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Juan Rosellón y Dagobert Brito

TIMING OF INVESTMENT IN LPG PIPELINES IN MEXICO

Abstract

This paper addresses the timing of optimal investment in LPG pipelines when the goal is to maximize consumer surplus less private cost and social of transporting LPG. The loss of consumer surplus is small. The important elements are the private cost of transporting LPG and the congestion created by trucks.

Resumen

En este artículo se analiza el momento óptimo de inversión en los sistemas de transporte de gas LP cuando el objetivo es maximizar el excedente del consumidor menos los costos privados y sociales de transportar gas LP. La pérdida del excedente del consumidor es pequeña. Los elementos importantes son el costo privado de transportar gas LP y la congestión creada por los carrotanques.

Key words: gas líquido de petróleo, bienestar, precio, México, regulación

Introduction

The question we are addressing is the timing of investment in liquid petroleum gas (LPG) pipelines. There are three technologies to do so, trucks, railroads and pipelines. Trucks and railroads are characterized by mobile capital and high variable costs. The second technology is pipelines. Pipelines are characterized by high fixed costs and low variable costs. The questions we want to address are: 1) if the demand for gas is increasing, at what point is it the optimal to invest in pipeline capacity; 2) when a pipeline is built, what is the optimal capacity that should be installed.

In the general case this is a difficult problem. It has many of the elements of a integer programming problem in that pipe comes in discrete nominal diameter. Fortunately, the economics of solving any particular problem is not difficult as the number of cases that have to be solved is small and many of the cases can be ruled out by inspection.

Solving actual cases, however, does involve major special difficulties. First, the cost of building any particular pipeline will depend on topography. Second, the externalities created by trucks carrying LPG in the form of congestion and damage to highways may be one of the most important public policy reasons to build pipelines. This however depends on the particular case.

The savings to PEMEX that come from using pipelines is substantial. However, the consumer surplus that would result from a decrease in the cost of LPG (assuming these savings were passed on to the consumer) is small. Since the savings are on the order of two to four percent and the elasticity of demand is small, on the order of -0.1 to -0.2, the welfare loss from a failure by PEMEX to invest in LPG pipelines is small.

Since the problem is so case specific and since the benefits are so small, the timing of investment in LPG should perhaps be left to PEMEX or better yet to the market.

Truck Technology

Trucks do not involve any medium run fixed costs. They can be bought, sold or leased and can be shifted between markets as the demand for trucks changes. The costs associated with trucks have two components. Part of the cost of using trucks to ship LPG can be attributed to the distance traveled, this includes such items as fuel, wear and tear, and the other part of the cost can be attributed to time in transit. This includes such items as the capital cost of the truck and labor cost. Thus, the cost of shipping LPG by truck is

$$c_1 = [\alpha_1 L + \alpha_2 (T_1 + T_2)]Q \tag{1}$$

where L is the distance, T_1 is the time in transit and T_2 is the time loading and unloading the cargo and Q is the volume of LPG.α_1 and α_2 are parameters. The time in transit depends on two parameters, the capacity of the road and the level of traffic. We will assume that the time in transit is given by

$$T_1 = \left(\frac{X}{w}\right)^k L \tag{2}$$

*Department of Economics [MS-22] Rice University 6100 Main Houston, TX 77005 email: Brito@rice.edu
** Centro de Investigación y Docencia Económicas, A. C. Carret. México Toluca 3655 Lomas de Santa Fe, 01210 Mexico D. F e-mail:jrosellon@dis1.cide.mx

where k and w are parameters that depend on road characteristics and X is the volume of traffic on the road.

