CIDE

NÚMERO 228

Dagobert L. Brito y Juan Rosellón

A GENERAL EQUILIBRIUM MODEL OF PRICING NATURAL GAS IN MEXICO

Abstract

The Comisión Reguladora de Energía has implemented a netback rule for linking the Mexican market for natural gas with the North American market. This paper shows that in an open economy where agents can chose between gas and alternative fuels and where the density function describing the distribution of agents along the pipeline can have intervals that are empty and mass points, the net back rule is Pareto optimal.

Resumen

La Comisión Reguladora de Energía ha implementado una regla de "enlace hacia atrás" para vincular el mercado mexicano del gas natural con el mercado norteamericano. Este artículo demuestra que dicha regla es optima de Pareto en una economía abierta en la que los agentes pueden elegir entre gas y combustibles alternativos, y en la que la función de densidad que describe la distribución de los agentes a lo largo del gasoducto puede tener intervalos vacíos o con puntos de acumulación.

Introduction[1]

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. The oil industry was initially owned by foreign interests and its nationalization in 1938 is viewed by many as an expression of Mexican sovereignty. Privatization of Pemex is politically impossible. Pemex is a monopoly and 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[2]. 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 Texas, the arbitrage point and the net transport costs[3]. 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 theses 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[4]. 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 netback rule was published by the CRE IN 1996[5]. It came under attack in December of 2000. The price of gas in Houston rose from around \$2.00 per MMBTU in January 2000 to almost \$10.00 per MMBTU by January 2001. Many

[1] The research reported in this paper was supported grant from the Center for International Polotical Economy to Baker Institute for Public Policy at Rice University and the Comisión Reguladora de Energía in a grant to the Centro de Investigación y Docencia Económicas, A.C. We would like to thank William Laney Littlejohn his suggestions.

[2] See Adelman (1963) and Brito, et. al. (2000).

[3] See Comisión Reguladora de Energía (1996), section 4.

[4] See Litttle and Mirrless (1968) p. 92.

[5] Pemex had been using a very similar rule base on another Texas marker (Tetco and Velero). See Rosellón and Halpern (2001).

Mexican firms had not hedged and as a result found themselves in serious troubles. Plants were being forced to close. There was strong pressure on the CRE to drop the Houston benchmark in pricing gas. Pemex rescued the firms in trouble by offering a \$4.00 per MMBTU three year take or pay contracts. The netback rule based on the Houston price remains.

Part of the attack on the net back policy was an effort to show that the economics supporting the netback rule were faulty. Two assumptions in Brito and Rosellon (2002) have been criticized[6]. First, the assumption that density function that described the distribution of agents along the pipeline was strictly positive and second, the assumption that there are no substitutes for gas in the model. These simplifying assumptions were made for convenience in modeling. In this paper, the optimality of the netback rule will be analyzed in a model that does not make these assumptions. The cost is a significant increase in the complexity of the mathematics. It will be shown that under a very general set of assumptions, the net back rule is Pareto efficient.

The Mexican Natural Gas Market

The Mexican pipeline system is 9,043 kilometer 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 (bcfd). This volume includes 231 million cubic feet (Mmcfd) of gas imports, 779 Mmfcd of non associated gas, and 2.2 bcfd of associated gas from processing plants.

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 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.

However, the problem can be simplified exploiting some technical and institutional properties of the Mexican pipeline network. The problem of pricing gas can be treated as a single pipeline connecting Burgos with Ciudad Pemex. The

[6] See Arteaga, J. C. and D. Flores, (2002). Interestingly enough, if the markets were segmented, then the argument made in that paper would imply that the price of gas in the south of Mexico could be higher that the price that would result of the netback rule.

connections at Los Ramones and Cempoala are mass points in the distribution of demand[7].

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 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.

We will assume that individuals are located along a pipeline. They can spend their income on goods, an alternate fuel or gas. The price of gas is given by an nonlinear price schedule that is a function of location and the quantity of gas purchased. We show that under such conditions, the general optimal price of gas is the net back rule. A general optimal nonlinear price schedule for gas is a very powerful instrument in that it permits location specific taxation. However, the net back rule is also optimal without location specific charges if there are no income effects. Further, the netback rule is always Pareto efficient. The net back rule is the optimal way of pricing gas unless there are redistributional goals that must be met using this instrument and location specific charges are ruled out.

