A Study of Productivity and Efficiency in the Mexican Energy Industry: The Case of Pemex

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Abstract

We study the optimizing behavior of Pemex by estimating the cost shares. We undertake the estimation using duality between the cost and production function, which facilitates our specification. This approach allows us to find the cost shares under different levels of returns to scale. Our results indicate the presence of substantial distortions in cost shares. The suggestion is thus to increase the capital use and decrease the labor use to remove such distortions.

1. Introduction

Latin American investment in the oil business has been booming in recent years, in part due to deregulation efforts. Argentina, for example, was able to raised billions by selling its woefully inefficient state-run oil company, Yacimientos Petrolíferos Fiscales (YPF), in 1993. Since YPF was privatized, production has doubled. The oil majors have invested $10 billion into joint ventures with state-owned Petróleos de Venezuela, S.A. (PDVSA) of Venezuela. Colombia, Peru, and Brazil have been actively pursuing oil investors.

Even though it was one of the pioneer countries in Latin America to embrace free-market reforms, Mexico's energy industry has yet to benefit from competition. Nationalized in 1938, the oil industry remains largely off limits to private-sector companies. This has hindered the exploitation of Mexico's vast subterranean wealth. Juan

Camilo Mouriño, president of the Energy Commission of the lower house of Congress puts it quite succinctly: "Oil riches only benefit a country if they are efficiently used and serve as a tool for development. Here, that hasn't been the case."

Of the many reforms contemplated by Mexico's current President, Vincente Fox, none seems more problematic than his plans for Petroleos Mexicanos (Pemex). Privatization of the state oil monopoly is not contemplated. Instead, the more feasible goal is envisioned of transforming Pemex, which had revenues of an estimated $40 billion in 2003, into a competitive enterprise. Opposition to this creeping competitiveness is spearheaded by the powerful Oil Workers Union.

Mexico's Energy Secretary, Ernesto Martens, estimated that the country must spend around $14 billion a year over the next decade to meet the increased demand for energy. Much of this investment is expected to come from private investors. However, Mexico's constitution bans private participation in the most attractive areas of the oil business--exploration and production. Instead, of amending the constitution, Mexico's current leadership is expected to push the legal envelope as much as possible by involving private companies in activities where Pemex lacks experience, such as gas-field management. Most other Latin nations have shed fears of foreign participation in the oil sector. Because of a lack of investment, proven reserves have stagnated for nearly two decades, at 28.3 billion barrels of crude oil.

Lack of investment has been complemented with a bloated payroll that will have to be reduced substantially. At 129159, its workforce is nearly 2 1/2 times that of Venezuela's PDVSA, a state-run oil company with comparable revenues.

As Tybout (2000) indicates, many observers have come to believe that the complex system of regulations and bureaucratic burdens are major obstacles to the development of the manufacturing sectors in many developing countries. This is true of the Mexican energy industry as well where institutional constraints have hampered the activities of its state monopoly, Pemex. In this study we analyze the impact of regulatory and institutional distortions on Pemex. We study the impact that economic reforms, were they undertaken, would have on the sector's performance and we examine the impact of distortions by the size of the enterprise.

Our study will begin with a model as our estimation framework, and then a detailed accounting of the institutional background that has dictated the operations of Pemex study over its recent history. We will then describe our data collection and processing. The empirical specification is followed. Our empirical results will allow us to see the inefficiency of Pemex, which, to a great extent, lies in the overuse of labor and under use of capital. Conclusion

2. Model

In this section, we follow the dual approach that Marc Nerlove (1963) used to examine Pemex production and operating efficiency. Similar to Lau and Yotopoulos(1971), we specify the functional form as Cobb-Douglas. Due to the data constraints, we only involve two factors of production, labor and capital. Our Cobb-Douglas production function is:

$$Q = A(t)x_1^{\alpha_1}x_2^{\alpha_2} \tag{0.1}$$

where Q is Output, x_1 is Capital input, x_2 is Labor input, and $A(t) = Ae^{\delta t}$ is the technical change during time.

The degree of homogeneity of the Cobb-Douglas is:

$$v = \alpha_1 + \alpha_2 \tag{0.2}$$

This degree of homogeneity is also the elasticity of scale:

$$v = \alpha_1 + \alpha_2 = \varepsilon \tag{0.3}$$

From the production function, we could obtain the cost function due to duality:

$$C(p_1, p_2, Q) = \psi p_1^{\alpha_1/v} p_2^{\alpha_2/v} Q^{1/v} \tag{0.4}$$

where

$$\psi = v(\alpha_0 \alpha_1^{\alpha_1} \alpha_2^{\alpha_2})^{-1/v} \tag{0.5}$$

Taking log of the cost function yields:

$$\ln C(p_1, p_2, Q) = \ln \psi + \frac{\alpha_1}{v} \ln p_1 + \frac{\alpha_2}{v} \ln p_2 + \frac{1}{v} \ln Q \tag{0.6}$$

Reparameterizing the function gives us:

$$\ln C(p_1, p_2, Q) = \beta_0 + \beta_1 \ln p_1 + \beta_2 \ln p_2 + \beta_3 \ln Q \tag{0.7}$$

where:

$$\beta_0 = \ln \psi \tag{0.8}$$

$$\beta_1 = \frac{\alpha_1}{\alpha_1 + \alpha_2} \tag{0.9}$$

$$\beta_2 = \frac{\alpha_2}{\alpha_1 + \alpha_2} \tag{0.10}$$

$$\beta_3 = \frac{1}{\alpha_1 + \alpha_2} \tag{0.11}$$

The cost function for firms that minimize cost subject to an output constraint is:

$$\min \ln C(p_1, p_2, Q) = \beta_0 + \beta_1 \ln p_1 + \beta_2 \ln p_2 + \beta_3 \ln Q \; s.t. \; f(X, \xi, \alpha) \le Q \tag{0.12}$$

where all variable definitions are as before, and ξ is a random variable. The random variation could be due to factors unobservable to the econometrician, but known to the firms, or due to optimization errors.