The private cost of transporting LPG by trucks is then given by given by

$$c_1 = \left\{ \left[\alpha_1 + \alpha_2 \left(\frac{X}{w} \right)^k \right] L + \alpha_2 T_2 \right\} Q \tag{3}$$

The cost of transporting LPG between various points by truck in Mexico was obtained from various industry sources. The private cost function in pesos per ton was calculated as

$$C=[77.2+0.552L]Q \tag{4}$$

or using 12 barrels of LPG per ton as a conversion factor the cost in pesos per barrels is

$$C=[6.43+0.46L]Q \tag{5}$$

Congestion

If there is congestion on the road, there is also an externality associated with using trucks to transport LPG since an increase in the number of trucks carrying LPG will increase the travel time for all other traffic as given by

$$\frac{dT}{dQ} = \alpha_2 k \left(\frac{X}{w} \right)^{k-1} \frac{dX}{dQ} \tag{6}$$

where $\frac{dX}{dQ}$ is a parameter that depends on the size of trucks carrying LPG. So the externality imposed by an increase in the volume of LPG shipped is then given by

$$X\frac{dT}{dQ} = \alpha_2 k \left(\frac{X}{w} \right)^{k} \frac{dX}{dQ} \tag{7}$$

and the sum of social and private marginal costs of moving LPG is

$$MC = \left[\alpha_1 + \alpha_2 \left(\frac{X}{w} \right)^k \right] L + \alpha_2 T_2 + \alpha_2 k \left(\frac{X}{w} \right)^k \frac{dX}{dQ}. \tag{8}$$

Railroads

Like trucks, railroad transport of LPG does not involve any medium run fixed costs. Tank cars can be bought, sold or leased and can be shifted between markets as the demand changes. The costs associated with rail transport has two components. Part of the cost of using rail to ship LPG can be attributed to the distance traveled, this includes such items as fuel, wear and tear, and the other part of the cost can be attributed to time in transit. This includes such items as the capital cost of the tank cars and labor cost. Thus, the cost of shipping LPG by rail is

$$c_3 = [\rho_1 L + \rho_2 (T_1 + T_2)]Q \qquad (9)$$

where L is the distance, T_1 is the time in transit and T_2 is the time loading and unloading the cargo. ρ_1 and ρ_2 are parameters. Unlike trucks, congestion may not be an important factor.

The cost of transporting LPG between various points by railroad in Mexico was obtained from distinct industry sources. Railroads are similar to trucks in their cost structure, however they to not impose congestion externalities. The private cost function in pesos per ton is

$$C=[67.8+0.14L]Q \qquad (10)$$

or using 12 barrels per ton as a conversion factor the cost in pesos per barrels is

$$C=[5.65+0.011L]Q \qquad (11)$$

Pipeline Technology

Pipelines use power and pipe to transport the liquefied LPG. The equation for transporting LPG is of the form

$$Q=K_0 HP^{\nu} D^{\gamma} \qquad (12)$$

where ν and γ are parameters This function can be used to derive a cost function of the form

$$c_2=F(D)+G(Q,D) \qquad (13)$$

where $F(D)$ represents the fixed costs associated with installing a pipeline of diameter D, and $G(Q,D)$ are the variable costs. Some data on pipeline capacity are given in the table below.[1]

