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ENERGY POLICY PROJECT:

PETROLEUM AND NATURAL GAS IN EGYPT

FINAL REPORT

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Preface

The Energy Policy Project, focusing on petroleum and natural gas, is designed to provide a comprehensive view of these sources of energy in the Egyptian economy. The purpose is to identify the longer term supply and production possibilities associated with oil and gas and to identify the effects on supply and demand of different prices and quantities of oil and gas available for consumption internally.

The research project is composed of two parts:

- o the supply side, which focuses on discovery and production of petroleum and natural gas; and
- o the demand side, which focuses on uses of oil and gas in the Egyptian economy and the ways in which domestic uses would change if there were changes in domestic prices for these two products or changes in the amounts available for domestic use.

This report is a Final Report summarizing the main work and conclusion of both the supply and the demand sides to date. It presents some results for discussion, criticism, and suggestions. The research team included participants from Cairo University, Egyptian government agencies, and M. I. T. The Cairo University research team, under the direction of Dr. M. Zaki Shafei, included Dr. Gaber Barakat, Professor of Geology, Cairo University, and Dr. Sakr A. Sakr, National Institute for Planning. The graduate students from Cairo University include Ahmed Niazy Elbarkouky, Nader M. Salama, Ola el Khawaga and Laila Iskandar.

From the Egyptian General Petroleum Corporation, Dr. Mostafa Ayouti, Vice Chairman, collaborated in the formulation of the supply-related issues and discussion of the geological surveys for petroleum bearing potential. Dr. Gamal Hantar, Manager, Exploration Department, collaborated in discussions of geological potentials. Mr. Ibrahim Radwan, Manager, Agreements Department, provided insights into the structure of contracts and concessions in Egypt. Mr. Raouf Fayek, Vice Chairman for Gas Affairs, reviewed with members of the research team the natural gas prospects in Egypt.

Dr. Hamed Amer, Chairman of AGIBA Petroleum Company, collaborated throughout the analysis as an advisor and guided discussions of natural gas prospects. Dr. Hussein Abdallah, Senior Undersecretary, Ministry of Petroleum, remained in contact with the Principal Investigators throughout. From the Ministry of Planning, Dr. Abdel Mohsen Abdel Ghani Ibrahim, Undersecretary, contributed the Ministry of Planning's perspective.

The M. I. T. team, directed by Professor Nazli Choucri, included Dr. David Woodruff, Department of Electrical Engineering, Mr. Michael C. Lynch, Research Associate, Energy Laboratory, Professor Lance Taylor, Department of Economics, and Dr. Supriya Lahiri, Research Associate, TAP. Mr. Peter Haas, Ph. D. candidate, provided basic and extensive research assistance. Ms. Phoebe Green assumed full responsibility for typing and final preparation of this and all reports of the Project

Finally, this study is undertaken as part of the Energy and Development Research Program at M.I.T. under the direction of Professor Choucri. It is designed to contribute to understanding energy-economy interactions in development and the constraints and opportunities created by the existing geological and technological configurations of energy systems.

This report highlights the major elements and conclusion of the research to date. Technical details and supporting materials are presented in the companion volumes for this report. The conclusions contained in this report are subject to review, discussion, and reassessment. Completion of the next phase may also lead to revisions.

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CHAPTER 1

INTRODUCTION

1.1 The Problem

Petroleum has made a substantial contribution to the Egyptian economy over the past five years. In fiscal 1981/82 oil exports contributed approximately $2.76 billion to the country's balance of payments.[1] However, due to rising consumption domestically and geological uncertainties about reserve generation and future production possibilities, this favorable picture cannot persist. Changes in either the supply or the demand side (or both) must take place if domestic demand is to be met and oil exports maintained.

This project focuses on the role of petroleum and natural gas in the Egyptian economy, looking at both the demand and the supply sides. We are concerned with production, end uses, and possibilities for substitutions. A comprehensive picture of energy in Egypt is necessary in order to determine tradeoffs and implications of policies for petroleum and natural gas on other energy sectors.

1.2 Supply of Petroleum and Natural Gas

On the supply side, two sets of analyses have been completed:

(1) a comprehensive survey of Egyptian geological conditions, taking into account exploration activities, was undertaken to assist in estimating future levels of reserves and production possibilities. The survey focused in detail on the four petroliferous provinces of Egypt. These are the Gulf of Suez, the Nile Delta, the Sinai, and the Western Desert. Some regions of the country appear to be extremely promising. Recent information released by the Ministry

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of Petroleum and by the Egyptian General Petroleum Corporation regarding new reserves and new concessions bears this out.

(2) a model of Egyptian oil production to simulate oil production for Egypt over the next twenty years was developed as a dynamic simulation model that incorporates and makes use of geological data for the four petroliferous provinces of Egypt. This model is used to generate information about future production possibilities and potential results of increases in exploration activities given the geological configuration of the country.

1.3 Demand for Petroleum and Natural Gas

On the demand side, a detailed analysis of petroleum and natural gas uses in the Egyptian economy has been completed, disaggregating the economy into 10 sectors and differentiating the energy sectors into petroleum production, refining, and electricity uses. This analysis entailed:

(1) determining the precise macroeconomic changes that have taken place in Egypt over the past several years on the basis of sector-by-sector analysis; and

(2) identifying the best uses of natural gas and the best prices for its uses.

(3) providing some initial estimates of the effects of changing domestic prices of petroleum and the impacts on the economy, as well as estimating the effects of greater oil production on internal consumption and uses throughout the economy.

(4) formulating a short-run structural macro-economic model of the Egyptian economy to evaluate the macro-economic consequences of higher petroleum price.

The major sources of information and data have been published materials by EGPC, the Ministry of Planning, and the Ministry of Electricity, in addition to reports by the World Bank, the United States Department of Energy, and the U.S. Agency for International Development. In addition, reports prepared by international consultants on the Egyptian economy and on energy in Egypt have also been used.

1.4 Policy Analysis

Our above studies have also helped us to analyze the current projections and assessments of the oil sector that have been made by government officials in designing Egyptian energy policy. For example, on March 22, 1983, the Middle East Economy Survey conducted an interview with Egypt's Deputy Prime Minister for Production and Minister of Petroleum, Dr. Ahmed Hilal. This section examines the assessments of the oil sector and future plans presented by Minister Hilal. This assessment is made by analyzing the Minister's projections in the context of the Egyptian Petroleum Model (EPM) developed in the context of the Cairo University/MIT Technological Planning Program.

On the Supply Side

1. Production for 1983 is estimated by Minister Hilal to be 263 million barrels per year. The EPM model forecasts a slightly higher annual production for 1983, nearly 302 million barrels per year.

2. Minister Hilal projects oil production in Egypt by 1985 will be 1 million barrels per day. The EPM model estimates .89 million barrels per day for that year.

3. Hilal estimates oil revenues in 1984 to be 2.3 billion dollars. The EPM model estimates revenues to be slightly higher, at $2.8 billion.

These comparisons indicate that the Minister of Petroleum's projections are essentially sound. They are entirely consistent with the results of a robust simulation of oil production processes in Egypt and responsiveness to investments in exploration and development.

We must note that Minister Hilal's investment figures are $300 million per year in exploration and $800 million in development. The EPM results are based on substantially greater investment in exploration ($751 million per year) and substantially lower investment in development ($77 million per year). This last figure is clearly unrealistic.

Minister Hilal provided projections of aggregate investments for the petroleum sector as a whole. The EPM model targets investment requirements for the different regions of the country. Egypt's geological configuration is such that investment requirements are substantially different for different basins and regions.

Our overall assessment is that the interview carried by MEES reveals sound expectations on the part of Egypt's Minister of Petroleum. The simulation analyses undertaken through use of the EPM model reveal the plausibility of production projections.

On the Demand Side

The above note points to the fact that rising domestic consumption is a major handicap for Egypt's oil industry. Dr. Hilal states that "one obstacle to a rise in prices is the fear of its effect on individual incomes."

Our preliminary macro-economic analysis shows that even a small increase in the domestic price of petroleum towards international prices (by 10 percent relative to the current domestic/world price ratio) wil lead to a fall in real

GDP by 2 percent and an increase in the rate of inflation by 3 percent.

To compensate for these negative effects, our analysis suggests the following policy measures:

1. An increase in government expenditure by 8 percent from the current level will result in eliminating the contractionary effects and produce negligible added inflation.

2. If the government encourages substitution from oil to natural gas in production processes, two consequences will result:

   (i) conservation of petroleum in industrial consumption (equivalent to cutbacks)

   (ii) substitution by natural gas would eliminate the negative effects (provided there are no bottlenecks in the natural gas sector)

3. However, there must be a short-run policy of reducing bottlenecks in the natural gas sector, since the effects of those bottlenecks would aggravate the negative macro-economic effects.

4. If bottlenecks in natural gas continue to exist in the short run, the real price of natural gas (as opposed to the government administered price) will increase by 30 percent.

5. If short-run bottlenecks in natural gas are not reduced, conversion to natural gas will increasingly aggravate the negative macro-economic consequences and increase the aggregate price of energy as a whole.

These results are preliminary. More detailed dynamic analysis with current data will provide more insights into energy issues in Egypt.

The main conclusion of this note is that energy demand management alone cannot bring about desirable impacts on the economy unless efforts are made to prevent cost increases which occur in other sectors of the economy.

1.5 Report Organization

The final report for the Energy Project is composed of five parts.

Part I focuses on the energy profile in Egypt and on major recent changes in the structure of the Egyptian economy which inevitably affect energy use.

Part II examines in detail uses of energy in the Egyptian economy, in terms of industrial uses as well as overall macro-economic flows.

Part III presents the results of the supply-side analysis in terms of the geological surveys undertaken and in terms of the forecasts from the Egyptian Petroleum Model.

Part IV identifies the best uses of natural gas in the Egyptian economy and the prices that should be charged for these uses.

Part V describes the short-run macro-economic adjustment problem and policy issues corresponding to higher domestic petroleum prices. It is based on analysis undertaken through use of a short-run ten-sector macro-economic model of the Egyptian economy.

The conclusion to the report identifies the steps yet to be undertaken for completion of this project.

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CHAPTER 2

ENERGY PROFILE

An initial report on Egypt's energy situation prepared for this project provided a detailed survey of Egypt's energy profile according to source of energy, uses in the economy, and prospects asssessed by national and international agencies. The following are some highlights of the main characteristics of the country's energy profile:

- o Energy demand in Egypt grew by an average of 12 percent per year throughout the 1970s (with the exception of 1973). Some declines are apparent in 1979-1980.
- o EGPC acknowledges the continued growth of demand to 1985, but anticipates some downward adjustments (9 percent in 1984 and 4 percent for 1985).
- o Demand for petroleum products is projected by EGPC to increase by 1.3 over the five year plan period.
- o Natural gas is assuming greater importance in the Egyptian economy. Government programs call for more than a threefold increase of gas production between 1981 and 1985.
- o Demand for electricity doubled between 1970 and 1979. International sources suggest a 15.6 percent increase in electricity consumption by 1985 (U. S. Department of Energy).

The major users of commercial energy are the following:[2]

- o industry (37%);
- o residential uses (18%);

- o transportation (19%);
- o agriculture (5%);
- o other (21%).

Petroleum products are used primarily for industry, followed by transportation and residential sectors. Petroleum allocated for electric power generation was 15 percent in 1975 and expected to grow to 28 percent in 1985. EGPC estimates a decline by 2000.

Natural gas prospects are extremely encouraging. Although it is a very small producer, Egypt ranks as the fiftieth producer of natural gas internationally. We estimate that production can be made at competitive prices internationally.

- o In 1977 the energy sectors' final demand accounted for 2.2 percent of GDP (at market prices). By 1979 it accounted for 17.6 percent.
- o In 1977 energy accounted for 11.6 percent of the value of Egyptian exports, by 1979 energy accounted for 54 percent of Egypt's exports.
- o Although rising in its importance to the overall economy and to foreign exchange earnings, energy declined in its role within intermediate production (purchases of energy by other productive sectors for use in intermediate steps of production) from 9.2 percent of intermediate production to 7 percent.

Due to expanding refinery capacity Egypt's energy imports have steadily declined after 1975.

- o Liquefied petroleum gas was the largest item of total Egyptian products imports.
- o EGPC's Five Year Plan predicts a further decline in products imports in the 1980s.
- o Imports of crude oil will increase over the next few years.

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With respect to exports there is an impressive growth:

- Exports of crude petroleum climbed at a high annual average rate from 1975 to the present.
- Petroleum products are also exported. Products exports rose 30-fold from 1970 to 1979.[3]
- Western Europe is the largest customer for Egyptian petroleum. Italy and Greece are among the major customers. Egypt exports oil to twenty countries. Ten percent of Egyptian petroleum in the 1970s went to the United States.

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CHAPTER 3

CHANGES IN THE EGYPTIAN ECONOMY

3.1 Accounts for the Egyptian Economy

There exist four detailed macroeconomic profiles of the Egyptian economy: 1971, 1976, 1977, and 1979.

- o The Ministry of Planning prepared the input/output table of the economy for 1971. The 1976 and 1979 matrices were prepared in collaboration with the Development Research and Technological Planning Center, Cairo University.
- o The Ministry, in conjunction with researchers at the Development Research and Technological Planning Center and M.I.T., prepared the 1976 social accounting matrix of the economy, composed of 32 sectors.
- o The 1977 input-output table was prepared at M. I. T. based on the 1976 definitions and with the following modifications:
    - o reducing the number of key sectors from 32 to 10 sectors
    - o focusing specifically on energy sectors

The purpose of the 1977 matrix was to produce a view of the economy that is clear, with not too much detail, and which can easily be read and understood by analysts for policy purposes. A simple social accounting matrix (SAM) for 1977 was also prepared based on data from the Egyptian National Accounts (United Nations Yearbook of 1979). In the 1977 SAM, value added has been disaggregated into two categories, namely the household sector and the government sector.

Table 3-1 presents the composition structure of industrial sectors for two years: the 1977 social accounting matrix (prepared at M. I. T.) and the

TABLE 3-1

Composition of Industrial Sectors for the Egyptian Social Accounting Matrix: Input-Output Table

Ten Sector Category	Thirty-Two Sector Category
1. Agriculture	staple food; non-staple food; cotton; other agriculture
2. Construction	construction; housing
3. Heavy Industry	chemical industry; basic metals; metallic products
4. Light Industry	food industry; beverage industry; tobacco industry; spinning & weaving industry; final wear industry; wood and wood products; paper and paper products; publishing & printing; leather & leather products; rubber; non-metallic products; non-electrical machinery; electrical machinery; means of transport; .5 miscellaneous industry
5. Transportation	transportation; communications and storage
6. Rest of Economy	tourism; other services; .5 miscellaneous industry
7. Suez Canal	Suez Canal
8. Oil Production & Mining	mining & quarrying; crude oil
9. Oil refining & coal	oil production & coal
10. Other energy	electricity

1979 input-output table of the Ministry and the DRTPC. The 32 sectors of the original 1979 table were aggregated into the 10 sectors for consistency and ease of comparison with 1977 data.

The definitions of sectors and components remain consistent between the different tables for the Egyptian economy. The results presented in this summary report are based specifically on the 1977 and 1979 input-output tables since the data sources, collection procedures, and presentation were made to be consistent.

3.2 Structural Changes in the Egyptian Economy

This section summarizes the major change between 1977 and 1979 in the productive sectors specifically and within the overall Egyptian economy more generally. This is done by comparing the proportions of overall intermediate expenses, intermediate revenues, and final demand from different sectors in 1977 and 1979. To highlight the extent of the changes, comparisons were made at the aggregate sectoral level, rather than by focusing on the details in the original full tables prepared by the Ministry of Planning.

Structural change may be identified by a change in the structure of the economy, in other words, in the change of the proportional contribution of a given sector to the overall economy from one point in time to another. The contribution of specific industries to overall interindustry flows of goods and services in 1977 and 1979 are identified below, followed by some conclusions regarding the extent of changes in the structure of the Egyptian economy between the two years. The existence of important changes (i.e. changes in technical coefficients) suggests that assessing the economy or evaluating performance based on one year's structure will generate erroneous forecasts. This is especially important for the energy sectors where major changes have

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taken place and are reviewed in detail in Part II of this report.

3.3 Changes in Final Demand: GNP Accounting

The major changes in the Egyptian economy with respect to demand for finished products or end use are presented in Table 3-2. The highlights of the changes in the economy are as follows:

- o Households increased their purchases of goods from the rest of the economy from 25.1 percent of all their purchases in 1977 to 37.2 percent of their 1979 purchases. This was balanced by a decline in their use of agricultural goods (down from 20.7 percent of the household budget to 15.8 percent) and light industrial wares (down from 41.6 percent and 38.1 percent), which include purchases of packaged food and textiles.
- o The government relied slightly more heavily on purchases of light industrial goods. Its proportional purchases from the rest of the economy dropped slightly.
- o Investment patterns shifted slightly: the demand for investment goods from the construction sector increased and that from light industry and the rest of the economy declined.
- o In the structure of exports the major change is a dramatic increase in the contribution to exports from crude and refined oil and, in context, a decline in the contribution to total exports from agriculture, light industry, and the rest of the economy.

The contributions of different sectors to gross value added is presented in Table 3-3. The figure on gross value added changed substantially from 1977 to 1979. Contributions to gross value added in agriculture, heavy industry,

TABLE 3-2

Components of GNP

	1977 Percentages					1979 Percentages				
	C	G	I	S	X	C	G	I	S	X
Agriculture	20.8	3.7	0	7.1	15.6	15.8	4.1	0	27.1	9.8
Construction	3.5	4.9	62.6	0	0	4.6	4.1	58.2	0	0
Heavy Industry	2.9	2.5	4.3	14.3	3.1	1.2	2.0	0.9	0.8	2.3
Light Industry	41.4	8.2	14.7	60.3	18.0	38.1	9.6	11.9	54.5	7.5
Transportation	4.2	1.8	0	0	4.6	1.8	1.6	4.1	0	5.5
Rest of Economy	25.2	76.7	18.4	15.9	35.7	37.2	75.6	15.0	1.6	10.1
Suez Canal	0	0	0	0	11.6	0	0	0	0	11.0
Oil Extraction	0	0	0	1.9	7.8	0	0	0	15.5	46.2
Oil Refining	1.2	1.6	0	0.5	3.4	0.8	1.8	0	0.5	7.7
Other Energy	0.9	0.6	0	0	0	0.6	1.3	0	0	0

C = Household consumption
G = Government expenditures
I = Investment
S = Change in stocks
X = Exports

TABLE 3-3

Payments to Value Added:
Contributions from Employment in Economic Sectors
(percentage)

	1977	1979
Agriculture	29.7	23.0
Construction	6.0	8.6
Heavy Industry	3.7	2.5
Light Industry	14.1	11.2
Transportation	4.2	4.1
Rest of Economy	34.5	29.5
Suez Canal	2.4	3.6
Oil Extraction	3.2	14.2
Oil Refining	1.0	4.6
Other Energy	1.2	8.8

light industry, and the rest of the economy declined, whereas those from construction, the Suez Canal, oil extraction, oil refining, and the other energy sectors all increased. We also observe a market increase from 3.4 percent to 14.2 percent in the share of value added from the oil extraction sector.

3.4 Changes in Industrial Structure

Some degree of change in the structure of industry appears to have occurred within the economy between 1977 and 1979. The following conclusions are clear:

- From 1977 to 1979, the technological coefficients have changed substantially. Approximately 60 percent of the technological coefficients have changed by more than 15 percent. In certain sectors the change has been more than 100 percent.
- Both the share of imports and (gross) value added in the different sectors have changed between 1977 and 1979.
- The share of imports to the construction sector more than doubled between 1977 and 1979.
- The share of imports to the light industry sector increased by 11.5 percent.[4]

3.5 Changes in Value Added

With respect to the composition of value added, the main changes are:

- The percentage share of value added in oil refining rose by 10.8 percent.
- The percentage share of value added in the the rest of the economy dropped by 4 percent, and that of heavy industry, by 1.2 percent. The

percentage share of oil refining also increased from a mere .7 percent to 2.4 percent. The share of the "rest of the economy" (which includes largely services and financial transactions) declined by 5 percent.

3.6 The Role of Exports

Total final demand in the economy from 1977 to 1979 has changed by more than 50 percent.[5] For the significantly large sectors it was 60 percent change.

The main conclusions are as follows:

- The largest changes between 1977 and 1979 were in the role of exports for the petroleum sectors.
- From 1977 to 1979 the role of foreign markets as a source for revenues increased dramatically mainly because of the petroleum sector exports. The share of energy in the value of Egyptian exports increased by more than 42 percent from 1977 to 1979.

3.7 Conclusion

The most significant transformations between 1977 and 1979 occurred in energy sectors. Part II of this report presents the major factors regarding the role of energy in the Egyptian economy in terms of oil production, oil refining, electricity, and "other" sources. The conclusions are based on two types of analysis: a micro-level view, looking at energy within the inter-industrial structure of the economy, and a macro-level view, which examines the broad economy-wide contributions of energy to growth.

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PART II

ENERGY IN THE EGYPTIAN ECONOMY: DEMAND AND INTERSECTORAL USE

CHAPTER 4

ENERGY AND INTERINDUSTRY RELATIONS: THE MICRO-VIEW

Although they are only two years apart, the input/output matrices for Egypt (1977 and 1979) show some of the major changes that are taking place in the economy with respect to energy.

The energy sector as presented in this accounting is composed as follows:

- oil extraction;
- oil refining;
- other energy, consisting largely of electricity and natural gas production, essentially marginal for the two years.

This chapter presents a micro-level view of energy in the Egyptian economy, i.e., the interindustry linkages. This view indicates the sectoral relations between the energy producing sectors of the economy on the one hand and, on the other, (1) the consuming sectors and (2) the sectors supplying inputs to energy.

4.1 Inputs from the Egyptian Economy to the Energy Sector: Interindustry Expenses

Interindustry expenses refer to the amounts of money spent by one sector of the economy (the column in the table) into another sector of the economy (the rows). Table 4-1 presents the percentage share of each sector in the total intermediate expenditures. This shows that energy increased its purchases from the other sectors of the economy, from 4.5 percent in 1977 to 7.2 percent in 1979 of all inputs into industrial processes in Egypt (techni-

<u>TABLE 4-1</u>

<u>Contribution to Intermediate Expenses</u>

(percentage)

	1977	1979
Agriculture	16.3	12.8
Construction	5.0	5.4
Heavy Industry	6.0	6.0
Light Industry	44.3	32.4
Transportation	2.7	3.6
Rest of Economy	20.0	32.3
Suez Canal	0.2	0.1
Oil Production	0.5	3.1
Oil Refining	3.9	3.5
Other Energy	0.3	0.3
Total Intermediate Expenses (in millions of current pounds)	4,075,103	7,070,400

cally termed interindustry inputs). This means that the Egyptian economy increased its direct contributions to the activities of the energy sector. (Technically, of course, this also means that at least for energy the technical coefficients in the input/ output table are not fixed. This fact provides an important indication of the changes in the relationship of the energy sector in Egypt to the rest of the economy.)

Oil Extraction

- The oil extraction sector greatly expanded its purchases from heavy industry in 1979 compared to 1977.
- Inputs of construction into oil extraction in Egypt rose slightly.
- Oil extraction's percentage share of inputs from oil refining, light industries, and electricity declined slightly in these two years.
- The overall share of the oil extraction sector in total intermediate expenses increased from .5 in 1977 to 3.3 percent in 1979.

Oil Refining

- There is a sharp increase of more than 100 percent in the oil refining sector's purchases from its own sector of intermediate products.
- There is a dramatic increase in this sector's purchases of goods and services from the rest of the economy. In 1977, about 16 percent of the refining sector's inputs came from the rest of the economy. In 1979 this proportion doubled to 38 percent. (The "rest of the economy" in this accounting consists of financial services and some miscellaneous light industries.)

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Electricity

- o There is a slight increase in the electricity sector's overall purchases from the "rest of the economy."
- o Construction, heavy industry, and the "rest of the economy" contributed slightly more to production in the electricity sector between 1977 and 1979.

Energy Total

The most important change by 1979 is that the energy sector overall diversified the nature of its reliance on inputs from other sectors of the economy (see Table 4-2).

- o The Egyptian economy as a whole increased its inputs into the energy sector from 28.8 percent in 1977 to 62.3 percent in 1979 of all energy purchases).
- o The energy sector itself decreased its intrasector transfers and purchases.

This means that two somewhat contradictory trends are developing in Egypt:

(1) more reliance on the Egyptian economy for the country's total energy purchases (or inputs necessary for the performance of this sector); and

(2) less dependence between the activities in the oil production sector, the oil refining sector, electricity, and other energies. This second fact may reflect the absence of integrated planning for the energy sector as a whole.

