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Energy Policies and the Mexican Economy

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Acknowledgments

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Abbreviations and Acronyms

ARE	Aprovechamiento sobre Rendimientos Excedentes
BLT	Build-lease-transfer
CES	Constant elasticity of substitution
CFE	Comisión Federal de Electricidad
CGE	Computable General Equilibrium
CGT	Combined cycle gas turbine
CNA	Comisión Nacional de Agua
CRE	Comisión Reguladora de Energía
DEP	Derecho a la Extracción de Petróleo
DSH	Derecho sobre Hidrocarburos
ESMAP	Joint UNDP/World Bank Energy Sector Management Assistance Programme
GAAP	Generally accepted accounting principles
GDP	Gross Domestic Product
GOM	Government of Mexico
INEGI	Instituto Nacional de Estadística, Geografía e Informática
IPP	Independent Power Producers
ISR	Impuesto a los Rendimientos Petroleros
LFC	Luz y Fuerza del Centro
LPG	Liquid Petroleum Gas
OECD	Organisation for Economic Co-operation and Development
OPEC	Oil-Producing and Exporting Countries
PEMEX	Petróleos Mexicanos
PGPB	Pemexgas y Petroquímica Básica
PIDEREGAS	Programa de Impacto Diferido en el Registro del Gas
PROGRESA	Programa de Educación, Salud y Alimentación
SAM	Social Accounting Matrix
SEMARNAP	Secretaría de Medio Ambiente, Recursos Naturales y Pesca
SENER	Secretaría de Energía
SHCP	Secretaría de Hacienda y Crédito Público
SOE	State-owned enterprise
US EIA	United States Energy Information Agency
WTI	West Texas Intermediate

Units of Measure

Bcm/y	Billion cubic meters per year
Bcfd	Billion cubic feet per day
mmcfd	Million cubic feet per day
MW	Megawatts
mbd	Million barrels per day
kWh	Kilwatt hour
bpd	Barrels per day
toe	Tons of oil equivalent

Preface

1. Mexico is both a major energy producer and consumer. How the sector is managed and performs therefore has profound implications for economic growth and public finances and by extension for broader social policies and programs which depend heavily on federal funding.

2. If Mexico is to achieve the growth rates of GDP recently forecast (4.5 percent in 2002-2010), the demands on the energy sector will be enormous. Meeting the growing demand for energy will require a quantum increase in investment which the government cannot hope to finance itself, unless it severely curtails spending on other important social goals, such as health and education. However, if the necessary investment in the energy sector is not forthcoming, the impact on the macroeconomy could be quite adverse.

3. The government has been under pressure for at least a decade to cut federal funding for investment in the energy sector and to allocate the tax revenues to meet growing social and economic needs. As a consequence, the government is looking for ways in which the energy sector can efficiently meet at least a high proportion of the demands upon it without burdening public finances.

4. The energy sector finds itself in a vicious circle—reduced budget and borrowing capacity are leading to insufficient sector investment. This in turn will result in declines in future production and hence government revenue, making it more difficult to fund priority poverty reduction programs going forward.[1] The government is increasingly forced to choose between the call to spend now on urgent social programs, such as health, education, and rural infrastructure and the concurrent need to invest in energy to meet the growing demand for energy and to provide resources to finance future public spending. Breaking out of this vicious circle is one of the most important challenges Mexico faces today. Attracting finance for energy sector investment on a major scale without government support lies at the heart of the problem.

5. Many have called for implementation of far reaching reforms in sector policies as a necessary condition to attract sufficient private sector finance, improve efficiency, lower costs, and sustainably expand the sector's contribution to the federal budget and the broader economy. Three key areas for reform stand out:

?? Achieving permanent gains in operational efficiency of the power and hydrocarbons sectors to lower costs and improve service quality

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[1] *Note:* Non-oil tax revenue has remained alarmingly low at about 10 percent of GDP and is not anticipated to increase significantly for the remainder of the sexenio.

?? Restructuring electricity subsidies, targeting them to the poorest households

?? Opening the hydrocarbons sectors to new players to attract the funds and skills needed to efficiently undertake exploration and development of Mexico's plentiful oil and gas resources.

6. In 1999, the Mexican authorities requested World Bank assistance in evaluating the macroeconomic impact of adopting various energy sector reform proposals. This study provides a critique of existing energy sector policies in terms of poor incentives for productive and allocative efficiency and for mobilizing private financing. The results of simulations of the macroeconomic impact of changes in key sectoral policies using a dynamic macroeconomic model are then presented. The simulations provide a first indicator of order of magnitude of changes in key macroeconomic aggregates associated with several stylized, yet realistic policy shifts. Data used in the analysis is from 1996–2000 and the period of simulation is 2000–2015.

7. The simulations of the macroeconomy examine three sets of policy changes, both singly and in combination. These include the removal of energy sector subsidies, improvement in productive efficiency of the energy sector, and the alteration of oil output levels. The equilibrium requirements of Computable General Equilibrium (CGE) modeling imply two important assumptions. First, the overall budget balances in every period—an increase in revenue from a reduction in subsidies is balanced by increased social spending on other goods and services, and an increase in tax revenue from increased oil production is balanced by increased public spending. This assumption is plausible and, as is usual with balanced budget multipliers, means that in macroeconomic terms the fiscal impact itself appears to be relatively small while the sectoral impacts can be quite large. The second assumption, which is relaxed in later simulations, is that the labor force is perfectly mobile and real wages are flexible downward. This implies that the level of unemployment does not rise above the starting level which is considered frictional. Finally, the simulations treat hydrocarbon resources as a factor which contributes to GDP and real wages, so that increased oil production raises the growth rate temporarily, while reductions in production depress the growth rate. Since Mexico has raised aggregate output and employment in part because of oil production, in order to keep the growth rate at recent historic levels, further increases in oil output would be required. With insufficient growth in oil production, the real wage would fall to absorb the current labor force, while GDP growth would be lower. If real wages were to be sticky (at their present levels) higher unemployment could result with a low oil output scenario.

8. The main simulations confirm these precepts:

?? The removal of power subsidies and offsetting increased social spending produces small effects on GDP and trade. It does however reduce the demand for electricity and simultaneously affects household welfare with the lowest quartile experiencing the largest negative impact (since subsidies for them were the most important in proportional terms).

?? Gains in energy sector efficiency lead to a rise in GDP of 1.5 percent over the status quo by the end of the 15-year period, while power output increases substantially from the impact of lower costs. The GDP gain is also converted into a welfare gain for all households across the income distribution. Even if wages are sticky downward, the comparison of scenarios with and without subsidy removal and efficiency gains indicates increases in GDP and household welfare from these reforms.

?? The alternative oil production scenarios show the most dramatic effects. A policy which results in insufficient investment to maintain output would result in a substantial fall in GDP over the period, with an associated deterioration in the balance of payments surplus. Under this scenario, all groups in the income distribution become worse off. Alternatively, if oil output is increased above present levels of around 4 mbd to a level of 5 mbd by 2015, the result would be a substantial growth in GDP, in the balance of payments surplus, in total government revenue and hence social spending, and consumer welfare, particularly of the higher income groups. An increase in output to 6 mbd (a high case) would produce a further increase in GDP, the balance of payments surplus, consumer welfare, and public spending. At such a level of oil output, sticky wages are irrelevant since wages would tend to rise rather than fall. This is in the sharpest contrast to the oil steady scenario of crude output at 4 mbd, where sticky wages would ultimately result in a significantly lower GDP, consumer welfare and social spending. Hence if the Mexican authorities are unwilling or unable to increase oil output substantially, and if the labor market remains rather rigid with a tendency for wages to be sticky downward, the economy faces risks of steadily rising unemployment.

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Introduction

1.1 Mexico is well endowed with hydrocarbon resources and its industrial base relies heavily on low-cost energy. For this reason, the performance of the energy sector is seen as key to generating growth and employment. Mexico's substantial reserves of oil and gas have the potential to continue to create considerable wealth for Mexican society. Without an adequate and efficient low-cost supply of energy, the economy will not grow at its full potential and improvements in the living standard of the Mexican people will be restrained. Access to modern forms of energy is also an important element in reducing poverty. Improved lighting, heating, and motive power can substantially raise the productivity and quality of life of poor households.

1.2 Exploitation of Mexico's abundant oil and gas resources makes it possible not only to supply the energy requirements of the country, but also to make a large contribution to the federal budget and through it, to the financing of core social services such as health and education. Given the availability of carbon-based fuels, potential renewable energy resources, and the existence of an extensive transmission and distribution network, it is also possible to provide electricity services at a relatively low cost to all Mexicans.

1.3 The magnitude of the demands placed on the energy sector over the past decade have been enormous. These demands will grow dramatically as the Mexican economy continues to expand. At the same time, there will be increasing claims on federal funds to expand social services to meet the needs of a young and rapidly growing society. Conservatively estimated, the energy sector's capital requirements for the next 10 years are MXP1,400 billion in constant 2000 pesos. This equates to approximately MXP140 billion a year, representing 2.5 percent of current GDP, more than the total health and education budgets and more than double the rate of investment in the sector in the late 1990s. It is neither feasible nor desirable to finance the necessary expansion of the energy sector, neither out of the public purse nor through government-backed borrowing. This is especially true given the urgent competing demands for support to critical social and sub-national development programs.

1.4 Mexican policymakers recognize the challenge and have instituted a number of incremental changes (discussed below). Broader, more far reaching changes in sector policy have been called for over the past decade by various Mexican groups to ensure gains in sectoral efficiency, financial resource mobilization, and output sufficient to sustain the kind of economic growth needed to productively absorb Mexico's rapidly growing labor force and to finance priority social programs. The reforms under discussion imply large-scale changes in industry structure, management, oversight and regulation, and for electricity, pricing and subsidies. That such proposals have not been acted upon in part reflects concerns among policymakers about whether the benefits of reform would be sufficient to offset the costs, economic and political, of instituting such changes. One element to inform the debate, heretofore absent, is an assessment of how proposed sector reforms would influence performance of the economy at large. Assessing the magnitude of potential gains from energy sector reforms from an economy-wide perspective rather than from a narrower sector view would permit capturing potentially important feedbacks and spillovers for a sector which looms large in the overall economy. Doing this calls for the use of different approaches—general rather than partial equilibrium analysis—and makes use of different models, in this instance dynamic general equilibrium modeling rather than sectoral accounting or simple public finance models.

1.5 The report is organized in five sections: overview of current status of the energy sector in Mexico and major challenges facing the sector; exposition of key policy choices; description of model and specification of policy scenarios, presentation of results of simulations; and conclusions. A detailed description of the model and references are provided in the annex.

Current Status

1.6 Mexico has built its present economy in part on two pillars of the energy sector: the state-owned companies PEMEX (*Petróleos Mexicanos*) and CFE (*Comisión Federal de Electricidad*). Both have made large contributions to Mexico's development. PEMEX is one of the world's largest oil companies; contributes more than 30 percent of federal tax revenues; and thus is a major source of funds for general socioeconomic spending. CFE is among the largest utilities in North America, and together with LFC (*Luz y Fuerza del Centro*) provides electricity to 95 percent of the population.

1.7 **Recent Policies.** Government policy over the past decade has emphasized sound macroeconomic management, structural reforms, and modernization of public administration to foster sustained economic growth, reduction of poverty, and improvement in social welfare. In the *hydrocarbon* sector, the principal policies have been:

?? Continuing priority for production and export of higher quality crudes

?? Increasing the degree of self-reliance in production of refined products while processing a greater proportion of high-sulfur crude

?? Permitting private participation in some downstream activities such as secondary petrochemicals and natural gas transport and distribution

?? Decelerating the increase in air pollution by upgrading the quality of automotive fuels, expanding availability of natural gas and renewable energy resources in the energy matrix.

1.8 For the *electricity* sector, principal policy goals have included:

?? Ensuring capacity expansion to maintain service quality and coverage

?? Subsidizing the consumption of a very large proportion of the population in an effort to maintain their purchasing power

?? Fostering private participation in construction and financing of new thermal generation capacity

?? Conversion of fuel-oil-fired power plants to comply with Mexican emission standards

?? Mitigating the environmental impact of the combustion of fossil fuels by encouraging the adoption of end-use efficiency measures, cogeneration and renewable energy technologies

1.9 Recently, both the Fox Administration and the prior administration proposed comprehensive power sector restructuring aimed at fostering competition and mobilizing private capital in a manner which would not burden federal finances as well as for opening up upstream nonassociated natural gas development to the private sector.

1.10 **Recent Performance.** While the energy sector has been generally successful in providing energy to meet current needs, it has not performed to its full potential and has not been able to make adequate provision for the future. The operations of the state companies (PEMEX, CFE, and LFC) have been constrained by federal budget ceilings, dependence on implicit sovereign guarantees for borrowing, and for entering into long-term service agreements (for example, (Built-lease-transfer BLTs) and independent power producers [IPPs]), and are subject to extensive political intervention, particularly when it comes to pricing, tariffs, and execution of investment priorities. Electricity tariffs have generally been held below the cost of service, preventing the sector from recovering costs of operations and investment, leading to gradual decapitalization of state-owned service providers. In the hydrocarbon sector, activities to find, produce, and process oil are taxed at among the highest rates in the world, making many otherwise economic activities unprofitable. A growing proportion of oil tax revenues which the reserve base generates has been directed at addressing social and economic needs outside the sector. This has precluded reinvestment of sector revenues sufficient to sustain crude production and improve product quality. At the same time, being insulated from meaningful competition, these enterprises have been characteristically slow to adapt and innovate in response to changing market conditions, technologies, and management practices.

1.11 During the 1990s, the energy use in Mexico grew at 2.5 percent per year. These are substantial figures but still leave the per capita use well below levels seen in OECD countries. Table 1.1 gives an indication of the potential for growth in Mexico's per capita energy use.

Table 1.1: Index of Primary Energy Consumption Per Capita in 2001

Country	*Consumption per capita of Energy (toe)*
Mexico	1.29
United States	7.60
Japan	4.06
OECD	4.68

Source: BPAmoco Statistical Review of World Energy 2002

1.12 In developing countries the energy consumption grows faster than the economic growth rate, as consumers spend higher proportions of their income on energy-intensive goods as their living standards rise. The Mexican economy is forecast to grow at 4.5 percent per year over the next decade, and this indeed will lead to strong increases in demand for various types of energy.

1.13 Mexico has large reserves of both oil and gas, but relatively low production levels compared to countries such as Canada, Norway, and the United Kingdom (table 1.2). There is clearly substantial room to increase production and oil tax revenues without jeopardizing longer-term production potential.

Table 1.2: Reserves and Production of Select Oil Producers in 2001

	Oil		*Gas*		*Reserve/Production*	
	Reserves (bbls)	*Production (mb/d)*	*Reserves (TCM)*	*Production (BCM/y)*	*Oil (Years)*	*Gas (Years)*
Canada	6.6	2.8	1.7	172	8.8	9.8
Norway	9.4	3.4	1.3	58	7.8	21.7
United Kingdom	4.9	2.5	0.7	105	5.6	7.0
Mexico	26.9	3.6	0.8	35	21.7	24.0
United States	30.4	7.7	5.0	555	10.7	9.2

1.14 While the oil sector is no longer the principal source of export earnings, it continues to make a substantial contribution to federal finances, accounting for roughly 30 percent of federal fiscal tax revenues during the 1990s. However, because the sector operators are state-owned enterprises, a large part of these revenues have been returned to the sector to finance operating expenses and a restricted investment program, to cover very large, generalized electricity subsidies, and to provide for financial obligations to private sector financiers under the leveraged lease schemes (for example, BLTs, PIDEREGAS) and IPP purchase agreements. As a consequence, the sector's net contribution to the treasury has been very modest. This has limited the extent to which oil rents could be devoted to financing high-priority social programs and other national goals. In 1998, the oil sector's contribution on a net basis to funding public expenditures was MXP20 billion, after deducting PEMEX investment of MXP74 billion. Deducting power sector subsidies of MXP31 billion left a net energy sector deficit of MXP11 billion. Against this, 1998 total spending on health was MXP117 billion, and on education MXP118 billion. In fact, PEMEX investments have been sharply curtailed for much of the past six years and only began to recover in 2000.

1.15 The continuing dependence of fiscal revenues on hydrocarbon taxes leaves public finances vulnerable to changes in world oil prices. In the absence of alternative sources of fiscal revenue (Mexico's ratio of nonoil taxes to GDP at below 10 percent is alarmingly low), the preponderance of the burden of fiscal adjustment to oil price swings and other external shocks has fallen on public expenditures. Current expenditures are difficult to reduce in the short term, so the primary source of fiscal adjustment to external shocks has come from sharp cuts in capital expenditures. Because PEMEX and CFE investments comprise a large share of the capital budget, and given the high priority afforded to social programs, the investment budgets of these enterprises have borne a disproportionate share of such unanticipated cuts. While the effects of such cuts are not felt immediately by consumers. Energy development is highly capital intensive, requiring long gestation undertakings which, if deferred or suspended, inevitably lead to escalating costs.

1.16 The energy sector finds itself in a vicious circle—reduced budget and borrowing capacity have restricted sector investment. This in turn will limit expansion of production and hence government revenue, thus making it more difficult to fund future financial needs. The government is increasingly forced to choose between the call to spend now on urgent social programs and the concurrent need to invest in energy to maximize value creation from oil production to meet the growing demand for energy and for resources to finance future public spending.

Future Energy Demand and Supply Estimates

1.17 Projections for oil, gas, and electricity demand growth are given in the following sections. These projections are compared to past and projected supply and to the implied investment requirements in order to indicate the magnitude of the challenge that the sector now faces and the tradeoffs to be made. The investment estimates, based on unit cost approximations, are meant to provide a rough indication of orders of magnitude rather than precise cost projections.[2]

1.18 **Oil and Oil-Based Products** The historic supply/demand balance for oil is shown in Table 1.3. The table highlights the growth in oil production and the contribution it makes to exports. Domestic refinery capacity has not increased over the period, despite the increased demand for products. The product slate, however, has changed markedly to meet increasingly stringent product quality requirements. Delays in reconfiguring the domestic refineries to adapt to the phase-out of lead in gasolines in the mid-1990s led to much larger-than-expected imports of blending components and finished gasolines. Oil product imports are still growing rapidly, particularly gasolines, fuel oil, and LPG. PEMEX is carrying out an extensive refinery revamping program which will increase the production of high-octane gasoline and diesel. There have been a number of delays in approval and financing of this program.

Table 1.3. Oil Supply/Demand Balance for 1990–2000 (000b/d)

Year	*Production of Crude*	*Supply of Crude to Domestic Refining*	*Exports of Crude*	*Net Imports of Refined Products**	*Consumption of Products**
1990	2548	1271	1277	-1	1341
1991	2676	1287	1369	44	1403
1992	2668	1265	1368	55	1429
1993	2673	1295	1377	21	1442
1994	2685	1333	1307	79	1553
1995	2617	1267	1305	39	1432
1996	2858	1267	1544	86	1481
1997	3022	1242	1721	206	1573
1998	3067	1296	1741	213	1650
1999	2906	1297	1553	175	1657
2000	3012	1301	1652	363	1728

Note: *Products include LPG.