Model

Assume that individuals are located on the interval $[0,\bar{n}]$ with a general density function $f(s)\geq 0$ which represents a pipeline of length $\bar{n}$. This density function allows the possibility of intervals with no demand as well as mass points. A special case is where demand is on a set of discrete points along the pipeline. The typical individual located at point s has a utility function of the form

$$v = u(x,y,z) \tag{1}$$

where x is a bundle of goods, y is the consumption of natural gas and z is the consumption of a substitute fuel for natural gas. Each individual is assumed to furnish one unit of labor at a wage $w(s)$.

[7] See Brito and Rosellón (2002)

Individuals maximize utility subject to the constraint

$$w(s) = x + t(y,s) + q(s)z \tag{2}$$

where $t(y,s)$ is the price schedule for gas and is the market determined price of the substitute fuel. The price of x is one. The Lagrangian for the individual's maximization is:

$$L = u(x,y,z) + \lambda[w(s) - x - t(y,s) - q(s)z] \tag{3}$$

The if we assume that there are no corner solutions, the first order conditions are[8]:

$$\frac{\partial u(x,y,z)}{\partial x} - \lambda = 0 \tag{4}$$

$$\frac{\partial u(x,y,z)}{\partial y} - \lambda\frac{\partial t(y,s)}{\partial y} = 0 \tag{5}$$

$$\frac{\partial u(x,y,z)}{\partial z} - \lambda q(s) = 0 \tag{6}$$

The planner can redistribute income by location as a function of the consumption of gas, so $\frac{\partial t(y,s)}{\partial s}$ is a possible control instrument. Define $\alpha(y,s) = \frac{\partial t(y,s)}{\partial s}$. Individuals differ in their location and income, so using the envelope theorem it follows that the utility of individuals along the pipeline is given by the solution of the differential equation,

$$\frac{dv}{ds} = \lambda\left[\frac{dw(s)}{ds} - \alpha(y,s) - z(s)\frac{dq(s)}{ds}\right]. \tag{7}$$

Using the first order condition for x, this can be written as

$$\frac{dv}{ds} = \frac{\partial u(x,y,z)}{\partial x}\left[\frac{dw(s)}{ds} - \alpha(y,s) - z(s)\frac{dq(s)}{ds}\right]. \tag{8}$$

[8] This assumption does not change any of the results.

Let $v(s)$ be the solution of the differential equation, then we can use the relationship $v = u(x, y, z)$ to write

$$x = x(v, y, z). \tag{9}$$

The variable $v(s)$ is a state variable and the variables $y(s)$ and $z(s)$ are control variables. Define the aggregate amount x by X, of y by Y and z by Z. The good X_1 is consumed and X_2 is exported. For gas, Y_o is produced domestically, Y_1 is imported at a price p, Y_2 is used to produce X, Y_3 is imported gas consumed by individuals and Y_4 is domestic gas consumed by individuals. For the substitute fuel, Z_1 is imported at a price $\bar{q}$, Z_2 is used to produce X and Z_3 is consumed by individuals.

We will assume that the good X is produced by a technology that uses energy

$$X = F(Y_2, Z_2) \tag{10}$$

where $F(Y_2, Z_2)$ is a well behaved strictly concave function and Y_2 and Z_2 is the energy used to produce the good. Production of the good is assumed to occur at $n = 0$ and it is assumed the good x can be transported without charge.

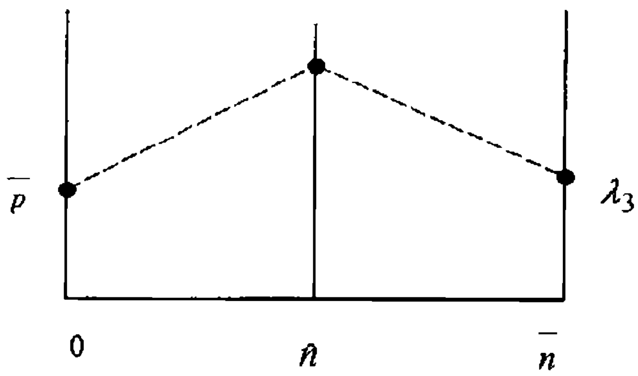

Figure 1

Production of gas is assumed to occur at $n = 0$ and it is assumed the gas can be transported at a cost c. Define $\hat{n}$ as the point of arbitrage. The cost of moving imported gas to point of arbitrage is $\hat{n}c$ and the cost of moving domestic gas to point of arbitrage is $(\bar{n} - \hat{n})c$.