The sharp increase in the energy sector's total purchases from heavy industry and construction indicate the extensive building of energy-related

TABLE 4-2

Inputs to the Energy Sector

(percentage)

	1977				1979			
	Oil Production	Oil Refining	Electricity	Energy	Oil Production	Oil Refining	Electricity	Energy
Agriculture	0	0	0	0	0	0	0	0
Construction	2.3	1.4	2.3	2.0	2.8	3.3	2.8	3.0
Heavy Industry	23.0	1.9	0.9	8.6	31.1	3.6	1.2	15.0
Light Industry	27.8	1.5	4.8	11.4	20.5	1.4	2.9	10.1
Transportation	2.8	0.1	13.7	5.5	2.1	0.2	11.1	1.5
Rest of Economy	20.2	15.8	20.1	18.7	23.6	38.0	25.8	31.0
Suez Canal	0	0	0	0	0	0	0	0
Oil Extraction	1.0	69.7	0	23.6	16.9	36.5	0	18.9
Oil Refining	19.9	8.8	58.2	30.0	1.7	15.9	55.9	18.0
Other Energy	2.9	0.7	0	1.2	1.9	0.8	0	1.2
Total Energy	23.8	79.2	58.2	54.8	19.4	53.2	55.9	38.1

(may not sum to 100 due to rounding)

facilities in Egypt.

4.2 Intermediate Sales of the Energy Sector to the Egyptian Economy: Interindustry Sales

Table 4-3 shows the percentage shares of intermediate sales of the energy sector to the other sectors of the economy in 1977 and in 1979. The most important factors are the following.

Oil Extraction

- Intermediate sales to heavy industry by the oil extraction sector increased slightly.
- Sales to construction by the oil extraction sector declined somewhat.
- The overall proportion of intermediate sales to the oil refining sector is very high, consisting of over 75 percent of intermediate sales of the oil extraction sector.

Oil Refining

Major changes in Egyptian refinery output occurred between 1977 and 1979, both in terms of quantity and in terms of destination within the economy.

- Refined products to transportation grew from 10.7 percent of all refinery sales to 14.1 percent.
- The share of sales of refined products to the oil extracting sector increased by more than five times.
- The input requirement from within its sector almost doubled.
- The entire energy sector in Egypt doubled its uses of products from the refinery sector.

For some sectors there is a decline in purchases of products from Egypt's

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TABLE 4-3

Sources of Energy Sector's Revenues
(percentage)

	1977				1979			
	Oil Production	Oil Refining	Electricity	Energy	Oil Production	Oil Refining	Electricity	Energy
Agriculture	0.1	6.5	0.3	3.2	0.1	3.5	0.1	2.2
Construction	8.1	3.3	2.2	4.9	6.8	1.9	0.6	3.0
Heavy Industry	6.7	18.1	29.0	15.6	8.8	16.7	20.2	15.3
Light Industry	5.4	10.5	25.0	10.9	6.5	9.1	19.1	10.0
Transportation	0	11.3	8.9	6.8	0	14.1	8.7	9.8
Rest of Economy	0.4	34.8	31.0	21.6	9.6	23.7	42.8	21.0
Suez Canal	0	0.9	0.6	0.5	0	0.6	0.5	0.5
Oil Extraction	0.2	2.4	1.1	1.4	1.6	12.9	5.0	8.9
Oil Refining	79.0	7.6	2.0	32.8	75.0	13.6	2.8	27.2
Other Energy	0	4.6	0	2.2	0	3.8	0	2.3
Total Energy	79.2	14.6	3.1	36.4	76.6	30.3	7.8	38.4

(may not sum to 100 due to rounding)

own refineries.

- o Construction activities' use of refined products dropped slightly, as did heavy industry, light industry, and the "rest of the economy," which is financial, service, and related activities.

Electricity

The "rest of the economy"'s share in the increased its use of the output from the electricity sector almost doubled between 1977 and 1979. The oil extraction sector expanded its purchases of electricity and electricity sales to oil refining also increased slightly.

This concentration of electricity sales to the energy sector and to the "rest of the economy" was balanced by some decline in sales to the following economic sectors:

- o construction;
- o heavy industry;
- o light industry.

Energy Total

The energy sector's overall structure changed between 1977 and 1979. However, its total intermediate sales to the Egyptian economy did not change overall. The composition of sales of energy products and inter-industrial relations changed. There appears to be a greater concentration of inter-energy flows and greater sales to transportation.

CHAPTER 5

MACRO-VIEW OF ENERGY IN THE ECONOMY

5.1 Contribution of the Energy Sector to the Economy

This section summarizes the overall macro-economic contributions of the energy sectors in the Egyptian economy. The major changes are summarized as follows:

TABLE 5-1

Energy Contribution (percentage)

	1977	1979
final demand[6]	2.2%	17.6%
value added (gross)	5.3%	17.5%
gross production	5.2%	12.5%

This table indicates the increasing importance of the energy sector in the Egyptian economy in terms of its contribution to Gross Domestic Production -- by use (or final demand), to value added, and to the gross level of output.

5.2 Total Inputs to the Energy Sector

Table 5-2 presents the expenditures (or purchases) of the energy sector as a whole, from the other sectors of the economy in terms of intermediate inputs and primary inputs (in percentages). In other words Table 5-2 presents the technical coefficients of the energy sector in percentages. It is clear that most of the energy expenses are directed toward primary inputs and im-

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TABLE 5-2

Full Inputs to the Energy Sector
(percentage)

	1977			1979		
	Oil Production	Oil Refining	Electricity	Oil Production	Oil Refining	Electricity
Agriculture	0	0	0	0	0	0
Construction	0.2	0.7	0.2	0.3	1.3	0.4
Heavy Industry	2.0	1.0	0.1	3.7	1.4	0.2
Light Industry	2.0	0.8	0.6	2.7	0.6	0.4
Transportation	0.3	0.1	0.8	0.3	0.1	1.6
Rest of Economy	1.7	8.1	2.7	2.8	14.4	3.8
Suez Canal	0	0	0	0	0	0
Oil Extraction	0.1	35.7	0	0.1	13.8	0
Oil Refining	1.7	4.5	7.8	2.0	6.0	8.2
Other Energy	0.3	0.4	0	0.2	0.3	0
Value Added	87.7	22.3	75.7	86.9	42.2	74.8
Imports	4.0	26.4	10.9	1.0	19.9	10.5

(may not sum to 100 due to rounding)

ports.

Oil Production

- o We find that the ratio between expenditure on intermediate inputs and total primary inputs has changed slightly whereas the sectoral gross output level in the oil extraction sector increased by more than six times between 1977 and 1979.
- o The technical coefficients from the heavy industry construction sector and the rest of the economy into the oil extraction sector have changed by more than 50 percent.
- o The proportion of imports to the oil extraction sector have also declined.

Oil Refining

The rise in expenditure by the oil refining sector towards primary inputs must have increased: the proportion of the oil refineries' total expenses that go toward value added almost tripled between 1977 and 1979. Other important factors are:

- o a near doubling of gross sectoral output;
- o a doubling (proportionally) of purchases by the refining sector from the "rest of the economy";
- o a rise in the purchase of intermediate refined products by the refinery sector; and
- o the share of purchases of domestic crude dropped significantly.

The decline in purchase of crude oil by the refinery sector is due largely to the low <u>price</u> of oil domestically which is reflected in the accounting of the economy's expenses and revenues. The role of imports into the refinery sector declined (from 33.5 percent of refinery inputs in 1977 to 19.9 percent in 1979) which must signify that in actual fact the refinery sector increased its purchases from the oil production sector, but this fact is obscured by the prices used, which indicate (erroneously) an artificially low volume.

Electricity

The electricity sector's purchases from the Egyptian economy's other sectors remain fairly stable between 1977 and 1979.

5.3 Total Sales from the Energy Sector

Table 5-3 presents the percentage distribution of revenues of the energy sector according to the different sources. It shows the disposition of the energy sectors gross output between total intermediate use (i.e. use for future production) and "final use" (i.e. to satisfy final demand for household consumption, government expenditure, investment demand, and exports). The most important fact is the increases in revenues to the energy sectors coming from exports. The share of export revenues more than doubled in both the oil production and the oil refining sectors. In 1979, 90 percent of revenues for the oil production sector came from exports, oil refining obtained over 40 percent of its revenues from exports. Overall, the energy sector's revenues doubled as a percent of all industrial revenues in the country.

Oil Production

There is a clear concentration of oil production sales for exports.

- In 1977, oil production split its sales between the internal and the

TABLE 5-3

Sources of Energy Sector's Full Revenues

(percentage)

	1977			1979		
	Oil Production	Oil Refining	Electricity	Oil Production	Oil Refining	Electricity
Agriculture	0.1	3.9	0.2	0	1.6	0.1
Construction	4.5	2.0	1.2	0.4	0.9	0.3
Heavy Industry	3.7	10.7	16.2	0.6	7.4	11.4
Light Industry	3.0	6.2	14.0	0.4	4.0	10.8
Transportation	0	6.7	5.0	0	6.3	4.9
Rest of Economy	0.2	20.6	17.3	0.1	10.5	24.1
Suez Canal	0	0.5	0.3	0	0.3	0.3
Oil Extraction	0.1	1.4	0.6	0.1	5.7	2.8
Oil Refining	43.4	4.5	1.1	4.8	6.0	1.6
Other Energy	0	2.7	0	0	1.7	0
Household Consumption	0	16.9	34.9	0	7.6	26.3
Government Expenditures	0	8.0	9.2	0	5.1	17.5
Investment	0	0	0	0	0.3	0
Change in Stocks	1.4	0.3	0	3.4	0.3	0
Exports	43.6	15.6	0	90.2	42.7	0

external markets. In 1979 oil production rates were almost exclusively for direct exports.

- o The ratio of intermediate to final use of crude oil changed dramatically from 1977 to 1979.

Oil Refining

Oil refining also concentrated sales to exports.

- o Exports grew from 15.6 percent to 42.7 percent of all total sales.
- o The percentage share of total sales to all other sectors of the economy declined.
- o Sales of refined products to the oil extraction sector rose sharply (to 5.7 percent).

Electricity

The most important fact is that electricity's sales grew in some sectors but not in others:

- o Sales to the "rest of the economy" increased.
- o Government purchases grew.
- o Sales to oil production expanded.

Proportionally, electricity sales to other sectors declined somewhat:

- o Household purchases declined.
- o The ratio between intermediate and final sales remained more or less stable.

5.4 Macro-Economic Assessment: Final Demand

The greatest contribution of the energy sector to the economy as a whole is by acquisition of foreign exchange through exports of crude oil. Energy contribution to final demand is shown in Table 5-4. In only two years, exports of crude oil expanded from 8.1 percent of all exports to 46.2 percent. Exports of refined products doubled: from 3.5 percent of all exports in 1977 to 7.7 percent in 1979.

As noted earlier the energy sector's final demand accounted for 2.2 percent of GDP by use (or final demand) at market prices. By 1979 this ratio increased to 17.6 percent. Table 5-5 gives a disaggregated view of the energy sector contribution to GDP by use.

TABLE 5-4

Energy Contribution to GNP

(percentage)

	1977			1979		
	Oil Production	Oil Refining	Electricity	Oil Production	Oil Refining	Electricity
Household Consumption	0	1.2	0.9	0	0.8	0.6
Government Consumption	0	1.6	0.6	0	1.8	1.3
Investment	0	0	0	0	0	0
Change in Stocks	1.9	0.5	0	15.5	0.5	0
Exports	7.8	3.4	0	46.2	7.7	0

TABLE 5-5

Contribution of Energy to GDP (by use)

percentage

	1977	1979
Oil Extraction	1.5	15.2
Oil Refining	.3	2.0
Other Energy	.4	.4
Total Energy	2.2	17.6

CHAPTER 6

THE ROLE OF ENERGY IN THE EGYPTIAN ECONOMY

6.1 Production and Supply of Energy

The energy sector increased in importance in the economy from 1977 to 1979.

- o Inputs to the energy sector increased from 4.5 percent of all industrial inputs to 7.2 percent.
- o Energy's share of final demand rose from 2.2 percent to 17.6 percent.
- o Energy's contribution to gross production rose from 5.2 percent to 12.5 percent.
- o The share of gross value added supplied by the energy sector rose from 5.3 percent to 17.5 percent.

6.2 Demand for Energy

The focus of activity within the energy sector reflected a changed market shift towards international markets. In 1977 42 percent of the total sales of the crude oil and mining sector were in terms of exports and 15.6 percent for that of the oil refining sector. By 1979 the share of exports to total sales increased to 90.2 percent and that of the oil refining sector rose to 42.7 percent. Exports of crude grew from 8.1 percent of Egypt's exports in 1977 to 46.2 percent in 1979. Exports of refined products rose from 3.5 percent of 1977 exports to 7.6 percent of 1979 exports. By 1979 exports of petroleum came to account for over 50 percent of Egypt's foreign exchange earnings.

(,))

There was a marked diversion of crude oil to the international market away from domestic markets, and an enormous increase in the sectoral output levels of crude oil. The gross sectoral output level for crude oil increased by more than six times and that of refined products almost doubled. The oil production sector's reliance on inputs of refined products also increased.

These changes reflect an increase in production and capacity of the oil extraction industry from 1977 to 1979. The level of gross value added from the refining sector increased by more than five times from its 1977 level and that of the crude oil sector by almost 15 times. The electricity sector moved its clientele away from consumers to business and the government.

6.3 Policy Issues for the Future

The role of energy in the Egyptian economy has changed drastically from 1977 to 1979. It now accounts for 17.6 percent of Egypt's final demand and commands 7.2 percent of Egyptian inputs. These are sizeable increases from 1977, when energy accounted for only 2.2 percent of final demand and claimed only 4.7 percent of all inputs. Hence, policy for the energy sector is far more pressing because of its greater impact on the economy. Furthermore, because of this significant short-term change, forecasting based on a recent accurate data baseline is critical.

The energy sector is now far more reliant on exports for revenues, so policy analysts must be aware of foreign demand projections for crude and refined petroleum products, including foreign supply and price projections. With this greater importance for the foreign sector, setting prices at world figures appears as an important potential policy instrument for inducing the necessary adjustments in the economy.

PART III

THE SUPPLY SIDE: GEOLOGICAL POTENTIAL AND PRODUCTION FORECASTS

CHAPTER 7

GEOLOGICAL PETROLEUM BEARING POTENTIALS

7.1 Petroliferous Provinces of Egypt

The distinguishing characteristic of Egypt's geology is its complexity -- lack of uniformity and major differences in structure for various regions of the country. This chapter summarizes the country's geological classifications and identifies areas where further research and investment would be expecially profitable. The surface of Egypt is covered by rocks ranging in age from the Pre-Cambrian to the Recent. Those of the Pre-Cambrian cover one-tenth of the land surface and are reported in southern Sinai, the Red Sea mountain ranges of the Eastern Desert, and the southern parts of the Western Desert. The sedimentary cover occupies the remaining nine-tenths of the surface and attains variable thickness, ranging from a few meters to more than ten thousand meters. These sediments are mostly marine, variable, unmetamorphosed, and attain large volumes. Some are reported to contain considerable amounts of deeply buried organic matter and exhibit no signs of strong diastrophism. Those demonstrating these characteristics are commonly found in the Gulf of Suez, the Nile Delta, the northern half of the Western Desert, and Northern Sinai. These regions contain not only the petroliferous provinces already discovered, but also those likely to be discovered in the future.

Petroliferous provinces drawing the attention of operating companies in terms of production and output potential rank as follows:

- o the Gulf of Suez province;
- o the Nile Delta province;

- o the northern half of the Western Desert; and
- o the northern half of the Sinai Peninsula.

Since the establishment of the Ministry of Petroleum in 1973, these provinces were covered by over 70 agreements, including 45 oil companies belonging to 18 nationalities. Nine of these agreements were implemented in 1980-1981 and 20 are under study and will be granted in 1981-82. As a result of increasing investments in exploration there were 12 discoveries in 1980 and 10 in 1981. Of the last ten discoveries seven were oil fields and three gas accumulations.

7.2 The Gulf of Suez Petroliferous Province

The most prolific and prospective oil province in Egypt is the Gulf of Suez basin. Its productive history dates from ancient times when oil was recovered from seepages at Gebel El-Zeit by the Pharaohs along the south-western side of the Gulf. In modern times petroleum was discovered in the galleries of a sulphur mine at Gemsa, south of Gebel El-Zeit (1868). By 1905 the first economic discovery was made in the Gemsa headland through deep drilling, developing the first oilfield in Egypt. This initial success naturally encouraged further exploration drilling by a variety of smaller companies.

The Gulf of Suez covers the region delineated by latitude 27 30', north to 30 north, and includes the western part of Sinai, the Gulf itself, and the eastern stretch of the Eastern Desert. It extends from northwest to southeast and measures some 400 kms. from end to end. Its sides vary in width from 30 kms. to about 100 kms. The surface area measures some 25,000 kms.^{2}

Exploration

At the present time the whole area is covered by petroleum agreements, except for 175 kms.^{2} in the form of separated quadrangles. More than 40 oil fields have been discovered within this basin, with more than 3.0 billion barrels of recoverable oil. Still other major oil reserves are expected to be found with continuing exploration activities. They are expected in the Pre-Miocene clastics, particularly the Nubia sandstones, which have already been proven by deep drilling beyond the conventional payzones in the July and Ramadan oilfields.

Hydrocarbon Potential

There are certain prerequisites for the accumulation of commercial hydrocarbons. These are the source rock, the reservoir rock, the cap rock, and the trap. Considering these elements in the Gulf of Suez basin, the Miocene sediments not only provide the source and seal for all oil accumulation, but also reservoirs for a major portion of the present reserves. In addition, the Pre-Miocene highs provide structural and stratigraphical focal points for oil accumulation. They act as a competent core, over which the Miocene sediments were draped by the effect of differential compaction and the continual subsidence of the Pre-Miocene lows, thus forming compactional anticlinal traps.

The Gulf basin is composed of three distinct sectors:

- a northern sector with a limited number of oilfields;
- a middle sector where most of the discovered pools are located; and
- a southern sector where there has been a recent discovery.

More than 400 exploratory wells have been drilled in the Gulf throughout the history of its exploration.

Prospects for Generating Reserves

It has been determined that the Miocene sands are unequally distributed in the Gulf. Furthermore, their genesis, paleogeology, and the structural elements controlling their occurrence are not fully understood. In addition, the Paleozoic sands were productive in some of the wells that were discovered early and were underestimated in later discoveries.

These issues and the problems they pose require intensive and detailed study to understand the geology of this prolific basin. This kind of investigation would be necessary in order to increase the possibilities of additional giant discoveries in the Gulf of Suez.

7.3 The Nile Delta Petroliferous Province

The Nile delta is the classic example that led Herodotus to apply the Greek letter "delta" as a geomorphological term nearly 2500 years ago. Several distributaries of the Nile once existed through the delta. All but two are now defunct. These are the Rosetta branch to the west and the Damietta branch to the east.

The Nile delta as a petroliferous province covers an area of about 26,400 $kms.^2$, of which 19,200 $kms.^2$ are on land and 7200 $kms.^2$ are offshore.

Until 1966 no exploration drilling for oil research was carried out in the delta except for two wells drilled in the eastern sector in 1947 by the Anglo Egyptian Oil Company (AEO). these were Abu Sultan-1 and Abu Sultan-2; they were bottomed and abandoned as dry holes because of technical difficulties. Water wells, however, were drilled in large numbers, and a few of them reached considerable depths (500 meters). Two wells gave valuable stratigraphic information, the Tamuh and Manawat boreholes drilled southwest of

Cairo. Hydrocarbon shows were reported in the former (8.5 cubic meters methane/day).

Exploration

The first concession in the Nile delta area was granted to IEOC on December 18, 1963. Since then 30 wildcats have been drilled, resulting in the discovery of four proven gas fields. These are Abu-Madi, El-Wastani, Abu Qir, and the new discovery north of Abu Qir. More discoveries are currently undergoing inspection and evaluation. These include the condensate at Qantara west (discovered by IEOC), gas offshore El-Manzala (discovered by Mobil), and oil and gas offshore west El-Bardawil Lake (discovered by IEOC). These discoveries reflect a success ratio of 1:5, which is considered high compared with the international scale, ranging between 1:13 to 1:9. The primary reserves of Abu Madi and Abu Qir fields are estimated to be 2202 billion cubic feet gas and 43.5 million barrels condensates. These reserves are liable to change; additional wells recently drilled give a figure calculated to be three times higher.

Hydrocarbon Potential

Sediments deposited in, offshore, and east of the Nile delta fulfill requirements for hydrocarbon generation. They are commonly thick, fine-grained, rich in organic matter, and possess suitable depth of burial. Among these the Sidi Salem and Kafr El-Sheikh formations are most appropriate as source rock. Sands and sandstones that acquire variable thicknesses and a real extent with fair porosity would be excellent reservoir rock. The fine-grained impervious shales and evaporites are capable of forming cap rock.

These are reported in Sidi Salem and Kafr El-Sheikh formations in addition to the Rosetta anhydrites.

Traps would be mainly stratigraphic in nature due to facies change. Structural traps, however, are expected in tilted fault blocks of early Miocene where there is a dip reserval on the middle Miocene unconformity, providing a good seal for underlying truncated beds.

Prospects for Generating Reserves

Generally speaking, the Nile delta represents one of the most promising hydrocarbon prospects. The following factors merit close and detailed investigation to determine revenue increasing potentials:

- Areas of intersection of ancient shorelines and paleo-drainage courses where sub-deltas or tributary fans which may be promising: these include, for example, the Abu Qir gas field is related to the Canopic fan; the Abu Madi gas sands represent channel fill acquisition; the form of separated sand lenses or fluvial deltaic series is probably related to Sebennytic fan; and the newly discovered Tina oil and gas deposit is related to the Pelusiac fan.
- Data provided by the hydrocarbon shows recorded in stratigraphic formations, on the upthrown side of the delta, should be carefully analyzed: oil shows in lower Eocene limestones at Burg El-Arab well-1 and possibly the recent condensate of Qantara west, for example.
- Estimations of flared gases in general, either in the delta or outside it (in the Gulf region or the Western Desert) should be made and their economic feasibility and potential as source material for energy, fertilizers, petrochemical industries, domestic use, and other industries must be evaluated.

7.4 The Western Desert Petroliferous Province

The northern half of the Western Desert covers an area of about 250,000 kms.^{2}, nearly one-quarter of the total surface area of Egypt. It forms the major part of the unstable shelf extending across the northern half of the territory. The extending surface geological features, which are simple, monotonous, and flat over the region, become exceedingly complicated in the subsurface.

Exploration

Exploration activities in this petroliferous province started in 1940 when the AEO drilled the Daba exploratory well on the coastal belt. This was followed by the Khatatba well, drilled by SOMED in 1944, and Abu Roash wells 1 and 2 drilled by SOE in 1946. From 1954 to 1958 SAPETCO drilled nine wells. This was followed by PPCO in 1964, when exploration drilling intensified. The first commercial oil discovery in the Western Desert, the Alamein field, was recorded in 1966. Since then other companies such as AMOCO, CONOCO, ARCO, and GPC carried out more exploration drilling, resulting in more than 200 wells. Some tested the basement complex.

These wells delineated a number of sedimentary basins and discovered oil and gas accumulations. Among these and in addition to Alamein field, the most important are: the Abu El-Gharadig oil and gas field (1971), the Razzak oilfield (1972), the Umbarka field (1971), Yidma (1969), Meleiha (1972), and the recent oil and gas discovery of the Abu Sennan field (1981).

Recoverable reserves are estimated to be 54.5 million barrels of oil in addition to natural gases, mixed gases, condensates, and liquefied gases from the Abu-El-Gharadig field.

Hydrocarbon Potential

Stratigraphically, the northern half of the Western Desert possesses a relatively thick non-marine series of sedimentary rocks overlying the basement complex. This is followed by a primarily marine succession that varies greatly from one place to another. The geology of the deep-seated basement complex was not studied in detail for lack of authentic data, particularly in the northern part. The sedimentary sequence acquires great thicknesses in sedimentary basins having different geologic ages. These are the Paleozoic, Jurassic, Lower Cretaceous, Upper Cretaceous, and Tertiary basins. Since it is difficult to judge whether these basins are superimposed or not, each was studied separately and its hydrocarbon potential was evaluated.

Prospects for Generating Reserves

The currently producing horizons are dated to the Lower Cretaceous, being composed of sands (as in the Umbarka field), or vuggy dolomites (as the Alamein field), or sands and dolomites (as in the Razzak field). The Upper Cretaceous, however, was reported to be gas-bearing. Most of the wells drilled in the Abu El-Gharadig basin found oil and gas shows in the Turonian and/or Cenomanian. Gas is recorded as well in the Turonian of the Abu Sennan well.

These facts will raise the oil prospects of the Cretaceous in general and the western extension of this prominent basin in particular.

The Lower Cretaceous rock stratigraphic units in this petroliferous province should be revised. They are given different names by different workers and their lateral facies changes have not been ascertained. Therefore, regional correlation was problematic and the subsurface picture remain vague, deiying stratigraphic control.

