THE INTERNATIONAL PETROLEUM MARKET

-SOME BEHAVIORAL OPTIONS-

By

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Abstract

This thesis describes a behavioral model of the international petroleum market and presents the results from it. The purpose of this study is to develop a framework for analysis of the implications of the likely degree of non-competitive behavior to be observed in the international petroleum market. The focus of the model 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 modelling 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 described 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. The change of the decision rules being applied provides for the evolution of the market price. An attempt has been made to combine the merits of formal competitive and monopoly models with those of the informal "story-telling" approach. The price- and quantity-paths consistent with the various "stories" over the period from 1974 to 1990 are reported.

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CHAPTER 1
INTRODUCTION

1.1 The International Petroleum Market

The price of crude oil in the international petroleum market, the imports/exports market, is determined in the same way as the price of any other product, by demand, production costs, and the kind and the extent of non-competitive behavior. What makes the current price of crude oil interesting from a theoretic as well as an empirical point of view is the unprecedented degree of non-competitive behavior that the current price level represents. The current price is fifty times the marginal production costs of the marginal source of petroleum, the Persian Gulf producers (1). When the most important commodity in international trade becomes subject to such a degree of non-competitive behavior, then the repercussions for the world economy for both consumers and producers of oil are many and complex. The need for a formal framework to analyze the likely extent of non-competitive behavior was therefore being felt. This effort was undertaken to provide such a formal framework.

For the purpose of analyzing the significance of non-competitive behavior to be observed in the international petroleum market, the circumstance faced in this market may be summarized in the following way:

(1) There is a set of petroleum importing countries, dominated by the industrialized economies of the U.S., Europe, and Japan. The net demand of each of these countries for imported oil is determined by the total energy demands of each of the countries, less the domestic supplies available, and less imports of other fuels such as coal.

(2) There is a fringe of petroleum exporters, which includes various non-OPEC sources such as the producers of the North Sea, the USSR, and China, and potentially other countries such as Mexico. In this group may also be included some members of OPEC which have great needs for foreign exchange and who are "expansionist" in their oil production policies, such as Indonesia, Iraq, and Nigeria.

(3) There is a small group of Persian Gulf nations who are the "price makers." This group includes Saudi Arabia, Kuwait, and others in the Gulf; under some definitions it also may include Libya, Iran, and Venezuela. These countries face a residual demand for world oil, which is the total demand less that supplied by the fringe. The members of this group form the active core of the oil exporters; their control over price involves two parts: (1) the setting of the price itself, and (2) the control of production, so it does not outstrip the residual world demand at that price.

The members of OPEC controlled 90% of the international market in 1973 and 73.3% of the world's proven recoverable reserves of oil as indicated in Table 1.1. Saudi Arabia alone controlled 23% of the imports/exports market and almost 25% of the world's proven recoverable reserves in 1973, the year the oil exporters were able to increase the average cost of crude to the oil companies from a low of $1.62 to $9.25, as pointed out in Table 2.1.

The structure of the international petroleum market is oligopolistic, and the exporters have been able to take advantage of the oligopolistic structure to raise the price of oil. The world economy has suffered from the most poisonous level of "oligopollution" ever experienced.

An oligopolistic market cannot be analyzed with the confidence with which a competitive market is analyzed. The fact that some exporters have entered into an explicit agreement to limit competition for mutual benefit, a cartel agreement, does not reduce the uncertainty associated with the market solutions to emerge. We are faced with critical uncertainty regarding the ability of the Persian Gulf states to restrict production cooperatively, or the willingness of a single country to bear the burden of output restraint, so as to support the price received by all of the world's petroleum exporters. We also expect to observe deviations from competitive behavior by the non-colluding exporters, the exporter fringe. There is considerable uncertainty associated with the extent and the effect of various fiscal and non-fiscal regulatory regimes on the rate of production in non-OPEC countries like Canada, Norway, and the United Kingdom. The future escalation of costs and the uncertainty with respect to the total number and location of geological traps containing hydrocarbons in commercial quantities, as well as the future path of international prices, render evaluations of the relationships between these policy parameters and the level of activity in non-OPEC countries extremely difficult.