Recall that:

$$\ln \psi = \ln \nu(\alpha_0 \alpha_1^{\alpha_1} \alpha_2^{\alpha_2})^{-1/\nu} = \ln \left\{ (\alpha_1 + \alpha_2)(\alpha_0 \alpha_1^{\alpha_1} \alpha_2^{\alpha_2})^{-1/(\alpha_1+\alpha_2)} \right\} \tag{0.13}$$

We have over-identifying problem which could be overcome by an imposition of restriction:

$$\alpha_1 + \alpha_2 = \omega \tag{0.14}$$

where ω is a constant.

Then we can estimate our Cobb-Douglas production function with different returns to scale restriction. Actually, we can rewrite our specification function as below:

$$\ln Q = \ln \alpha_0 + \alpha_1 \ln x_1 + (1 - \alpha_1) \ln x_2$$
$$\text{Alternatively,} \quad \ln Q - \ln x_2 = \ln \alpha_0 + \alpha_1 (\ln x_1 - \ln x_2)$$

3. Background Information

3.1. Background Information

Back in 1869, the first petroleum well in Mexico was drilled by explorers. However, commercial production of crude oil began in 1901. In 1938 President Lázaro Cárdenas nationalized the petroleum industry, giving the Mexican government a monopoly in the exploration, production, refining, and distribution of oil and natural gas, and in the manufacture and sale of basic petrochemicals.

Since the nationalization of the oil industry in 1938, the state-owned Pemex has monopolized the production and marketing of hydrocarbons. For decades the government tolerated Pemex's waste and inefficiency because the company produced nearly all public revenues. Problems mounted, however, as a result of Pemex's poor administration, low productivity, overstaffing, and corruption. By the late 1980s, Mexico's economic recovery had come to depend heavily on reform of the state oil sector.

By early 1993, both crude oil production and exports had begun to decline. The drop in exports resulted from both increased domestic demand and lower total production. For all of 1993, Mexico's oil exports averaged 1.3 million bpd, 2 percent less than in 1992. Exports fell even more sharply in terms of value--to US$7 billion--because world oil prices fell steadily during much of 1992 and 1993. In 1994 Mexico's revenue from oil exports was more than US$7 billion.

For the first ten months of 1995, total mineral production (including oil) contracted by a modest 1 percent. For all of 1995, oil production fell to an average of 2.6 million bpd from 2.7 million bpd in 1994. However, oil output in the first quarter of 1996 increased by 6 percent over the first quarter of 1995 to an average of 2.8 million bpd.

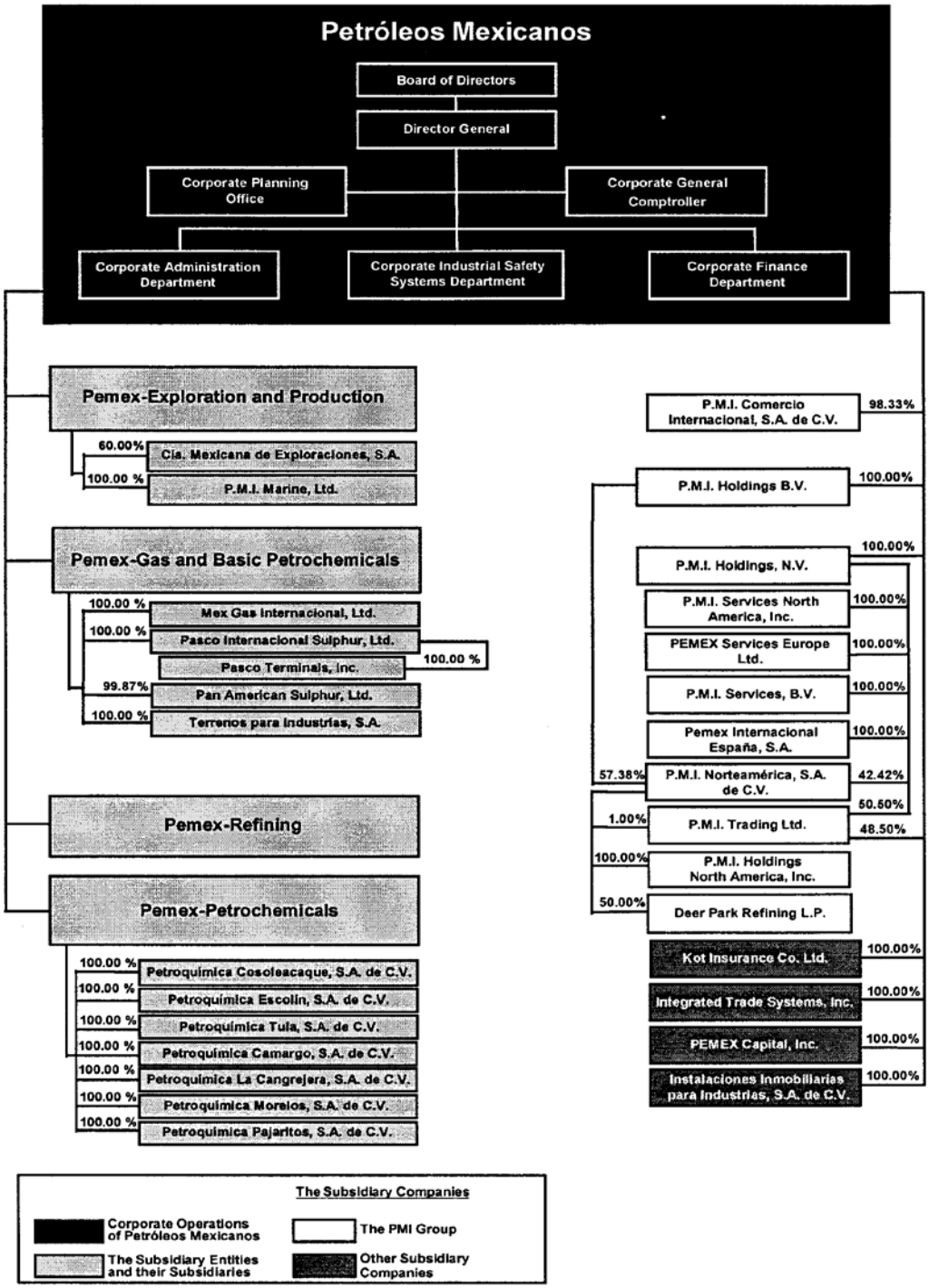
The operations of Pemex are regulated and supervised by the Mexican Government via four bodies:

- The Ministry of Energy monitors Pemex's activities. The Secretary of Minstry of Energy is the chairman of Pemex’s Board of Directors

- The Ministry of Finance and Public Credit incorporates the annual budget and financing program of Pemex and its subsidiary entities into its annual consolidated budget, which is subject to approval by the Mexican Congress.
- The Ministry of Environment and Natural Resources, in coordination with other federal and state authorities, regulates Pemex's environment-related activities.
- The Ministry of Public Function appoints the external auditors of Pemex[4].