7.5 Northern Sinai Petroliferous Province

The Sinai Peninsula covers an area of 61,000 $kms.^2$. It is triangular in shape and is separated geographically from Africa by the Gulf of Suez and the Suez Canal. Its eastern border extends for a distance of about 200 kms. from Rafah on the Mediterranean to the head of the Gulf of Aqaba. The southern end of this peninsula consists of high and very rugged igneous and metamorphic mountains. The northern two-thir is occupied by a wide lowland and a great limestone plateau, the higher part of which is called Gebel El-Tih. Its central part is occupied by the yet higher Gebel Egma. The northern part of the peninsula shows a northward dip and is interrupted by hill masses of considerable sizes.

Exploration

Exploration drilling in northern Sinai dates from 1923 when the AEO tested the area east of the great Bitter Lakes. There they drilled a well on the crest of the Habashi anticline. This well was bottomed and abandoned as a dry hole in the Eocene at a depth of 720 meters.

From 1944 to 1947 five deep exploratory wells were drilled. None of then reported hydrocarbon indications except for minor oil shows from the Cenomanian of Nakhl wildcat. After this failure the oil companies become disappointed and regarded northern Sinai as a non-prospecting territory.

From 1966 on, however, about 20 deep bore holes were drilled in northern Sinai. The data of four of these are available: two are located on the lowland south of the Mediterranean and two are offshore. The first two, Katib El-Makhazen-1 (drilled in 1966) and Sneh-1 (drilled in 1969), were bottomed and abandoned as dryholes at depths of 1002 meters and 2990 meters respectively. The offshore wells, Tina-1 and Gal-1, occupy locations northeast of Port Said and Northwest of Rafah respectively. Both wells and Timsah-1 (northeast of Damietta) recorded good oil and gas shows. These are encouraging signs for the Sinai offshore belt, where thick, marine, variable, rich organic matter and unmetamorphosed sediments at drillable depths are well-developed.

Hydrocarbon Potential

The offshore belt is now the focal point for oil companies, particularly the Jurassic, Cretaceous, and Miocene formations, since they would be good source rocks. Porous beds are also developed in these formations and would serve as good reservoirs. The shale beds intercalating these successions would be appropriate for cap rocks.

Prospects for Generating Revenues

It must be concluded that the few, widely-spaced wells drilled in northern Sinai are not sufficient for judging its oil potential. In addition, stratigraphic traps may produce oil in regions where structural traps are barren because of early migration. Thus the barrenness of structural traps, which are generally the first to be drilled, is not a valuable indicator for this region.

7.6 Conclusions

The uneven exploration activities undertaken over the territory of Egypt -- which covers about one million kms.^{2} -- has led to major differences in the extent to which the four petroliferous provinces are considered rich in petroleum-bearing rock. The success in the Gulf of Suez area has been extensive. However, it has overshadowed the actual potentials of other provinces. The relatively poor showing for the Western desert must be considered in the context of the limited drilling that has taken place in the region. There is simply not enough data or information of a sound geological nature to condemn this province. To date, however, foreign oil companies have been reluctant to assume risk and to explore extensively in the Western desert. This reluctance, in itself, has contributed to the pessimistic assessment of the Western desert relative to the other petroliferous provinces in Egypt.

The following chapter presents the results of the Egyptian Petroleum Model, a simulation model which forecasts the production possibilities in various provinces of Egypt -- and for the country as a whole. The model is based on existing geological information and publically available data on investment in exploration and in development. Although the parameters of the model must be refined further, its analytical structure is robust and the results can be accepted, if only tentatively at present.

CHAPTER 8

THE EGYPTIAN PETROLEUM MODEL

In Egypt there is a system of production sharing whereby investments in the exploration and development phase are made entirely by the foreign companies. Once reserves have been established Egyptian incorporated producer companies take over. Foreign companies are compensated through a certain percentage of the oil produced. The remainder goes to the Egyptian government, which uses it to meet domestic demand and for exports. These exports are the country's major source of foreign exchange. Thus, policies affecting exploration, production, and domestic consumption play a very major role in the development of the domestic economy. This chapter describes the structure of the Egyptian Petroleum Model which focuses on the supply side and presents some results and forecasts.

8.1 The Egyptian Petroleum Model: Overview

The Egyptian Petroleum Model (EPM) is a dynamic simulation model of the Egyptian petroleum industry. It projects the supply of petroleum from the different regions of Egypt, and the resulting financial revenues -- all to the end of the century. The EPM model is interactive in nature, designed for easy alteration of parameters to examine the effects of different assumptions about the resource base or about investment activities.

EPM (written in the simulation computer language) was initialized in 1970, to allow analysts to validate its projections and results, and make analyses to a time horizon of 2000. The major characteristic of the model is

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that it represents interactions and processes isn the petroleum sector and it incorporates the geological configurations of the country and its regional differentiations.

Petroleum Sector Processes

The Egyptian Petroleum Model includes four specific aspects of the oil industry in Egypt:

Supply

- exploration investments and activities
- field discoveries and reserve generation
- development investments and decision making
- petroleum production

Demand

- base demand forecasts adjusted by price effects

Finance

- production sharing agreements and financial accounting
- oil revenue for the Egyptian government

Government Policies

- policy inputs into the model which represent the government's policies and preferences on factors like the decline rates, production sharing, government investments, etc.

8.2 Geological Regions and Industry Characteristics of the EPM Model

The EPM model is structured in such a way as to allow two different types of analysis, disaggregation by region and by actor. The regions represented in EPM/7 (the seventh iteration of the model, September 1982) are the Gulf of Suez, the Western Desert, North Sinai, and "Other Egypt" (Nile Delta, Red Sea, and Upper Egypt). The actors are the foreign oil companies, the Egyptian operating companies, and the Government of Egypt.

The model is disaggregated by geological region because the different regions each represent different costs and opportunities. Since costs are a function of infrastructure and accessability as well as the actual field characteristics (such as depth, size and flow rate), and these vary by region, accordingly it is important to provide a separate accounting for each region. However, our main concern was that parameters affected by such factors as frequency of deposits be accurately measured. For instance, the Gulf of Suez is much more desirable for exploration to the oil companies due to the high success ratio there. Consequently, it will probably be fully explored earlier than other regions. This situation can be more easily represented in a regionally disaggregated model. Regions such as the Red Sea, where no commercial discoveries have been made, or the North Sinai, where only one deposit has been found, are obviously difficult to simulate, given little or no data concerning possible production or costs.

For the "Other Egypt" sector, which consists of all regions where no discoveries have been made, the EPM model is formulated so that little or no production occurs, and reserves remain small. This is accomplished by estimating costs to be very high.

For North Sinai, it was necessary to make tentative estimates concerning costs and possible future production, since specific information is not readily available.

Within the geological regional sectors of the model there is a further breakdown according to the actor, i.e. foreign oil company vs. governmental. The rationale behind this stems from the fact that both are active within the Egyptian petroleum industry, but with different goals.

International oil companies are motivated by profit and, as such, tend to act to maximize their revenues, almost to the exclusion of all else. Of course, foreign companies also seek good relations with the producer government in order to ensure continuation of their operations.

The Egyptian government, on the other hand, has a wide variety of developmental and social concerns which will influence its actions. The government is, clearly, especially concerned with generating oil revenues.

8.3 Model Structure

The following section describes in some detail the specific workings of the Egyptian Petroleum Model and the reasons for its structure.

8.3.1 Supply Determination

The supply of petroleum in the EPM model is determined by the desire to produce petroleum, expressed by the actors' investments in exploration. The model assumes that any oil discovered will in fact be produced.

Exploration is undertaken by both foreign oil companies (referred to as "corporate investments") and the Egyptian government (referred to as "government investments." The current version of the model does not yet include a mechanism for determining government investments, and they are set at zero.

8.3.2 Decision Making for Exploration Investment

Naturally, any decision-making process is highly subjective, varying from one person to the next, as well as one organization to the next. Not surprisingly, we do not have any significant documentation as to the explicit decision-making process that occurs in the companies exploring in Egypt, nor do we pretend that this model is an explicit simulation of that process. Rather, we have used our knowledge about corporate behavior in the oil industry in general to allow us to simulate the results according to what we feel are the likely criteria considered by those companies. Specifically, a feedback mechanism is incorporated into the model by which the expected profit to investment ratio is determined endogenously within the EPM model (and hence within the oil industry) and used to influence corporate exploration investments.

The initial step in model calculations is the estimation of costs; in this case the current marginal cost per barrel is used to represent expected costs, since they represent the best information available on future costs. The total expected costs of the deposit can then be estimated by multiplying the expected costs per barrel times the expected size of the discovery. Discovery costs are a function of the amount of oil remaining to be discovered out of the original resource base, and development costs increase as a function of time.

The corporate share of oil can then be calculated using the cost of the deposit and the price of oil to determine the expected cost recovery oil, and the production-sharing ratio determined elsewhere in the model (see below) to show the amount of profit-sharing oil that will be available to the company. The economic value of the oil is then derived using the world price of oil. Price is used rather than some expected price on the assumption that price expectations have a very short horizon.

Given the expected value of the profit-sharing oil the company can expect to receive for its investment, along with the expected cost to be incurred in discovering and developing the field, the profit-to-investment ratio can be determined. This is used to calculate the impact of the corporate commitment to on exploration.

8.3.3 Field Discovery

Reserves are very simply calculated as a function of effective exploration investments and discovery costs. The former represent lagged exploration investments, and the latter are calculated, as discussed above, from an increasing curve representing the amount of oil remaining to be discovered. In other words, the more oil is discovered and the less remaining to be discovered, the more expensive it is to do so. This yields an average discovery rate over time and, combined with depletion from production, gives the amount of proved reserves at any given time.

8.3.4 Development Decision-Making

Although the caveats about decision-making noted in the previous section apply here as well, industry behavior in this sphere is much less subjective and much better understood. After oil has been discovered, the uncertainty involved is greatly reduced; it becomes a matter of making the most efficient recovery of the earlier investment. This involves production of oil at what is known as the Maximum Efficient Rate (MER).

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Despite substantial variation from field to field for technical reasons, a good rule of thumb sets aggregrate MER at a 15 to 1 ratio. In other words, the technical limit to production is considered to be 6.7 percent of a field's reserves. In order to recover investments as rapidly as possible, oil companies generally aim for this level, although in some instances, especially in OPEC countries , policy decisions prevent them from doing so.

In Egypt, however, producing companies are relatively free in their operations. Government supervision is designed mainly to ensure no loss of oil recovery due to overproduction. Thus we have assumed that development investments represent a desire to reach a capacity equivalent to one-fifteenth (6.7 percent) of reserves, plus an allowance for capacity to be shut in for maintenance, weather, etc. Investments are also made to replace capacity lost to depreciation. Following the appropriate lag-time for development investments (which we assume to be two years in the Gulf of Suez), the capacity comes on-line.

8.3.5 Production

Since Egypt has a severe need for its oil revenues, it has been assumed that measures will be taken, especially concerning pricing policies, to ensure that production will be maintained at full capacity. (Inasmuch as the government's petroleum prices have always been competitive, that is, consistent with maximizing gains for Egypt, we feel confident that this assumption will not be challenged.) As a result, production is directly proportional to production capacity, but 10 percent less. This 10 percent is the margin allowed for maintenance, etc.

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8.3.6 Demand

No attempt at a sophisticated portrayal of demand was made in the EPM model, since the model does provide the capability to test the effects of alternative scenarios regarding both economic growth and pricing policies.

Base Demand

As in many other formulations of demand in simulation models, we have used a base demand, which is then modified by price. This represents the effects of price on demand. The base demand consists of previous demand plus demand growth, which is a function of economic growth and income elasticity. (Income elasticity is estimated from past economic growth and demand, and appears to be approximately 1.) Egyptian economic growth in the model was set at 6 percent from 1980 to 2000. The current version of the EPM model does not include a feedback effect from oil income into the domestic economy.

Price Responsiveness

Since domestic prices in Egypt have been roughly constant for the last decade, estimating the price elasticity on demand is very difficult. However, if it is assumed that prices do not change significantly over the next twenty years, i.e., if subisidies continue, then the price elasticity is unimportant. Since the cost of the subsidies, both directly and in terms of lost oil export revenues, are of great interest, and we wish to test different pricing policies, we have included a price multiplier effect on demand using an elasticity of -.3, which is approximately the same as in most industrial countries. Energy analysts still disagree as to whether the elasticity is higher or lower in developing countries.

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For the base case scenario, we have assumed that domestic product prices will slowly increase, as they have recently, on the order of $1/bbl. of crude equivalent every five years. In a subsequent section of this report the results of different price paths will be discussed.

8.3.7 Financial Sector

Since August 1973, Egypt has used production-sharing contracts in the concessions leased to foreign oil companies. The standard contract divides oil produced into cost recovery and production-sharing oil, with the precise division varying from contract to contract. In most cases, a maximum of 40 percent of oil produced is reserved for cost recovery, although the exact amount actually allocated depends on the cost of the oil, and the world price at the time of production. In fact, the recent increases in oil prices has kept the percentage of oil needed for cost recovery well below 40 percent and recent contracts have been written specifying 30 percent as the maximum.

Methods of Financing Specified in EPM

The costs to be recovered consist of discovery, capacity, and operating costs. The first two, determined by exploration and development investments respectively, are actually incurred, for the most part, before production begins. Thus, the contracts explicitly provide for recovery to occur after production startup, over a predetermined period, usually four to eight years for exploration investments and five to ten years for development investments. (Operating costs are recovered during the same year in which they are incurred.)

In recent years approximately 10 percent of oil produced in Egypt has gone to cost recovery, with the remaining 90 percent going to production sharing. Although the division of oil between the oil companies and the EGPC varies somewhat among contracts, a split of about 80/20 in favor of the government is prevalent, with variations according to depth of water for offshore contracts and/or production levels reached.

Once the oil has been divided, the government must allocate its share between domestic consumption and exports. Inasmuch as domestic product sales are at very low prices, profits to the EGPC are currently non-existent, so profits are largely determined by the level of government exports and the world price of oil. Of course, recent changes in domestic pricing policies could alter this.

Model Specification of Finance

The determination of the division of oil in the Egyptian Petroleum Model is based largely on the formula described above. Cost recovery oil is subtracted from total production on the basis of the price of oil and total costs. Total costs are calculated on the basis of lagged exploration and development investments and current operating costs. The remaining oil, labelled total production-sharing oil, is then divided between the companies and Egypt, according to an exogenous factor based on rough observations by the modeller. Unfortunately, because of the slight variations between contracts, projecting the precise percentage division that will exist involves predicting discoveries and production levels by field, something which is virtually impossible.

For the current scenarios examined in the model, a constant division of 80/20 was used as the base government/company split, which is admittedly conservative. Added to that is a production level share, which increases the

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government's split by 1 percent for every 200 million barrels per year produced, as a rough approximation of the individual gradations appearing in many of the contracts.

The final step, allocation of oil between domestic consumption and exports, uses the formulation described above. It does not provide for product imports and exports which occur to even out the disparities between demand and refinery output, but rather computes net exports. There is some loss of precision thereby, since Egypt has traditionally imported lighter, more expensive products and exported heavier, less valuable ones. However, unless we can predict demand by domestic sector or for different products, as well as forecasting accurately the refinery activity in Egypt, this loss of precision in the forecasts cannot be corrected easily.

Oil Revenues in the EPM Model

Egyptian oil revenues in the EPM model therefore consist of governmental exports of crude times the current world price. No effort has yet been made to correct for quality differentials of crudes and nothing can be done to simulate short-term price movements.

8.3.8 Government Decision-Making Sector

At present, the model incorporates a sector to cover all exogenous policy decisions that must ultimately come from the government. Its contents include variables covering desired decline rates, the production-sharing fraction, domestic petroleum porduct prices, and government investments in the oil industry. All have been discussed in the appropriate sections above.

8.4 Forecasts for the Base Case

For this chapter, one set of results for the Egyptian Petroleum Model is presented and examined: it is the base scenario, to indicate general functioning of the model. In a companion report three alternative scenarios are examined to show responses to changing inputs. This section will discuss the base results, with figures generated by the computer as illustration of the types of results from the EPM model.

We may note that these resykts are different from the results that were reported in an earlier report entitled "Resource Development and Policy in Egypt: Petroleum and Natural Gas: Summary and Conclusions," TAP Report 83-3, 1983. The current version is based on more up to date assumptions on parameters. The following is a list of assumptions with respect to the different parameters in the two alternative versions of the model:

		Earlier Version	Current Version
1.	Prices	DOE projections of prices	MIT projections of prices
2.	Gulf of Suez desired decline rate	.067	.070
3.	Effective development investment lag	2 years	3 years
4.	Initial corporate exploration investment	100 million LE	120 million LE

Both versions are based on estimates of discovery costs which have been taken as a function of remaining reserves. However, the cost estimates on the latter version are slightly lower than the earlier one.

8.4.1 Basic Results for Egypt

Since the EPM model is intended to be self-sufficient for the most part, the main exogenous variables are domestic and international crude prices. The prices which we have used for the base scenario (and elsewhere unless specifically stated otherwise) are shown in Figure 8-1. Both international and domestic crude prices are assumed to climb gradually, although the domestic prices more gradually than international prices. These prices are inputs into the model as follows: international prices influence the level of exploration investments made by oil companies, which determines reserves and, ultimately, production, as well as setting the value of exports, while domestic prices affect domestic consumption, which helps determine exports levels.

The resulting production in Egypt by region is shown in Figure 8-2. The peak in Suez Gulf production is indicative of the success of the exploration effort in the early 1980s, which occurred as a result of the price hikes in the 1970s, and saw the large, low-cost deposits discovered and exploited. Subsequently, exploration and production slowed. Rising prices of crude oil led to increased interest in the Western Desert and the North Sinai regions (the latter showing also the delaying effect of the Israeli occupation) and result in increased production there. Other Egypt produces oil, but on such a small scale that it is not observable here.

Figure 8-3 shows the manner in which the petroleum produced is disbursed and Figure 8-4 shows the manner in which Egypt disposes of its share. The importance of domestic consumption in reducing oil available for export can be clearly seen.

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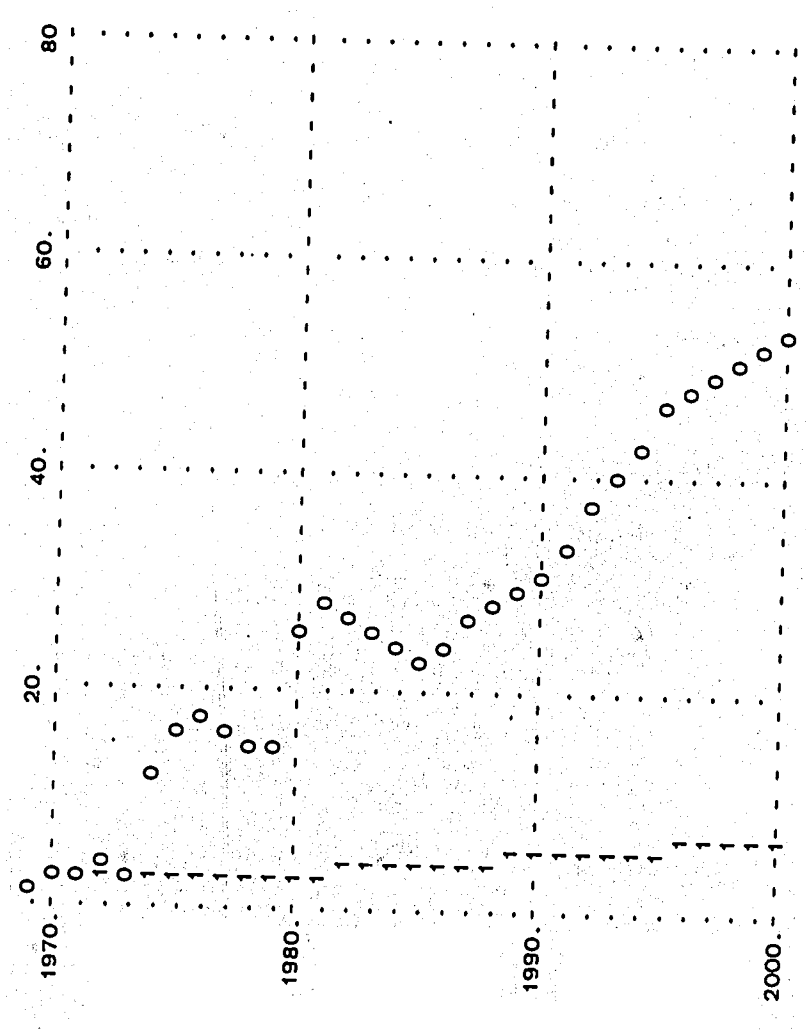
FIGURE 8-1

Prices

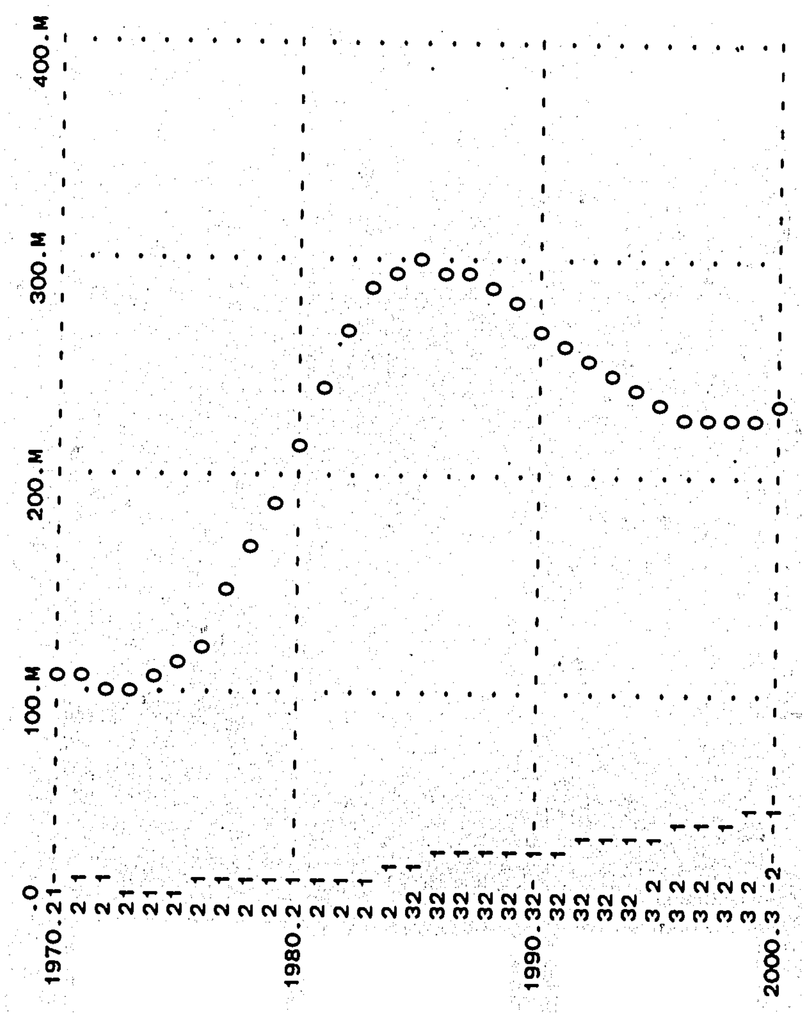
(1980 dollars)



0 = Price of Saudi Light
1 = Egyptian Domestic Prices

FIGURE 8-2

Production by Region
(million barrels per year)



0 = Gulf of Suez
1 = Western Desert
2 = North Sinai
3 = Other

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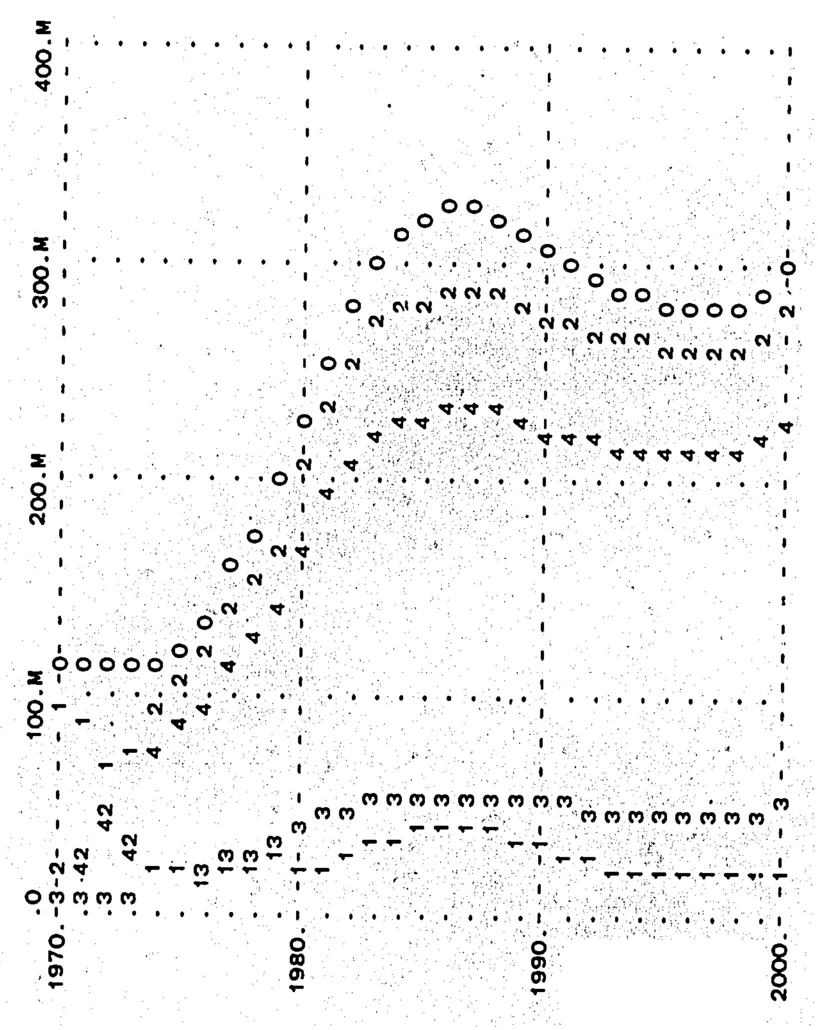
FIGURE 8-3