Source: PEMEX

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[2] Principal sources of data include *Programa Sectorial de Energía 2001-2006*, SENER 2000, *Prospectivas de Gas Natural, Electricidad*, SENER 2000, 2001, and industry sources.

1.19 The table shows that the entire increase in crude production went into an increase in the exports of crude. At the same time, the increase in the domestic demand for products resulted in an increase in the net imports of petroleum-based products.

1.20 It is assumed that it is desirable and technically feasible to at least hold oil production at its likely 2001 peak level of around 3.1 million bpd for the rest of the decade. This level of production would be sufficient to stop exports from declining from their 2001 peak of 1.8 mbd, unless a significant amount of crude is diverted to supplying domestic refineries. Beyond the current refinery revamping program, there do not appear to be plans to expand domestic refining capacity in the foreseeable future.

1.21 The costs of undertaking an investment program to sustain this production level is on the order of MXP400 billion . In addition, other needed investment would be on the order of MXP140 billion in refining and MXP50 billion in petrochemicals, so that in total the oil sector would require some MXP590 billion over the next decade. That is, it would require, on average, an investment of MXP59 billion a year for 10 years.

Natural Gas

1.22 Mexico has ample gas reserves to supply domestic needs. At present, production is largely associated gas, although there are substantial reserves of nonassociated gas. Over the last decade the natural gas production grew at an annual rate of 2.5 percent, but there has been a recent acceleration in the gas use, driven in part by the introduction of gas-fired electricity generation and by the liberalization of gas transport and distribution. This has involved both the introduction of competition and the commitment of Mexican and international private sector capital.

1.23 Between 1996-2000, CRE awarded 21 gas distribution permits under which concessionaires are obligated to serve 2.3 million customers by 2004. This represents a 15-fold increase in the customer base over 1995. The permitees have pledged to investment US$990 million to develop the distribution networks and paid roughly US$500 million to acquire existing distribution facilities previously operated by PEMEX and CFE.

Table 1.4: Natural Gas Permits Issued 1996-August 2000

Service	*Permits (#)*	*Capacity (mmcfd)*	*Length (km)*	*Investment Planned ($M)*
Transport	63	9,900	11,475	1,168
Open Access	14	7,450	10,893	1,015
Self-Use	49	2,450	636	152.
Distribution	21	1,493	28,042	989
Total	**84**		**39,517**	**2,156**

Source: *Comisión Reguladora de Energía CRE*: *info. CRE-Diciembre 2000*

1.24 Fifty-three transport permits have also been granted over the same period, 14 for open access and 49 for self-use. Of the US$1 billion in investments committed under open access permits, roughly half is for private sector projects, the other half being PEMEX PGPB commitments for maintaining and expanding the main trunk network. Self-use transport permits carrying investment commitments of about US$150 million have been secured primarily for spur lines to connect large industrial users (steel, mining, cement, chemicals) and new power generation facilities to gas fields or to the trunk network. These have been private sector undertakings.

1.25 The 11,000 kilometers of transport pipelines will have a capacity to deliver approximately 7.5 bcfd of dry gas. Much of that capacity will be used to supply gas for power generation, industrial processes, and to a lesser extent, distribution services in most major urban areas. The preponderance of new power generation capacity installed and/or contracted since the mid-1990s has relied upon combined-cycle gas turbine technologies and the share of combined-cycle gas turbine (CGT) technology in the power generation base is expected to more than double over the next decade because of its low investment costs, high thermal efficiency, and low emissions performance. As indicated in Table 1.5 below, by 2000, the Mexican authorities had contracted more than 11,000 MW of gas-fired power generation, equivalent to roughly one-third of total thermal power generation capacity in the country.

Table 1.5: Generation Permits

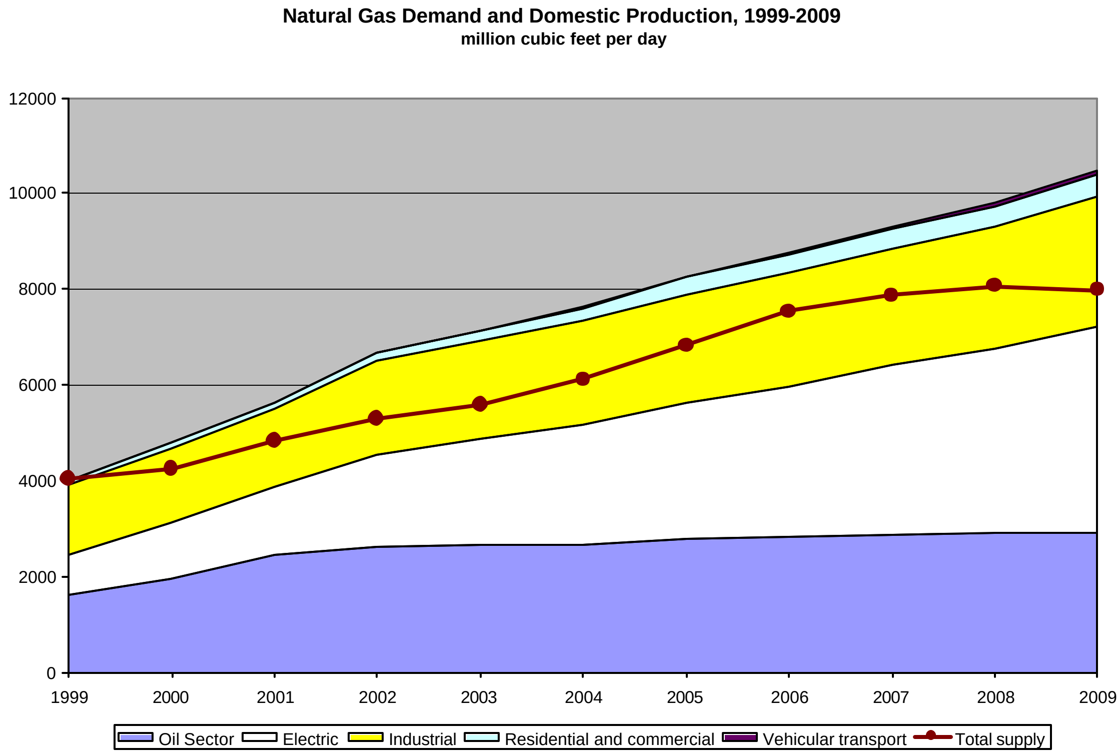
(Granted from 1994 to August, 2000)

Scheme	*Permits*	*Capacity (Mw)*	*Investment (Mus$)*
Self Generation and Cogeneration	144	6,703	4,409
Private	109	4,996	3,263
Pemex	35	1,707	1,146
Independent Power Producers	11	5,028	2,396
Export	1	258	116
TOTAL	**156**	**11,989**	**6,921**

*Source***:** CRE, *Informe Quincenal,* Octubre de 2000

1.26 The rapid increase in demand, coupled with only modest investment spending on supply, has led to a surge in imports from the United States as local markets have begun to develop. Natural gas demand is expected to continue to grow rapidly over the next decade. The key drivers are electricity generation demand, environmental standards that require fuel oil–run industrial facilities in critical zones to convert to natural gas, and the build-out and operation of distribution systems throughout the country. The Gulf region will continue to absorb a large, but decreasing, share of gas consumption based on projected increases in crude extraction and refining/ petrochemicals processing activities in PEMEX installations that require large quantities of natural gas. These figures for demand growth imply a significant increase in gas penetration in the energy matrix. Between 1999 and 2009 the share of natural gas in energy consumption is expected to increase from approximately 20–70 percent for thermal power generation, 50–70 percent for industrial use, and, most remarkably, from 7 percent to 25 percent for distribution systems serving residential, commercial, and municipal users. (see figure 1.1)

Figure 1.1: Natural Gas Demand and Domestic Production, 1999-2009



Source: Prospectiva Gas Natural, Secretaría de Energía 2000

1.27 Domestic production, while projected to increase significantly, will not keep pace with demand: imports are projected to grow from 800 mmcfd in 2001 to 2.5 bcfd in 2009. This represents roughly 25 percent of gas consumption, which in financial terms is more than the entirety of PEMEX's total sales revenue in 2000. The deficit in production already incorporates planned PEMEX investment in exploration, field development, and production facilities amounting to more than US$50 billion over the next decade. Slightly less than a quarter of this sum is to be devoted to finding and exploiting nonassociated gas reserves. These investment levels will fall far short of meeting demand, implying massive future dependence on imports

1.28 Closing the projected gap will require extensive investments in upstream and downstream aspects of nonassociated gas development. The former is significantly more costly than exploiting associated gas and is estimated at MXP $210 billion. Because the transport system at present has some excess capacity and distribution has recently been taken over by the private sector, downstream infrastructure costs associated with meeting Mexico's rapidly growing demand for natural gas are excluded from these estimates.

Electricity

1.29 Mexico's pattern of economic growth and the high level of connections resulted in a 5.2 percent per year growth rate in electricity demand over the last decade. Another contributory factor to rapid growth in demand has been the extensive subsidies. The average tariff charged to residential customers in 2000 covered just 43 percent of costs, and the average tariff for agricultural use covered 31 percent of costs. Industry and services paid almost 95 percent of costs. These implicit subsidies amounted to MXP54 billion in 2000, an amount equal to one-quarter of oil tax revenues in that year.

1.30 To meet this demand, Mexico had as of 2000 36,000MW of generation capacity, the preponderance of which is thermal (53 percent) and hydroelectric (28 percent). Future demand has been forecast to grow at about 6 percent per year until 2010. This would require an additional capacity of approximately 27,000MW plus 5,000MW in self supply. The costs of meeting this demand, including additional transmission and distribution capacity, would amount to MXP600 billion during 2001–10. Of this total, MXP some MXP242 billion would be needed for generation, MXP151 billion for transmission, and MXP126 billion for distribution. If the present subsidy and tariff regime remains unchanged, the total subsidies would amount to a staggering MXP600 billion over the same period.

Challenges Facing the Sector

1.31 Very substantial investments will be required for the energy sector to maximize its potential contribution to the economy and to efficiently meet the demand for energy supplies. As indicated above, funding on the order of MXP $1.4 trillion over the next decade will be needed to meet the majority of projected growth in demand and to make a start in addressing the backlog of deferred investment. If electricity subsidy policies remain unchanged, the total will exceed MXP $2.0 trillion. These sums represent a full 3–4 percent of GDP per year. Moreover, with projected average GDP growth of 4.5 percent per year and holding the current account deficit at 3.5 percent of GDP, these investment requirements will constitute 10–15 percent of the consolidated federal expenditures, and 70–85 percent of the federal investment budget, at a projected price for Mexican crude of US$22/bbl. Financing them largely through the budget implies massive cuts in other programs already under way and would sharply restrict the ability to introduce new initiatives to address national priorities.

1.32 While the sector's state enterprises have contracted debt to finance a fraction of their investment requirements, the scope for borrowing on the scale required is likewise restricted by governmentwide limits on public sector borrowing that is required to maintain sound public finances. The policy of maintaining electricity tariffs well below cost, and the high level and poor structure of hydrocarbon taxes, have undermined and will continue to undermine the creditworthiness of the state enterprises, further limiting the ability to take on further debt. The various schemes employed to date for attracting private financing (BLT and IPP) have proven costly and are ultimately unsustainable, because the financing burden with all its attendant risks ultimately redound to the Federation.

1.33 Faced with the specter of rapid, sustained growth in demand, it is crucial that energy be produced and supplied as efficiently as possible, something not realized under the prevailing organization of the sector. PEMEX, CFE, and LFC are neither permitted the autonomy to operate along commercial lines nor are subject to adequate arms-length regulatory oversight and competitive pressures to improve efficiency. As a consequence, accountability for performance is weak. As *organismos descentralizados*, they are subject to a myriad of rigid public administration and civil service rules (for example, hiring, salaries, procurement). Revenues are not retained within the enterprise, their budgets being set through the political process, as are prices of key services (for example, electricity tariffs) and episodic debt writeoffs in the case of CFE and LFC. At the same time, they lack transparent, consistent policies for required returns on capital and dividend payments, and they do not face the discipline of capital markets in valuing performance. They do not report financial performance according to GAAP and their financial statements are not made available for public scrutiny. In addition, they do not face the same regulatory controls and sanctions that apply to commercial entities (for example, environmental compliance, service quality, and contract enforcement).

1.34 Effectively responding to these challenges is crucial for the energy sector to contribute to the maximum extent to the growth and development of the Mexican economy. Doing so will require concerted action on at least three fronts: (1) expanding production and delivery systems of energy resources to support growth and employment; (2) attaining international levels of efficiency in all segments of the industry; and (3) minimizing the demands of the sector on public finances. Mexican policymakers face a series of choices in pursing these sectoral objectives. The following sections discuss the nature of the choices and the shifts in policy they imply. This serves as a basis for subsequent presentation of simulations of the impact of such shifts on economywide performance.

2

Choices to Increase Efficiency

2.1 Utilities owned and run by the state, even when established as separate entities, have generally been found to be seriously inefficient. The cost of production per unit of output is substantially greater than that observed in other countries where a different ownership or management structure is used. Also, those countries which have transferred the utility ownership or management to independent entities have seen substantial decreases in total costs and often increases in output without using extra inputs.

2.2 The direct sources of inefficiency can arise at several points in the supply chain, including:

?? Overpurchasing inputs, especially labor (known as overmanning) relative to the output needed

?? Purchasing inputs at a higher cost per unit than necessary, which can include the lack of shopping around for the most competitive supply, or overinvoicing

?? Using a combination of inputs that does not achieve the maximum output (underproduction)

?? Using out-of-date technologies

?? Employing commercial practices that fail to maximize revenues (such as underbilling, failure to collect bad debts, unreasonably high accounts due, and so forth), which is equivalent to higher costs per unit than necessary

?? Engaging in production practices that result in lost output, such as transmission losses, which result from failure to implement low cost maintenance and timely rehabilitation

2.3 The extent of such inefficiencies in the Mexican power sector and hydrocarbons sectors is not public knowledge. Though internal benchmarking studies have been carried out, in order to compare inputs per unit output with other firms of a similar nature worldwide, these have not been publicly disclosed which, in a situation where there is no transparent budget constraint, provides weak incentives for management to improve performance.

2.4 Evidence from advanced industrialized countries, such as the United Kingdom, has suggested that the impact of full competition and forceful regulation over time was able to encourage very substantial cost savings, and this was from companies (British Gas and The British Electricity Board) generally regarded as fairly well run. Similarly, Argentina's experience in both the power and gas sectors has illustrated the potentiality of such savings.

2.5 The causes of such inefficient practices, when seen on a substantial scale, come from two related features of sector organization:

?? the lack of a hard budget constraint which simulates the effect of capital market discipline

?? the lack of competition or of a regulatory device that simulates the effect of competition by enforcing more efficient practices

2.6 Where a utility does not face a hard budget constraint, it is simpler and less painful for management to avoid hard decisions to eradicate any of the practices outlined above, but rather to permit costs to rise, since the excess cost can be passed onto the government, and there is no disincentive to management for doing so. This source of inefficiency can be dealt with in part by fully corporatizing and commercializing the enterprise so that it has to cover its costs from revenues and cannot expect any financial help from the treasury. Whatever the country, this solution by itself merely prevents the inefficiencies from growing, since it tends to establish the current level of costs as the ones which have to be recovered. In addition, where the output has been subsidized, so that the sale price to some or all groups of users is below long-run costs (those which include a margin for investment that will be required to meet future growth in demand) the subsidy needs to become explicit and met either by a transfer from the treasury to the utility, or by a transfer from the treasury to selected users which allows the utility to charge full costs. In addition, since firms in this position have often been underinvesting because of the retained cash flow shortage and the inability to access financial markets, current costs actually exclude an element that is needed for long-run investment and sector sustainability.

2.7 The utility needs to cover its costs and reduce them over time. In certain markets and situations this has been achieved by privatization of the industry in such a way that there are many rivals for the same market. Where there is potential excess supply this can result in aggressive pricing to capture market share which leads to cost cutting to permit the price reductions. Where, for any reason, the conditions for direct competition are not present, incentives to reduce costs can be simulated through price regulation, with minimum controls on quality (to prevent firms from offsetting price reductions with quality reductions rather than with cost reductions). This type of regulation can work through approaches such as the RPI–X model, where prices are allowed to rise less quickly than costs (as measured through the retail or consumer price index) over a number of years which, combined with the budget constraint, forces the company to find more efficient modes of operation.

2.8 Applying these broad concepts to the energy sector in Mexico raises distinct issues for the power and hydrocarbons sectors. Power is inherently nontradeable and faces little external competition, while output prices are subsidized in a way that forces the utilities to carry the costs. In addition, pricing does not appear to reflect long-run costs which include an element for investing at a rate sufficient to keep power supply in line with GDP growth. Three steps are therefore required to allow a substantially more efficient sector to emerge. First, all subsidies need to become explicit so that the effects on the balance sheet of the power companies are born by the treasury and are of a transparent nature. Over time the government may well wish to redesign whatever subsidy scheme is in place in order to reduce costs to the treasury, and to divert resources away from the better-off households to more urgent needs. Second, the power companies should be established as fully corporatized and commercialized entities, which would make them independent of the treasury and would require them to finance investment in the sector. This might require an increase in average tariff levels early on to allow for the higher investment required. All purchasing and hiring would need to be done in normal business fashion, and procedures would have to be open to scrutiny by public audit. The operation of a fully commercial company might require further management strengthening. Third, some device to incentivize cost reductions over time needs to be put in place. Benchmarking studies that are publicly available can form a valuable starting point, since it would reveal how large a gain might be expected over a number of years, and hence what rate of price decline (relative to current input cost) could be anticipated. This in turn would need to be supported by prices regulation that is designed to vigorously stimulate efficiency gains. The various models of regulation are well known, and Mexico already has substantial experience in the gas subsector.

2.9 The oil and gas sectors present somewhat different challenges. Since oil is a highly tradable commodity its selling price on the export market is fully competitive, as are product imports, and the input costs of product to domestic refineries should be fully competitive also if any implicit subsidies through transfer pricing within the sector are removed. The problem is shown in the interaction between costs and the government fiscal system. At present, although there is a set of formal rules on upstream royalties and taxes (discussed below), the revenue from oil sales are passed to the treasury, which then returns some funds to PEMEX for operations and investment depending on the current demands on the federal budget. Such a procedure can have a huge distortionary effect on the sector, and would undermine efforts to become more cost effective. First, even if the procedures were transparent, which would reveal the PEMEX's costs and revenues to general scrutiny, it does not impose a hard budget constraint, because when financing becomes tight for the company, the treasury can release more money back to it. Second, the lack of funding level predictability makes capital planning and expenditure management difficult and leads to both higher costs and underinvestment: this is the obverse of the situation for the treasury which can use this variable return policy to smooth out its own net tax retention against swings in the oil price and associated tax liabilities of PEMEX. Third, the effective tax on the company is high by international standards, and even higher than the formal tax system which itself if out of line with most mature oil nations: this suggests that, as well as smoothing out its retentions net of returns to PEMEX, the treasury also has a higher average retention than the tax code would justify. This means that the investments in further production that can be justified on de facto returns are very limited, even more than the regressive formal system would suggest.

