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CIDE

NÚMERO 120

JUAN ROSELLÓN Y DAGOBERTO BRITO

PRICING NATURAL GAS IN MEXICO

Pricing Natural Gas in Mexico

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Abstract

Natural gas in Mexico is produced by a state monopoly (Pemex). The price of gas at the Houston Ship Channel and the arbitration point between imported gas and gas produced in Mexico is used in a formula based on the *netback* to determine the price of gas in Mexico. This paper will show that the price implied by this methodology is equal to the shadow price of the domestic gas production constraint in a welfare maximization problem and therefore, this formula for regulating the price of gas in Mexico is consistent with the objectives of a regulator seeking to maximize social welfare.

The netback formula, however, leads to incentives to divert or reduce production in the south in order to move the arbitration point south and increase the price of domestically produced gas. Since gas produced in the north is a substitute for gas from the Texas market, an increase in production in the north will not change the location of the arbitration point as the marginal gas is exported.

The elimination of import tariffs in Ciudad Juarez does not affect the prices at Los Ramones and Ciudad Pemex unless limited pipeline capacity at Burgos restricts exports. If there is an export bottleneck at Burgos, the price of gas at Burgos will reflect the shadow price of that restriction.

If the arbitration point is north of the junction at Los Ramones, elimination of tariffs at Juárez implies a reduction of the price at Ciudad Pemex. Gas imported from the Permian Basin will displace gas imported from Texas at Burgos and move the arbitration point north.

Only modifications in demand and supply that change the relevant arbitration point will affect the price in Ciudad Pemex. Changes in demand and supply between the relevant arbitration point and the border will not change the arbitration point.

Key words; natural gas, pricing, Mexico, regulation

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1. Introduction

Natural gas in Mexico is produced by a legal monopoly of the state called Petróleos Mexicanos (Pemex) and its price, therefore, must be regulated. Consequently, the Energy Regulatory Commission of Mexico (CRE) created a price-cap methodology based on international prices to ensure allocative and distributive efficiency in the national natural gas market.

Currently, some problems related to this methodology have been detected in Mexico. Firstly, there is a generalized perception that the price implied by this methodology is too high. Mexican industrial consumers believe that the national gas price does not reflect the production and exportation potentiality of the country due to Pemex monopoly over production. Secondly, future increases in the gas price are feared since national gas demand will grow due to demand increases from electricity generators and local distribution companies. These demand increases will most likely be met with imports that, under the current price methodology, will push the price of domestic gas up. Finally, since the methodology is based on a US benchmark price, the Mexican price is very sensitive to North American weather variations. These stational changes generate additional rents for Pemex.

This paper describes and makes a formal analysis of the CRE´s methodology for regulating the domestic natural gas price (*firsthand sales price*). Contrary to the perception of various consumers, we show that the firsthand sales formula has solid microeconomic foundations and is consistent with the objectives of a regulator seeking to optimize social welfare subject to Pemex individual rationality constraint in its gas sales.

The following section describes the firsthand sales methodology as it is conceived in official documents as the Directive on the Determination of Prices and Rates for Natural Gas Regulated Activities.[1] The superiority of this methodology over others is also presented in this section. Section three presents the formal analysis of the methodology. After studying spatial and intertemporal implications, a formal microeconomic analysis is carried out. This last analysis shows that the methodology results from solving an optimization problem. The methodology´s efficiency is analyzed in the context of four models with increasing complexity. Finally, this paper concludes with some comments regarding the *arbitration point* concept and the system of natural gas prices, topics that have been recently debated by market players in Mexico.

[1] See Comisión Reguladora de Energía (1996)

2. *Description of the Methodology*

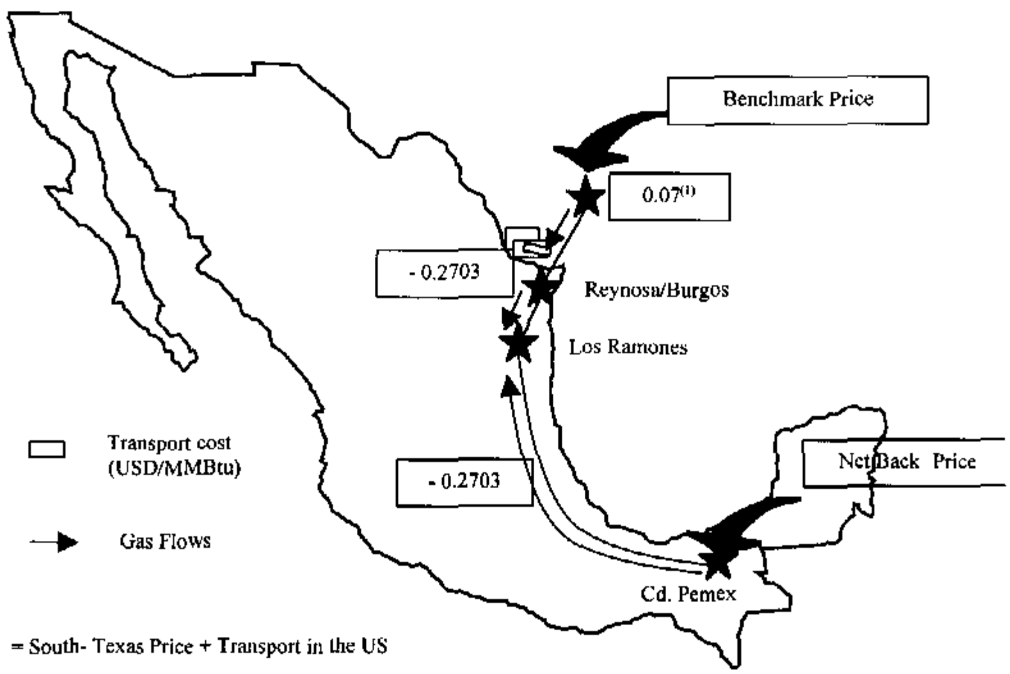
The Netback Concept

The netback methodology used in Mexico to set the price of national natural gas takes as its benchmark a South Texas price and adds costs of net transportation from this region to Ciudad Pemex, in the Southeast of Mexico, where most of the associated gas is produced.

In the netback methodology, the last point where imported gas is consumed, and where import and domestic flows and prices coincide, is defined as the arbitration point. The price of Mexican natural gas is therefore defined as the sum of the Texas benchmark price plus the transport cost from the border to the arbitration point less the transport cost from this point to Ciudad Pemex.

The arbitration point moves as the balance between imports and domestic production of natural gas changes. This point moves north (south) as imports decrease (increase) In practice, due to administrative reasons, the arbitration point moves discretely (rather than continuously) every time there is a change in the commercial balance.

Netback Mechanism



Price at Reynosa = South- Texas Price + Transport in the US

Price at Cd. Pemex = Price at Reynosa +
(Transport from Reynosa to Los Ramones) -
(Transport from Los Ramones to Cd. Pemex)

= Price at Reynosa - 0.1467 USD/MMBtu

(1) Estimated transport cost in the US

The Firsthand Sales Price Formula

More specifically, the methodology that regulates the price of Mexican gas links this price to the dynamic behavior of the "Houston Ship Channel" hub and uses, as initial condition, the price charged by Pemex by March 1996:

$$\begin{aligned} VPM_i^d &= B_0 + HSC_{i-1} - HSC_0 + TP_i - TP_0 \\ &= TV|_0 + TP_0 + HSC_{i-1} - TV|_0 - 0.7 + TP_i - TP_0 \\ &= HSC_{i-1} - 0.7 + TP_i \end{aligned}$$

where:

VPM_i^d	maximum first-hand-sale price on day i;
B_0	base price of first-hand-sales at Ciudad Pemex on March 1st, 1996;
HSC_{i-1}	price at Houston Ship Channel on day i-1;
HSC_0	base price at Houston Ship Channel on March 1st 1996; this price is equal to the average of the Texas Eastern Transmission price and the Valero price on March 1st 1996, plus a seven-cent price differential;
TP_i	transportation rate from Reynosa to the arbitration point less transportation rate from the arbitration point to Ciudad Pemex on day i;
TP_0	transportation rate from Reynosa to the arbitration point less transportation rate from the arbitration point to Ciudad Pemex on March 1st, 1996, and
$TV|_0$	average of the Texas Eastern Transmission price and the Valero price on March 1st 1996.

