explanation of natural gas demand in Mexico. Furthermore, the base scenario could be used with confidence because the inelastic behavior of demand suggests that results from the demand equation are not so sensitive to measurement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

In parallel, demand was estimated using criteria for the technical and market conditions of the ZMCM. This scenario, termed 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 base 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 base 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.

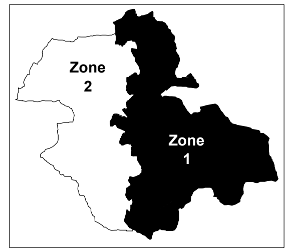
The calculation of demand by consumer class was used to estimate natural gas distribution costs for several hypothetical symmetric and non-symmetric partitions of the ZMCM. In the symmetric case the ZMCM was divided into five distribution franchise zones with the same number of clients, the same volume of delivered gas, and the same amount of urban territory. This was deemed unrealistic because it assumed that load and all other variables are uniformly distributed. The next step was to account for heterogeneity in population density and load characteristics by using non-symmetric 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

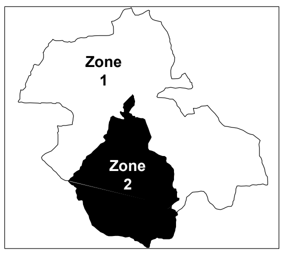
Single zone



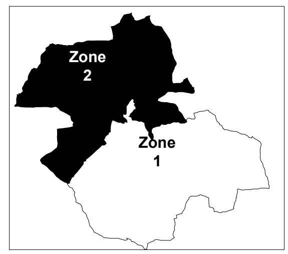
East and West



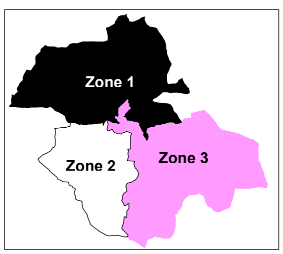
Federal District and urban municipalities of the State of Mexico



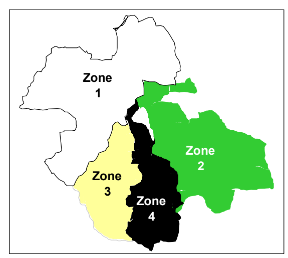
Southeast and Northwest



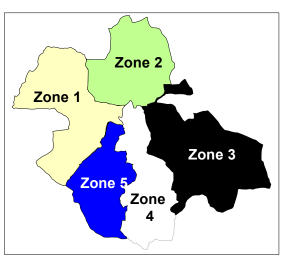
Northern urban municipalities, southwestern urban municipalities and the western part of the Federal District, and southeastern urban municipalities and the eastern part of the Federal District



Eastern and Western Federal District, Eastern and Western State of Mexico



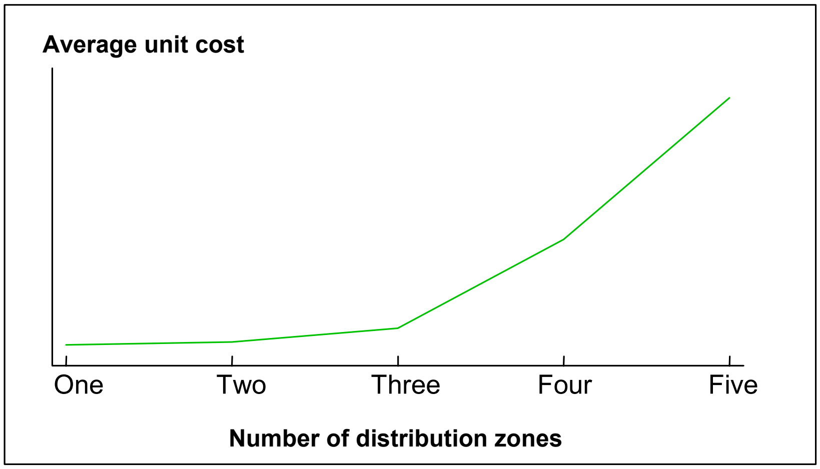
Eastern and western Federal District, Eastern, Western, and Northern State of Mexico



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



The data indicate that even with similar estimated volumes of operations, unit costs vary considerably with more distribution franchise zones. The design of distribution franchise zones is therefore an important determinant of 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 partition options and the lowest difference with respect to the single-distribution franchise zone option.

Synthesis of Decision Criteria

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

- Static 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 extending distribution service and in providing related services such as connection, metering, reconversion, maintenance and repair of equipment, gas marketing, and energy management services. Creating geographic distribution franchise zones requires balancing these criteria with the financial risk criterion.

More distribution franchise zones implied more information for comparative regulation, greater 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 influenced 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 corresponded to the Federal District and urban municipalities, and to the Northwest and Southeast options. The other alternatives would have required breaking the integrity of pre-existing infrastructure, diminishing its value.

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 distributor can better manage growth in demand in large zones because the 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.

- 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) and 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 assessment suggested that the Federal District–urban municipalities option was the best. This was supported by consultations with interested public and private parties.[10] Consultations centered on three issues: the viability of each partition option, the desirability of promoting competition in related services, and making best 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 specific interconnection agreements should be negotiated when part of the infrastructure that is relevant for one distributor lies in the zone of the other distributor.

Results to Date

Unlike other privatizations in Mexico, in the natural gas distribution bids the government only establishes the number of consumers that must be covered at the end of the first five years. When applicable, it sets the value of the preexisting distribution facilities to be acquired by the winning bidder. It also requires that two-thirds of total investment must be financed by capital owned by the firm; restricting debt financing to one-third. 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 activities and how they may be financed (Rosellón and Halpern 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 and Halpern 2000).

[10] Parties to the consultations included, among others 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.

Because the minimum number of consumers to be served at the end of the first five years of operation is the principal award criterion, the local distribution companies have an incentive to expand the network to connect as many consumers as possible.[11] This implies extending the distribution network quickly despite the inconvenience to the public. The bidding criteria therefore provided a strong incentive to start building the network in high-density areas—as opposed to a looped network that could grow in a more gradual, less disruptive fashion—in order to comply with minimum consumer coverage obligations.

The bidding package for the ZMCM distribution concessions 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 investment commitments (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 winning bidders 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).[12] Maxigas is a consortium of Gaz de France (75 percent) and Buffete Industrial (25 percent).

Metrogas' average revenue cap of $2.42 per gigacalorie is higher than the national average of $1.49. Maxigas' 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' existing industrial consumers pay more than new ones, partly because the Metrogas distribution network has conducted lower volume than the Maxigas network. 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.

[11] The other criterion is the lowest average revenue.
[12] 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).

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 were 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 installations be performed with "directional drilling" to minimize inconvenience to city dwellers and traffic. This is particularly difficult in the ZMCM because there is little mapping of underground water and cables systems in the distribution franchise zone. The only practical solution is the "open trench" method, which, causes disruption of traffic and other services. Both distribution companies report that a March agreement between the CRE and the Federal District states that pipes may 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 and safety of natural gas.

Local distribution companies in the ZMCM also perceive 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 interference with granting of rights of way for private distribution pipelines that pass near PEMEX oil pipelines. This is being handled through meetings among the Ministry of Energy, the CRE, and Pemex legal counsels. 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 National 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 specific 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 whether and how Maxigas and Metrogas may seek to 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 trend.

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 trend.

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

Explanatory 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 trend.

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 trend.

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 trend.

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 trend.

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. Projected Demand for Natural Gas in 2010

	Volume (M3/day)		Number of users		Average consumption (M3/day/ 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$/M3)		Per user (US$)	
	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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