

Archive

ANALYSIS OF THE WORLD OIL MARKET

H.D. Jacoby, et al.

MIT Energy Laboratory Report no. MIT-EL 80-016

April 1978

Final Report to the
National Science Foundation

for the period March 1, 1975 to February 28, 1978

of project on

ANALYSIS OF THE WORLD OIL MARKET

(Grant No. SIA75-00739)

being carried out by the

M.I.T. Energy Laboratory in Cooperation With
the Sloan School of Management
and Department of Economics

M.I.T. Energy Laboratory Report No. MIT-EL 80-016
April 1, 1978

CONTENTS

	<u>Page</u>
Project summary	i
1. Introduction	1
2. Review of Work to Date	2
2.1 Framework Analysis	3
2.2 The Analysis and Simulation of World Energy Demand	4
2.3 Analysis and Simulation of World Oil Supply	8
2.4 Models of Cartel Behavior	11
2.5 Simulation Model	14
2.6 Special Studies	17
2.6.1 Contract Arrangements and Trade Patterns	17
2.6.2 Financial Aspects of the Oil Market	17
2.6.3 Transport and Quality Differentials and Refinery Margins	18
2.6.4 Extension to Other Resources	18
3. Applications to Policy Analysis and Dissemination of Results	19
 <u>Appendices</u>	
A. Reports and Papers from the M.I.T. World Oil Project	
B. List of Meetings, Lectures, Conferences and Testimony	
C. Organizations which have Received Data from the M.I.T. World Oil Project	

PROJECT SUMMARY

The M.I.T. World Oil Project is developing improved methods and data for analysis of the future course of the world oil market. Market forecasts depend on analysis of likely demand for oil imports by major consuming countries, and the supply from exporters who behave as "price-takers" in their oil exploration and production. The resulting net demand for oil from the core members of the oil cartel determines the ability of OPEC to set prices. In the World Oil Project, study of net demand for cartel oil is accompanied by analysis of the likely behavior of the price-setters themselves, and exploration of the details of market structure as they influence price behavior and trade patterns.

The work involves a set of studies of oil supply from key producer areas, import demand from major consumers, and the integration of estimated supply and demand functions into a simulation model for studying future developments. The simulation framework is combined with a separate set of behavioral models of the cartel-core nations and their price-setting decisions, and with studies of evolving contract arrangements, trade patterns, and financial factors.

The research is contributing to our understanding of the workings of the world oil market and of the likely effects of various national policies. Results include forecasts of likely future price paths, studies of possible causes of cartel instability, evaluation of various consumer and producer country policies, and study of likely trade patterns in oil and their implications for national security and international finance.

1. INTRODUCTION

The World Oil Project is being carried out by the M.I.T. Energy Laboratory in association with the Sloan School of Management and the Department of Economics. The work was initiated in Summer 1973, with seed money from the M.I.T. Energy Laboratory. Beginning in March 1975, the project received support from the National Science Foundation. The original grant request was for a 3-year period. Funding was first granted for an 18-month period, March 1, 1975 to August 31, 1976. Later, a continuation proposal was approved, providing support for the period September 1, 1976 through February 28, 1978. Currently, the research is also being supported, in part, by the M.I.T. Center for Energy Policy Research.

The work has been led by three co-principal investigators:

M.A. Adelman -- Professor of Economics,

Henry D. Jacoby -- Professor of Management and Director of the M.I.T.
Center for Energy Policy Research,

Robert S. Pindyck -- Associate Professor of Management.

Over the course of the project several other faculty and M.I.T. staff have contributed to the work. Also, students play a significant role in the research; in the past three years 17 graduate students have been employed as research assistants, for periods ranging from a semester to two years or more.

2. REVIEW OF WORK TO DATE

Over the three years of the grant period the M.I.T. World Oil Project has completed a considerable amount of research on the behavior of world energy demand, the analysis of the supply of oil in various regions of the world and its response to price changes and changes in other variables, the behavior of the OPEC cartel, and the implications of higher energy prices on world financial markets. Also, through the integration of our analytical studies into a large-scale simulation model, we are able to analyze the possible future behavior of the world oil market. The output of the research has taken the form, first, of a functioning simulation model, and second, a large number of published and unpublished articles, books, working papers, and research memoranda. The purpose of this review is to summarize the written material that has come out of the Project, and to provide a guide to the reading and interpretation of this material.

Many of the studies conducted under the aegis of this project were motivated by our particular approach to the analysis of the world oil market. It is therefore appropriate to begin our survey work to date with a brief review of our framework of analysis. Next we will turn to the studies of world energy demand conducted under this project, and the studies of world oil supply, and to the simulation model that incorporates the results. Finally, we will survey our work on cartel behavior, and on special studies of other issues associated with the world oil market. Throughout we refer to the published and unpublished reports and papers listed in Appendix A.

2.1 Framework of Analysis

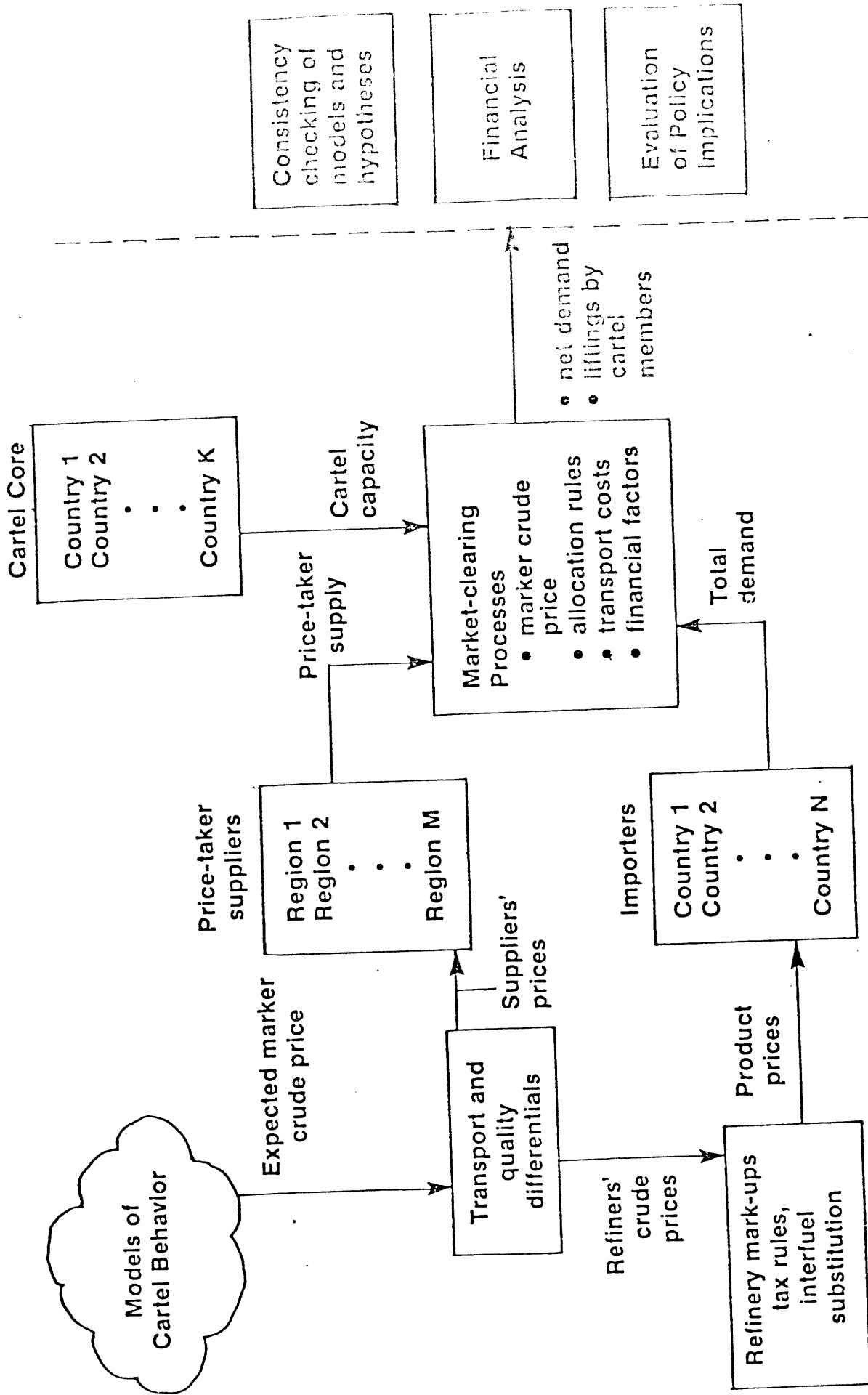
Our basic approach to the analysis of the world oil market is shown in Figure 1. In addition to displaying the various analytical studies conducted under this project, Figure 1 also serves as a simplified flow diagram of our simulation model of the world oil market. (Simulations studies done early in the Project, and which helped to define our current approach, are discussed in the work of Eckbo (8).)

The heart of this project is the set of supply and demand studies shown in the middle of Figure 1. These studies are valuable in their own right in that they help to improve our understanding of the effects of fundamental market forces on energy demand and supply. In addition, these studies serve to provide estimates of supply functions for price-taker suppliers and demand functions for importers that are needed for our simulation model. Because these studies served two functions, they often went beyond the level of analysis that would have been sufficient simply to develop equations for the simulation model.