The corporate structure of Pemex is as followed:

[4] Pemex's website: www.pemex.com


Petróleos Mexicanos
Board of Directors
Director General
Corporate Planning Office
Corporate General Comptroller
Corporate Administration Department
Corporate Industrial Safety Systems Department
Corporate Finance Department
Pemex-Exploration and Production
60.00% Cía. Mexicana de Exploraciones, S.A.
100.00 % P.M.I. Marine, Ltd.
Pemex-Gas and Basic Petrochemicals
100.00 % Mex Gas Internacional, Ltd.
100.00 % Pasco Internacional Sulphur, Ltd.
Pasco Terminals, Inc. 100.00 %
99.87% Pan American Sulphur, Ltd.
100.00 % Terrenos para Industrias, S.A.
Pemex-Refining
Pemex-Petrochemicals
100.00 % Petroquímica Cosoleacaque, S.A. de C.V.
100.00 % Petroquímica Escolín, S.A. de C.V.
100.00 % Petroquímica Tula, S.A. de C.V.
100.00 % Petroquímica Camargo, S.A. de C.V.
100.00 % Petroquímica La Cangrejera, S.A. de C.V.
100.00 % Petroquímica Morelos, S.A. de C.V.
100.00 % Petroquímica Pajaritos, S.A. de C.V.
P.M.I. Comercio Internacional, S.A. de C.V. 98.33%
P.M.I. Holdings B.V. 100.00%
100.00%
P.M.I. Holdings, N.V.
P.M.I. Services North America, Inc. 100.00%
PEMEX Services Europe Ltd. 100.00%
P.M.I. Services, B.V. 100.00%
Pemex Internacional España, S.A. 100.00%
57.38% P.M.I. Norteamérica, S.A. de C.V. 42.42%
50.50%
1.00% P.M.I. Trading Ltd. 48.50%
100.00% P.M.I. Holdings North America, Inc.
50.00% Deer Park Refining L.P.
Kot Insurance Co. Ltd. 100.00%
Integrated Trade Systems, Inc. 100.00%
PEMEX Capital, Inc. 100.00%
Instalaciones Inmobiliarias para Industrias, S.A. de C.V. 100.00%
The Subsidiary Companies
Corporate Operations of Petróleos Mexicanos
The PMI Group
The Subsidiary Entities and their Subsidiaries
Other Subsidiary Companies

3.2 Data Description

Our analysis and estimates are based on data collected from various sources. Some data were constructed when direct and more relevant data are not available.

Our variables are:

- Output Quantity
- Output Price
- Labor Input Quantity
- Labor Input Price
- Capital Input Quantity
- Capital Input Price

Our main sources of data are from Pemex's consolidated financial statements and Pemex's statistical yearbooks. We also obtain data from Mexico's Ministry of Finance and Public Credit, Mexico's Ministry of Energy, and some other resources.

Pemex's consolidated financial statements (form 20-F) are filed with the United States Securities and Exchange Commission pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934. Pemex's consolidated financial statements are prepared in accordance with Mexican Generally Accepted Accounting Principles (herein referred to as Mexican GAAP). The amounts shown there are expressed in thousands of Mexican pesos as of December 31 of the year reported. We will use a Consumer Price Index data series to adjust for inflation. Mexican GAAP does differ from United States Generally Accepted Accounting Principles (herein referred to as U.S. GAAP) in certain significant respects. However, such differences do not appear in the data.

Pemex's statistical yearbooks are published by Pemex and not subjected to independent auditing. To ensure uniformity, we restrict ourselves to only non-financial data when using Pemex's statistical yearbooks.

Below we will discuss in details our data sources and construction method.

3.3. Data Construction

3.3.1. Revenue Weighted Output Index

Pemex produce several hydrocarbon products. Therefore, to accommodate the model with one output, we create a product index. We use revenue as weight for output groups reported by Pemex. These outputs are: Crude oil, Natural Gas, Petrochemical, and Oil Products.

The formula for output index is:

$$\text{Output Index Quantity} = Q_1 S_1 + Q_2 S_2 + Q_3 S_3 + Q_4 S_4 \qquad (0.15)$$

where:

Q_1 : Crude Oil Output Quantity

S_1 : Cruide Oil Share in Total Revenue,

Q_2 : Natural Gas Output Quantity

S_2 : Natural Gas Share in Total Revenue

Q_3 : Petrochemical Output Quantity

S_3 : Petrochemical Share in Total Revenue

Q_4 : Oil Products Output Quantity

S_4 : Oil Products Share in Total Revenue

and share of each product in Total Revenue is calculated by dividing the revenue from that product to total revenue.