Define

$$V = \int_0^{\hat{n}} [\beta(s)v(s) - scy(s)] f(s)ds + \int_{\hat{n}}^{\bar{n}} [\beta(s)v(s) - (\bar{n} - s)cy(s)] f(s)ds \tag{11}$$

where $\beta(s)$ is the welfare weight of individuals located at point s. Now let us consider a planner trying to maximize welfare

$$W = V + G \tag{12}$$

where G is public expenditures. The maximization is subject to the constraints that

$$X_1 = \int_0^{\bar{n}} x(s) f(n)ds \tag{13}$$

$$Y_3 = \int_0^{\hat{n}} y(s) f(n)ds \tag{14}$$

$$Y_4 = \int_{\hat{n}}^{\bar{n}} y(s) f(n)ds \tag{15}$$

$$Z_3 = \int_0^{\bar{n}} z(s) f(n)ds \tag{16}$$

Equations (13) through (16) represent the aggregate demand for goods and energy. If we assume that net redistribution is zero, then

$$0 = \int_0^{\bar{n}} \alpha(s) f(n)ds \tag{17}$$

The aggregate constraints are:

$$X_1 + X_2 + G = F(Y_2, Z_2) \tag{18}$$

$$Y_0 + Y_1 = Y_2 + Y_3 \tag{19}$$

$$Z_1 = Z_2 + Z_3 \tag{20}$$

$$X_2 - pY_1 - qZ_1 = 0 \tag{21}$$

The constraints given by equations (13) through (17) can be converted to differential equations

$$\frac{dX_1}{dn} = x(n)f(n) \tag{22}$$

$$\frac{dY_3}{dn} = y(n)f(n) \tag{23}$$

for $n < \hat{n}$

$$\frac{dY_4}{dn} = y(n)f(n) \tag{24}$$

for $n > \hat{n}$[9].

$$\frac{dZ_3}{dn} = z(n)f(n) \tag{25}$$

$$\frac{dA}{dn} = z(n)f(n) \tag{26}$$

[9] If $f(\hat{n})$ is a mass point in the distribution function the demand for domestic gas will be that such that $Y_0 \leq Y_4$.

where A is aggregate redistribution. The aggregate constraints given by (18) to (21) define the transversality conditions for the differential equations. The planner's problem can be written as maximizing

$$W = V + G + \delta_1[F(Y_2 + Z_2) - X_1 - pY_1 - \bar{q}Z_1 - G] + \delta_2[Y_0 + Y_1 - Y_2 - Y_3] + \delta_3[Z_1 - Z_2 - Z_3] \qquad (27)$$

The variables $\delta_i, i = 1,3$ are the Lagrange multipliers associated with the aggregate constaints. Recall that V is the aggregate welfare of agents. This is an optimal control problem and the maximization with respect to the aggregate variables give the transversality conditions. To simplify notation we will not use the arguments of the variables. The Hamiltonian is

$$H = \beta v + [\lambda_1 x + (\lambda_2 - cn)y + \lambda_4 z + \lambda_5 \alpha]f(n) + \theta \frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right) \qquad (28)$$

for $n < \hat{n}$ and

$$H = \beta v + \{\lambda_1 x + [\lambda_3 - c(\bar{n} - n)]y + \lambda_4 z + \lambda_5 \alpha\}f(n) + \theta \frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right) \qquad (29)$$

for $n > \hat{n}$,where $\lambda_i, i = 1,5$, are the costate variable associated with (22) through (25) respectively and θ is the costate variable associated with (8). The control variables are y, z and α . The first order conditions with respect to y is

$$\left[\lambda_1 \frac{\partial x}{\partial y} + (\lambda_2 - nc)\right]f(n) + \theta \frac{\partial}{\partial y}\left[\frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right)\right] = 0 \qquad (30)$$

for $n < \hat{n}$ and

$$\left[\lambda_1 \frac{\partial x}{\partial y} + (\lambda_2 - (\bar{n} - n)c)\right]f(n) + \theta \frac{\partial}{\partial y}\left[\frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right)\right] = 0, \qquad (31)$$

for $n > \hat{n}$

The first order condition with respect to z is

$$\left[\lambda_1 \frac{\partial x}{\partial z} + \lambda_4\right]f(n) + \theta \frac{\partial}{\partial z}\left[\frac{\partial u}{\partial x}\left(\frac{dw}{ds} - \alpha - z\frac{dq}{ds}\right)\right] = 0 \qquad (32)$$