The simulation model itself is designed to accept an anticipated or assumed oil price trajectory, and to compute the resulting demands, supplies, and other market characteristics over a particular simulation horizon. The development of hypotheses about likely cartel pricing behavior represents another area of research conducted as part of this project. Several behavioral models of cartel pricing were developed, and the price hypotheses themselves are represented by the cloud at the upper left of Figure 1. Note that our behavioral models of the cartel represent only one means of

Figure 1

OVERALL ANALYSIS FRAMEWORK



generating price scenarios; price scenarios based on the analysis or judgment of others can also be tested using the simulation framework.

One might ask why we approach the analysis of the world oil market using two separate types of models -- one to represent cartel behavior, and the other a detailed simulation model of market supply and demand. The reason for this division is largely analytical convenience. The determinants of import demand and price-taker supply are complex, and to analyze the likely response of the market to one or another price pattern, one needs a method that can accept unwieldy functional relationships. This requirement leads to a simulation framework for the overall analysis of market demand and supply outside the cartel. The analysis of cartel behavior, however, involves dynamic optimization calculations that are generally feasible (given limited computer resources) only with simplified supply-demand relationships. The two analyses feed on one another, however, as shown in Figure 1.

2.2 The Analysis and Simulation of World Energy Demand

One part of the World Oil Project has been a detailed econometric analysis of the characteristics of energy demand in about 10 of the world's major energy-consuming countries. It was our feeling that to understand world oil demand one had to also understand the demand for other fuels, since these fuels are competitive with each other. Thus, one of our objectives has been to obtain a firm quantitative grasp on the characteristics of total energy use, again on a sector-by-sector basis. In the case of the residential sector, for example, this means understanding the role of energy as part of total consumption expenditures, and understanding how energy might be

substituted with other categories of expenditures in response to price or income changes. In the case of the industrial sector, this means better understanding the role of energy as a factor of production, and the degree of long-run substitutability between energy, capital, and labor.

Our analysis of world energy demand began with the development of an extensive data base. This data base itself represents an important product that has come out of our project; already our data are being used by several research groups around the world (see Appendix C). We have gone out of our way to organize and store the data in a manner that assures easy access by other research groups. Many of these data are described in detail in a "User's Guide" (19).

Econometric work on the residential and industrial sectors is largely completed. Our analysis of the residential sector indicates elasticities to consumer-level product prices that are larger (around -1.0 for total energy use) than had been commonly assumed earlier. In addition, there seems to be considerable potential for interfuel substitution, at least in the long-run. Our analysis of the residential sector is described in a detailed working paper (25).

Our work on the industrial sector also indicates that the total price elasticity of the demand for energy is larger than had been previously thought. We find, for example, that the price elasticity of total energy demand in the industrial sector is around -0.8 in a 3-factor study such as this (capital, labor, energy). Also, energy and capital are shown to be substitutes. This is in contrast to other studies, with somewhat different data bases, structure and assumptions, which indicate complimentary between

energy and capital. These differences may be due in part to the likelihood of our having picked up long-run rather than short-run elasticities through the use of pooled international data. Our work on the industrial sector is also summarized in a detailed working paper (26).

Work on the transportation sector is so far limited to the demand for motor gasoline. Here we have formulated a model that describes the total stock of automobiles, the average number of miles driven per year for each automobile, and the average fuel efficiency. Analyzing gasoline demand in this way will allow us to introduce and test different dynamic adjustments for each of the three component variables. Our work on estimating functions for gasoline demand is well under way, and preliminary results are available. Documentation of the initial stages of this work is now being drafted.

We have used some rather crude econometric models (largely logarithmic models with Koyck lag adjustments) to model the demands for petroleum products in other sectors, and to model the demands for all petroleum products in countries that consume smaller amounts of energy and that, because of data limitations, have not been included in our detailed analyses. Although our econometric approach has been somewhat simpler, we find that in many cases we can obtain fairly robust estimates for price and income elasticities of demand. Once again, we find price elasticities that are somewhat larger than had been previously assumed, and we attribute this to the use of pooled international data to capture long-run effects. This econometric work will also be documented shortly. In addition, all of our econometric work on energy demand will be described in detail in a forthcoming monograph by Pindyck, to be completed in Summer, 1978.

In carrying out a demand simulation, we need a framework for calculating consumer product prices as well as the relationship of demand to those prices. We therefore had to develop a model that translates exogenous Persian Gulf crude oil prices for particular products in particular countries. In developing this model, we have assumed that transport, refining, and marketing costs will increase mildly, in real terms, by 1980, and will be constant thereafter. In the existing model, consumer taxes may be held constant, or may be assumed to vary under alternative sets of changing tax rules. Non-tax restraints on demand are not yet a part of the model, but might be approximated by the appropriate tax simulations. The description of this part of the demand simulation model is presented in a forthcoming working paper.

The equation structure of the demand simulation as of March 1, 1978 is shown in Figure 2. As the figure indicates, the current model is based on the results of the detailed (translog) econometric work on residential and industrial demand in the major consuming countries. (Data problems in Japan and Belgium lead to the only exceptions here.) Likewise, oil demand estimates for the transport and "other" sectors have been implemented for the big consumers. During April 1978, individual 4-sector demand models will be implemented for another six Western European countries.

Experience with demand estimation for LDC's has been disappointing, due largely to the paucity of reliable data. Various methods have been tried, but at present these countries (which represent less than 20% of world demand) are handled in a highly simplified manner, as indicated in Figure 2.

There are several high-priority items for future research on demand estimation and simulation. Experience with the model to date has shown the

Figure 2

EQUATION STRUCTURE OF MIT WORLD OIL DEMAND MODEL

REGION SECTOR/FUEL	USA CANADA	JAPAN	BELGIUM	FRANCE, ITALY, NORWAY SWEDEN, NETHERLANDS, UK, W. GERMANY	OTHER WESTERN EUROPE	BRAZIL AUSTRALIA SOUTH AFRICA	OIL EXPORTING COUNTRIES	NON OIL EXPORTING LOC'S
INDUSTRIAL	Translog	Translog	Smoothed log-log with lags	Translog	---	---	---	---
RESIDENTIAL	Translog	Smoothed log-log with lags	Translog	Translog	---	---	---	---
TRANSPORTATION MOTOR GAS DIESEL	Smoothed log-log with lags	Smoothed log-log with lags	Smoothed log-log with lags	Smoothed log-log with lags	Regression on translog Europe	Regression on developed countries	---	---
ALL OTHER	Smoothed log-log with lags	Smoothed log-log with lags	Smoothed log-log with lags	Smoothed log-log with lags	---	---	---	---
EVERYTHING BUT MOTOR GASOLINE	---	---	---	---	Regression on translog Europe	Regression on developed countries	---	---
TOTAL PRODUCTS	---	---	---	---	---	---	Growth of historical prices	Tied to Europe
PRODUCT PRICES	Mark-up mechanism	Mark-up mechanism	Mark-up mechanism	Mark-up mechanism	---	---	---	---
PRODUCT TAXES	Alternative options	Alternative options	Alternative options	Alternative options	---	---	---	---

NOTES: (1) Equations in box estimated with pooled cross section of time series.
 (2) The "translog" method involves estimation of total energy demand and fuel shares.
 (3) The "log-log" method involves estimation of oil demand directly.

"other" category to present the biggest difficulties. The major problem is an unfinished item of business from the most recent grant period -- i.e., the electric power sector. In future work we hope to develop a fuel-choice model for electric power -- one that takes account of the unique influence of nuclear energy and the role of government policies -- and re-estimate an "other" category net of electric power production.

Another priority task is to improve the existing model of gasoline demand in the U.S. and other industrial countries. Much of the estimation work is completed, but work remains to be done to implement, test, verify (and perhaps re-estimate) until the best equation structure and parameters have been determined. The quantities are large in this sector, and even minor improvements in accuracy are significant.

As a result of our exhaustive work on the residential and industrial sectors, we have considerable confidence in our estimates of long-run elasticities. However, important research remains to be done to better understand the lag structure -- i.e., the time it takes to realize the adjustments implicit in long-run elasticities. There are improvements to be had as well in the estimation of oil demand by some of the larger LDC's (e.g., Brazil and India) and more data gathering and analysis is justified. Also, special attention needs to be devoted to the oil exporting LDC's, whose demand is small but growing at a very high rate.