(0.15) is therefore equivalent to:

$$\begin{aligned}\text{Output Index Quantity} = {} & \text{Crude Oil Quantity} * \frac{\text{Crude Oil Revenue}}{\text{Total Revenue}} + \text{Natural Gas Quantity} * \frac{\text{Natural Gas Revenue}}{\text{Total Revenue}} \\ & + \text{Petrochemical Quantity} * \frac{\text{Petrochemical Revenue}}{\text{Total Revenue}} + \text{Oil Product Quantity} * \frac{\text{Oil Product Revenue}}{\text{Total Revenue}}\end{aligned} \tag{0.16}$$

Total Revenue is the sum of Domestic Sales and Exports. Pemex has a subsidiary called Pemex International which handles Pemex's export and import activities. Pemex's reports business results by subsidiaries, not by individual products. In particular, all revenues from domestic sales are reported under Pemex-Refining, Pemex-Gas and Basic Petrochemicals, and Pemex-Petrochemicals. All revenues from export are reported under Pemex International. All revenue data were adjusted to 2000 constant Mexican pesos using CPI.

$$\text{Output Index Price} = \frac{\text{Total Revenue}}{\text{Output Index Quantity}} \tag{0.17}$$

Since the Total Revenue was CPI-adjusted, the Output Index Price is in real pesos in the year 2000.

Note that total revenue, hence our calculation here, could be affected by certain political and geo-political conditions that lie outside Pemex's control. For example, the Mexican Government does impose price controls in the domestic market on Pemex products. In particular, in the third quarter of 2005, the Mexican Government imposed a freeze on the prices of natural gas and liquefied petroleum gas (LPG) sold by Pemex in the domestic market and, as a result, Pemex was not able to pass on all of the increases in

the prices of its product purchases to its customers in the domestic market[5]. Also, even though Mexico is not a member of OPEC, in the past it has entered into agreements with OPEC and non-OPEC countries to reduce global crude oil supply. A reduction in our oil production or exports could reduce our revenues. Another note is in 1995 the Mexican Congress amended the Regulatory Law to allow private and social sector companies, which include labor-controlled organizations and industries, to participate, with the Mexican Government's approval, in the storage, distribution and transportation of natural gas. According to this law, private sector could essentially construct, own and operate pipelines, installations and equipment. Pemex are still allowed us to retain exclusive authority over the exploration, exploitation, production and first-hand sale of natural gas, as well as the transportation and storage inextricably linked with this type of exploitation and production.[6]

3.3.2. Labor Input

We recorded the labor quantity (number of workers) from Pemex statistical yearbook for the period of 1990-2005. For Labor Price, we obtain the Total wage and pension and retirement expenses paid by Pemex reported to the Ministry of Finance and Public Debt's Statement of Cash Flow. The data were reported as one single entry for each year before 2001 and after that, wages were reported separately from pension and retirement expenses. Our labor price data is then calculated as:

$$P_{labor} = \frac{\sum \text{Salary + Pension}}{\text{Total Employee}} \tag{0.18}$$

[5] Pemex Form 20-F 2005 p.9
[6] Pemex Form 20-F 2005, p. 14

Here the price unit would be pesos/employee/year. We use CPI data to adjust to the base year of 2000.

3.3.3. Capital Input

We obtain Pemex's total investment for each year from Pemex statistical yearbook. We only have data from 1991 to 2005. To construct 1990 data, we first obtain average investment increment from 1991 to 1999. Then take a way the amount equal to average increment from 1991 investment number to get our 1990 investment approximation.

For the price of capital, we use formular for user's cost of capital, which is:

$$UCC = \frac{\text{Nominal 10 year Government Bond - Inflation - Effective Depreciation}}{(1 - \text{Effective Tax Rate}) * \text{Price of Capital}} \quad (0.19)$$

To get the effective depreciation rate, we use the formula:

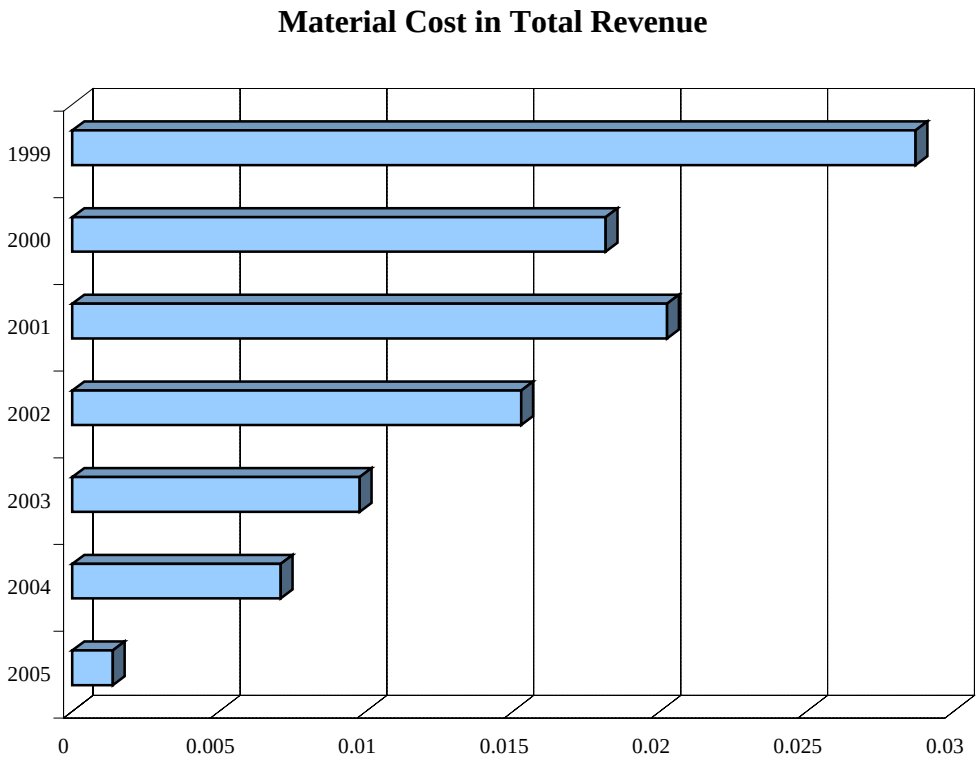
$$\text{Effective Depreciation} = \frac{\text{Total Depreciation and Amortization}}{\text{Total Asset}} \quad (0.20)$$