After public hearings carried out during 1996, CRE considered the HSC market the most relevant since it satisfied the following fundamental criteria:

It is a liquid market, which assures that the benchmark price is neither subject to manipulation nor influenced by Mexico's gas trade balance;

It has an associated hedging market which enables gas marketers to reduce price volatility to their customers; and

It is geographically close to the Pemex pipeline system connected to the South Texas area.[2] From this point of view, the Houston Ship Channel is a better selection for a hub relevant to the economics of the Mexican gas market than, say, a hub or a set of

[2] Texas Eastern Transmission (Tetco) and Valero Transmission (Valero) are the South Texas pipes which have a physical connection to the Pemex network. A historical price differential between Tetco and Valero and the Houston Ship Channel of .07 USD was calculated by CRE. This price differential is a *proxy* for transport cost.

hubs in regions of North America not physically linked to the Mexican market.[3]
In addition, the benchmarking methodology does not differ greatly from the methodology that Pemex had previously employed. Thus, the transition to the new formula will not create large distortions in prices. In fact, the prices resulting from the application of the formula will not differ substantially from the current ones and will remain less than the HSC prices:

Natural Gas Prices (Annual Average)

USD/MMBtu	1996	1997	1998
Houston Ship Channel	2.37	2.53	2.19
Cd. Pemex CRE´s Methodology*	2.13	2.30	1.95

*Computed with preliminary transport rates.
SOURCE: Comisión Reguladora de Energía

Methodology's Rationale

Principles similar to the firsthand sales price methodology are used internationally. For example, in Germany, the Netherlands, Switzerland, Spain, Sweden, and Denmark, gas prices are set according to prices of substitutes. Countries such as Belgium, France, and Italy use a mix of this last method with cost-based pricing, while the price of imported gas is set in countries such as Japan and the United States by adding the price at the border plus costs of transportation, distribution, and storage.[4]

Regulators in Mexico did not choose a cost-based pricing formula since more than 80% of the natural gas production is associated with oil production. This means that oil and natural gas are joint products and that there is no way to isolate the marginal cost of producing Mexican natural gas alone.[5] Hence, there is no way to compare the marginal cost of producing natural gas with its marginal product.

Neither was comparing prices with other fuels a very attractive option since prices of natural gas substitutes in Mexico (such as fuel oil, diesel, and liquid petroleum gas) are neither competitively determined nor do they respond to prices in markets with different dynamics to the natural gas market.[6]

[3] Therefore, CRE decided not to use a weighted average of prices from different trading U.S. gas centers as suggested by Swydan (1996).

[4] International Energy Agency (1991).

[5] See M.A. Adelman (1963).

[6] See Brito, D. L., Littlejohn, W., and J. Rosellon, (1998) for a detailed analysis of the methodology used in Mexico to set the price of domestic liquid petroleum gas.

In light of the foregoing, the methodology based on an international benchmark price in the US seemed to be the best option since it considered the opportunity cost of Mexican gas with respect to the North American gas market, one of the biggest and most competitive in the world.

3. Microeconomic Foundations

Efficiency

The main question regarding the natural gas pricing methodology used in Mexico is what is the implication for overall efficiency. This seems to be a problem in the theory of the second best in which two equilibrium conditions have to be satisfied for efficiency: spatial and intertemporal conditions. In the spatial market, the price of natural gas must be linked to transport costs while in the intertemporal market the price of natural gas at any two points in time should be linked by the interest rate and the cost of holding natural gas.

The current methodology implies an equilibrium in the spatial market since the marginal cost of imported gas and the marginal cost of domestic gas are the same at the arbitration point. However, the methodology may cause intertemporal distortions due to the high cost of transporting natural gas. For example, transporting the energy equivalent to one barrel of crude one thousand miles costs:[7]

- Natural gas transported by pipeline: $3.00 dollars;
- Liquified natural gas transported by sea: $10.20, and
- Crude oil: $ 0.10

These factors may cause the Mexican supply to react inappropriately to demand changes in the United States. For example, by linking the US and Mexican natural gas prices the netback methodology introduces distortions generated by the US weather into the Mexican market. Thus, a very cold winter in the northeastern USA during 1996-97 caused a dramatic increase in the natural gas bills paid by Mexican consumers.[8]

When the intertemporal equilibrium condition is violated, is it sensible to impose the spatial condition? The theory of the second best suggests that the answer to this question is unclear. Having the price of natural gas reflect the cost of imported gas means that the marginal gas will be used efficiently, but imputing this price to domestic production results in rents to Pemex and creates intertemporal distortions such as a wrong selection of technology over time. A second best solution, such as a two-part tariff, would reflect gas' long-term opportunity cost. Natural gas would be priced in terms of its scarcity and not in terms of pipeline bottlenecks.

[7] See Brito, D. L., and E. Sheshinski (1997).

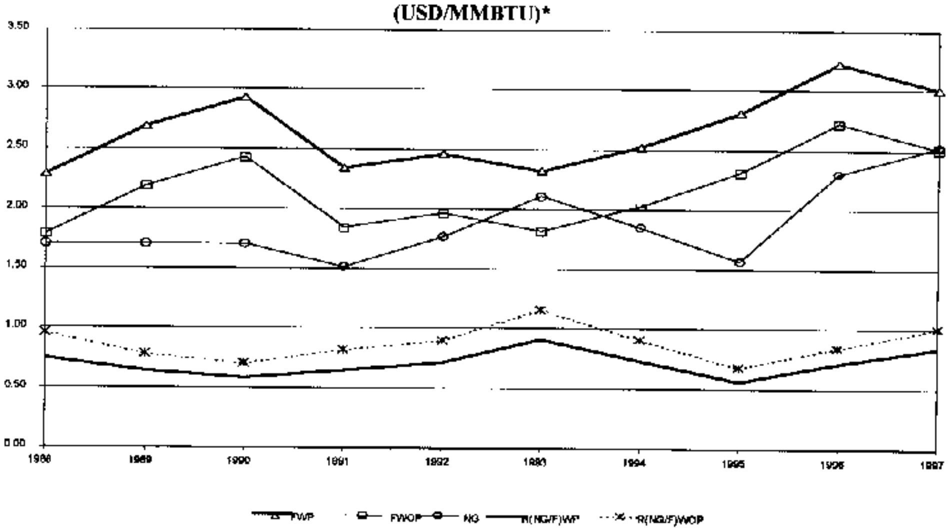
[8] Natural gas price in Mexico increased by 135% between October 1996 and January 1997.