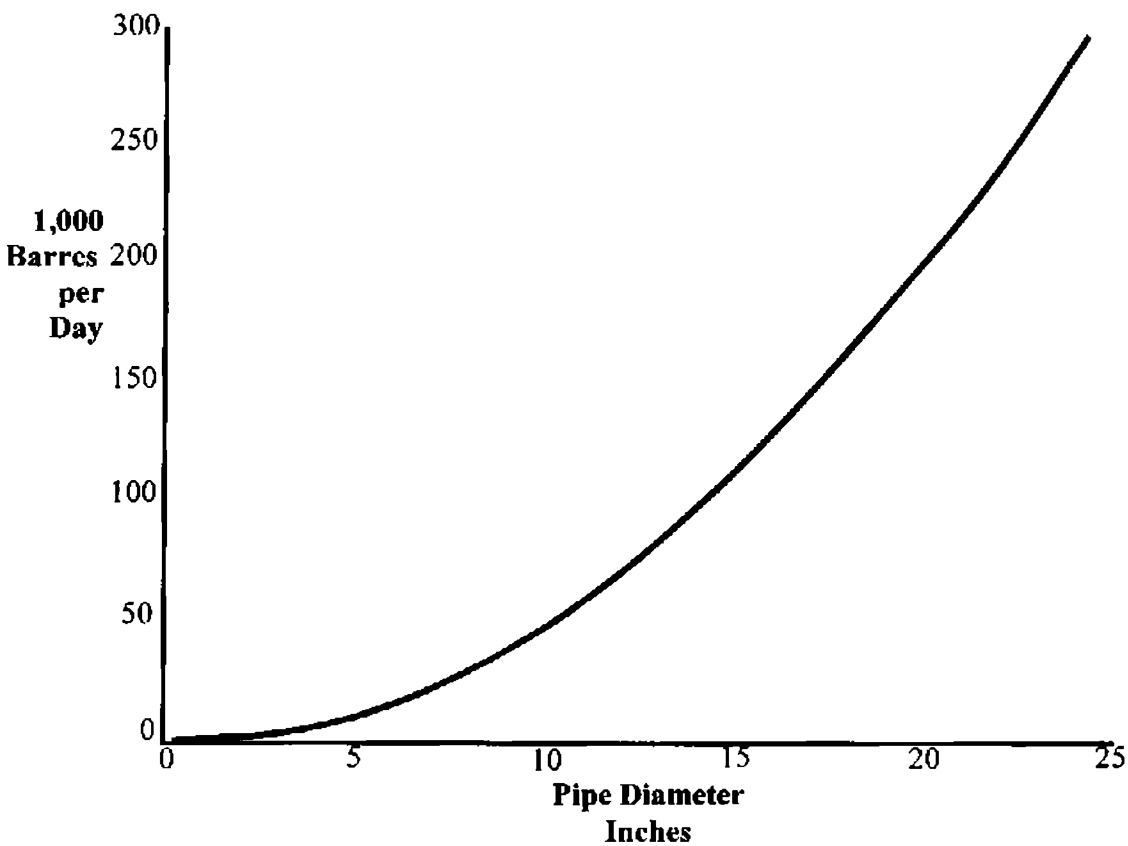
[1] This is at an optimal speed of 6 feet per second and a maximum pressure of 75 Kilograms per squared centimeter.

Table 1

Pipe Diameter	Throughput Barrels/day
8	32,000
10	50,000
12	72,000
20	200,000
24	288,000

This data can be used to estimate the relationship between pipe diameter and throughput.

