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The Hydrocarbon Sector in Mexico: From the Abundance to the Uncertain Future

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Abstract

Oil in Mexico has been the cornerstone on which the Mexican State has built upon since its nationalization. It has been the main federal income source, it has supported industrial development and has allowed the State to increase international reserves. Petróleos Mexicanos (PEMEX), the National Oil Company (NOC), is a supply of vital resources for the government by financing public spending, providing certainty to the economy as well as providing extra resources for local governments. However, for decades, fiscal, institutional, legal and organizational constraints have not allowed the NOC to fully behave as a profit maximizing firm that chooses optimal strategies for reinvesting its own resources and/or subcontracting other firms with advanced technologies, such as deep-water technology. In this paper we describe the history of the hydrocarbon sector in Mexico, discuss its performance, analyze its legal, contractual and fiscal conditions, and study the corporate governance of PEMEX as well as its financial, operative independence and regulatory architecture. We further study the main aspects related to geology and technology, the evolution of discoveries and the success rates of exploration in the Mexican oil industry. We also analyze details of investment strategies, and the role of Cantarell and the deep and ultra-deep oil fields. We finally analyze the drivers of performance, counterfactual scenarios, and alternative hypotheses.

Resumen

El petróleo en México ha sido la piedra angular sobre la que el Estado mexicano se ha construido desde su nacionalización. Ha sido la fuente principal de ingresos federales, ha apoyado el desarrollo industrial y ha permitido al Estado aumentar las reservas internacionales. Petróleos Mexicanos (PEMEX), la compañía nacional de petróleo (NOC), es una fuente de recursos vitales del gobierno para la financiación del gasto público, proporciona seguridad a la economía, así como proporciona recursos adicionales para los gobiernos locales. Sin embargo, durante décadas, las restricciones fiscales, institucionales, jurídicas y de organización no han permitido que la NOC se comporte plenamente como una empresa de maximización del beneficio que elige estrategias óptimas para reinvertir sus propios recursos y/o subcontratar otras empresas con tecnologías avanzadas, como la tecnología de aguas profundas. En este artículo describimos la historia del sector de hidrocarburos en México, discutimos su desempeño, analizamos sus condiciones fiscales, contractuales y legales, y estudiamos el gobierno corporativo de PEMEX, así como su independencia operativa y su arquitectura regulatoria. Estudiamos también los principales

aspectos relacionados con la geología y la tecnología, la evolución de los descubrimientos y las tasas de éxito en la exploración en la industria petrolera mexicana. También analizamos los detalles de las estrategias de inversión, y el rol de Cantarell y de los campos profundos y ultraprofundos. Finalmente, analizamos los determinantes del desempeño, escenarios contrafactuales e hipótesis alternativas.

Introduction

In this paper we analyze the Oil Sector in Mexico. The study is divided into four sections. In the first section, we describe the history of the sector. In the second section, we discuss the performance of the sector in terms of evolution of production, reserves and investment. We subsequently analyze the legal, contractual and fiscal conditions of *Petróleos Mexicanos* as well as internal hydrocarbon prices and their effects on investment, in the third section. We also study issues related to the corporate governance of PEMEX and their evolution as well as the financial, operative independence and regulatory architecture. In the fourth section, we study the main aspects related to geology and technology, the evolution of discoveries and the success rates of exploration in the Mexican oil industry. We analyze as well details of investment strategies, and the role of *Cantarell* and the deep and ultra-deep oil fields. We further analyze the drivers of performance, counterfactual scenarios, and alternative hypotheses. Finally, we conclude some remarks.

Historical Evolution

Oil explorations in Mexico started in 1870 when the first oil companies, *London Oil Trust* and *Mexican Oil Corporation*, were established. However, real development started until the first oil wells were discovered during the Porfirio Diaz regime by the end of 1890. In December 24th, 1901, the first oil law was issued. It allowed the Federal Government to grant concessions to oil companies to explore oilfields and import refinery equipments free from import tariffs. It also eliminated any taxes on invested capital. This promoted the emergence and growth of oil companies such as *S. Pearson & Son Limited* (later known as *El Águila Company*), *Huasteca Petroleum Company* and the *Compañía Transcontinental de Petróleo, S.A.*

This scheme did not change very much during the next few years. Companies could explore and extract oil on the continental shelf, lakes and lagoons. It was not until the government of Francisco I. Madero (1911-1913) when the first tax on oil companies was established: twenty cents per ton of crude oil. This action was interrupted by the collapse of Madero's government. Then, in 1914 the government of Venustiano Carranza imposed a new tax on all existing companies (80 producing and 17 exporting companies). All of them had Anglo-American ownership. These companies were the support for the Mexican consolidation as the second largest producer of oil in the world. However, this decade was so complicated that the oil companies did not allocate any resources to expand their activities.

It was until 1917, with the design of the Mexican Constitution (particularly, with *Article 27*) that the Mexican State took control of the oil resources. The same year, a tax on oil production was established which (it was actually, a tax on exports). Since then, the Mexican Government undertook different measures and tax regimes for all companies participating in the oil production (Silva, 1973). The oil sector then grew at a steadily pace until the early 1930's generating substantial resources for the Mexican Federal Government.

This market architecture changed dramatically in 1937. A dispute between the Mexican Government and the oil companies intensified when the government of Lázaro Cárdenas refereed a conflict between the oil labor union, *Sindicato de Trabajadores Petroleros de la República Mexicana* (created in 1935), and the oil companies trying to prevent a strike in 1937. This conflict later evolved into a social movement that fostered the nationalization of the Mexican oil industry in 1938 during the Cárdenas government. There was an immediate international reaction through a blockage of Mexican oil in foreign markets. However, World War II helped Mexico since the attention of the United States was concentrated on the war, relaxing almost completely the blockage (Gutiérrez, 1998).

After 1938, this new market architecture allowed the Mexican State to design the oil sector according to its interests. On the one hand, the Mexican policy for hydrocarbons was developed according to three basic principles. First, the government granted subsidies on hydrocarbon energy input prices for the transport and the industrial sectors. Second, the Mexican State tried to set an autonomous national technological capacity. And third, the State also implemented welfare improvements for oil workers that still prevail nowadays. On the other hand, the development of exploration, extraction, construction of refineries and the expansion of distribution networks were sought under a tight public budget constraint (Wionczek, 1983).

The ulterior development of the nationalized industry was not easy due to financial shortages, organizational problems, as well as union conflicts. This situation was made even more complex due to the 1944 decree that required *Petróleos Mexicanos* to pay to the expropriated oil firms. However, the Second World War had a positive impact on the growth of the Mexican industry in general, including the oil industry, since it importantly fostered oil demand.

From 1950 to 1970 the growth dynamics were interrupted and, for the first time, oil exports ceased in 1966. This fact reflected an unfavorable financial situation for the *NOC* as well as the failure of the low-price policy. During 1971-1972, Mexico started to import oil. However, explorations carried out in the Mexican southeast during 1972-1974, led to the discovery of many important oilfields. Afterwards, Mexico increased production and, consequently, exportation, starting an important period with no economic

crisis. However, from mid 1980 through 1981 there was an excessive public expenditure due to high oil revenues so as to keep high economic growth rates within the world recession. A new world energy circumstances by mid 1981 —oriented towards savings and the substitution of oil by natural gas, and other energy alternative sources— caused a reduction in oil demand and, therefore, in the crude oil price. This translated into drastic austerity economic measures in Mexico (Wionczek, 1983).

During the development of the Mexican oil sector from 1982 to 2008, the international oil prices played two key roles. First, in most recent years the price of the Mexican crude-oil export bundle increased, implying more income for *PEMEX*. Second, the global cost of energy in Mexico has increased owing to the high dependence on fossil fuels in the industrial, transportation and energy sectors, as well as the increasing growth in the exports of fuels. Even more, the oil production costs have increased due to the intensive utilization of fossil fuels and depletion of the main oilfields. However, in the last years revenues from the relatively high oil international prices have covered the requirements of the federal government and the needs of *PEMEX*, resulting in a tense economic stability that dangerously depends on the random behavior of the international oil market prices.

Likewise, the financial crises that Mexico has experienced (in 1970, 1982, 1985 and 1994) have affected the progress of hydrocarbon production. Such problems have occurred due to diverse factors like variations in international energy prices, and the poorly developed Mexican public policies. Even more, the increase in import costs for machinery and equipment has deteriorated the utilization of capacity and investments in Mexico, which has also implied a decrease in the short-run and long-run productivity in the sector.

Regarding natural gas, its production has been hindered by a policy approach to the natural gas industry that lacks of infrastructure compared to the one in the oil extraction. Natural gas in fact represents a secondary business for *PEMEX*, and does not get enough resources for its development. *PEMEX* only realized about the potential of natural gas until the early 1970s, when it started to develop a pipeline system along the gulf coast with the purpose of exporting gas to the United States. This facilitated gas consumption in the northern Mexican States, and helped to foster the development of some local concessions in natural gas distribution.

Additionally, the reform in the electricity industry in 1992 —opening this sector to private investment in electricity generation under self-supply, co-generation and independent-power-production projects— encouraged the development of the natural gas sector. Afterwards, the Natural Gas Reform of 1995 allowed private investments in distribution, transportation and storage projects. These reforms implied the creation of a regulatory entity, the *Comisión Reguladora de Energía* (*CRE*), with ample attributions to regulate transportation and distribution tariffs and biddings. The remaining market

power of *PEMEX* in production was also regulated by the *CRE* through yardstick regulation (Brito and Rosellón, 2002).

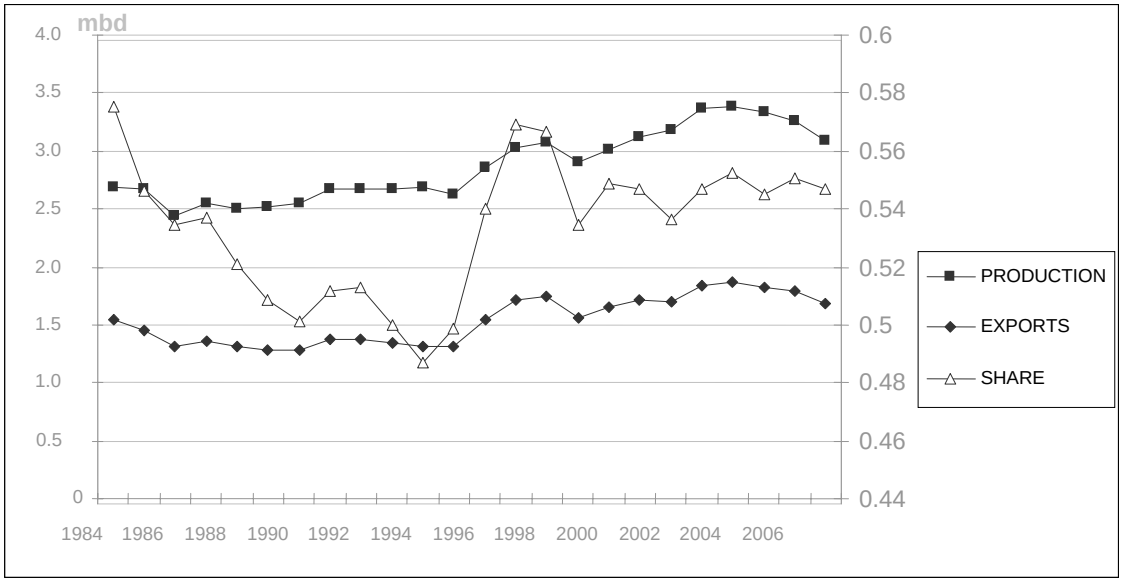
In the next section we will discuss the evolution of the sector in terms of production (barrels per day of oil, cubic meters of gas, exports, etc.), reserves (oil and gas) and investment (wells, rigs, dollars).

Performance of the Oil Sector

Production

In 2007, *PEMEX* produced 3.082 million barrels per day (mbd). It was the 3rd place in the world. Regarding refinery, *PEMEX* was in 13th place with 1,269 mbd processed. However, by 2008 Mexico was placed 6th regarding crude oil production, and 15th with respect to refinery capacity. *PEMEX* has reached this production status through an increase in its capacity during the period 1986-2003. But, since 2004, both *PEMEX*' production and exports have been reducing (see Figure 1). Mexico reached a maximum production level in 2004 with 3.883 mbd. But afterwards, production declined in 2007 from 3.4 mbd to 3.1 mbd. *PEMEX* has recently stated that it will try to keep its production above 3.0 mmbd until 2012(Lajous, 2008).

FIGURE 1. CRUDE PRODUCTION AND EXPORTS



Source: *PEMEX* (1995-2008), *IEA* (2008) and *SENER* (2008b).

Oil production in Mexico is divided into regions: *Marine Northeast*, *Marine Southwest*, *South* and *North*. The more productive fields are found in the *Marine Northeast* region, such as *Ku-Maloob-Zaap* and *Cantarell*, with four main fields: *Akal*, *Nohuch*, *Chac* y *Kutz*. In the *Marine Southwest* the main

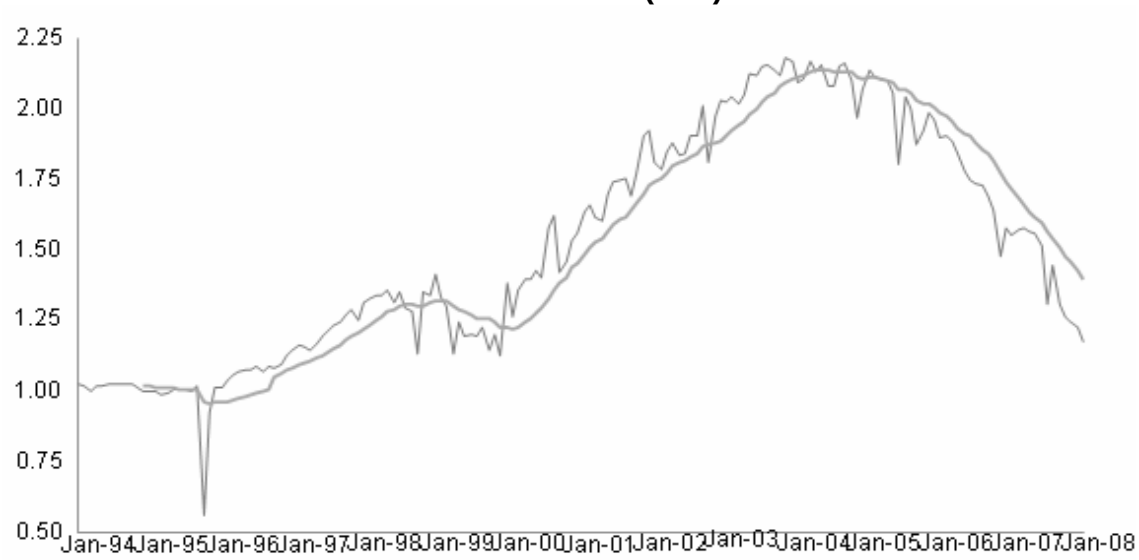
fields are *Ixtal* and *Sinán*. *Samaria*, *Jujo*, *Iride* and *Puerto Ceiba* are the most important fields in the *South region*. In 2007, the *Marine Northeast* region concentrated approximately 65.7% of the total crude oil production. *The Marine Southern* region ranks second in importance with 16.4%, the *South* and *North* regions concentrate 15.1 and 2.8%, respectively.