2.10 The longer-term solutions for the oil and gas upstream sectors that would allow a more efficient company to emerge and a more efficient stream of oil to be produced accordingly have three elements:

(i) Change the handling of tax payments via PEMEX. The company should keep the revenue from oil sales and make payments to the treasury according to the formal tax code. This might produce more variable receipts for the treasury than at present and lower average receipts in the short term. However, two factors could offset this. First, this might be done simultaneously with a general reduction in power subsidies, so that the overall impact on national budget will be very moderate. Second, over time the more favorable tax system will permit an expansion in production and hence increase the tax base.

(ii) Change the status of PEMEX subsidiaries to fully corporatized and commercialized companies. This would build on steps already undertaken to bring in more effective management, and to restructure in a meaningful fashion. Coupled with the first step this should ensure that the company has to cover all its costs and could expect no transfers from the treasury, while paying taxes due under the legal code. This by itself would not provide sufficient incentives to improve performance. Crude sale prices are set in competitive international markets, but local product prices may not be fully efficient. Products Import are at internal prices, but the mark up to selling to retail is a possible source of inefficiency and cross subsidy to other parts of the business. Explicit benchmarking of all parts of the supply chain will be needed, and some form of price regulation at every stage will be required in order to start to gain efficiency in the absence of unfettered competition from imports and from new entrants in the domestic market.

(iii) Alter the tax code to incentivize the new field production while retaining short-term revenue at as near to current levels as possible. This requires a judicious balancing of royalties versus profit taxes and a consideration of the extent to which grandfathering on existing fields should be utilized.

2.11 An important element for encouraging greater efficiency is to make present performance and expectations of future improved performance transparent. This requires general disclosure of the current levels and expected improvements, as well as an explanation of the change in status of the energy companies. It also requires new regulatory instruments and their public disclosure.

3

Choices for Electricity Subsidies

3.1 As discussed above, ensuring that Mexico is able to meet its future energy needs at the lowest cost requires attracting new market participants and distancing SOEs from the government apparatus, granting them commercial and financial autonomy. All market participants need to be permitted (rather than guaranteed) to recover efficient costs and to face the discipline of private capital markets. Cost reflective tariffs provide incentives to improve service and foster rational use of the resource. Integral to the separation of functions is the role of an autonomous regulator in setting or approving end user tariffs that agree with these principles.

3.2 In the electricity sector, these conditions have not been present. The following provides an overview of tariffs and subsidies in Mexico in recent years, their magnitudes and allocation among different user classes, regions, and income groups, and their impact on the state's energy enterprises and federal finances.

Tariffs in Mexico

3.3 **Tariff Levels.** During the past decade, average electricity tariffs in Mexico have been held below cost under the aegis of maintaining macroeconomic and social stability—through administrative control of prices of basic goods and services. At the same time, technological advances, principally in power generation, permitted CFE to reduce wholesale (high tension) costs of power, and successive debt bailouts (discussed below) reduced the previously high levels of debt service which CFE had incurred. These developments are reflected in the downward trend in real end user tariffs for most classes of customers and rather significantly for industrial users. The rise in tariffs for all classes in 2000 principally reflects the partial pass through of the increase in world fuel prices that year.

3.4 **Tariff Structure.** The electricity tariff structure is complex. Rates vary substantially according to a number of geographic, climatic, and end use criteria which depart significantly from supply costs.

Table 3.1: Mexico Electricity Tariff Schedule, 2000

Year	*Residential*	*Small Commercial Low Voltage*	*Services*	*Agriculture*	*Ind. & Comm. Medium Voltage*	*Industrial High Voltage*
1990	0.610	1.398	1.037	0.170	0.788	0.550
1991	0.670	1.481	1.084	0.299	0.797	0.573
1992	0.729	1.560	1.142	0.376	0.782	0.536
1993	0.696	1.528	1.129	0.433	0.738	0.475
1994	0.690	1.522	1.101	0.415	0.683	0.398
1995	0.604	1.444	0.998	0.324	0.580	0.369
1996	0.569	1.357	0.980	0.300	0.591	0.400
1997	0.555	1.342	0.963	0.290	0.632	0.435
1998	0.558	1.316	1.039	0.288	0.591	0.396
1999	0.540	1.295	1.019	0.281	0.574	0.388
2000	0.559	1.260	1.047	0.287	0.612	0.434

3.5 For medium- and high-voltage users (industrial and medium/large commercial enterprise), time of day tariffs based on marginal cost have become the norm above 1MW demand. These users accounted for 65 percent of electricity sales in 2000. For the remainder of user classes, low voltage tariffs continue to be set based on a complex set of criteria derived from embedded cost methodologies which do not fully reflect the costs their consumption imposes on the system and "special" tariff classes, most notably residential, agricultural, and water pumping users, where tariffs are set largely on political criteria. Water pumping users comprised about 30 percent sales in 2000.

3.6 **Tariff Adjustment.** For all tariffs, an interagency group comprised of CFE, LCF, SHCP, SENER, CRE, and CNA meet regularly and once a year prepare a tariff proposal for the subsequent year (in parallel with the federal budget cycle). Ultimate authority to approve tariffs rests with the political authorities rather than with the energy sector regulator, whose voice is one among many. In practice, tariffs for medium- and high- tension users have recently tended to be adjusted automatically to reflect changes in fuel costs and the producer price index—in line with the interagency group's recommendations. Those for smaller users, (for example, residential, agriculture, municipal) are frequently revised downward in an effort to shield these groups from facing cost increases.

Table 3.2: Mexico: Electricity Tariff Schedule

		Application				*Monthly Adjustment Factor (MAF)*
Tariff	*Charges*	*Regional*	*Seasonal*	*Hourly*	*Interruptible* [4]	
1[1]	Minimum and					Administered prices. MAF = 1.00682 during 2001.
1A	Three blocks of	X	X			
1B	Energy charges[2]	X	X			
1C	- Basic	X	X			
1D	- Intermediate	X	X			
1E	- Excess	X	X			
2	Fixed and three blocks of energy charges.					MAF is a function of the producer price index.
3	Demand and Energy charges					
7	Energy charges					
5	Energy charges	X	X			Administered prices. MAF = 1.00526 during 2001.
5A	Energy charges	X	X			
6	Fixed and energy charges					
9	Energy charges	X				Administered prices. MAF = 1.00526 during 2001.
9M	Fixed and energy	X				
O-M	Demand and energy charges	X	X			MAF is a function of the producer price index and the fuel mix.
H-M	Demand and energy charges	X	X	Peak	X	
HM-R	Fixed,	X	X	Intermediate		
HM-RF	Demand and	X	X	and		
HM-RM	Energy charges	X	X	Base		
H-S	Demand	X	X	- Peak	X	
HS-L	and	X	X	- Semi-peak[3]	X	
H-T	Energy charges	X	X	- Intermediate	X	
HT-L		X	X	- Base	X	
HS-R		X	X			
HS-RF	Fixed,	X	X	- Peak		
HS-RM	Demand	X	X	- Semi-peak[3]		
HT-R	and	X	X	- Intermediate		
HT-RF	Energy charges	X	X	- Base		
HT-RM		X	X			

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[1] Tariffs 1A to 1E apply during the summer months (6 months). Localities are allocated to tariffs according to local temperature levels. Tariff 1 applies to temperate localities during the summer and at the national level during the winter months.

[2] Four blocks of energy charges are applied to tariff 1E.

[3] The semi-peak hourly period is applied only in the Baja California region.

[4] Tariffs I-15 and I-30 consist of credit for Interruptible Demand.

NOTES:

Voltage level: Low: Less than or equal to 1 kV.
Medium: Greater than 1 kV and less than 35 kV.
High: Form 66 kV to 400 kV.

Source: SENER, "Sector Eléctrico, Prospectiva 2000-2009", México, 2000, p. 50.

Table 3.3: Historical increases in tariffs and inflation

(% change)

	1995	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*Cumulative 1995-2001*
Residential	30.00	21.40	15.40	15.40	13.00	10.00	8.50	183.40
Agriculture	17.00	21.40	15.40	15.40	13.00	10.00	6.50	150.40
Services	37.00	21.40	15.40	25.40	13.00	10.00	6.50	218.60
Inflation*	52.00	27.70	15.70	18.60	12.30	9.00	6.50	247.20

*Consumer Price Index

3.7 These polices and practices have led to gradual decapitalization of CFE and LFC, depriving them of revenues needed to finance modernization, replacement, and expansion, and have stimulated demand, adding significantly to future investment requirements. Moreover, the current procedures for setting tariffs provide little certainty as to future revenues which may be realized from current investments, being driven partially by daily political necessities. The lack of predictability, and transparency in the case of “special” tariff classes, in tariff setting is a major concern to current/potential investors in the sector. The electricity business, like other subsectors which comprise the energy industry, is characterized by large sunk investments with long payback periods. Attracting finance for such investments therefore requires a high degree of predictability as to future revenues.

Subsidies

3.8 **Subsidy Levels.** The magnitude of electricity subsidies has grown enormously over the past decade and they now constitute a significant portion of sectoral revenues, the sectoral investment program, and the overall federal budget deficit

3.9 As shown below, electricity subsidies grew from about MXN $5 billion in 1992 to MXN $54 billion in 2000. In real terms, this represented roughly a 300 percent increase in subsidies over the same period. In 2000, this equated to 46 percent total electricity sales, 280 percent of the total sectoral investment program, and 83 percent of the federal budget deficit.

3.10 The allocation of subsidies is disproportionately concentrated in LFC: LFC accounted for 16 percent of electricity sales in 1999/2000 yet accounted for 21 percent of electricity subsidies. This reflects several factors; CFE bulk power sales to LFC at less than cost-covering prices and budgetary transfers from the treasury to LFC to cover operating deficits. LFC's distribution costs and losses are double or triple that of CFE and the rate of uncollected bills is 3–7 times CFE's, depending on the data source.

Table 3.4: Electricity Subsidies

	Total	*CFE*	*LCF*	*Total*
	(nominal)			*(2000 NPs)*
1992	4.8	N/A		18.2
1993	5.6			19.4
1994	7.6			24.6
1995	18.7			44.9
1996	26.4			47.1
1997	30.9	20.6	10.3	45.7
1998	38.1	27	11.1	48.6
1999	46.4	32.4	14	50.8
2000	54	41	13	54.0

3.11 **Subsidy Structure.** The term subsidies, as defined by the Mexican authorities, bears mention: "Economic costs" of service is defined as marginal cost plus the accounting allocation of the "revenue gap" Revenue gap is defined as the revenue level that would permit CFE to earn the minimum required return on assets. This reflects the fact that in financial terms, average costs are well above marginal costs for both LFC and CFE, despite significant debt write offs and labor force downsizing in the case of CFE in past years.

3.12 Based on these definitions, though most user classes still enjoy some degree of subsidy, they are clearly most pronounced for residential and agricultural customers. As shown in the table below, in recent years, CFE's residential customers on average were billed at 45 percent of cost and LFC's at 28 percent. Agricultural customers were subsidized even more, being charged less than 30 percent of cost. These equate to roughly 70 percent and 20 percent respectively of total subsidies provided in the year 2000. While the subsidy rate held relatively constant during 1997–2000, growth in the number of connections and per customer consumption has continued apace, driving the acceleration of total subsidies shown in the prior table.

3.13 **Subsidy Incidence.** The subsidy incidence within these two classes of users is quite regressive. Energy consumption and income are strongly correlated, and the absolute magnitude of the subsidy per household rises with consumption. This is because the lower tariff blocks are so large as to cover most of the energy consumption of middle- and high income families (100-200 kWh/month). As a consequence, medium- and high-income classes capture the majority of residential subsidies.

Table 3.5: Allocation of Electricity Subsidies by User Class

User Class	*1999*		*2000*	
	price/cost	*% total subsidy*	*price/cost*	*% total subsidy*
CFE				
Residential	0.41	67	0.45	69
Agriculture	0.29	20	0.31	20
Services	0.91	2	0.94	2
Commercial	1	0	1.05	0
Medium Tension *	0.91	5	0.95	4
High Tension**	0.92	6	0.95	5
LFC				
Residential	0.26	63	0.28	68
Agriculture	0.17	5	0.18	4
Services	0.85	5	0.9	3
Commercial	0.67	15	0.68	17
Medium Tension *	0.67	7	0.74	5
High Tension**	0.68	5	0.78	3

Source: SENER, CFE, World Bank calculations

* Large commercial, small & medium industrial

**Large industrial

3.14 The regressive incidence of household electricity subsidies is accentuated by special tariffs afforded to customers in regions with warmer summer temperatures, ostensibly to offset air cooling costs. Households in those regions pay lower charges per block and the first two blocks of consumption are significantly larger than the blocks for other residential consumers. The regions where such subsidies are applicable tend to be those where household incomes are significantly higher than the national average (largely the northern states).

3.15 **Impact on Federal Finances.** The growth in subsidies in the 1990s have seriously impaired electricity sector finances, which in turn limit the sector's capacity to renew and expand its very large asset base to meet Mexico's growing demand for electricity. CFE and LFC income statements give a partial picture of the impact that growing subsidies have had on the sector. While CFE shows some positive net earnings over the period, it lacks authority to invest its earning as it is subject to budgetary restrictions imposed by governmentwide public spending ceilings. The sharp decline in earnings in 2000 reflects the government's decision not to pass through increased fuel costs to CFE's customers. LFC, in contrast, incurred large deficits every year, which are financed directly by the treasury.

Table 3.6: CFE Income Statement 1995-2000

Concept	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Revenues	29,734	42,956	57,228	72,983	89,298	96,953
Operating Expenditures	27,779	40,197	51,308	65,058	80,877	98,069
Income before Interest Charges	1,956	2,759	5,920	7,925	8,521	-1,116
Net Financing Costs	-4,307	-6,482	2,339	4,176	-4,899	-1,122
Income before Subsidies & Taxes	6,262	9,241	3,581	3,749	13,420	-6
Subsidies	11,124	18,171	20,512	23,709	34,665	42,057
Aprovechamiento	10,675	19,392	23,746	28,160	36,857	36,991
Taxes	93	111	123	179	332	445
Net Income	6,618	7,908	223	-881	9,973	5,730

Source: SENER, CFE, and LFC statements

**Note:* Individual items do not sum to totals as some minor items omitted in the table.

Table 3.7: LFC Income Statement 1995-2000*

Concept	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Revenues	8,348	12,002	15,832	17,874	19,254	20,456
Operating Expenditures	15,359	21,115	26,123	30,974	34,466	37,827
Income before Interest Charges	-7,012	-9,153	-10,292	-13,100	-15,213	-19,529
Net Financing + "other" Costs	-268	-194	1,377	-260	-2,685	-643
Income before Subsidies	-6,744	-8,959	-11,669	-12,840	-12,528	-18,889
Subsidies	2,299	3,942	6,148	8,133	10,114	11,328
Net Income	-4,445	-5,018	-5,521	-4,707	-2,414	-7,560

Source: SENER, CFE and LFC statements
**Note:* individual items do not sum to totals as some minor items omitted in the table

3.16 As SOEs are not subject to commercial accounting procedures, dividend payout policies, nor income tax, the treasury levies a kind of virtual "tax" or compulsory "dividend"—*aprovechamiento*—on CFE, defined as a statutory return on fixed assets, which has been set at 9 percent since 1989. The financial position of LFC is already dire (indeed it is functionally bankrupt). While CFE appears to have generated some positive net earnings, its financial position is expected to worsen considerably in the coming years. CFE's off-balance sheet liabilities have grown dramatically under the BLT and Pideregas financing schemes which picked up in the 1990s. Many of those projects are coming into operation which, given their very short amortization periods, will come to represent a very significant expense item over the coming years. This prospect has not escaped potential private financiers, whose appetite for investing in the sector has diminished markedly in the past 2–3 years. Indeed, a number of recent IPP solicitations have attracted only a single bidder and others have been deferred out of concern that no bidders would materialize. This contrasts with the early- to mid-1990s when 10–20 bidders was the norm for BLT and IPP projects. GOM projections of future investment requirements (*prospectiva del sector eléctrico 2001-2010*) assume that more than half of the MXP600 billion required over the next decade will come from private sources. Attracting such magnitudes of private financing is simply not achievable under current pricing and tariff policies.

3.17 In the absence of far reaching changes in the industry structure to bring costs down and in tariff policies which permit cost recovery, the sector's capacity to pay its way will continue to deteriorate, placing a growing burden on the public purse. This in turn may precipitate either major reductions in federal spending on priority social programs or deep cuts in sectoral investment in the face of growing electricity demand with the consequent deterioration in service quality.

Synthesis of Current Subsidy Policies

3.18 The impact of current subsidy policies on demand is clear: strong disincentives to conserve energy during periods of peak demand with the attendant increase in costs of operation and expansion of system capacity to serve, load, and maintain service reliability and quality

3.19 The incidence of benefits of holding tariffs below costs is clear: Subsidies are generalized across virtually all residential and agricultural consumers who receive more than three-quarters of the subsidy. Higher-income households and large commercial agricultural enterprises reap the majority of the implicit subsidy despite its representing a small share of their disposable income, a source of regressivity which is further exaggerated by special regional tariffs

3.20 The lack of transparency and predictability is also clear. Special tariffs are set by the political authorities under parameters which do not accord with the government's own technical tariff guidelines. They discriminate in favor of particular groups of consumers without regard to the costs they impose on the system, and being set annually without adhering to predetermined adjustment factors, engenders great uncertainty with respect to future revenues.

Basic Choices in Targeting Subsidies

3.21 A number of countries in the developing world have adopted electricity tariffs and subsidy schemes which provide strong incentives for productive and allocative efficiency while ensuring access of poorer segments of society to this service. While there is no unique "recipe" for achieving these objectives, several principles stand out as important: First, holding tariffs below cost for broad classes of consumers, while perhaps politically expedient in the immediate term, is not an effective instrument of macroeconomic management/inflation control. Second, permitting operators to recover efficient costs is essential for ensuring service expansion in line with demand and for attracting the resources necessary to finance such expansion. Third, tariffs should signal to users the economic costs their consumption imposes and to permit them to dimension their consumption accordingly. Fourth, "rules" governing tariff adjustments should be clear and the process for instituting such adjustment should be transparent. Lastly, subsidies to the maximum extent practicable, should be funded through the government budget rather than "taxing" operators or other consumer classes.

3.22 Tariffs have been structured in a myriad of ways to conform to these principles while addressing concerns of affordability to the poor, whether it be through two part tariffs, block tariffs, lifeline tariffs, differential tariffs which distinguish among service levels (for example, interruptible service), and so forth. The principle choices in deciding how to make electricity services more accessible to the poorest revolve around whether to subsidize the service itself or to augment the purchasing power of the poor households through income transfers. The Mexican government has already significantly altered its basic strategy for targeting assistance to the poor, shifting from subsidizing supply of services to income transfers. The PROGRESA program is emblematic of this fundamental shift in social policy.