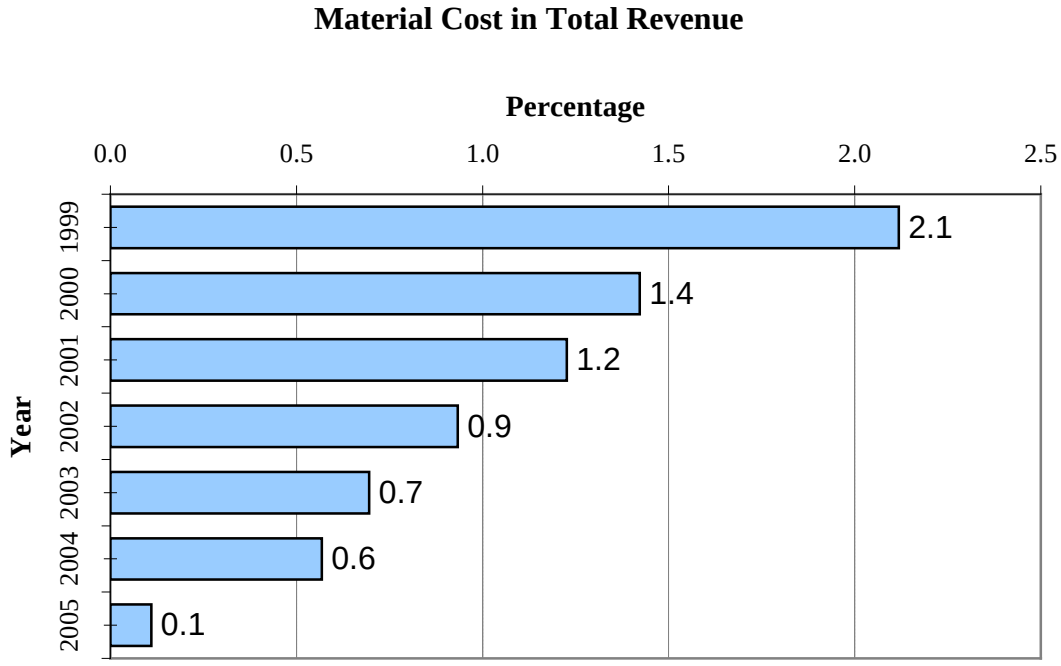
The Total Depreciation and Amortization as well as Total Asset data come from Pemex's financial statements. We use average of the year that we have data (1998-2005) for the years that we do not have data.

3.3.4. Material Cost

We obtain material cost from the Presupuesto de Egresos de la Federación of the government of Mexico for corresponding years. The Ministry of Finance and Public Credit provides the data from the year 1999 onward. We observed a decreasing percentage of material cost in the total revenue. In particular, the proportion of material cost in total revenue decreases on average 33% yearly. Graph 1 below shows the percentage of material cost in total revenue of Pemex for the period of 1999-2005.

Graph 1: Material Cost in Total Revenue – Absolute and Percentage





Based on this observation, we estimates the material costs for earlier years.

3.3.5. Tax

To calculate effective tax rate, we use the following formula:

$$\text{Effective Tax Rate } \frac{\text{Total Tax and Government Duties}}{\text{Total Income before Tax}} \qquad (0.21)$$

Again, we use average of the year that we have data for (1998-2005) for the years that we do not have data. Please note that Pemex and the Subsidiary Entities are subject to special tax laws, which are based upon petroleum revenues and do not generate temporary differences or deferred income taxes. Pemex and the Subsidiary Entities are not subject to the Ley del Impuesto Sobre la Renta ("Income Tax Law") or the Ley del Impuesto al Activo ("Asset Tax Law"). Some of the Subsidiary Companies are subject to the Income Tax Law and Asset Tax Law; however, such Subsidiary Companies do not

generate significant deferred income taxes. Pemex and the Subsidiary Entities are subject to the following duties and taxes: Hydrocarbon Extraction Duties, Hydrocarbon Income Tax and the Special Tax on Production and Services ("IEPS Tax"). Pemex and the Subsidiary Entities are also subject to the Value Added Tax ("VAT"). Hydrocarbon extraction duties are calculated at a rate of 52.3% on the net cash flow difference between crude oil sales and extraction costs and expenses. Extraordinary and additional hydrocarbon extraction duties are calculated at a rate of 25.5% and 1.1%, respectively, on the same basis. The hydrocarbon income tax is equivalent to the regular income tax applied to all Mexican corporations, a tax to which Pemex and the Subsidiary Entities are not subject to; the rate of this tax was 35% for all periods presented. The sum of the above duties and taxes must equal 60.8% of Pemex and the Subsidiary Entities' annual sales revenues to third parties. In addition, Pemex pays an additional 39.2% duty on excess gains revenues, i.e. the portion of revenues in respect of crude oil sales at prices in excess of 18.35 U.S. dollars and 15.50 U.S. dollars per barrel for 2003 and 2002, respectively. Therefore, to the extent that the sum of hydrocarbon extraction duties is less than 60.8% of sales to third parties, additional taxes are paid to reach that level.

The special Tax on Production and Services (IEPS Tax) is a tax on the domestic sales of gasoline and diesel. The applicable rates depend on, among other factors, the product, producer's price, freight costs, commissions and the region in which the respective product is sold.

Over the period of 1996-2005, Pemex's average effective tax rate is 103%.

3.3.6. Mexico's long-term interest rate

We obtain the Mexico's long-term interest rate from the OECD data service website. The data refer to the 364-day interest rate equivalent paid, tax-free, on one-year treasury certificates (364-day CETES) at primary auction. According to OECD, long term (in most cases 10 year) government bonds are the instrument whose yield is used as the representative `interest rate' for this area. Generally the yield is calculated at the pre-tax level and before deductions for brokerage costs and commissions and is derived from the relationship between the present market value of the bond and that at maturity, taking into account also interest payments paid through to maturity.

3.3.7. Consumer Price Index

We obtain Consumer Price Index (CPI) of Mexico for the period from two sources Econstat and OECD. Yearly CPI of Mexico is obtained from EconStat.com at http://www.econstats.com/ifs/IFS_Mex1v105.htm.

OECD data is online at http://stats.oecd.org/mei/default.asp?lang=e&subject=8&country=MEX.