Production Distribution

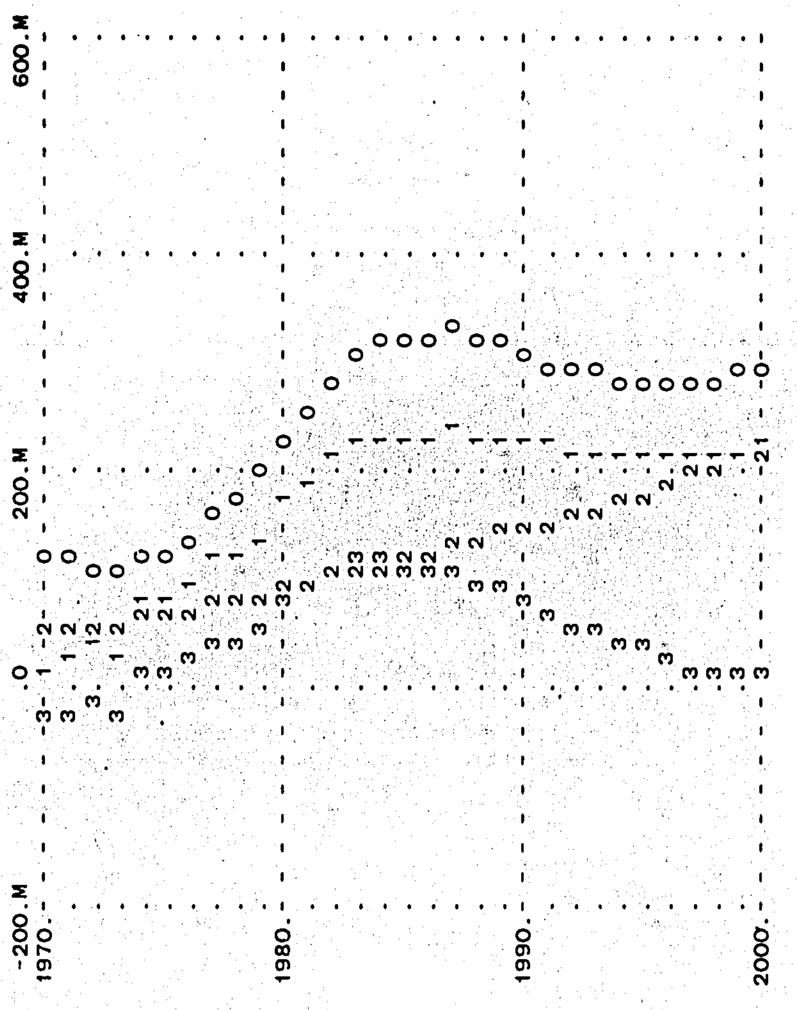
(million barrels per year)



0 = Total Production
1 = Cost Recovery Oil
2 = Production-Sharing Oil
3 = Oil Company Share of Production
4 - Egyptian Share of Petroleum

FIGURE 8-4

Egyptian Share of Production
(million barrels per year)



0 = Total Production
1 = Egyptian Share of Production
2 = Egyptian Domestic Oil Consumption
3 = Egyptian Governmental Oil Exports

8.4.2 Results for the Gulf of Suez

The subsequent figures provide a more detailed view of the behavior of the Gulf of Suez region, the most prolific petroleum province in Egypt. Figures 8-5 and 8-6 show the underlying resources and discovery and production rates, while Figure 8-7 indicates the capacity needed to provide the observed production. The investments which result in this production performance can be seen in Figure 8-8, with the influence of the price hikes in 1973-74 and 1979-80 clearly visible in the subsequent surges in exploration, with development following that. The trends and forecasts for costs of exploration and development can be seen in Figure 8-9, where increases are due to depletion of cheaper fields and the passage of time. Note also the increases in the marginal cost per barrel which is the ost of producing one additional barrel. The resulting behavior of the influences on corporate exploration investments are shown in Figure 8-10.

8.5 Sensitivity Analysis: The Effects of World Prices on the Petroleum Industry in Egypt

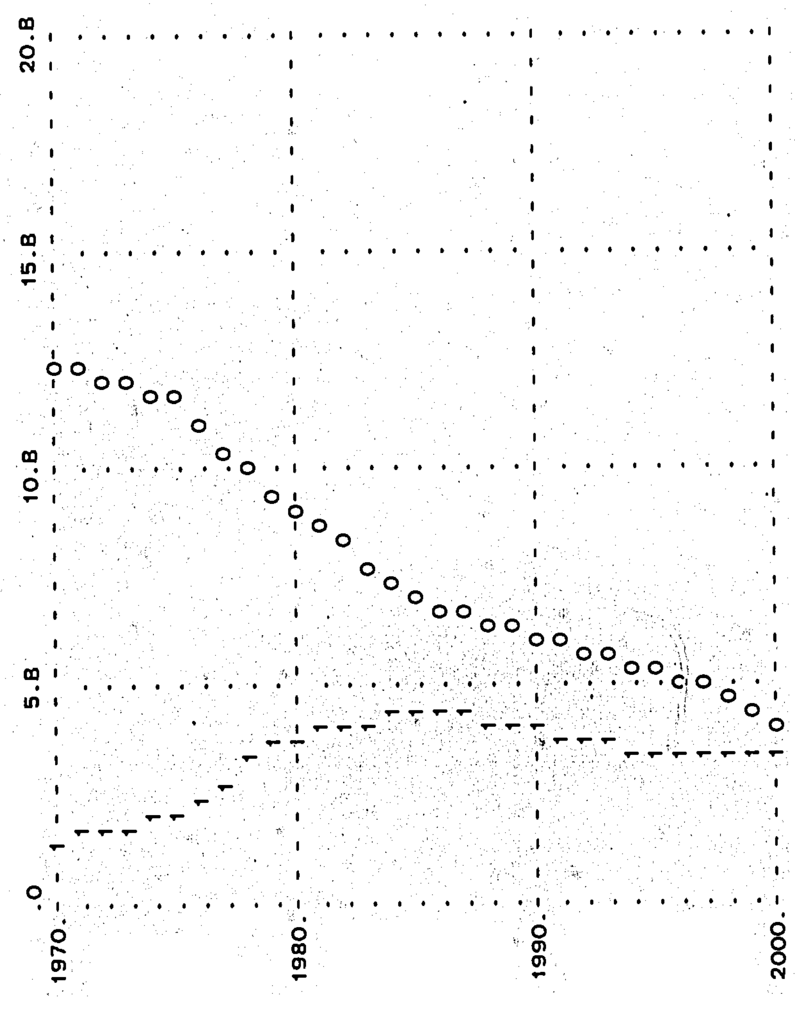
It is difficult to forecast world oil prices. Nonetheless, testing the effects on Egypt of the price assumptions in the model is very important. Figure 8-11 shows the "high" and "low" price paths used. These prices constitute the basis for different scenario analyses.

8.5.1 Investments in Exploration

The impact of different oil prices on expected profits from oil sales can be seen through the resulting exploration investments, shown in Figure 8-12. Since production costs are not directly affected by prices, the

FIGURE 8-5

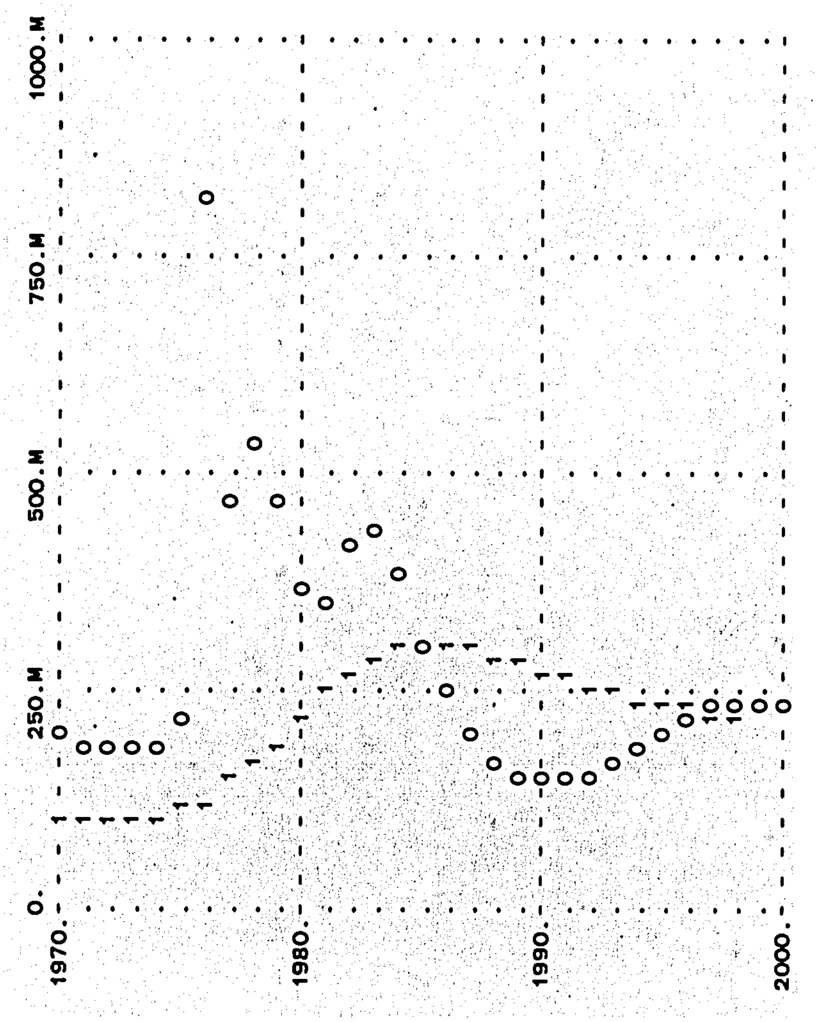
Gulf of Suez Resources
(billion barrels)



0 = Undiscovered Oil
1 = Proved Reserves

FIGURE 8-6

Gulf of Suez Discoveries and Production
(million barrels per year)



0 = Discovery Rate
1 = Production Rate

Note: The high discovery rate in 1976 represents the return of oil fields by Israel.

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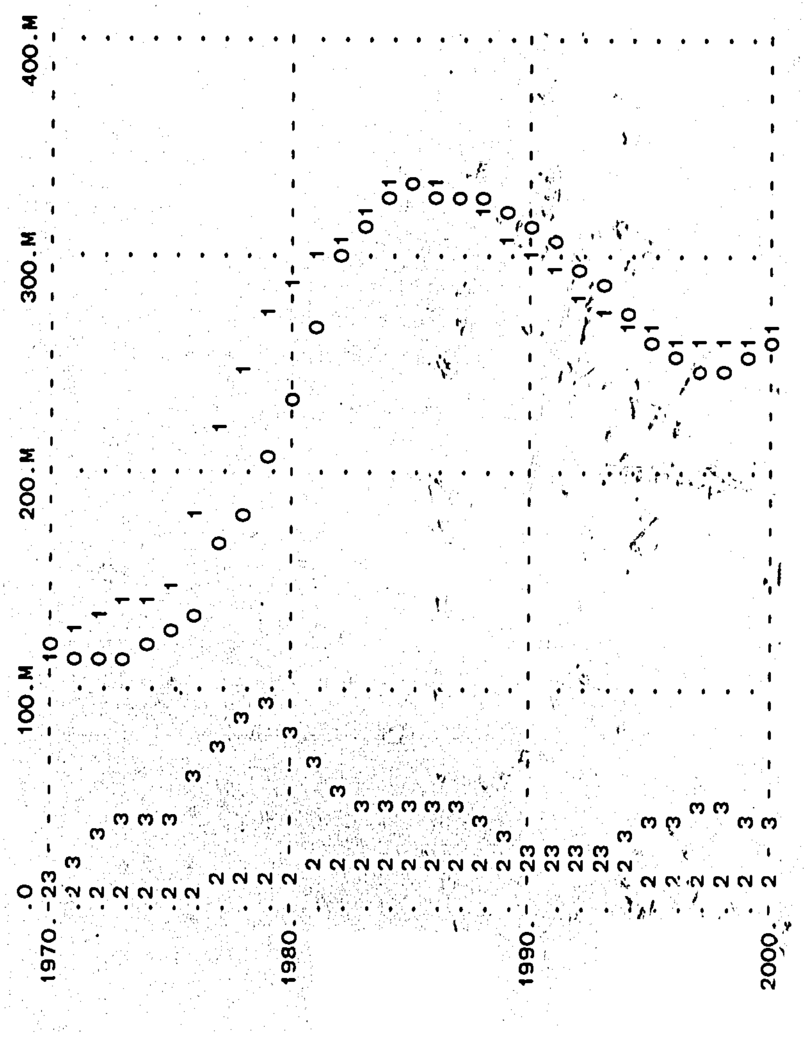
FIGURE 8-7

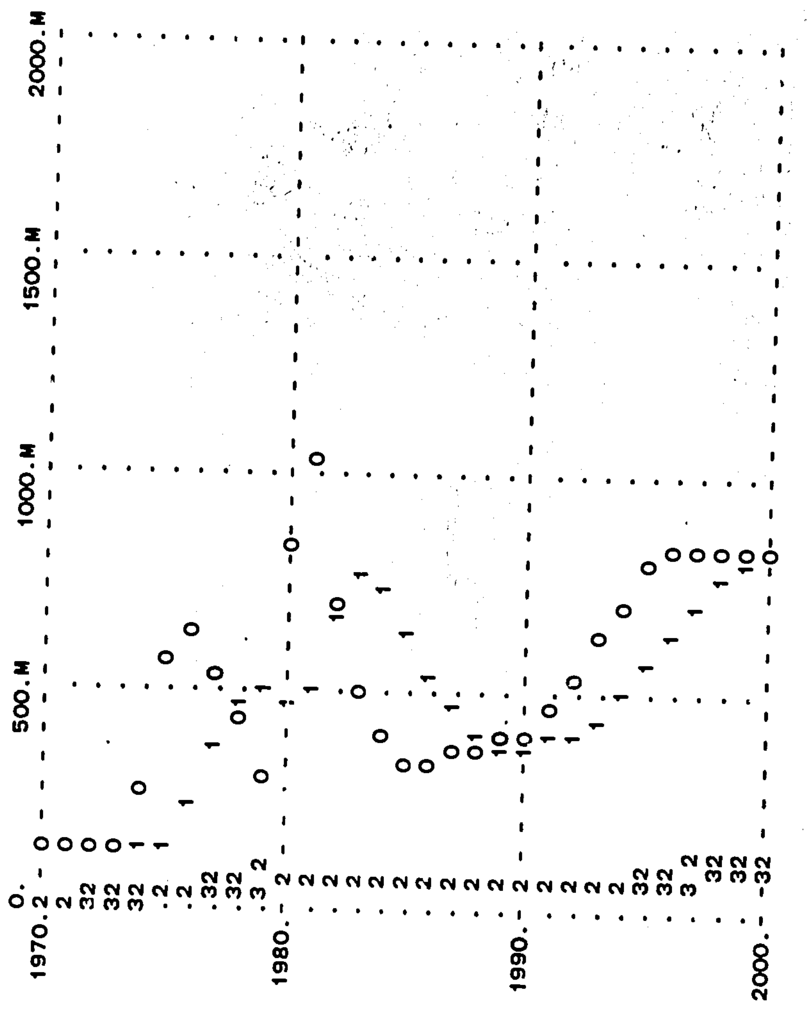
Gulf of Suez Capacity
(million barrels per year)



0 = Production Capacity
1 = Desired Production Capacity
2 = Capacity Loss to Depreciation
3 = Desired New Production Capacity

FIGURE 8-8

Gulf of Suez Corporate Investments
(million 1980 dollars per year)

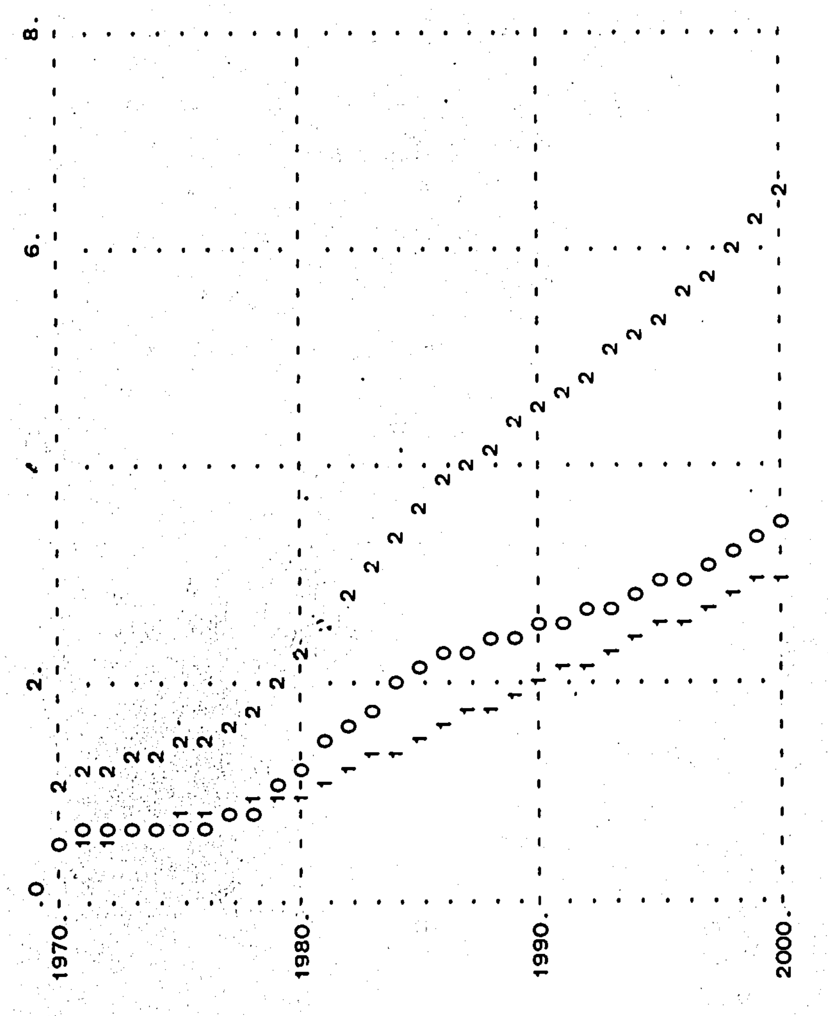


0 = Exploration Investments
1 = Lagged Exploration Investments
2 = Development Investments
3 = Lagged Development Investments

FIGURE 8-9

Gulf of Suez Costs

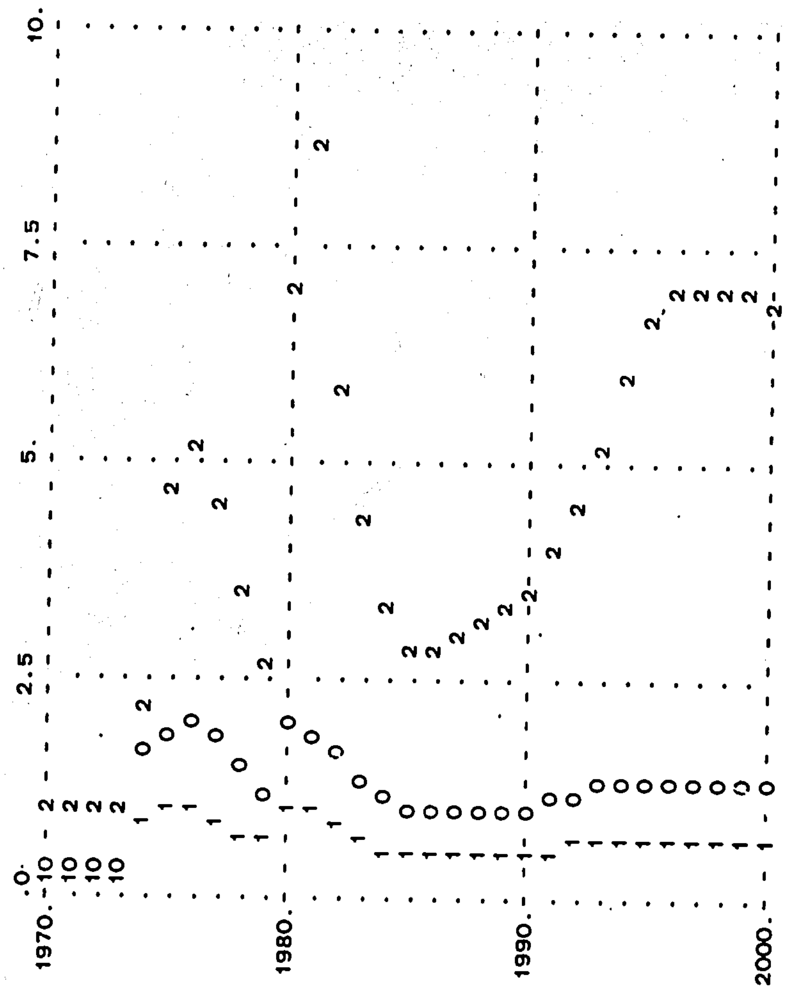
(1980 dollars per barrel)



0 = Discovery Costs
1 = Development Costs
2 = Marginal Cost per Barrel

FIGURE 8-10

Gulf of Suez Influences on Exploration



0 = Expected Profit to Investment Ratio
1 = Corporate Technical Inputs for Exploration (Elasticity)
2 = Corporate Impact and Results on Exploration (Multiplier)

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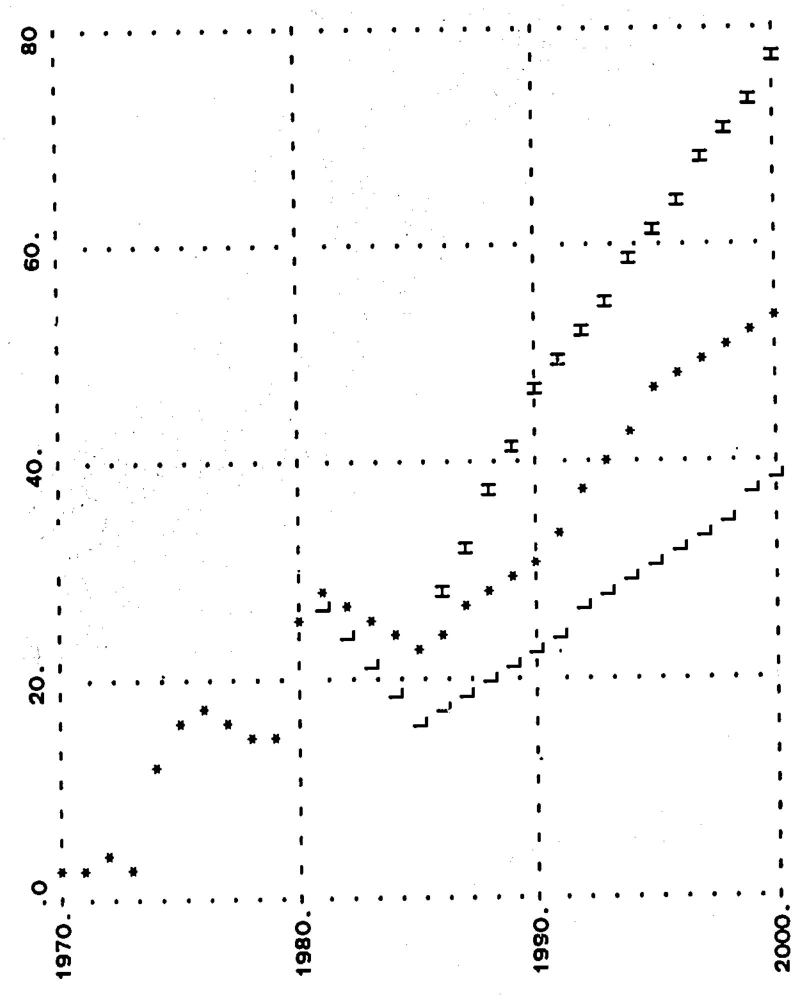
FIGURE 8-11

Price of Saudi Crude

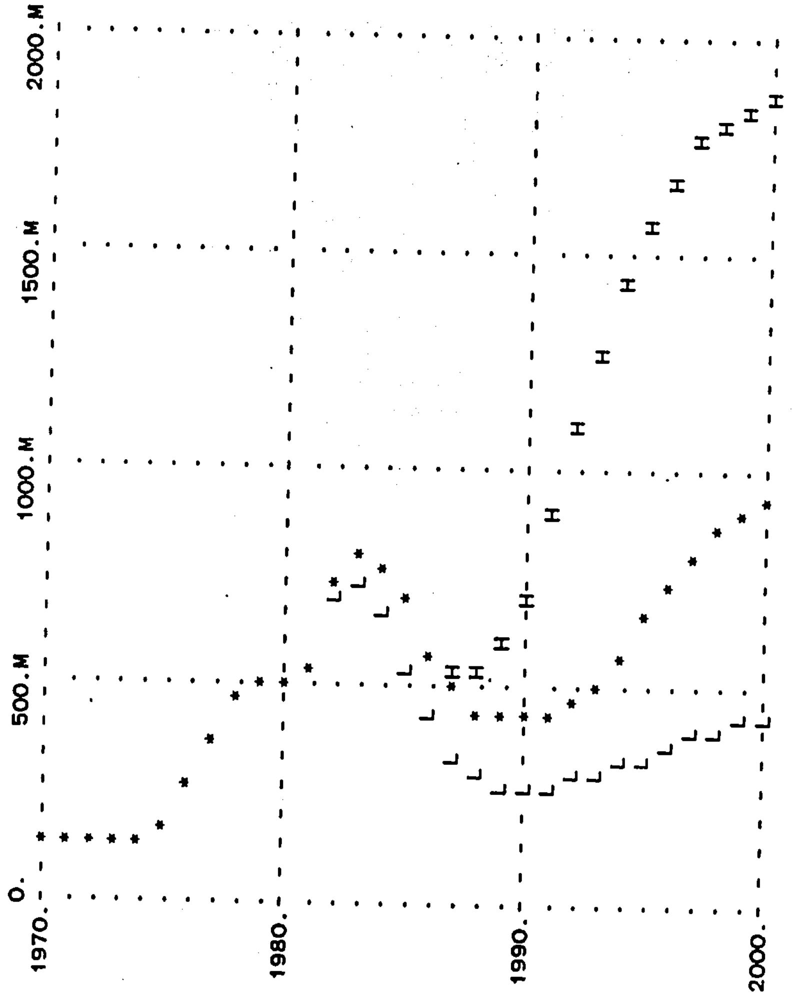
(1980 dollars/barrel)



* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

FIGURE 8-12

Effective Exploration Investments
(million 1980 dollars/year)



* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

relationship to prices and profits is not one-to-one. Thus, the influence on exploration is not linear. In fact, the impact of different world crude prices on exploration investments is, if anything, exaggerated, and this impact has serious policy implications: with higher world oil prices there will be a much higher level of investments in exploration.