2.3 Analysis and Simulation of World Oil Supply

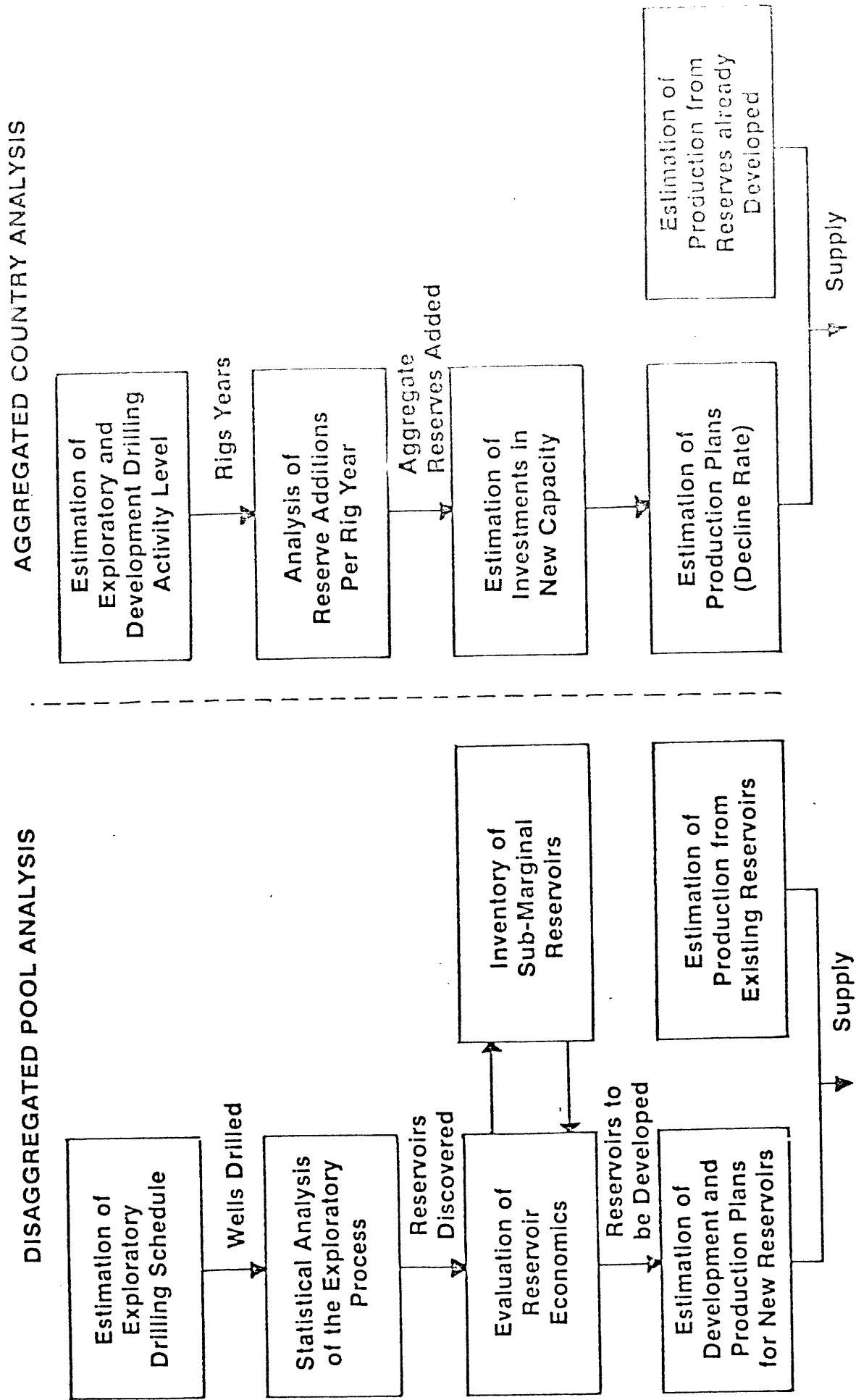
Petroleum exporters need to be grouped into two rough categories. First, there are what we will call "price-taker" suppliers. This is a group of

petroleum exporters who appear to act as price-takers in the sense that each takes the world price (which is being set by others) as given, and makes supply decisions accordingly. This group includes non-OPEC sources such as the North Sea, the USSR, China, and Mexico, and may also include some members of OPEC who have low per-capita incomes, such as Algeria, Indonesia, and Nigeria. Second, there is the "cartel core" -- a small group of nations who are the price-makers. This core includes Saudi Arabia, Kuwait, and others on the Arabian Peninsula; it also may include Iraq, Iran, Libya, and Venezuela. These countries face a residual demand for world oil, which is the total demand less that supplied by the price-taker exporters. These groupings are not hard and fast; indeed, a major focus of our inquiry is the circumstance in which a given exporter would change from one to another camp.

We have used several methods to analyze oil production capacity and supply. The two principal ones are shown in Figure 3; they are described in some detail, and compared, in a paper by Adelman and Jacoby (2). The Disaggregated Pool Analysis felt to be the more accurate of the two. It is discussed in detail in a paper by Eckbo, Jacoby and Smith (6), and background research is presented in projecting working papers (18, 20, 26). Thus far the disaggregated method has been applied to the North Sea (5, 6), and analytical results have been applied in discussion of development policy questions in the area (7, 9). The disaggregated method is costly in terms of its requirements in data, expert geological judgment, and computation, time and money. Work will continue on this method, but over the next year or two it will be applied, at most, to one or two of the most important areas of the world.

Figure 3

Outline of Alternative Supply Analysis Methods



In order to gain worldwide coverage, we have developed another method, the Aggregated Country Analysis (2), which can be carried through for all areas of the world based on data available in the public domain. The method proceeds as follows: For each of 39 producing areas, we calculate the average new proved reserves and capacity brought on by a rig-year (one rig operating per year) during 1972-75. As new proved reserves are impounded from the country's "ultimate" reserves (estimated mostly from the open literature, but drawing also in some private information) successive rig-years bring less new capacity -- unless the "ultimate" reserves are revised upward. The model registers discoveries, and allows for their effects, but does not forecast them. The resulting investment level and ultimate output, given a forecast of the drilling rate, is only weakly responsive to price, at least given our current cost functions.

Work is under way to develop methods of forecasting the response of drilling to price, but at present the drilling scenarios are exogenous. The introduction of endogenous functions must be done with care, for price increases do not necessarily generate additional drilling, and may often discourage it. In private-enterprise countries the government may take more than the incremental revenue; hence, despite the higher market price, the price as perceived by the operating company need not increase and may even decrease. Where the oil industry is government owned, higher revenues may suffice for all commitments and spending plans and dull the perceived need for additional reserves and production. A better explanatory variable than price may be "financial health." Accumulated foreign assets and good credit rating shield a government from the need to cut prices for higher short-term

revenues, or to invest in oil development for higher long-term revenues. Perverse price effects have been discerned in Canada, Norway, and the U.K.; Libya and Venezuela (perhaps considered "core" countries); and in Indonesia and Malaysia. An important change in Mexican policy seems explicable by its heavy debt.

Since the current model is basically inertial, projecting recent tendencies, it must be frequently updated, country by country; if possible, field by field. As the work proceeds, we will introduce functional relations for drilling rates for those countries that may prove responsive to price.

Based on the experience to date, we believe the approach represented by the two models in Figure 3 are a very fertile area for further research, data gathering, and model development. The pay-off is in four areas:

- Improved data for the aggregate model -- including better analysis of drilling rates and associated costs, more analysis of the influence of tax systems and other producer government policies, and better estimates of ultimate recoverable reserves.
- Adjustment of the aggregate model using insights and functions developed in the research on the disaggregated model -- essentially developing a hybrid that captures the importance of geology and engineering cost, as does the disaggregated model, but still requires only data that are readily available for most areas of the world.
- Further development of the disaggregated model itself, as a new and very useful analytic tool.
- Study of the influences on producer government policy -- particularly financial burdens and balance of payments problems.

2.4 Models of Cartel Behavior

We have conducted a number of studies of the structure of the OPEC cartel and its implications for the pricing of oil over the next two or three

decades. In these studies, the cartel is treated as an economic unit. There are, of course, constraints within the cartel slowing down or blocking evolution, and also from outside macroeconomic or political factors. The importance of these behavioral models is that they show the ultimate tendencies of the wealth-maximizing group.

This work has largely involved the application of nonlinear optimal control algorithms to several small and somewhat simplified models of the world oil market and the OPEC cartel. For example, in one study we treated OPEC as a unified monopoly that shared all production cutbacks evenly (4,12). We tried to determine the price trajectory for oil that would be optimal for this cartel, i.e., that would maximize the sum of present and future discounted revenues. This optimization was subject to the constraints of a simple model of the world oil market, in which the total demand for oil was a dynamic function of price and income, the supply of non-cartel oil was a function of price as well as resource depletion, and where OPEC's production costs would rise as its reserves were depleted. Later, this approach was applied to other cartels, including CIPEC (the copper cartel) and IBA (the International Bauxite Association) (14, 15).

We also extended our model of OPEC to account for the fact that there are countries within the cartel that operate under different constraints and that may have somewhat different objectives (10). In particular, we divided the cartel into two groups of countries. "Saver" countries were those that had very large reserves of oil and very little immediate need for cash, so that they would use a small discount rate in determining the present value of their oil revenues. "Spender" countries, on the other hand, have a higher immediate

need for cash, and also enjoy much greater reserves. We found that this division of the cartel leads to a clear-cut conflict in objectives, but that Nash bargaining theory could be used as a way of determining potential resolution to that conflict. Nash solutions call for not only an optimal price trajectory, but also an optimal division of cartel output, and in particular call for the "saver" countries to do most of the cutting back initially.

In addition to this, we have also been looking at some fundamental questions in the economies of resource exploration and production. In particular, we have examined the problem of the interrelationship between the optimal rate of nonrenewable resource exploration and the optimal rate of resource production. One of the problems with our earlier cartel studies is that they ignored reserve accumulation resulting from new exploration, and progress has been made in introducing this important influence (12)..

Much of our work on optimal cartel behavior was done during the first 18 months of the project. Though research on these issues has continued through the 18-month continuation period, the resources committed to this area have not been great -- the major new contributions being the introduction of exploration into the models, and the extension to minerals besides oil. Work is under way on the integration of the cartel behavioral analysis with the simulation framework, but full communication between the two models has not yet been achieved. The missing link is the use of the simulation framework to generate simplified supply and demand functions for the analytical models of cartel pricing, and the attainment of convergent solutions. This link-up remains a high-priority item of research.

Also, there are useful extensions of the cartel models themselves that are yet to be achieved. These include further work on the role of exploration (12), the introduction of financial variables in the supply equation, and possible extensions to cartels of more than two parts.

2.5 Simulation Model

As noted in Section 1, we have developed a simulation model which incorporates the demand and supply work discussed above, and makes use of insights into OPEC behavior drawn from continuing studies of the behavior of the cartel core. The overall simulation apparatus consists of three parts:

- A demand simulator, which includes a set of price determination routines, and which computes worldwide demand using the equation structure summarized in Figure 2.
- A supply simulator, which implements the aggregate model of oil supply, summarized in the left side of Figure 3.
- An integration package which computes supply-demand balances, and analyzes the allocation of excess capacity within the cartel core.