However, under the current methodology natural gas is a more efficient fuel (both technically and economically) than the high-sulphur fuel oil used in Mexico. This fact is more evident if a three dollar premium per MM cubic feet is added to the environmental cost of fuel oil:

Fuel Oil Prices in the US*

AÑO	USD/MMBTU Fuel Oil (premium)	Fuel Oil (no prem.)	Natural Gas	FO/NG (premium)	FO/NG (no prem.)
1988	2.29	1.79	1.71	0.75	0.96
1989	2.69	2.19	1.71	0.64	0.78
1990	2.93	2.43	1.71	0.58	0.70
1991	2.34	1.84	1.51	0.64	0.82
1992	2.46	1.96	1.77	0.72	0.90
1993	2.32	1.82	2.11	0.91	1.16
1994	2.52	2.02	1.85	0.73	0.91
1995	2.81	2.31	1.57	0.56	0.68
1996	3.22	2.72	2.30	0.71	0.84
1997	3.01	2.51	2.53	0.84	1.01

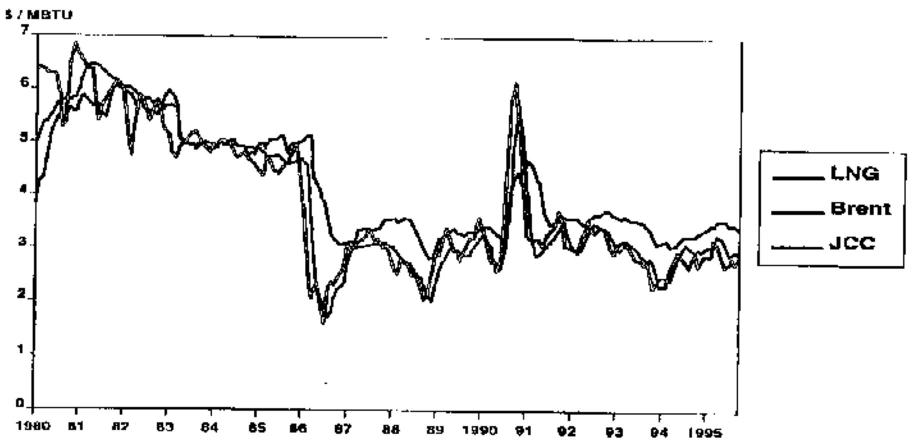
PRICES OF NATURAL GAS AND FUEL OIL (USD/MMBTU)*



*Calculated with data from the US Department of Energy and the International Energy Agency

A comparison of natural gas and fuel oil prices in Japan also illustrates the fact that natural gas is cheaper than fuel oil:

CIF JAPAN LNG / CRUDE PRICE COMPARISON



Superiority of natural gas over fuel oil in terms of efficiency --together with Mexican environmental laws that limit the use of highly polluting fuels -- implies a corner solution regarding intertemporal choice of technology. That is, <u>intertemporal distortions associated with the pricing methodology used in Mexico are irrelevant</u>.

Microeconomic Analysis

We must first point out that Pemex profit maximizing problem in the production of natural gas is not typical:

- Since Mexican natural gas is a joint product of oil, gas supply is determined by supply of oil. Production of natural gas does not react to any change in price or demand.
- Since there is no marginal cost of producing gas alone, there is no way to compare the marginal cost of producing natural gas with its marginal product.
- The location of the arbitration point is a function of the import-domestic production balance. This means that price and profits from selling Mexican natural gas are basically driven by domestic and international demand .

Therefore, even though it is a monopolist in the production of domestic gas, Pemex does not decide production, allocation, and price of natural gas by equating marginal cost and marginal revenue.

Nevertheless, the national gas price methodology has solid microeconomic foundations. In particular, it results from solving the optimization problem of a policy maker who maximizes welfare subject to demand and production constraints. In the next few pages, we formalize the analysis of the firsthand sales price regulation.

Basic Case

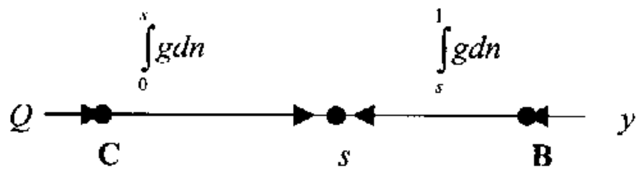


Figure 1

The essential features of natural gas pricing in Mexico are represented in figure 1. This diagram is a representation of the Mexican gas pipeline system. A fixed amount Q of (associated) natural gas is produced at point **C**. Imported gas y is introduced by point **B**. Both kinds of gas can be transported to points on the line between **C** and **B**. Point **C** can be thought of Ciudad Pemex, **B** as Reynosa-Burgos, and the line **C-B** as demand D in Mexico.

The point s is what is referred to as the "arbitration point" and is such that $s = \frac{Q}{D}$ ($s \geq 0$), where the origin is measured at **C**. At the arbitration point, the price of gas from **C** is equal to the price of gas from **B**. Imported and domestic gas flows also coincide at point s.

Assume that demand D is inelastic, distributed uniformly on line **C-B**, and given by the distribution function g. Total demand on **C-B** is then given by:

$$D = \int_0^s gdn + \int_s^1 gdn$$

Assume that the cost of moving natural gas from point **C** to a point located at n is cn, and the cost of moving natural gas from point **B** to a point located at n is $c(1-n)$. The first hand sales price methodology sets the price of gas at **C** as the sum of the benchmark price p (in the Houston Ship Channel) plus the transport cost from the border line to the arbitration point, less the transport from this point to Ciudad Pemex, that is:

$$\lambda = p + c(1 - s) - cs$$

or

$$\lambda = p + c(1 - 2s)$$

where λ represents the price at Ciudad Pemex.

This methodology satisfies two basic equilibrium conditions:

- When several distinct gas flows converge at a sales point, the price is the same for all flows and is independent of the origin of the flow (*One Price Law*), and
- The price differential between two places reflects the transport costs.

Likewise, the first hand sales price methodology is consistent with the objectives of a regulator who seeks to optimize social welfare $W(D)$ (as a function of gas consumption) respecting Pemex' maximization of benefits (see annex). This optimization exercise demonstrates that first hand sales price methodology has solid microeconomic foundations and that:

- The optimal value of the arbitration point s is set once D and Q are determined. That is, the arbitration point is located at the last place where imported gas is consume
- Changes of the benchmark price p imply modifications in the distribution of rents between Pemex and consumers
- A movement to the south of the arbitration point causes an increase in the Mexican gas price two times larger than the value of the marginal cost of transport: $\Delta\lambda = 2c\Delta s$

Production in Burgos

More complexity may be added to the basic model if production in the northern fields of Burgos is permitted. Suppose this production is Q_b and that production at **C** is Q_c. Under these assumptions, the arbitration point is now defined as $s = \frac{Q_c}{D}$. The arbitration point is characterized by the coincidence of gas flows from Ciudad Pemex and Burgos.

For this new scenario, we will next study the dynamics of the price methodology when production is increased at **C** or at **B**, with or without imports.

Additional Production in Burgos with Imports

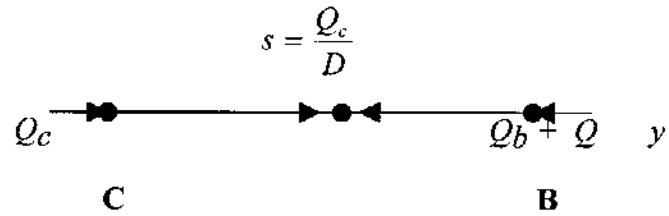


Figure 2

Figure 2 presents the situation of more production in Burgos, when imported gas is flowing into Mexico by its northern border. The increased production at **B** displaces imported gas thus not affecting the arbitration point's location.

