Pricing Natural Gas in Mexico: An Application of the Little-Mirrlees Rule

Dagobert L. Brito and Juan Rosellón

Volume 23, Number 3
International Association for Energy Economics

2002
Pricing Natural Gas in Mexico:
An Application of the Little-Mirrlees Rule

Dagobert L. Brito* and Juan Rosellón**

The Mexican energy regulatory commission—Comisión Reguladora de Energía (CRE)—has implemented a netback rule for linking the Mexican market for natural gas with the North American market. This paper describes the economic analysis that supported this policy. We show that the netback rule is the efficient way to price natural gas and it is in fact an application of the Little-Mirrlees Rule.

INTRODUCTION

Mexico has an energy market that is different from most other countries. The national oil company Petróleos Mexicanos (Pemex) is a very important political and symbolic institution. Oil production accounts for nearly 30 percent of the government’s revenue. The oil industry was initially owned by foreign interests and its nationalization in 1938 is viewed by many as an expression of Mexican sovereignty. Thus, privatization of Pemex is politically impossible.

The economic analysis of Mexico’s energy market is extremely difficult. Difficulties arise from three sources. First, Pemex is a monopoly and many of the markets involved are regulated. Prices in these markets are not a good guide for economic decisions as to production. Second, oil, gas and natural gas liquids are often produced jointly, and in such cases it is impossible to allocate costs of production to a specific product (see Adelman, 1963, and Brito et al. 2000). Finally, the goods produced are substitutes in consumption.

The Energy Journal, Vol. 23, No. 3. Copyright © 2002 by the IAEE. All rights reserved.

The research reported in this paper was supported by the Comisión Reguladora de Energía in a grant to the Centro de Investigación y Docencia Económicas. We would like to thank William Laney Littlejohn, Peter Mieszkowski and the anonymous referees for their suggestions.

* Department of Economics and James A. Baker III Institute for Public Policy, [MS-22], Rice University, 6100 Main Street, Houston, TX 77005-1892, USA. E-mail: brito@rice.edu

** Centro de Investigación y Docencia Económicas (CIDE), Carret. México Toluca 3655, Lomas de Santa Fe, 01210, Mexico D.F., Mexico. E-mail: juan.rosellon@cide.edu

81
Gas and oil are substitutes in the generation of power; natural gas liquids, gas and oil are substitutes as feedstocks. This creates very difficult problems in regulating prices.

The Comisión Reguladora de Energía (CRE) has been given the responsibility of regulating the price of natural gas. They solved the problem of pricing gas by using the Houston Ship Channel price as a benchmark. This policy links the price of gas at Ciudad Pemex in southern Mexico through a netback formula to the benchmark price in Houston, the arbitrage point and the net transport costs.¹ Figure 1 shows the location of Ciudad Pemex as well as of the point where northern and southern flows meet, defined as the arbitrage point. This point is currently located at Los Ramones in the north of Mexico. Since the price of gas from both sources must be the same at this point, the price of Mexican natural gas at this point is the Houston benchmark price corrected for the transport costs. The price of gas at Ciudad Pemex is the price of gas at the arbitrage point less the transport cost from this point to Ciudad Pemex. The price of gas in Mexico is then the price at the Houston Ship Channel adjusted for costs.

The pricing rule based on the Houston Ship Channel price is actually an implementation of the Little-Mirrlees proposal for pricing traded goods. They propose using the world prices for traded goods, not necessarily because these prices are more rational, but rather because these prices reflect the terms under which a country can trade. Thus the price of gas in Houston is a measure of the opportunity cost to Mexico of consuming the gas rather than exporting it to the United States.² The natural gas market in Mexico then has all the properties of the gas market at Houston. In particular, all agents are price takers with respect to the market and the Houston market can be used by agents in Mexico for hedging and other forward contracts. This pricing rule means that the price of gas in Mexico is insensitive to changes in the demand for gas in Mexico. Consumers of gas are facing a flat supply curve. The equilibrating factor is the amount of gas imported or exported.