The first order condition with respect to α is

$$\lambda_5 f(n) - \theta(s) = 0 \tag{33}$$

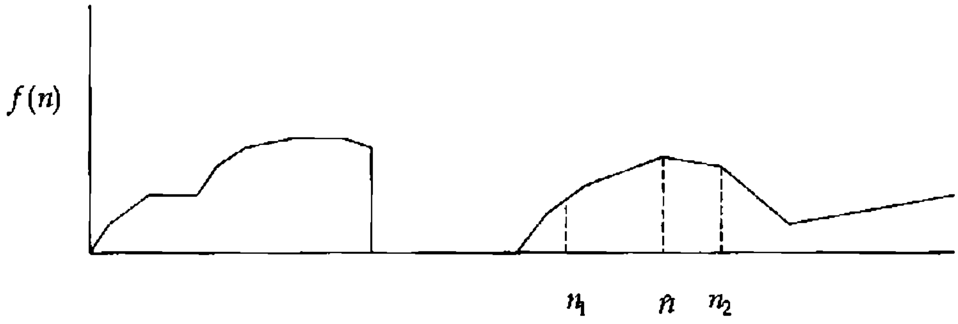

Figure 2

We will assume initially that the point $\hat{n}$ is in an interval (n_1, n_2) such that $f(n)$ is strictly positive, continuous and there are no mass points for n in (n_1, n_2). (See Figure 2) Then it follow from the continuity of the Hamiltonian that

$$\begin{aligned} &\beta v + \left[\lambda_1 x + (\lambda_2 - c\hat{n})y + \lambda_4 z + \lambda_5 \alpha\right] f(\hat{n}) + \theta \frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right) \\ &= \beta v + \left[\lambda_1 x + (\lambda_3 - c(\bar{n} - \hat{n}))y + \lambda_4 z + \lambda_5 \alpha\right] f(\hat{n}) + \theta \frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right) \end{aligned} \tag{34}$$

so

$$(\lambda_2 - c\hat{n}) = (\lambda_3 - c(\bar{n} - \hat{n})) \tag{35}$$

Equation (35) links the shadow price of imported gas with the shadow of domestic gas given the assumption that there are no mass points. Now suppose that $\hat{n}$ is a mass point. Then imported and domestic gas are both consumed at $\hat{n}$ and it follows from the first order conditions with respect to y given by (30) and (31) that

$$(\lambda_2 + nc) = \left[\lambda_3 + c(\bar{n} - n)\right] \tag{36}$$

which yields the netback rule. Intuitively the result follows from the law of one price. If imported and domestic gas are being sold at the point represent by $\hat{n}$, they must have the same price.

Since X_1, Y_3, Y_4 and Z_3 are not in the Hamiltonian, $\frac{d\lambda_i}{dn} = 0, i = 1,4$.

The first order conditions for the aggregate variables in (27) are

$$\delta_1 \frac{\partial F}{\partial Y_2} - \delta_2 \leq 0; Y_2\left[\delta_1 \frac{\partial F}{\partial Y_2} - \delta_2\right] = 0 \tag{37}$$

$$\delta_1 \frac{\partial F}{\partial Z_2} - \delta_2 \leq 0; Z_2\left[\delta_1 \frac{\partial F}{\partial Z_2} - \delta_2\right] = 0 \tag{38}$$

$$\delta_1 = 1 \tag{39}$$

$$\delta_1 p = \delta_2 \tag{40}$$

$$\delta_1 q = \delta_3 \tag{41}$$

These first order conditions are the transversality conditions for G, X_1, Y_3 and Z_3:

$$\lambda_1 = -1 \tag{42}$$

$$\lambda_2 = -\delta_2 = -p \tag{43}$$

$$\lambda_4 = -\delta_3 = -q \tag{44}$$

Since $v(0)$ and $v(\bar{n})$ are free end points, $\theta(0) = \theta(n) = 0$. The value of λ_3 is derived from (35) and results in

$$\lambda_3 = \bar{p} - 2c\hat{n} + c\bar{n} \tag{45}$$

Proposition 1 The optimal non-linear price schedule for natural gas is the netback rule.

proof

$v(0)$ and $v(\bar{n})$ are free end points so $\theta(0) = \theta(\bar{n}) = 0$, thus $\lambda_5 = 0$ at 0 and $\bar{n}$. Since λ_5 is constant, $\lambda_5 = 0$ for all n and thus $\theta(n) = 0$ for all n. The first order condition given by (30) can be written as

$$-\frac{\partial x}{\partial y} - (p + nc) = 0 \tag{46}$$

which is the desired result.