Since 1997, production has been very much correlated with the cyclical performance of the *Cantarell* field: an initial increase, followed by a subsequent declining tendency in recent years that has contributed to the increasing trend in imports to satisfy growing demand.[1] *Cantarell* is the most productive field in the *Campeche Bay*.[2] It is composed by ten subfields: *Akal* (the largest one), *Nohoch*, *Chac*, *Kutz*, *Ixtoc*, *Sihil*, *Balam*, *Ek*, *Takin* and *Utan*. *Cantarell* was randomly discovered in 1971, and its production started in 1979 with *Chac*. It has an extension of 162 squared kilometers. During 2007, reserves in the *Cantarell* complex represented 17% of total reserves, from which 64% are proved reserves, 19% possible reserves, and 17% are probable reserves. *Cantarell*'s production has observed three well-defined stages. The first one (1979-1996) was characterized by its initial development and exploitation which radically increased oil production in the *North* and *South* regions as well as in Chiapas. During the second stage (1997-2004) further development and investment allowed to reach maximum production level in 2003 (2.2 mbd). The last stage started in 2005 and is characterized by a decreasing production annual rate of 14% (see Figure 2).

[1] Demand for oil in Mexico is mostly determined by the high use of hydrocarbons among total energy inputs in the electrical, transportation, industrial and oil sectors: 70% between 1980 and 2007. Among hydrocarbon inputs, 75% are derived from oil.

[2] The quality of *Cantarell*'s crude oil is between ranges of 20 to 22 *API* (American Petroleum Industry) degrees (see section 4.2).

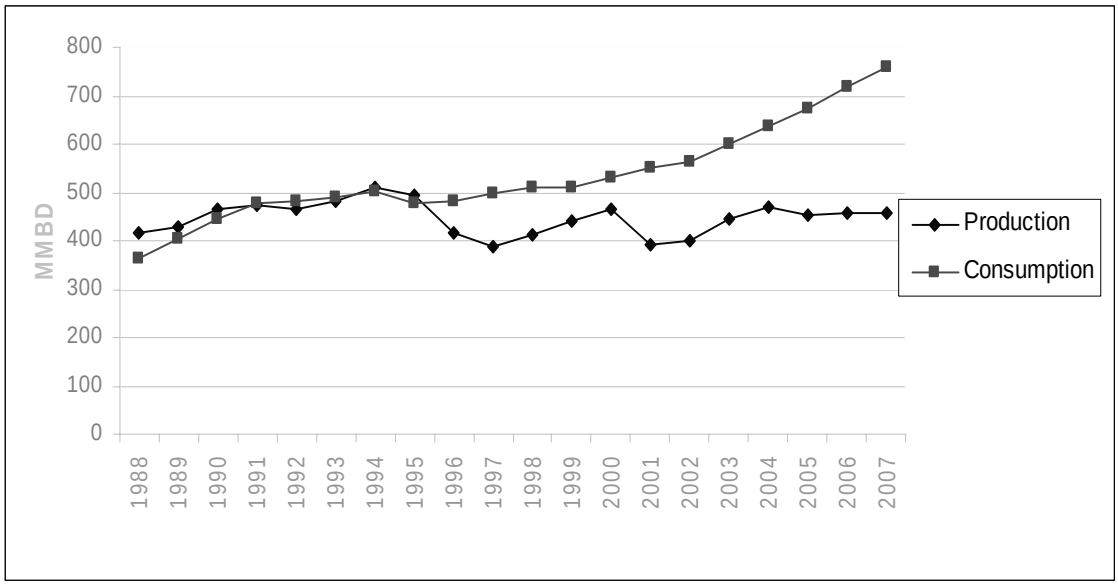
FIGURE 2. *CANTARELL*'S MONTHLY CRUDE OIL PRODUCTION AND 12-MONTH MOVING AVERAGE (MBD)



Source: Lajous A. (2008).

The decrease in oil production is also correlated with a deficit in distilled products. For example, in the gasoline market, *PEMEX* has been unable to satisfy the domestic demand and has been gradually forced to increase imports. In 2007, imports already reached 41% of total sales (see Figure 3).

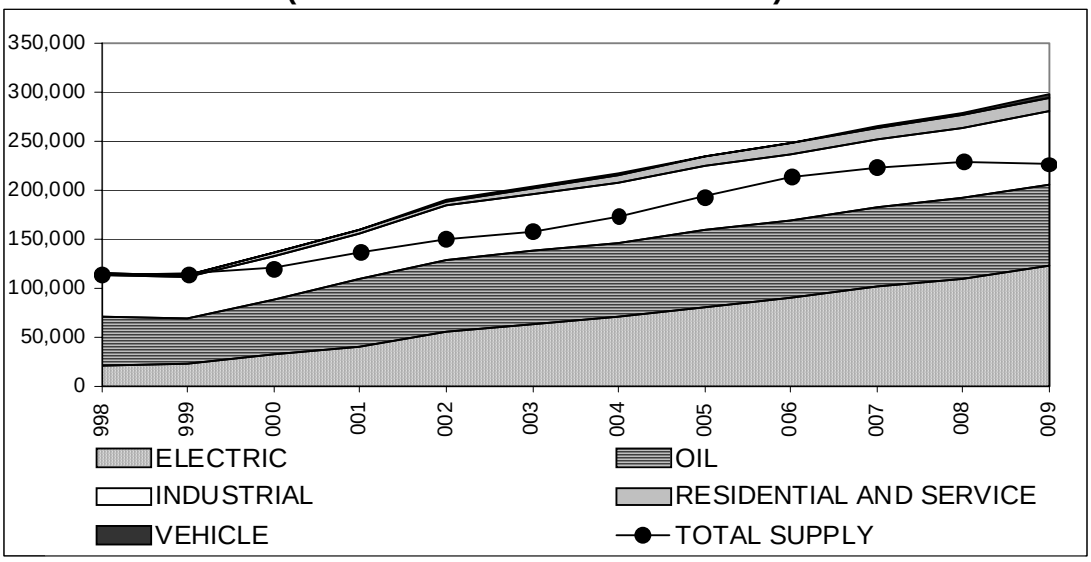
FIGURE 3. GASOLINE SUPPLY AND DEMAND IN MEXICO



Source: *PEMEX* (1995-2008) and *SENER* (2008a).

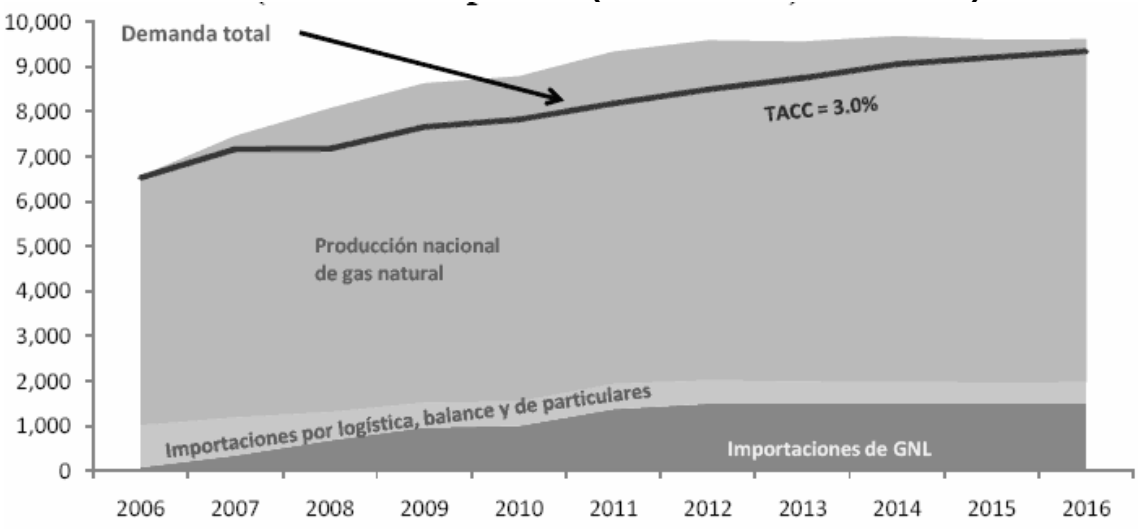
Similar to crude oil, natural gas production has been unable to satisfy the increasing domestic demand. Natural gas is a fundamental input in power generation, industrial consumption, as well as *PEMEX* own consumption. In recent years, it has become increasingly important in the residential and motor vehicle sectors. Its consumption has increased due to technological changes in power combined-cycle generation as well as due to environmental regulations (see Figure 4).

FIGURE 4. BASE SCENARIO OF CONSUMPTION AND NET PRODUCTION (THOUSAND OF CUBIC METERS PER DAY)



In 2007, gas imports (including *LNG*) represented 23% of total national consumption (including *PEMEX*' consumption). Imports have been therefore gradually growing, a trend that is expected to escalate in the next few years (see Figure 5).

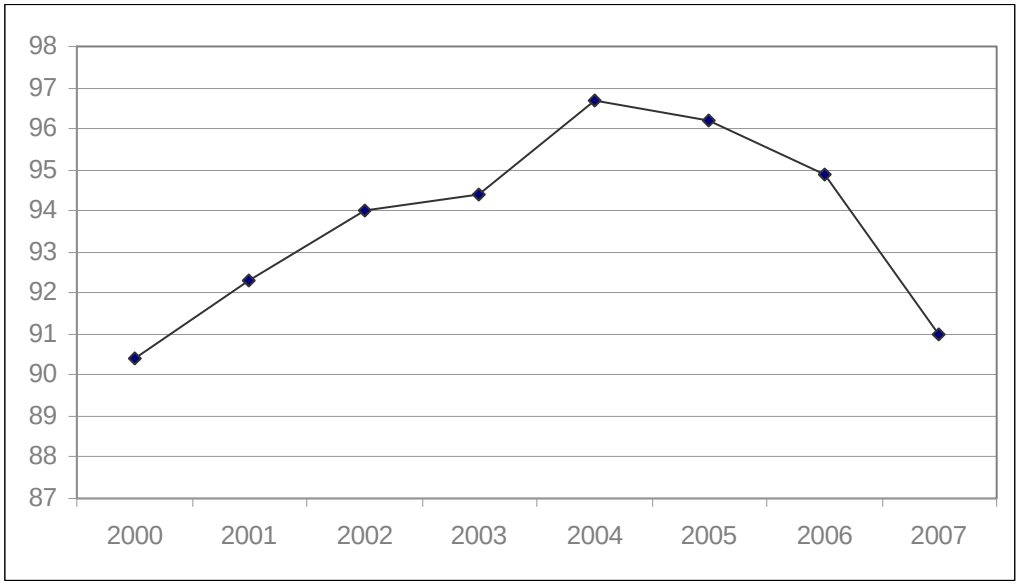
FIGURE 5. NATURAL GAS BALANCE (MILLION CUBIC FEET PER DAY)



Source: *SENER* (2008a).

Likewise, natural gas flaring in Mexico has remained at high levels, although some recent efforts have been done to reduce it (see Figure 6).

FIGURE 6. NATURAL GAS NET UTILIZATION (PERCENTAGES)
INTERNATIONAL BENCHMARK: 97%



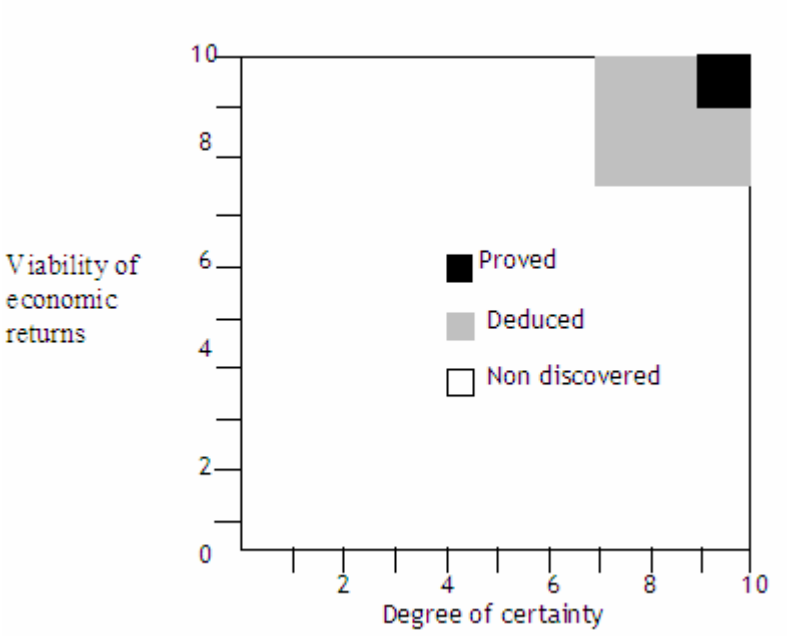
Source: *SENER* (2008a).

Reserves

Proved, probable, possible and total reserves

Oil reserves are a function of investment, exploration, technology and regional characteristics, as well as of the means of measurement. Proved reserves represent a small amount of total reserves (see Figure 7).

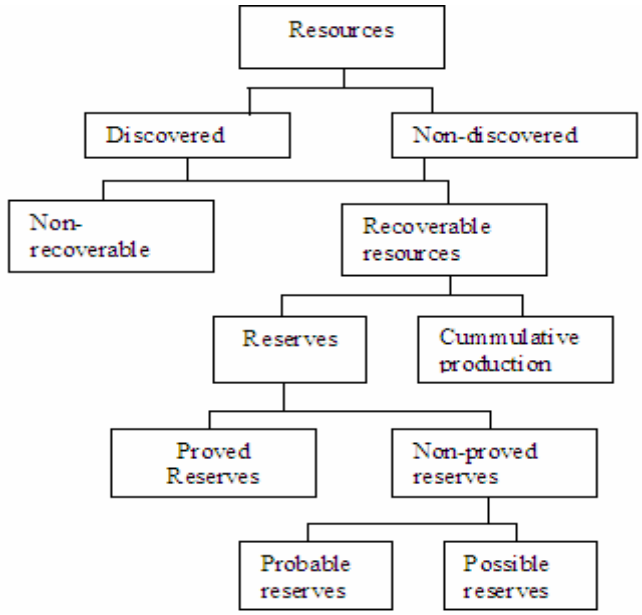
FIGURE 7. ACCURACY IN OIL RESERVE ESTIMATION



Source: Speight and Ösmü (2002).

The accurate quantification of reserves in certain country or region is a complex issue. They are dynamic, and precise gauging is complex. Figure 8 carries out a basic classification of resources and reserves.

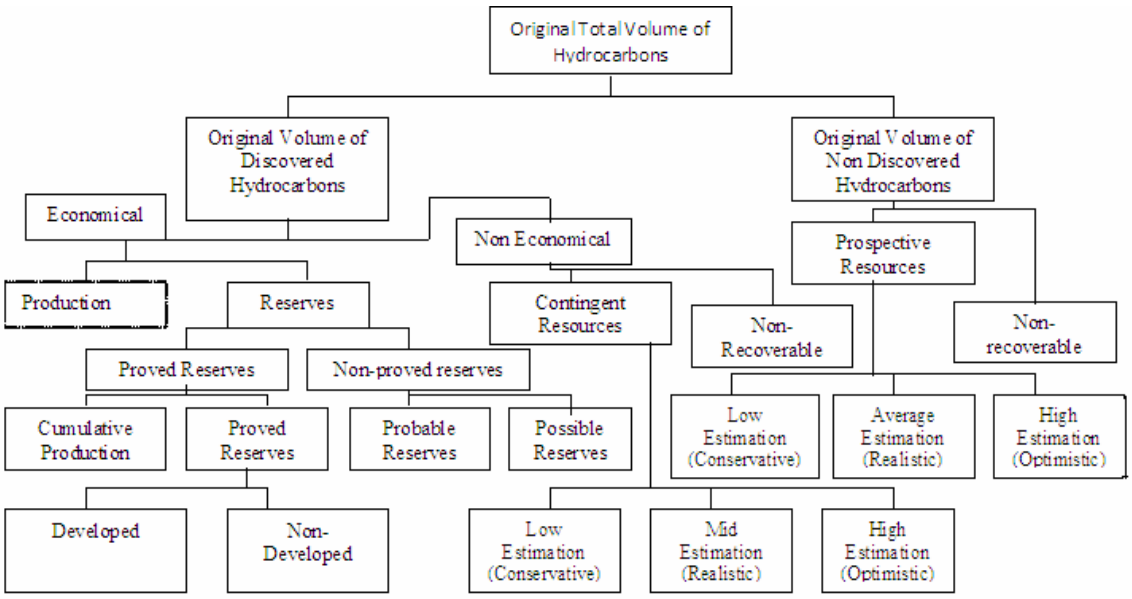
FIGURE 8. RESOURCES AND RESERVES



Source: Speight and Ösmü (2002).