The key to the implementation of this policy is that there is sufficient pipeline capacity so that the gas markets can clear and rents do not accrue to rights of access to the pipelines. If there is not sufficient pipeline capacity so that the natural gas markets in Mexico can clear at the Houston netback prices, it is impossible to implement the netback rule. At the netback price, demand

---

² See Little and Mirrlees (1968) p. 92. There were two other proposals discussed as a way of pricing natural gas in Mexico. One was to use the cost of production and the other was to use the cost of substitutes for natural gas. The first suggestion is not possible as most natural gas in Mexico is produced as a joint product with oil and there is no well defined cost of production. There is not a free market in many of the substitutes for natural gas in Mexico so it is not possible to use these prices. Note that using the price of gas in Houston does this in as much as the price of gas in Houston reflects the price of competitive sources of energy.
would be greater than supply. Another factor that argues for using the price of gas in Houston to price gas in Mexico is the existence of a broad market in future contracts in the Houston market. There are important and legitimate reasons why private individuals use forward markets to reduce risk. Linking the price of gas in Mexico to the Houston market permits buyers of natural gas in Mexico to enter into transactions in these sophisticated markets to hedge for gas delivered in Mexico. This market enables gas consumers in Mexico to hedge against intertemporal risks. Further, many of the potential investors in power generation in Mexico have experience in using the Houston gas market. This way of pricing gas will make it easier for them to operate in Mexico. A consequence of the netback rule is to make all participants in Mexico’s natural gas market price takers vis-a-vis the market in Houston. Further, for all consumers the price of natural gas reflects the opportunity cost of its use.

The Houston market can also serve as a buffer for fluctuations in Pemex’s production or in demand. Pemex can vary its sales in the Houston market to smooth fluctuation in Mexico. This buffer allows Pemex to only sell “plain vanilla” gas without having to engage in complex market operations in Mexico. Thus, it is very difficult to see what useful role can be played by Pemex acting as a gas marketer in Mexico. If Pemex wants to engage in speculative market behavior, it can do so in the Houston market. Houston has the advantage of being a well-developed market. Pemex’s transactions in that market would not create any regulatory issues for the CRE as long as Pemex sells gas in Mexico at the Houston spot netback price. As long as there is sufficient pipeline capacity so that there are no bottlenecks in transporting gas, this simple rule will result in an efficient and transparent natural gas market in Mexico.

In North America, gas is transported by pipeline. The cost of transporting 1000 cubic feet of gas 1000 miles by onshore pipeline is approximately $0.40 to $0.85. By contrast, the cost of transporting a barrel of residual fuel oil is approximately $0.10 per thousand miles. Since a barrel of residual fuel oil has the energy equivalent of 6000 cubic feet of gas, gas is more than twenty times more expensive to transport than fuel oil. The economics of transportation is a key element in the North American market for gas. This market is based on pipelines and there are pipelines connecting the United States, Mexico and Canada.

3. The CRE has consistently promoted price hedging along with the regulation of the price of domestic natural gas. [See Comisión Reguladora de Energía (1998 and 2000)].
4. The recent four-dollar three-year take-or-pay contracts offered by Pemex are a response to political pressures due to the increase in the price of natural gas (close to ten dollars per MMBTU during the winter of 2000-2001). These contracts do not change the use of Houston as the reference point for setting the price in Mexico. There has been political pressure to permit breach since the price of gas has dropped to below four dollars per MMBTU in late 2001.
2. THE MEXICAN NATURAL GAS MARKET