3.23 Where current social protection/income transfer systems are deemed to be inadequately developed for this purpose, service-specific subsidies may be justified— but this should be assessed rather than assumed. The first priority should be afforded to helping the poor gain access to electricity service rather than for ongoing consumption. In Mexico, less than 5 percent of the population is without electricity. Targeting subsidies to this segment of the populace would result in a dramatic reduction in the overall magnitude of subsidies from present levels. The service level provided to the unserved should agree with this populations' preferences and capacity to pay. In Mexico, most of the unserved reside in remote rural areas where conventional grid extensions that provide 24 hour/day service is prohibitively expensive. Unserved households would enjoy a substantial increase in welfare over their current situation from much less costly off-grid solutions: renewable energy technologies (wind, solar, microhydro), hybrid minigrids, diesel, and so forth. Such an approach would further reduce total subsidies to a minute percentage of the MXP54 billion incurred in 2000.

3.24 In those instances where even "minimum consumption" levels of service are deemed unaffordable to the poorest, lifeline tariffs which are targeted to such households could be considered. Such targeting involves a combination of restricting the quantity of electricity eligible for subsidization to minimum levels (for example, less than 50 kWh/months.) and providing such subsidies only to those households whose consumption does not exceed that amount. Similar targeting principles could be applied, with minor modification to agricultural users along the access-minimum consumption continuum. Any combination of these approaches would reduce the total volume of subsidies by 80–95 percent over current levels. Finally, consumption subsidies should be temporary. Here, industrial structure and competition, through their impact on technological change and incentives for management innovation, play a key role in reducing costs. And arms-length regulation must ensure that the benefits of such cost reductions are shared with consumers in the form of reduced tariffs, with the concomitant decline in per unit subsidies.

4

Choices for Efficiently Expanding Oil and Gas Output

Global Supply/Demand Forecasts for Oil

4.1 During the last 20 years world oil demand increased by approximately 1.1 percent per year (see table 4.1). During this period, Mexico, the world's fifth largest oil producer, after Saudi Arabia, the Russian Federation, the United States, and Iran, increased its oil production by 1.4 percent per year, more than retaining its share of total world output.

4.2 The change in world output was shaped by the actions of three distinct groups of oil producing countries: Some large and/or mature producers (United States and the Russian Federation) have seen output fall quite dramatically, while large OPEC countries (especially Saudi Arabia) have controlled expansion to achieve a target price and revenue position. A third group of countries have seen extensive exploration and development with large percentage increases in output. Mexico, which is believed to have very large, as yet unproven reserves of oil, has not pursued an aggressive exploration policy but it nevertheless has been able to steadily increase oil output until the present. This moderate position has been partly because of difficulties in attracting finance for exploration and development to the SOE (PEMEX) since it is not run as an independent, profit-making commercially based enterprise, but rather as an *organismo decentralizado* of the federation whose finances are adjusted so that more cash flows to the federal budget whenever the government needs more resources.

4.3 Turning to the future, world oil demand and supply and the share of various producers are expected to shift. Over the next 15 years, the annual growth rate for the demand and supply of oil will balance out at just above 2 percent, with a real price of oil of around US$20 to US$24 per barrel. This forecast sees oil supplies keeping pace with the total energy demand while the share supplied by gas will increase and the share of coal and other large scale sources will decrease. Although renewable energy will receive substantial attention, its share, starting from a low base, will not increase quickly enough to be able to reduce the growth in the demand for oil over this period.

Table 4.1: World Oil Production 1981–2001 (000 bbd)

	1981	*1990*	*2001*
World	59405	65415	74493
OPEC	23390	24555	30181
Non-OPEC	36015	40860	44312
Saudi Arabia	9985	7105	8768
Russian Federation	12330	10405	7056
United States	10180	8915	7717
Iran	1325	3255	3688
Mexico	2585	2975	3560
Norway	505	1740	3414
China	2035	2775	3308
Venezuela	2180	2245	3410

Source: BPAmoco *Statistical Review of World Energy*: various issues.

4.4 This relatively rapid growth in total oil demand has the potential to alter the relative positions of producing countries as shown in table 4.2, which is based on the U.S. Energy Information Agency's projections.[3]

Table 4.2: Projections of Future Oil Supplies (mbd)

	OPEC	*All Non-OPEC*	*Total*
2000	30.9	46.0	76.9
2005	35.3	49.6	84.9
2010	42.1	53.6	95.7
2015	49.4	57.8	107.2

Source: International Energy Outlook: Energy Information Administration 2002

4.5 The increment in world oil supply over the 15-year period will be approximately 30 mbd. Producers who are already mature players will not make a contribution to growth in global supply, and indeed are likely to see their output fall. Although there are many new producers whose output will rise rapidly from a low base, the total contribution of non-OPEC suppliers is projected to increase by only 12 mbd, equivalent to an annual rate of 1.5 percent. OPEC supplies are projected to rise by 18 mbd, at a growth rate of 3.1 percent, so that their total share of the world market will steadily increase. US EIA estimates indicate that Mexican production would rise from

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[3] US EIA data is based on slightly different definitions than that of BPAmoco used in table 4.1.

approximately 3.6 to only 4.1 mbd, which is a growth rate of 0.9 percent. This scenario shows the vivid contrast between OPEC countries, which are expected to increase output very rapidly, and Mexico, which has at times collaborated with OPEC in managing production quotas, and would see slower growth in oil output than other non-OPEC countries. Such a scenario, where Mexico's share of global production versus both groups of countries would steadily decline, might not be politically acceptable over the long run in a country where demands to increase government spending continue to grow.

4.6 There is consensus that Mexico, despite its large reserves, is not likely under present policies to match the rapid, sustained growth in output of OPEC countries. Under this scenario, if there were to be any substantial increase for Mexico in oil revenues during the next 15 years, it would come largely from increased prices, which is unlikely to happen if OPEC expands output at the rate forecast. This is a pessimistic scenario for the prospects of the Mexican oil sector and hence for the government. At a time when Mexico could increase its production by more than one-third while holding its total market share constant, the potential for revenue gain is clearly large, and there could be little fear that such a policy by itself would so weaken the world oil market that the price of crude would fall substantially. Of the required increase of 30 mbd to the total of around 107 mbd, the difference made for example by an extra 1.0 mbd of Mexican crude to the market clearing price would be negligible. Since under this forecast, virtually all oil producers are supplying as much as they could at the price expected to clear the market, an increase in Mexican production is not likely to elicit retaliation from other producers.

4.7 Mexico faces a number of questions with respect to future oil output:

?? Is it feasible to increase output at the price range expected?

?? How could such an increase be financed, and what changes in sector organization and conduct would be necessary so that such finance would be forthcoming?

?? If the increase is technically feasible and financially possible, what would be its effects on the macroeconomy?

Potential Output of Oil in Mexico

4.8 Without further capital expenditure, oil production in Mexico might be able to rise slightly above its current level of 3.6 mbd but would then commence a steady decline from a level of around 4mbd in 2003. A plausible rate of decline of 7 percent per year over a 12-year period until 2015 would take production to about half the present output. Operating expenses would be reduced proportionately, but so would total tax revenue collected.

4.9 In 1999, Mexico revised its proven reserves downward considerably, but the ratio of reserves to production is still much higher than in other countries where aggressive exploration and production programs have been followed, as shown in table 4.2. Developments in new technology and further exploration have permitted many hydrocarbon-producing countries to keep their reserves to production ratio nearly constant over a substantial period of time. Hence Mexico, by its very cautious production profile, has deferred receiving many of the benefits of natural resource exploitation until a future date. Faced with the heavy discounting involved, plus the urgent need for government spending on infrastructure and social services, such a policy is unlikely to have been optimal. Current oil reserves, estimated at 26.9 billion barrels, illustrates Mexico's anomalous position. These reserves equal 12 percent of world reserves outside of OPEC, while production of crude oil, at 3.6 million bpd, is equivalent to 8 percent of world production outside of OPEC. Such a comparison makes it clear that an increase of up to 50 percent in output would not have been out of line with trends outside of OPEC (which includes both mature and new oil producers).

The Tax System and Oil Production in Mexico

4.10 A major constraint to realizing large increases in oil production is the ability to finance the required capital expenditures. Mexico produces a variety of crude oils of differing quality. Heavy crudes, less favored by the market, dominate, and the Mexican basket typically sells at a discount of around 20 percent relative to the nearby West Texas Intermediate (WTI) marker. These quality disadvantages are offset by the very attractive cost conditions which apply to a high percentage of Mexico's production and reserve base. It is estimated that close to 80 percent of flowing oil, and a possibly higher percentage of reserves, can be produced at a cost of under US$5/barrel (US$2.5 for operating costs and another US$2.5 for capital costs).

4.11 At a Mexican basket price of around US$20/barrel, these conditions translate into very favorable pretax economics. Pretax cash margins (that is, before depreciation), on flowing oil range from an estimated low of US$14.00/barrel in the high cost Norte region, to US$17.00/barrel in the prolific low cost Marin area. Margins for the Sur region range somewhere in between. Pretax rates of return calculated for investments in new oil projects vary from a low of 26 percent in the Norte region, to highs in excess of 70 percent in the Marin area. If 15 percent is considered to be the threshold required to justify investment, that is, to recover costs including the capital costs, then these projects are all worthy of development on a pretax basis. Under normal circumstances, however, investors base their decisions on post- rather than pretax returns. If it is to achieve a socially desirable allocation of resources, the tax system, to the maximum extent possible, should ensure that all projects with acceptable pretax returns show acceptable, albeit reduced, post-tax returns. The increased activity that such a system would encourage would be not only desirable in its own right, but also attractive from a fiscal point of view in that it would expand the tax base and with it the trade balance and aggregate output.

4.12 In order to encourage oil production, whether by a state enterprise acting within a hard budget constraint and according to commercial principles, or by a private sector company, the tax regime must provide economic incentives for efficient development. To date, Mexico's choice of tax instruments has had a negative effect on investors, which directly opposes the requirements for such development.

4.13 The preferred tax instrument to deliver such a result would be a profits tax. Under profits-based taxation, a project which shows a positive pretax return will show a positive, albeit smaller, post-tax return, thus satisfying the important objective of encouraging a broad range of activity through encouraging the development of all fields whose economic benefits are greater than costs, and no fields whose costs are greater than benefits. In contrast, Mexico relies almost entirely on revenue taxes rather than profits taxes in its upstream oil sector. The profits-based character of the DEP (*Derecho a la Extracción Petrólera*) and ISR (*Impuesto a los Rendimientos Petróleros*) notwithstanding, it is the DSH (*Derecho sobre Hidrocarburos*) and the ARE (*Aprovechamiento sobre Rendimientos Excedentes*) both taxes based squarely on revenue, that dominate the oil tax regime. Because of the insensitivity of these taxes to profit, a significant share of production or projects with positive pretax returns will be unprofitable on a post-tax basis. The higher the revenue tax, and/or the more modest the pretax return, the more likely this outcome becomes, with the result that flowing production is not extended to socially desirable limits or is prematurely abandoned and investment in desirable new production is not pursued.

4.14 This is precisely what economic modeling has shown in the Mexico case. As costs increase on flowing oil, either by the extension of the production margin or as a result of reserve depletion, the tax system begins to take more than 100 percent of the pretax profit, which would limit the extent of viable post-tax production, or would cause production to be abandoned before the pretax margin approaches zero. Similarly, when it comes to investment in new projects, only the best marine projects will produce post-tax returns above a notional minimum of 15 percent. Even these results are probably a generous portrayal of the impact of the Mexican tax system. They assume the DSH applies at its nominal 60.8 percent rate to revenues solely from upstream activities (that is where rents are present). Actually, the effective rate is significantly higher because the 60.8 percent obligation applies to all PEMEX revenues, both upstream and downstream. The downstream sector, whether in Mexico or elsewhere, is incapable of supporting a revenue tax at this level or any level near to it. At the very best, it might be able to cover a 10 percent tax. To meet its overall tax obligation, PEMEX must pay an effective tax on its upstream operations well above 60.8 percent of revenues, and a correspondingly higher percentage of pretax profits. The revenue tax bite in Mexico's oil taxation system is much higher than the revenue tax component of any other of the major oil producing countries in the world. This indicates that the formal tax regime would not permit PEMEX, acting as a stand-alone state corporation, to finance a major expansion in production.

4.15 Under the present arrangements of fiscal integration of PEMEX and the Ministry of Finance, the actual revenue collected by the government is not even governed by this unsatisfactory scheme. All revenues above explicit costs are paid to the Ministry of Finance, which then returns to PEMEX for investment purposes a sum which the

Ministry feels is appropriate. Since the government has varying needs for tax revenue, depending on the state of the domestic and international economy, the amount going back to PEMEX is unpredictable, tends to be procyclical, and bears little relation to its needs for investment and the returns that could be earned on such investment even under the current tax regime.

4.16 Were PEMEX to be fully commercialized and corporatized, while still remaining state owned, the present tax regime would then become fully effective and would have the impact described above of severely limiting the range of otherwise commercially viable fields that could be developed. Thus, for Mexico to increase its oil production substantially and to benefit from the tax revenue that this would bring, two major reforms would be needed. The company would need to be put at arms length from the government, with predictable revenue flows (for a given price of oil) which would allow it to use financial markets effectively. At the same time, the tax regime would need to be modernized to permit economic exploitation of more fields. Although this might result in less revenue per field, the increase in the exploitable volume should be capable of supporting a substantially higher tax take than under the present arrangements.

Oil Production and the Macroeconomy

4.17 The preceding discussion indicates that a range of possibilities exist for the trajectory of oil output in Mexico over the next 15 years. These range from a “do nothing” policy, which would result in a very substantial decline output by 2015 from the failure to invest to maintain current production levels, to a more or less steady output over the period under a modest investment program which would continue the policy of maintaining a very high reserves-to-production ratio, to a more aggressive expansion program which could see output rise by 40–50 percent over current levels.

4.18 Achieving these goals implies dramatically different levels of investment, and would produce large differences in oil export earnings and in tax receipts for the Government of Mexico. Under the assumption that PEMEX remains the sole producer of oil and that its fiscal operation is continued as present, that is, the tax revenue is paid to the government and the government then returns funds sufficient to PEMEX to finance these alternative expansion paths, it is possible to simulate the effects on the macroeconomy. Even though the oil sector is not as dominant in Mexico as it is in many newly emerging oil states, it remains an important source of exports and a major contributor of tax revenues, so that large variations in production can be expected to have large impacts throughout the economy. Only a fully articulated macroeconomic model can track these impacts and feedbacks. Hence various oil production scenarios are analyzed with a CGE model designed for this purpose. The model is described in detail in the annex.

5

Policy Simulation Outline

5.1 Policies to address the three sets of issues detailed previously would have important effects on the energy sector itself as well as on the Mexican economy at large. To illustrate the potential economywide impacts of these policies, and to estimate their magnitude, a general equilibrium model is required, so that key aspects of a policy shift can be accounted for. Where large changes are involved, partial equilibrium analysis, can give one-sided accounts of the impact and importance of such policy changes. For example, the removal of subsidies, if analyzed through a partial analysis, would point to the impacts of higher prices on consumers and the resulting reduction of demand. But by ignoring the increase of revenue to the government, and its impacts on the budget and social spending, an important feedback would be ignored.

5.2 The detailed Computable General Equilibrium (CGE) model used for this simulation exercise is described in the annex. The data and information for 2000 are used as the starting point to calibrate the "benchmark" case—the latest year for which a complete balanced set of data was available. The input-output table, which links the productive sectors of the economy was based on a 1996 estimate. This may induce some inaccuracies, but comparing different policies using the same input-output table is not likely to introduce major errors. The data used in the model are consistent with each other and over time, but are not necessarily exactly the same as data used in earlier chapters to describe the current state of the economy. This difference will not effect the conclusions of the modeling exercise, since it is designed to answer questions about the impact of changes of policy variables on the main macro sectors. The qualitative and quantitative evaluation of these changes will not be affected by scaling of the general set of variables because of differences in data definitions.

5.3 The model is solved year by year for the period 2000–2015. This permits tracing out the time path of response of variables. As the model is formulated to focus on the long-run equilibrium growth path, it is not meaningful to interpret short-run variations, since these are not modeled through lagged responses, and so forth. Although the policy variables have specified time paths (for example, the gradual improvement of technical efficiency) this is done to ensure that the gains over the period are realistic. Stock variables, such as the capital stock, do reflect the time path of these inputs, so that these are important when considering what might be achieved by 2015. The results are not shown for the year by year simulations, because the large amount of detail would not add significantly to the interpretation of the impact of the various policy options.

5.4 A key assumption is that the growth rate of the labor force will be at 5.2 percent in labor efficiency units (numbers plus productivity). This in turn implies that balanced growth with no constraints would occur at 5.2 percent. Recent forecasts for the Mexican economy suggest a slightly lower growth rate of approximately 4.5 percent. Where there are no constraints incorporated in the model, the difference in the steady growth rate would not have significant implications for assessing the effects of changing policies on key variables. However, as discussed below, when constraints are introduced, the outcomes may be more sensitive to the growth rate assumption.

The Scenarios

5.5 Ten scenarios were run with the CGE model. By comparing between scenarios, particularly for the terminal date of 2015, for the range of variables calculated by the model, the impacts of policy changes made singly or in combination are obtained. The policies are :

?? Removing electricity subsidies

?? Improving efficiency of the energy sectors towards international good practice

?? Varying the oil output path, for which four trajectories are investigated

5.6 In addition, the model also investigates the impacts of these policies in the presence of downward rigidity in real wages in Mexico, thus relaxing the assumption of no involuntary unemployment, a basic premise of general equilibrium conditions.

5.7 **Scenario 1 (baseline case),** is used to establish the initial calibration of the model's parameters to ensure that all markets are balanced in the year 2000 at the actual levels of the data from the national accounts. For subsequent years, until 2015, all endogenous variables grow at the same rate, which is the rate of growth of the effective labor supply. This growth rate is assumed to be 5.2 percent per year, consisting of a predicted 1.3 percent growth in the labor force plus a 3.9 percent growth in labor productivity. This growth rate is used as a plausible representation of the average path of the Mexican economy over the next 15 years. It is not a forecast, but rather a reference case against which other cases could be calibrated. Since the model is calibrated on actual 2000 data, it takes the situation of that year as given. In particular, it assumes that subsidies to the power sector continue throughout the period, and that the technical efficiency of the power and oil and gas sectors also continue at the 2000 level. However, it has to assume that oil and gas output grow at the balanced growth rate (which would require massive investment in the sector) so that all parts of the economy grow at the same rate (for example, imports, exports, consumption, government expenditures, and production). This is equivalent to assuming that oil output would rise to 7.3 mbd, and that the requisite investment would be forthcoming to achieve this. Such a figure is beyond the bounds of reality, both because of the impact of depletion and the impact on the world oil market.