8.5.2 Production

Exploration investments lead to discoveries, reserves, and production in a logical sequence, and the different levels of investments have the anticipated impacts on them, as can be seen in Figure 8-13, 8-14, and 8-15.

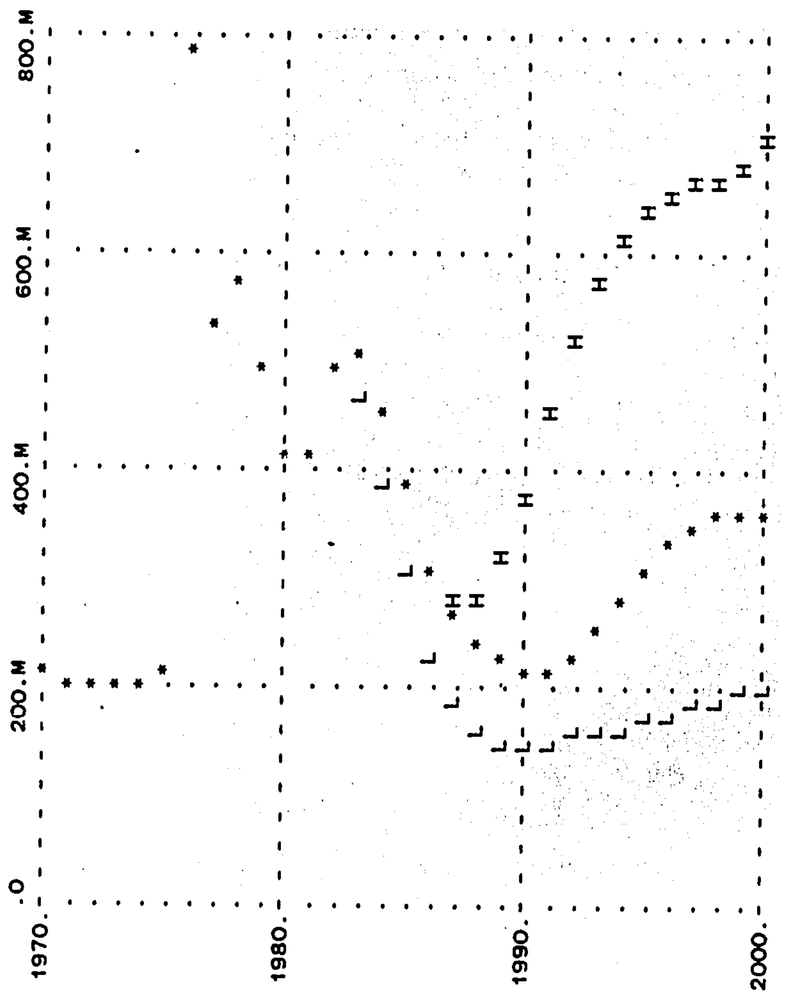
Higher world prices lead to higher production ultimately, just as lower world prices result in lesser amounts of oil actually produced. There is a time lag which takes into account the slow reaction of the system to the changes. Since government often relies on projections of its future oil production and revenue in its economic planning, it is important to understand this lag phenomenon as well as the tendency for the lag effect to be compounded.

8.5.3 Exports

One of the compounding factors stems from the fact that consumption and production are not directly interrelated in Egypt, and therefore exports, which are in essence a residual of the two, exaggerate the change in production levels, as can be seen in Figure 8-16. Lower world prices will lead to more than proportionate declines in exports relative to the base case. Higher world prices will substantially increase Egyptian exports. The impact is compounded again by the fact that governmental revenue levels are directly

FIGURE 8-13

Discovery Rate
(billion barrels/year)



* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

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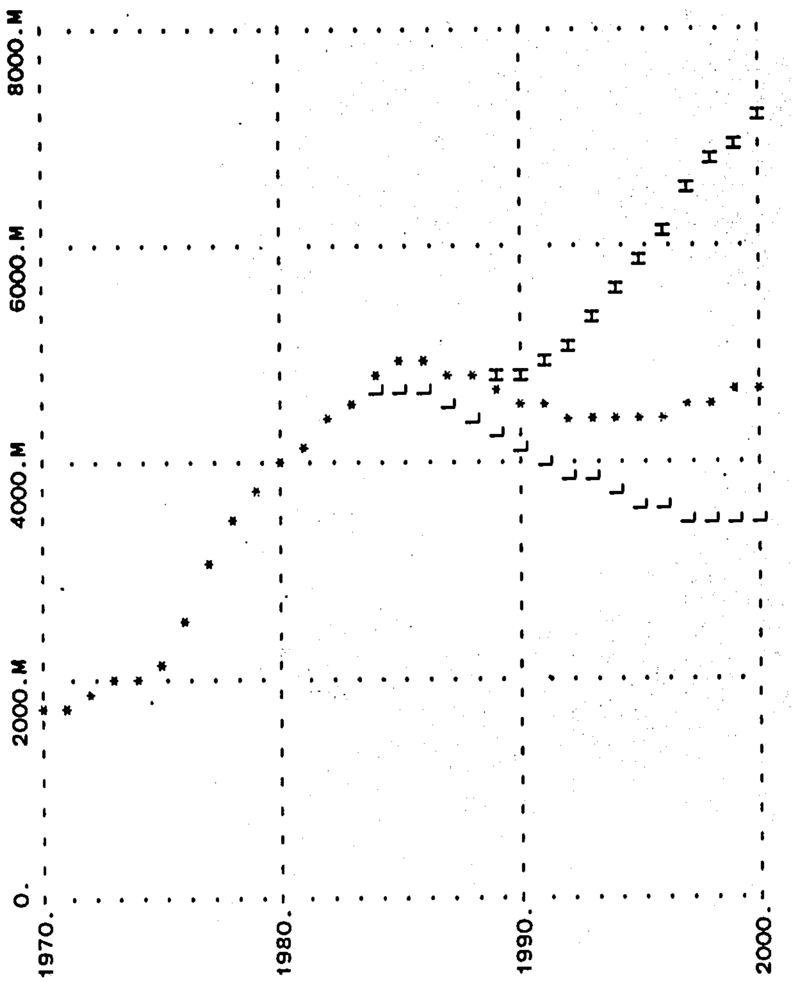
FIGURE 8-14

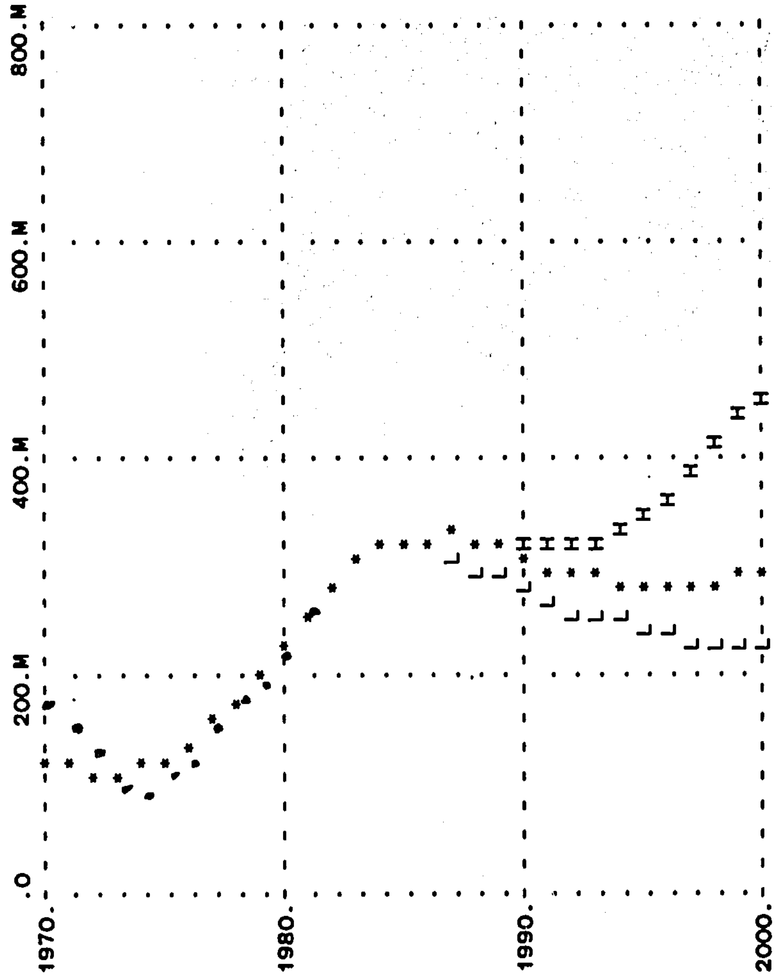
Oil Reserves
(billion barrels)



* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

FIGURE 8-15

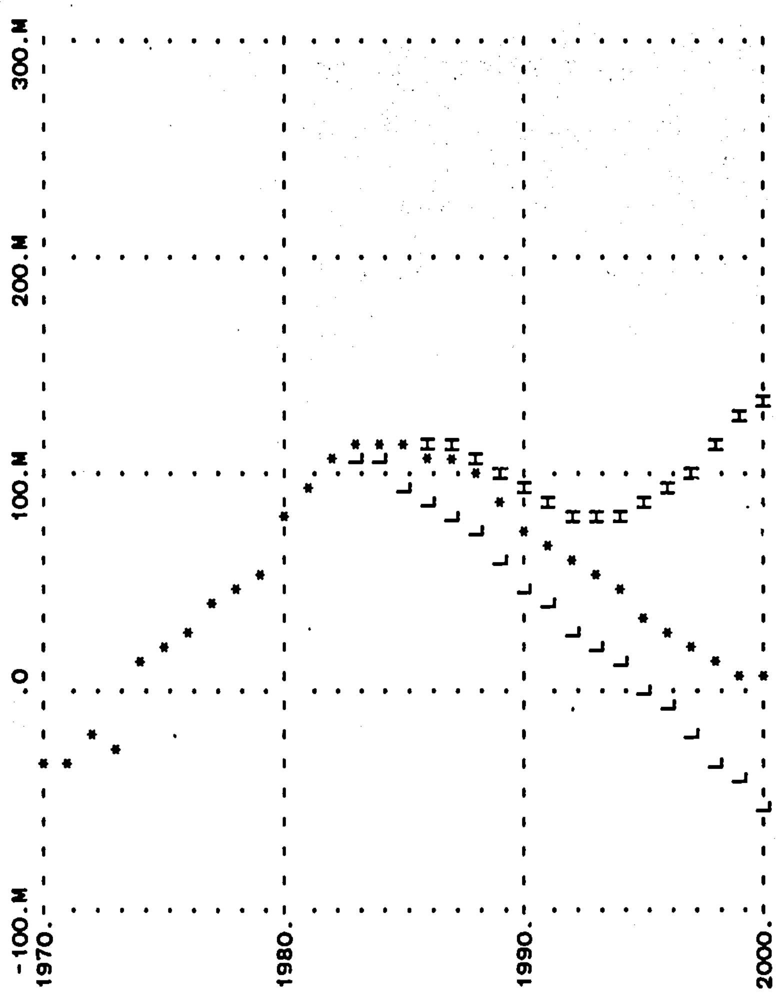
Total Oil Production
(million barrels/year)



• = Actual Production
* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

FIGURE 8-16

Egyptian Governmental Oil Exports
(million barrels/year)



* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

related to both exports and world price levels, so that the differences between the "low" and the "high" price paths is again substantial. Figures 8-17 and 8-18 show the results.

8.6 The Effects of World Prices on Egypt's Resource Base: Sensitivity Analysis

Although there are a variety of means of estimating the resource base of given area, none has ever proved particularly reliable. A success ratio of fifty percent is considered exceptional in the oil industry and until drilling is undertaken, the actual occurrence of petroleum remains uncertain.

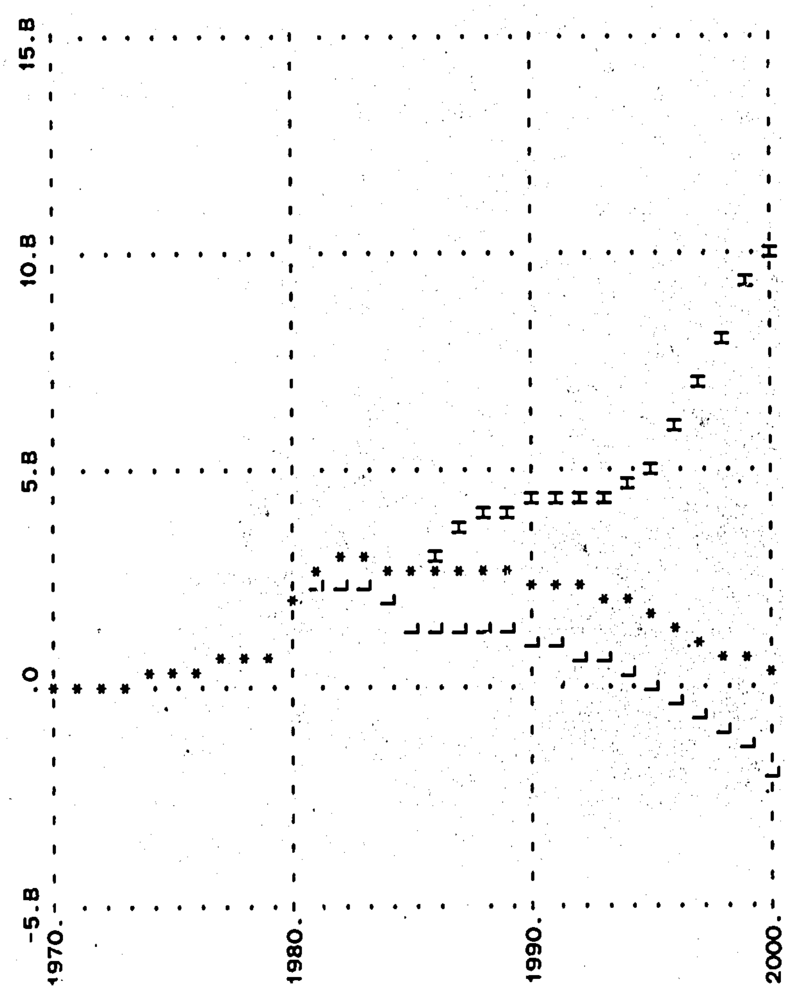
It is therefore essential to examine the impact of different assumptions about the underlying resource base in Egypt, that is, undiscovered oil. In this analysis we tested the effects of changing the initialization of the variable "undiscovered oil" for the year 1970 so that the results can be evaluated over the past decade as well as in the projection to 2000.

Since the model has not been fully parameterized yet, the fit with actual data should be only partially indicative of the validity of the assumptions regarding the "true" resources of Egypt. The sensitivity analysis is set as follows: For the high resource scenario, the amount of undiscovered oil is doubled to 45.6 billion barrels, including 10 billion barrels in the North Sinai region which is not initially available in the IPM model due to the Israeli occupation. In the low resource base scenario, 11.4 billion barrels remain to be discovered, including 2.5 billion barrels in North Sinai.

The results are illuminating. The amount of oil remaining to be discovered has a direct impact on expected costs and oil-related profits, and thus influences the amount of exploration investments, as shown in Figure 8-19. There is a tendency under all three scenarios to move towards an equilibrium,

FIGURE 8-17

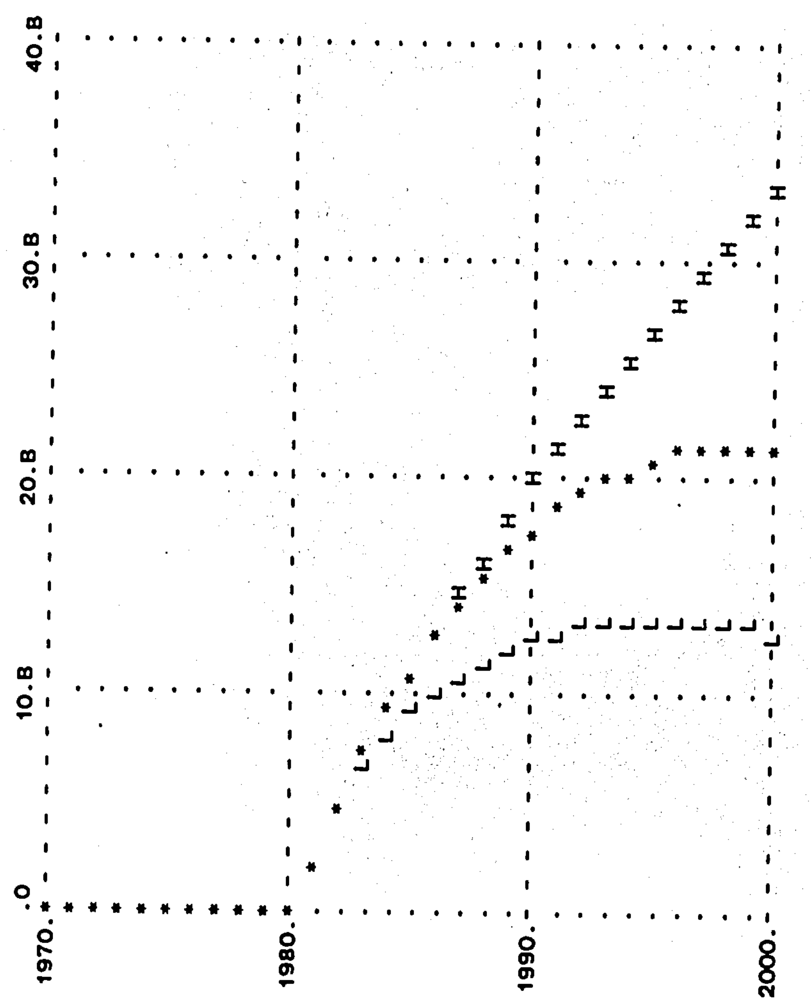
Government Oil Revenues
(billion 1980 dollars/year)



* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

FIGURE 8-18

Governmental Oil Income
(discounted and cumulated+ billion 1980 dollars/year)

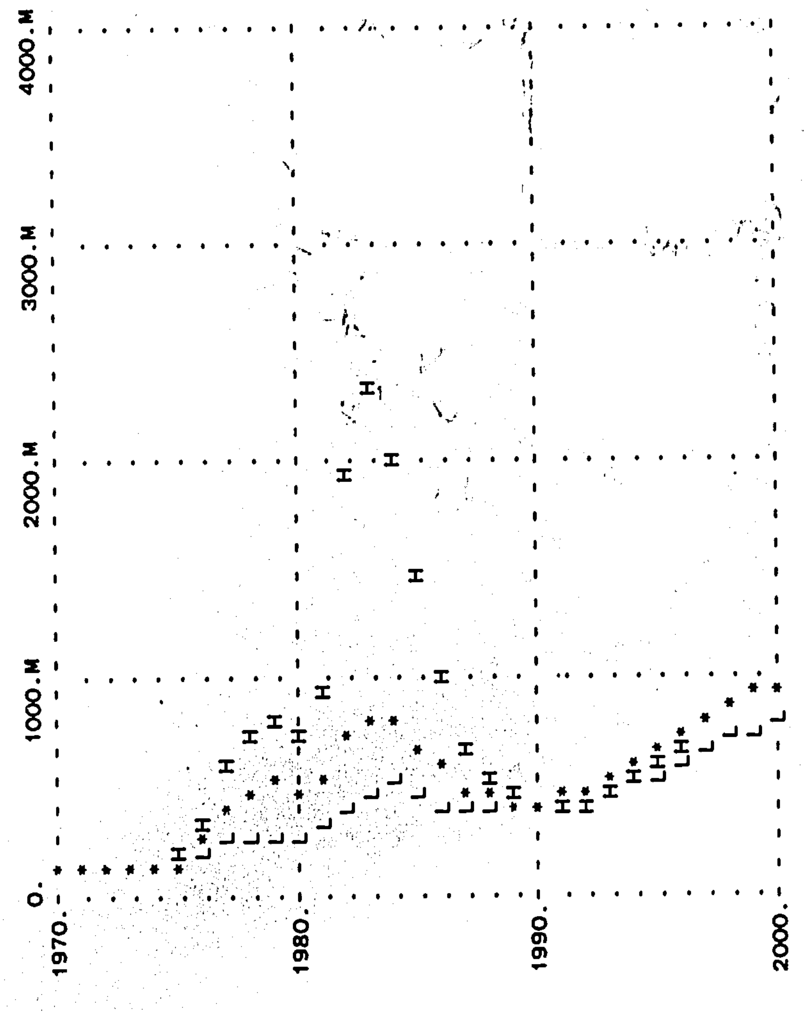


+Discounted from 1980 at a 10 percent discount rate.

* = Base Scenario
H = High World Crude Price
L = Low World Crude Price

FIGURE 8-19

Effective Egyptian Exploration Investments
(million 1980 dollars per year)



* = Base Scenario
H = High Resource Base
L = Low Resource Base

reached about 1990. At this point reserves, discoveries, and production are relatively stable and at higher levels than earlier. (See Figures 8-20, 2-21, and 2-22.)

It should be emphasized at this point that the large activity in exploration investments, discoveries, etc., which occurs most noticeably in the high resource base scenario is due in part to the addition of the undiscovered oil from the North Sinai whose impact is doubled under these assumptions. The 1979-80 price increases also account for much of the change.