The Mexican pipeline system is shown in Figure 1. This network is 9,043 kilometers long. It reaches most of the industrial centers with the exception of the Northwest North Pacific part of the country. In 2000 the pipeline system transported 3.03 billion cubic feet of natural gas per day (bcf/d). This volume includes 231 million cubic feet (Mmcf/d) of gas imports, 779 Mmcf/d of non-associated gas, and 2.02 bcf/d of associated gas from processing plants. As of 2000, 1,795 kilometers of new private pipelines have been added to the existing transportation system and the capacity has increased to 7.4 bcf/d. Mexico has approximately 78 trillion cubic feet of gas reserves (this represents 48 years of reserves at the present rate of consumption). In recent years over 44 trillion cubic feet of non-associated gas have been discovered near Burgos. These gas fields are close to the Texas border. At the present rate of consumption, this is over 35 years of reserves so there is a potential for this gas to be exported to the U.S. market. The pipeline linkage from these discoveries to the U.S. market is currently under expansion.\(^5\)

The Mexican pipeline system can be viewed as a pipeline connecting the production in the south with production in the north that has two branches. Ciudad Pemex is located at the bottom of this pipeline. This city is located in the Southeast region where Pemex produces associated gas (80% of total natural gas production). In the Northeast terminal of the pipeline is Reynosa-Burgos which produces non-associated gas (17.3% of total production) and is a link with the Texas pipeline system. The Northwest branch of the pipeline connects Ciudad Juárez, which is a point where gas is imported, and Los Ramones is the junction of the Southeast, Northwest and Northeast pipelines. The Southwest branch of the pipeline connects the cities in the center of the country with the main pipeline at Cempoala.

3. PRICING NATURAL GAS: IMPLEMENTING THE LITTLE-MIRRELLS RULE

Figure 2 captures the essential features of the complete Mexican gas pipeline system. \(Z_i\) represents imports at Juárez (J) from West Texas, \(Z_b\) represents imports at Burgos (B), \(Y_b\) represents exports at Burgos, and \(Q_b\) represents production at Burgos. \(R\) is Los Ramones, the point where the main system and the northwest subsystem are physically interconnected. \(D\) is Cempoala, the point where the main system and the central subsystem are physically interconnected. Demand is distributed on the lines \(JR\) which represents demand between Juárez and Los Ramones (Monterrey is located on this line), \(BR\) which represents demand between Los Ramones and Burgos, \(DM\)

---

\(^5\) The export-import capacity at the Reynosa sector for 2002-2003 will be 534 Mmcf/d.
which represents demand in the center of Mexico (Mexico City, etc.) and on the line RC which represents demand south of Mexico. C is Ciudad Pemex. Gas is supplied at J, B, and C by the amounts, $Q_a$, $Q_b$, and $Q_c$. The price at point J is given by $p_j$, at point B is given by $p_b$, at point C, by $p_c$, and at point R by $p_r$. There can be an arbitrage point between J and R, between B and R, and between C and R. The prices at the arbitrage points are denoted by $p_{jr}$, $p_{br}$, and $p_{cr}$ respectively. The price at Houston is $p_h$ and the cost of moving gas from Houston to Burgos is $\tilde{c}$.\footnote{The Houston Ship Channel is linked to the Mexican pipeline system via four U.S. pipelines (PG&E, Teico, Coral and Tennessee).}

Figure 2. A Model of the Mexican Pipeline System
arbitrage points must be in the Juárez-Los Ramones segment of the pipeline. Since gas is produced at Burgos and Ciudad Pemex, there must be an arbitrage point delineating these two sources of production. Thus, there are two arbitrage points and one of them must be in the Juárez-Los Ramones segment of the pipeline.

This enables us to treat the problem of pricing gas on the main branch connecting Burgos with Ciudad Pemex as a single pipeline where Los Ramones and Cempoala are mass points in the distribution of demand (see Figure 3). Once the price of gas at Los Ramones is determined, pricing gas on the Juárez-Los Ramones segment of the pipeline is simple.

The solution of this problem gives a formula for pricing natural gas on the Mexican pipeline system. We show that the netback rule follows from the solution of a welfare maximizing problem. The shadow prices in the optimization associated with the production of natural gas in Mexico are the prices of natural gas that are optimal. Intuitively, these rules can be derived by appealing to the condition, that at the margin, Pemex should be indifferent between the sale of gas at any point in Mexico and the sale or purchase of gas in Houston. Clearly if this condition does not hold, it is possible to construct an allocation of gas that will improve welfare. It is just necessary to shift the allocation of gas from activities whose marginal benefit is less than the price of gas to activities whose marginal benefit is higher than the price of gas.