Additional Production in Burgos without Imports

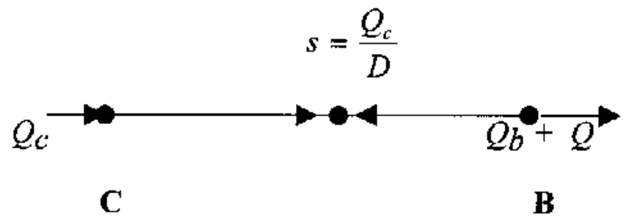


Figure 3

Figure 3 illustrates an increase of production at Burgos when there are no imports and gas from Burgos is being exported. In such a case, when production at Burgos is increased the arbitration point does not change and national gas prices are not modified unless the increased gas supply at Burgos has an influence over the benchmark price *p*.

Additional Production in Ciudad Pemex with Imports

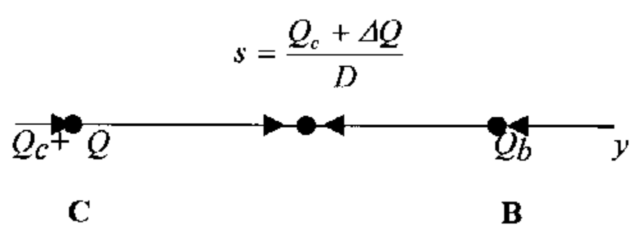


Figure 4

Figure 4 points out the case of an increase of production at Ciudad Pemex under the existence of imports. In this situation, the arbitration point will move northwards and the price at **C** will decrease by twice the marginal cost of transport: $\Delta p = \frac{2c\Delta Q}{g}$. The increase of production at Ciudad Pemex will cause that imported gas to be substituted with Burgos gas.

Additional Production in Ciudad Pemex without imports

$$s = \frac{Q_c + \Delta Q}{D}$$

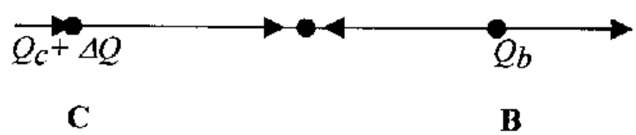


Figure 5

The case of an increase in production at Ciudad Pemex when the Burgos gas is exported is illustrated in Figure 5. The larger production at **C** moves the arbitration point to the north and the price at Ciudad Pemex decreases proportionally more than the decrease in the transport cost.

Location of Production

The previous analysis posits the question whether Pemex should direct its efforts to increase production in Burgos or in the southeast. This analysis may be carried out from a social viewpoint (ie., what is the social value of the gas produced in the north and in the south?) or from Pemex' perspective (ie., what are Pemex' incentives to produce in the south or the north?).

Since gas produced in Burgos is a substitute for gas imported from Texas, there is no change in the amount of resources needed for transporting gas when production at Burgos is increased. This implies that the social value of gas discovered in the north is equal to the savings in imports $p\Delta Q$, where p is Houston's benchmark price.

Conversely, gas discovered in the south must be transported a distance s but it replaces gas transported a distance $1\text{-}s$ from the northern border to the arbitration point. Therefore, the net total cost of transporting this gas is $c[s - (1\text{-}s)] = c(2s - 1)$. Social profits are then equal to $p\Delta Q - (2s - 1)c$.

If the arbitration point is located at $s = 0$ (ie., at Ciudad Pemex), profits from increased production in the south are equal to savings in imports, $p\Delta Q$, plus savings in transporting this gas from the Texas border, c. If the arbitration point is at $s = 1$ (that is, at the Mexico-Texas borderline), profits will equal savings in imports, $p\Delta Q$ less the cost c of transporting gas to the border so as to export it. When $s = ½$, the social profit of discovering gas in the south is equal to the savings in imports, $p\Delta Q$.

We have seen that an increase of production in the south will move the arbitration point northwards implying a price decrease two times greater than the reduction in the marginal transport cost. Therefore, there are incentives for Pemex to produce in the north since more production in the southeast implies a growth in consumer surplus due to price reductions.

Northwestern Subsystem and Tariff Policy

Assume now there is a subsystem northwest of the arbitration point. A pipeline that goes from Los Ramones (**R**) to Ciudad Juárez (**J**) passing through Monterrey, Torreón, and Chihuahua. Assume there is also a tariff for imports coming through the northwestern border at Ciudad Juárez. The essential elements of this new scenario are illustrated in figure 6.

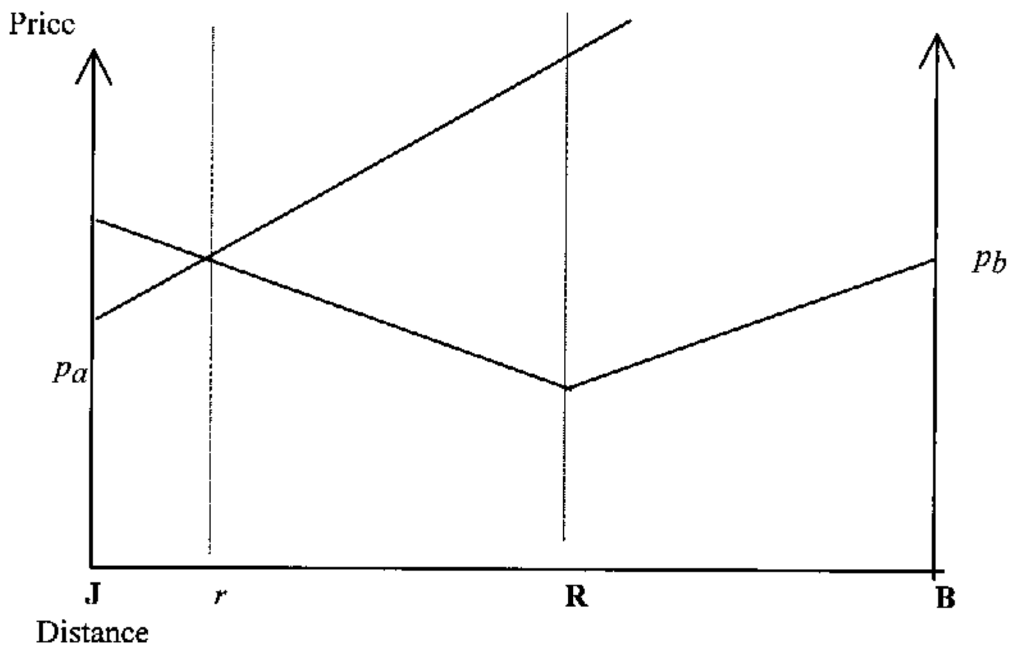


Figure 6

Suppose gas is produced at point **R**. **R** is located at the midpoint of the distance between **B** and **J**. Gas can be imported or exported at **B** and **J**, and the cost of transporting gas a distance n is given by cn. We will study the implications of having limited pipeline capacity at Burgos.