Table 1-1
WORLD OIL PRODUCTION AND PROVED RESERVES, 1973 (ESTIMATED)

Producing Area	million B/day	percent	billion barrels	percent
Western Hemisphere	16,122	28.9	76.1	13.4
United States	9,225	16.5	34.6	6.1
Venezuela	3,370	6.0	14.2	2.5
Canada	1,750	3.1	9.7	1.7
Others	1,777	3.3	17.6	3.1
Western Europe	396	0.7	15.9	2.8
Middle East	21,337	38.3	350.3	61.7
Saudi Arabia	7,671	13.8	140.8	24.8
Iran	5,870	10.5	60.2	10.6
Kuwait	3,144	5.6	72.7	12.8
Iraq	1,960	3.5	31.2	5.5
Others	2,692	4.8	45.4	8.0
Africa	5,840	10.5	67.6	11.9
Libya	2,190	3.9	25.6	4.5
Nigeria	2,020	3.6	19.9	3.5
Algeria	1,020	1.8	7.4	1.3
Others	610	1.1	14.7	2.6
Asia-Pacific	2,275	4.1	15.9	2.8
Indonesia	1,330	2.4	10.8	1.9
Others	945	1.7	5.1	0.9
Communist Countries	9,780	17.5	42.0	7.4
USSR	8,400	15.1	34.6	6.1
China	1,000	1.8	7.4	
Others	380	0.7		1.3
World Total	55,750	100.0	567.8	100.0
OPEC Members[1]	30,837	55.3	416.3	73.3
OAPEC Members[1]	18,400	33.0	299.8	52.8

Source: International Economic Report of the President
Transmitted to the U.S. Congress, February, 1974

[1]The members of the Organization of Petroleum Exporting Countries in 1973 were Algeria, Ecuador, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela. The members of the Organization of Arab Petroleum Exporting Countries are Algeria, Bahrain, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, and United Arab Emirtes. Gabon has recently been granted full membership (July 1975).

A distinctive peculiarity of a mineral industry is the need to take account of depletion. With any fixed stock of minerals, investment requirements and unit costs increase as depletion proceeds - both because of the tendency to go from more to less accessible deposits and because of the anticipation of higher future prices. On the other hand, this latter tendency may be retarded and even drastically reversed by the possibility of technological improvement or of discoveries of new deposits.

1.2 Approach of the Study

Given the structure of the international petroleum market and the critical uncertainties associated with the future development of this market, two broad areas of analysis were defined:

(i) What is the likely future path of the residual world demand faced by the key cartel members?

(ii) What is the likely behavior of this group under those demand conditions, given what is known about the producers themselves (reserves, production costs, resource needs, political goals, etc.)?

The approach that was made to the analysis of these two issues will emerge from a summary of the chapters of the thesis.

The contractual relationships between the oil companies and the exporter countries reflect the degree of decision-making power that each of the two parties enjoy and the interdependencies of the two parties.

To identify the location of decision-making power and the extent to which the possession of this decision-making power has been used or could be used to establish and/or to maintain a non-competitive price level, a review was made of the contractual relationships as they have evolved over time. Chapter Two summarizes the findings of this review.

There has been a number of commodity cartels in world trade. To learn about OPEC by analogy, a review was made of the experience of some previous international commodity cartels as reported in Chapter Three. The experience of these cartels was coded to indicate central factors to the operation of workable versus unworkable cartel agreements.