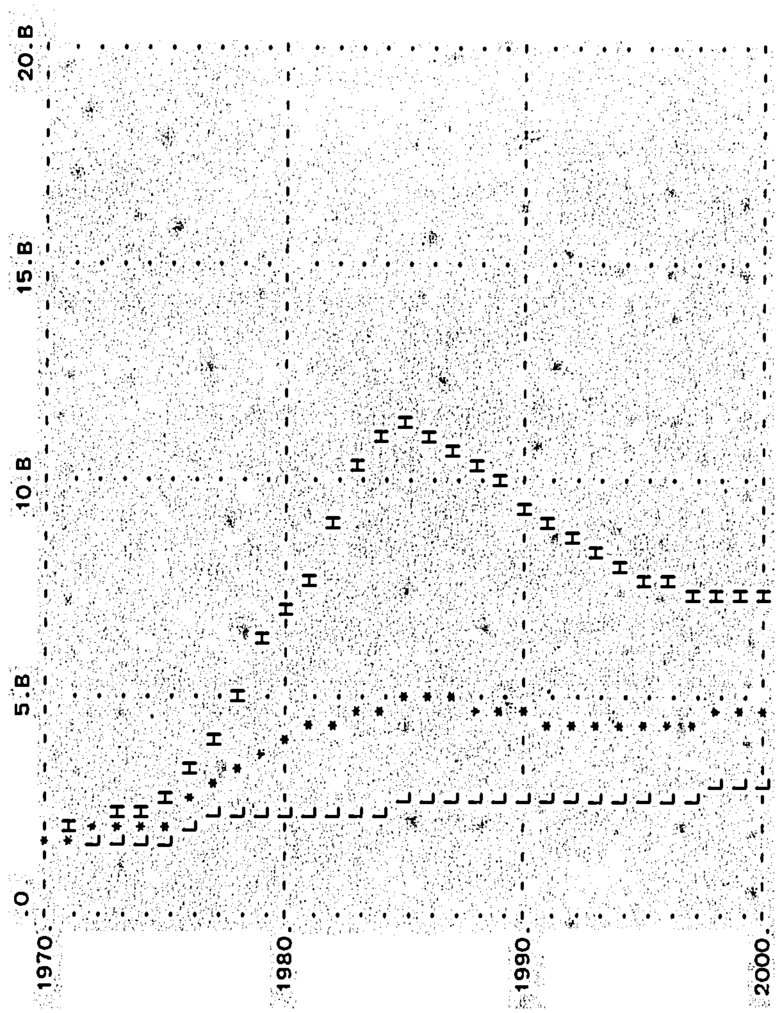
One clear result is that for a given price scenario and resource base, exploration and production will tend toward an equilibrium. Increasing prices are necessary to offset the impact of increasing costs. Without price increases a more normal bell curve, often used to show lifetime field production, would undoubtedly be seen.

The effect of these different assumptions on Egypt's petroleum exports can be seen in Figure 8-23. Since domestic consumption is not directly affected by these factors, the impact on exports is magnified greatly. If domestic consumption were lower than in the base case, i.e., with subsidized petroleum prices, then the difference would be less severe, due to higher levels of exports in every case.

Finally, of course, the amount of exports is directly and positively correlated to the revenue which the government receives, shown in Figures 8-24 and 8-25. The higher exports are, the higher revenues will be, given the same price assumptions.

FIGURE 8-20

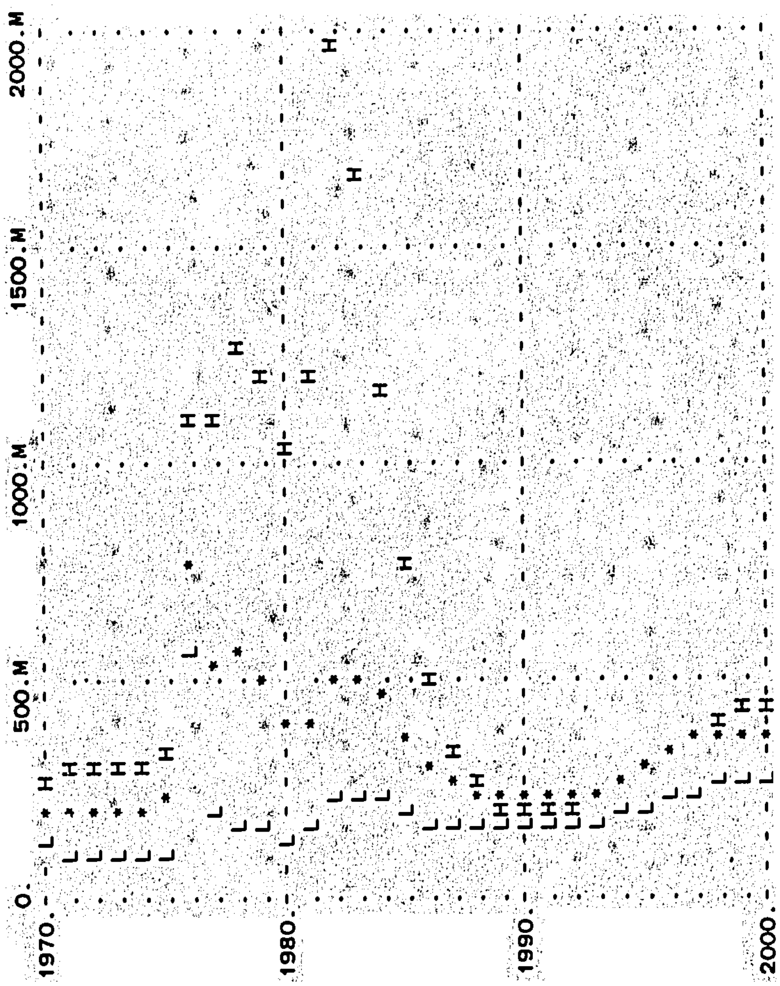
Egyptian Proved Reserves
(million barrels per year)



* = Base Scenario
H = High Resource Base
L = Low Resource Base

FIGURE 8-21

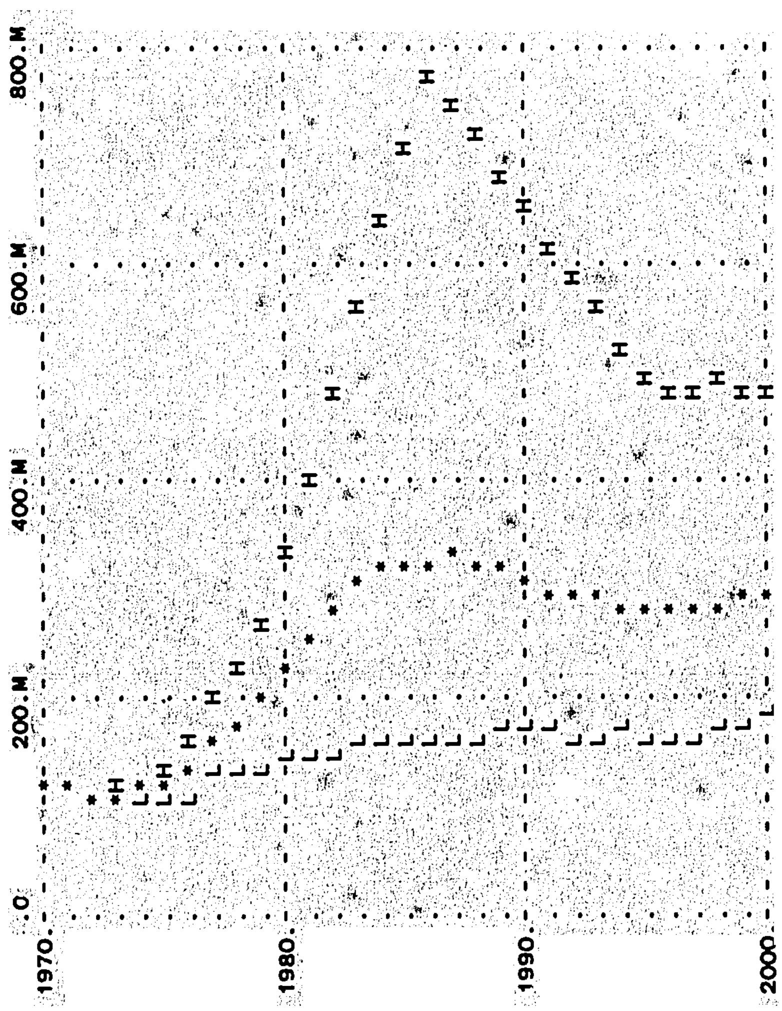
Egyptian Discovery Rate
(million barrels per year)



* = Base Scenario
H = High Resource Base
L = Low Resource Base

FIGURE 8-22

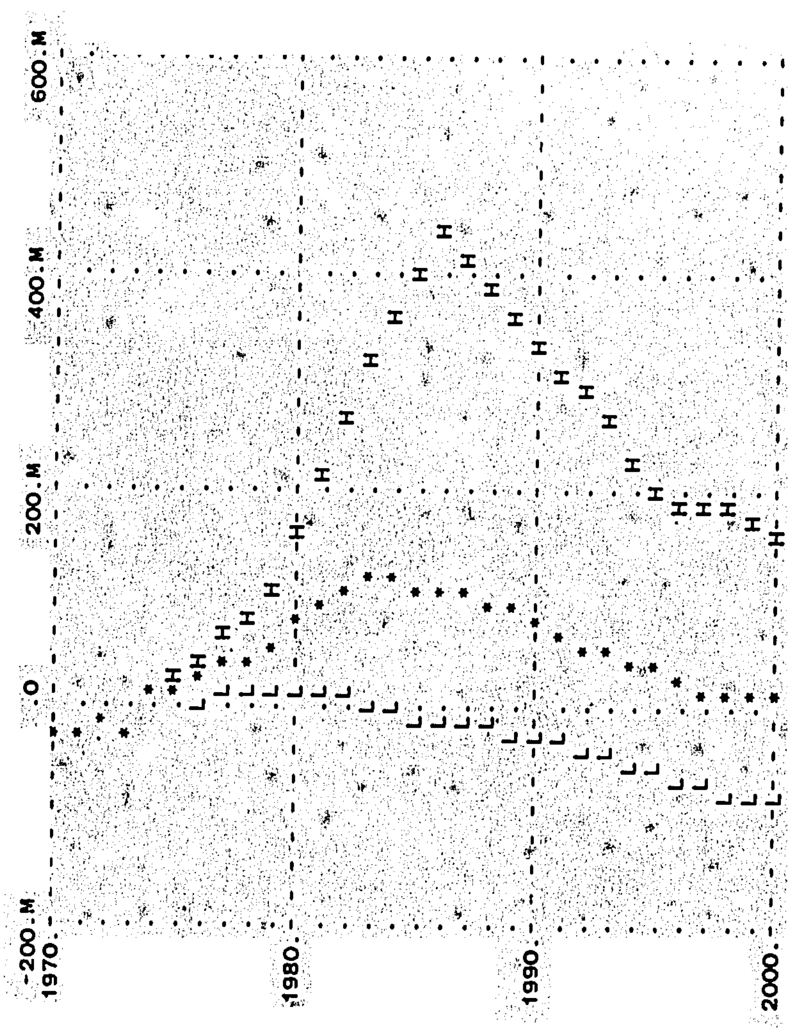
Egyptian Oil Production
(million barrels per year)



* = Base Scenario
H = High Resource Base
L = Low Resource Base

FIGURE 8-23

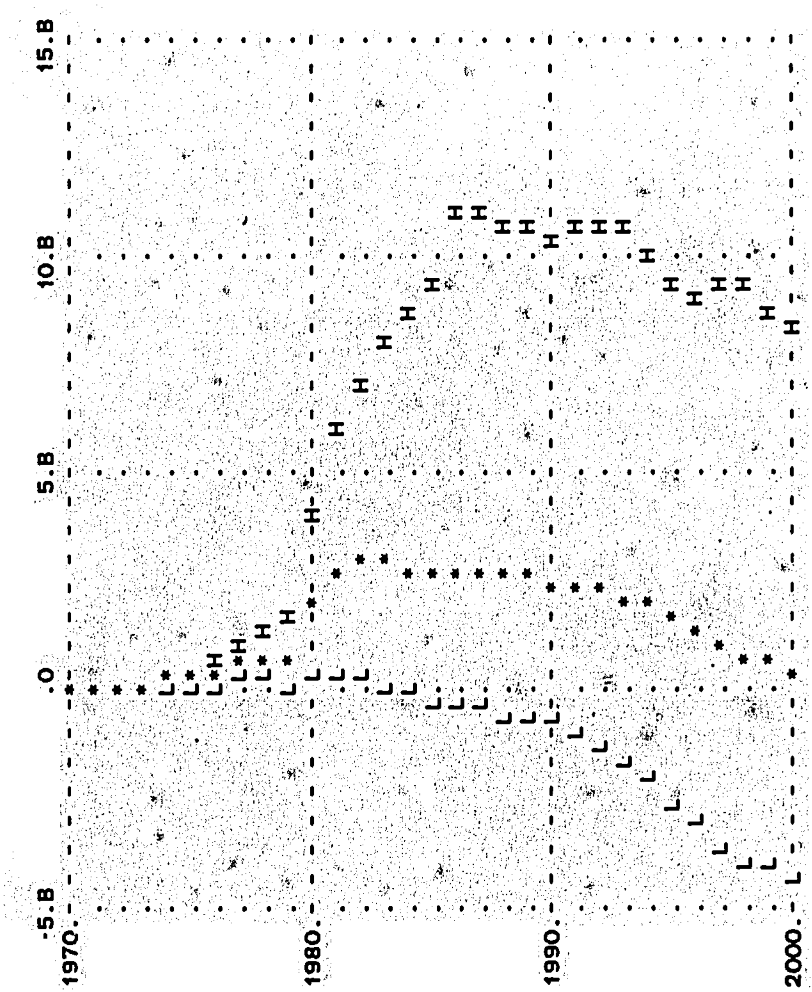
Egyptian Governmental Oil Exports
(million barrels per year)



* = Base Scenario
H = High Resource Base
L = Low Resource Base

FIGURE 8-24

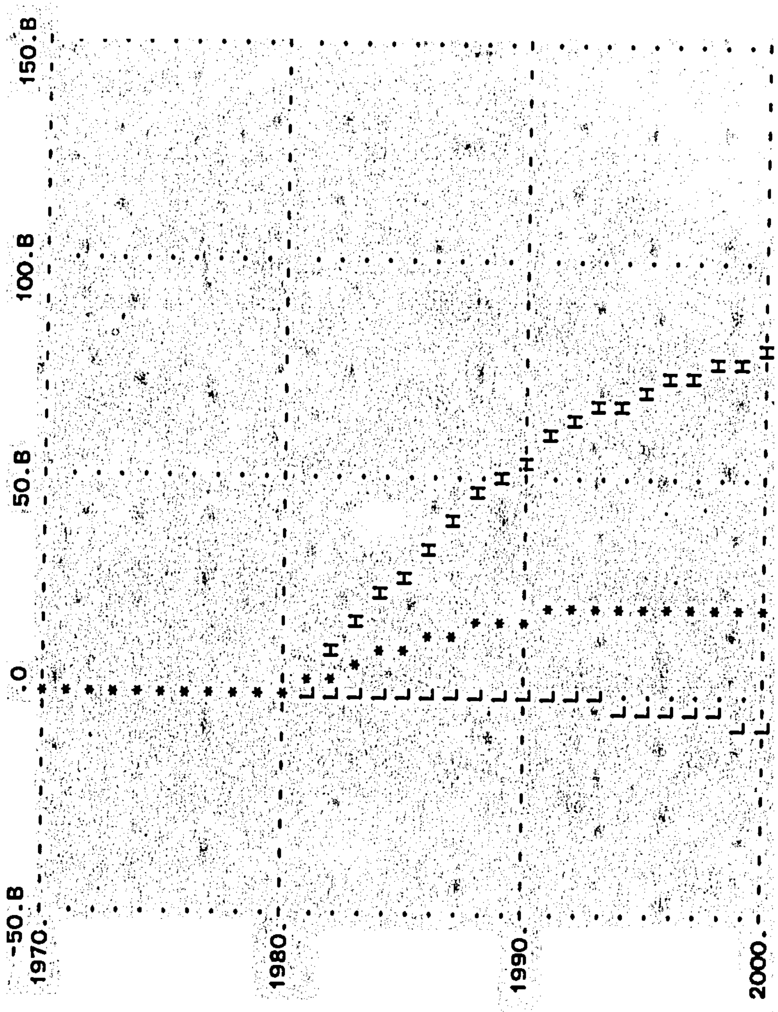
Egyptian Governmental Oil Income
(billion 1980 dollars per year)



* = Base Scenario
H = High Resource Base
L = Low Resource Base

FIGURE 8-25

Egyptian Governmental Oil Income
(discounted and cumulated+ billion 1980 dollars)



+discounted at a 10 percent rate and cumulated from 1980.

* = Base Scenario
H = High Resource Base
L = Low Resource Base

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8.7 Validation

These results can now be compared to actual data in order to determine the validity of the model behavior. Since many of the parameters, most notably costs and investment lag-times, have only been approximated at this time, the results are not expected to produce a good fit. However, the shape of the curves should be similar, and discrepancies ought to be indicative of errors in the approximations made. Table 8-1 shows these comparisons.

The differences between actual and simulated proved reserves are, unfortunately, more indicative of discrepancies in the data on reserves than the validity (or lack thereof) of the model. According to other data available to us, for instance, discoveries have outpaced production, yet reserves are shown to decline. Obviously, exogenous factors have forced revisions of reserve estimates such that the comparison is not truly meaningful. It is, however, informative that the figures converge.

For production, the comparison between the EPM results and actual production for Egypt is quite informative. Simulated production for the Western Desert is very similar to actual production, in part due to the fairly static nature of production there. In the Gulf of Suez, however, two discrepancies can be seen. First, the model does not simulate the severe production decline in the early 1970s, which was the result of the technical factors affecting production in the Morgan field. This occurrence will not be modelled due to its unique nature, but since it exists in the historical portion of the model, it will not have an impact on policy formulation.

Slower production growth in the second half of the decade in the Gulf of Suez is the second major discrepancy. Although the difference in 1980 is only 15.9 percent, the model at that point appears to be lagging behind reality by

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TABLE 8-1

Reserves
(million barrels at year end)

	Actual	Simulated
1970	4500	1700
1971	4000	1791
1972	3800	1880
1973	3800	1968
1974	3700	2053
1975	3900	2138
1976	3600	2511
1977	3400	3055
1978	3200	3428
1979	3100	3776
1980	2900	4015
1981	2900	4179

TABLE 8-1 continued

Validation

(million barrels/year)

	Gulf of Suez Production		Western Desert Production	
	Actual		Actual	Simulated
1970	107	105	11	10
1971	99	105	9	10
1972	65	102	13	10
1973	45	102	17	9
1974	45	105	9	9
1975	72	113	13	10
1976	107	123	15	11
1977	141	149	12	12
1978	167	164	10	12
1979	180	185	12	13
1980	207	212	11	13

TABLE 8-1 continued

Validation
(million barrels/year)

	Total Oil Exports		Domestic Consumption		Egyptian Oil Share	
	Actual	Simulated	Actual	Simulated	Actual*	Simulated
1970	70	66	49	49		
1971	63	63	45	52		
1972	26	57	51	55		
1973	14	53	48	59		
1974	2	52	52	62		
1975	26	56	49	66		
1976	52	63	69	74	97	
1977	71	86	82	79	120	115
1978	99	97	78	84	132	124
1979	112	114	80	89	145	137
1980	128	137	89	95	167[e]	167

*Assuming 7 bbl/metric ton.

Sources: Oil and Gas Journal, "Oil and Energy Trends"; Statistical Review 1981 and 1982; and EGPC.

approximately one year. This suggests that the lag-times on investments are too long, perhaps by a year. When final estimation of parameters is done, this should be corrected.

For domestic oil consumption, the model generally overestimates by about 10 percent. Although we do not wish to match actual economic performance on an annual basis in a long-term model, some adjustment should be made to correct this.

The combination of overestimation of consumption and underestimation of production leads to the underestimation of total oil exports. Since this is, essentially, a direct algebraic relationship, the error is quite predictable. Again, the error in the early 1970s is due to the model's inability to predict the technical problems in the Morgan field.

The columns showing the Egyptian share of oil are quite revealing, since the error appears to be almost entirely due to the underestimation of production. This indicates that the EPM mechanism which allocates oil production shares performs fairly well, although final parameterization has not yet been done. Overall, actual production in Egypt appears to be greater than is generated by the EPM model. On the whole, then, the structure of the model is robust, although some data-related discrepancies remain to be resolved in the next stage of analysis.

8.8 Model Estimation and Documentation

Most of the parameters used in the model as it stands are estimates based on general knowledge of the industry and data officially available, both within Egypt and from international sources. Thus, the results from this model can be considered for discussion only, and are not meant to be conclusive. However, they should be indicative of the type of behavior that will be seen when the model is completed.

8.9 Uses of the Egyptian Petroleum Model

Preliminary analyses of the EPM model have been made to examine the potentials of the Egyptian petroleum sector. The following are some examples:

- effects of alternative levels of investments in exploration and in development show potential discoveries resulting from greater exploration investments, and also greater production which can take place if investments in development are increased. Of course, these additions to reserves and to production are bounded or constrained by geological data and by estimates of remaining reserves.
- forecasts of the effects of changing domestic prices of petroleum for local consumption show the impacts on government share for exports.
- forecasts of the effects of changing international oil prices show the effects of the value of Egyptian oil (given different production policies).

More detailed results for these and other forecasts are presented in a companion report.

PART IV

USES AND PRICING OF NATURAL GAS

CHAPTER 9

NATURAL GAS IN EGYPT

The prospects for natural gas in Egypt appear extremely encouraging. This chapter summarizes a study undertaken in this project which seeks to identify the best uses of Egypt's gas and the price that should be charged for these uses.

9.1 The Natural Gas Industry in Egypt and its Customers

The major natural gas producing fields in Egypt are at Abu Gharadiq in the Western Desert, Abu Madi in the north of the Delta, Abu Qir near Alexandria on the Mediterranean coast, and Suez.

The supplies at Suez are the only supplies in Egypt produced in association with oil, and were badly affected by the 1974 war. Facilities are presently under repair and will soon serve many industries in the Suez area. Shortly some Suez gas will be used to supply domestic needs in Cairo. There is a fertilizer plant at Suez which is presently being supplied from the Western Desert, but it will switch over to Suez gas as facilities are brought up to operation.

Natural gas from Abu Gharadiq supplies not only the fertilizer plant at Suez but also a large industrial complex at Helwan, just south of Cairo. The industries that use natural gas there are: the iron and steel complex, electric power generation, and cement production.

Natural gas produced at Abu Madi is used primarily at the large Talkha fertilizer plant. Some supplies are available for electric power generation

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at Mahalla, and ultimately gas will be used there for the extensive textile facilities.

Abu Qir gas is available for fertilizer production and electric power generation. A large expansion is expected in this region as both onshore and offshore fields are further developed.

These major centers presently operate independently of one another. A national pipeline grid which will link them in the future is in the planning stages.

9.2 Linear Programming Analysis of Natural Gas in Egypt

Natural gas can be used in many applications to displace the use of other fuels. For example, any use of gas to offset the use of oil will free oil which then can be sold abroad to gain foreign exchange for Egypt. This chapter summarizes our results about the extent to which natural gas can replace other fuels in Egypt. The purpose of the study is to determine how natural gas could best be used to improve Egypt's foreign exchange position.

This chapter also identifies the shadow price of natural gas in Egypt, namely the price that should be charged to users which reflects the value of natural gas to the Egyptian economy. The results indicate $.112/cu-m (for Abu Gharadiq gas) and $.115/cu-m (for Abu Madi gas).

The shadow prices of production capacity for processes which use natural gas have also been identified. These price provide an understanding of how valuable the use of natural gas is for each particular industry in improving Egypt's foreign exchange position. The shadow (or actual real) price depends on the particular industry, a larger shadow price indicating a more valuable application for natural gas.

9.3 Method of Analysis

For this analysis a linear programming model has been constructed which describes both Egyptian natural gas production and transportation facilities and production in existing industries that use natural gas and other fuels. The procedures imbedded in linear programming as it is used in this study systematically search certain variables to find out what values for them will result in a minimal value for some linear function of the variables. The search is restricted to only those values which are specified by linear constraint equations, namely, equations which state certain limitations which must not be exceeded by the variables. Upon reaching the minimum solution, the algorithm reports shadow prices, each of which is a measure of how important some specific variable limitations is: the shadow price expresses by how much the solution may be improved by a unit easing of the given constraint.

The industries of the natural gas model were depicted as being capable of using a variety of fuels. The objective of the model is to minimize foreign exchange costs by choosing fuels for use in production in such a way as to meet exogenously specified demand for goods. The capacities for production and transportation of natural gas must not be exceeded by the model, as is true also for the capacities of the industries which are producing goods. The shadow prices express the willingness of planners to obtain extra production capacity if their only objective is to improve Egypt's foreign exchange position.

A strictly operational model was constructed where only presently existing facilities are considered, and the object is to find the best operating policy at a moment of time. The model is not for future investment planning, although some of the results indicate useful areas for investment.

The costs charged by the model against foreign exchange (which is to be minimized) are of two types: natural gas production and transportation costs, and world market costs of fuels other than natural gas. Note that the pricing of natural gas depends on its interactions with other fuels, as presently there are no import or export possibilities for this fuel in Egypt. Thus the only cost to be charged for natural gas in the model is the foreign exchange costs of production and distribution, and its price to users is a shadow price which is determined by the model. This shadow price represents the economic rent which should be charged in view of its value in displacing other fuels, whose prices are determined by external international conditions.

9.4 Results of Analysis

Results of the natural gas model run have been provided for two cases:

- when demand for electricity is high (less than 4 percent of electric power generation is unused); and
- when electricity demand is low (demand is about half of full generation capacity).

Table 9-1 shows the load factors of the natural gas fields and pipelines for the two study cases. Bottlenecks in supply appear for Abu Gharadiq and for the Abu Madi pipeline in the high electricity demand case.

The price shown in the table is the shadow (real) price of natural gas and can be interpreted as the amount that planners should be willing to pay to obtain an additional cu-m of natural gas. If gas were only obtainable at a higher price, alternate fuels would be used instead. Where there are additional unutilized supplies of natural gas, the shadow price is zero, since there is no demand for more gas.