Figure 1



The capacity that results from this data is

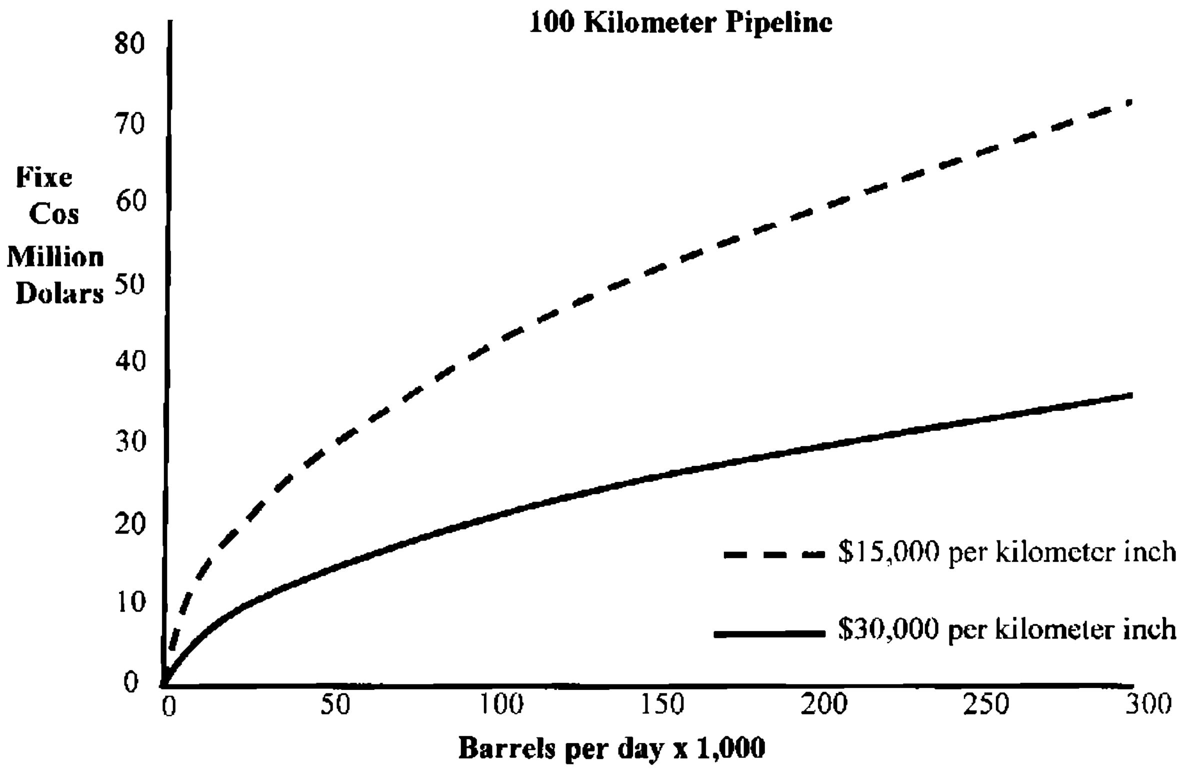
$$\overline{Q} = 500D^2$$

Let β be the cost per mile inch of building a pipeline. The fixed cost of a pipeline with capacity $\overline{Q}$ is given by

$$FC = \beta\sqrt{\frac{\overline{Q}}{500}}. \tag{14}$$

Using the rule of thumb that the cost of a pipeline is between U.S. $15,000 to $30,000 per kilometer inch [2]. The capital costs of building a 100 kilometer pipeline is given in Figure 2 below.

Figure 2



Consumer Surplus

Now let us assume that demand for LPG at time t is given by

$$Q = e^{\gamma t} H(p) \tag{15}$$

where γ is the growth rate of the demand. The planner can satisfy this demand by investing a pipeline, using trucks, or both. Investment in pipe lines is lumpy. The cost associated with using pipelines is given by

$$C_2(0) = \sum_{i=1}^{\infty} e^{-rT_i}\left[F_i(D_i) + \int_0^{\Delta T_i} e^{-rs} G(Q, D_i) ds\right] \tag{16}$$

[2] Thus a ten-inch pipeline one-kilometer long would cost between $150,000 to $300,000.

where $\{T_i, i = 1,\infty\}$ is the set of times where there is investment in pipeline capacity, D_i is the diameter of the installed pipe and $\Delta T_i = T_{i+1} - T_i$.

A market has demand given by (15) which is being supplied by trucks at some constant cost c_1 per unit. The planner can build a pipeline and supply this market at a cost given by (16). Assume that the charge for transporting gas by pipeline in the period $[T_i, T_{i+1}]$ is given by $\overline{\tau}_2(i)$ and that the price of LPG at the point of origin is given by $\overline{p}$. Then

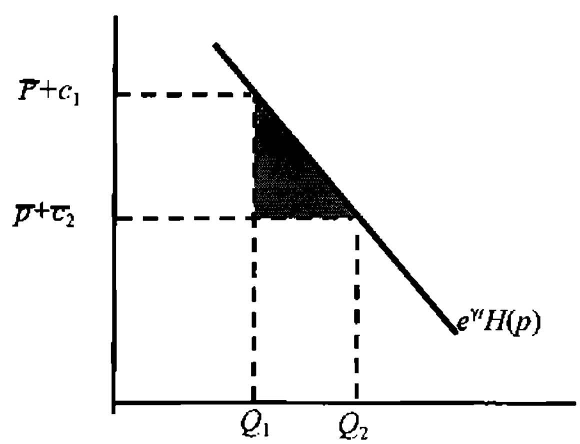
$$Q_1 = e^{\gamma t} H(\overline{p} + c_1) \tag{17}$$

is the demand for LPG if it is transported by truck and

$$Q_2 = e^{\gamma t} H(\overline{p} + \overline{\tau}_2(i)) \tag{18}$$

is demand if it is transported by pipeline.