The OECD obtains data from the Bank of Mexico. The data were collected based on the structure of private consumption taken from the National Income and Expenditure Household Survey (Encuesta Nacional de Ingresos y Gastos de los Hogares, ENIGH) carried out by INEGI in 2000. From this survey, 315 generic items were selected to be representative of household consumption. Urban Mexican cities with more than 20000 inhabitants are covered in survey.

3.3.8 Producer price

We obtain producer price from the U.S. bureau of labor services: http://www.bls.gov/opub/hom/homch14_b.html.

4. Empirical Results

4.1 Estimation

Our estimation is based on the production function (0.2), and duality is utilized to get the cost shares. We also imposed different levels of returns to scale to remove the over identification problem. We append additive error term to the logarithm of the production equation, and the function is estimated via Least Square to get the parameters $\alpha_1, \alpha_2, \delta$ and the intercept $\ln A$. Using the relationships between the parameters in the production function α_1 and α_2 and those in the cost function β_1 and β_2, as shown in Section 2, the cost shares β_1 and β_2 are derived from equation(0.10) and (0.11). Table 1 provides the $\beta's$ under different levels of returns to scale.

Table 1: Cost Share Estimates

Return to Scale Level	Cost share	
	β1-Capital	β2-Labor
1	0.684190795	0.315809205
1.05	0.691569063	0.308430937
1.1	0.698276579	0.301723421
1.15	0.704400833	0.295599167
1.2	0.710014733	0.289985267
1.25	0.71517952	0.28482048
1.3	0.719947016	0.280052984
1.35	0.724361364	0.275638636
1.4	0.728460402	0.271539598
1.45	0.732276748	0.267723252
1.5	0.73583867	0.26416133

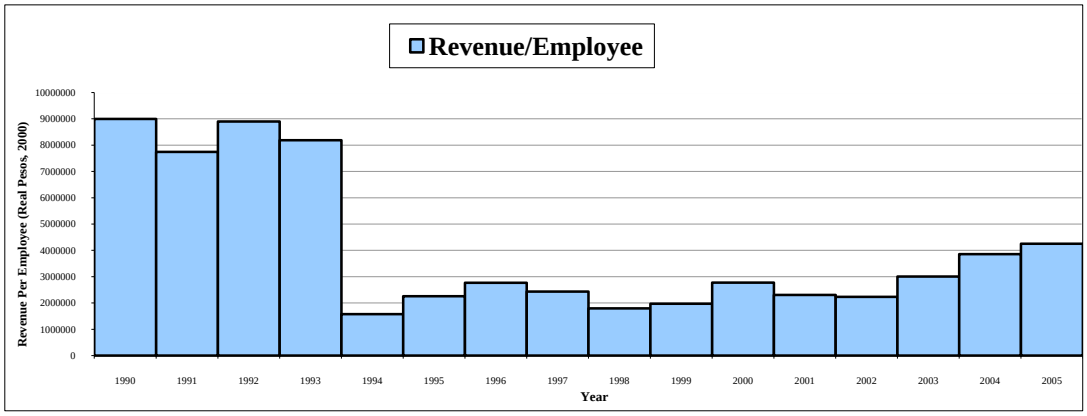
4.2 Pemex Efficiency in Labor Usage

The efficiency in labor usage of Pemex is worth special attention as it epitomizes the impact of the interference that the government of Mexico used. Inefficiency is not an unknown issue with Pemex as even in the 70s, Pemex need three times the staff to produce as much oil as Venezuelan national oil company, PDVSA.

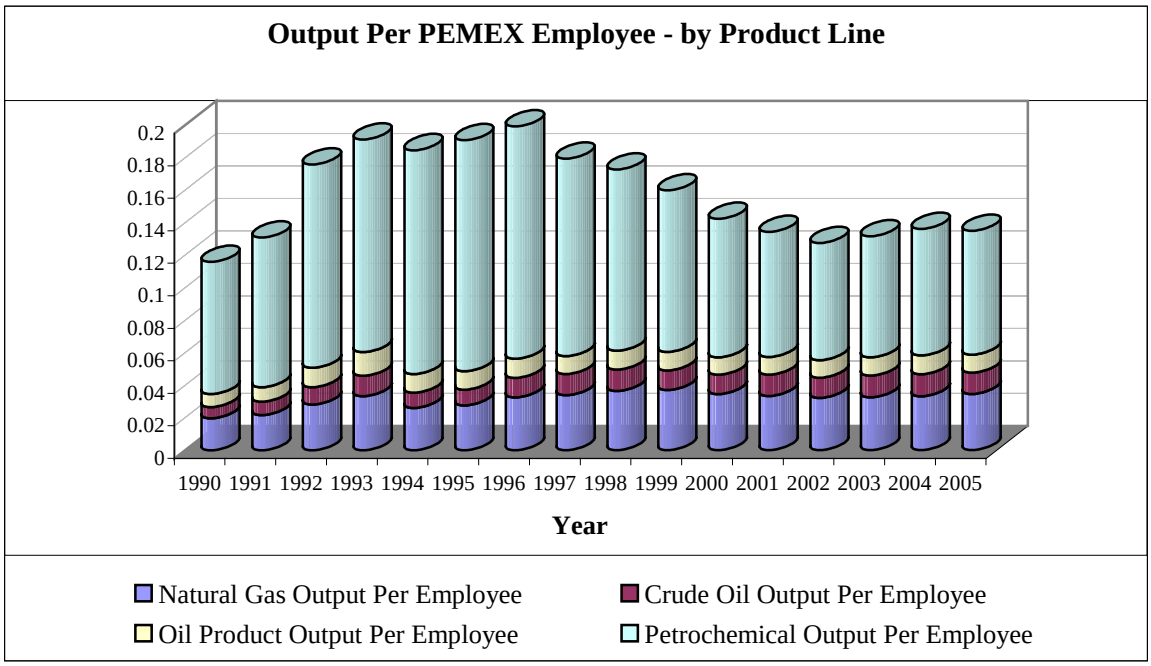
Graph 2 shows the counter effect of Mexican labor regulatory policy as we could observe the drop in the revenue per employee from 1994 onward when the regulatory adjustment came into effect. In 1990, a Pemex employee generates 9 million pesos in revenue. During 1990-1994 periods, a Pemex employee on average brings in between 8 to 9 million pesos.