No Export Restrictions at Burgos

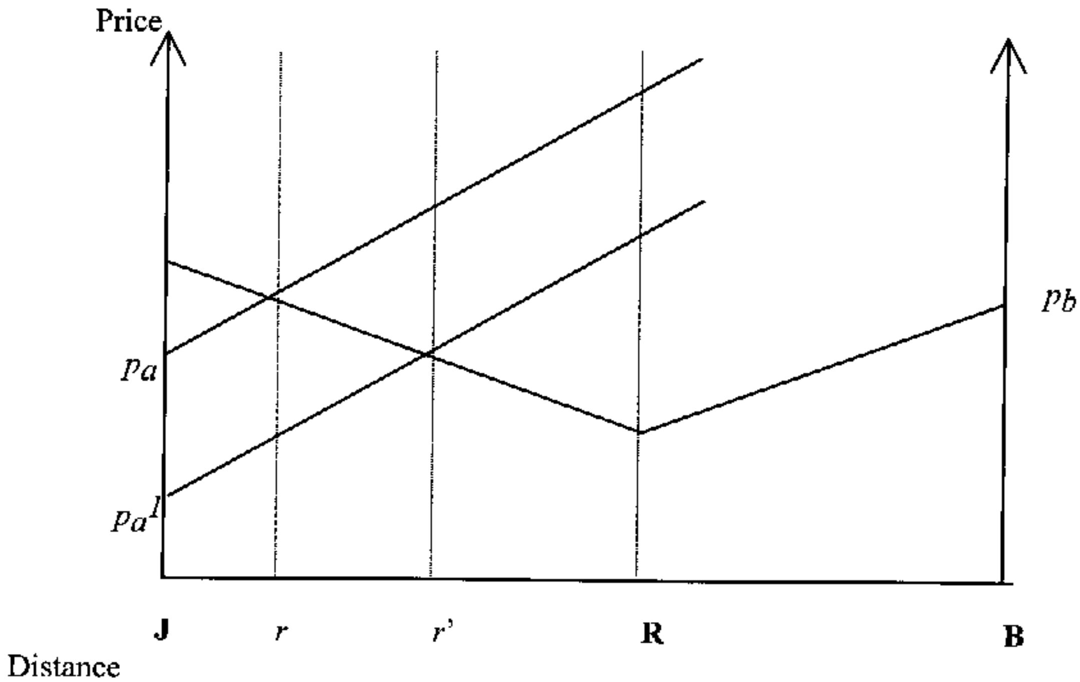


Figure 7

If the price at Ciudad Juárez is less than the Burgos price, $p_j < p_b$, gas will be exported through point **B**. This will determine the price at **R** and the arbitration point r will be determined according to the *One Price Law*.

Suppose now that the import tariff is eliminated at Ciudad Juárez. This will cause a reduction in price at **J** from p_a to $p_a{}^1$, and a movement of the arbitration point from r to r' due to the larger amount of imports coming through **J** (see figure 7).

Technical Export Restrictions at Burgos

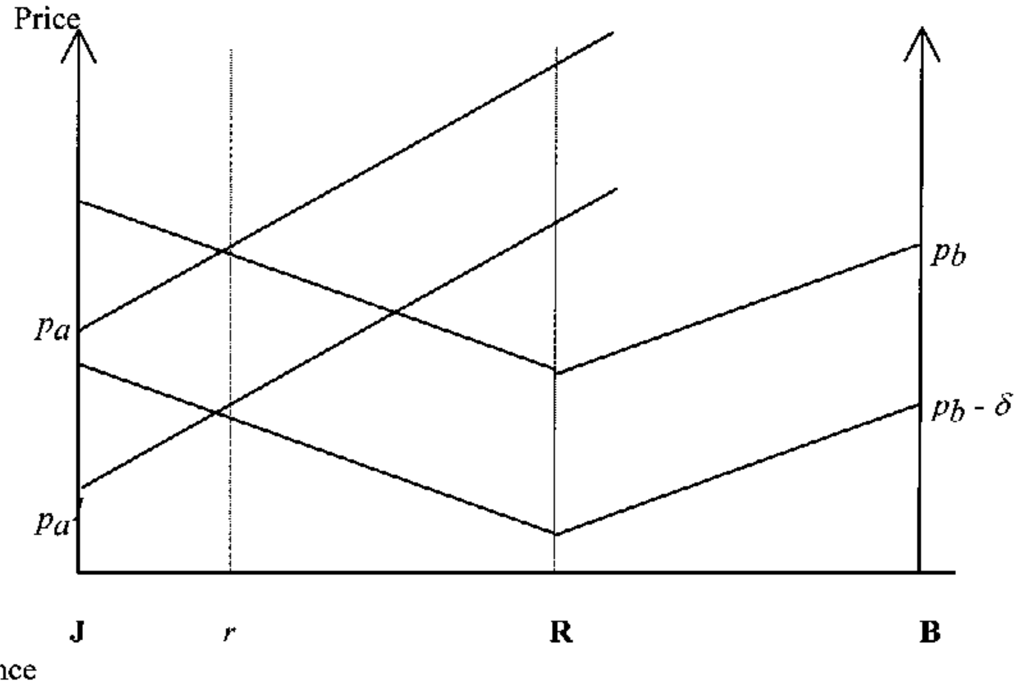


Figure 8

Now assume there is an export bottleneck **K** at point **B**. Under price p_j, restriction **K** is not binding. Therefore, p_b will determine the price in **R** and the arbitration point r will be established according to the *One Price Law.*
When the import tariff at **J** is eliminated, price at Ciudad Juárez p_a will decrease to $p_a{}^1$, the arbitration point will tend to move right, and more gas will be available to be exported through **B**. However, restriction **K** will be binding for the new price $p_a{}^1$ and the equilibrium conditions will require a general decrease in prices. The arbitration point r will then remain fixed.
In fact, $p_a{}^1$ will now be the new benchmark for the price in **R.** Likewise, there will be a price discontinuity in the price at Burgos which will change from p_b to p_b -δ where δ is the shadow price of the export restriction (see figure 8).

The General Model

Figure 9 captures the essential features of the complete Mexican gas pipeline system. Q_a represents imports from West Texas, Q_b represents production at Burgos, and **R** is Los Ramones, the point where the main system and the northwest subsystem are physically interconnected. The line **JR** is demand between Juárez and Los Ramones

(Monterrey is located on this line), **BR** is demand between Los Ramones and Burgos, and the line **RC** is demand in the center and south of Mexico. **C** is Ciudad Pemex. Other assumptions and notations are:

- The distribution of gas on lines **JR, BR,** and **CR** is given by the general density functions $f(n)$, $g(n)$, and $h(n)$.
- Gas is supplied at **J**, **B**, and **C** by the amounts Q_a, Q_b, and Q_{cpm}.
- The price at the arbitration point between **J** and **R** is given by p_{ar}.
- The price at the arbitration point between **B** and **R** is given by p_{br}.
- The price at the arbitration point between **C** and **R** is given by p_{cr}.
- The price at point **J** is given by p_a.
- The price at point **B** is given by p_b.
- The price at point **C** is given by p_{cpm}.
- The price at point **R** is given by p_r.
- The arbitration point between **J** and **R** is given by r.
- The arbitration point between **B** and **R** is given by s.
- The arbitration point between **C** and **R** is given by t.
- The cost of moving gas a distance n is cn.