In 2002, Mexico adopted a classification of its hydrocarbon resources according to the criteria of the Securities and Exchange Commission (*SEC*). The adoption of this classification did not affect the quantification of total reserves (or *3P*), there was only a reclassification among the different groups. There was a reduction in proved reserves compensated with an increase in probable and possible reserves (*SENER,* 2008a). All other types of reserves follow the criteria established by the Society of Petroleum Engineers (*SPE*), the American Association of Petroleum Geologist (*AAPG*) and the World Petroleum Congresses (*WPC*) since 1996 (see Figure 9).

FIGURE 9. CLASSIFICATION OF HYDROCARBON RESOURCES AND RESERVES IN MEXICO



Source: Elaborated with information from *SEC* 2007, and *PEMEX'* publications on hydrocarbon reserves in 2007.

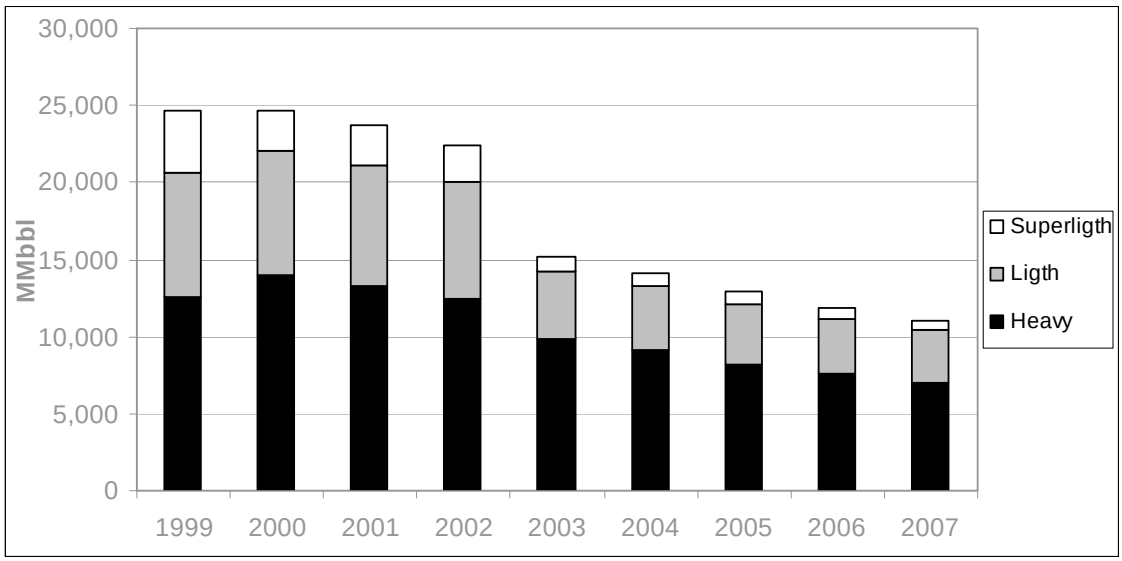
According to *SEC* criteria, *PEMEX* categorizes as proved reserves (*1P*) the oil estimated quantities that can be extracted with a "reasonable" certainty, and that are expected to be recuperated in future years under the existent economic-operative conditions.[3] *1P* reserves are divided into developed and non-developed reserves. The former are the ones that can be extracted using current infrastructure (in 2007 they accounted for 10.7 thousand of equivalent million of crude oil barrels (mbpce), while the latter cannot be extracted immediately due to short-run economical and technical reasons. Probable reserves are those that have at least 50% probability of being greater than or equal to the sum of proved and possible reserves. Possible reserves have a lower certainty of being commercially developed than probable reserves (probability of 10%).

Figures 10 through 12 provide data on all types of *PEMEX'* oil reserves, while Figure 13 provides data on total reserves for crude oil, condensates, liquids and dry gas. In 2007, natural gas proved reserves accounted 13,162 mbpce, probable natural gas reserves were 20,562.1 mbpce, while possible reserves were estimated in 22,719.7 mbpce. The largest natural gas reserves were discovered in Tabasco and Chiapas in 1976. In 2002 some new discoveries were carried out in Veracruz. In the north of Mexico, there are

[3] In addition to *1P* reserves, there exist *2P* and *3P* reserves. *2P* are the sum of proved and probable reserves. As mentioned before, *3P* are total reserves; that is, the sum of proved, probable and possible reserves (see Figure 8).

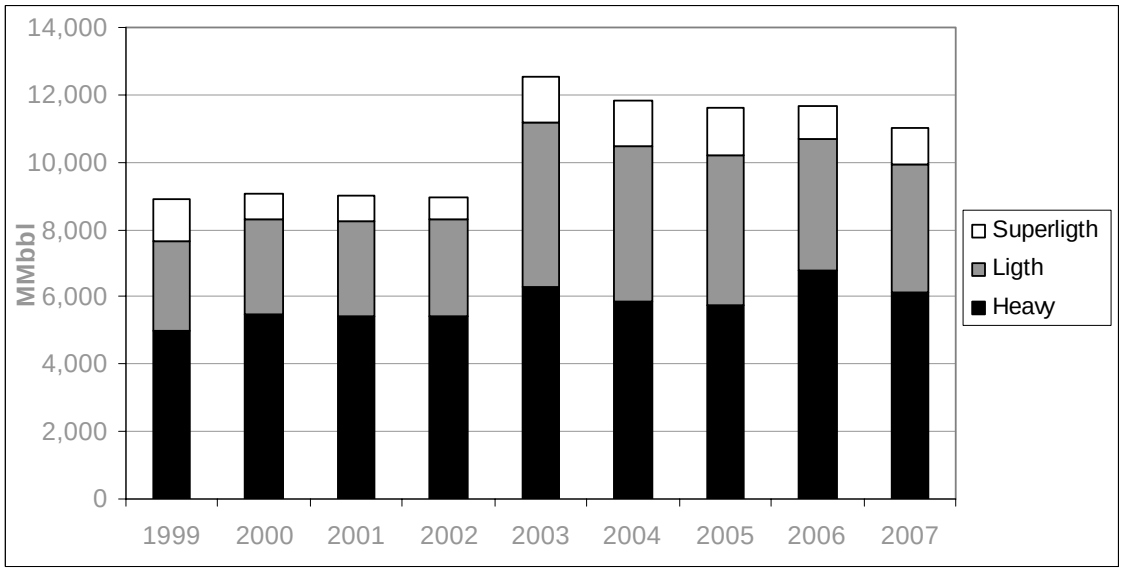
also some other important basins such as Sabines-Tamaulipas and Burgos. The *North* region concentrates 61.2% of total natural gas reserves (*3P*), the *Southern* 16.6%, the *Marine Southwest* 13.5% and the *Marine Northeast* 8.8%.

FIGURE 10. PEMEX TOTAL PROVED RESERVES OF CRUDE OIL



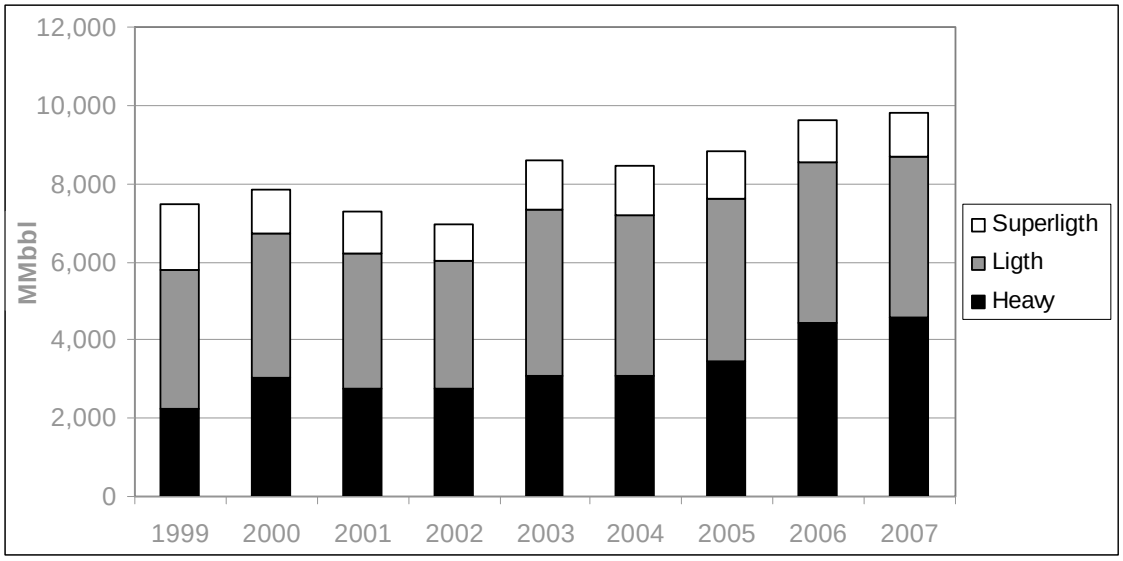
Source: *PEMEX* (2008b).

FIGURE 11. TOTAL PROBABLE CRUDE OIL RESERVES



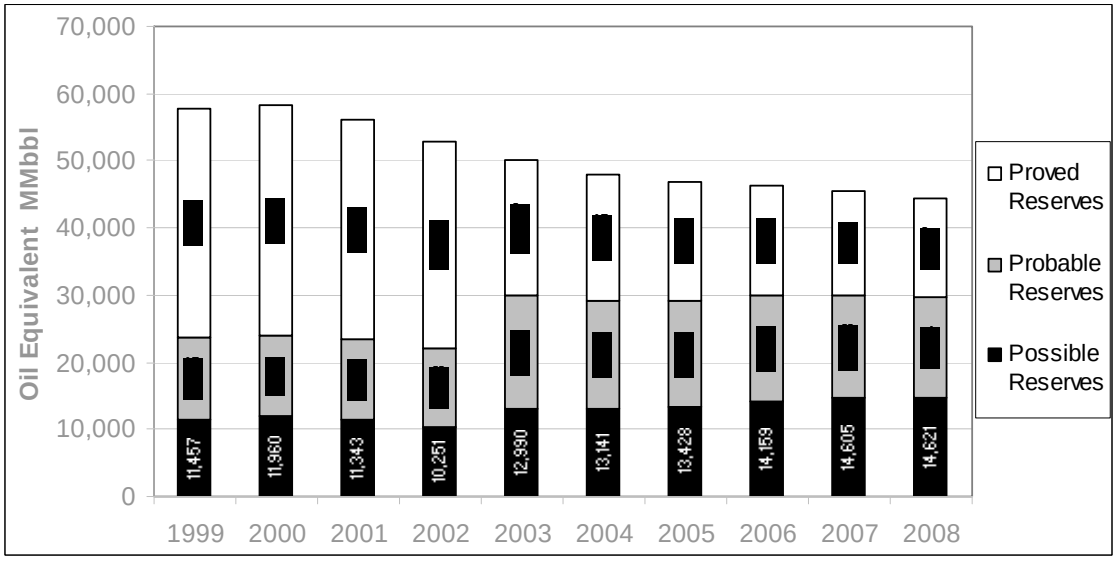
Source: *PEMEX* (2008b).

FIGURE 12. TOTAL POSSIBLE CRUDE OIL RESERVES



Source: *PEMEX* (2008b).

FIGURE 13.TOTAL RESERVES
(CRUDE OIL, CONDENSATES, LIQUIDS AND DRY GAS)



Source: *PEMEX* (2008b).

Prospective and contingent resources

Prospective resources are not part of hydrocarbon reserves (see Figure 9). Their potential exploitation is much more uncertain. They are defined as the amount of hydrocarbons that are inferred at a certain point in time and that are potentially exploitable, but whose commercial viability is not initially defined (*PEMEX*, 1995-2008). Their estimation is based on tridimensional seismic information, regional geological and geophysical models, geochemical and oil-physical information, as well as uncertainty considerations. Of course, their estimation does not require the perforation of exploratory fields. The importance of prospective resources has increased due to the secular decrease in reserves. *PEMEX* has recently stated that its prospective resources could be equivalent to 60% (53.8 Mmbpce) of the sum of total reserves and the historical cumulative production (see Table 1). The main prospective oilfields are located in the *Deep Gulf* basin (55%), and the *Southeast* basin (34%).

Contingent resources are similar to prospective resources, but their potential exploitation is defined from already discovered hydrocarbon accumulations (see Figure 9). They can include accumulations where no previous market existed, where the exploitation depended of development of new technologies, or where the evaluation of the accumulations has not been finished (*PEMEX*, 2008b). *PEMEX* uses several means to extract contingent resources from productive formations when the oilfield pressure is not enough, or when the oilfield is re-pressured so as to extract additional oil.

TABLE 1. PROSPECTIVE RESOURCES

Basin	Mmmbpce	%
Sabinas	0.3	0.6
Burgos	3.1	5.8
Tampico-Misantla	1.7	3.2
Veracruz	0.8	1.5
Southeast	18.1	33.6
The Deep Gulf	29.5	54.8
Platform of Yucatán	0.3	0.6
Total	**53.8**	**100**

Source: *SENER* (2008b).