One could argue that since our measure is exchange-rate dependent revenue, the result could be due to the large-scale capital flight that led to a heavy devaluation of Mexican pesos during the 1994-1995 periods. We look at two other measures that would be less prone to exchange rate volatility. The measures are output per Pemex employee and output per Million pesos spent on labor. For each measure, we calculate the output per line of product (natural gas, crude oil, oil products, and petrochemicals). The unit for each measure is therefore the product unit per employee or million

Graph 2: Pemex's Revenue Per Employee - 1990-2005:

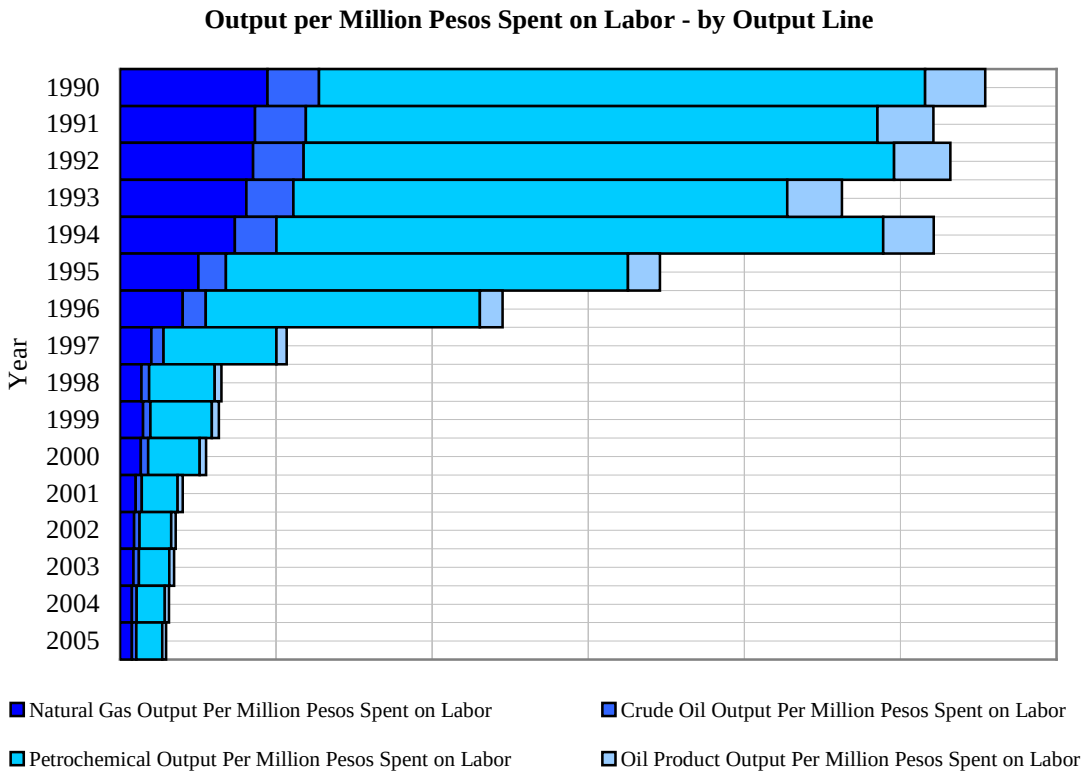


Graph 3: Pemex's Output Per Employee - 1990-2005

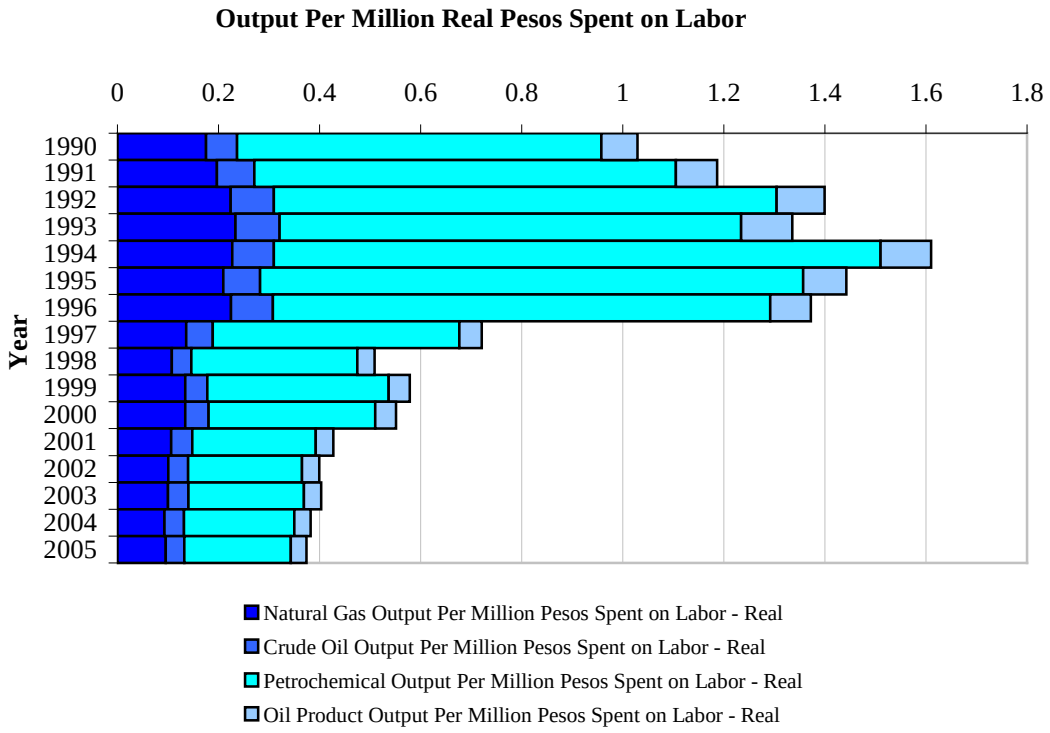


By measuring output per million pesos spent on labor, we could minimize the effects of exchange rate. The following Graph 4 and Graph 5 show the output per million pesos spent on labor, in nominal pesos and 2000-based pesos.