The simulation program is written in the computer language TROLL, with the supply analysis being written in FORTRAN and imbedded in the TROLL structure. User's guides to the overall simulation package, and to various supporting programs are in draft.

The large-scale simulation model has gone through several stages. It was first completed and used for analysis in July 1977, a Phase II version was completed in October 1977, and further modifications were incorporated into a Phase III version which constitutes the operating program as of February 1978.

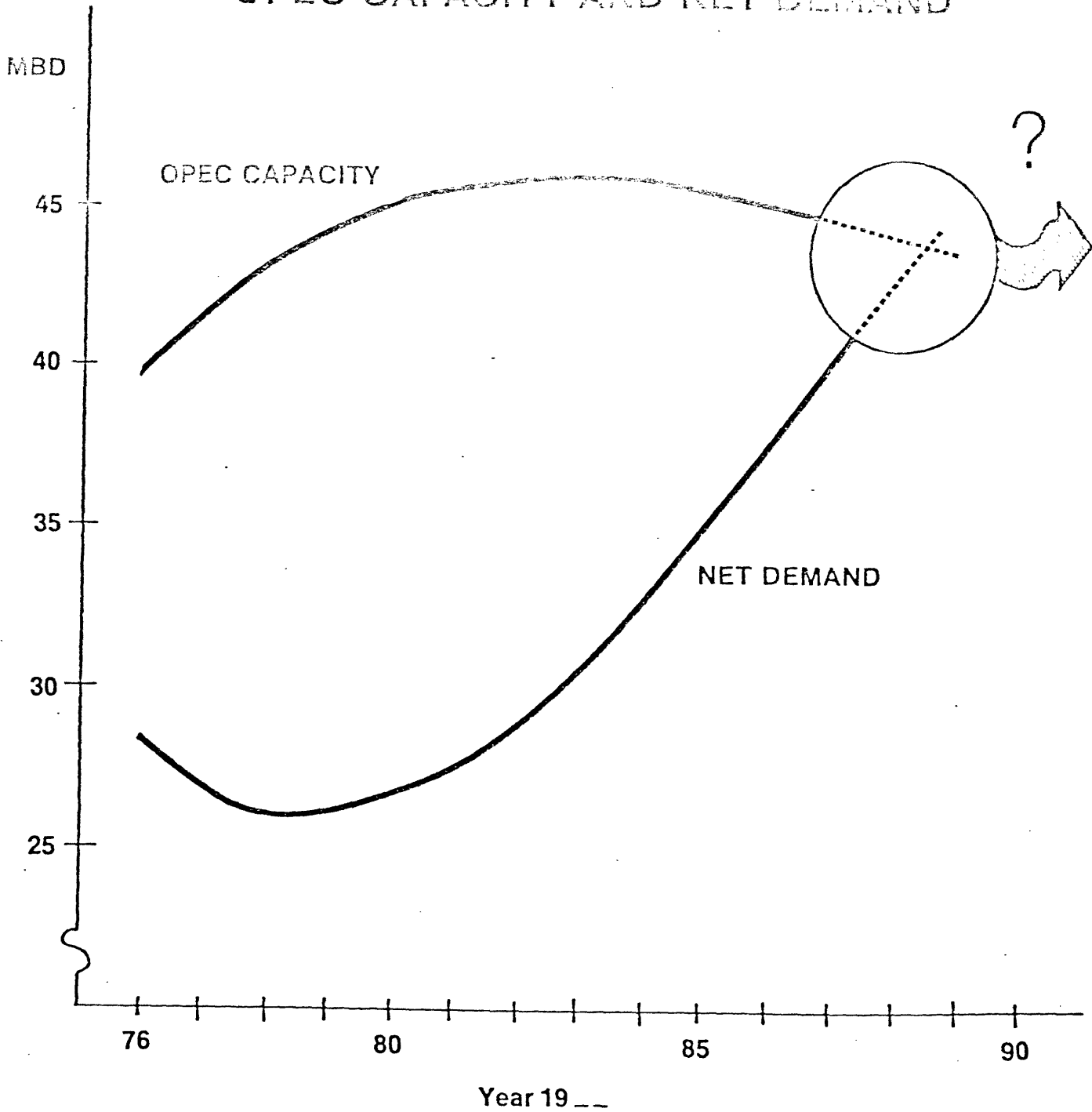
A sample of the simulation output is shown in Figure 4. Assumptions behind this particular calculation are shown at the bottom of the figure. In addition, consumer taxes are held constant in the sample results shown here.

Note that any scenario is only valid up to the point where demand rises near to capacity -- not beyond. If demand exceeds the amount supplied, or if it is expected to, prices will rise in advance of the "crossover," with a feedback effect upon demand, probably magnified through effects on the world trading and money system. Thus the results shown in Figure 4 lead to subsequent stages of analysis for clearly the crossover point shown in the figure cannot be reached. Some years before the excess capacity actually dried up, the oil price would begin to rise -- perhaps outside the cartel's control. The effect of such a price change (and in this example we show only one of several possible hypotheses about what might happen to price) is shown in Figure 5. First, the effect, given continuous healthy economic growth, is shown. Second, the figure shows the results of a hypothesis of serious worldwide recession being precipitated by a sudden price increase of the magnitude assumed in Figure 5.

The serious economic and political implications of the picture shown in Figure 5 raises doubts that such an event would actually be allowed to happen, and leads to subsequent stages in analysis. The logical next step (not shown here) is to look further into the role of expectations of future price problems, and the likelihood of a gradually rising price through the 1980's, perhaps with a retardant effect on worldwide economic growth. Note that the figures shown here are based on preliminary model results, and are intended

Figure 4

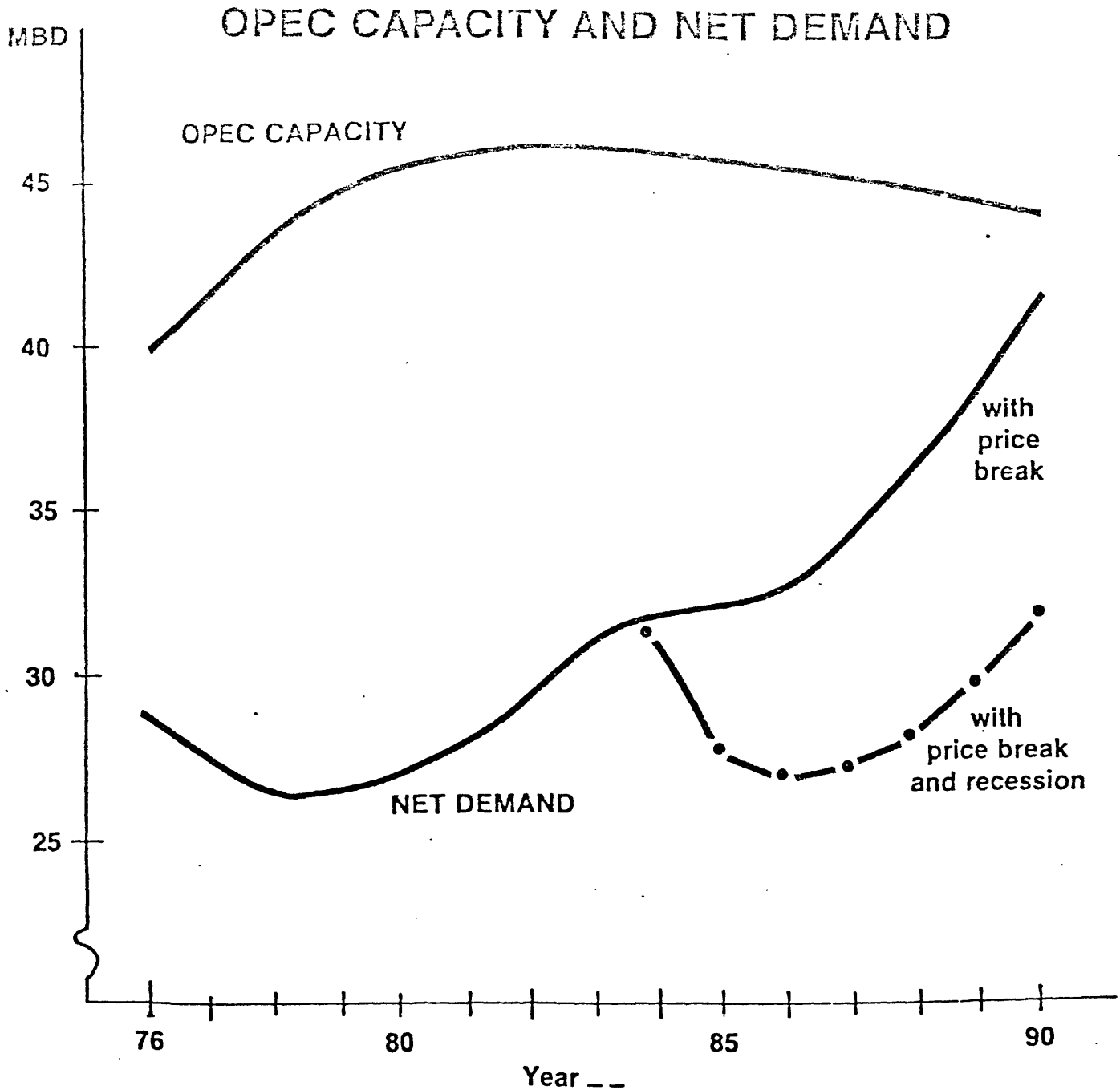
OPEC CAPACITY AND NET DEMAND



Assumptions:

- Constant real price at \$12.50 (1977 prices)
- Healthy growth
- Drilling rising at 5% per year

Figure 5



Assumptions:

- Price break. Price jumps to \$15 in 1984, \$25 in 1985, and returns to \$18 by 1987.
- Recession. No growth in 1984, negative 3-5% in 1985, returning to base growth level by 1990.
- Drilling rising at 5% per year.

only to demonstrate the current status of the models and analysis. These figures may change as data development and analysis proceed. Also, here we do not explicitly consider any divergent conduct or frictions within the cartel, which has been successful so far but with much tension.