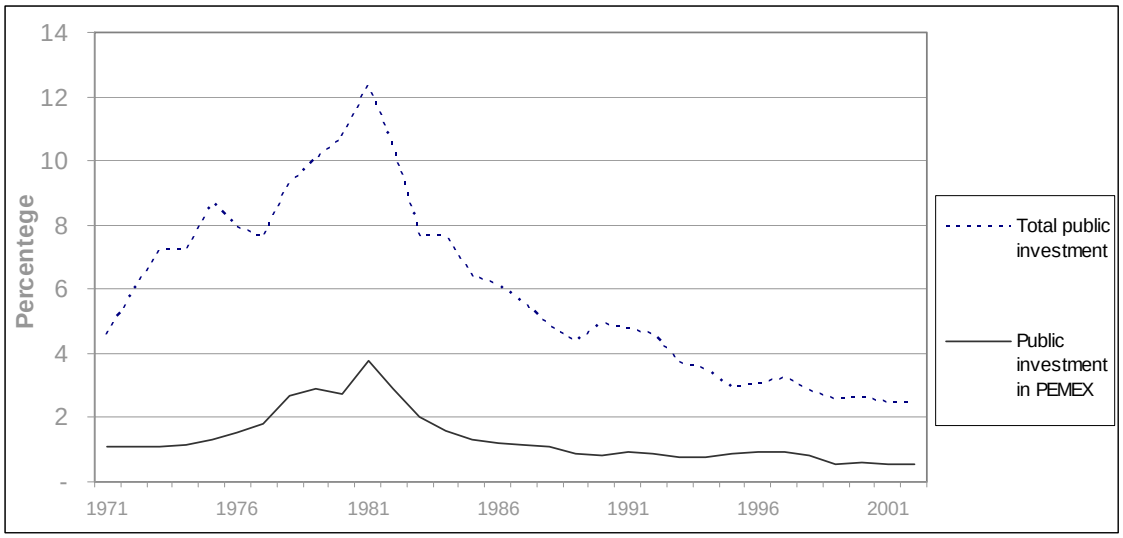
Investment

Public investment

Since 1981 —when the highest public investment in *PEMEX* as a percentage of GDP took place (3.8%)— investment has consistently diminished up to 2002 at an annual rate of 9% (see Figure 14). This has happened even during periods where tax income has considerably increased, such as in 1973-1985 and 1991-

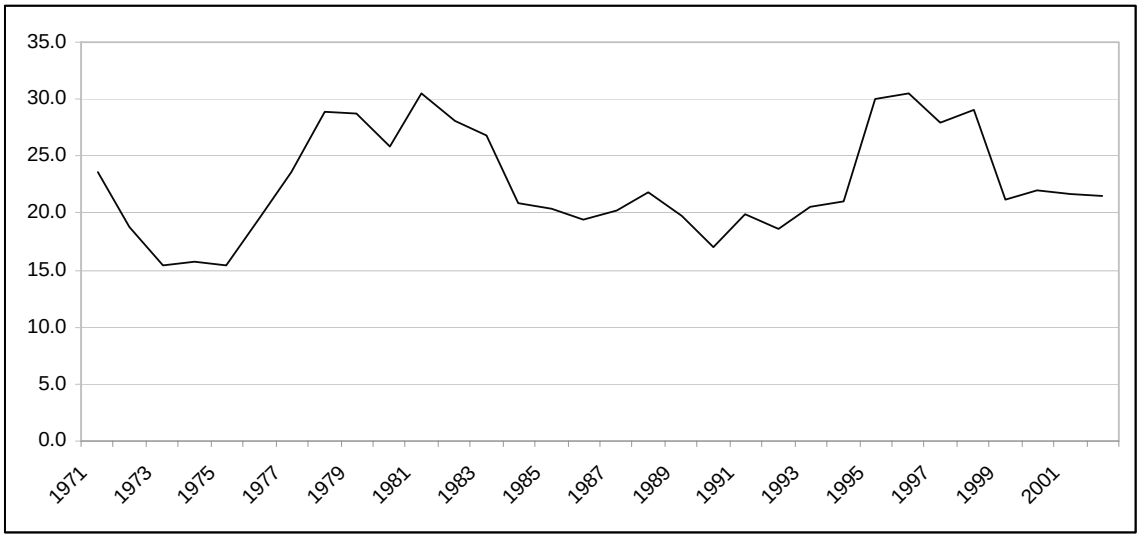
2004. Additionally, *PEMEX* only gets one-fourth of total public investment (see Figure 15); and only 10% of the total tax income collected by the Secretaría de Hacienda y Crédito Público (*SHCP*).

FIGURE 14. PUBLIC INVESTMENT IN *PEMEX* (AS A PROPORTION OF GDP)



Source: *INEGI* (2008).

FIGURE 15. PUBLIC INVESTMENT IN *PEMEX* AS A PERCENTAGE OF TOTAL PUBLIC INVESTMENT



Source: *INEGI*, (2008).

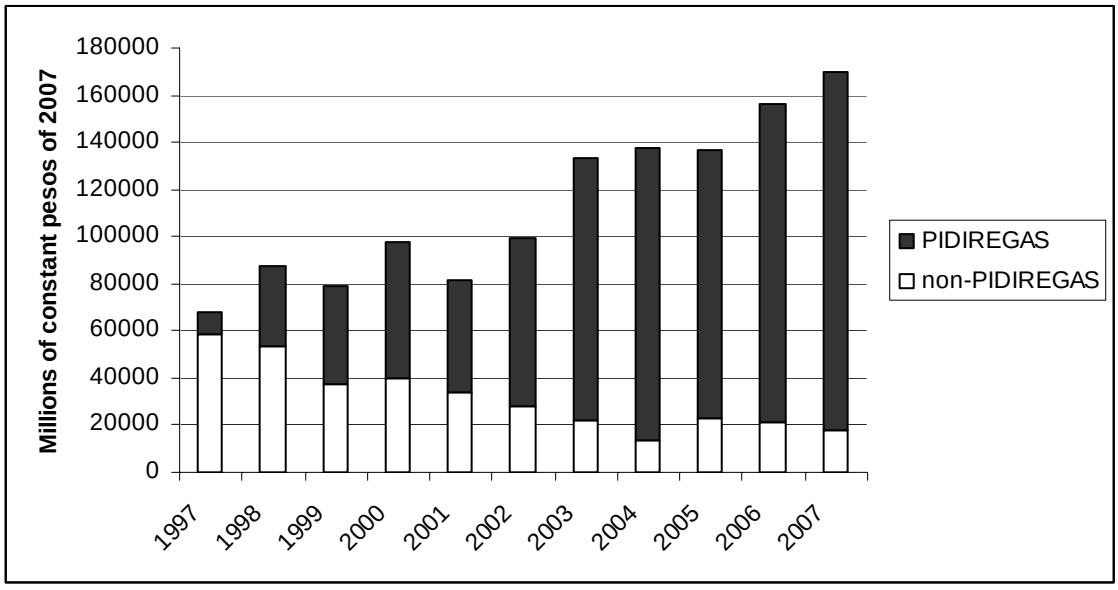
Private investment

After the 1994 financial crisis in Mexico, some measures were taken trying to attract private investment in the oil sector. One of these measures took place

at the end of 1995 when the Mexican Congress approved an amendment to Article 30 of the Public Budget Law (*Ley de Presupuestos, Contabilidad y Gasto Público Federal*) as well as to Article 18 of the Public Debt Law (*Ley General de Deuda Pública*), which allowed private investment in the oil industry. This process culminated with the creation of the *PIDIREGAS* (*Proyectos de Infraestructura Productiva de Impacto Difererido en el Registro del Gasto*) scheme in 1997, which seek to attract long-run investment to the energy sector through long-run public debt (Centro de Estudios de las Finanzas Públicas, 2007a). *PEMEX's* investment financed through *PIDIREGAS* increased rapidly from 2003 to 2008 as a consequent weakening of the public budget.

As Figure 16 shows, *PIDIREGAS* allowed *PEMEX* access to private loans in 1997. By this year, *PEMEX* began to borrow trough this scheme. The widely use of these private loans has been perverse. During 1999-2008 repayments have demonstrated to be unfeasible.

FIGURE 16. *PIDIREGAS* AND NON-*PIDIREGAS* INVESTMENTS



Source: *PEMEX* (1995-2008).

The consolidated balances for 2005 and 2006 show that the long-term liabilities increased by 5.7%. This increase was attributable to *PIDEREGAS*. The growth in the long-term debt was not affected by the reduction in short-term liabilities. Nevertheless, total *PEMEX's* equity increased by 243% (see Table 2). On the other hand, the long-term liabilities decreased 4% by 2007, and short-term liabilities increased by 64%. Total *PEMEX's* equity increased by 6.4% (see Table 3).

TABLE 2. CONSOLIDATED BALANCE 2005-2006 (MILLIONS OF 2006 PESOS)

	2005		2006		Change	
	Amount	%	Amount	%	%	Amount
Assets						
Current assets	304,629	28.1	384,924	32.0	26.4	80,295
Property and Equipment	669,308	61.7	710,488	59.0	6.2	41,180
Other assets	110,881	10.2	109,322	9.1	-1.4	-1,559
Total assets	**1,084,818**	100.0	**1,204,735**	100.0	11.1	119,917
Liabilities						
Short-term liabilities	171,143	15.8	169,927	14.1	-0.7	-1,216
Long-term liabilities	941,634	86.8	994,854	82.6	5.7	53,220
Total liabilities	1,112,777	102.6	1,164,781	96.7	4.7	52,004
Total equity	-27,959	-2.6	39,954	3.3	242.9	67,913
Total liabilities and equity	**1,084,818**	100.0	**1,204,735**	100.0	11.1	119,917

Source: *PEMEX* (2008a), *Reporte de resultados de cifras dictaminadas 2008.*

TABLE 3. CONSOLIDATED BALANCE 2006-2007 (MILLIONS OF 2007 PESOS)

	2006		2007		Change	
	Amount	%	Amount	%	%	Amount
Assets						
Current assets	399,393	32.0	428,561	32.2	7.3	29,168
Property and Equipment	737,196	59.0	793,846	59.7	7.7	56,650
Other assets	113,432	9.1	107,874	8.1	-4.9	-5,558
Total assets	**1,250,021**	100.0	**1,330,281**	100.0	6.4	80,260
Liabilities						
Short-term liabilities	176,314	14.1	289,464	21.8	64.2	113,150
Long-term liabilities	1,032,251	82.6	990,909	74.5	-4.0	-41,342
Total liabilities	1,208,565	96.7	1,280,373	96.2	5.9	71,808
Total equity	41,456	3.3	49,908	3.8	20.4	8,452
Total liabilities and equity	**1,250,021**	100.0	**1,330,281**	100.0	6.4	80,260

Source: *PEMEX* (2008a).

Moreover, as it is evident from *PEMEX*'s consolidated income statements during 2002-2006, *PEMEX* taxes in each year are the highest share of revenues (see Table 4). Additionally, the comprehensive financial cost (incurred trough *PIDIREGAS*) became a serious financial restriction. As a consequence, in almost each year the net income was negative.

TABLE 4. CONSOLIDATED INCOME STATEMENTS 2002 TO 2006 (MILLIONS OF 2006 PESOS)

	2002		2003		2004		2005		2006		2002-2006	
	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Change	%
Total revenues	582,205	100	710,724	100	843,763	100	978,601	100	1,132,236	100	550,031	94.5
Total revenues net of the IEPS tax	443,726	76.2	604,321	85.03	784,943	93.0	957,567	97.9	1,132,236	100	688,510	155.2
Operating income	334,466	57.4	415,726	58.49	489,437	58.0	518,970	53.0	581,348	51.3	246,882	73.8
Comprehensive financing cost	7,057	1.2	34,770	4.89	7,578	0.9	4,661	0.5	22,983	2.0	15,926	225.7
Net income (loss) for the period	-27,795	-4.8	-45,970	-6.47	-27,413	-3.2	-79,374	-8.1	45,252	4.0	73,047	262.8

Source: *PEMEX* (2008a).

In the next section we discuss the institutional, legal and fiscal frameworks of the Mexican hydrocarbon sector.

Legal, Institutional and Fiscal Framework

Legal and institutional framework

Since its nationalization, the oil sector has been regulated by the 1917 Mexican Constitution, by international treaties like the Chapter 6 in the North American Free Trade Agreement (NAFTA) signed in 1992, and the treaty between Mexico and the United States regarding the delimitation of the continental platform beyond 200 nautical miles in the west region of the Gulf of Mexico ("Doughnuthole Treaty"). The main public institutions which oversee the sector are the *CRE* (the regulator of natural gas since 1995), the Energy Ministry (*SENER),* the Finance Ministry (*SHCP)*, and the Ministry of the Economy (*SE)*. Each one of these institutions plays a different role in the sector; *SHCP* has the ultimate authorization for all projects presented by *PEMEX*, and sets the final tariffs for fuels by setting taxes and subsidies. The combination of all of them results in a complex set of rules and restrictions that *PEMEX* must satisfy (see table 8).

The Mexican Constitution in its Constitutional Article 27 establishes that the Nation has direct ownership of petroleum and all solid, liquid or gaseous hydrocarbons, and of the national territory to the extent and terms fixed by international laws. Moreover, this ownership is inalienable and essential, and the exploitation, use, or enjoyment of these resources by individuals or by associations governed by Mexican law cannot take place except by means of concessions granted by the Federal Executive according to the rules and

conditions which the laws establish. However, no concessions or contracts can be granted for the extraction of petroleum or solid, liquid, or gaseous hydrocarbons, or for radioactive minerals. The Nation is the only one that can carry out the exploitation of these products. On top of this, Article 28 determines that the exclusive functions exercised by the State will not constitute monopolies in the case of petroleum and the various hydrocarbons, basic petrochemicals, radioactive minerals and generation of nuclear energy and electricity. The status quo concepts of *PEMEX* are also included in Articles 25, 28, 42 and 73. This legal framework prohibits the commercial operation of international oil firms within Mexico as well as the granting of concessions, risk contracts, and incentive contracts. As a consequence, the resulting oil market architecture is such that the *NOC, PEMEX*, is in charge of all the activities related to the oil sector.

Such architecture has been very restrictive in allowing private participation in the oil sector. There was virtually no private investment until the early 1990's. Moreover, *NAFTA* reinforced this structure since it establishes that the Mexican State reserves to itself the strategic activities and investment in *(a)* exploration and exploitation of crude oil and natural gas, refining or processing of crude oil and natural gas as well as production of artificial gas, basic petrochemicals and their feedstock, and pipelines; and *(b)* foreign trade, transportation, storage and distribution, up to and including first hand sales of the following goods: crude oil; natural and artificial gas, goods covered by Chapter 6 obtained from the refining or processing of crude oil and natural gas, and basic petrochemicals.

In addition to these legal restrictions, the internal organic law of *PEMEX*, the secondary laws on administration rules, and the rules related to *PEMEX'* financial contributions to the federal government constitute the legal framework for this firm.

Since the Mexican State was unable to get private investment under this market structure and did not have enough financial resources to do it by itself, it had to implement some changes after 1992, including the *PIDIREGAS* scheme (see Figure 16) for project financing. However, as discussed before, it has not been solution in the long run.

In 1992, the new organic law of *PEMEX* was designed. It created four subsidiaries: *PEMEX Exploration and Production*, *PEMEX Refining*, *PEMEX Gas and Basic Petrochemicals*, and *PEMEX Petrochemicals*. Likewise, a new *Board* was created (whose functions include operation, administration, finance, engineering and project development), as well as a *General Direction* and an *Administration Board*. The *Administration Board* carries out the supervision of *PEMEX's* activities. It is composed by 11 members, and it designs the financial and commercial strategies as well as the rational use of resources.

The structure of *PEMEX* regarding natural gas and liquid petroleum gas (*LPG*) is regulated by the *CRE*. The *SENER* —whose Minister influences all

decisions on *PEMEX*, the Comisión Federal de Electricidad (*CFE*), and Luz y Fuerza del Centro (*LFC*)— supervises the financial health of the energy entities, and fosters businesses and technology development in the energy sector. The *SHCP* evaluates the projects presented by *PEMEX*, and affects various aspects of the energy policy. The *SE* administers the prices for the energy products.

Given this structure, there is no close relationship between the generation of revenues and the expending needs mainly related to investments. Any business decision in *PEMEX* —including investments, perforations, exploration, and the development of new oilfields— requires transiting among distinct government instances and institutions such as *SENER*, *SHCP* as well as the Congress. The first stage of a new project in *PEMEX* typically begins within the subsidiaries, which take care of the elaboration of prospective projects.[4] Such projects are evaluated by the corporative division. Once the project has passed through this stage of revision and evaluation, it returns to the subsidiaries for its modification if the project is rejected. It later returns to the corporate division and is subsequently approved by the *Administration Board*. Once this internal acceptance process is completed, the project proposal is sent to *SENER* who is in charge of carrying out another evaluation. When this filter is overcome, the *SHCP* subsequently evaluates the project and, when approved, it is finally sent to the Congress for its final discussion and approval. Implementation would come after all these administrative stages have been fulfilled.

The operative framework in *PEMEX* has proved to be ineffective in fostering project implementation. Unforeseen substantial changes (for example in initial parameter values) that could hinder the start of the project cannot be appropriately handled by its administrative structure. The hierarchical administrative structures are an obstacle for the decentralization of operative decisions, and required investments. The patterns of administrative liability promote an increasing risk aversion, and accountability evasion. All this thwarts technology diffusion, and administrative and industrial efficiency within *PEMEX*.