Consider a planner trying to allocate the consumption of gas in Mexico so as to maximize welfare given by

\[ W = \int_{0}^{1} v(q(n), n) \, dn \]  

(1)

where \( v(q(n), n) \) is the utility of gas at point \( n \).\(^7\) Gas is produced domestically and gas is either exported to or imported from the Houston market.

Let \( t \) be the arbitrage point in the Ciudad Pemex - Burgos segment of the pipeline, \( t = 0 \) is at Ciudad Pemex and \( t = 1 \) is at Burgos (see Figure 3). Let the demand at any point on the line B-C be given by \( q(n) \). Let \( n_p \) and \( n_c \) be the locations of Cempoala and Los Ramones respectively.\(^8\) The choice variables

\(^7\) The problem is actually more complicated as the utility of the consumption of gas depends on the consumption of other goods including substitute fuels. A more general treatment of this problem is carried out in a related paper by the authors, available upon request [Brito and Rosellón (2002)].

\(^8\) Note that because gas can be imported from Texas at Ciudad Juárez, \( v(q(n), n) \) is actually a function of the amount of gas imported at Ciudad Juárez. Ignoring this complication does not change the result and simplifies the exposition. It is just necessary to show that the condition given by equation (10) will hold for any level of imported gas and thus will hold for the optimal level [see Brito and Rosellón (2002)].
are exports, $Y_b$, imports $Z_b$, the amount of consumption and the arbitrage point $t$. The variables of interest are the arbitrage point and the price of gas at Burgos and Ciudad Pemex.

**Figure 3. A Single-Pipeline Model of the Mexican Pipeline System**

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 cost of moving natural gas from Burgos to Ciudad Pemex is $c$.

The objective function of our model is then to maximize

$$
\int_0^t q(n) (cn) dn - \int_0^1 q(n)c(1-n) dn
$$

$$
= (p_h + \overline{c}) Z_b + (p_h - \overline{c}) Y_b
$$

where $\int_0^t q(n)cn dn$ is the cost of delivering gas to the arbitrage point from Ciudad Pemex.

The term $\int_0^1 q(n)c(1-n) dn$ is the cost of delivering Burgos gas to the arbitrage point. If $\overline{c}$ is the cost of transporting gas from Houston to Burgos, the term $(p_h + \overline{c}) Z_b$ represents the cost of imports and the term $(p_h - \overline{c}) Y_b$ represents the income from exports. The constraints are:

$$Q_b + Z_b - Y_b - \int_0^1 q(n) dn = 0$$

(3)

$$Q_c - \int_0^t q(n) dn = 0$$

(4)
where equation (3) is the resource constraint at Burgos, and equation (4) is the resource constraint at Ciudad Pemex. The planner chooses imports, $Z_b$, exports $Y_b$, the distribution of consumption, $q(n)$, and the arbitrage point, $t$. The Lagrangian is

$$
L = \int_0^1 v[q(n), n] dn - \int_0^t q(n) c n dn - \int_0^1 q(n) c(1-n) dn - (p_h - \bar{c}) Z_b \\
+ (p_h - \bar{c}) Y_b + \alpha \left[ Q_b + Z_b - Y_b - \int_0^t q(n) dn \right] + \beta \left[ Q_c - \int_0^1 q(n) dn \right]
$$

(5)

where $\alpha$ is the dual associated with the value of natural gas at Burgos, $\beta$ is the dual associate with the value of natural gas at Ciudad Pemex.