There are more improvements that should be made to the simulation framework. First and foremost, the model must be corrected, and rechecked and calibrated, each time some results are incorporated from the demand and supply estimation work. The structure of the overall simulation has been made highly modular to make this process as painless as possible. Also, as the model begins to be used for analysis by groups outside the Project, the users are requesting features that were not in the original model design. (As an example, an early outside request was for simulations involving complex variations in GNP growth rates between countries and over time, whereas the original design allowed only a single growth rate for each country.)

Thus far, these minor changes have been accommodated without great difficulty. In addition, there are other improvements that are worth making, even with the current demand and supply modules:

- More flexible means of handling consumer tax policies, by product and by country.
- More flexible assumptions regarding drilling rates in the aggregate supply model.
- Changes in the year-to-year supply/demand balance, to allow more flexible cartel allocation hypotheses, and pricing algorithms.

Also, the closer integration with the analytic models of cartel behavior is a priority area for additional research.

2.6 Special Studies

2.6.1 Contract Arrangements and Trade Patterns

Work continues on the monitoring of developments in the oil market. The results of this survey and study activity are reflected in a number of the models (particularly the work on supply (2, 5) and cartel behavior (12), and in the various papers that discuss market structure and performance and related policy issues (1, 13). However, we have not written papers dedicated exclusively to the details of day-to-day market evolution.

Continuing study of this area is an essential component of further work on the world oil market.

2.6.2 Financial Aspects of the Oil Market

We have done a number of studies of the financial aspects of the world oil market and its evolution over time. This work began with the gathering and analysis of some key data on financial markets (17). Related efforts explored the phenomena of primary and secondary recycling of oil funds (16, 3). Due to limitations on project resources, the work on financial aspects has, so far, been a small part of our overall activity. However, one important result of this work has been a clearer understanding of international financial markets as they are impacted by oil deficits, and the important role played by adjustments in good markets (i.e., adjustments in the balance of trade) in the worldwide equilibrating mechanism. A good deal of our work in this area is brought together in a paper by Agmon, Lessard and Paddock (3).

2.6.3 Transport and Quality Differentials and Refinery Margins

Considerable data gathering and analysis has been completed on these costs and margins. The results are used in the simulation model to calculate export prices for crude oil and product prices to consumers (see Figure 1).

Documentation of this work, and the results, are contained in a forthcoming working paper.

2.6.4 Extension to Other Resources

The formal analysis of cartel behavior has been extended to other minerals (14, 15), but Project funds devoted to these extensions during the past year have been small. Based on experience to date, the most productive extension to other resources would be to incorporate more explicit analysis of the supplies, demands, and markets for LNG and steam coal, which are closely related to the oil market.

3. APPLICATIONS TO POLICY ANALYSIS AND DISSEMINATION OF RESULTS

We feel that our work is readily applicable to a number of important policy questions. For this reason, we are now beginning to use some of our results as a basis for the analysis of particular policy programs. We expect that this work will result in published papers on policy (1, 13), as well as analyses performed in response to the requests of government agencies and Congressional committees. Other policy-oriented papers are now in draft.

In addition, we are developing the documentation necessary to make our data bases and models available to other research groups and to government agencies. As mentioned earlier, we are preparing detailed and comprehensive documentation for our world energy demand data base (19). Appendix B shows the research groups who are already making use of this data resource. In addition, we are developing documentation that will enable other groups to use our simulation models.

Dissemination of results also takes place through the involvement of project leaders and members in professional meetings, by the giving of seminars, lectures and testimony, and through participation in conferences on international energy issues. In addition, project members are in working contact with many groups who are working on oil issues, who are sources of data and assistance, or who are clients for results. A list of these contacts over the grant period is provided as Appendix B.

APPENDIX A

Publications and Working Papers from the M.I.T. World Oil Project

PUBLICATIONS

1. Adelman, M.A., "Producers, Consumers, and Multinationals: Problems in Analyzing a Non-Competitive Market", October 1977. Originally released as Working Paper MIT-EL- 77-038WP, a revised version of this paper appeared as: "Constraints on the World Oil Monopoly Price," Resources and Energy, Vol. 1, No. 1, 1978. A summary appears in Petroleum Economist, September 1977.

The consuming nations have the power to damage or wreck the world oil monopoly, but prefer cooperation because of their fixed belief that otherwise the market will fail to clear and generate a "gap." Yet they may use the power inadvertently. The monopoly acts essentially as a loose cartel, with a safety net: a large seller (Saudi Arabia) would, if need be, act as the restrictor of last resort. But this would maximize Saudi profits at a much lower price, penalizing the other sellers. The conflict can be held off by ad hoc agreements while raising the price. But the risk of conflict and highly uncertain long run demand and supply make it likely that the cartel will only slowly and gradually approach profitor wealth-maximization. "Political objectives" coincide with economic and can be neglected.

2. Adelman, M.A., and H.D. Jacoby, "Alternative Methods of Oil Supply Forecasting", in R.S. Pindyck (ed.), Advances in the Economics of Energy Resources, Vol. 11, J.A.I. Press, 1979. Originally distributed as Working Paper MIT-EL-77-023WP.

Analysis of likely developments in the world oil market is ultimately dependent on some method of forecasting oil supply from key regions. Unfortunately, data problems tend to dominate work in this area, and much of the analysis task reduces to making the best use of the limited information that is available. Here we report on two alternative approaches to this forecasting problem, both avowedly data-oriented.

Petroleum exporters need to be grouped into two rough categories. First, there are what we call price-taker suppliers. Second, there is the "cartel core"--a small group of nations who are the price-makers. Their groupings are not hard and fast; indeed an exporter would change from one to another camp.

In this paper our focus is on the price-takers. Our analysis seeks an understanding of the fundamental market forces, and to provide estimates of supply functions for price-taker suppliers and demand functions for importers. These functions are to be incorporated into a simulation model of overall market performance.

3. Agmon, T., D.R. Lessard, and J.L. Paddock, "Financial Markets and the Adjustment to Higher Oil Prices", in R.S. Pindyck (ed.) Advances in the Economics of Energy and Resources, Volume I, J.A.I. Press, Greenwich, Conn., forthcoming. Originally distributed as Working Paper MIT-EL 77-039WP.

This paper explores the linkages between the world energy and financial markets. The role of international financial markets in the adjustment of the real markets for energy is analyzed from both a conceptual and empirical viewpoint. Financial intermediation is found to be an important accommodation mechanism in the market-clearing behavior of price and quantity. Finally we look at the portfolio aspects of producers' "surplus funds," and the implications of stress for world financial market.

4. Cremer, J. and M.L. Weitzman, "OPEC and the Monopoly Price of World oil", European Economic Review, Vol. 8, 1976, pp. 1555-164. Originally distributed as Working Paper MIT-EL 76-015WP.

This paper presents a dynamic model of the behavior of OPEC viewed as monopolist sharing the world oil market with a competitive sector. The main conclusion is that the recent increase in the price of oil was a once-and-for-all phenomenon due to the formation of the cartel. The model form used here indicates that real oil prices should remain approximately constant over the next twenty years.

5. Eckbo, P.L., "A Basin Development Model of Oil Supply," in R.S. Pindyck, (ed.) Advances in the Economics of Energy and Resources, Vol. II, J.A.I. Press, Greenwich, Conn., forthcoming.

The paper describes a procedure for estimating the supply potential of a region given an exogenously specified time profile for exploratory drilling. The procedure involves analysis of the exploration for finding development, and production of reservoirs. The Basin Development Model relies on a deterministic discovery decline relationship to generate an expected discovery sequence. This discovery decline relationship serves as a first approximation to the joint analysis of the exploration for plays and reservoirs inside a play. The reservoirs found enter into a reservoir model which takes account of costs and expected future prices, and allows detailed consideration of the tax regime. By separating exploration and finding activities from development and production activities, the Basin Development Model allows consideration of the two major aspects of resource depletion, the depletion of producible reservoirs from the population of reservoirs to be found, and the depletion of recoverable reserves from the existing population of producible reservoirs. The price elasticity of the level of ultimate recoverable reserves falls out of the interaction between the exploration and reservoir analysis as demonstrated in the paper.

6. Eckbo, P.L., H.D. Jacoby, and J.L. Smith, "Oil Supply Forecasting: A Disaggregated Process Approach," Bell Journal of Economics, Spring 1978. Originally distributed as Working Paper MIT-EL 77-001.

Work is under way on a forecasting method that incorporates explicit representations of the steps in the oil supply process: exploration, reservoir development, and production. The discovery history of a region and other geological data are input to a statistical analysis of the exploratory process. The resulting estimate of the size distribution of new reservoirs is combined with an evaluation of reservoir economics--taking account of engineering cost, oil price, and taxes. The model produces a forecast of additions to the productive reserve base and of oil supply. Progress to date is demonstrated in an application to the North Sea.