TABLE 9-1

Results in the Natural Gas Sector

(annual production in percent of capacity, shadow (real) prices in $/cu-m)

field:	low electric demand: production	price	high electric demand: production	price
Suez	6%	0	6%	0
Abu Madi	29%	0	83%	0
Abu Qir	18%	0	65%	0
Abu Gharadiq	80%	0	100%	.112
pipeline:				
Suez to Cairo	7%	0	7%	0
A. Madi to Talkha	35%	0	100%	.115
A. Qir to K. Dauwar	18%	0	65%	0
A. Gh. to Helwan	80%	0	100%	.112

TABLE 9-2

Shadow Prices for Capacity in Some Gas-Using Industries

plant	shadow price of production ($/cu-m): high electricity demand:	low electricity demand:
cement	.775	.887
Suez fertilizer	.666	.779
Abu Qir fertilizer	.317	.317
Talkha fertilizer	.221	.335
Dauwar gas boiler	.135	-
Helwan gas boiler	.044	-
iron and steel	-	.027
Cairo distribution	.017	.017

Table 9-2 lists the shadow prices for new capacity of those industries in the model which are fully utilized in production. The unit used is \$/cu-m, and thus represents the importance of using natural gas in the particular installation listed. The table is ordered in terms of the most important applications being listed first.

The model states that the most important application for natural gas is the manufacture of cement. Although the importation of cement was not considered in the model, it is unlikely that inputs can substantially affect the result. The cement sector demand was chosen to reflect demand for domestically produced cement more faithfully than total demand, so that the inclusion of a term for imported cement would have little effect on the study conclusions.

The amount of natural gas consumed by sector for the two study cases are shown in Table 9-3. The industries are listed in the table in order of the importance of the use of natural gas, the cement sector having first priority. Note that iron and steel production switches away from natural gas use in the case of high electricity demand.

A few shadow costs for the expansion of electric power generation were derived in the study. These are shown in Table 9-4. Comparison of these with reported costs for electric power generation capacity expansion show that it is beneficial for Egypt to investment in additional gas fired capacity at kafr el-Dauwar, but not at Helwan.

The national gas model results indicate that the use of natural gas in the iron and steel sector is of little importance <u>assuming</u> that coal is priced at \$35/tonne. If this price were higher than \$107/tonne, gas would be <u>important</u> in this sector.

TABLE 9-3

Consumption of Natural Gas
(million cu-m per year)

	Low Electric Demand	High Electric Demand
Cement sector	725	725
Fertilizer sector	633	633
Electricity sector	29	1591
Iron and steel	83	0
Residential/commercial	70	70

TABLE 9-4

Shadow Costs for Electric Power Capacities

Hydroelectric:	$480/kW
Helwan gas fired boiler:	$120/kW
Kafr Dauwar gas fired boiler:	$377/kW

9.5 Natural Gas Prices: Actual Prices and Natural Gas Prices Derived from the Model

It is almost impossible to determine a world market price for natural gas because of the special character of the trade. The size of the international gas market is small in comparison with crude oil, being less than 5 percent of world oil production in energy terms. Secondly, exports tend not to be concentrated in one region as they are for oil, so there is less pressure for the setting of a unified price. In fact two-thirds of total gas trade comes from four exporters in quite different locations: the Netherlands, the USSR, Canada, and Algeria.

Furthermore, natural gas does not have the delivery flexibilities of crude oil. Trade projects in gas involve enormous costs and long lead times since these involve pipeline construction or development of LNG facilities. Particular tankers or pipelines are dedicated to particular trades. There is then no equivalent to the crude oil spot market which can lead, check, or stabilize price movements.

There have been movements for pegging the price of gas to the price of oil on a BTU basis, and the highest prices have risen rapidly to be on a par with the price of oil. OPEC has stated that gas export prices should be in line with those of crude oil on a BTU basis, but has been vague on whether the pricing parity should be set on the basis of the landed (cif) price or at the port of exit (fob) price. Japanese gas imports have followed landed crude costs to within a close margin throughout the 11 year duration of LNG purchases by Tokyo.

Two shadow prices were found for natural gas in Egypt in the study: \$.112/cu-m for Abu Gharadiq gas and \$.115/cu-m for gas from Abu Madi. Since

TABLE 9-5

Natural Gas Prices

($/cu-m, cif)

CU/MIT Energy Project (1979 to 1982)	.130
USA (March 1980)	
from Algeria (LNG):	.120
from Canada:	.168
from Mexico:	.136
Japan (March 1980)	
from Abu Dhabi (LNG):	.201
from Indonesia (LNG):	.186
from USA (LNG):	.131
Austria (March 1980)	
from USSR	.142
United Kingdom (March 1980)	
from Algeria (LNG):	.116

TABLE 9-6

Natural Gas Production Rates

(million cu-m per year)

	CU/MIT Energy Project	PIEDA estimate 1981/82
Abu Gharadiq	1100	1080
Abu Madi	1000	1160
Abu Qir	850	1080
total	2950	3320

they represent the most Egyptian planners are willing to pay for gas if their intent is to improve the foreign exchange position, these are demand prices. These prices are exclusive of the costs of producing and delivering the gas. If these costs are added, the prices for gas from the two fields both rise to $.130/cu-m. This represents a world market cif price as observed by Egyptian industries, since it includes delivery infrastructure costs.

Table 9-5 below includes a range of cif gas prices as reported by Segal and Niering in "Special Report on World Natural Gas Pricing," Petroleum Economist, September 1980. The price found for natural gas by the study falls within the range of quoted prices.

9.6 Comparison of Prices of Natural Gas from Other Studies

In what follows, references to "the study" or "the model" are references to the study of natural gas in Egypt in the references to this chapter. The data used for the study were collected from a range of sources published in different years, so that no exact date can be applied to the results. The sources used range in date roughly from 1978 to 1982.

9.6.1 Natural Gas Production Rates

Table 9-6 presents the production of natural gas at three fields to compare the natural gas study results in this project with the PIEDA report. The CU/MIT Energy Project study figures are from the medium and high electricity demand cases. It is apparent that the study may underestimate production at Abu Madi (by 13 percent) and at Abu Qir (by 21 percent). Production at Abu Madi is constrained by pipeline capacity in the study, so that the 13 percent deviation may reflect some modelling error in the assumed capacity. The larger error for the Abu Qir production figure may be due to a study underestimate of the capacity for gas use in the Alexandria area.

In Table 9-7 we present a range of estimates and projections from various sources for the years 1980-1982. The Energy Project study result falls within the range of estimates.

9.6.2 Natural Gas Consumption

Tables 9-8 and 9-9 comapre the natural gas study of this project and the PIEDA report in terms of the proportion of gas used by the various gas consuming sectors. The largest discrepancies occur in the electrical sector and the iron and steel sector. The natural gas model may overestimate natural gas utilization in electrical generation for several reasons: our model makes use of name plate capacities of generation, rather than real operation capacity; generation unplanned outage and outage for maintenance is not accounted for; and no allowance is made for the use of alternate fuels in gas turbines and boilers. In so far as the iron and steel sector is concerned, it is probable that an obsolete value was used for the natural gas consumption capacity.

9.7 Conclusion

Our study on natural gas shows that this resource is most valuable in cement and fertilizer production and that any increase of the use of natural gas in electric power generation must be met by a large expansion of production. Even with the crudeness of the data base used, the linear programming model of natural gas industry in Egypt can be used to assist decision-making about the allocation of natural gas.

TABLE 9-7

Total Gas Production
(million cu-m per year)

year of estimate	1980	1980/81	1981	1981/82
Petroleum Economist Aug. 1982	2190		2430	
Five Year Plan projected		2410		3560
PIEDA estimate (consumption)		3045		

CU/MIT Energy Project: 3020

TABLE 9-8

Gas Sales, First Half of 1980

(percent of total sales,
PIEDA Report)

	Abu Gharadiq	Abu Madi	Abu Qir	Total
Electricity	8.9	12.6	11.7	33.2
Cement	24.9			24.9
Fertilizer		12.6	15.8	28.3
Aluminum	0.2			0.2
Iron and Steel	9.7			9.7
Dyeing		1.0		1.0
Weaving		2.7		2.7

TABLE 9-9

Consumption of Natural Gas by Sectors

(percent of total)

	Abu Gharadiq	Abu Madi	Abu Qir	Total
Electricity	11.2	21.9	20.8	53.9
Cement	24.6			24.6
Fertilizer	1.5	12.0	8.0	21.5
Aluminum (1)				
Iron and Steel	2.8 (2)			2.8
Dyeing (1)				
Weaving (1)				

CU/MIT Energy Project (high and medium electric demand)

(1) These sectors were not covered in this chapter.
(2) This figure is from the low electricity demand case.

CHAPTER 10

MACRO-EFFECTS OF A RISE IN THE DOMESTIC PRICE OF PETROLEUM BASED ON A SHORT-RUN STRUCTURAL MACRO-ECONOMIC MODEL OF EGYPT

10.1 Economic Context

Despite rapid changes in the Egyptian economy, several features continue to stand out. These include a dominant agricultural sector, a growing construction sector, an expanding industrial base, and a dramatic growth in the petroleum sector. Domestic economic policies -- inherited from the revolution of 1952 -- include extensive subsidies for industrial inputs, energy prices, and foodstuffs. In agriculture, imports serve to clear the market. Only in construction are prices allowed to adjust. In all other sectors quantities adjust to demand. The traditional dualism in the economy -- agriculture vs. the rest of the economy -- may well be supplanted by a trilateral structure: agriculture, rest of the economy, and a strong energy sector. With these distinctive features in mind, we have a short-run, 10-sector, macro-economic model of the Egyptian economy to examine its critical adjustment problems.

Recent developments suggest that the Egyptian economy has entered a transitional phase in its growth process, undergoing a period of transformation towards a new equilibrium. Processes of adjustment and adaptation are inevitable in being characteristic transitional phases as distinct from the steady state phenomenon which is consistent with and observed in long-run equilibrium. Therefore, it is important to understand the shortrun adjustment mechanism of the interdependent economic system which would provide reasonable guidelines for appropriate policy measures. There are many countervailing forces in the Egyptian economy, and these five factors differ in their impacts and their overall contribution to growth.

Clearly, the most significant contribution to the recent economic upsurge has been provided by the petroleum sector, which is strong, well managed, and provides a steady stream of revenue for the government. The petroleum sector does not exist in isolation from the rest of the economy and analysis of its effects must take into account the strong two-way linkage with the economy.

A major problem arises from the question of whether the increased earnings from the petroleum sector can be maintained in the face of two obstacles: a highly subsidized domestic price of oil which is encouraging domestic consumption and a large degree of uncertainty that prevails in reserve generation and the future production possibilities of oil.

The domestic price of petroleum in Egypt is about one-fifth of the international market price quivalent. Low petroleum prices have led to rapid increases in domestic utilization. Government officials have recently stated that by 1984 both consumption of petroleum products and output will rise by 11 to 12 percent and the exportable surplus of domestic petroleum production over consumption may be eliminated completely.[7]

This twofold dilemma has heightened awareness for energy conservation and better management of energy demand at the national level such that petroleum reserves are not entirely diverted from exports to the domestic market. The crucial policy issue in this context is to change the administered price system of petroleum products toward a more viable domestic price structure. The problem is whether price induced conservation is likely to occur and to determine the macro-economic consequences of an overall reduction in petroleum use.

Among the critical questions to be resolved are the following: What will be the effects of rising energy costs on the other sectors of the economy? Will the economy be able to adapt to this change? To some extent the adjustments will depend on the flexibility of energy use in the consumption pattern of households and in the production functions underlying industrial sectors. In other words, the structure of energy/economy interactions depends to a large extent on the critical role that petroleum plays both in the consumption basket and as a factor of production (that is, on the values of the relevant elasticities).

Egypt's energy profile can be characterized as follows: almost fify percent of energy use is petroleum-based, the remainder is mainly hydroelectric power, with small, but potentially important prospects for natural gas. In a macro-economic context, therefore, if substitution possibilities exist in production processes (eg., between petroleum and natural gas), it is important to determine whether the negative macro-economic impact of rising energy prices can be mitigated through appropriate price policies or if other constraints in the economy will need to be recognized as well. In this context, for Egypt's energy predicament, it is useful to investigate whether the production possibilities in the natural gas sector impose significant constraints on the economy's adjustment process. The effects of the above kinds of restructions can be examined under alternative assumptions regarding how the different sectors of the economy adjust to reach market equilibrium (i.e. alternative rules for model closures). We know full well that price determination differs substantially across sectors and these differences are critical to the overall economic adjustments and to the policy options available for changing domestic price structures. Among issues of concern are the following: If the short-run adjustment to an oil price increase drives down output and puts upward pressure on prices -- can the short-run underutilization of productive capacity be mitigated through appropriate macro-economic policies? With these questions in mind we have formulated a macro-economic model of the Egyptian economy to trace the short-run energy-economy interactions and address issues of the above nature.

10.2 Theoretical Structure

The theoretical structure of this model is specified along the lines of the computable general equilibrium models formulated by Taylor (1983)[8] and Taylor and Lysy (1980),[9] emphasizing the particular structural characteristics of developing countries. Such models are based around the identities of a social accounting matrix (SAM) and incorporate additional technical and behavioral relationships to make the model determinate and represent the distinctive characteristics of the specific economy being analyzed. The closure rules behind these models are based on a combination of different schools of thought inspired by Keynes, Kalecki, and the different adherents of the Cambridge school. The model focuses attention on the particular variables that need to adjust to bring about the overall macro balance, i.e. saving equal to investment. Different models can be constructed around the different accommodating variables that would adjust to satisfy the basic macro identity in the economy. Aggregate demand determined markets of the Keynesian type are included where chronic excess capacities are the essential features of the sectors and price clearing markets are assumed where bottleneck and shortages are present. Generalized models of development are not useful for analyzing particular cases. Different structural characteristics are important in case of different countries and the appropriate adjusting variables need to be emphasized accordingly.

The Egyptian macro-economic model is built around a social accounting matrix (SAM) for the Egyptian economy in the national accounts year of 1977.[10] The model incorporates a complex set of general equilibrium interactions in the price and quantity clearing sectors in the commodity market. The model, however, is of a short-run nature and does not incorporate the dynamics of the system. It is designed specifically around a base year to assist in understanding immediate responses to policy changes. Investment has been modelled merely as a component of aggregate demand and the capital accumulation process of investment has not been considered. It has been specifically designed to explore the short-run adjustment mechanism of the system.

The ten sectors along which the model is built are the following: (1) agriculture; (2) construction and housing; (3) heavy industry; (4) light industry; (5) transportation; (6) sectors in the rest of the economy; (7) Suez; (8) oil extraction; (9) oil refining; and (10) other energy, namely electricity and a nascent natural gas component.

The overall macro balance in this structural model is decomposed sectorally. The mechanisms through which excess demand in each sector adjusts to zero are the following:

(i) The agricultural sector is assumed to have an adjusting "competitive impoort" level. Both prices and supply are assumed to be fixed in the short-run.

(ii) The construction sector's stability mechanism is built around an adjusting price. Prices are assmed to vary freely to bring about equilibrium because capacity in the construction sector is fully utilized in the short-run.

(iii) for all the other sectors in the economy adjusting outputs occur due to the prevalence of chronic excess capacities.

Prices in all the quantity clearing sectors are determined by fixed producers' markup over variable costs as opposed to the neoclassical cost function. The wage rates are assumed to have been determined institutionally (which corresponds to the Keynesian assumption of short-run predetermined nominal wages) and the coefficients of production are fixed in the initial version of the model. Some of the technological coefficients have been taken as flexible in a subsequent version of the model (results are reported below). The model draws upon the well-known linear expenditure system of demand equations to arrive at the sectoral consumption level. Given the different behavioral assumptions and the different identities built around the social accounting matrix, the solution is determined through several adjustment mechanisms, namely the Keynesian output response in the quantity-clearing sectors, the "forced saving" mechanism via the rise in the prices of output relative to wage, adjustments in the trade deficit, and the surplus available in the government current account.

10.3 Relevance for the Egyptian Case

Models of the above general equilibrium nature in a multisectoral framework may provide highly useful insights and guidelines for investigating macro policy issues. They are especially relevant in the Egyptian case, where the government is actively engaged in bringing about economic changes through direct policy measures. Such models are different from the earlier computable general equilibrium models, popularly known as GEM models, which were applied in case of Pakistan by McCarthy and Taylor (1978)[11] and by Eckaus, McCarthy, and Mohie-Eldin (1979).[12]

Earlier views of the Egyptian economy specified in the GEM models incorporated the general equilibrium links between production structure, income of different groups, and patterns of demand through flexible prices. Thus, a market clearing mechanism provided the interaction between demand, production, and factor use. These models are essentially neo-classical in spirit and follow the general equilibrium notion that goes back to Walras. The GEM model assumes Cobb Douglas production functions which allow for smooth substitution, constant return to scale, and constant factor shares. Moreover, perfect competition is usually assumed in the factor markets for arriving at the dual cost function. Thus the obvious disadvantage of the GEM models is the highly neo-classical nature of the models, which is clearly suspect in the framework of developing countries like Egypt.

Clearly, the important assumption of price responsiveness, smooth substitutability between the different primary inputs, and the perfectly competitive nature of factor markets does not hold in developing economies where institutional features and structural rigidities result in behavior far removed from the neo-classical assumptions. This is especially the case in Egypt where institutional factors established since the 1952 Revolution have introduced large-scale rigidities which blatantly violate neo-classical assumptions. Such notions impose serious distortions in analysis and for identifying policy adjustments. In short, neo-clasical, general equilibrium analytical structures are singularly appropriate in the Egyptian case, where public policy -- social and economic programs -- is clearly in violation of the most cherished neo-classical assumptions.

10.4 Empirical Results

Egyptian energy pricess have been extremely low and average about one-fifth of their international market price equivalent. They obviously have not provided the appropriate price signals to the economy.[13] Our objective in this policy run is to evaluate the short-run adjustment burdens to the economy which would result from a rise in the price of oil.

This section presents some results of the macro-economic impacts of a rise in the domestic price of petroleum on the Egyptian economy. For purposes of analysis, the domestic price of petroleum has been taken as 20 percent of the international price in the base run of the model. The results are based on analysis undertaken through use of the ten-sector macro-economic short run structural model of the Egyptian economy described above. It differs fundamentally in analysis structure and assumptions from prevailing models of the Egyptian economy. A detailed description of the equations and closure rules of the Egyptian Structural Model is presented elsewhere.

10.4.1 Base Case

The rise in the price of petroleum has been simulated by increasing the prespecified markup rate in the petroleum sector by 200 percent. This increases the price of petroleum by 54 percent, which brings the petroleum prices closer to the international market-price equivalent by 10 percent. This is a modest increase in the direction of the international market price equivalent, but one that departs substantially from current price structure. The immediate consequence of this price increase is a rise in the variable costs of production in the other sectors of the economy which is reflected directly in terms of higher prices for their products. The results of changes

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in the relative prices of the different outputs are depicted in Table 10-1. A major effect is a cost-push inflation which occurs in the other sectors of the economy. This is due to the significant role of petroleum as an intermediate input.

The responses of the increases in the sectoral price levels will vary over the different sectors. The price level in the heavy industries, transportation, crude oil, and other energy sector will increase by 7 percent, 5 percent, 8 percent, and 11 percent respectively. The aggregate level of prices in the economy will increase by almost 3 percent.

The changes in relative prices will lead to a rise in the level of profit income from the petroleum sector. A large proportion of the profit income will be going into the hands of the Egyptian government owing to the large share of the government in the petroleum sector and the other sectors of the economy. This will result in higher government savings leading to leakages of purchasing power. Real wages will fall because of the assumption of short-run predetermined nominal wages. Thus income will be redistributed from wage to profit recipients.

The level of consumption will decline as a result of the higher relative prices. All these effects together would generate a downward pressure on the level of aggregate demand. This depression of demand will result in lower prices in the construction sector, lower level of competitive imports in the agricultural sector, and a decline in output in all of the quantity clearing sectors.

Thus an increase in the domestic price of oil will lead to a reduction in the level of economic activity of the different sectors of the economy. Real value added will fall by approximately LE 120 million (2 percent) and house-

TABLE 10-1

Empirical Results of Different Simulation Runs

Sector		A	B	C
	Prices			
Construction and Housing	P2	1.0	.983	.996
Heavy Industry	P3	1.0	1.067	1.068
Light Industry	P4	1.0	1.01	1.01
Transportation	P5	1.0	1.047	1.048
Rest of the Economy	P6	1.0	1.023	1.023
Suez	P7	1.0	1.04	1.041
Oil Extraction	P8	1.0	1.076	1.077
Oil Refining	P9	1.0	1.535	1.536
Other Energy	P10	1.0	1.11	1.11
	Gross Output (in million LE)			
Heavy Industry	X3	785.619	774.598	785.915
Light Industry	X4	3655.81	3609.49	3664.79
Transportation	X5	494.243	478.732	492.358
Rest of the Economy	X6	3958.58	3914.80	4042.32
Suez	X7	185.40	185.316	185.558
Oil Extraction	X8	266.333	262.311	265.006
Oil Refining	X9	287.856	277.368	284.039
Other Energy	X10	116.538	112.893	115.689
	Competitive Imports (in million LE)			
Agriculture	M1	568.198	545.68	578.022
	Consumption (in million LE)			
Agriculture	C1	933.667	925.598	934.449
Construction and Housing	C2	156.763	155.752	157.29
Heavy Industry	C3	128.834	122.267	124.467
Light Industry	C4	1873.40	1837.63	1866.74

A = Base Case
B = Increased Petroleum Markup (200 Percent)
C = Increased Fiscal Expenditure Policy (8 Percent)

TABLE 10-1 continued

Sector		A	B	C
	Consumption (in million LE)			
Transportation	C5	186.453	173.377	178.82
Rest of the Economy	C6	1132.80	1094.96	1117.67
Oil Refining	C9	53.4077	46.0192	46.44
Other Energy	C10	39.4407	36.7453	37.373
	Sources of Saving (in million LE)			
Government Savings	GSAV	1574.54	1603.01	1524.64
Household Savings	HHSAV	1469.07	1461.07	1485.46
Trade Deficit	DEF	-555.144	-568.972	-514.969
	Sources of Income (in million LE)			
Agricultural Income of Households	HYA	1581.48	1575.09	1575.07
Profit Income of Household	YHP	1469.05	1472.11	1518.86
Wage Income of Household	YW	2979.43	2949.91	3009.37
Government Profit Income		1575.3	1699.47	1729.4
Aggregate Price Index		1.00	1.028	1.030
Real Value Added (in million LE)		7605.22	7485.17	7607.3
Nominal Value Added (in million LE)		7605.22	7696.56	7832.7

hold consumption of petroleum products will decline by LE 7 million (13 percent).

Overall, the rise in domestic petroleum prices will create difficult adjustment problems in the short-run involving increased inflation (due to costpush inflationary pressures originating in the petroleum sector) and contraction of output (brought about by a fall in aggregate demand) leading to underutilization of capacity.

This contraction can be offset through fiscally neutralizing measures, namely an expansion in the government expenditure policy. If government expenditure is increased by 8 percent, for example, this policy might offset the negative impact on real value added and add negligibly to inflation.

The results corresponding to this policy run are presented in the fourth column of the table. This analysis also helps to separate income effect from the substitution effect by keeping the real value added at its original level. The new consumption basket represented by column C now gives the demand responses generated by the substitution effect alone. We may also note that the conservation in the uses of petroleum arises mainly due to the operation of the substitution effect (of a change in price) due perhaps to the small share of petroleum in the consumers' budget. In terms of the sectoral responses of output we find that sectors which receive a higher share of government expenditure gain more than the others.

10.4.2 Effects of a Rise in the Price of Petroleum with Some Price Responsive Technological Coefficients and Alternative Rules for Closures for the Natural Gas Sector

Much of the demand for petroleum products comes from the industries in the form of intermediate inputs. So far, we have assumed that technological coefficients are fixed in that they are used in fixed proportion and no substitution is possible. In fact, we know that there exist possibilities of substitution away from the petroleum input, especially by natural gas. Considerable scope for conversion exists in a number of industries in the Egyptian economy such as iron and steel, cement, fertilizers, and cotton textiles. Since most of these industries are aggregated in two sectors of the model we have replaced the constant technological coefficients using petroleum and natural gas in these sectors by making them price responsive. For this analysis, we now assume that substitution possibilities exist between petroleum and natural gas in these two industry sectors.

By assuming that petroleum and natural gas enter separably into the unit cost function we obtain a unit cost function corresponding to the use of "aggregate" energy (in terms of petroleum and natural gas) derived from the factor demand equations and natural gas in these two industry sectors.

Given severe data constraints at present, no formal econometric estimation of the elasticity of substitution between oil and natural gas has been attempted. There are very few estimates available for the elasticity of substitution even for other developing countries. For example, in studies of Mexico it has been revealed that the elasticities of substitution between petroleum oil and natural gas in the Mexican manufacturing industries turn out to be higher than unity. For our purposes, an elasticity of substitution of 1.5 has been assumed for both the sectors in the Egyptian case.