There is also an extensive literature on oligopolistic markets and on cartels. This literature was searched for possible clues to the study of this particular market, namely the international petroleum market. Conventional oligopoly models do not, however, seem to be very useful when studying particular markets. The conclusion of Chapter Four is that a more detailed study, "story-telling," is needed to hypothesize which coalitions are likely to emerge under the different circumstances the exporters might face. The need to combine aspects of formal modelling with informal "story-telling," makes a simulation model the most ambitious approach that can be made to the analysis of a particular oligopolistic market without sacrificing the empirical validity of the analysis. The representation of the international petroleum market in the model reflects the need to combine formal and informal modelling as reported in Chapter Five. The focus of this representation is on the

behavioral characteristics of the exporters. A set of decision-rules has been defined for each of the exporters, and an explicit analytic expression for the market price consistent with each combination of exporter decision rules has been derived. The evolution of combinations of decision rules to be observed over time, and the resulting price- and quantity-paths consistent with the evolution of these decision-rules are determined by "story-telling." Cartel theory, the experience of previous cartels, and the price-responsiveness of the consumer markets as well as the special characteristics of the exporters as indicated in Chapter Six are used to construct the "stories." The "stories" are told and the results of the "story-telling" or of the model simulations are reported in Chapter Seven.

A simulation model has consequently been constructed in response to the need for a formal framework applicable to an analysis of the international petroleum market. The operation of such a model corresponds to the simultaneous solution of a set of time-dependent equations. The simulation model is highly adaptable to changed or improved functional inputs. That portion of the model that calculates demand for imports can be linked up with anyone of several representations of exporter fringe behavior and of likely cartel behavior. The structure of the model is flexible enough to allow features of formal models to work with informal "story-telling" to explore the extent of and the implications of non-competitive market behavior to be observed in the international petroleum market in the years to come.

1.3 Studies of the International Petroleum Market

The lack of formal models relevant to a study of a particular oligopolistic market is reflected in the approach taken in the major studies of the international petroleum market or of the world oil market. The studies made of this market are mostly informal studies of the "story-telling" or the industrial organization type. More recent attempts to introduce formal models have been made. To accomodate these models, however, the oligopolistic structure is assumed to be replaceable with either a perfectly competitive structure or a monopolistic structure.

The industrial organization type study of a market allows the researcher to make snapshots of an industry from any angle. The richness of detail may be overwhelming, but if artfully sorted and put together in a consistent framework, an industrial organization type study may give a better understanding of a particular non-competitive market than any collection of formal models. An outstanding example of an artful study of the international petroleum market, the imports/exports market, in a larger world petroleum market context is Adelman [1]. The underlying hypothesis of the study by Adelman as well as the more recently published study by Jacoby [5], is that of a convergence towards a perfectly competitive market. These studies provide evidence that a number of markets that we include in the term "the world petroleum market," such as transportation and refining, were already competitive, and that the world petroleum market as a whole was actually converging against a competitive market structure in the 1960's. Adelman in his study, however,

pointed out the unexploited market power of the producer countries and the instability that might result from this.

The evidence on an emerging competitive market and the need for quantitative rather than qualitative conclusions induced Houthakker and Kennedy [6,8] to construct a formal model as a competitive structure. The inclusion of an exogenous export tax as done in their model is a proxy for the level of monopoly rent to be collected by a producing country, does not alter the competitive structure of the model. By solving the model for any given, future year, assuming an export tax level, the model provides projections of consumption, supply, and trade flows for that year. The Houthakker/Kennedy model is thus similar in kind to a number of other studies [4,9,11] that have focused on the composition of the future world energy market under various assumptions about the price of crude oil in the Persian Gulf. Neither OECD, Ford Foundation, nor FEA do, however, consider the world market as a problem in cartel behavior. But these studies have made a significant contribution by evaluating some of the implications of OPEC pricing scenarios, and thus have indicated the responsiveness of the world's oil/energy markets to the price of crude oil in the Persian Gulf. A scaled-down version of the price-responsiveness of the world's oil/energy markets as indicated by the studies of OECD and FEA, has been used as a basis in this study when determining some of the pricing strategies of the producer countries.