7. Eckbo, P.L., "Planning and Regulation in the North Sea", Northern Offshore, No. 9, September 1976.

This article discusses the impact on North Sea exploration, production, and reserve levels of Norwegian Government block-allocation and tax policies.

8. Eckbo, P.L., The Future of World Oil, Ballinger Publishing Company, 1976. Originally distributed as Working Paper MIT-EL 75-017WP.

This paper describes a behavioral model of the international petroleum market and presents the results from it. The purpose of the study is to develop a framework for analysis of the implications of non-competitive behavior in the international petroleum market. The focus is on the market strategies that may be pursued by the world's oil exporters on a joint or an individual basis. The structure of the model is designed to combine features of formal modeling and of informal "story-telling" in a consistent framework. Such a structure requires a simulation type model.

The "stories" that are being told are constructed from cartel theory, from the empirical evidence on previous commodity cartels and from the special characteristics of the individual oil exporters. The model is evolutionary in the sense that each exporter is assumed to behave according to a set of decision rules which may reflect a competitive market structure, a monopolistic market structure or any combination of the two. Changes in the decisions rules being applied provides for the evolution of the market price. An attempt has been made to combine formal competitive and monopoly models with those of the informal story-telling approach.

9. Eckbo, P.L., and J.L. Smith, "Needed Exploration Activity Offshore Norway", Northern Offshore, August 1976.

This article analyzes the linkages between North Sea Block allocations and their effect on future production. A statistical model is developed to explore the methodology by which Norway influences attainment of its target production rate by allocating blocks to producers.

10. Hnyiliczka, E. and R.S. Pindyck, "Pricing Policies For A Two-Part Exhaustible Resource Cartel: The Case of OPEC", European Economic Review, Vol. 8, 1976, pp.139-154. Originally distributed as Working Paper MIT-EL-76-008WP.

This paper examines pricing policies for OPEC under the assumption that the cartel is composed of a block of spender countries with large cash needs and a block of saver countries with little immediate need for cash and a lower rate of discount. The decision problem for the two-part cartel is embodied in a game-theoretic framework and the optimal bargaining solution is computed using results from the theory of cooperative games developed by Nash. The set of feasible bargaining points--and the corresponding Nash solution--is computed under two assumptions on the behavior of output shares: that they are subject to choice and that they are fixed at historical values. The results suggest that, for fixed output shares, there is little room for bargaining and the price path approximates the optimal monopoly price path. If the shares are subject to control, optimal paths depend significantly on the relative bargaining power of each block.

11. Jacoby, H.D., "M.I.T. World Oil Project", in K.C. Hoffman (ed.), Proceedings of the Workshop on World Oil Supply-Demand Analysis (June 1-2, 1977), Brookhaven National Laboratory, forthcoming.

A description of the structure of the project, methods being used, and problems of data and analysis.

12. Pindyck, R.S. "Optimal Exploration and Production of a Nonrenewable Resource", Journal of Political Economy, forthcoming. Originally distributed as Working Paper MIT-EL-77-013WP.

Most studies of nonrenewable resource production and pricing assume there is a fixed reserve base to be exploited over time, but in fact with economic incentives reserves can be increased. Here we treat the reserve base as the basis for production, and exploratory activity as the means of increasing or maintaining reserves. "Potential reserves" are unlimited, but as depletion ensues, given amounts of exploratory activity result in even smaller discoveries. Given these constraints, resource producers must simultaneously determine their optimal rates of exploratory activity and production. We solve this problem for competitive and monopolistic markets, and show that if the initial

reserve endowment is small, the price profit will be U-shaped; at first production will increase as reserves are developed, and later production will decline as both exploratory activity and the discovery rate fall.

13. Pindyck, R.S., "OPEC's Threat to the West", Foreign Policy, Spring 1978. Originally distributed as Working Paper MIT-EL-78-001WP.

This paper examines three important issues in international energy markets, and the implications for American energy and economic policy. First, the paper considers the likely pricing behavior of the OPEC cartel, and argues that OPEC is most likely to set the price of oil at the optimal level, i.e., the level that maximizes the sum of present and future discounted revenues. Some predictions regarding OPEC pricing are offered, and the implications for world energy markets are considered. We argue that the kind of crisis that has been of concern to the CIA, namely a major shortage of oil beginning around 1982, is extremely unlikely to occur, and instead we need to be more concerned with the possibility of an embargo in the short term. Finally, the implications of higher energy prices for GNP growth, unemployment, and inflation in the industrialized countries is discussed. The paper concludes with a set of energy and economic policy recommendations.

14. Pindyck, R.S., "Gains to Producers from the Cartelization of Exhaustible Resources", The Review of Economics and Statistics, May 1978. Originally distributed as Working Paper MIT-EL-76-012WP.

The potential gains to producers from the cartelization of the world petroleum, copper and bauxite markets are calculated under the assumption of optimal dynamic monopoly pricing of an exhaustible resource. Small quantitative models for the markets for each resource are developed that account for short-term resource are measured by calculating optimal price trajectories under competition and under cartelization, and comparing the sums of discounted profits resulting from each.

15. Pindyck, R.S., "Cartel Pricing and the Structure of the World Bauxite Market", March 1977, Bell Journal of Economics, Autumn 1977. Originally distributed as Working Paper MIT-EL-77-005WP.

A cartel is unstable if one or more of its members can earn higher revenues in the long run by undercutting the cartel price and expanding production. In this paper dynamic and static models of the world bauxite market are used to assess the stability of the International Bauxite Association, to suggest possible changes in its configuration, and to determine the likely impact of the cartel on the structure of the bauxite market and the future of bauxite prices.

WORKING PAPERS AND REPORTS

16. Agmon, T, D. R. Lessard and J. L. Paddock, "Accommodation in International Capital Markets: Paying for Oil, Financing Oil and the Recycling of Oil Funds", MIT-EL-76-010WP, April 1976.

This paper focuses on the accommodation role served by the international financial markets in facilitating world oil market equilibration. We analyze the specific roles of primary and secondary recycling of oil funds in the international adjustment process. An extensive empirical study is then conducted using data for 1973, 1974, and early 1975. This study reveals the magnitudes and important interrelationships between flows in the markets for goods and financial assets. We conclude with a general equilibrium model which derives the supply behavior of an oil-producing country.

17. Agmon, T., D.R. Lessard and J.L. Paddock, "The International Finance Aspects of OPEC: An Informational Note", MIT-EL-76-005WP, March 1976.

The purpose of this paper is to set forth the relevant questions and problems confronted by the world's capital markets due to the structural changes in the world oil market. It presents a summary description of several financial aspects of OPEC, including the organization of relevant information and data into a form useful for subsequent analysis. A brief analysis of this information is included, but the main purpose is to collect and present the information in a systematic way, including sources.

First, it presents an analysis of the many forecasts of OPEC accumulated financial surpluses and their estimated investment disposition--with particular focus on the U.S., U.K., and Euromarkets. There follows a brief discussion and extensive source listing of the various financial proposals which arose to deal with these financial surpluses. Concluding sections present a chronology of the major international financial events which led up to the 1973 price rise and thereafter, and a summary of the subsequent changes in U.S. corporate tax policy.

18. Beall, A.O., "Dynamics of Petroleum Industry Investment in the North Sea", MIT-EL-76-007WP, June 1976.

The purpose of this study is to assess the economic potential of petroleum fields of the North Sea, as reflected in financial flows to the operating companies and host governments. Financial flows include future streams of exploration and development investment expenditures, and sales and tax revenues which accrue in the private and public sectors.

A prerequisite for the economic analysis is an evaluation of current petroleum potential of prospective North Sea Acreage, conducted at a disaggregated (pool) level. This part of the study relies heavily on geological insight and judgemental analysis provided by the author, as well as on published information and formal analytical methods.

The level of cash flows associated with the estimated resource potential is shown to depend on host government tax and investment policies, the world price of crude oil and current industry perceptions of the profitability of individual fields.

19. Carson, J., "A User's Guide to the World Oil Project Demand Data Base", MIT-EL-78-016WP, due, August 1978.

A description of all the data used for demand analysis in the World Oil Project. Cites sources used, range of years available, and provides a description of all conversions, aggregations, and other standardization of units. An index of computerized data files, information on how to access the computerized data or obtain the information in other formats included. Purchasing power parities and issues involving energy unit conversion are discussed.

20. Crandall, M.S., "The Economics of Iranian Oil", MIT-EL-73-003WP, March, 1975.

This paper presents an analysis of the production pattern and development cost structure of the Iranian "Consortium" oil fields. Production capacity of existing fields under alternative development technologies (e.g., water and gas injection systems) is analyzed first. This includes capacity maintenance and growth plans. The paper then presents a comparative cost study for these fields and derives per-barrel capital costs and present worth of each field.

Next the paper reviews Iran's potential new fields and performs a similar production/cost study based on the published series of "Look Ahead and Capital Development Plans" through 1978 as issued by both the Iranian government (through its National Iranian Oil Company) and the Oil Service Company of Iran (OSCO - a private company owned by the former Consortium companies).

21. Eckbo, P.L., "The Supply of North Sea Oil", MIT-EL-77-015WP, July, 1977.

This paper discusses reserves and production estimates for oil reservoirs in the North Sea already in the production or development stage, for reservoirs recently discovered and likely to enter the development stage, as well as for reservoirs likely to be discovered. The statistical version of a disaggregated process model is used to analyze "drilling up" scenarios for the North sea. the significance of

the tail of the discovery decline curve when analyzing the long-term elasticity of oil supply with respect to price is thereby demonstrated.