In order to capture the particular characteristics of the Egyptian economy and its unique "distortions," three alternative assumptions (on closures) have been made regarding the natural gas sector:

1. the natural gas sector is assumed to be quantity clearing (which has been the assumption throughout our analysis);
2. the supply of the natural gas sector is taken to be fixed in the short-run and the adjustment mechanism is built around flexible prices;
3. the short-run supply response function in the natural gas sector responds positively to change in its own price and takes the following form:

$$X_{10} = \overline{X}_{10} \left(\frac{P_{10}}{\overline{P}_{10}}\right)^{\gamma}$$

where γ is the parameter of the supply response function.

$\overline{P}_{10}$ = initial price of natural gas

$\overline{X}_{10}$ = predetermined level of natural gas output

X_{10} = level of gross output in the natural gas sector.

The results of our analysis are summarized in Table 10-2. We observe that the technological coefficients are fairly sensitive to changes in petroleum prices in all three cases. However, the price responsiveness (i.e., the resulting induced conservation of petroleum products) vary with the particular assumptions on closures that have been made for the natural gas sector. Given the assumption of excess capacity in the natural gas sector, the substitution away from petroleum to natural gas does not cause any additional increases in the price of natural gas. The flexibility of petroleum use helps to ameliorate some of the contractionary impact on the real value added to the economy.

However, if the supply in the natural gas sector remains fixed, this leads to a substantial rise in the price of natural gas (almost 30 percent). This results in a high rate of inflation in the economy and the contractionary

TABLE 10-2

Results of Simulation Runs with an Increase in Markup in the Petroleum Sector by 200 Percent*
and Flexible Technological Coefficients under Alternative Closure Rules for the Natural Gas Sector

				Flexible Technological Coefficient		
					Price Clearing Natural Gas Sector	
Sectors		A	B	C	D	E
Heavy Industry	Ratio of Petroleum Use to "Aggregate Energy"	.655	.655	.532	.595	.549
Heavy Industry	Ratio of Natural Gas Use to "Aggregate Energy"	.344	.344	.492	.409	.468
Light Industry	Ratio of Petroleum Use to "Aggregate Energy"	.561	.561	.432	.497	.449
Light Industry	Ratio of Natural Gas Use to "Aggregate Energy"	.439	.439	.595	.509	.571

A = Base Case
B = Rigid Technological Coefficient
C = Quantity Clearing Natural Gas Sector
D = Fixed Supply of Natural Gas
E = Incorporation of Short-Run Supply Response Function in the Natural Gas Sector

*The mark-up rate in the petroleum sector has been increased three times to simulate the modest oil price rise scenario.

A threefold increase in the markup of the petroleum sector leads to an increase of approximately 54 percent in the price of petroleum (P9 = 1.535).

TABLE 10-2 continued

Sectors	Prices	A	B	C	D	E
				Flexible Technological Coefficient		
					Price Clearing Natural Gas Sector	
Construction and Housing	P2	1.00	.983	.984	.981	.985
Heavy Industry	P3	1.00	1.067	1.063	1.077	1.058
Light Industry	P4	1.00	1.01	1.01	1.012	1.009
Transportation	P5	1.00	1.047	1.047	1.052	1.046
Rest of the Economy	P6	1.00	1.023	1.023	1.026	1.022
Suez	P7	1.00	1.04	1.040	1.044	1.039
Oil Extraction	P8	1.00	1.076	1.076	1.08	1.074
Oil Refining	P9	1.00	1.535	1.535	1.542	1.532
Other Energy	P10	1.00	1.11	1.11	1.288	1.051
	Gross Output					
Heavy Industry	X3	785.619	774.598	774.96	773.115	775.65
Light Industry	X4	3655.61	3609.49	3611.65	3603.18	3614.77
Transportation	X5	494.243	478.732	479.266	477.152	480.032
Rest of the Economy	X6	3958.58	3914.80	3915.63	3909.33	3917.93
Suez	X7	185.40	185.316	185.318	185.306	185.334
Oil Extraction	X8	266.333	262.311	258.761	259.988	258.334
Oil Refining	X9	287.856	277.368	267.417	270.976	266.175
Other Energy	X10	116.538	112.893	125.121	116.538	128.561
	Competitive Imports					
Agriculture	M1	568.198	545.68	546.717	542.696	548.206

TABLE 10-2 continued

Sectors		A	B	C	D	E
				Flexible Technological Coefficient		
					Price Clearing Natural Gas Sector	
	Aggregate Price Index	1.00	1.028	1.0264	1.032	1.0278
	Real Value Added	7605.22	7485.17	7496.89	7472.93	7489.68
	Total Value Added	7605.22	7695.56	7694.78	7710.21	7697.61

effect becomes more severe. The results are summarized in column D of Table 10-2. This shows that a high elasticity of substitution may not give us the desirable results and it is important to capture and analyze the macro impact of the other restrictions in the economy.

If the supply of natural gas responds to changes in prices then the upward pressures on the price of natural gas may be offset to a large extent. The price of natural gas increases by merely 5 percentage points. The results of this analysis are shown in column E of Table 10-2. The solution indicates that if the substitution possibilities between oil and natural gas are high in certain sectors and the supply of the natural gas sector responds accordingly, the negative macro-economic impact of rising energy prices may be mitigated to a certain extent.

This preliminary analysis illustrates the importance of the implications of the alternative closure rules for determining an appropriate petroleum price strategy. In other words, energy demand management alone cannot bring about the desirable impacts on the economy unless efforts are made to remove cost pressures originating from other structural constraints.

10.4.3 Effects of a "Quantum Jump" in the Domestic Price of Petroleum[14]

The above analysis reports the results of a relatively small increase in the price of petroleum towards its international market price equivalent. We further conducted a series of alternative simulatiton runs by increasing the petroleum sector mark-up tenfold. A tenfold increase in the petroleum sector mark-up increased the price of petroleum by approximately 300 percent (i.e., to four times the current domestic prices). The increase is more in line with the quantum jump scenario proposed by the Egyptian authorities.

TABLE 10-3

Effects of a "Quantum Jump"* Rise in the Price of Petroleum: Empirical Results

Sector		Rigid Technological Coefficient	Flexible Technological Coefficient: Quantity Clearing Natural Gas Sector	Flexible Technological Coefficient: Price Clearing Natural Gas Sector
	Prices			
Construction and Housing	P2	.908	.917	.898
Heavy Industry	P3	1.376	1.310	1.408
Light Industry	P4	1.058	1.048	1.064
Transportation	P5	1.265	1.262	1.290
Rest of the Economy	P6	1.130	1.126	1.143
Suez	P7	1.226	1.221	1.244
Oil Extraction	P8	1.427	1.412	1.456
Oil Refining	P9	3.986	3.959	4.054
Other Energy	P10	1.613	1.607	2.454
	Gross Output (in million LE)			
Heavy Industry	X3	738.96	741.325	733.188
Light Industry	X4	3418.03	3441.1	3395.21
Transportation	X5	422.97	426.725	417.793
Rest of the Economy	X6	3744.89	3757.09	3725.74
Suez	X7	184.993	185.016	184.98
Oil Extraction	X8	254.609	246.755	248.94
Oil Refining	X9	258.639	236.358	243.10
Other Energy	X10	101.878	141.918	116.50

*The mark-up rate in the petroleum sector has been increased 10 times to simulate the "quantum jump" scenario.

TABLE 10-3 continued

Sector		Rigid Technological Coefficient	Flexible Technological Coefficient: Quantity Clearing Natural Gas Sector	Flexible Technological Coefficient: Price Clearing Natural Gas Sector
	Competitive Imports (in million LE)			
Agriculture	M1	451.158	461.933	439.815
Agriculture	C1	890.379	894.242	886.05
Construction and Housing	C2	151.094	151.575	150.45
Heavy Industry	C3	100.755	103.754	98.93
Light Industry	C4	1688.18	1706.85	1670.32
Transportation	C5	126.955	129.291	122.56
Rest of the Economy	C6	948.949	960.021	933.124
Oil Refining	C9	37.566	37.6677	37.417
Other Energy	C10	29.178	29.6106	25.21
	Sources of Saving (in million LE)			
	Government Savings (GSAV)	1705.16	1682.95	1725.92
	Household Savings (HHSAV)	1429.11	1434.7	1427.25
	Trade Deficit (DEF)	-608.896	-596.772	-624.629

TABLE 10-3 continued

	Rigid Technological Coefficient	Flexible Technological Coefficient: Quantity Clearing Natural Gas Sector	Flexible Technological Coefficient: Price Clearing Natural Gas Sector
Sources of Income (in million LE)			
Agricultural Income of Households (HYA)	1545.85	1547.13	1544.32
Profit Income of Household (YHP)	1483.05	1489.79	1487.65
Wage Income of Household (YW)	2837.08	2853.00	2826.8
Government Profit Income	2239.02	2199.45	2308.95
Aggregate Price Index	1.15764	1.14977	1.175
Real Value Added (in million LE)	7001.32	7035.64	6954.18
Nominal Value Added (in million LE)	8105.00	8089	8167.71

TABLE 10-4

Elasticity Measures with Respect to Modest and "Quantum Jump" Oil Price Increases

	Modest Price Increase		"Quantum Jump" Price Increase	
	A	A'	A	A'
Gross Output in Oil Refining	-.0879	-.1744	-.0893	-.1646
Real Value Added	-.04	-.036	-.07	-.065
Rate of Inflation	.065	.061	.12	.133

A Rigid Technological Coefficient

A' Flexible Technological Coefficient

The results of the alternative simulation runs are presented in Table 10-3. The logic of the analysis will run along the same lines of argument presented earlier. Table 10-4 represents the elasticity measures of the important macro-economic indicators. The elasticity responses of the important macro-economic variables present some interesting insights to the adjustment process. The elasticity measures of gross output in the petroleum sector remain almost unchanged in both the modest and the "quantum jump" increase cases. This result implies that the degrees of responsiveness of curtailment of petroleum use by the economy will remain almost unchanged in both the modest and the "quantum jump" cases. The elasticity responses corresponding to the real value added are -.04 and -.07 respectively.

These responses reveal that the degree of contractionary responses will be more severe in the "quantum jump" case. The argument holds good in case of the rate of inflation as well. The values of the elasticity measures reveal the extent of non-linearity present in the structure of the macro-economic responses corresponding to oil price changes. This outcome clearly points to the fact that a gradual increase towards the world price level might be preferable to a "quantum jump" increase in terms of the adjustment burdens for the economy. Thus an increase in the Egyptian domestic price of petroleum to world price level in one shock will not contribute to increasing the degree of responsiveness of the curtailment of energy use but would invariably hit the economy harder.

The results of these analyses are in line with the alternative price increase scenarios currently being considered by the Egyptian authorities and international agencies, including the U.S. Agency for International Development.

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10.4.4 Conclusion

The analysis in this report suggests the following conclusions

First, an increase in the domestic price of oil will encourage the curtailment of petroleum use and induce some amount of conservation of oil resources. This may be redirected to exports or conserved for future use.

Second, the reduction in petroleum use, however, will impose painful adjustment problems for the economy in terms of an increase in inflation, fall in the share of wage income, and sharp output losses. A gradual increase in the price of oil would be less painful than a "quantum jump" rise and would not necessarily induce more conservation of petroleum use in relative terms. An increase in aggregate demand through expansionary government expenditure policies may help to restore some of the lost income and stimulate the economy.

Third, the popular emphasis in macro-economic policy for counteracting the negative economic effects to date has been effective energy-demand management policies. Since household consumption forms a very small portion of total petroleum demand in Egypt, the demand effects will have to operate through interfuel substitution in the industrial sector. Our analysis suggests that a high elasticity of substitution in the production processes between petroleum and natural gas will not bring about the desirable changes in terms of conservation of petroleum use and amelioration of the negative macro-economic impacts <u>unless</u> efforts are made to increase the short-run supply of natural gas as well. In other words, for the price of oil to provide the right signal for resource allocation in the economy, the other institutional and structural constraints need to be recognized and analyzed as well.

Fourth, the macro-economic implications of domestic petroleum pricing strategies in Egypt are extremely important and should be considered carefully. Simply suggesting lifting of domestic subsidies, increasing domestic energy prices to world prices, will not have the intended effects unless other measures are adopted as well. Treating the energy sector in isolation from the rest of the economy will be counterproductive and lead to adoption of measures that may even have detrimental effects. An overall energy/economy strategy is required in which adjusting domestic prices toward international prices is only one element.

CHAPTER 11

NEXT STEPS

This report has presented some of the highlights of the energy project. The next steps include:

11.1 Natural Gas

- o undertaking a sectoral analysis of natural gas reserves and potential in Egypt;
- o comparing the results of our assessments on natural gas with other government and international assessments.

11.2 Petroleum Supply

The next steps in the supply-side analysis include presenting the results of the forecasts of the Egyptian Petroleum Model in terms of:

- o effects of alternative rates and levels of investments of exploration and development;
- o future effects of government/foreign company shares;
- o effects of policy changes in the petroleum sector for Egyptian exports.

11.3 Energy Demand

An analysis of energy demand in Egypt at a disaggregated sectoral level for different fuel types will illuminate the dynamics of demand changes and provide better management of energy demand at the sectoral level.

This will also enable us to formulate appropriate energy demand functions and make improved energy demand forecasts at the sectoral level in the long run.

11.4 Energy-Economy Interactions

The primary objective in this study would be to expand the static macro-economic model of the Egyptian economy completed so far into a dynamic multi-sectoral macro-economic model in order to trace energy-economy interactions over time.

The dynamic macro-economic model will be a useful tool to map out appropriate trade-offs between potentially conflicting objectives, such as growth, equity, unemployment, and conservation, and make appropriate policy recommendations for the future course of the Egyptian economy.

Acknowledgments

This project is based on the works of the members of the research team. Chapters 3-6 draw upon reports prepared by Mr. Peter Haas and revised by Dr. Supriya Lahiri. Chapter 7 was written by Dr. Gaber Barakat. Chapter 8 summarizes the structure of the Egyptian Petroleum Model from a report prepared by Mr. Michael Lynch. Chapter 9 draws upon a report on natural gas prepared by Dr. David Woodruff. Chapter 10 summarizes the structure and results of a macro-economic model specified by Dr. Supriya Lahiri with collaboration from Dr. Lance Taylor and early inputs from Mr. Desmond McCarthy. The petroleum sector plans and programs are derived from official reports by EGPC and from a paper written by Dr. Abdel Mohsen Abdel Ghani Ibrahim.

LIST OF WORKING PAPERS AND REPORTS

1. Abdelmohsen A. G. Ibrahim. "Highlighting the Main Features of Egypt's Petroleum Sector Plans." TAP Report 83-4. Cairo: Ministry of Planning, September 1982.
2. Sakr Ahmed Sakr, "Interactions between Energy and Economic Growth in Egypt." October 1982.
3. Nazli Choucri (M.I.T.) and M. Zaki Shafei (Cairo University). "Resource Development and Policy in Egypt: Petroleum and Natural Gas: Summary and Conclusions." TAP Report 83-3. January 1983.
4. David Woodruff (M.I.T.). "Linear Programming Analysis of the Use of Natural Gas in Egypt: Energy Project: Petroleum and Natural Gas in Egypt." TAP Report 83-5. November 1982.
5. Nazli Choucri and Supriya Lahiri (M.I.T.). "Short-Run Energy-Economy Interactions in Egypt." TAP Report 83-7. May 1983.
6. M. Gaber Barakat (Cairo University). "General Review of the Petroliferous Provinces of Egypt with Special Emphasis on their Geologic Setting and Oil Potentialities." TAP Report 83-1. June 1982.
7. Nazli Choucri and Michael C. Lynch (with the assistance of David Woodruff). Egyptian Petroleum Model (in preparation).

NOTES

1. See Petroleum Economist, vol. 50, no. 3 (March 1983).
2. Egyptian General Petroleum Corporation, Ministry of Energy and Electricity. The above figures are based on the data available for the year 1975.
3. United Nations, Yearbook of World Energy Statistics, 1979.
4. Comparisons have been made in terms of percentage shares of imports of each sector to total imports by all sectors.
5. The changes in final demand are in nominal terms because the 1977 input/output are in current 1977 prices and the 1979 input/output are in current 1979 prices.
6. The above estimate has been calculated in terms of the energy sector's final demand contribution to the GDP (estimated on the basis of final demand at market prices).
7. See Middle East Economic Survey (28 March 1983).
8. Lance Taylor, Structuralist Macroeconomics: Applicable Models for the Third World (New York: Basic Books, 1983).
9. Lance Taylor, Edmar L. Bacha, Eliana A. Cardoso, and Frank L. Lysy, Models of Growth and Distribution for Brazil (New York: Oxford University Press, 1982).
10. The Social Accounting Matrix for Egypt is presented in Appendix A.
11. F. Desmond McCarthy and Lance Taylor, "Macro Food Policy Planning: A General Equilibrium Model for Pakistan," Review of Economics and Statistics (1978).

12. Richard S. Eckaus, F. Desmond McCarthy, Amr Mohie-Eldin, "Multi-Sector General Equilibrium Models for Egypt," Monograph No. 233, Cairo University/Massachusetts Institute of Technology Technological Planning Program (1979).

13. See J. R. La Pittus, CDSS Policy Issues Facing Egypt (USAID/Cairo, February 11, 1982) for an extremely useful discussion on energy price distortions in Egypt.

14. The Egyptian authorities proposed a "quantum jump" scenario which involves a rise in fuel oil prices from L.E. 7.5 a ton to L.E. 32 a ton. This approximates a fourfold rise in the domestic price of oil.

APPENDIX A

Social Accounting Matrix of Egypt, 1977
(in million LE)

		1 Agriculture	2 Construction	3 Heavy Industry	4 Light Industry
1.	Agriculture	474.22	0.0	3.39	1039.70
2.	Construction	.60	13.21	1.63	4.36
3.	Heavy Industry	14.34	96.20	157.83	91.59
4.	Light Industry	7.31	134.21	19.74	592.39
5.	Transportation	2.51	5.00	6.11	23.16
6.	Rest of Economy	24.66	215.39	36.86	152.50
7.	Suez	0.0	0.0	0.0	0.0
8.	Oil Extraction	.17	18.11	11.26	8.28
9.	Oil Refining	9.72	9.66	39.32	20.95
10.	Other Energy	.16	2.07	20.65	16.39
11.	$\sum(1-10)$	533.69	493.85	296.79	1949.32
12.	H.H. Wage Income		405.74	124.87	581.53
13.	H.H. Profit Income		295.89	32.76	259.03
14.	Agricultural Income	1581.48			
15.	Total Private Income $\sum(12-14)$	1581.48	701.63	157.63	840.56
16.	Government Income	142.20	78.65	139.67	481.09
17.	Gross Savings				
18.	Imports	83.25	91.66	114.42	427.69
19.	Producer/ Consumer Subsidy	-46.03			-299.24
20.	Indirect Taxes			77.18	257.28
21.	Direct Taxes				
22.	Total Gross Output	2294.59	1365.79	785.69	3656.70

		5 Transportation	6 Rest of Economy	7 Suez	8 Oil Extraction
1.	Agriculture	8.71	86.72	0.0	0.0
2.	Construction	10.39	13.32	0.0	.54
3.	Heavy Industry	1.61	86.38	.64	5.27
4.	Light Industry	20.26	214.35	4.06	6.36
5.	Transportation	5.34	163.04	.39	.71
6.	Rest of Economy	43.87	216.04	2.44	4.63
7.	Suez	0.0	7.53	0.0	0.0
8.	Oil Extraction	0.0	.67	0.0	.23
9.	Oil Refining	22.0	69.48	1.68	4.55
10.	Other Energy	5.67	20.27	.36	.68
11.	$\sum(1\text{-}10)$	117.85	877.80	9.57	22.97
12.	H.H. Wage Income	123.24	1384.25	17.59	10.09
13.	H.H. Profit Income	13.14	812.09	0.0	34.53
14.	Agricultural Income				
15.	Total Private Income $\sum(12\text{-}14)$	136.38	2196.34	17.59	44.62
16.	Government Income	205.94	110.74	158.24	157.26
17.	Gross Savings				
18.	Imports	49.51	327.04	0.0	7.24
19.	Producer/ Consumer Subsidy	-15.35	-15.35		
20.	Indirect Taxes		463.11		34.30
21.	Direct Taxes				
22.	Total Gross Output	494.33	3959.68	185.40	266.39

		9 Oil Refining	10 Other Energy	11 $\sum(1\text{-}10)$	12 Private Consumption
1.	Agriculture	0.0	0.0	1612.74	933.89
2.	Construction	2.06	.35	46.46	156.77
3.	Heavy Industry	2.86	.14	456.86	128.84
4.	Light Industry	2.22	.73	1001.63	1874.08
5.	Transportation	.21	21.11	208.58	186.51
6.	Rest of Economy	23.32	3.10	722.81	1133.01
7.	Suez	0.0	0.0	7.53	0.0
8.	Oil Extraction	102.94	0.0	141.66	0.0
9.	Oil Refining	12.94	8.97	199.27	53.61
10.	Other Energy	1.09	0.0	67.34	38.29
11.	$\sum(1\text{-}10)$	147.64	15.40	4464.88	4505.00
12.	H.H. Wage Income	10.88	21.59	2679.78	
13.	H.H. Profit Income	11.10	11.65	1470.19	
14.	Agricultural Income			1581.48	
15.	Total Private Income $\sum(12\text{-}14)$	21.98	33.24	5731.45	
16.	Government Income	50.53	49.77	1574.09	
17.	Gross Savings				1469.41
18.	Imports	58.38	8.41	1167.60	
19.	Producer/ Consumer Subsidy	-7.67		-383.64	-188.96
20.	Indirect Taxes	17.15	8.58	857.60	
21.	Direct Taxes				246.00
22.	Total Gross Output	288.01	115.40	13411.98	6031.45

		13	14	15	16
		Government Expenditures	Gross Fixed Investment	Stock Changes	Total Exports
1.	Agriculture	58.63	.18	18.97	238.88
2.	Construction	75.80	1086.76	0.0	0.0
3.	Heavy Industry	38.61	74.49	39.12	47.77
4.	Light Industry	144.83	288.77	172.23	217.56
5.	Transportation	28.53	0.0	0.0	70.71
6.	Rest of Economy	1195.40	319.20	43.6	545.66
7.	Suez	0.0	0.0	0.0	177.87
8.	Oil Extraction	0.0	0.0	5.22	119.51
9.	Oil Refining	24.43	0.0	1.46	52.04
10.	Other Energy	9.77	0.0	0.0	0.0
11.	$\sum(1\text{-}10)$	1576.00	1769.40	280.60	1470.00
12.	H.H. Wage Income				300.00
13.	H.H. Profit Income				
14.	Agricultural Income				
15.	Total Private Income $\sum(12\text{-}14)$				
16.	Government Income				
17.	Gross Savings	529.09			490.00
18.	Imports		438.50		
19.	Producer/ Consumer Subsidy	572.60			
20.	Indirect Taxes				
21.	Direct Taxes				
22.	Total Gross Output	2677.69	2207.90	280.60	2260.00

$\underbrace{2207.90 \quad 280.60}_{2488.50}$

		17 Competitive Imports	18 Indirect Taxes	19 Direct Taxes	20 Total Gross Output
1.	Agriculture	-568.70			2294.59
2.	Construction	0.0			1365.79
3.	Heavy Industry	0.0			785.69
4.	Light Industry	-42.4			3656.70
5.	Transportation	0.0			494.33
6.	Rest of Economy	0.0			3959.68
7.	Suez	0.0			185.40
8.	Oil Extraction	0.0			266.39
9.	Oil Refining	-42.8			288.01
10.	Other Energy				115.40
11.	$\sum(1-10)$	-653.90			13411.98
12.	H.H. Wage Income				2979.78
13.	H.H. Profit Income				1470.19
14.	Agricultural Income				1581.48
15.	Total Private Income $\sum(12-14)$				6031.45
16.	Government Income		857.60	246.00	2677.69
17.	Gross Savings				2488.50
18.	Imports	653.90			2260.00
19.	Producer/ Consumer Subsidy				0.0
20.	Indirect Taxes				857.60
21.	Direct Taxes				246.00
22.	Total Gross Output	0.0	857.60	246.00	27973.22

APPENDIX B

The following table describes the total production of oil in Egypt in the alternative simulation runs. "Previous simulation" refers to the simulation results recorded in an earlier report, "Resource Development and Policy in Egypt: Petroleum and Natural Gas: Summary and Conclusions," by Nazli Choucri and M. Zaki Shafei, TAP Report 83-3, January 1983.

Total Production of Oil in Egypt
(million barrels/year)

	Actual	Previous Simulation	Current Simulation
1970	170	110	115
1971	151	111	115
1972	128	106	112
1973	93	104	111
1974	84	107	115
1975	108	114	122
1976	119	120	133
1977	151	142	161
1978	175	152	176
1979	192	168	198
1980	215	187	226
1981	252	205	256