5.8 **Scenario 2 is the business as usual case**, against which alternative policies are evaluated. It assumes that subsidies continue at current levels, that the power and oil and gas sectors continue to perform at current efficiency levels, and that oil and gas output remain steady after the impacts of initial investment decisions are felt. Investment in the oil and gas sectors is then determined by this "planned output" and the model then solves for all other variables. These assumptions combine to produce a picture of how the energy sector and economy would perform if none of the three policy areas were subject to substantial change. While the actual magnitudes cannot be taken as forecasts of the future state of the economy, the sensitivity to variations in the assumptions of the values obtained does give an indication of the importance of the various policy changes discussed. The oil production path is shown in table 5.1, and climbs from 3.4 mbd in 2000 to 4 mbd in 2003 and stays constant thereafter, which requires continual investment to prevent a decline from depletion.

Table 5.1: Projected Oil Output Under Various Scenarios

(million barrels per day)

	"Steady" Scenarios 2,4,5,8,9	*"Decline" Scenario 3*	*"Moderate Increase" Scenario 6*	*"High Increase" Scenarios 7, 10*
2000	3.4	3.4	3.4	3.4
2005	4.0	2.6	4.8	4.8
2010	4.0	2.0	5.0	6.0
2015	4.0	1.5	5.0	6.0

5.9 **Scenario 3 illustrates an "oil decline" path**, in which the only policy change from scenarios 1 and 2 the base case—business as usual scenario is that no further investment in oil and gas takes place, so that there is a steady decline in output over the period. This serves as the mirror image of an aggressive investment in oil scenario and serves to highlight the importance of continuing to invest in the sector. Oil production declines steadily from 3.4 mbd to 1.6 mbd by 2015. The impact of a no investment versus a modest investment in oil program can then be seen by comparing scenarios 2 and 3.

5.10 **Scenario 4 focuses on the removal of subsidies.** This is based on the same assumptions as for scenario 2, with steady oil production and historic energy efficiency levels, but with all power sector subsidies removed. The extra revenue to the government is spent on the same mixtures of goods, services, and transfers as in scenario 2. This essentially redistributes resources from one group to another and also raises the price of electricity. It is assumed that the subsidies are removed in 2004. The present subsidies (table 5.2), are shown as sector averages, with the exception of the household sector where the average subsidy for each of the four income quartiles is calculated. The sectors shown correspond to those used in the CGE model.

Table 5.2: Average Electricity Subsidies by Sector

Sector	*Subsidy as % of True Cost*
Agriculture	70
Manufacturing	10
Chemicals	10
Mining	10
Transportation	50
Services	0
Oil and Gas	10
High-Income Households	50
Low-Income Households	65

5.11 To obtain an appreciation of the incremental impact of removing power sector subsidies, scenarios 4 and 2 are compared, since both assume steady oil output and both assume no efficiency gains in the energy sector.

5.12 **Scenario 5 combines the removal of power subsidies with a gain in efficiency in the energy sector.** The model introduces a steady gain in the productivity of labor and capital (Hicks neutral technical progress) in both the power and the oil and gas sectors over the period. The time phasing of the assumed increases is shown in table 5.3. Considered as an average gain in efficiency over the whole period, the model assumes about 15 percent, but the final figure of 30 percent by 2015 corresponds to a substantial, although not unrealistic, gain in efficiency. Most state-owned companies, when benchmarked against equivalent private sector companies, particularly if they have not been fully commercialized and corporatized, exhibit considerable inefficiency. A 30 percent gain, postulated to be achievable over a 15-year period as a result of extensive efforts to move the performance of the energy sector toward that which could be attained under competition, improved governance, and private sector ownership, is a rather modest target, but one which will serve to indicate the qualitative impacts on the economy. Basically, this type of technical progress implies that the same output could be attained in 2015 with 30 percent lower costs for labor and capital. The reduction in input costs then impacts on the choice of inputs, and on the output of the power sector, since output responds to prices, which in turn depend on costs. For the oil and gas sector, where output is exogenously determined by one of the policies simulated in the model, the increase in productivity translates simply into a reduction in labor and capital inputs of 30 percent, and hence into a reduction of costs of these items of 30 percent.

Table 5.3: Increase in Technical Progress in Energy Sectors

Period	*% Increase in Efficiency*
2000–2003	0
2004–2005	5
2006–2007	10
2008–2009	15
2010–2011	20
2012–2013	25
2014–2015	30

5.13 For the purpose of evaluating policy shifts, the incremental impact of improving sector efficiency can be obtained by comparing scenarios 4 and 5, since both have oil output steady and both assume that power subsidies have been removed.

5.14 **Scenario 6 corresponds to a moderate expansion of oil output to 5 mbd.** Oil output is assumed to rise to a plateau of 5 mbd by 2006. The scenario assumes that power sector subsidies are removed and that the efficiency gains in the energy sectors are experienced, so that to evaluate the impact solely of increasing oil supply from 4 mbd to 5 mbd, scenario 6 should be compared to scenario 5. Scenario 6 may correspond to the most realistic target for Mexico if a positive series of measures were taken to improve the performance of the energy sectors and to invest sufficiently in oil to increase its output by 25 percent by 2015. This corresponds to Mexico increasing its share of global output from about 3.7 percent (steady case) to 4.8 percent, which in effect maintains its share of global output relative to that of the 1990s, rather than seeing it slowly fall as would be the case if output were held steady after 2003.

5.15 **Scenario 7 corresponds to an expansion of oil output to 6 mbd**. Oil output is now assumed to reach a plateau level of 6 mbd by 2009. This scenario assumes subsidies are removed and efficiency gains are experienced, so that the impacts of a high oil output versus a no increase case can be judged by comparing scenario 5 and scenario 7, and the impacts of increasing from the medium 5 mbd case to the high 6 mbd case can be obtained by comparing scenarios 6 and 7. This scenario would take Mexico's share of world oil output to around 5.6 percent, which is somewhat higher than it has ever reached before, but which would still not be a major threat to other oil-producing countries.

5.16 **Scenario 8 corresponds to the case where wages are sticky with steady oil output.** In all the preceding scenarios it has been assumed that wages are fully flexible downwards, so that labor markets clear and the only source of unemployment is from frictional forces. This is achieved by allowing the supply of hours by the exogenous number of workers in the labor force to vary freely, in accordance with the trade-off between wages and the supply of labor expressed through the relative preferences for labor and leisure. Since wages and labor supply are both free to vary in a downward direction, the impact of a fall in the demand for labor has been felt partly in a fall in hours demanded and supplied, and partly in a fall in the wage rate—every worker is able to supply the number of hours desired at this lower wage rate. However, if wages were sticky downward, the same fall in demand would produce an equivalent fall in the number of hours actually supplied, with workers wishing to supply more hours than are actually demanded. This excess desire to supply hours is in effect a measure of the "unemployment" created by the sticky wages in the face of a demand fall.

5.17 In an economy with strong trade unions, as is the Mexican case, the assumption of flexible wages is an important restriction, since it implies that any policy which puts downward pressure on labor demand is met in part by wages adjusting downward, hence avoiding any increase in unemployment, and reducing the decrease in hours worked. All three policies considered under the simulations can be expected to have some impact on the labor market. First, the gains in labor and capital efficiency, assumed to be from better management of the energy sectors, would put downward pressure on employment and wages, since the same outputs can now be produced with less labor; second, raising power prices, as a result of subsidy removal, would reduce power demand and output and hence have sectoral employment impacts; and third, the lower the oil output trajectory, the less economic growth and less tax revenue with which to sustainably finance incremental public spending and hence the less the demand for labor and the more likely that there would be downward pressure on wages.

5.18 Thus, as an alternative to the flexible wage solution, which is conventionally used in CGE modeling, a real wage constraint is built into the model. This assumes that the level of real wages experienced in 2000 is sticky downward, and that wages cannot be reduced below this level. Any overall fall in the aggregate demand for labor would therefore produce rationing in the labor market, with an implicit increase in unemployment. To determine the potential market clearing labor supply and wage rate, the demand for labor is compared to the supply of effective potential labor, which is assumed to grow at the exogenous rate of 5.2 percent per year (1.3 percent increase in numbers of workers available and 3.9 percent increase in effectiveness per worker). The supply of hours, at unchanged preferences for labor and leisure per individual, therefore also increases at 5.2 percent. Hence, if demand grows slower than 5.2 percent a year, there is downward pressure on wages which, in a sticky wage context, produces reduced actual labor hiring (compared to the flexiwage case) and increased unemployment (excess of willingness to supply hours against hours demanded at that wage rate).

5.19 Scenario 8 assumes that the production of oil is steady, subsidies are continued, and efficiency remains at 2000 levels. By comparing this case with scenario 1, where the sole difference is the flexibility of wages, the impacts of rigid wages on the basic business as usual case is highlighted. If scenario 2 relies on real wages falling, during some or all of the period, in order to clear markets with the exogenous growth in the labor force, then scenario 8 will instead produce less employment, as well as lower levels of other macroeconomic changes because of the higher real wage imposed by the sticky wage assumption.

5.20 **Scenario 9 imposes the rigid wage constraint on the reformed case with the steady oil production of scenario 5.** This assumes that power sector subsidies are removed and that there are efficiency gains in the energy sectors, while oil production is kept steady at 4 mbd. A comparison with scenario 5 will show how the policy reforms of subsidy removal and energy sector efficiency gains impact the economy when there is little oil production increase and wages are sticky downward. With the effective labor force growing rapidly, the real wage constraint, in the face of policies which tend to put downward pressure on wages, may become even more strongly binding than if none of the policy changes are introduced (scenario 8 versus scenario 2).

5.21 **Scenario 10 imposes the rigid wage constraint on the reformed case with the high oil production of scenario 7.** This scenario assumes that power sector subsidies are removed and there are efficiency gains in the energy sector, while oil production substantially increases to 6 mbd. A comparison with scenario 7 would indicate the extent to which the real wage constraint bites when there are strong counteracting forces on labor demand created by the large investment into the oil sector and ensuring increases in exports, tax receipts, and public spending. The removal of subsidies and increase in efficiency can both be expected to decrease the labor demand while the increase in oil output can be expected to increase the labor demand.

Special Features of the Model Relevant to the Simulations

Growth and Technology in the Model

5.22 As explained in the annex, the model used here is a modified empirical variant of a dynamic growth model first introduced by Ramsey in 1927. In that model the growth in output is proportional to the growth in population when the model achieved its steady state. In the present model it is assumed that in the steady state, the output growth rate is proportional to the population growth rate (here assumed to be 1.3 percent per year) plus an additional amount of growth from overall technological change throughout the economy (here assumed to equal 3.9 percent per year).

5.23 If only the first component of growth were included, as assumed in Ramsey's original formulation, income per worker would remain the same over time. By including the second component, however, each worker's income would increase by 3.9 percent per year (assuming that there is no change in the real wage rate over that same period of time). Given the empirical evidence from Mexico, this is a more realistic assumption, and one that conforms more readily to the existing empirical data. The model was run also in a "low-growth" mode which assumed an annual growth of 3.9 percent for the purposes of sensitivity analysis. In effect, this kept the population growth at 1.3 percent per year and lowered technological growth to 2.6 percent per year, with a resulting wage growth of 2.6 percent per worker. However, qualitatively the results for the low-growth scenario are very similar to the high-growth scenario and for brevity are not included.

Investment and Depletion in the Model

5.24 The model has been specially modified to simulate both the depletion of Mexican oil reserves over time and the impact of exogenously determined investment in oil exploration activities by the Mexican government. The treatment of depletion is quite straightforward and merely requires the model to reduce oil output levels (in the absence of incremental investment) according to a predetermined depletion rate after the year 2003. In the absence of investment into the sector, this produces the oil path used in scenario 3. This explicitly recognizes that this particular variable cannot evolve along a balanced growth path as is the case in the benchmark solution.

5.25 In scenarios other than scenario 3, however, things are more complicated. Here the model allows for depletion to take its course as before, but then lets the government invest enough to allow oil production to rise to the specified level. By so doing, the model quantifies the investment levels and economic costs involved in raising or maintaining Mexican oil output and associated foreign exchange earnings over the next 15 years. There are several reasons for doing this. First, any macro model which focuses on a nonrenewable natural resource has to account for these resources being finite and may be more costly to extract in the future. Second, one of the primary objectives of this model is to assess the magnitude of investment in the oil sector required for Mexico to remain a major player in the world energy market in the initial part of the 21st century.

Government Investment in the Model

5.26 In the model, the government uses all the tax and tariff revenue, and spends them on labor transfers and a variety of goods and services for use in government operations. Spending on government goods and services then can be seen as a residual between revenues from taxation and labor plus transfers. The assumption of a balanced budget (all taxes spent) corresponds approximately to the 2000 position and is the simplest to simulate—since otherwise taxes and spending would have to grow at different rates. Indeed past experience supports this assumption. Following the financial crisis in 1994, the United States and the IMF gave aid to Mexico with the understanding that Mexico would be fiscally responsible. And this is precisely what the government of Mexico did. Indeed, in the years after all of these loans were paid back, the government continued to practice restraint and cut back on spending when the oil price declined and tax revenues from PEMEX shrank.

5.27 In the simulations, government investment is modeled as a government capital subsidy to energy production. Hence, insofar as such transfers increase while tax revenues remain the same, the spending on goods and services by the government must decline. Moreover, the spending on each sector declines proportionally.

Labor and Leisure

5.28 For purposes of the model, leisure is not defined in terms of time per se, but rather as the amount of money that could be earned if the laborer chose to work rather than be idle during that period of time. The model assumes that initially a worker works 40 hours per week and has 20 hours left for leisure. Hence, the value of that leisure time is equal to one half of his or her earned income. Thus, it follows that, if their wages were to rise for some reason, the implicit value of their leisure time would rise proportionally.

5.29 In reality of course, though the value of both income and leisure both rise with wages, the mix of leisure and labor is likely to change. Put differently, consumers make the labor/leisure choice depending on the opportunity cost of time. Labor theorists often separate an income and substitution effect from an income change. As income increases, the relative value of labor goes up causing workers to opt for more labor. At the same time, however, the worker gets wealthier and demands more of the normal good leisure. The final outcome then depends upon the strength of these two effects. For most lowwage workers it is believed that the substitution effect dominates and that the amount of labor offered increases with the wage. With higher-income groups, however, theorists speculate that the income effect dominates and that the labor supply may bend backward over this range. The substitution is determined by the parameters of the household utility function used in the benchmark case.

Determination of Exports

5.30 The model assumes that exports (with the exception of oil) are exogenous, and that they grow at the balanced growth rate of 5.2 percent per annum assumed for the macroeconomy. This means that, in the benchmark case, exports and imports grow at the same rate. In simulating alternative scenarios it is assumed that exports of sectors, other than oil, remain as in the balanced growth case (growing at 5.2 percent) but that, if there is a different level of oil production from the benchmark case, the gap between that production and the associated domestic consumption of oil generated by the model will be exported. Hence, high oil production scenarios are likely to result in higher total exports than low oil production scenarios.

Solving with Constraints

5.31 Solving the CGE model with constraints on what are initially endogenous variables, such as the level of oil output and the real wage, requires an iterative approach to solutions. The model is solved and then resolved until the values of these variables coincide with the constrained levels chosen. This approach means that the solutions obtained are not absolutely identical to the constrained values—a solution that is very near is accepted in order to save on very intensive calculations to achieve ever closer approximations.

6

Simulation Results

6.1 A series of ten simulations are run. The principal results are summarized in table 6.1 for ease of comparison between scenarios. Further detail on sector outputs and values year by year were calculated but are not discussed here.

Scenario 1: The Benchmark Case

6.2 The first scenario run is the benchmark case. Each equation is calibrated so that the initial level of each variable matches the actual level observed in 2000. The scenario assumes that there is no change in policy or technology over the 2000–2015 time horizon, beyond the 3.9 percent growth per year in labor effectiveness discussed previously. Furthermore, it is assumed that oil production grows at the same rate as the rest of the economy, in spite of decreasing reserves.

6.3 The results for this scenario are highly predictable with all variables growing at the 5.2 percent rate, producing terminal values in 2015 which are the compounded initial values. As a result of the balanced growth assumption, there are no changes in sector shares or income distribution. This also assumes that the balance of trade, consumption, imports and exports, government revenue and expenditure, economywide savings, and the effective labor supply in hours worked all grow by this exogenously determined growth rate. Accordingly, since all components of income and the amount of leisure grow at the same rate, the income distribution remains constant, while welfare for each group grows at a common rate.

6.4 The balanced growth assumption means that total oil production would start at a level of 3.4 mbd in 2000 and end at 2015 at a level of 7.3 mbd. In reality, such balanced growth would be impossible, given that oil is being depleted from existing reserves and the production of oil under current conditions could not rise so much in the foreseeable future.

6.5 The individual results are important only as a computational check that the dynamic solution of the model is successful and that the model has indeed been programmed correctly so that all sectors are linked and grow uniformly under the single driving force and absence of constraints.

Scenario 2: Business as Usual Case

6.6 In scenario 2, the level of oil produced is allow to rise according to the overall rate of economic growth until the year 2003, but from that time onward the amount of oil production is held constant at 4 mbd. This is done because the depletion of existing petroleum stocks would make it impossible for extraction to rise with the rest of the economy without substantial investment in oil and gas exploration activities and field development. Put another way, capping extraction at its 2003 levels in the absence of major increases investment in exploration and production gives a much more realistic trajectory of oil output and a sensible reference case against which to measure the impact of policy shifts.

6.7 The overall growth of the economy is again set at 5.2 percent, and it assumes that existing subsidies in the power sector remain in place. Finally, it assumes that there is no further technological change in either the oil and gas sector or the power sector above that assumed in the benchmark case for the growth of labor productivity.

6.8 The main results from this scenario (see table 6.1) show that by 2015, the value of crude oil production is just over half that of the steady state benchmark case (scenario 1). This is reflected in GDP which is some 2 percent lower than in the benchmark case by 2015—the difference between the two reflecting the effect of a gradual build up of the capital stock and the relatively small share of oil output in GDP in the economy. As can be seen, the lower level of oil production results in a significant curtailment of total exports and a large reduction in the balance of payments surplus.

6.9 Some of the results are counterintuitive and go against a priori expectations. It might be expected, for example, that the lower growth would be accompanied by a decrease in the aggregate level of consumption. This is not what the dynamic CGE model predicts. The reason for this lies in the downturn in private investment. Faced with lower incomes and decreased returns to capital, agents 3 and 4 (the higher-income groups who do all of the formal savings) turn away from savings and turn to consumption—leading to a net increase in total consumption.

6.10 This decrease in savings, in turn, explains the upturn seen in the level of welfare for the two top agents. In this model, the welfare of an individual income class is measured by the value of the goods and services consumed plus the amount of leisure available and, by this measure, the welfare of the top two agents goes up. This finding is partly a reflection of how the dynamic model has to be solved. Since much of the income of the top two groups is going into the buildup of the capital stock, any decrease in savings reduces the size of the capital stock, which reduces earnings and welfare in the future. To the extent that agents 3 and 4 (and their heirs) would not be able to draw on the capital stock for future consumption, their welfare would go down, and indeed in an infinite horizon dynamic model it would go down. Unfortunately, practical considerations limit calculations to a finite number (fairly small) of periods and the capital stock is not given time to build itself up as economic agents practice austerity in future periods.