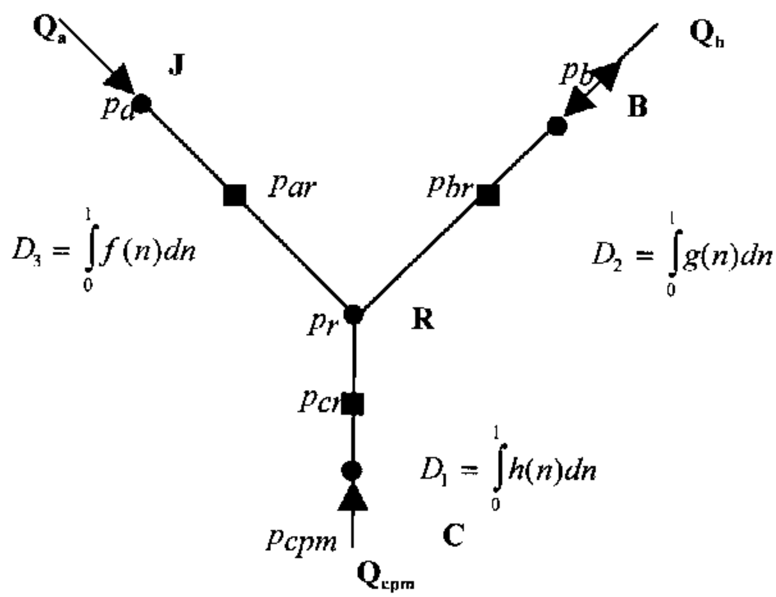


Figure 9

Our analysis is based on the following remark:

*There cannot be equilibrium with three arbitration points, as this would require that **R** be a production source.*

We next analyze three cases that correspond to three direction options for the gas flows arising from Burgos and Ciudad Pemex. Firstly, we analyze the case where gas from Burgos contributes to satisfy demand in the Ciudad Pemex-Los Ramones segment and in the Los Ramones-Juárez segment. Secondly, we study the case when gas from Burgos and Ciudad Pemex are enough to satisfy segments Burgos-Los Ramones and Ciudad Pemex- Los Ramones, respectively, and also contribute to satisfy demand in Juárez- Los Ramones. Finally, we study the case when Ciudad Pemex gas contributes to satisfy demands in Juárez- Los Ramones and Burgos-Los Ramones.

*Case 1: The arbitration points are located between **CR** (Ciudad Pemex-Los Ramones) and **JR** (Juárez-Los Ramones)* (figure 10).

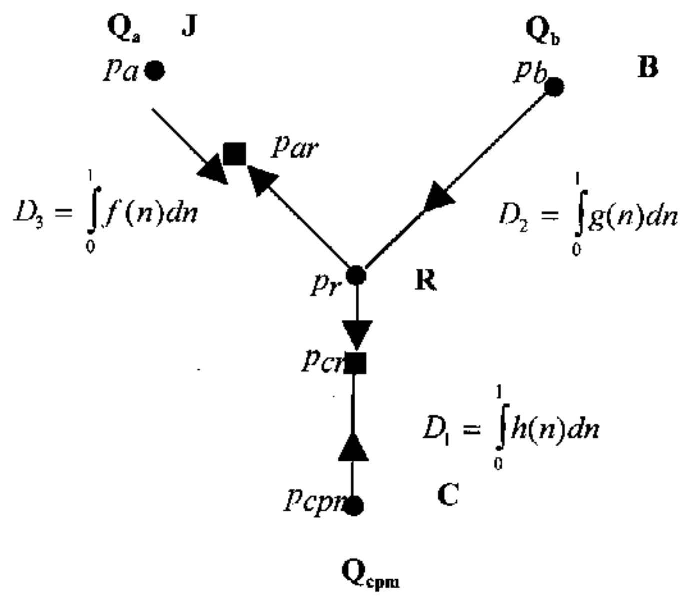


Figure 10

In this case, the price of gas is determined by the following relationships:

$$D_1 = \int_0^t h(n)dn \qquad (1)$$

$$pr = p_b + c \quad (2)$$

$$pcpm = pr + c(1\text{-}t) = p_b + c(2\text{-}t) \quad (3)$$

$$par = pr + cr = p_b + c\ (1+r) \quad (4)$$

Equation (1) is sufficient to determine t and equation (2) is sufficient to determine *pr*. Equation (3) also determines *pcpm*. The following relationship must hold for the distribution in figure 10 to be an equilibrium:

$$pa = pr + c(2r\text{-}1) = p_b + 2\ cr \quad (5)$$

As the price *pa* of gas at **J** drops (due to trade liberalization), the arbitration point on the **JR** segment moves closer to **R**, and the gas surplus is exported through Burgos. However, as long as gas is flowing from **B** to **R**, the price at **R**, *pr*, remains unchanged and thus *pcpm* remains unchanged. Only a variation in demand D_1, can change *pcpm*. If *pa* drops to the level where the arbitration point is in **BR**, then *pa* becomes the benchmark price.

Case 2: The arbitration point is in JR (figure 11).

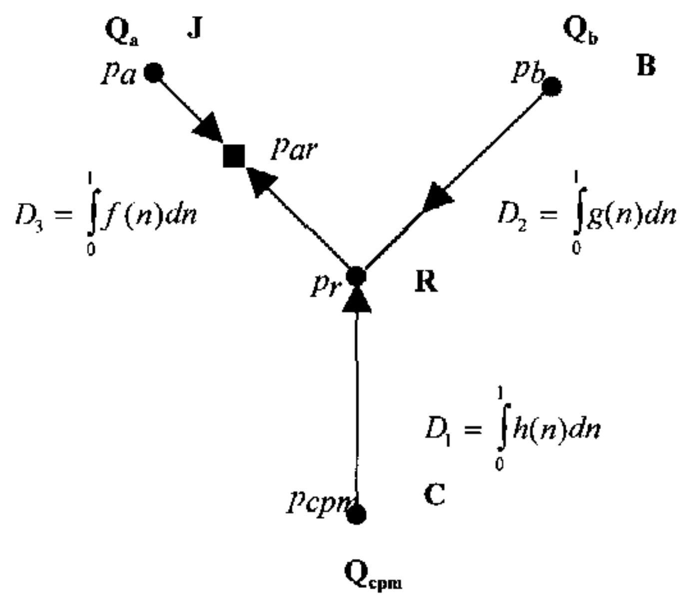


Figure 11

The price of gas is determined by the following relationships:

$$p_r = p_b + c \tag{6}$$
$$p_{cpm} = p_r - c \tag{7}$$
$$p_{ar} = p_r + cr = p_b + c\,(1+r) \tag{8}$$

The relationship:

$$p_a = p_b + 2\,cr \tag{9}$$

must hold for the distribution depicted in figure 11 to be on equilibrium.

As the price of gas at **A** drops, the arbitration point on the **JR** segment moves closer to **R,** but as long as gas is flowing from **B** to **R**, the price at **R**, *pr*, remains unchanged and thus *pcpm* remains unchanged. The price of gas is independent of demand. If *pa* drops to the point where the arbitration point is in **BR**, then *pa* becomes the benchmark price.

*Case 3: The arbitration points are in **BR** (Burgos-Los Ramones) and **JR** (Juárez-Los Ramones)* (figure 11).