In order to loosen such constraints that drilled the *NOC*, some changes were introduced in a 2008 energy reform. In such a reform the *PEMEX*'s law was modified so that the definition of subsidiary organisms stops being rigid. The *Administration Board* will also be able to modify its structure besides keeping the faculty to propose the creation of other subsidiaries The *Administration Board* is now integrated by 15 members grouped into 3 divisions: 6 professional representatives of the State, 4 advisors and 5 representatives of the union). The first two member segments are designated

[4] Sometimes *SENER*, *SHCP* as well as the Congress carry out prospective projects and business proposals for *PEMEX*.

by the Federal Executive. The president of the *Board* is the head of the *SENER* and it has a vote of quality in case of tied voting.

The Congress now approves the national energy strategic plans of 15 years. The *SENER* will take care of fixing the platform of hydrocarbon production. Likewise, the *SENER* is now authorized to integrate the *National Council of Energy* (*CNE*), which will program the exploration, operation and transformation of hydrocarbons. Furthermore, according to the *Law of National Hydrocarbons Commission* (*LCNH*) a *National Hydrocarbons Commission* (*CNH*) is created. It will be in charge of regulating and supervising the exploration and extraction of hydrocarbons, including derivatives as well as refining activities, transport and storage projects.

In addition, budgetary autonomy is granted to *PEMEX* and freed from the authorization from the *SHCP* which will now only approve specific rules with respect to indebtedness. As long as *PEMEX* fulfills its productivity goals, *PEMEX* will be able contract financing in the money market.

Regarding the relationship among *PEMEX*, *SENER* and *SHCP*, *SENER* will exclusively grant to *PEMEX* and its subsidiaries the allocation of areas for oil exploration and operation. The joint border basins will be operated according to international treaties. The subsidiaries of the *NOC* and its organisms will be able to carry out construction and service contracts with private investors. The remuneration of these contracts will be paid in cash and will not grant in return the property of hydrocarbons. It will then prohibit to subscribe production share contracts with private firms that include a percentage of oil production, sales or utilities.

Fiscal framework

It was during the government of Francisco I. Madero (1911-1913) that the first tax for oil was established (20 cents for each ton of crude oil produced). The government of Venustiano Carranza also established, in 1914, taxes on oil production and exports. Both the Madero and Carranza tax schemes lasted only during their respective administrations. In 1917, the new constitution established a basis for the later ownership of oil resources by the Mexican Government. In that same year, taxes on exports were again reinstalled and, from then on, stringent tax policies in the oil industry prevailed (Silva, 1973). After 1920, there were minor changes in the fiscal schemes for three main reasons. First, there was turmoil in the country after the Mexican Revolution. Second, the oil companies were nationalized in 1938. Third, the oil sector was not as important as it became after 1980.

Tax regime before 2005

The tax regime of *PEMEX* before 2005 was characterized by a diversity of taxes and rights. On rights for oil extraction (*DEP*), *PEMEX* had to pay 52.3% of its income, net of costs and investment. On extraordinary rights on oil

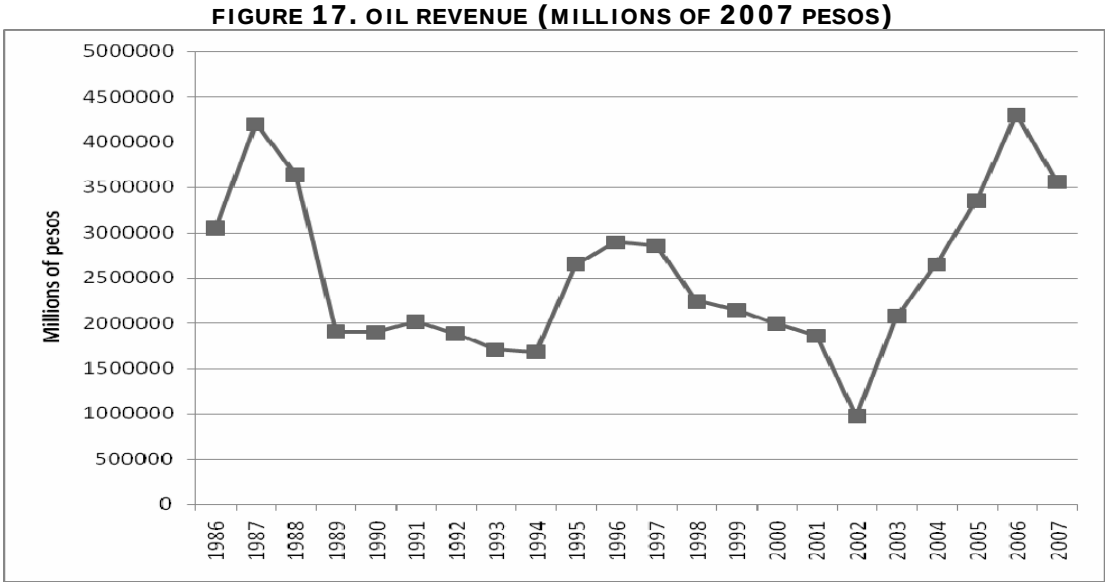
extraction (*DEEP*), it had to pay 25.5% over the *DEP* basis, while on the additional right on oil extraction (*DAEP*) *PEMEX* paid 1.1% over the *DEP* basis. Moreover, on hydrocarbons rights (*DSH*) the transfer was 60.8% of the sales value, including the special tax on production and services (*IEPS*).

Under such a scheme, the following relationship had to be met:

$$DSH = DEP + DEEP + DAEP + ISRP + IEPS.$$

If this relationship was not met, the *DEP* and *DEEP* rates were adjusted (see Figure 17 for the oil revenues from 1986 to 2007).

FIGURE 17. OIL REVENUE (MILLIONS OF 2007 PESOS)



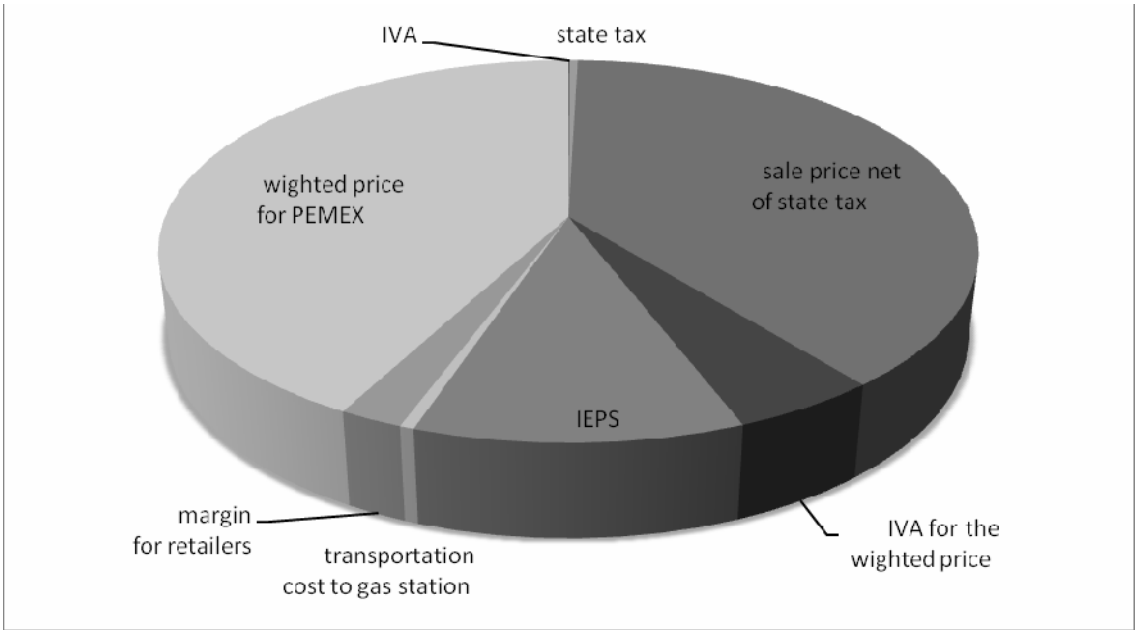
Source: *PEMEX*.

PEMEX had to pay three taxes. The first tax was on oil returns (*ISRP*). It forced *PEMEX* to pay 30% of net return.[5] The second tax was the *IEPS* which applied a variable rate that was calculated according to international prices and transport costs. The *IEPS* was applied to a basis consisting of the final price less commissions, transport tariffs, the production price and the value added tax (*IVA*). The third tax was the IVA, under which *PEMEX* had to pay 15% of its products sales. Additionally, there was a share on surplus returns (*ARE*) that forced *PEMEX* to pay 39.2% of the difference between a reference price and the current average price.[6] Figure 18 illustrates the above taxes for the case of diesel.

[5] Net return: incomes minus admissible costs, where admissible costs included: expenses, costs, investment, research and development.

[6] The reference price was the fiscal price that was used to estimate the federal oil incomes. It was determined annually in the federal income law.

FIGURE 18. TAX SCHEME ON DIESEL



Source: *PEMEX*.

The 2005 regime

Under the 2005 regime, *DEP*, *DEEP*, *DAEP* and *DSH* were eliminated, while *ISRP*, *IEPS*, *ARE* and *IVA* prevailed. Likewise, the following rights were added. First, the right for the fund for technological and scientific research (*DFCIT*), which made *PEMEX* to pay 0.05% of its crude oil and gas sales. Second, the right on "fiscal oil" (*DFP*), which made *PEMEX* pay 0.003% on the value of its sales. Third, the extraordinary right on oil exports (*DEEXP*) which is paid by *PEMEX* whenever the current oil price exceed the fiscal price. *PEMEX* paid 13.1% of the difference between both prices over the value of oil exports. Fourth, the right on hydrocarbons for the stabilization fund (*DSHFE*). This right applied whenever the export price of crude oil was above a reference price of USD $22.00. In such a case, a rate that linearly increases with the export price was applied to the crude oil sales. The *ARE* and the *DEEXP* were accredited against the *DSHFE*.[7] Fifth, an ordinary right on hydrocarbons (*DOH*) that make *PEMEX* pay 79% of the sales value minus the authorized deductions.[8]

Therefore, the 2005 regime permitted more deductions from costs than the previous regime. It was based on a net right or tax on benefits, while the principal instrument in the previous regime was a gross right. The new regime

[7] When *DEEXP* is larger than *DSHFE*, *DEEXP-DSHFE* will be subtracted from *DOH*.

[8] Authorized deductions costs and investments in exploration, development and exploitation minus *DSHFE*, *DFICT* and *DFP*. Deductions of expenses on oil and gas extraction have a ceiling of USD6.5 per barrel, and USD2.7 per thousand cubic feet, respectively.

had more additional rights such as *DEEXP* and *DSHFE* which became binding when the oil price was higher than expected.

The 2006-2007 regime

In the 2008 regime the additional right (*DA*) disappears. *DA* was applied until 2007, and it was paid due to the reduction in the oil production platform. *ARE* also disappeared. *DEEXP*, *DSHFE* and *DFP* remained without changes, while some other modifications were carried out. First, the *DOH* was reduced from 79% to 71.5%. The percentage of *DOH,* which is part of the shared federal tax collection (*RFP*), increased from 76.6 to 85.3%, and the maximum limits on the allowed deductions for *DOH* were USD$6.5 for oil, and USD$2.7 for gas. Second, the applicable *DFCIT* rate also increased from 0.05 to 0.65% on the extraction of crude oils and natural gas.

Tax collection from *PEMEX* as a percentage of total tax collection during 1970-2004 is shown in Figure 19.

The regime under the reform of 2008

In this new fiscal regime three new rights are added. Likewise, DEEXP, DSHFE and DFP remain without changes, but other specific modifications were carried out:

- DOH increased from 71.5 to 73.5%.
- DFCIT reduced from 0.65 to 0.30% on the extraction of crude oil and natural gas.
- DU changed according to the level of the average price of the export barrel (see table 5).
- A new right on hydrocarbon extraction (DEH) is created. It is also based on the average price of the export barrel (see Table 6).
- A new special right on hydrocarbon fields in the *Paleocanal* of *Chicontepec* (DEHPCH) is created. It is based again on the export price level. It is calculated applying a 75% rate to the difference between the annual value from extracted crude petroleum and natural gas.

- A new special right on hydrocarbons for deep water fields (DEHAP) is introduced based as well on the average export price level of oil barrels (see Table 7).

TABLE 5. ANNUAL AVERAGE PRICE PER BARREL OF CRUDE OIL (USD) AND DU

Level	Percentage
0.01-29.99	37
25.00-29.99	42
30.00-39.99	47
40.00-49.99	52
50 forward	57

Source: (DOF, 2008).

TABLE 6. ANNUAL AVERAGE PRICE PER BARREL OF CRUDE OIL (USD) AND DEH

Level	Percentage
0.01-40.00	10
40.01-60	t
60.01 forward	20

Where $t = \left(0.1 + (\frac{p - 40}{200}) \right) * 100$

Source: (DOF, 2008).

TABLE 7. ANNUAL AVERAGE PRICE PER BARREL OF CRUDE OIL (USD) AND DEHAP

Level	Percentage
0.01-60.00	60
60.01-80.00	64
80.01-90.00	68
90.01 forward	71.5

Source: (DOF, 2008).

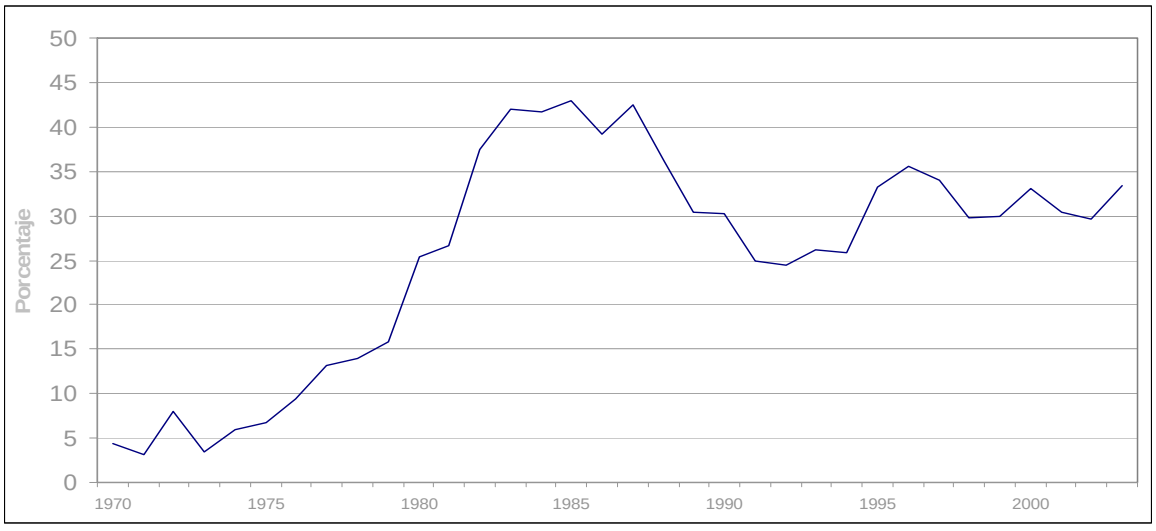
Table 8 presents the restrictions that *PEMEX* faced under the different regulation and tax schemes, before and after 2008. It can be observed that some activities were simplified in terms of the roles of the different involved institutions.

TABLE 8. REGULATORY SCHEMES

	BEFORE 2008	REFORM OF 2008
Budget planning	*PEMEX*	*PEMEX*
Budget approval	*SHCP*	*SHCP/CONGRESS**
Project planning	*PEMEX*	*PEMEX*
Project approval	*SHCP / SENER / CONGRESS*	*PEMEX*
Contracting with third parties	Not allowed	*PEMEX*
Contacting approval	Not allowed	*PEMEX*
Debt approval	*SHCP / SENER / CONGRESS*	*PEMEX/SHCP** *
Monitoring	Board (11 members)	Board (15 members)
Price fixing	*SHCP / CRE*	*SE / CRE*
Regulatory Agencies	*CRE / SENER*	*CRE / SENER / CNH*

*SHCP receives budget proposals but the Congress makes the final approval. **According to debt rules.