Hence, the terminal conditions for solving the model fix the capital stock lower than the steady state level and thus overestimate welfare levels for the top two agents.

6.11 When the level of oil production is set at a substantially lower path, both the revenues from and investment in the oil sector decline, although the cumulated revenues shown do not decline by the same fraction as final output, reflecting the similarity in output and revenue levels in the early years. The same is also true for the power sector. Interestingly, cumulated government revenues from sources other then power and oil are higher than in the steady state. This occurs because the declining profits in energy-related industries shifts capital and labor resources to other sectors of the economy, such as services, chemical, agriculture, mining, and other manufacturing. This in turn has the effect of moderating revenue losses from those industries and increasing the level of taxable labor and capital outside of the energy related sectors. Finally, the number of hours worked is lower than in the balanced growth case because households choose to switch to leisure at the new wage rate.

Scenario 3: Oil Decline Case

6.12 Under scenario 3 the oil level declines in a manner consistent with decreasing reserves coupled with a policy of no investment in production. This is a worst-case scenario and corresponds to what may transpire if the Mexican government does nothing whatsoever to support the oil production, and technological progress does not advance at a rate faster than that assumed of the economy at large.

6.13 Oil production by 2015 is only 40 percent of that in the “business as usual” scenario 2. Under this scenario, economic activity is significantly curtailed, with GDP 4.5 percent lower by 2015. This decline in GDP then causes only a slight decrease on the overall domestic demand for oil. When this modest demand decrease is combined with the sizeable decrease in oil supply the relative domestic oil price rises rather dramatically, and domestic oil consumers are not shut out of the market. In the international market, however, Mexico is a price taker and the demand for Mexico’s oil is simply treated as a residual in the account balance. In the face of relatively higher domestic prices, oil producers redirect the majority of their sales to internal markets from external markets, and the results indicate that there would be a 60 percent decline in oil exports and a 96 percent decline in the balance of payments surplus to a position where the surplus effectively disappears. Oil is an important contributor to the present balance of payments surplus and, without readily available substitute items to export, the external balance deteriorates.

6.14 Indeed, all of the variables in scenario 3 decline relative to those of scenario 2 with two exceptions. First, the level of overall consumption rises slightly because the upper two agents move ever-increasing amounts from savings to consumption. However, unlike scenario 2, their overall welfare declines because of the overwhelming negative employment (wage) effects as measured in CGE units (these units are the amount of labor that is necessary to purchase one dollar’s worth of goods in one year). Second, there is-a further slight rise in revenue generated for the government outside of oil and power, as taxable capital and labor shift out of the energy sectors to more profitable uses in other industries. The reasons for this are the same as mentioned in connection with the comparison between scenarios 1 and 2 and occur because of the general equilibrium nature of the analysis. It should be noted, however, that here these gains are much smaller than in the previous comparison and they are overwhelmed by the losses in energy sector revenue from both oil and power.

6.15 One important feature of these three scenarios is the behavior of the terminal capital stock—this falls sharply as cumulative oil production is reduced. As between the steady growth scenario 1 and the constant oil output scenario 2, and again between scenario 2 and the decline in oil scenario 3, there are decreases of approximately 10 percent in terminal capital stock. Clearly, the potential for future growth is also heavily influenced by the accumulation that oil makes possible, so that the whole stream of GDP in the succeeding years will be substantially reduced as a result of less factor inputs being available.

Scenario 4: Power Sector Subsidy Removal Case

6.16 The results of scenario 4 are similar to those of scenario 2. Again oil production is held steady after 2003, and the levels of efficiency in the energy sectors remains at 2000 levels. The one difference is the elimination of subsidies now provided in the electricity sector. For a number of years, electricity tariffs have been subsidized for such sectors as agriculture and residential consumers. The government has been selective in the industries that are heavily subsidized, and most service industries are not subsidized at all, so that the total amount of all subsidies in the power sector amount to less than 1 percent of aggregate GDP.

6.17 The simulation results confirm that, if all of the present subsidies were removed, there would be little economywide effect, with GDP, exports, imports, and employment all experiencing small declines. This is a reflection of the assumption that the government balances the budget so the impact of the reduction in subsidies is largely matched by the impact of the resulting increase in government spending.

6.18 This is only one part of the story, however. The power sector is not all that large, but it is an important sector in that it plays a crucial role in various types of productive activity and in terms of consumer welfare (since consumers are dependent on power for a variety of household needs). As expected, power output goes down significantly as consumers switch away from electrical power following the price increases. Although GDP drops slightly, the terminal capital stock increases slightly because more money is funneled into investment when aggregate consumption declines, and more funds are made available (through savings) for increased investment.

6.19 Welfare declines for all income classes, but the bulk of this decline is concentrated in the lower income groups. This is because subsidies are more important in proportionate terms for the lower-income groups. The net welfare impact of this substantial change in electricity prices is particularly noteworthy. Although the rise in prices creates a downward pressure on welfare, the impact of the increased government spending (which is shared between items in the same proportion as in 2000) partly to offset this. Furthermore, the welfare calculation does not come from the traditional partial equilibrium area under a demand curve, which is not a close approximation for large price changes, but rather from an exact calculation based on a utility function, which takes all goods, services, and leisure chosen into account.

Scenario 5: Energy Sector Efficiency Gain Case

6.20 In scenario 5, the production of oil is held steady in a manner consistent with that described in scenarios 2 and 4, rising from 3.4 mbd in 2000 to a plateau of 4 mbd in 2003, and remaining at that level thereafter. As in scenario 4 the subsidies on electric power are removed. In addition, the model imposes an increase in the efficiency of production in both the power and oil sectors, which could be viewed as the gradual result of moving these sectors toward full corporatization/commercialization, the introduction of competition in some segments of the energy industry, and arms-length regulation in others. In technical terms, "Hicks Neutral" technological change is assumed in which both the labor and capital inputs are allowed to become more efficient by the same amount. That is, it is assumed that increased efficiency and technological improvement is brought about by better investment decisions and improved management of services. It is very important to note that this change, which averages 2 percent per year over the 15-year time span of the model, is separate and distinct from the 3.9 percent annual improvement in the labor force efficiency assumed in all the scenarios—the latter is applied to the inputs into every productive sector in the Mexican economy, while the change involved in scenario 5 applies only to the extraction of oil and gas and the production of electrical power.

6.21 Table 6.1 shows that in scenario 5, relative to scenario 4 (to which it is identical except for the improvement of efficiency) power output rises substantially (33 percent) and GDP increases by 1.5 percent, while the balance of payments surplus improves slightly. There is no significant change in consumption, but the value of the final capital stock increases by 1.5 percent. Oil output does not change as it is exogenously held at 4 mbd, but a small rise in the domestic price raises its value slightly.

6.22 Of particular interest here is the substantial increase in output experienced by the electrical power sector. This occurs because power benefits from technology change at several stages of the production process. First, and most obviously, electricity production increases when productivity increases within that industry. This increase can be thought of as a "direct effect" of technological change. Second, electricity benefits when there is an increase in productivity and a decrease in the cost of oil and gas extraction. These lower costs translate into lower energy input prices for electricity and cause the power industry to adapt to a more energy intensive mode of operation. This second increase can be thought of as an "indirect effect" of change in input technology. Combined, the "indirect" and direct" effects serve to amplify the total change brought about in the power sector and lead to significant increases in electricity output.

6.23 Importantly, there is a decrease in the government revenues collected from the oil sector and no change in those from the power sector. This occurs because, with the advent of new technology, both power and oil sectors can produce the same output of their products with fewer inputs. In the oil sector, with the same output, this results in a fall in the input volume, so that labor and capital are released from the oil sector with the result that capital and labor tax revenues decline in this sector. In the power sector, the lower input costs and output price result in increased demand which keeps the volume of factor inputs roughly constant. Tax revenue from other sources rises sufficiently that government spending rises. Since government investment in both power and the oil sectors falls, as less is needed because of the increased productivity, this leaves more spending for transfers and government goods and services.

6.24 Employment increases slightly, and consumer welfare also rises when measured against scenario 4 (only subsidy removal). Comparing scenario 5 with scenario 2 shows that the impact of reduced subsidies on consumer welfare is largely offset by the impact of the increased productivity.

Scenario 6: Medium Oil Growth Scenario

6.25 In scenario 6 it is again assumed that all electricity subsidies are removed and substantial efficiency gains are realized in the hydrocarbon and power sectors. Here, however, the level of oil production is assumed to rise to five mbd by 2006 and then to level off. This amount is 25 percent greater than the level assumed in scenarios 2, 4, and 5, and it would come about through substantial new investment of capital in oil exploration and development by the Mexican government. Comparing scenario 6 with scenario 5 gives an evaluation of the incremental effects on the economy of raising oil production by another 1 mbd.

6.26 Table 6.1 shows that almost every variable increases relative to scenario 5. GDP is about 1 percent higher in 2015, and oil output, power output, and consumption all rise with this higher level of oil output. The foreign sector is also positively affected, with exports rising 2 percent, driven by the extra availability of oil, resulting in a substantial increase in the balance of payments surplus.

6.27 As anticipated, there is a substantial rise in the value of the terminal capital stock of about 2.5 percent, while government revenue from the oil sector rises some 8 percent, which more than offsets the rise in investment required to finance the extra oil production. Tax revenue from sources other than oil falls because, with 5 mbd rather than 4 mbd output, the investment in oil is greater than before and more capital and labor therefore remain in the oil sector. There are consequently less resources elsewhere in the economy and hence government tax revenues from other sources decreases. In total, tax revenues actually fall, so that total government spending outside of the oil sector also falls as a result of the decision to increase the level of oil production to 5 mbd.

6.28 The number of hours supplied increases as the positive impact on real wages encourages a substitution from leisure. Finally, welfare for agents 1 and 2 goes up relative to scenario 5, but as in previous cases the welfare index for the two higher quartiles actually falls slightly, because of increased savings on their part as reflected in the higher level of the terminal capital stock (as explained above).

Scenario 7 : High Oil Production Case

6.29 In scenario 7, all assumptions are the same as for scenario 6 except that oil production is now assumed to reach a level of 6 mbd by 2009 and to stay at that level thereafter. This requires a yet further increase of investment in the oil sector.

6.30 By and large the results of scenario 7 are qualitatively similar to those of scenario 6. With the further increase in the oil output level there is a further rise in GDP and of consumption by nearly 1 percent by 2015, while the balance of payments surplus also increases further. The terminal capital stock rises by another 2.5 percent. Again, there is a decline rather than an increase in government revenues from sources other than the oil sector, and, as before, the fall in the total tax revenue means that government spending outside of the oil sector falls.

Scenario 8: The Effect of Sticky Wages on the Business as Usual Case

6.31 In scenario 8 we introduce the concept of nonfrictional unemployment and sticky wages. One of the underlying assumptions of the classical general equilibrium model is that all markets clear, and that there are no surpluses or shortages when prices are above zero. This assumption is critical to CGE models, and throughout the first six scenarios it was assumed that no market violated it. As explained in the annex, however, a number of economists have introduced the concept of sticky wages into their analyses and examined its effect on their models' conclusions. Such a constraint is introduced into scenarios 8,9, and 10 (chapter 5) already presented above.

6.32 In scenario 8 the same assumptions as in scenario 2 (business as usual case) are used, with the addition of a constraint that the 2.4 percent unemployment experienced by Mexico in the year 2000 was from sticky wages. This constraint is introduced into the model by assuming that wages are sticky downward at the level experienced in 2000, so that any forces which would tend to reduce the real wage, in order to clear the labor market, now produce involuntary unemployment as expressed by the number of hours hired being less than the labor force would wish to supply at the constrained wage. This effect is shown by the employment figure, measured in hours, relative to the employment figure for scenario 2.

6.33 In the simulation of "business as usual," the existence of a real wage constraint has a major impact on employment and hence on the whole economy. The slow oil sector growth, given the large increase in the effective labor force (5.2 percent per year) is associated with a substantial fall in real wages to employ all the labor force which is both more numerous and more efficient. Without downward flexibility of real wages this cannot be achieved, and the economy suffers severe effects. For the three years while oil reaches the new level of 4mbd the real wage does not need to fall and

GDP can rise. However, the time path of the simulation shows that the gains are short-lived and after year 8 aggregate GDP experiences a substantial decline. Indeed, by the final period of the model aggregate GDP has declined by 13 percent relative to the scenario 2 case. Investment also declines precipitously, so that the capital stock ends up at just 81 percent of the scenario 2 level. As a result of this economic decline, welfare for all income groups also falls, and government revenues, exports, and the balance of payments all experience significant declines. Tax revenues from all sources declines as does total government spending, which, with the same oil production and investment, means that spending on other government goods and services and transfers also falls. Corresponding to the large fall in GDP is a large decline in aggregate employment of 17 percent which represents a major increase in unemployment.

6.34 The reason for these losses relates to the interconnection between unemployment, GDP, the price of capital, the price of labor, and the new investment. level. When unemployment from sticky wages occurs, two things happen. First, the employment of fewer workers affects the economy’s ability to produce and directly slows the growth. At the same time, the labor price rises relative to that of capital and reduces the productivity and profitability of capital. Both of these serve to slow investment, and the decrease in investment further slows the growth of GDP. The decrease in GDP now forces prices down, except for the labor price. This leads to even more unemployment and the cycle continues.

6.35 The detailed sectoral analysis produced by the model also shows that those industries which are heavily dependent on new capital investment (such as manufacturing, refining, chemicals, and mining) all start to shrink in the latter period of the simulation, while industries such as transportation and services experience much less significant output losses.

6.36 Overall this scenario shows that if the labor force, measured in efficiency units, continued to grow at a rapid rate, while oil output were stagnant, the economy would suffer a serious recession if there were substantial real wage rigidity.

Scenario 9: The Effect of Sticky Wages on the Efficiency Gains Subsidy Removal, Steady Oil Production

6.37 Scenario 5 presented the case where the energy sectors experienced substantial efficiency gains and power subsidies had been removed, while oil output was steady as in scenario 2. Since both efficiency gains and higher power prices are likely to lead to reduced demand for labor which, in the face of sticky wages, would result in increased unemployment, a comparison between scenarios 9 and 8 shows the impact of sectoral reforms when there are sticky wages. This pairwise comparison can be contrasted with the comparison between scenarios 5 and 2, which shows the impact of sector reforms when wages are flexible. A comparison between scenarios 9 and 5 shows the impact of wages being sticky in a situation where reforms have been carried out. Contrasting the pairwise comparisons of subsidy removal and increased efficiency with and without stick wages allows a deeper understanding of how effective sector reform might be in a situation where wages are not fully flexible in a downward direction.

6.38 If wages are assumed to be sticky, then the effect of removing power subsidies and improving energy sector performance (scenario 9 versus 8) is still to increase GDP in part due to the extra power output that can be supplied. The balance of payments worsens slightly due to the reduction in the availability of oil for export. Employment falls slightly, so that the impact of sector reform in the context of a sticky wage scenario is to increase the unemployment beyond that which would occur as a result of the growth in productivity in the economy in the case where oil output is growing considerably slower than the supply of effective labor. This comparison indicates that the pairwise comparison between scenarios 2 and 5, which highlights sector reform in the context of flexible wages tends to understate the impact on unemployment and the general level of output, but that the increment in output from reform and subsidy removal is seen to be similar whatever the state of the wage market.

6.39 The comparison between scenarios 5 and 9, which highlights the impact of sticky wages on a reformed energy sector, is dramatic—output is hugely different, despite the same level of oil production, and this is seen most strongly for the lower income groups who suffer from having no non-labor income. The other major difference is on the terminal capital stock, which also is strongly impacted by the sticky wage assumption and finishes about 25 percent lower as a result.

Scenario 10: The Effect of Sticky Wages on the High Oil Increase Case of Scenario 7

6.40 Scenario 10 imposes the sticky wage constraint on scenario 7, in which subsidies are removed and the energy sectors experience efficiency gains, while oil output is raised to 6 mbd. A similar simulation with sticky wages at 5 mbd output could be compared to scenario 6, where there is no wage constraint, but the present comparison is sufficient to illustrate the extent to which a higher oil investment and output policy could offset the effects of sticky wages.

6.41 The results of this simulation are very striking with respect to earlier simulations, particularly those of scenarios 7 and 10. When compared to scenario 7 the simulation shows that the imposition of nonfrictional unemployment via sticky wages leads to no significant change in most of the economic aggregates. Within the rounding accuracy incurred through the iterative solutions need for solving the CGE model subject to constraints, it can be seen that with such a high oil growth the frictional wage constraint is nonbinding, and so the macrovariables are not altered.

6.42 Turning to the comparison with the experience of other scenarios in which the sticky wage constraint is imposed shows that the high oil case is very different. In the cases of steady oil, whether or not the sector had been reformed (scenario 8 versus 2, and 9 versus 5) when sticky wages were imposed all of the aggregates fell significantly. Here, however, the imposition of a sticky wage constraint certainly does not curtail investment or economic growth. The reason for this difference is that in this case, unlike those of scenarios 8 and 9, the sticky wage constraint is nonbinding. Put another way, the high amount of government investment in the oil sector creates significant demand for new labor and increases the price of labor relative to most other factors and goods. Under this condition the actual level of nonfrictional unemployment falls below its initial level of 2.5 percent. Hence, the presence of high oil sector investment makes the added sticky wage constraint inconsequential, even despite the presence of the large efficiency gains and increase in power prices (with their associated downward pressure on demand).

6.43 However, it should be pointed out in the final periods of the simulation, both GDP growth and investment growth begin to slow. Sectoral growth also begins to slow and, as in scenario 8, this decline in growth is concentrated in the capital intensive energy sectors, such as refining and mining. At the same time, nonfrictional unemployment begins to increase and the sticky wage constraint moves nearer to being binding. Government investment in oil would need to be increased still further if economic growth were to be maintained in the longer term if real wages continue to be sticky downwards.

6.44 Scenarios 8, 9, and 10, impose a sticky wage constraint, which shows that, given the exogenous growth in the effective labor force, to keep real wages at the level of the benchmark value, oil output would have to increase steadily. Otherwise the growth in the model will be constrained and unemployment will increase because real wages are unable to adjust.