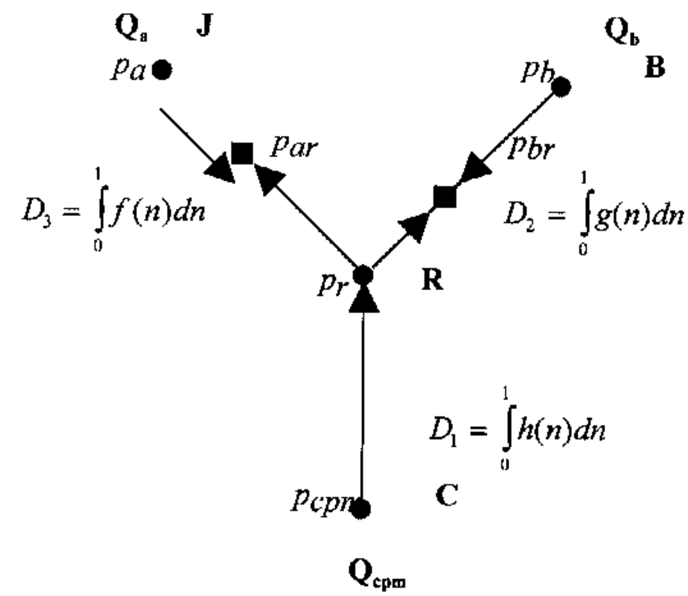


Figure 12

In this case, the price of gas is determined by the following relationships:

$$Q_{cpm} = \int_0^r f(n)dn + \int_0^s g(n)dn + D_1 \qquad (10)$$

$$p_r = p_a + c(1\text{-}2r) \qquad (11)$$

$$p_r = p_b + c(1\text{-}2s) \qquad (12)$$

$$p_{cpm} = p_r - c = p_b - 2cs \qquad (13)$$

which can be solved for r, s, p_r, and p_{cpm}. Equations (11) and (12) can be solved to yield:

$$r = s + \frac{p_a - p_b}{2c} \qquad (14)$$

This can be substituted into equation (10):

$$Q_{cpm} - D_1 = \int_0^{s+\frac{p_a-p_b}{2c}} f(n)dn + \int_0^s g(n)dn \qquad (15)$$

Equation (15) can be solved for s. Equation (13) in turn yields p_{cpm}. The solution for equation (15) is illustrated by figure (13) below.

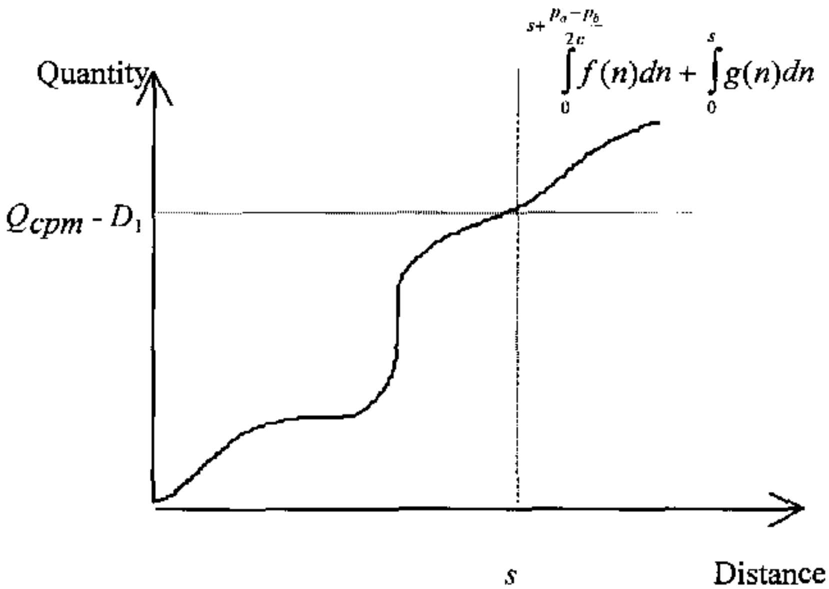


Figure 13

This general formulation permits mass points in the distribution for cities, generation plants, etc. An increase in the demand south of the arbitration point (either an increase in D_I or in the density functions in $\int_0^{s+\frac{p_a-p_b}{2c}} f(n)dn + \int_0^{s} g(n)dn$) will lower supply, reduce s and increase p_{cpm}. An increase in the supply south of the arbitration point (an increase in Q_{cpm}) will lower p_{cpm}. Anything that happens north of s will have no impact on prices. If we differentiate (15) with respect to p_a, , we get:

$$\frac{ds}{dp_a} = \frac{-f(s)}{2c(f(s)+g(s))} < 0 \qquad (16)$$

If we differentiate (15) with respect to p_b , we get:

$$\frac{ds}{dp_b} = \frac{f(s)}{2c(f(s)+g(s))} \qquad (17)$$

Note that the equation (16) implies that decreasing the price at **A** will move the arbitration point in **BR** north towards point Burgos implying a reduction in p_{cpm}.

4. Conclusions

The arbitration point concept has been questioned by some players of the Mexican natural gas market. We have shown that such a concept is an essential element of a methodology with solid microeconomic foundations. In this final section, we sum up the implications on the behavior of the arbitration point and the system of natural gas prices in Mexico of the four models analyzed in section three.

The Basic Model

In the basic model, the arbitration point s is defined as that point on the Ciudad Pemex-Reynosa segment where the price of imported gas and the price of domestic gas are equal. Under the assumption of an inelastic and uniformly distributed national demand, s is such that $s = \frac{Q}{D}$, where Q is production at Ciudad Pemex and D is demand along the segment.

Likewise, the arbitration point is characterized by the coincidence of import and domestic physical flows of natural gas. This is illustrated in figure 9 where the lines have a slope equal to *c*.

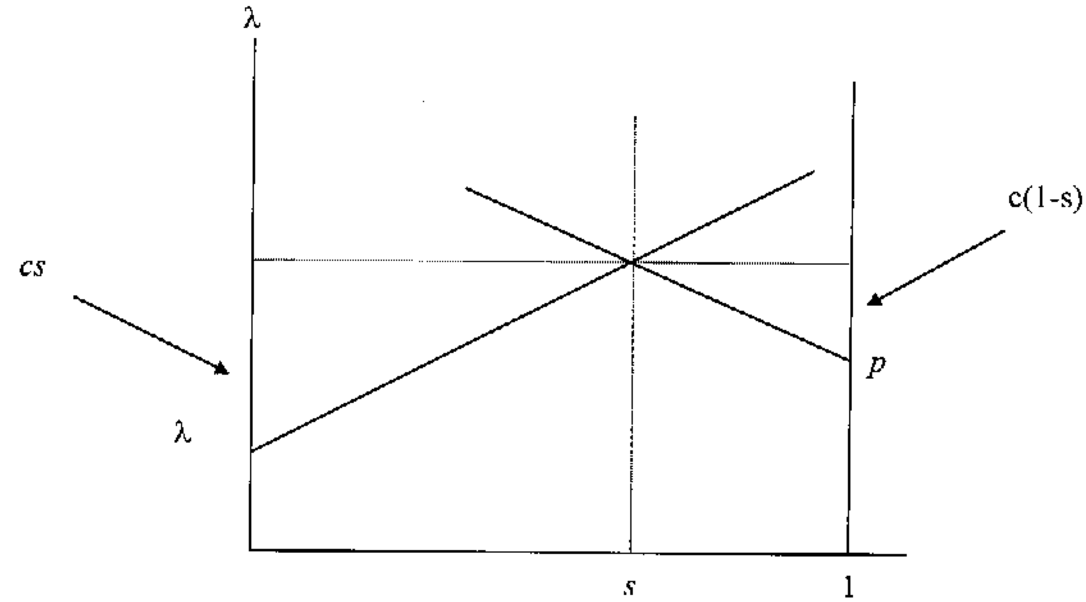


Figure 14

Under the basic model, the balance between imported and domestically produced gas fixes the arbitration point: when imports increase (drop) the arbitration point moves southwards (northwards).

Production at Burgos

The existence of production in Burgos turns the basic model into a more complex one. The arbitration point is now the place where gas flows from Ciudad Pemex and Burgos meet. An increase of production at Burgos has no effect on the location of the arbitration point. However, such an increase may have an effect over the price level once the production increase in Burgos completely substitutes imports and when Burgos exports modify the benchmark price at Houston.

An increase of production at Ciudad Pemex implies a northward movement of the arbitration point and causes a price decrease two times greater than the decrease in the marginal cost of transport. Once again, this price reduction may be magnified when the gas exported from Burgos has an impact on the price at the Houston Ship Channel.