The Kuhn-Tucker conditions with respect to $Y_b$ and $Z_b$ are

$$
p_h - \bar{c} - \alpha \leq 0, \quad Y_b (p_h - \bar{c} - \alpha) = 0
$$

(6)

$$
\alpha - p_h - \bar{c} \leq 0, \quad Z_b (\alpha - p_h - \bar{c}) = 0
$$

(7)

The Euler equations for $q(n)$ are

$$
\frac{\partial v[q(n), n]}{\partial q(n)} - c n - \beta = 0
$$

(8)

for $n < t$ and

$$
\frac{\partial v[q(n), n]}{\partial q(n)} - c (1-n) - \alpha = 0
$$

(9)

for $n \geq t$. The first order conditions with respect to $t$ under the assumption that $0 < t < 1$ can be written as

$$
[t c - c (1-t) - \alpha - \beta] = 0
$$

(10)

The Kuhn-Tucker conditions (6) and (7) determine the price of gas at Burgos. Substituting equation (6) or (7) into equation (10) gives the price of gas at Ciudad Pemex. This is the CRE netback formula. If Mexico is exporting gas then...
\[ p_c = p_h + c - 2ct - \bar{c} \]  \hspace{1cm} (11)

and if Mexico is importing gas then

\[ p_c = p_h + c - 2ct + \bar{c} \]  \hspace{1cm} (12)

and note that

\[ \frac{\partial p_c}{\partial t} = -2c \]  \hspace{1cm} (13)

so a change in the arbitrage point changes the price of gas by a factor of two.

Equation (9) and (10) can be solved for \( \hat{q}(n) \) where the \( \hat{\ } \) represents the optimal solution. Note that if Mexico is importing gas, demand for gas north of the arbitrage point is independent of the location of the arbitrage point and depends only on the price of gas at Burgos. The price of gas at Burgos depends on whether Mexico is importing or exporting gas and the price of gas in Houston.

The value of \( \hat{r} \) is obtained by solving

\[ Q_c - \int_0^r \hat{q}(n) \, dn = 0 \]  \hspace{1cm} (14)

Note that an implied necessary condition is \( \hat{q}(\hat{r}) > 0 \) in any open interval that contains the arbitrage point. In practice, this suggests that the arbitrage point is likely to be either at Los Ramones or Cempoala as they are mass points in the distribution of gas consumption.

Now suppose that there is a change in the production at Burgos that does not change whether Mexico is importing or exporting gas. There is no change in the price of gas at \( \hat{r} \) and \( \hat{q}(n) \) is still a solution for \([0, \hat{r}]\). The price of gas and demand for gas in Mexico are independent of the production at Burgos as long as the import/export condition does not change and there are no bottlenecks in the pipeline.
4. EXPORT CONSTRAINT

The previous analysis was done under the assumption that the export of gas at Burgos was not constrained by pipeline capacity. The policy of linking the price of gas on the Mexican pipeline system to the price of gas in Houston requires that gas is able to move so that markets clear. This requires that there is sufficient investment in pipelines so that pipeline capacity does not bind. The capacity in the Mexican pipeline system and the links with the Texas pipeline system have expanded. There are government forecasts that the demand for gas will grow at a rate of 10 percent a year. At that rate of growth, demand will double in less than seven years, so it is necessary to start planning if there is to be sufficient pipeline capacity to prevent bottlenecks. In theory, financing this investment should not be a problem. The demand for gas is so inelastic and the distances involved are reasonably short so a transport charge sufficient to finance the construction of the pipelines would have little effect on prices or welfare. The political constraints may be more serious given that Pemex has an exogenous capital budget.

If these flows are constrained, then it is necessary to add a constraint, \( \bar{Y}_b \), for exports at Burgos and a constraint, \( \bar{Z}_a \), for imports at Juárez to the optimization problem. These can be written as

\[
\bar{Y}_b - Y_b \geq 0 \tag{15}
\]

\[
\bar{Z}_a - Z_a \geq 0 \tag{16}
\]

The Lagrangian is

\[
L = \int_0^1 \left[ v(q(n),n) \, dn - \int_0^1 q(n)c(1-n) \, dn + (p_a + e)Z_a + (p_b - e)Y_b \right] + \alpha \left[ Q + Z_b - Y_b - \int_0^1 q(n) \, dn \right] + \beta \left[ Q_e - \int_0^1 q(n) \, dn \right] + \delta_1 (\bar{Y}_b - Y_b) + \delta_2 (\bar{Z}_a - Z_a) \tag{17}
\]