Table 6.1: Summary CGE Results Data for Mexico for 2015

	Scenario 1 *5.2% growth* *inefficiency* *subsidies*	*Scenario 2* *Oil steady* *inefficiency* *subsidies*	*Scenario 3* *Oil decline* *inefficiency* *subsidies*	*Scenario 4* *Oil steady* *inefficiency* *no subsidies*	*Scenario 5* *Oil steady* *efficiency* *no subsidies*	*Scenario 6* *Oil 5 mbd* *efficiency* *no subsidies*	*Scenario 7* *Oil 6 mbd* *efficiency* *no subsidies*	*Scenario 8* *Scenario 2* *plus* *sticky wages*	*Scenario 9* *Scenario 5* *plus* *sticky wages*	*Scenario 10* *Scenario 7* *plus* *sticky wages*
GDP, trillions pesos	7.316	7.119	6.804	7.107	7.227	7.302	7.355	5.847	6.011	7.356
Oil output, trillions pesos	0.280	0.152	0.059	0.152	0.156	0.201	0.250	0.152	0.155	0.252
Power output	0.129	0.112	0.094	0.104	0.138	0.146	0.153	0.097	0.121	0.154
Consumption	4.891	4.927	4.958	4.918	4.936	4.939	4.944	4.894	4.931	5.028
Imports	2.156	2.154	2.147	2.155	2.155	2.156	2.156	2.156	2.156	2.156
Exports	2.344	2.233	2.150	2.231	2.242	2.287	2.332	2.224	2.240	2.356
Exports oil	0.253	0.138	0.055	0.138	0.141	0.182	0.222	0.146	0.148	0.229
BoP surplus	0.188	0.078	0.003	0.076	0.087	0.131	0.176	0.069	0.084	0.201
Cumulated welfare agent 1	1.449	1.446	1.406	1.443	1.445	1.447	1.448	1.416	1.418	1.464
Cumulated welfare agent 2	4.330	4.321	4.200	4.313	4.320	4.323	4.327	4.229	4.236	4.374
Cumulated welfare agent 3	6.700	6.717	6.572	6.706	6.710	6.706	6.704	6.699	6.700	6.773
Cumulated welfare agent 4	11.123	11.220	11.075	11.216	11.208	11.182	11.162	11.443	11.435	11.281
Terminal capital stock	14.877	13.822	12.488	13.792	14.015	14.385	14.680	10.700	11.021	14.690
Cumulated Govt. revenue from oil	0.751	0.646	0.547	0.647	0.616	0.668	0.718	0.634	0.603	0.716
Cumulated Govt. revenue from power	0.120	0.115	0.111	0.110	0.110	0.112	0.113	0.111	0.106	0.113
Cum. Govt revenue from other sources	2.092	2.231	2.281	2.250	2.311	2.236	2.160	2.199	2.282	2.145
Cumulated Total Govt. Revenue	2.962	2.993	2.939	3.007	3.037	3.015	2.992	2.943	2.991	2.974
Investment in power	0.031	0.028	0.024	0.037	0.026	0.028	0.028	0.024	0.022	0.029
Investment in oil	0.195	0.106	0.041	0.106	0.083	0.108	0.132	0.106	0.083	0.135
Employment	47.069	46.375	45.456	46.340	46.479	46.699	46.873	38.700	38.050	47.070

7

Conclusions

7.1 The purpose of this modeling exercise has been to assess the economic impact of alternative Mexican energy policies within an economy wide computable general equilibrium (CGE) framework. The multiperiod framework permitted these impacts to be quantified dynamically in order to examine their repercussions over the 16-year period from 2000 to 2015. Ten scenarios were run to simulate the effects of alternative policy options and economic assumptions on economy-wide performance. This exercise has yielded a large number of statistically significant results, the key points of which are summarized below:

7.2 First, the analysis has pointed out the importance of taking account of the depletion of nonrenewable resources, such as oil and natural gas, when examining policies to be pursued in the energy sector. While this point would appear obvious, CGE models have been built for a number of countries, including Mexico, and the majority of these studies have largely ignored the fact that such resources are depletable and may become more costly to extract over time. The results obtained show that the exploitation rate of a natural resource is an important factor in long-term growth of the economy and is especially important if there is a real wage constraint.

7.3 Second, the scenarios illustrate how important it is to recognize that the quality of labor does change over time, and that labor effectiveness is modified by technological change. Put differently, if all growth were based solely on the physical growth of the labor force, then each individual's welfare would remain constant over time. It is through the augmentation of the labor force that general increases in consumer welfare and income are possible over time. At the same time, this recognition that the effective labor force can grow rapidly, as simulated here, means that balanced growth, where there is a natural resource as a major sector, will become more difficult because of the tendency of the resource to deplete.

7.4 Third, the simulations show that removing subsidies to the electricity sector may, at the same time, have both a small aggregate impact and a large impact within a sector or group. Their removal, with the redeployment of resources to other items of government expenditure, keeps overall GDP at a nearly constant level. However, unless this incremental government spending is targeted to poorer users of electricity, their welfare may suffer as a result of the policy change.

7.5 Fourth, we have seen that significant investment in energy extraction is essential if Mexico is going to maintain strong growth, enhance consumer welfare, and stimulate export development. Indeed the simulations have found the balance of payments to be quite sensitive to changes in oil extraction and depletion.

7.6 Fifth, if there is extensive energy sector reform which results in increased efficiency and oil output grows fast enough to offset the real wage constraint, the resulting gain in efficiency is translated into a valuable gain in GDP and terminal capital stock, as well as a rise in government spending on programs outside the energy sectors. Where wages are sticky, and oil production is not growing so fast as to offset the wage constraint, the introduction of sector reform can translate partially into an increase in unemployment.

7.7 Sixth, the role of natural resources in a dynamic CGE model is noteworthy. When the only driving force is assumed to be labor, the implicit assumption for balanced growth is that natural resource output will increase in line with labor supply. When this is not possible (because of resource constraints or policy) then the macroeconomy will grow more slowly. The real wage will adjust to absorb the surplus of labor (relative to the natural resource) and living standards will be lower than they would have been had there been no resource constraint. If, in addition, there is downward rigidity of real wages (from their 2000 level) then once the real wage is forced back down to this level, unemployment will start to emerge. It appears that natural resources can grow less rapidly than the effective labor force for a period without the real wage constraint binding, but that eventually the difference in growth rates will be binding.

7.8 Finally, the model illustrates the importance of taking into account employment constraints brought about by the presence of sticky wages. Such a constraint can have negative consequences on the macroeconomy when energy investment is low while the growth of the effective labor force is high. Policy analysis, which does not investigate the potential for wages to be sticky; and the process whereby these wage thresholds are determined, may produce a substantially overoptimistic picture of the economic performance and of the impact of various sector reform strategies. Conversely, the importance of increasing oil production will be undervalued if the wage constraint is ignored, since this may be the single most important variable for ensuring that the real wage constraint does not bite.

Annex 1

The Dynamic General Equilibrium Model

Introduction

A.1.1 Over the past 100 years most of the empirical work done in economics has relied upon "partial equilibrium analysis." This type of analysis concentrates on a single market and quantifies the changes in supply, demand, prices, quantities, and welfare brought about by exogenous shocks and/or parametric changes. This type of analysis has been well suited to markets of limited size or with weak linkages to other economic sectors.

A.1.2 Many economic issues, however, do not fit easily into this category. Often, the economic sector analyzed is large and changes in that sector can have important economywide repercussions. Such problems are more appropriately dealt with using "general equilibrium analysis." In this type of analysis, all the sectors in the economy are examined as one linked system where changes in one sector may affect prices and output economywide.

A.1.3 Mathematically, an interlinked economy cannot be described in one or two equations, but rather by a large system of simultaneous equations. In an economy with N markets, N minus 1 equations are required to solve for all of the prices and outputs in the system. Needless to say, while the theory behind general equilibrium can be described fairly easily, the computations involved in solving such a system are fairly complex. Indeed, it was not until the advent of high-speed computers and efficient solution algorithms that large economywide problems could be solved.

A.1.4 In a simple static model, the actual solution of a general equilibrium problem relies on construction of a Social Accounting Matrix (SAM). In a SAM, production in all markets, all tax revenues of the government, and consumption by all consumers for a specific base year first has to be replicated. Hence, for a country like Mexico, it is necessary to specify the amount of manufacturing, agricultural, energy, and all the other sector outputs that actually occurred in the base year. Supply and demand elasticities must also be specified, and the model calibrated, through constants in each equation, so that each consumer group is assigned the amount they actually consumed in that year. The equations are solved and the results checked to see that the base year is indeed replicated (benchmark run).

A.1.5 The model is then run under a counterfactual scenario. One or more unit of supply, demand, or tax, is altered and the new results from solving this model are compared with the original "benchmark" run to show the changes in prices and output in each of the model's sectors caused by the policy shifts. In both runs, the total level of consumer welfare and GDP are also calculated and the two are compared to see the impact of the exogenous changes on these economywide variables.

A.1.6 The use of equilibrium analysis to calculate the impact of various economic policies dates back to the early work of Harberger (1962, 1964). Such analyses, however, were generally limited to two or three sectors until the advent of the more sophisticated computable general equilibrium (CGE) models in the early 1970s. Cornerstone works related to taxation models include Shoven and Whalley (1972), Whalley (1975), Shoven (1976), Ballentine and Thirsk (1979), Keller (1980), Piggot (1980), Slemrod (1983), Serra-Puche (1984), Pigott and Whalley (1985), and Ballard, Fullerton, Shoven, and Whalley (1985). The policies that have been analyzed through these models include changes in various kinds of taxes and tariffs, technological change, natural resource policy, and employment policy. Both efficiency and distribution impacts are presented in these studies (for the main features of the above models, see Shoven and Whalley, [1992]).

A.1.7 The extension of a static CGE model to a dynamic framework is fairly straightforward. Although computationally more complex, a dynamic CGE model differs from its static counterpart only by the inclusion of a driving force to move the economy from period to period. In most dynamic models this force is provided by the growth in the underlying labor force, and/or by a change in the level of technology in one or more sectors of the economy. These changes are facilitated by new investments and the growth of the capital stock in the economy.

A.1.8 As with the static model, the actual output for each sector in a specific base year is replicated through the calibration. In addition, however, the economy is now expected to grow; and in the initial benchmark run, all sectors, quantities, and factors of production are required to grow at the same steady state rate. When a counterfactual shock is applied to a dynamic CGE model, two things occur. First, the effected prices and quantities traverse to a new growth path in the years following the shock. Second, the new growth path itself returns to a steady state but with economic variables at a level different than they would have been at in the benchmark case. Generally, the interest in these dynamic models is on the new path and how much higher or lower it is than the original benchmark path.

A.1.9 Analytical treatment of aggregate economic growth has its origin in the work of early theorists such as Ramsey (1928), Solow (1956), and Koopmans (1965). Nonetheless, because of their heavy computational requirements, true dynamic extensions of CGE models are a fairly recent development. In the past few years, authors such as Summers and Goulder (1989), Jorgenson and Wilcoxen (1990), and Rutherford, Montgomery, and Bernstein (1997) have begun to use dynamic CGE models to explore a variety of policy issues using a single consuming agent.

A.1.10 New models have been developed to address the issue of energy policies and carbon taxes to prevent global warming. A comparison of many of these models is found in Goulder (1995b). They all estimate the economic impact of imposing a tax on carbon emissions. Most of these models have been applied to the United States (Shakelton, and others [1992], Goulder [1995a and 1995b], Jorgenson and Wilcoxen [1995]) and to other industrialized nations. However, there are also some applications to India, Indonesia, and Pakistan (Shah and Larsen, 1992). Other important studies on this topic may be found in Nordhaus (1993), Bovenberg and Ploeg (1994), Bovenberg and de Mooji (1992 and 1994), Poterba (1991 and 1993), and Manne and Rutherford (1994). Boyd and others (1995) have also developed a model to analyze the net benefit of energy taxation and energy conservation as policies to reduce CO_2 emissions.

Overall Structure of the Present Model

A.1.11 The model used in the present study is disaggregated into nine producing sectors, sixteen production goods, four household (income) categories, seven consumption sectors, a foreign sector, and the government (see table A.1.1). The economic variables determined by the model are investment, capital accumulation, production by each sector, household consumption by sector, imports and exports, relative prices, wages and interest rate, the government budget expenditures and revenues, and the level of employment. The rate of depreciation and the initial return to capital are taken as exogenous, as is the rate of labor force growth.

A.1.12 This particular model is designed to focus primarily on the workings of the energy sector in Mexico and to show that sector's linkages to the economy at large. Hence, it contains a some special features not commonly found in countrywide CGE models.

A.1.13 Output in oil and gas extraction is also broken down into its constituent parts, namely crude oil production and natural gas production. These two outputs do not necessarily occur in fixed proportions and can be altered according to transformation elasticity. As with the other sectors, the oil and gas outputs are used as inputs in other production and consumption sectors and are sold to foreign consumers.

Production

A.1.14 The production portion of the model is built upon information from a balanced data set that is flexible in regard to the substitution between both the primary factor inputs (capital and labor) and the material (semifinished) inputs from other production sectors.[4] The material inputs enter in a manner similar to that in an input-output model, except that their substitutability can differ from zero. Technologies are

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[4] The input-output table used is an updated version of the 1990 table. The update was performed with information provided by SEMARNAP.

represented by production functions which exhibit constant elasticities of substitution. Technical progress is taken as exogenous to the model.[5]

A.1.15 Production in each sector for every time period is represented as a constant elasticity of substitution (CES) function of capital, labor, and material inputs where the elasticity of substitution can vary between zero and infinity.[6] Hence:

$$(1) \qquad V_t = ?_t [\, ?_L L_t^{(?-1)/?} + ?_K K_t^{(?-1)/?} \; ? \; ?_M M_t^{(?-1)/?} \,]^{(?/?-1)}$$

where V_t is value at time t, $?$ is the elasticity of substitution between inputs that is estimated econometrically for the different sectors, $?_t$ is an efficiency parameter for the entire production function, L_t is labor at time t, K_t is capital at time t, M_t are materials at time t, and the ?´s are the share parameters defined so that:

$$d_L, ?_K, ?_M > 0 \text{ and}$$

$$?_L + ?_K + ?_M = 1$$

A.1.16 The materials input, M_t, does not represent a single factor input, but rather a host of inputs from the various production sectors. Hence, in the model, M_t is a composite input produced by a nested CES production function whose arguments are the actual inputs from the model's production sectors. All of this is depicted in Figure A.1.1. In that diagram the total output of the production good V_t is shown at the apex of the figure. The labor, capital, and composite materials inputs are placed at the second tier, and each of the individual materials inputs are placed at the third tier. Besides being more flexible, this setup has the distinct advantage of allowing the elasticity of substitution between materials inputs to vary from the elasticity of substitution between the primary inputs.

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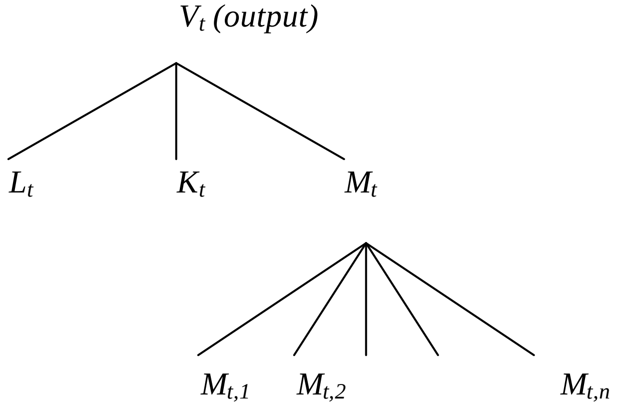
[5] For endogenous technological change, see Romer (1990). Another good reference is den Butter, Dellink, and Hofkes (1995).

[6] Substitution elasticities between capital and labor for agriculture and manufacturing were derived from case studies (Hueter (1997) and Skuta (1997)); (Wylie (1995)); the elasticities of substitution for petroleum were US estimates since no appropriate Mexican estimates were found, except for gasoline (SEMARNAP (1995)).

Figure A.1.1: Structure of Production Inputs



A.1.17 In each time period producers maximize profits in a competitive environment. Output and input prices are treated as variables. Taxes are also included, with producers facing tax exclusive prices and consumers (and input consuming firms) facing the tax inclusive prices. Profit maximization, based on the described production technology, yields output supply and factor demands for each production sector and factor market in the model.

A.1.18 It is important to note that the goods produced in the model's production sectors are not the same as goods consumed by final consumers. Agricultural products, for example, must be combined with transportation services, manufacturing, and chemicals before they can be consumed by individuals as food. Hence, in the model a matrix (referred to as a *Z* matrix by Ballard and others [1985]) is used to map from the vector of production goods to the vector of consumption goods. More specifically, this matrix assigns output to each of seven consumer goods categories in direct proportion to the amount of value added that is given to that good by each of the nine production sectors.

Labor Market

A.1.19 Equilibrium in the labor market is endogenous, with a single wage rate clearing the market. The firms in the model pay out a wage, gross of all labor taxes, while the consumers in the model receive a wage net of all labor taxes. Demand for labor is determined by the firms as a result of their profit maximization process. The growth of the labor force is determined exogenously, but the supply of hours from this is determined by the labor leisure choice, subject to the constraint that 60 hours per week is the maximum available. This leisure/labor choice is made by individuals (in this case by the income groups) depending on preferences and on the marginal tax rate on income. The higher this marginal tax rate, the less labor supplied and the more leisure consumed. Effective labor supply grows at rate ?, the exogenous rate of population growth plus technical progress. This, in effect, means that the underlying growth in the model has two components and depends on both Mexico's growth in population and its rate of technical progress.

A.1.20 In the initial set of runs it is assumed that the aggregate Mexican economy operates at full employment and that wages are fully flexible in both directions. Indeed, such an assumption is commonly made and is standard practice for most CGE applications. A large body of literature (see, for example Ball and Romer (1990) and Lebow, Sacks, and Wilson [1999]) however, suggests that union power and other forces may cause workers to refuse lower wages and for aggregate wages to be "sticky" downward. The presence of sticky wages can, in turn, lead to long term unemployment and affect both aggregate economic output and income distribution. In several of the later runs aggregate wages are constrained to stay above or equal to some predetermined level and the impact of this on sectoral output, employment levels, and consumer income is simulated.

Consumption

A.1.21 On the demand side, the model reflects the behavior of domestic consumers and foreigners (who can also invest) as well as of the government. Domestic consumers are assigned to one of four groups (agents) according to income (as in table A.1.2) and a demand equation is specified for each group. Each group has a different consumption bundle depending on its income. All four groups are endowed with labor. However, since only the wealthy actually have formal savings in Mexico, only the top two groups actually own capital. These resources are sold to firms in order to finance the purchase of domestic or foreign goods and services, save, or pay taxes to the government.

A.1.22 For each household, c, total utility is modeled by the function:

$$(2) \qquad U_c = ?_t\, U_{c,t}\,(X_{c,t}, R_{c,t}) * (1+?\,)^{-t} \qquad t = 1, \ldots, n$$

where U_c is household utility over all n time periods, $U_{c,t}$ is the utility derived from the present period consumption of goods and services $X_{c,t}$ (a seven-dimensional vector) and leisure $R_{c,t}$, and where ? is the discount rate (time preference).[7] Each U_c is taken to be a nested CES utility function defined over all consumer goods as well as all time periods.[8] The value of household utility is given by the addition of the value of consumption and the value of leisure, which is equal to the number of hours devoted to leisure multiplied by the net wage per hour worked; the latter represents the price of leisure (foregone wages).

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[7] To rule out the possibility of a Ponzi game it is assumed that the credit market puts a limit on the amount of consumer borrowing. This is specified by the constraint that the present value of the assets owned by the consumer must be non-negative.

[8] For the purpose of this analysis, all consumers have a constant intertemporal elasticity of substitution (CIES) utility function, and use values for this elasticity which are consistent with the empirical literature.