Figure 3

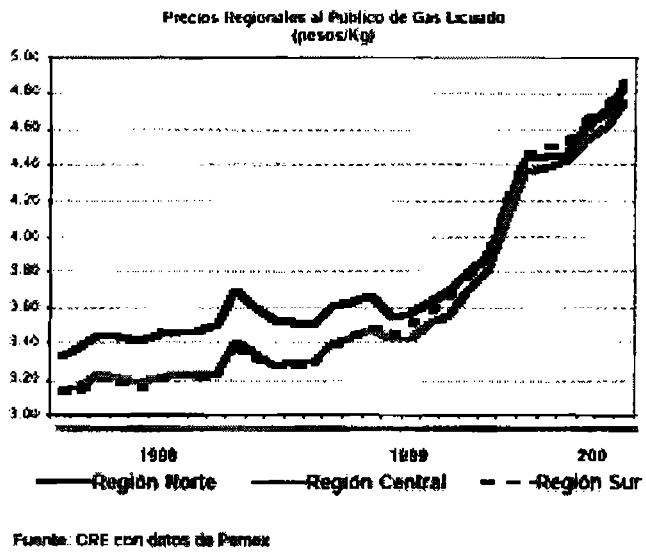


The present value of consumer surplus at T_0 is given by

$$S(T_0)=\sum_{i=0}^{\infty}e^{-rT_i}\left[\int_0^{\Delta T_i}e^{-rt}\left(e^{\gamma t}\int_{p+c_2(i)}^{p+c_1}D(p)dp\right)dt\right]. \tag{19}$$

The elasticity for LPG is estimated to be on the order of -0.1 to -.02.[3] The price of LPG in Mexico is given in Figure 4.

Figure 4



These problems have some of the elements of integer programs in that nominal pipe diameters are integers, however this is not a particularly difficult problem in that the number of possible combinations are few. We will use an example to illustrate.

[3] See Dahl (1992).

An Example

Assume that there is a market whose current consumption of LPG is 3500 tons per day and where demand is growing at the rate of 10 percent per year. After 30 years the demand is expected to remain stable. It is currently being supplied by trucks and the problem is to find the optimal investment policy for pipelines, To keep the problem simple assume that pipelines last forever and that we will meet this demand with either and 8 and 10 inch pipeline or a 12 inch pipeline; further we will assume that once the pipeline is in place it is not possible to reintroduce trucks to argument pipeline capacity.

Let us first solve the problem of using one 12 inch pipe. so that there are only two periods. In the first period LPG is carried by truck and in second period a pipeline is used. The planner wants to maximize consumer surplus less the cost of moving gas.

$$W = \int_{T_1}^{T_2} e^{-rt}\left[e^{\gamma t}\int_{\overline{p}+\overline{c}_2}^{\overline{p}+c_1} H(s)ds\right]dt - e^{-rT_1}(F(D)) - \int_{T_1}^{T_2} e^{-rs}G\left(e^{\gamma s}H(\overline{p}+\overline{c}_2), D\right)ds + \int_{T_1}^{T_2} e^{-(r-\gamma)s}c_1 H(\overline{p}+c_1)ds \tag{20}$$

which can be written as

$$W = \int_{T_1}^{T_2} e^{-(r-\gamma)s}\left[\int_{\overline{p}+\overline{c}_2}^{\overline{p}+c_1} H(s)ds\right]dt - e^{rT_1}(F(D)) - \int_{T_1}^{T_2} e^{-rs}\left[G\left(e^{\gamma s}H(\overline{p}+\overline{c}_2), D\right) - e^{\gamma s}c_1 H(\overline{p}+c_1)\right]ds \tag{21}$$

In equation (21) the first term is consumer surplus, the second term is the present value of constructing a pipeline, the third term is the difference in the variable cost of moving gas through a pipeline, and the cost of moving the gas by truck. If we maximize with respect to T_1

$$\frac{\partial W}{\partial T_1} = -e^{-(r-\gamma)T_1}\left[\int_{p+c_2}^{p+c_1} H(p)dp\right] + re^{-rT_1}(F(D)) + e^{-rT_1}\left[G\left(e^{\gamma T_1}H(\overline{p}+\overline{c}_2), D\right) - e^{\gamma T_1}c_1 H(\overline{p}+c_1)\right] = 0 \tag{22}$$