9. The Energy Ministry of Mexico estimated the following elasticities of demand for natural gas: national -0.21, northwest -0.47, northeast -0.13, west -0.33, center -0.05, gulf -0.15 (see Secretaría de Energía (1998), Dahl (1992) and Brito and Rosellón (1999)). The national relative price elasticity with respect to fuel oil is 0.11 (see Secretaría de Energía (2000)).
where $\delta_1$ is the Lagrange multiplier for the export constraint at Burgos and $\delta_2$ is the Lagrange multiplier for the import constraint. Since the gas produced at Burgos is non-associated gas, production at Burgos can be adjusted and the only cost to Mexico is the opportunity cost of selling the gas. However, suppose that the constraint on imports at Burgos is binding. The first order condition with respect to $Z_a$ is

$$\alpha = p_h + \delta_2$$  \hspace{1cm} (18)

The differential between the price at Burgos and the Houston Ship Channel price (adjusted) would be reflected in the Lagrange multiplier associated with the capacity constraint on exports, $Z_{\varphi}$. (See Figure 4). This multiplier reflects rents to the control of access to the pipeline.\(^{10}\) In that case the netback rule cannot work as the flow of gas cannot equilibrate the market. There are two alternatives: gas is rationed or the price of gas is allowed to adjust and rents accrue to the scarce factor, pipeline capacity.

Figure 4. Capacity Constraint on Exports

5. CONCLUSIONS

This paper studies the implications of the Comisión Reguladora de Energía using a netback rule based on the Houston Ship Channel price for natural gas to link the Mexican market for natural gas to the North American market. This is an implementation of the Little-Mirrlees proposal for pricing

\(^{10}\) This is an example of the more general proposition that if there are pipeline bottlenecks, the Lagrange multiplier associated with the pipeline capacity constraint reflects those rents. Who captures the rents depends on institutional arrangements.
traded goods. This pricing rule means that the price of gas in Mexico is
insensitive to changes in the demand for gas in Mexico. The equilibrating factor
is the movement of gas. Thus, this policy is conditional on the existence of
adequate pipeline capacity to transport the needed gas.

Linking the price of gas in Mexico to the Houston market permits
buyers of natural gas in Mexico to enter into transactions in sophisticated
financial markets to hedge gas delivered in Mexico. Gas consumers in Mexico
can hedge against intertemporal risks. Potential investors in power generation
in Mexico have experience in using the Houston gas market. This way of pricing
gas makes it easier for them to operate in Mexico. A consequence of the netback
rule is to make all participants in Mexico’s natural gas market price takers vis-à-
vis the market in Houston.

The key to this policy is that there be sufficient investment in pipeline
capacity so that bottlenecks do not develop. Calculations support a policy that
guarantees enough pipeline capacity so that gas markets can always clear. That
policy would result in sufficient savings to gas consumers that they would be
willing to pay for this capacity. The only argument against investing in pipeline
capacity is the loss of public revenue created by rents to the pipeline.

REFERENCES

Journal 66(3): 742-753.
Comisión Reguladora de Energía (1996). "Directiva sobre la Determinación de Precios
y Tarifas para las Actividades Reguladas en materia de Gas Natural," CRE, Mexico.
http://www.cre.gob.mx
Comisión Reguladora de Energía (2000). "Resolución que Promueve la Contratación Generalizada
de Instrumentos Financieros de Cobertura de Riesgos para hacer Frente a la Volatilidad del Precio
reso0208-2000.pdf
Little, I.M.D. and J.A. Mirrles (1968). Manual of Industrial Project Analysis in Developing
Countries. Development Centre of the Organization for Economic Co-Operation and
Development., Paris: OECD.
http://www.energia.gob.mx/frame4.html
http://www.energia.gob.mx/frame4.html