A.1.23 Each consumer's expenditure constraint can be written as:

$$\sum_{t=1}^{n} (TG_{c,t} + TF_{c,t} + (P_{L,t} * L_{c,t}) + (r * K_{t} * S_{c,t})) = \tag{3}$$

$$\sum_{t=1}^{n} ((INV_{t} * S_{c,t}) + (P_{I,t} * X_{c,t}) + (P_{L,t} * R_{c,t}))$$

where endowments are given on the left-hand side of the equation and expenditures are placed on the right-hand side. $TG_{c,t}$ and $TF_{c,t}$ represent the transfer to the consumer from the government and from the foreign agents, $P_{L,t}$ is the tax exclusive price of labor and r is the rental rate of capital. K_t is the level of capital stock in period t, $S_{c,t}$ is the share of total capital owned by consumer c, INV_t is the total investment in time period t, and $P_{I,t}$ is the tax inclusive vector of prices for consumer goods. Thus, transfers to consumers from both the government and the foreign sector (that is, net income from abroad) plus income from labor and capital earnings are used toward savings, consumption of goods and services, and the consumption of leisure. Theoretically, households can borrow, with the interest being, in essence, collected by themselves. In this particular model, however, there is net saving, which is used to build up the value of the capital stock through investment.

A.1.24 Maximizing the nested utility function (2) with respect to the expenditure constraint (3) simultaneously determines the consumption level of the seven consumer goods and services, the amount of labor supply, and the consumers' level of saving and investment in each of the n time periods.

Government

A.1.25 The government sector is treated as a separate agent (Ballard and others, 1985). The government agent is modeled with an expenditure function similar to the household expenditure functions (that is, based on a CES utility function). Revenues derived from all taxes and tariffs are spent according to this expenditure function. Within this expenditure function, the government spends its revenues on goods and services from the various private production sectors discussed above. It also spends its revenues on labor. Together, these arguments represent the government's purchases and the payment of government employees necessary for it to carry on its work. The government also separately redistributes income through exogenously set subsidies and transfer payments, and it is assumed that all revenues are spent.[9]

A.1.26 It should be pointed out, however, that it is assumed that the government sector does not save as such and there is a zero surplus[10] in the government account.

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[9] Hence there is no elasticity of substitution between government expenditures and payroll expenses on the one hand, and subsidies and transfer payments on the other.

[10] Interestingly in the 1996 base year used, government revenues were quite close to expenditures and the balanced government assumption actually fits quite well.

Hence the government does not own capital, and the capital needed for government provided goods, such as education, is rented from the private sector.

A.1.27 Taxes in the model are expressed ad valorem and include personal income taxes, labor taxes, capital taxes, property taxes, revenue taxes (such as payments from oil and gas activities), value added taxes, sales taxes, and import tariffs and export taxes. As stated above, in the initial calibration of this model, taxes are calculated in such a way as to produce exactly the amount of revenue as they actually did in Mexico in 2000. The taxes on final goods, such as gasoline, differ from other consumer goods because of special taxes levied on them by the government. By the same token, final goods, such as electricity, differ in treatment because of the presence of government subsidies. When applicable, taxation is based on marginal tax rates. To capture the incentive effect of the tax system, the highest marginal rate is levied on the relevant revenue base. Since this procedure would result in over taxation, the difference between the revenue generated by the highest marginal tax rate and the average tax rate is rebated to consumers as a lump-sum transfer.

A.1.28 Subsidies in the model are essentially treated as negative taxes, and in these cases the government transfers funds back to a sector in proportion to that sector's output. Thus, if these subsidies are abolished, the government has more revenue, and to keep aggregate revenues equal to aggregate expenditures the government will increase spending on all items in proportion to existing government expenditures on the different goods and services.

A.1.29 In most CGE applications it is appropriate to treat all government income, regardless of the source, as equivalent and to send it directly to the government sector for spending without differentiating between sources. In this project, however, it is important to distinguish those funds that come from oil sector, those funds that come from the power sector, and those that come from all other sources throughout the economy. To do this, two "dummy" sectors in the economy are created. The purpose of these sectors is collect the funds from oil and power and then transfer them on to the government general fund. By so doing it is possible to obtain a measure of all government revenues derived from these sectors.

Income Distribution

A.1.30 Consumers in this model are divided into four groups according to their income level. The lowest class, called Agent 1, consists of the lowest two deciles in terms of income. Agent 2 is made up of the next three deciles. Agent 3 consists of the following three deciles, and Agent 4 includes the top 2 deciles. In the benchmark case the gross income of each group rises by the rate of population growth plus the rate of technological change, which is taken as labor augmenting. As indicated above, all groups are taxed at their marginal rates and the choice for the group between labor and leisure depends on their relative price. Under steady growth the proportion of time spent in leisure activities is assumed to remain constant.

A.1.31 Various forces affect the income distribution within this model. In the 2000 base year the income distribution depends on the actual factor payments going to each agent during that 12-month period. Furthermore, in the initial benchmark run there is no change in distribution, because all income components of income grow at the same rate, and all relative prices of goods are constant. In subsequent counterfactual scenarios, however, the distribution of income may change if: (1) capital grows relative to labor; or (2) the relative price of various consumption goods change. It is not, however, affected by government spending and tax revenue since transfers are divided between groups on the basis of 2000 shares.

Trade

A.1.32 International trade within the model is handled by means of a foreign agent. Output in each of the producing sectors is exported to the foreign agent in exchange for foreign-produced imports. Under this setup, the aggregate level of imports is set and grows at the steady state level, but the level of individual imports may change in response to changes in relative prices. Exports also are exogenous and are assumed to follow a constant growth path. They are, however, responsive to changing prices, and can change as individual sectors are shocked. Transfers, on the other hand are endogenous and act to clear the model. Price-dependent import supply schedules are derived from elasticity estimates found in the literature.[11]

A.1.33 In specifying the substitutability between foreign and domestically produced goods we replace the classic Heckscher-Ohlin assumptions, and rely instead on the Armington (1969) assumptions. Under these assumptions, foreign imports and domestically produced goods are considered to be imperfectly substitutable goods (as opposed to Heckscher-Ohlin where foreign and domestically produced goods are considered to be perfect substitutes). Armington postulates that domestic and foreign goods are both inputs in a CES production process, the output of which is a combination of the two, and it is this combined good that is consumed domestically. The benefit of such a setup is that a country can both import and export goods from the same industry sector. Furthermore, under this setup domestic prices can differ from world price levels, but the more closely substitutable the foreign and domestic goods, the closer the two prices are to each other. Under the Heckscher-Ohlin assumptions, by contrast, all goods are perfect substitutes and foreign and domestic prices must be equal.

A.1.34 The balance of trade relationship is given by:

$$(4) \qquad ?\, P_{m,t} * IM_{j,t} = ?\, P_{j,t} * EX_{j,t} + ?\, TF_{c,t} \qquad t = 1, ..., n$$

where $IM_{j,t}$ is a nine-dimensional vector representing the quantity of each of the producer goods imported, $P_{m,t}$ is the vector of imported goods prices, $EX_{j,t}$ is the vector of producer goods exported, $P_{j,t}$ is the tariff inclusive vector of producer goods prices, and TFc,t is the level of foreign transfers which can be positive, zero, or negative. Because of the

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[11] See, for example, Serra-Pache (1981) Romero (1994) Fernandez (1997), and Wylie (1995).

Armington assumptions, the import prices are not required to equal their domestic counterparts. The prices of exports are identical to their domestic price (adjusting, of course, for any export taxes). For each time period, the total import value is equal to the total exports value plus foreign transfers. Since these transfers are used to finance domestic investment, this relation provides the closure rule, namely, that investment is equated to domestic savings minus net exports. This, of course, includes balanced trade as a special case.[12] Certain goods, such as transportation and electricity, are strictly produced for domestic consumption, and enter into the model as nontradable goods. This serves to make the model a more accurate description of the Mexican economy. It could also serves to give a measure of the real exchange rate defined as the price of tradable over the price of nontradable.

A.1.35 In this model it is assumed that Mexico has no market power in the world oil market. Hence the international oil price is treated as given, and Mexican oil sellers are treated as price takers in the world oil market. Consequently, when the Mexican government institutes investment policies to increase aggregate oil output, the domestic price drops as output increases, and more is exported as the domestic price falls relative to the international price.

Labor Growth and Capital Formation

A.1.36 Growth within the dynamic CGE model is brought about by the changes over time in both the labor force and the capital stock. In keeping with the theoretical underpinning of the Ramsey model (1928) the changes in the population are modeled as exogenous and constant over the time period considered. More formally, the growth in the effective labor force over time is given by the equation:

$$L_{t+1} = L_t(1+?) \tag{5}$$

where ? is the composite of the growth rate over time of population and the growth in the effectiveness of the typical worker. It is assumed that the participation rate remains constant. In the absence of any perturbation, the Ramsey model predicts that the economy will grow at the labor supply growth rate in the steady state. The labor supply function is then determined by the effective labor force times the hours supply function per worker, which reflects the willingness to offer more hours as the net of income tax rate changes, as modeled by the consumer choice equations.

A.1.37 In the model it is assumed that there is only one type of raw capital good, which goes into the various sectors. In addition, to add realism, it is assumed that the capital which goes into a sector, is of a putty-clay nature. More specifically, it is assumed that capital which is new can be readily combined with other inputs to produce outputs. Over time, however, this capital becomes locked into an older technology (that is, clay) and has a harder time combining with other inputs. This is plausible in sectors such as

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[12] Capital flows are the remainder of the exports minus imports, or net exports, since the deficit in the current account must be made up for by the capital account. Mexican investment abroad is permitted within the model because in 1994 Mexico was a net exporter.

electricity production, which has been subject to a great deal of technological change over the years.

A.1.38 The rate of growth of capital is modeled in accordance with capital theory, and is represented by a system of three equations. For each time period t:

$$(6) \qquad P_{A,t} = P_{k,t+1} \qquad t = 1, ..., T$$

where $P_{A,t}$ is the weighted (aggregate) tax exclusive price of consumption (that is, the weighted average of the $P_{I,t}$'s) and $P_{k,t+1}$ is next year's tax exclusive of the capital price. This says that the opportunity cost of acquiring a unit of capital next year is a unit of consumption in the present period. Also:

$$(7) \qquad P_{k,t} = (1+r_t)\, P_{k,t+1} \qquad t = 1, ..., T$$

meaning that the price of capital in this period must be equal to the present period's rental value of capital plus next period's price of capital. Finally:

$$(8) \qquad K_{t+1} = K_t(1-?) + INV_t \qquad t = 1, ..., T$$

where $?$ stands for the rate of depreciation, and INV stands for gross investment. This states that the capital stock in the next period must be equal to this year's capital stock plus net investment. Taken together, equations 6–8 insure that economic growth will be consistent with profit maximizing behavior on the part of investors.

A.1.39 The actual process of calibrating a dynamic CGE model requires that exogenous estimates for technology and population growth $?$, the return to capital r, and economywide depreciation $?$ are used. Hence, estimates of these are obtained from the literature (see the bibliography) for Mexico and are all listed in Table A.1.3. Given the values for these three values, the program solves for the unique value of $?$, the discount rate. This rate of time preference, in turn, is then used to discount all prices and values in all time periods subsequent to the benchmark year for Mexico.

Terminal Conditions

A.1.40 One potential drawback of a dynamic computable model is that it can be solved only for a finite number of periods. Consequently, a few adjustments are necessary to design a model which, when solved over a finite horizon, approximates infinite horizon choices. First, to keep consumers from consuming all of the remaining capital in the final period, in essence the model must trick them. They are endowed with capital in the initial period, and then in the terminal period all capital is taken away from the capital owning agents, thus preventing them from consuming it all.

A.1.41 Following Lau, Puhlke, and Rutherford (1997) the problem is divided into two distinct subproblems, one defined over the finite period *from* $t = 0$ *to* $t = T$, and the second the infinite period from $t = T+1$ *to* $T = ?$. Hence, the first problem is:

$$(9) \qquad \text{Max} \overset{T}{\underset{t=0}{?}} \left(\frac{1}{1+?}\right)^t U_{c,t}(X_{c,t}, R_{c,t})$$

subject to

$$(10) \quad \overset{T}{\underset{t=0}{?}} P_{A,t} X_{c,t} = \overset{T}{\underset{t=0}{?}} P_{L,t} \overline{L}_{c,t} + P_{k,0} K_{c,0} S_{C,t} \; ? \; P_{k,T+1} \overline{K}_{c,T+1} S_{C,T+1} \qquad \text{and}$$

$$(10a) \quad \overline{L}_{c,t} = L_{c,t} + R_{c,t} \text{ for all t = 0, 1, ... T}$$

and the second problem is

$$(11) \quad \text{Max} \overset{?}{\underset{t=T+1}{?}} \left(\frac{1}{1+?}\right)^t U_{ct}(X_{c,t}, R_{c,t}) \text{ subject to}$$

$$(12) \quad \overset{?}{\underset{t=T+1}{?}} P_{I,,t} . X_{c,t} = \overset{?}{\underset{t=T+1}{?}} P_{L,t} L_{c,t} + P_{K,T+1} \overline{K}_{c,T+1} S_{c,t+1}$$

$$(12a) \quad \overline{L}_{c,t} = L_{c,t} + R_{c,t} \text{ for all t=T+1, ...8}$$

where $?$ is the rate of time preferences, r_o and $K_{c,o}$ refer to the rental value of capital and quantity of capital before the terminal period, r_{T+1} and $\overline{K}_{c,T+1}$ refer to these variables after the terminal period, and $\overline{L}_{c,t}$ is total labor plus leisure for each agent in the tth time period. $P_{K,t}$ stands for the tax exclusive price of capital, and, as before, $P_{I,t}$ and $P_{L,t}$ stand for the tax inclusive price of consumer goods and the tax exclusive price of labor respectively.

A.1.42 It is necessary to specify an equation or specific value for $\overline{K}_{c,T+1}$. At first glance it might seem best to impose the long-run steady state level, but then the model horizon would have to be sufficiently long to eliminate terminal effects. As an alternative, the level of post-terminal capital is included as a variable, and a constraint on investment growth is added in the final period. Thus:

$$(13) \qquad INV_T/INV_{T-1} = Y_T/Y_{T-1}$$

where Y_T represents GDP at time T. This constraint imposes balanced growth on the final period, but does not require that the model achieve steady-state growth. The advantage of this approach is that it alleviates the need to determine a specific target capital stock or a specific terminal period growth rate.

Depletion

A.1.43 All of the meaningful runs of the model assume that oil resources in Mexico are finite, and that they are subject to depletion after some point in time. Thus, in most of the model's runs, output is restricted to some exogenous level. In some cases this means that output is held at some pre-determined level, while at other times the level of oil output is reduced in line with existing depletion estimates.

A.1.44 At the same time that output is restricted through depletion, there can be increased investment into the oil sector via the government, and thereby increased oil output. In some of the scenarios it is assumed that the government makes major investments into oil, in order to increase output and foreign exchange earnings. In the model this new investment is handled by equating it to a government subsidy, and thereby assuming that capital earnings increase by the amount of the government subsidy. This subsidy also serves to increase the overall level of the capital stock but to decrease the amount of funds that the government can employ elsewhere.

Calibration and Data

A.1.45 The model was originally calibrated to a 1996 data set with these data coming from a variety of sources. However, since the original year of our simulations is to be the year 2000, the model was subsequently updated to 2000 by using later additions of those same sources used in the original calibration. Benchmark year (1996, 2000) data were obtained for income and expenditure for each of the income categories. Data on consumer expenditures on final goods by income category were taken from *the Encuesta Nacional de Ingresos y Gastos de los Hogares*, 1996, 2001 published by the Instituto Nacional de Estadística, Geografía e Informática (INEGI). Data on imports and exports are from *International Financial Statistics*, various editions, published by the International Monetary Fund (IMF), *The Mexican Economy*, 1995, 2000 published by the Banco de México, and the *Anuario Estadístico de los Estados Unidos Mexicanos*, 1996, 2001 published by INEGI. Data on inputs, outputs, and use of labor and capital by production sector comes from data compiled by INEGI and supplied by the Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP). This same source, along with the *Anuario Estadístico de los Estados Unidos Mexicanos*. was used to calculate the transformation matrix as well as to find investment levels by sector. All results on fossil fuel consumption (both aggregate and sectoral), fuel prices, fuel imports and exports, and government consumption of various fuels were provided by the Secretaría de Energía (SE), PEMEX, and INEGI.

A.1.46 Tax levels and rates were calculated from the input-output tables as well as from *El Ingreso y el Gasto Público en México*, 1996, 2001 by INEGI. The latter document, along with *The Mexican Economy 1995* and *Encuesta Nacional de Ingresos y Gastos de los Hogares 1996, 2001*, were also used to obtain data on government expenditures and transfer payments. Finally, data on interest rates, capital earnings, and depreciation were obtained from *The Mexican Economy 1995, 2001*, as well as from Barro and Sala-i-Martin (1995). The substitution elasticity between capital and labor was taken from Heuter (1997) and Skuta (1997),[13] and import demand elasticities were taken from Wylie (1995).[14,15]

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[13] As noted above Heuter (1997) and Skuta (1997) were responsible for most of these. Where necessary these were supplemented by Tarr (1989) and Ballard et al (1985) estimates for the United States.

[14] Wylie (1995) obtained estimates on various imported items.

[15] One central modification to the model is made here. It consists of introducing nested functions in the production side of the economy as well as in the production of final consumption goods and services. These nests allow for different degrees of substitution for the inputs considered, in the particular case of

Table A.1.1: Classification of Producing Sectors, Production and Consumer Goods and Services

Producing Sectors	*Production Goods*	*Consumer Goods and Services*
Manufacturing	Manufacturing goods	Food
Coal mining	Coal	Energy
Chemicals and plastics	Chemicals and plastics	Autos
Agriculture	Agricultural goods	Gasoline
Services	Producer services	Consumer transport
Transportation	Transportation for production	Consumer services
Electricity	Electricity	Housing and household goods
Oil and gas	Crude petroleum	
	Natural gas	
Refining output	Coke	
	Diesel	
	Fuel oil	
	LPG	
	Gasoline	
	Kerosene	
	Petrochemicals	

Table A.1.2: Household Categories Based on Income

Category	*Income*
Agent 1	Bottom 2 deciles: 8-10
Agent 2	Deciles 6-8
Agent 3	Deciles 3-5
Agent 4	Top 2 deciles: 1-2

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production it allows substitution between labor, capital, energy, and non-energy inputs. In the case of the production of consumption goods, between food and housing, transport, and household energy use.

Table A.1.3: Basic Parametric Assumptions

Elasticities of Substitution, ? , between capital, labor, and materials by production sector.	
Manufacturing	0.98
Coal mining	0.64
Chemical and plastics	0.98
Agriculture	0.96
Services	1.0
Transportation	1.0
Electricity	0.4
Oil and natural gas	0.4
Refining output	0.8
Labor growth	1.3% per year
Technical progress	3.9%
Depreciation ?	5% per year
Return to capital r	21%
Calibrated discount rate ?	14%

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