22. Eckbo, P.L., "OPEC and the Experience of Previous International Commodity Cartels", MIT-EL-75-008WP, August, 1975.

This study presents a review and analysis of the available literature of the history of international commodity cartels. Evidence was gathered on 51 cartel agreements in 18 industries. Cartel "success" was defined in terms of the ability of the organization to raise the price to at least two times the unit cost of production and distribution. Of the 51 cartel organizations reported in the literature, 19 achieved price controls which raised the level of charges to consumers significantly above what they would have been in the absence of collusive agreements.

The experience of these previous cartels shows that few were able to survive for very long. Those who did succeed in raising prices for four years or more were characterized by markets where the concentration of production was high, the demands inelastic, the cartels market share was high and the membership had cost advantages over outsiders. In addition a characteristic of the successful cartels was that governments were not directly involved in their operations. The paper attempts to draw conclusions about the future of OPEC based on its characteristics in comparison to those of successful and unsuccessful cartels in the past.

23. Members of the M.I.T. World Oil Project, "Progress on Analysis of the World Oil Market," MIT-EL-75-015WP, October, 1975.

This is the 6-month report on the Project. It presents an overview of the research design and the details of work in progress as of Fall 1975, including the demand analysis, the supply studies, and the various studies of market-clearing processes. It also includes a revised version of the work schedule presented in the original proposal.

24. Pindyck, R.S., "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison", "review of Economics and Statistics", May, 1977. MIT-EL-77-026WP, August, 1977.

This paper describes the specification and estimation of some alternative models of energy demand for the industrial sectors of a number of industrialized countries. All of the models are based on a two-stage determination of energy expenditures. The first stage of each model determines the fraction of the cost of production allocated to energy, as opposed to other factor inputs such as capital and labor. In the second stage, energy expenditures are allocated to different fuels.

The most promising results came from the use of a two-stage translog cost function as a description of the production process. The advantage of this translog function is that it is a general approximation to any cost function, and therefore does not a priori impose constraints of homotheticity, or separability on the structure of production. These functions were estimated using pooled data for 10 countries. Other models, including static and dynamic logic models, were also tested. Results from this study seem to indicate that price elasticities for industrial energy demand are larger than had been thought earlier, and that in the long run there may be substitutability between energy and capital. The own price elasticity for total industrial energy demand was estimated to be about -0.8.

25. Pindyck, R.S., "International Comparisons of the Residential Demand for Energy", MIT-EL-77-027WP, August, 1977. This is an updated version of MIT-EL-76-923WP.

This paper describes alternative models of energy demand in the residential sectors of a number of industrial countries. The models are based on a two-stage determination of energy expenditures. The first stage of each model determines what fraction of consumers' total budgets will be spent on energy, as opposed to such other consumption categories as food, clothing, etc. In the second stage, energy expenditures are allocated to alternative fuels.

The most promising results came from the use of a two stage indirect translog utility function. The advantage of the translog function is that it is a general approximation to any utility function and therefore does not a priori impose constraints of homotheticity, separability, or additivity on the structure of demand. These functions were estimated using pooled data for nine countries. Other models, including the logit model, were also tested. Results from this study seem to indicate that price elasticities for energy demand are larger than had been thought earlier. The own price elasticity for total energy demand was estimated to be about -.9.

26. Supply Working Group, M.I.T. World Oil Project, "Supply Forecasting Using Disaggregated Pool Analysis", MIT-EL-76-009WP, May, 1976.

This study develops and illustrates a methodology for forecasting additions to reserves and production in a relatively young petroleum province. Components of the analytical method include an exploration process submodel which predicts the arrival and size of new discoveries and a reservoir development submodel which determines the rate at which discovered resources become available as economic reserves.

Both submodels emphasize the influence which economic variables such as oil price, development costs, and government taxes exert on the rate and pattern of resource exploitation. Consequently, the analytical framework neatly accommodates policy simulations which arise from varied economic scenarios.

Implementation of the forecast methodology is demonstrated for the North Sea petroleum province. Projection of future additions to reserves and annual production are carried out in detail, so as to reveal both the flexibility and the limitations of the analytical procedure in its present form.

Appendix B

LIST OF MEETINGS, LECTURES, CONFERENCES, AND TESTIMONY

Date	Description
March 1975	<p>Testimony before the Joint Economic Committee on "The FEA's Project Independence Report," by M.A. Adelman, H.D. Jacoby, and others of the M.I.T. Policy Study Group.</p> <p>Participation by M.A. Adelman at meeting on oil and Middle-East policy, sponsored by the Boston Council on Foreign Relations</p> <p>Address on the oil market by M.A. Adelman to State Department personnel.</p>
April 1975	<p>Participation by H.D. Jacoby and R.S. Pindyck in NSF-sponsored conference on energy modeling, held at Harvard University.</p> <p>Participation by M.A. Adelman in the Annual Petroleum Economics and Management Conference, Northeastern University.</p> <p>Participation by M.A. Adelman in symposium on energy policy, Los Angeles Center for Law in the Public Interest.</p> <p>Participation by M.A. Adelman in symposium on world and domestic oil, Salmon Brothers (New York).</p> <p>Presentation by M.A. Adelman of a paper on Energy Markets and the Threat to World Economic Order, Japan-U.S. Assembly.</p> <p>Participation by M.A. Adelman in a Twentieth Century Fund Task Force on Paying for Energy (April to December).</p> <p>Address by M.A. Adelman to the Fulbright Scholars of Cambridge, on international oil and cartel problems.</p> <p>Address by M.A. Adelman on the economics of the oil cartel, at Resources for the Future (Washington, D.C.).</p>

Date	Description
April 1975 (Con't.)	Address by M.A. Adelman on world energy, to the American Society of Newspaper Editors (Washington, D.C.).
May 1975	Participation by M.A. Adelman and H.D. Jacoby in a conference on "United States Energy Policy--Analysis and Evaluation," sponsored by the M.I.T. Club of South Texas, Houston, Texas. Testimony before the U.S. Senate Banking Committee on support for development of energy substitutes, by M.A. Adelman.
June 1975	Participation by H.D. Jacoby in the ERDA/NSF sponsored Seminar on International Energy Analysis, Washington, D.C.
July 1975	Participation by M.A. Adelman in a symposium on energy and foreign policy, National War College. Address by H.D. Jacoby on problems of the world oil market, sponsored by the Bangladesh Energy Study and the Bangladesh Atomic Energy Agency (Dacca).
September 1975	Participation by H.D. Jacoby in seminar presented to executives of the Gulf Oil Corporation, Pittsburgh, Pennsylvania. Address by M.A. Adelman on cartel analysis, given to the economic staff, Bell Telephone Laboratories.
October 1975	Address by M.A. Adelman on aspects of the world oil market, Conference on New England and the Energy Crisis sponsored by the Federal Reserve Bank of Boston.
November 1975	Participation by H.D. Jacoby in the Nuclear Fuel Policy Working Group of the Atlantic Council (ended April 1976). Participation by H.D. Jacoby in the National Petroleum Council, Committee on Future Energy Prospects (ended November 1976).

Date	Description
November 1975 (Con't.)	<p>Participation by M.A. Adelman in a Conference on World Petroleum, Salmon Brothers (New York).</p> <p>Presentation by T. Agmon, D. Lessard, and J. Paddock on "Accommodation in International Capital Markets: Paying for Oil, Financing of Oil, and the Recycling of Oil Funds," given at the International Trade and Development Seminar, M.I.T. Economics Department.</p>
December 1975	<p>Presentation by M.A. Adelman of the David Kinley Lecture, University of Illinois, on "Scarcity and Monopoly in the World Oil Market."</p> <p>Presentation by T. Agmon, D. Lessard, and J. Paddock on "Investment Decisions of a Country Endowed with an Exhaustible Resource: An Adaptation of the Intertemporal Capital Asset Pricing Model" and "Capital Markets, Portfolio Adjustments and the Pricing of Oil by an OPEC Member," given at the Finance Theory Seminar, M.I.T.</p> <p>Seminar by R.S. Pindyck on cartel models, presented at the World Bank.</p>
January 1976	<p>Seminar on cartel models and on energy demand presented by R.S. Pindyck at the University of Tel Aviv, Israel.</p> <p>Seminar on the OPEC pricing model given by R.S. Pindyck at the Weitzman Institute, Israel.</p> <p>Presentation by H.D. Jacoby on "El Mercado Mundial de Petroleo," given to a management conference sponsored by the Banco de Comercio of Mexico and the M.I.T. Club of Mexico, Mexico City.</p>
February 1976	<p>Presentation by P.L. Eckbo on "The North Sea Supply Forecast," at the Federal Energy Administration.</p>

Date	Description
February 1976 (Con't.)	Address by M.A. Adelman on "The Tanker Industry in the Context of the World Oil Market," at a conference sponsored by Den Norske Creditbank and R.S. Platou, Sanderstollen, Norway.
	Talk by M.A. Adelman on market structure in world oil, Princeton University.
	Talk by M.A. Adelman on the outlook in world oil to 1985, given to the New York Society of Security Analysts.
	Participation by M.A. Adelman in a conference on world energy problems, sponsored by the United Nations Secretariat.
March 1976	Presentation by R.S. Pindyck of a seminar on cartel pricing models, Industrial Organization Workshop, University of Pennsylvania.
	Address by M.A. Adelman on aspects of the petroleum market, American Bar Association and Pennsylvania Law School Conference on Economic Independence.
April 1976	Presentation by R.S. Pindyck of a seminar on cartel pricing models, University of Montreal.
	Participation by M.A. Adelman in the Annual Petroleum Economics and Management Conference, Northeastern University.
	Seminar by M.A. Adelman on analysis of the oil cartel, Boston University.
	Address by M.A. Adelman on interaction of foreign and domestic energy policies, Dartmouth University.
	Seminar on the M.I.T. World Oil Project, presented by H.D. Jacoby to the Department of Mineral Economics, College of Earth and Mineral Sciences, Pennsylvania State University.
	Testimony by H.D. Jacoby before the House Committee on Science and Technology on "Loan Guarantees for Commercial Demonstration Facilities, with special emphasis on the role of the world oil price in program design and implementation.