Proposition 2 If there are no income effects, the optimal non-linear price schedule for natural gas is the netback rule and there is no redistribution.

proof

A sufficient condition for the result to hold is that in the first order condition given by (30), the term $\theta \frac{\partial}{\partial y}\left[\frac{\partial u}{\partial x}\left(\frac{dI}{dn} - \alpha - z\frac{dp}{dn}\right)\right] = 0$ so that the condition $-\frac{\partial x}{\partial y} - (p + nc) = 0$ holds.

Denote derivatives by subscripts, then

$$\frac{\partial}{\partial y}u_x = u_{xy} + u_{xx}\frac{\partial x}{\partial y} = u_{xy} - u_{xx}\frac{u_y}{u_x} = u_x\left[\frac{u_{xy}u_x - u_{xx} - u_y}{u_x^2}\right] \tag{47}$$

This is the income effect term from Slutsky's equation.

Proposition 3 The netback rule for pricing natural gas is Pareto optimal.

proof

A sufficient condition for the result to hold is that the welfare weights, $\beta(n)$ be such that the term $\theta(n) = 0$ for all n in $[0, n]$. Since $v(0)$ is a free endpoint, $\theta(0) = 0$ so a sufficient condition for the term $\theta(n) = 0$ for all n in $[0, \bar{n}]$ is that

$$\frac{d\theta}{dn} = -\left[\beta(n) - \frac{dx}{dv}\right] f(n) + -\theta \frac{\partial}{\partial v}\left[\frac{\partial u}{\partial x}\left(\frac{dw}{dn} - \alpha - z\frac{dq}{dn}\right)\right] = 0 \qquad (48)$$

so

$$\left[\beta(n) - \frac{\partial x(s)}{\partial v(s)}\right] = 0 \qquad (49)$$

is a sufficient condition for $\theta(0) = 0$ for all n and the welfare weights are such that no redistribution is optimal. This implies that any redistribution cannot be Pareto improving and thus the solution is Pareto optimal.

Propositions 1 through 3 were derived under the assumption that the point of arbitrage, $\hat{n}$, is in an interval (n_1, n_2) such that $f(n)$ is positive and continuous in (n_1, n_2). Let us relax these assumptions. (See Figure 3.)

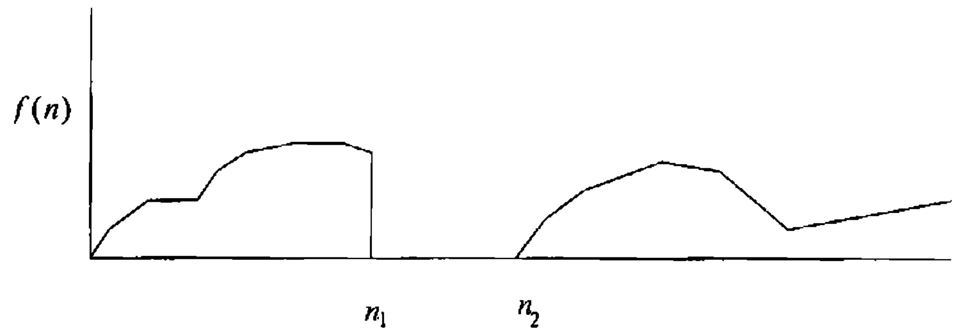

Figure 3

Now suppose that there exist an open interval (n_1, n_2) such that

$$Y_0 = \int_{n_2}^{\bar{n}} y(s) f(s) ds \qquad (50)$$

and $f(n) = 0$ in (n_1, n_2). The two markets are now separated and the value of λ_3 is determined by (50). This seems to suggest that the netback rule does not apply.

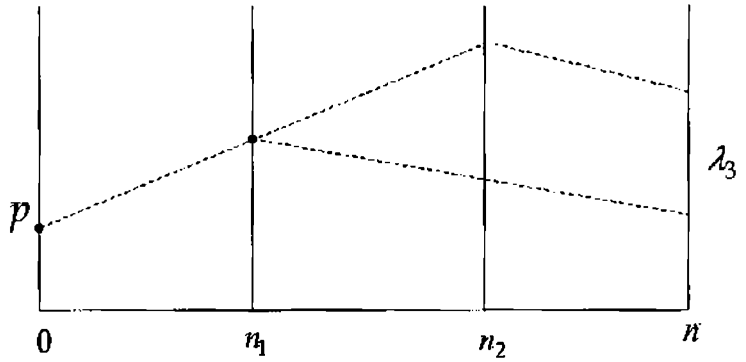

Figure 4

However, suppose that the solution for λ_3 is such that $\lambda_3 > \bar{p} + n_2 c + (\hat{n} - n_2)c = p + 2cn_2 - c\hat{n}$, then the solution can not be optimal as it can be improved by increasing the amount of imported gas. Now suppose that the solution for λ_3 is such that $\lambda_3 < \bar{p} + n_1 c + (\hat{n} - n_1)c = p + 2cn_1 - c\hat{n}$, then the solution can not be optimal as it can be improved by decreasing the amount of imported gas. Thus, a necessary condition for optimality is