FIGURE 19. TAX COLLECTION FROM PEMEX (AS A PERCENTAGE OF RFP)



Source: INEGI (2008).

Fiscal policy

Historically, oil has been a source of important resources for the development of Mexico (see Figure 19). The government determines the amount of tax collection from *PEMEX* based on the volume of *PEMEX*' annual final sales, and according to the different fiscal schemes discussed above. Since the 1990s, tax collection from *PEMEX* by the Mexican Government in average represents one-third of the Federal Tax Revenue. Since 2005, some reductions in tax collections from *PEMEX* have been implemented. However, a more aggressive tax liberalization for *PEMEX* would in turn require deeper global tax reforms that include increasing effective collection from other sectors; a task that would of course have strong political implications.

On the other hand, Table 9 shows how the oil revenue is distributed among the different parties. We see that *PEMEX* has been getting more and more resources from 2000 on. In 2000, it got nothing from the extra resources that were obtained by the federal government when the budgeted price was well below the real international market price. By 2006, it got 50% of such extra resources and it allocated them to its own investment strategies.

TABLE 9. RULES FOR SHARING OIL REVENUES ABOVE THE BUDGETED PRICE

2000	2001 Y 2002	2003 Y 2004	2005 Y 2006
40% *FEIP*	33% *FEIP*	25% *FEIP*	25% *FEIP*
60% public debt repayment	33% public sector balance	25% public sector balance	25% public sector balance
	34% infrastructure: water and exploration projects	50% investment in infrastructure spending in states	50% *PEMEX* investment

In the next section we now carry out an analysis of the additional drivers that, together with the institutional issues studied in section four, might provide insights on the production and investment results described in section three. We in fact provide a counterfactual analysis intended to support the benefits that might be reached with reforms that seek to promote investment, such as the 2008 reform.

Analysis of the drivers of performance, counterfactual scenarios, and alternative hypotheses

There are three crucial variables that may explain the past and current performance of the Mexican oil sector, and the most probable scenario for the near future. These are the geology, the legal setting and the lack of investment. The first is the key one, since the oil endowment in Mexico has been very important since its commencement. However, there have been

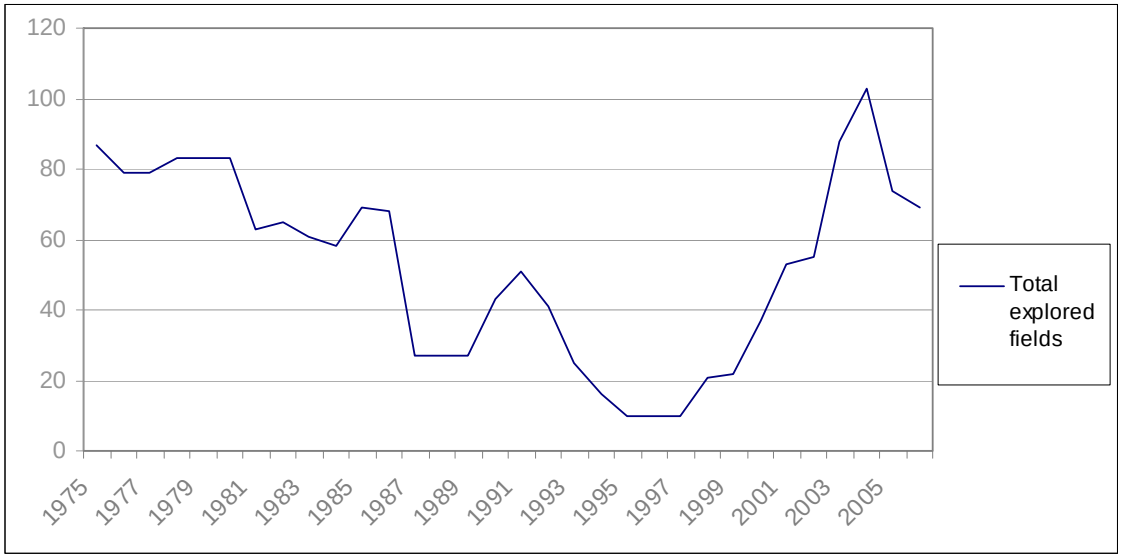
technical problems to extract all the oil that *PEMEX* would have desired. Likewise, the other two variables are closely related and have a decisive impact on the first one. As it was previously discussed, the legal setting restrains private investment, implying lack of resources to extract oil from where technically difficult projects. In the following subsections, we discuss these issues and perform a counterfactual analysis which seeks to simulate the possible effects of a more favorable legal framework on PEMEX behavior from 1993 thru 2008.

Geology

Evolution of discoveries

Oil production consists of various stages. The segment with the most risk is perforation. Perforation involves exploration, and the further oilfield development. Exploration obviously involves more risk. During 1975-2006 oilfield exploration in Mexico has not been constant. In fact, exploration has significantly decreased during four periods: 1974-1984, 1985-1987, 1991-1995 and 2004-2006 (see Figure 20).

FIGURE 20. TOTAL EXPLORED OILFIELDS PER YEAR



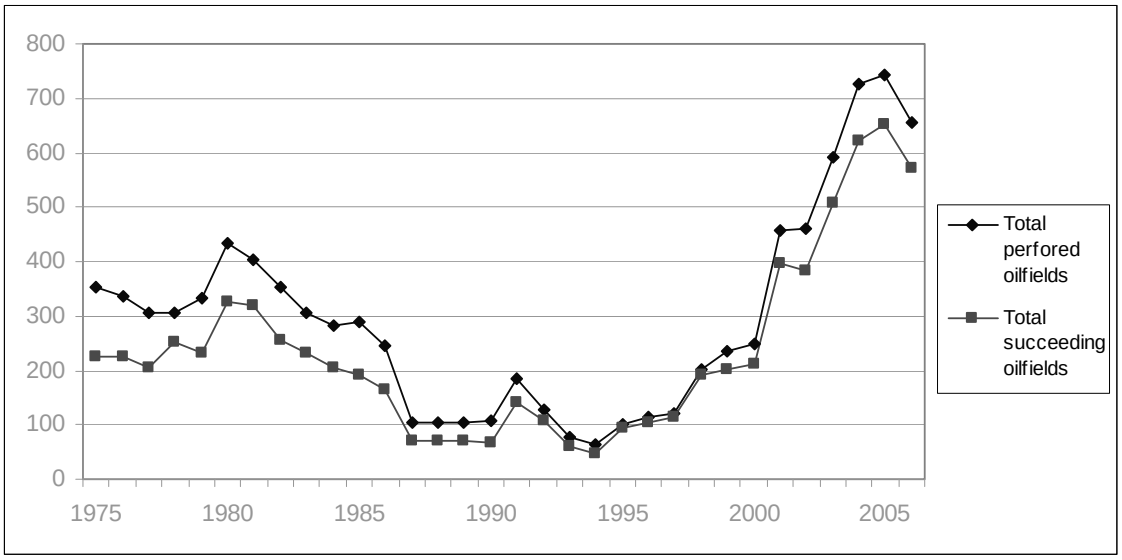
Source: *PEMEX* (2008c).

However, the investment (public investment) in exploration was increased from 2002 and reached its maximum in 2004, elevating the volume of total discovered hydrocarbon reserves, and therefore reducing its declination by 3.6% during 1999-2004 to 1.9% during 2004-2008. This amounts to an increase in the rate of restitution of total reserves from 21.3% in 2000 to 65.7% in 2007.

Negative variations in exploration and perforation can be explained by the various periods of economic crisis that have affected Mexico (see Figures 20 to 22). Among the principal factors that have negatively affected the country are the fall in oil prices, the tax system for *PEMEX*, the lack of investment in the sector, and, in recent years, the precarious financial situation of *PEMEX*. That is, the crucial explanatory variable is the lack of investment.

On the other hand, success in perforation depends on technology, specific methods employed, and learning-by-doing processes. On top of this, perforation further depends on the approval granted by the Congress. By 2006, the success rate in oil development was 92% (see Figure 22). It is important to point out that the main production of *PEMEX* takes place in the southeast of the country, in the so called *"Bahía de Campeche"* and *"Plataforma de Yucatán"*. More than 90% of the fields in these regions are located in shallow waters and the rest correspond to deep waters, which impose a technological challenge to *PEMEX*.

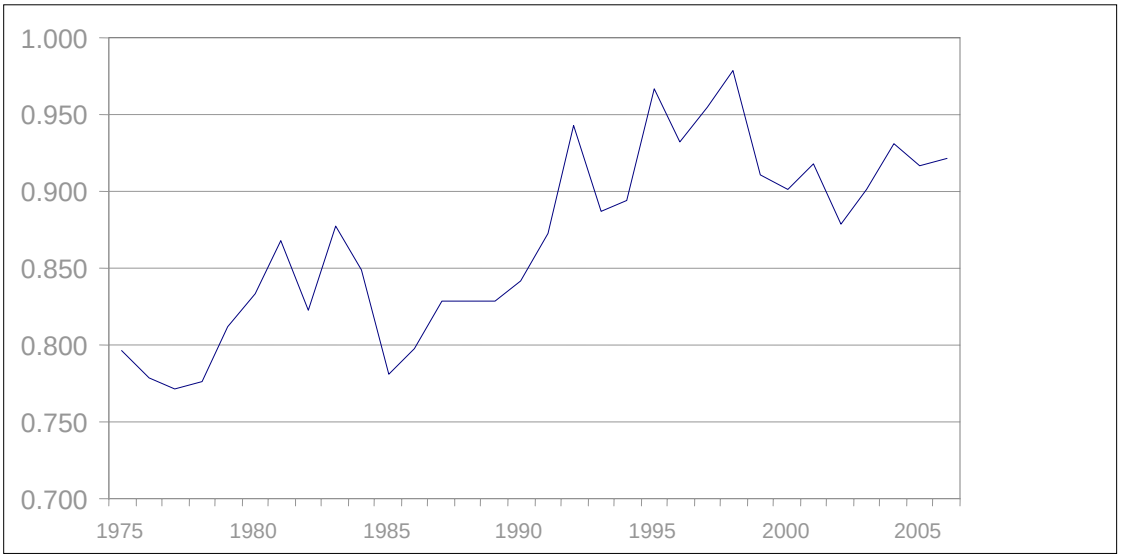
FIGURE 21. TOTAL OILFIELDS



Source: PEMEX (2008c).

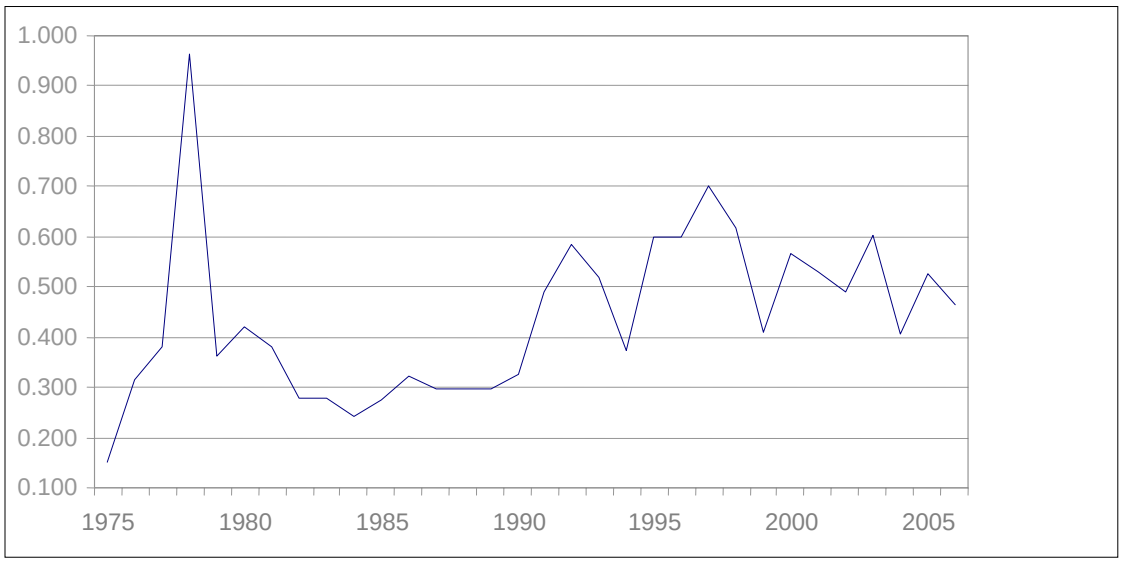
The ratio of fields explored with success is almost 46% (see Figure 23). Exploration in deep waters started in 1999. The Veracruz-Tabasco seashore has been explored since then, and from 15 oilfields only *"Lakach"* (Coatzacoalcos) has the potential of becoming commercially viable. The other fields are mainly crude oilfields. Exploration in ultra-deep waters began with the exploration of only ten oilfields and some natural hydrocarbon emanations from the bottom of the Gulf of Mexico. Results have been so far scarce due to the lack of technology, equipment and human resources, which may be closely related to being short of resources.

FIGURE 22. SUCCESS RATE IN DEVELOPED OILFIELDS



Source: *PEMEX* (2008c).

FIGURE 23. RATIO OF OILFIELDS EXPLORED WITH SUCCESS



Source: PEMEX (2008c) and IMP (2008).

Quality of Mexican crude oil

As it is well known, oil is a hydrocarbon that has some contents of sulfur, nitrogen and metals. It varies in color, odor, origins and age. The precise chemical components of oil —as well as its physical properties— are difficult to be determined. Several other hydrocarbons are derived from oil. They are

characterized according to their capacity of isolation through different techniques, such as refining or distillation. By convention, the physical properties that are used for their classification include boiling point, density (or specific gravity), *API* gravity and resistance (viscosity). Table 10 presents the different specifications according to the diverse physical-chemical properties.

TABLE 10. OIL GENERAL SPECIFICATIONS

ORIGIN AND AGE	RESISTANCE[9]	SPECIFIC GRAVITY[10]	API GRAVITY[11]	BOILING POINT °F[12]	ODOR	TYPES OF REFINEMENT		
REGION	SUPER-LIGHT	.86>.794	34.1> 46,7	30-300	SWEET (LOW SULFUR CONTENT)	CARBON REJECTION (VISBREAKING, PIROLISIS, ETC..)	HYDROGEN ADDITION (CATALISIS, ETC)	SEPARATION (DESTILATION AND EXTRACTION
	LIGHT	0.92>0.86	22.4 > 34	300-400				
	HEAVY	0.99>0.92	10.1> 22.3	400 - 800	SAUER (HIGH SULFUR CONENTY)			
	EXTRA-HEAVY	1.0>	10>	800 - 1100				

Source: Own elaboration with information from Torres R. (2002).

Similarly to reserves, the classification by type of crude oil, according to *API* degrees, changes through time (reclassification due to changes in the refining processes). In Mexico there are four types of crude oil: Maya, Istmo, Olmeca and Marino Ligero (see Table 11). In general, heavy crudes dominate the Mexican crude-oil bundle. In its raw form, crude oil has low commercial value. It requires several refining processes to add value to the final product. These heavy crudes require the removal of non-desired elements.[13] On the other hand, light crudes require less number of refining steps to get gasoline.

[9] The opposition of substances against surface contact is known as "viscosity".

[10] $GE = (\frac{141.5}{API + 131.5})$ is a comparison between density of a substance and water density.