Date	Description
May 1976	Seminar by R.S. Pindyck on cartel pricing models at the NBER Workshop on Control Theory and Economics, Palo Alto, California.
	Presentation by P.L. Eckbo on oil supply modeling, to the Norwegian School of Economics and Business Administration.
	Presentation by P.L. Eckbo on oil production functions, to the Norwegian Ministry of Finance.
	Address by M.A. Adelman on the future of the oil cartel, to a Brookings Institution Conference.
	Testimony by M.A. Adelman to the Senate Banking Committee, on the investment in domestic substitutes for world oil.
	Address by M.A. Adelman on world oil issues, to the National Conference of Security Analysts.
	Service by M.A. Adelman on the Twentieth Century Fund panel on international and domestic energy policy (through January 1977).
June 1976	Seminar by R.S. Pindyck on cartel models, Industrial Organization Seminar, Department of Economics, University of California at Berkeley.
	Boston Society of Security Analysts, address by M.A. Adelman on world energy and oil developments.
July 1976	Session by R.S. Pindyck on Energy Models, at Summer Computer Simulation Conference, Washington, D.C.
	Paper presented by R.S. Pindyck on the Pricing and Production of Exhaustible Resources, at NSF Workshop on Natural Resources, Stanford University, Palo Alto, California.

Date	Description
September 1976	Presentation by R.S. Pindyck on Optimal Pricing Models for Exhaustible Resource Cartels at the National Science Foundation, Washington, D.C.
	Presentation by R.S. Pindyck on Optimal Pricing Models for Exhaustible Resource Cartels at Department of Economics, University of Maryland, Silver Spring, Maryland.
	Presentation by R.S. Pindyck of paper, "International Comparisons of the Residential Demand for Energy: A Preliminary Analysis," at Econometric Society Meetings, Atlantic City, New Jersey.
	Session on Energy and Natural Resources, American Economic Association Meetings, Atlantic City, New Jersey; chaired by R.S. Pindyck.
	Paper on Pricing Models for Exhaustible Resources, presented by R.S. Pindyck to the Econometric Society Meetings, Atlantic City, New Jersey.
	Seminar on Optimal Pricing Models for Exhaustible Resource Cartels presented by R.S. Pindyck at Concordia University, Montreal, Canada.
October 1976	Presentation by M.A. Adelman to M.I.T. Industrial Liaison Program of special symposium on "The Economic and Political Aspects of American Industry and Energy Dependence", Cambridge, Massachusetts.
	Paper by H.D. Jacoby on M.I.T. World Oil Supply Models, presented at Clarkson College of Technology, Potsdam, New York.
	Seminar by R.S. Pindyck on Exploration and Production of Nonrenewable Resources, at London School of Economics, London.
November, 1976	Paper on M.I.T. World Oil Project Supply Forecasting Methods, presented by H.D. Jacoby to I.E.A. Supply Workshop, Paris, France.

Date	Description
November, 1976 (Con't.)	<p>Seminar by R.S. Pindyck on Measuring International Differences in the Structure of Energy Demand, Tel-Aviv University, Tel-Aviv.</p> <p>Seminar by R.S. Pindyck on Models of Optimal Exploration and Production of Nonrenewable Resources at Hebrew University, Jerusalem, Israel.</p>
December 1976	<p>Address by M.A. Adelman to the Inter-American Defense College, Fort Leslie J. McNair, Washington, D.C.</p>
January 1977	<p>Participation by H.D. Jacoby and R.S. Pindyck in U.S./German Energy Conference, Spitzingsee, Bavaria.</p> <p>Address by M.A. Adelman on international energy and oil, to the National Bureau of Standards, Conference on Energy, Columbia, Maryland.</p> <p>Testimony by M.A. Adelman before the Joint Economic Committee, Subcommittee on Energy.</p> <p>Participation by M.A. Adelman in American Enterprise Institute, Conference on Oil-Industry Divestiture.</p> <p>Participation by M.A. Adelman in Hearings before the Subcommittee on Energy, 95th Congress, "Energy Independence or Interdependence: The Agenda with OPEC".</p>
February 1977	<p>Discussion of international and domestic energy policy questions by M.A. Adelman and H.D. Jacoby, in meeting with Secretary Schlesinger and other members of the White House Energy Staff preparing the National Energy Plan, Washington, D.C.</p>
March 1977	<p>Participation by M.A. Adelman in the 17th Annual Institute on Petroleum Exploration and Economics, International Oil and Gas Educational Center, Richardson, Texas.</p>

Date	Description
March 1977 (Con't.)	<p>Lectures, by M.A. Adelman on international oil supply and demand, to the Northwestern University Petroleum Economics & Management Conference.</p> <p>M.A. Adelman serves as member of panel advisory panel to Bureau of Competition, Federal Trade Commission, on suit against certain oil companies (through October 1977).</p>
April 1977	<p>Address by H.D. Jacoby to the Time, Incorporated Energy Conference, Williamsburg, Virginia.</p> <p>Address by H.D. Jacoby to an M.I.T. Energy Seminar, sponsored jointly with the California Energy Commission, Ojai, California.</p>
May 1977	<p>Address by H.D. Jacoby on "The Energy Policy of the United States--International Implications for Political Relationships and World Trade," to the 4th Annual International Trade Conference of the Southwest, Dallas, Texas.</p> <p>Paper by H.D. Jacoby presented to the Harvard-M.I.T.-Penn. Seminar on World Energy Models and Studies, Cambridge, Massachusetts.</p>
June 1977	<p>Participation by M.A. Adelman and H.D. Jacoby in a Workshop on World Oil Supply-Demand Analysis, Brookhaven National Laboratory, Upton, New York.</p> <p>Address by H.D. Jacoby to a Symposium on "An Energy System for the 21st Century," Sponsored by the M.I.T. Club of Southern California, Los Angeles, California.</p> <p>Presentation by R.S. Pindyck on Models of Resource Exploration and Production, at Electric Power Research Institute, Palo Alto, California.</p>
September 1977	<p>Presentation by M.A. Adelman of Lecture on energy economics and policy, to Sloan Fellows and Senior Executives convocation at M.I.T.</p>

Date	Description
October 1977	Interview of M.A. Adelman by <u>Tokyo Shimbun</u> (appeared in 12 parts, January 1978).
December 1977	Presentation by R.S. Pindyck of talk on "The Future of World Energy Markets," The Conference Board of Canada, Toronto, Canada.
	Presentation by R.S. Pindyck of talk on "International Problems in Energy Policy," University of Southern California, Los Angeles, California.
	Seminar by R.S. Pindyck on "Models of Optimal Resource Exploration and Production," University of Southern California, Los Angeles, California.
	Seminar by R.S. Pindyck on "The International Cartelization of Exhaustible Resources," California Institute of Technology, Pasadena, California.
	Participation by R.S. Pindyck as discussant at Session on "Economics of the Middle East," American Economic Association Meetings, New York.
	Session on Optimal Resource Exploration, AEA Meetings, New York; chaired by R.S. Pindyck.
January 1978	Participation by H.D. Jacoby in U.S./Japanese meeting on international energy issues, Tokyo, Japan.
	Briefing on the M.I.T. World Oil Project, given by H.D. Jacoby to representatives of the D.O.E., including persons from S.P.R.O., the Energy Information Administration, International Affairs, and Planning and Evaluation, Washington, D.C.
	Participation by H.D. Jacoby in U.S./German Energy Policy Workshop, Airlie House, Airlie, Virginia.
	Presentation by J.L. Paddock of a Seminar on "The Integration of Petroleum Engineering and Economics in an Aggregate Model of Oil Supply" to the Department of Industrial Engineering, Stanford University.

Date	Description
March 1978	<p data-bbox="591 293 1425 395">Presented by R.S. Pindyck, talk on "Models of Optimal Resource Exploration and Production," Resources for the Future, Washington, D.C.</p> <p data-bbox="591 427 1425 529">Seminar by R.S. Pindyck on "Models of Optimal Resource Exploration and Production," Stanford University, Stanford, California.</p> <p data-bbox="591 561 1425 661">Talk by R.S. Pindyck on "OPEC, Oil Prices, and the Western Economies," Louisiana State University, Baton Rouge, Louisiana.</p>

Appendix C

Organizations Which Have Received Data from theM.I.T. World Oil Project

<u>Person/Organization</u>	<u>Material Sent</u>
Jim Reddington OECD, Paris	- entire demand data base
Eithan Hochman UC Berkeley Tel Aviv University	- price and quantity information - data for developing countries
Boum Jong Choe The World Bank	- energy products prices
Tamir Agmon Tel Aviv University	- entire demand data base
Resources for the Future	- entire demand data base
Dr. F. Thys-Clement L'Universite Libre de Bruxelles, Belgium	- energy products prices
FEA (now Department of Energy) Washington, D.C.	- entire demand data base
Electric Power Research Institute Palo Alto, California	- entire demand data base
Mary Headley A.D. Little	- private consumption expenditure on fuels - retail price on fuels
Stanford Research Institute, International Menlo Park, California	- entire demand data base
Shell Oil	- entire demand data base