$$\bar{p} + n_1 c + (\hat{n} - n_1)c = \bar{p} + 2cn_1 - c\hat{n} \leq \lambda_3 \leq \bar{p} + n_2 c + (\hat{n} - n_2)c = \bar{p} + 2cn_2 - c\hat{n} \qquad (51)$$

In this case the netback rule with n_1 or n_2 as the arbitrage points creates an upper and lower bound on the price of gas in the segmented market and the price can vary by $2c(n_2 - n_1)$. This is not very important. To illustrate suppose the price of gas is \$2.00 per MMBTU, the gap was 200 miles (which is roughly the distance between Los Ramones and Cempoala) and the cost of transporting gas is \$.50 pr MMBTU per 1000 miles. If the elasticity of demand for gas was .1, then

$$.1 = \frac{\frac{\Delta Y}{Y}}{\frac{2 \times .50 \times 200}{2.00 \times 1000}}$$

or

$$\frac{\Delta Y}{Y} = 0.1$$

A one percent change in demand is enough to eliminate the gap in our example. Segmented markets may occur for a brief period of time. However, given the fluctuations in demand for gas and production, this is not an important phenomena. Moreover, the net back price is a lowerbound on the price in a segmented market. Thus, while a segmented market creates the possibility that Pemex can extract rents in the southern market, it cannot be used to argue for a subsidy for gas. If the critics of the netback rule are motivated by a desire for a lower price than the netback price; arguing that the markets is segmented would lead to a Pyrrhic victory as it would justify a higher price for gas.

Conclusions

This paper studies the optimality of the netback rule based on the Houston Ship Channel price to price natural gas in Mexico that has been implemented by Comisión Reguladora de Energía in an open economy where agents can chose between gas and alternative fuels and where the density function describing the distribution of agents along the pipeline can have intervals that are empty and mass points.

The paper shows that if the gas market is not segmented the netback rule is Pareto optimal. The Mexican gas market has not been segmented as gas from Ciudad Pemex reaches Los Ramones. However, if the market should become segmented the netback rule defines an upper and lower bound to the price in the segmented market. The possible segmentation that could occur in the Mexican gas market is between Los Ramones and Cempoala. If such a gap such occur, a one percent change in demand or supply would eliminate it, so this is not a very important issue.

References

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

Arteaga, J. C. and D. Flores, (2002), "Una Nota sobre la Regulacion del Precio del Gas enMexico", *El Trimestre Economico*, vol. LXIX(1), Num. 273,Mexico

Brito, D. *L., W. L.* Littlejohn and J.Rosellón, *2000,* "Pricing Liquid Petroleum Gas in Mexico, *Southern Economic Journa*l, 66 (3), 742-753.

Brito, D. L. and J.Rosellón, 2002, "Pricing Natural Gas in Mexico: an Application of the Little-Mirrlees Rule," manuscript.

Comisión Reguladora de Energía, 1996, "Directiva sobre la Determinacion de Precios y Tarifas para las Actividades Reguladdas en materia de Gas Natural," MEXICO. (WEB SITE:http://www.cre.gob.mx)

Little, I. M. D. and J.A. Mirrlees, 1968, "Manual of Industrial Project Analysis in Developing Countries", (Development Centre of the Organization for Economic Co-Operation and Develpment, Paris)

Mirrlees, J. A. (1971), "An Exploration in the Theory of Optimal Taxation," Review of Economic Studies, 38:175-208.

Pemex, 1998, "Indicadores Petroleros y Anuario Estadístico".

Rosellon, J. and J. Hulpren, 2001, "Regulatory Reform in Mexico's Natural Gas Industry: Liberalization in Context of Dominant Upstream Incumbent," Policy Research Working Paper 2537, *The World Bank.*

Secretaría de Energía, 1998, "Prospectiva del Mercado de Gas Natural, 1998-2007." (WEB SITE:http://www.energia.gob.mx/frame4.html)