[11] $API = (\frac{141.5}{GE}) - 131.5$, where GE is the specific gravity. In general terms, the API degrees show how heavy is crude oil compared to the weight of water. In most cases, the higher are the API degrees obtained from the equation the lighter will be the crude and the smaller the sulfur quantity.

[12] It is the point where substances evaporate.

[13] It has been recently discovered that crude oil possesses larger anti-detonating properties than light crudes. This has contributed to technological changes in the structure of refinement processes (Torres, 2002).

Therefore, light crudes have a higher price. The Mexican bundle has several crude qualities, ranging from super-light to heavy (see Table 10). Heavy crudes have a higher weight within proved reserves. This means that *PEMEX* requires higher investments to adequate refineries with catalyst converters that are able to reduce the sulfur-nitrogen-oxygen-chlorine concentrations, and produce fuels at large scales that comply with the quality, economic and environmental standards set in the international markets.

TABLE 11. CLASSIFICATION OF MEXICAN CRUDE OIL

Region (principal)	Resistance	Name	API Gravity		Odor (% of sulfur)	
			1991	2000	1991	2000
North and South	Super-light	Olmeca	39.8	38.9	.8	.93
North, South and Southwest	Light	Marino	---	34.5	---	1.23
		Istmo	34.8	32.9	1.5	1.4
Marine Norheast and North	Heavy	Maya	22.2	21.5	3.3	3.4
---	Extra-heavy	---	---	---	---	---

Source: Own elaboration from information in Torres R. (2002).

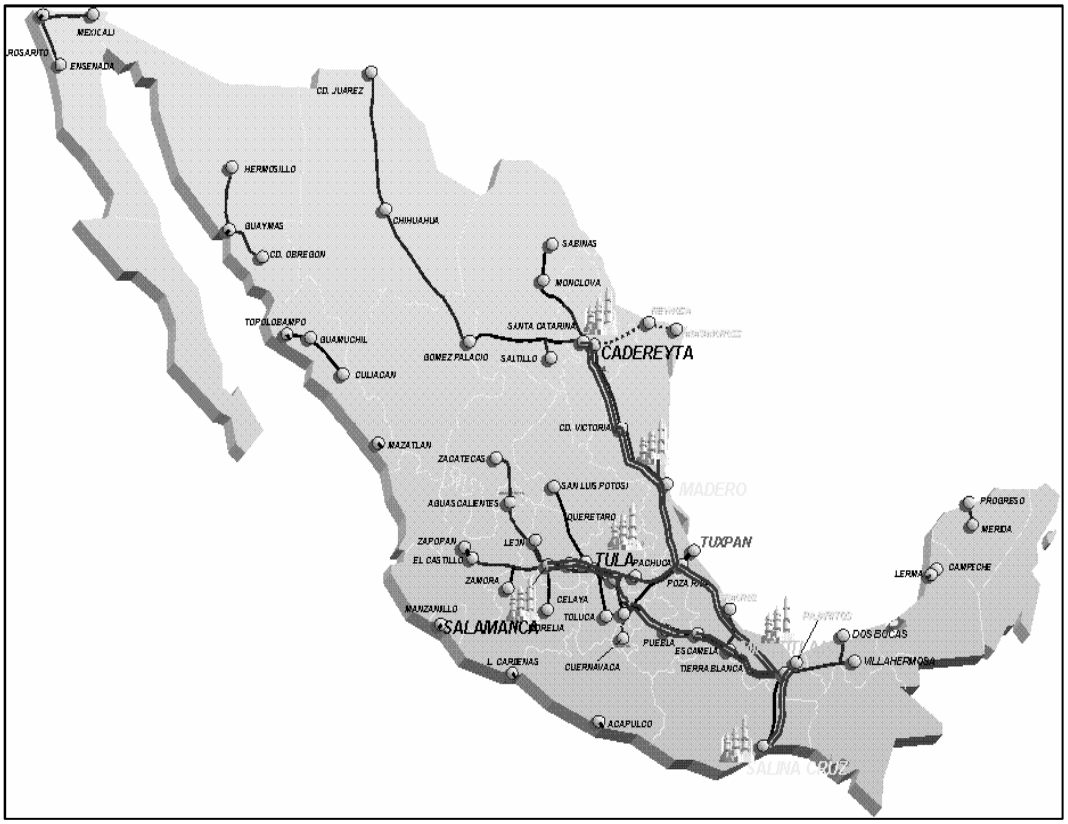
PEMEX and its refining technology

The *National Refining System* in Mexico is composed by six refineries: *Cadereyta* and *Madero* (both reconfigured for crude oil processing), *Minatitlán* (in process of reconfiguration), *Salamanca*, *Tula* and *Salina Cruz*. There has been no investment in new refineries since 1979 when the last one started its operations. Additionally, *PEMEX* owns since 1993 50% of the refinery located in Deer Park, Texas, while Shell owns the other 50%.

Besides refineries, *PEMEX*'s infrastructure includes 15 maritime terminals, 5,197 kilometers of oil pipelines, 8,835 kilometers of multipurpose pipelines, 77 storage and distribution terminals (see Map 1). Regarding natural gas, *PEMEX* has 10 processing centers, 25 gas and condensate sweetening plants, 16 liquid recuperating plants, 7 fractioning plants, 12 sulfur recuperation plants, 8,985 km of gas pipelines, 3,051 km. of *LPG* pipelines, and 20 *LNG* terminals.

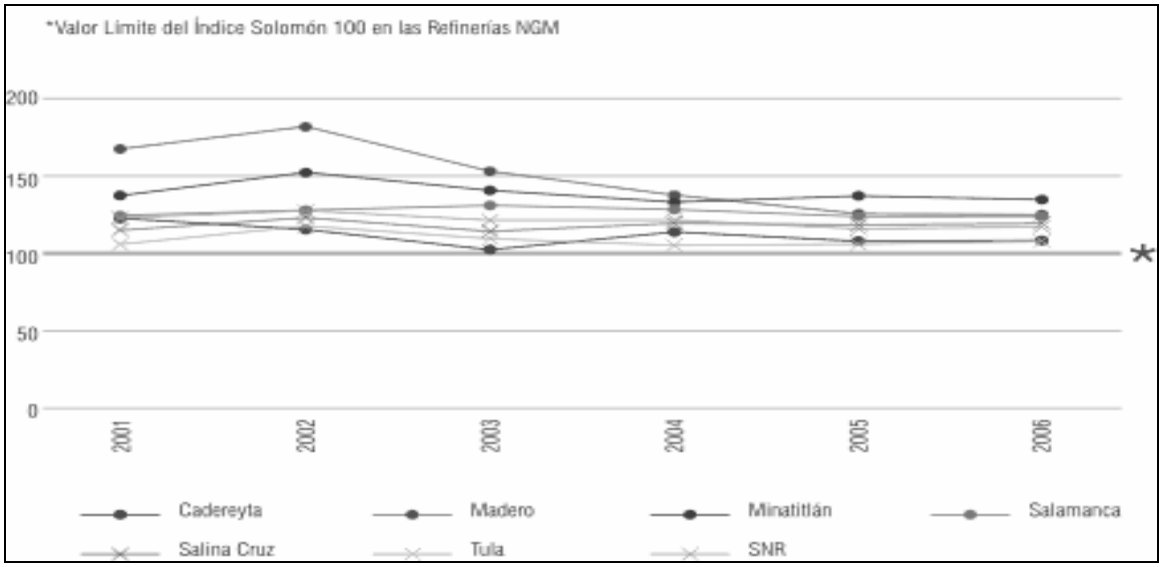
However, *the National Refining System* is not adequately designed for heavy-crude oil processing. Additionally, the energy efficiency in most of the Mexican refineries is higher than the international efficiency standards. According to the Solomon Index, Mexican refineries range between 120 and 140 (international references range between 90 and 92). This reflects that energy utilization in Mexico is inefficient, and that current infrastructure requires important modifications to reach international energy-efficiency standards (see Figures 24-25).

MAP 1. INFRASTRUCTURE OF *PEMEX*



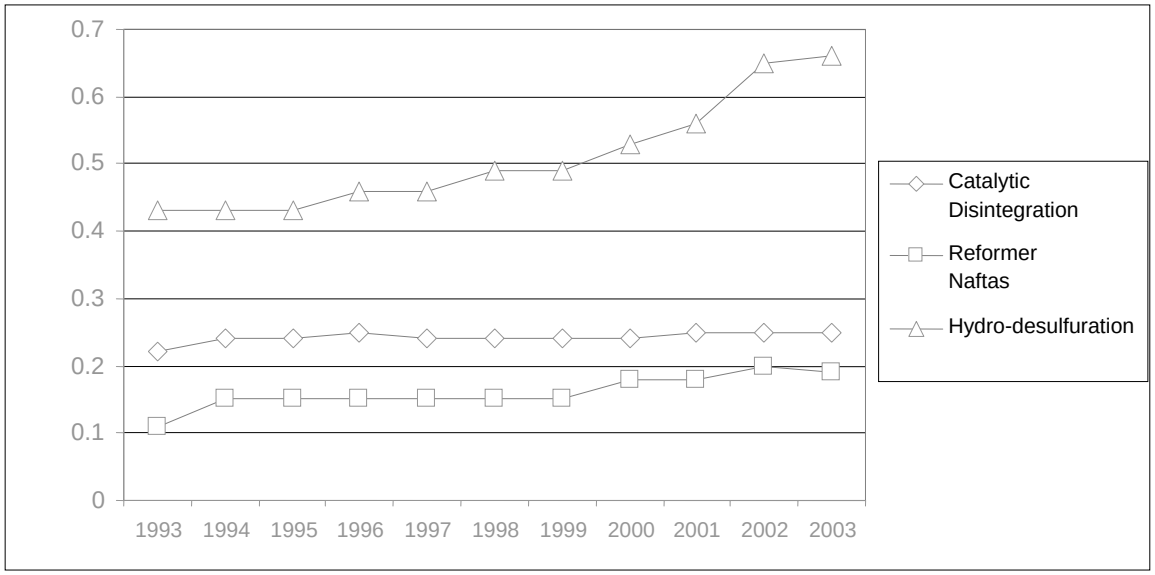
Multi-purpose pipelines
Oil pipelines
Source: SENER (2008a).

FIGURE 24. INDEX OF ENERGY INTENSITY



Source: *SENER* (2008b).

FIGURE 25. COEFFICIENT OF COMPLEXITY IN THE NATIONAL REFINING SYSTEM[14]



Source: *SENER* (2008b).

The experience from exploration, development and long-run production —as well as the administration in the decline of *Cantarell*— has given *PEMEX* some valuable technology expertise, especially in shallow water and land projects.

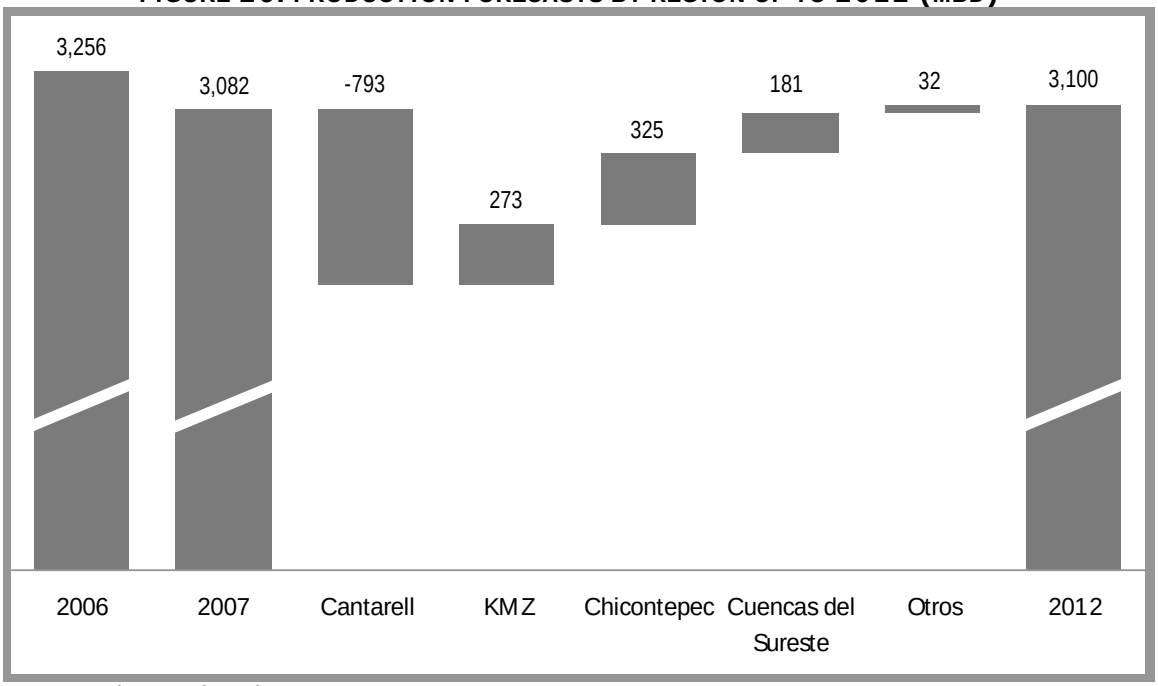
[14] This coefficient states the relationship between capacity of secondary processes and the capacity of the primary distillation plants. It also reflects a decrease in lower sulfur content (*SENER*, 2008b).

However, *PEMEX* lacks of technology and human resources for deep-water and ultra-deep water projects. Even more, it lacks of sufficient internal administrative skills to subcontract such resources.

Oil sector requirements: scenarios, forecast and goals

The main challenge for *PEMEX* in the medium run is to maintain its current production levels and to achieve a smooth controlled decline path of its oil resources. It is supposed to be achieved through the efficient use of energy, the revision of high export levels when proved reserves are declining, the improvement of production technologies, and the technological change in exploration and development activities as well as in operation processes. The specific goal of keeping the current oil production level of 3.1 mbd until 2012 includes the administration of *Cantarell* —together with the perforation of new fields within the area— so as to extend its life. The development of the *Ku-Maloob-Zaap*, *Burgos* and *Chicontepec* fields and the *Southeast* basin would help to countervail the 14% production decrease of *Cantarell*. It is expected that *Ku-Maloob-Zaap* will approximately produce 0.8 mbd by 2010. Additionally, the strategy of *PEMEX* to manage the decline in production includes returning to mature oil basins, mainly in the *Southeast* (Tabasco, Chiapas and Campeche) (see Figure 26).

FIGURE 26. PRODUCTION FORECASTS BY REGION UP TO 2012 (MBD)



Source: Lajous A. (2008).

PEMEX would also like to restore, by 2012, its proved reserves (*1P*) in 100%, through the increase of the average life of its reserves in 10 years. To accomplish this goal, *PEMEX* would have to attain proved reserves of 7.6 mmb (crude-oil equivalent), which would imply achieving half of the proved reserves in 2007 plus one-fourth of the sum of proved and probable reserves. This would also imply that *PEMEX* would increase its probable reserves at *Ku-Maloob-Zaap* as well as perforation at *Chicontepec* (achieving the reclassification of probable reserves into proved reserves), and add new deep and ultra-deep water reserves. Likewise, proved and probable reserves must increase their recuperation factors in already known fields (e.g., *Cantarell*, *Ku-Maloob-Zaap*, *Chicontepec*). For instance, *Chicontepec*'s reserves in 2007 were 17.7 mmb (crude-oil equivalent), 34% of which are proved reserves. *PEMEX* expects that *Chicontepec* will substitute *Ku-Maloob-Zaap* in 2010, but this is a technically difficult task because *Chicontepec*'s exploitation started from a high-cost modest base, so that it requires the perforation of a huge number of oilfields and it must improve its production and recuperation techniques.