Tariff Policy

In this model, we analyzed the movement of the arbitration point of the northwestern system. When there were no technical export restrictions at Burgos, we showed that a reduction of the import tariff at Juárez moves the arbitration point t in a southeast direction according to the *One Price Law*.

When there were no export bottlenecks, the arbitration point remained fixed but prices decreased according to the shadow price of the export restriction. Therefore, a clear policy recommendation is derived. As a response to import tariff reductions, Pemex should reduce its prices so as to compete with imported gas rather than cut (or burn) production.

The General Model

In the general model we defined three arbitration points r, s, and t for segments Ciudad Juárez-Los Ramones, Burgos-Los Ramones, and Ciudad Pemex-Los Ramones, respectively. We analyzed three cases. The first case addressed the situation where Burgos gas contributes to satisfy demand both in Ciudad Juárez-Los Ramones and Ciudad Pemex-Los Ramones segments. We showed that the elimination of the import tariff at Ciudad Juárez moves r toward Los Ramones and causes an increase in the gas exported through Burgos. However, this tariff policy does not originate a price change in any other system: prices at Los Ramones and Ciudad Pemex remain constant. However, a change in demand D_1 in the Ciudad-Pemex-Los Ramones segment could modify the price at Ciudad Pemex. Additionally, if the tariff reduction at Juárez causes complete Los Ramones-Juárez segment to be supplied with imported gas and, therefore, changes the arbitration point to Los Ramones-Burgos, then the benchmark price for Ciudad Pemex will be the Ciudad Juárez (or *Permian Basin*) price p_a.

In the second case, gas from Burgos and Ciudad Pemex meets the demand along the Burgos-Los Ramones and Ciudad Pemex-Los Ramones segments, repectively, and also contributes to satisfy demand in Juárez-Los Ramones. Under these assumptions, tariff elimination at Juárez leads to a movement of r towards R and to more exports through Burgos. However, as in the previous case the, Los Ramones and Ciudad Pemex prices do not change and the tariff drop in Juárez can cause a jump of the arbitration point to the Los Ramones-Burgos segment, resulting in a new benchmark price at p_a.

Finally, when Ciudad Pemex gas helps to meet demands along the Juárez-Los Ramones and Burgos-Los Ramones segments, we showed that a demand increase south of arbitration points s and r will reduce supply in Ciudad Pemex, will move these points southwards, and will increase the price at Ciudad Pemex. Likewise, an increase in supply Q_{cpm} at Ciudad Pemex implies a decrease in this city's price of gas p_{cpm}. Changes in supply and demand north of s or r will have no impact on prices. tariff removal in Ciudad Juárez moves northwards the arbitration point in Los Ramones-Burgos segment. This movement implies a reduction of the price of gas at Ciudad

Pemex.

Calculation of the Arbitration Point

So far we have analyzed the implications of the *netback* methodology under different scenarios. We have also shown that this methodology can be derived from an optimization problem consistent with the regulator's objectives. From the methodology's formula, we know that the benchmark price can be modified to change the natural gas price in Mexico implying a redistribution of rents between Pemex and its industrial and commercial consumers and distributors.

However, reference prices cannot be modified so easily in practice. The Houston Ship Channel market was selected by CRE after public hearings that showed that this market was the most relevant for the natural gas Mexican industry.

Another parameter of the formula is the marginal cost of transport which has been calculated by Pemex through a cost of service methodology. This parameter must be considered fixed.

We conclude that the arbitration point is the unique available instrument for a decision maker. As we demonstrated, the arbitration point is a function of the commercial balance and of natural gas supply and demand conditions. A regulator could decide to arbitrarily move the arbitration point to achieve similar effects on rent redistribution as those achieved through a change in the benchmark price. Nonetheless, if in practice the arbitration point cannot be varied, the only remaining option for the regulator is to make sure that the exact import and domestic-production amounts be used in the calculation of the arbitration point.

This practical problem may be a substantial one. The recent closing of some Pemex ammonium plants (such as Cosoleacaque) and the opening of cryogenics plants could have increased the disposability of gas for first hand sales. Moreover, some logistic imports, should not be included in the netback methodology since they are so far away from Pemex' main pipeline system (e.g., Pemex, Hermosillo, Piedras Negras). Likewise, the benchmark prices used in Pemex' internal transfers could be very low and might reduce the gas supply for the rest of the market.

All this suggests that the arbitration point shoud be located closer to the northern border than it is now. This conclusion is supported by the existence of few commercial deficits in the Mexican natural gas balance during 1996 and 1997 (1% and 2.5% of the national production, respectively).

References

Adelman, M. A. (1963), *The Supply and Price of Natural Gas*, B. Blackwell, Oxford

Brito, D. L., Littlejohn, W., and J. Rosellon, (1998), *Pricing Liquid Petroleum Gas*, Working Paper no. 108, Centro de Investigación y Docencia Económicas, México.

Brito, D. L., and E. Sheshinski (1997), *Pipelines and the Exploitation of Gas Reserves in the Middle East*,Working Paper, Baker Institute for Public Policy, Rice University, Houston.

Comisión Reguladora de Energía (1996), *Directiva sobre la Determinación de Precios y Tarifas para las Actividades Reguladas en Materia de Gas Natural*, México.

International Energy Agency, 1991, *Natural Gas. Prospects and Policies*, Paris: OECD/IEA.

Swydan, M., 1996, "Comments on Proposed Policy Decisions Concerning: Tariffs and Pricing, Bidding Procedures for distribution Zones, and Natural Gas Quality Issued by the "Comisión Reguladora de Energía" (CRE) of Mexico", *Gas Energy Review. American Gas Association*, June, Vol. 24, No. 6.

ANNEX

The objective function of our model is to maximize social welfare less the cost of imported gas and the cost of transporting gas:

$$\max \; W(D) - D\left[\int_0^s gcndn + \int_s^1 gc(1-n)dn\right] - py \qquad \text{(I)}$$

The constraints are:

$$\int_0^1 gdn - D = 0 \qquad \text{(II)}$$

$$\int_0^s gdn - Q = 0 \qquad \text{(III)}$$

$$\int_s^1 gdn - y = 0 \qquad \text{(IV)}$$

Note that equation (III) implies that $D = g$ and that once D and Q are fixed the arbitration point, s, is given by (IV). The Lagrangian for the problem is given by:

$$L = W(D) - D\left[\int_0^s cndn + \int_s^1 c(1-n)dn\right] - py + \lambda\left[Q - \int_0^s Ddn\right] + \beta\left[y - \int_s^1 Ddn\right] \qquad \text{(V)}$$

where λ is the value of natural gas and β is the dual associated with the import constraint at **B**. The first order conditions for the case where imports are positive, $y > 0$, are:

$$\frac{\partial W}{\partial D} - \left[\int_0^s cndn + \int_s^1 c(1-n)dn\right] - \lambda\int_0^s dn - \beta\int_s^1 dn = 0 \qquad \text{(VI)}$$

$$Q - \int_0^s Ddn = 0 \qquad \text{(VII)}$$

$$y - \int_s^1 Ddn = 0 \qquad \text{(VIII)}$$

$$-p + \beta = 0 \qquad \text{(IX)}$$

$$-\left[cs - c(1-s)\right] - \lambda + \beta \qquad \text{(X)}$$

If we examine (IX), we see that the shadow price of imported natural gas, β, will equal p if imports are positives. From (X) we see that the shadow price of natural gas is given by:

$$\lambda = c(1-2s) + p \qquad \text{(XI)}$$