Equation (22) can be written as

$$e^{\gamma T_1}\left[\int_{\overline{p}+\overline{c}_2}^{\overline{p}+c_1} H(s)ds\right] + \left[e^{\gamma T_1}c_1 H(\overline{p}+c_1) - G\left(e^{\gamma T_1}H(\overline{p}+\overline{c}_2), D\right)\right] = rF(D) \tag{23}$$

and if we make the additional assumption that

$$G\left(e^{\gamma T_1}H(\overline{p}+\overline{c}_2), D\right)=e^{\gamma T_1}H(\overline{p}+\overline{c}_2)g(D), \tag{24}$$

then

$$e^{\gamma T_1}\left\{\int_{\overline{p}+\overline{c}_2}^{\overline{p}+c_1}H(s)ds+\left[c_1H(\overline{p}+c_1)-H(\overline{p}+\overline{c}_2)g(D)\right]\right\}=rF'(D) \tag{25}$$

Let us assume:

Price of gas is $5,000 a ton or $420 a barrel

Cost of transporting gas by truck 100 km is $12.00 a barrel.

Variable cost of transporting gas by pipeline 100 km is $2.00 a barrel.

The cost of building the pipeline is MN $320 million for the 100 km 12 inch pipeline.

The cost of building the pipeline is MN $270 million for the 100 km 10 inch pipeline.

The cost of building the pipeline is MN $215 million for the 100 km 8 inch pipeline.

Interest rate is 10 percent.

Elasticity of the demand for gas is - 0.2.

If the cost savings is passed on to the consumer then the percentage change in the price of gas is $-\frac{10}{\frac{420+410}{2}}=-0.024$. The increase in demand is $.005Q$ or at 70,000 barrels/day the increase is 340 barrels per day. The consumer surplus is MN $1,700 at peak throughput. When demand is 3,500 barrels per day, the consumer surplus is MN $85. Substituting the values of the parameters into equation (25) we can compute the optimal time to build the 12-inch pipeline.

$$e^{0.1T_1}(85+35{,}000)=83{,}725 \tag{26}$$

and T_1=8.7 years.

Similarly, we can calculate the optimal time to build the pipeline ha starts with an 8-inch pipeline and is augmented with a 10-inch pipeline. To compute T_1 for the 8-inch pipeline we get

$$e^{0.1T_1}(85+35{,}000)=58{,}500 \tag{27}$$

and T_1=5.1 years. The 10 inch pipeline is constructed at T_2=22.2 when the 8-inch-pipeline reaches capacity.

Table 2

	12 inch pipeline	8 and 10 inch pipelines
Gross Benefits	$272,558,421	$318,624,633
PV Capital Investment at T_1	$134,064,496	$129,106,549
PV Capital Investment at T_2	-	$29,324,459
Net Benefits	$138,493,925	$160,193,624
PV Consumer Surplus	$660,833	$772,523
T_1	8.7 years	5.1 years
T_2	-	22.2 years

Conclusions

Computing the timing of optimal investment in LPG pipelines does involve major special difficulties. However, the cost of building any particular pipeline will depend on topography. The externalities created by trucks carrying LPG in the form of congestion and damage to highways may be one of the most important public policy reasons to build pipelines. This also depends on the particular case.

The savings to PEMEX that come from using pipelines is substantial. However, the consumer surplus that would result from a decrease in the cost of LPG (assuming this saving was passed on to the consumer) is small. Since that savings is on the order of two to four percent and the elasticity of demand is small, on the order of -0.1 to -0.2, the loss in consumer surplus loss from a failure by PEMEX to invest in LPG pipelines is small.

Since the problem is so case specific and since the benefits in terms of consumer surplus are so small, the timing of investment in LPG should perhaps be left to PEMEX or better yet to the market.

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