To date, more than half of the original reserves have been already produced, and the remaining proved reserves represent less than one-fourth of the original proved reserves. In the medium run, reloading proved reserves will be achieved through the development of probable reserves that would later become proved reserves. The evaluation of reserves therefore takes for granted a dynamic approach of their development that considers geology, technical difficulty and the economical viability of the distinct reserve classes and potential resources.

With respect to exploration, *PEMEX* short run strategy is to develop it in the *Southeast* basin and in deep water fields. Moreover, in the medium run, *PEMEX* is planning to develop exploration in ultra-deep oilfields. The exploration of deep water (less than 1,500 meters) and ultra-deep water (more than 1,500 meters) new oilfields in the Gulf of Mexico has not been developed. According to *PEMEX*'s information, from its total prospective resources, 55% are in the Gulf of Mexico and, of this percentage, approximately 70% belong to ultra-deep water resources. But in fact, only 30% of the exploratory opportunities have been inferred to date. Additionally, there exist joint border fields with the United States in the *Perdido Foldbelt* area. This is a large oilfield area whose extension is equivalent to the Washington D.C. and Cuba combined areas.[15]

PEMEX purchased two ultra-deep water platforms during 2004-2007. Another one was purchased for 2009-2010. Since then, four more contracts have been assigned through public bidding for the development of ultra-deep

[15] The most important oilfields are Thunder Horse, Atlantis, Holstein, Mad Dog, Kinas Peak, Diana Hoover, Auger, Mars Na Kika, Neptune and Ursa in the United States, and Magnánimo and Alaminos-1 in Mexico (see Anderson and Boulanger, 2003, and *SENER*, 2008a).

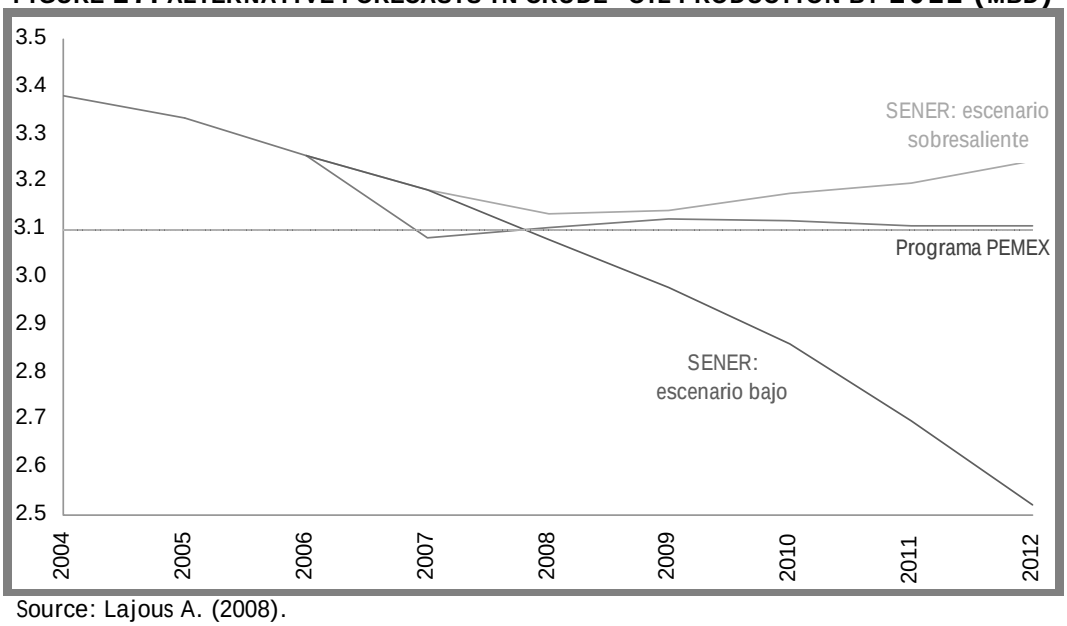
water fields, even though nowadays the convenience of their development is under discussion. These platforms are supposed to allow an ambitious program which is superior to any program carried out by any individual exploration firm. But *PEMEX* will have to achieve enough administrative skills so as to coordinate and oversee the specialized firms that will perform such a task. *PEMEX* itself does not have the organizational, technical and management capacities or the human resources so as to carry out exploratory perforation in ultra deep waters (*SENER*, 2008a, and Lajous, 2008).

Development of projects in shallow waters has not been a priority for *PEMEX*. Since such projects are located in areas that have been already extensively explored and exploited, the fields that could be discovered are most probably very small. Both shallow and deep-water projects have advantages and disadvantages for their development. Shallow-water projects are closer to the already existing infrastructure. In deep-water waters, technical production costs per barrel tend to be low but infrastructure costs are high. Generally speaking, costs plus risks in ultra-deep water projects tend to be higher than in shallow-water projects.

The achievement of the above goals is hindered by the corporate governance of *PEMEX* characterized by a high hierarchy which makes difficult the decentralization of operative and investment decisions (see section 4.1).

The above *PEMEX'* plans could be modified by potential private investment. The *SENER* has forecasted two investment scenarios: a basic scenario and an outstanding scenario (see Figure 27). In the first one, investment substantially decreases.

FIGURE 27. ALTERNATIVE FORECASTS IN CRUDE- OIL PRODUCTION BY 2012 (MBD)



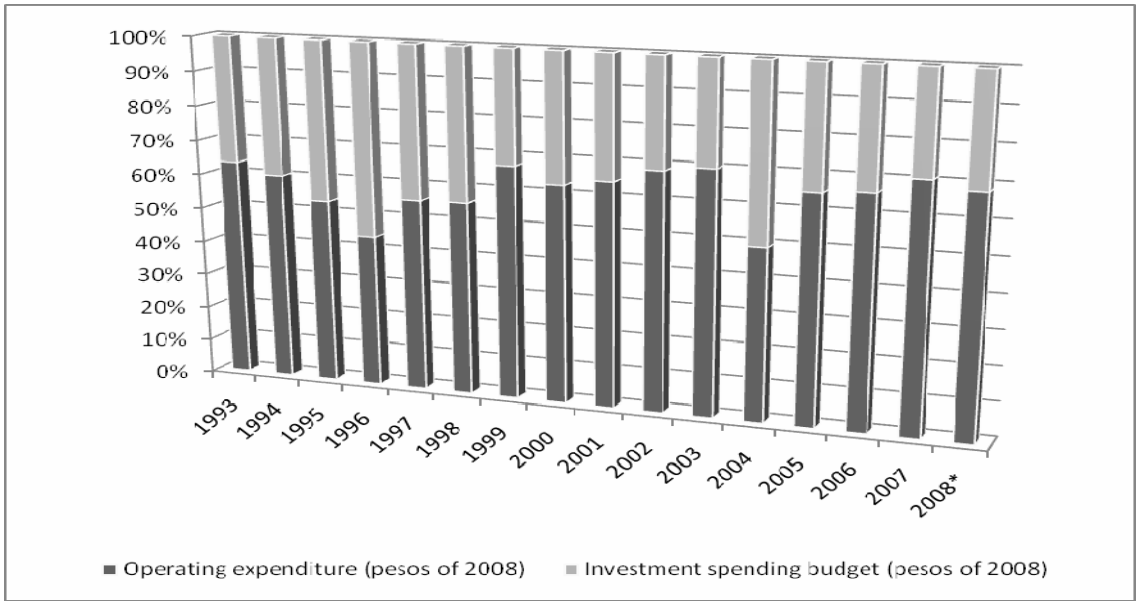
Source: Lajous A. (2008).

The second scenario presupposes further legal changes that substantially increase private investment, both in production and exploration, during 2007-2012. With the reform approved in 2008 (see section 4.1), *SENER* has planned a substantial program of investments with 62.6% to production, 20.8% to exploration and 16.6% to future developments, from the average investments programmed during 2008-2017. Also, it has considered continuing with the medium and long run strategies. Additionally, the development of projects in deep waters will represent 17.9% of the total investment that is planned for 2017.

Counterfactual scenarios

We have been discussing the restrictions imposed by the legal architecture prevailing in the Mexican oil sector. This has been one of the main drawbacks in the sector. Another drawback comes from the fiscal policy applied to *PEMEX*. The combination of the two factors causes an underinvestment in the *NOC*. In previous sections we have analyzed the tax scheme that must be satisfied by the enterprise. It is hard to find similar tax restrictions around the world. Even though it has somewhat changed over time, such a combination of taxes, duties, and rights keep restraining the investment plans for the firm. Although *PEMEX* has received significant resources, most of them has been allocated to extraction and operating spending. Investment in exploration has not been relevant. Figure 28 shows the evolutions of investment for the main components.

FIGURE 28. INVESTMENT FOR *PEMEX*



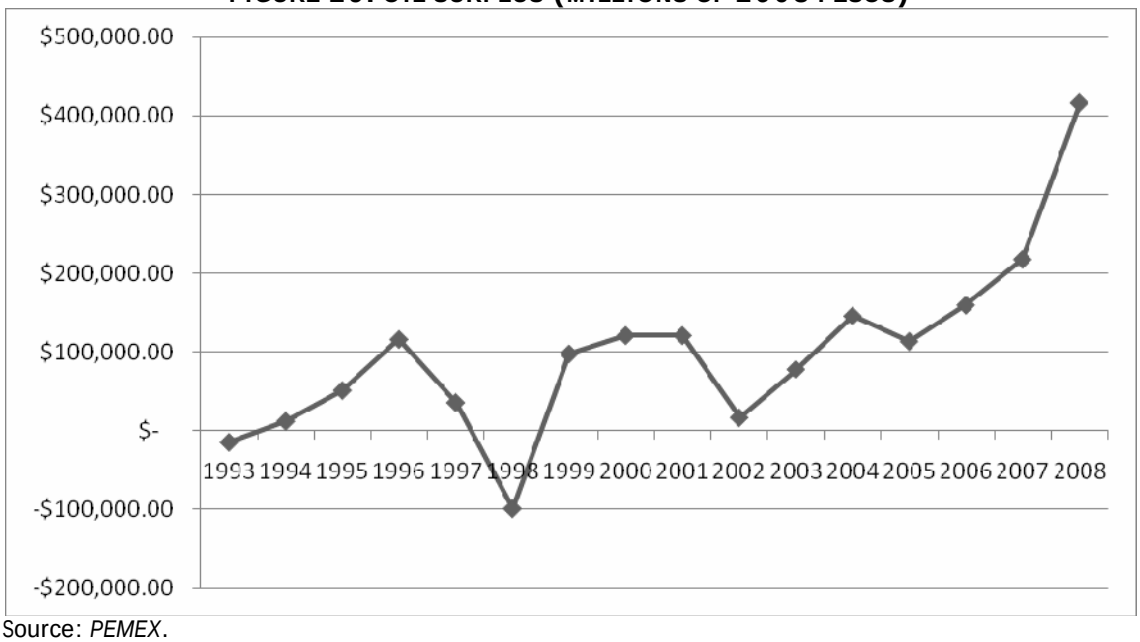
Source: *PEMEX*.

The final budget is finally approved by the *SHCP* taking into account the original proposal submitted by *PEMEX*. However, invariably the final budget is below the one solicited by the *NOC*. The reason is simple. The *SHCP* must balance its books bearing in mind the total requirements received by all public entities. This process usually ends up in an unfavorable setting for *PEMEX*. On top of this, *PEMEX* is forced to provide significant resources to the federal budget (again, around 30-35% each year).

In Table 4 we showed the rules followed by the Mexican State to share the excess oil income. Based on this table and in the extra resources gotten by the Federal government, we next construct our counterfactual as follows.

In Figure 29 we present the extra resource that the federal government got during 1993-2008. Except for 1993 and 1998, this amount has always been positive. It then means that the budgeted oil price was below the average market price for the Mexican bundle for the rest of the years. For example, the nominal budget price in 2005 was USD $27.00, while the market price was USD $42.71. This difference multiplied by the exported oil barrels constitutes the excess oil income for that year.

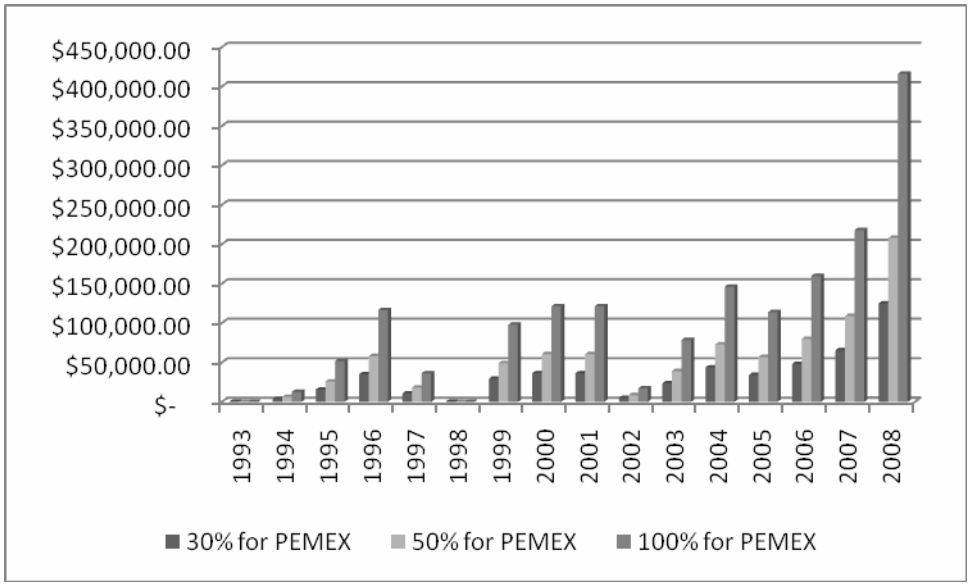
FIGURE 29. OIL SURPLUS (MILLIONS OF 2008 PESOS)



Source: *PEMEX*.

We now construct three counterfactual scenarios by modifying the rules for sharing these additional resources from 1993 on. In the first one, PEMEX receives 30%, in the second, gets 50%, and in the last one it obtains 100%. These amounts are shown in Figure 30.

FIGURE 30. ADDITIONAL RESOURCE THAT COULD HAVE GOTTEN *PEMEX* (MILLION 2008 PESOS)



Therefore, the amount of additional resources that could have been allocated to *PEMEX* during the period from 1993 to 2008 is huge. It is on average more than 100,000 million pesos a year in the case of 100% transfers to *PEMEX*. It is hard to gauge the potential impacts of such scheme on PEMEX investments, but it suggests that the current production and exploration situation could be completely different.

Conclusions

Oil in Mexico has been the basis on which the Mexican State has built upon since its nationalization. It has been the main federal income source; it has supported industrial development and has allowed the State to obtain foreign currency. Moreover, *PEMEX* is a supply of vital resources for the government by financing public spending, providing certainty to the economy, and providing extra resources for local governments. However, for decades fiscal, institutional, legal and organizational constraints have not allowed the Mexican *NOC* to fully behave as a profit maximizing firm that chooses optimal strategies for reinvesting its own resources and/or subcontracting with other firms with advanced technologies.

The current institutional and regulatory frameworks in the Mexican hydrocarbon sector hinder the development of *PEMEX* in all its stages of production. For many years there has not existed a coherent public strategy to foster investment possibilities of this state monopoly. If the federal government would have decided to allocate all extra resources to *PEMEX*, the firm would have obtained up to 100,000 million pesos per year. This is almost four times the investment in the best year of the *NOC*.

The federal government is expecting that the changes introduced in 2008 will deliver a better market architecture for the sector that favors investment increases. It is expected that the Mexican *NOC* will face less restrictions in its budget and project planning processes, and, consequently, that it will obtain substantially increase its resources. A comparison with the experiences of other Latin American countries however suggests that deeper reforms might be needed in Mexico to seriously attract the needed investment resources of its oil industry.

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