Graph 4: Pemex's Output Per Million Pesos Spent on Labor - 1990-2005:



Graph 5: Pemex's Output Per Million 2000- Pesos Spent on Labor- 1990-2005:



Pemex inefficiency in labor usage has been an issue to the government of Mexico for a long time. However, the government had not taken any action to reduce the inefficiency before the 1990s due mainly to the fact that Pemex was the largest, and almost the sole, contributor to the public revenues. In our sample, we observe a significant deduction of labor in the early 1990s. Such deduction was the result of the Mexican government effort to reform the state oil sector, starting with labor efficiency improvement. More than 40 percent of employee was laid off during the 4 year period of 1989-1993 to reduce expenses. The results above suggests a result that was not expected from such expense reduction policy. On reason for such result could be that expense were not cut entirely since right after the labor reduction policy, there was a new policy to increase Pemex's employee's benefits such as housing, child-care and retirement. This

again is due to the Mexico's Federal Labor Law which allows collective employment contract to be modified *ex post* when the labor union and employer reach a new argreement. Essentially, the law of the company can be changed whenver the labor union could pressure the company into a new accord. Pemex's labor union has great influences in Mexican politics. In the 1990s, at the height of it, Pemex's labor union leader was granted a seat in Parliament. The Pemex's inability to really cut down labor cost led to over-usage of labor in the production process, which in turns create in efficiency. We expect the results from our analysis substantiate this explanation.

4.3. Pemex Production Efficiency

In a study of national oil company efficiency, Hartley (2007a) developed a theoretical model which implies that government ownership of a NOC will redistribute revenue via over-employment and underinvestment in reserves and by subsidizing domestic consumption. Hartley (2007b) provides evidence that "increased government ownership makes the firm less effective at producing revenue from employment and reserves" and over-employment was a strong common feature of government owned firms. In addition, domestic price subsidies negatively affect an NOC's ability to generate revenue and the relative technical inefficiencies of NOCs, which are observed when one considers only commercial objectives, are largely the result of governments exercising control over the distribution of rents.

From our estimation, we found the cost shares of capital and labor. As we vary the level of return to scale imposed on the production, the results vary as expected. In

particular, as we increase the level of return to scale, from 1 to 1.5, the cost share of capital increases and the cost share of labor decreases (see Figure 1 below).

Table 1: Cost Share Estimates

Return to Scale Level	Cost share	
	β1-Capital	β2-Labor
1	0.684190795	0.315809205
1.05	0.691569063	0.308430937
1.1	0.698276579	0.301723421
1.15	0.704400833	0.295599167
1.2	0.710014733	0.289985267
1.25	0.71517952	0.28482048
1.3	0.719947016	0.280052984
1.35	0.724361364	0.275638636
1.4	0.728460402	0.271539598
1.45	0.732276748	0.267723252
1.5	0.73583867	0.26416133

The results of estimated cost shares suggest a more intensive use of capital and less usage of labor. However, the observed share from Pemex data shows that Pemex still over-used its labor resource. Compared to cost shares that Pemex should use to obtain the level of return to scale of 1.25, the observed cost shares of labor is consistently higher, while the cost shares of capital is consistently lower over the 16 year period of 1990-2005. Table below details such discrepancies over the period.

Table 2: Observed Cost Shares vs. Estimated Cost Shares

Year	Observed		Difference from Estimated Share.	
	Labor Share	Capital Share	Labor Share	Capital Share
1990	0.318798	0.681202	0.033977	-0.033977
1991	0.317406	0.682594	0.032585	-0.032585
1992	0.317216	0.682784	0.032395	-0.032395
1993	0.343085	0.656915	0.058264	-0.058264
1994	0.329726	0.670274	0.044906	-0.044906
1995	0.320654	0.679346	0.035834	-0.035834
1996	0.288412	0.711588	0.003592	-0.003592
1997	0.376733	0.623267	0.091912	-0.091912
1998	0.396612	0.603388	0.111792	-0.111792
1999	0.379969	0.620031	0.095148	-0.095148
2000	0.314434	0.685566	0.029614	-0.029614
2001	0.370674	0.629326	0.085853	-0.085853
2002	0.372463	0.627537	0.087642	-0.087642
2003	0.342680	0.657320	0.057860	-0.057860
2004	0.330170	0.669830	0.045350	-0.045350
2005	0.324819	0.675181	0.039998	-0.039998
Est., CRS=1.25	**0.284820**	**0.715180**	**0**	**0**

The results confirm our expectation that Pemex's inefficiency comes from over-usage of its labor resource and under-investment of capital. Pemex's inability to achieve a better allocation of resource is the result of its regulatory constraint, notably the burden of labor expenses required by the Mexico government. The results also imply that should Pemex have more autonomy in its decision making process regarding allocation of its resources, Pemex would be able to adjust the cost share to achieve higher level of efficiency. For Pemex to have such autonomy, more efforts from the government will be needed. Note that we study Pemex over the period of 1990-2005 when there have been efforts to improve efficiency of Pemex. Such efforts include restructuring the corporation into four semi-autonomous subsidiaries in 1992, allowing outside parties to participate in

bidding for certain services previously reserved from unions, authorizing foreign partnership and service providers participation.

5. Conclusion

In this study, we incorporate a model that captures the optimizing behavior on cost minimizing subject to production constraint and specify the functional form of the cost function. Using duality, we get the production function and the relationship between the parameters of the production function and the cost function repectively. Thus the cost shares under different scenarios of returns to scale are estimated through the production function. Our empirical result reveals the distortions of the cost shares and the direction and extent of such distortions. As bad news from the depleting Cantarell is confirmed, the pressure for Pemex to resolve its inefficiency problem is mounting. The overuse of labor and underuse of capital is the problem that leads to the inefficiency, which reduces the international competitiveness of this key and strategic industry. In any case, for Pemex to be more competitiveness in the international market, the inefficiency observed in this study should be addressed and resolved.

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