Allocation of crude oil and petroleum products was the problem being approached by the large LP-type models traditionally being formulated by the oil companies. The Deam effort [3] and the forthcoming Rapoport study [10] exemplifies this tradition. The rigid structure of these models makes an analysis of the uncertainties we face today within these models difficult.

Some recent efforts have been made to consider oil price setting from the producer countries' point of view. The model developed for the World Bank's Energy Task Force by Blitzer, Meeraus, and Stoutjesdijk [2] simulates the world oil market under a set of OPEC pricing strategies and ranks the strategies according to some possible policy criterions. Kalymon [7] has developed two models to compute the long-term pricing strategies for OPEC which maximize the total discounted value of oil reserve exploitation for OPEC as a whole or for some sub-group, and to compute the desirability of various market sharing mechanisms within OPEC to the membership of OPEC.

The world bank model is informal in the sense that the world oil market is simply extrapolated under an arbitrary set of pricing strategies, and the outcomes of these pricing strategies are ranked according to how "likeable" they appear. Kalymon has developed a model of a monopolistic structure, which can be used to determine the "optimal" price-path to the individual countries that are assumed to belong to the monopoly unit. The Kalymon approach is thus the extreme counterpart of the Houthakker/Kennedy approach, the former assuming a given and unchangeable monopoly structure, the latter a competitive structure.

In an oligopolistic market the price level may fall below the competitive level, as has happened in price-wars, and also increase above the monopoly level as in the case of a cartel exploiting its short-term market power and the uncertainty associated with the emerging price level. That is, if a cartel increases the price above a level considered to be the monopoly level, the market may not respond to the whole price increase because the market expects the price to come down, which implies that the cartel may benefit from an "uncertainty premium." The fact that a competitive structure as well as a monopolistic structure might emerge from an oligopolistic market structure implies that a model designed to understand the likely development of such a market, must be flexible enough to change structure or price-behavior over time. The simulation model of this study is designed to explore the implications of pricing behavior reflecting different market structures in various periods over the simulation horizon. The model described here 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. The change of the decision rules being applied from period to period provide for discontinutities in the price path as we would expect in a cartel-dominated market. An attempt to combine the merits of formal competitive and monopoly models as well as the informal "story-telling" approach has been made.

CHAPTER 2
COMPANIES VERSUS EXPORTER GOVERNMENTS

2.1 Introduction

The relationship between the oil companies and the governments of the exporting countries has changed dramatically over the last few years. A major aspect of this change is the transfer of decision-making power from the oil companies to the exporter governments. When analysing a cartel-like organization like OPEC it is essential to determine to which extent the organization controls the instruments required to successfully operate a cartel. In the following a review is made of the contractual relationships between oil companies and producer countries as they have evolved over time. The focus is on the location of the decision-making power and the extent to which the exploitation of this decision-making power has been used or could be used to establish and/or maintain a non-competitive price level. The degree of decision-making power and the ability to use this power will determine the longevity of OPEC as a cartel-like entity.

2.2 The Pioneering Period

When the oil companies began looking for oil in Latin America and the Far East, these areas were politically dominated by the industrial countries of the west. No local petroleum expertise existed. Petroleum was not considered to be an essential commodity. The industrial countries were therefore often in a position to determine both who should be given

the rights to explore for and produce oil and the terms on which these activities were to be undertaken, the terms of the concession agreements.

The main characteristics of the earliest concession agreements (1901-1951) were:

1. The large concession areas and the long duration of these concessions.
2. The small number of concessionaires.
3. The homogeneity and simplicity of the concession conditions.
4. Royalties constituted the main financial compensation.
5. The modest financial compensation for the concession due to the low value of crude oil and the limited need for it in the earlier years as well as to the limited bargaining ability and bargaining power of the prospective producer countries.
6. The slow development of the concession conditions.

The oil companies controlled completely all aspects of oil production and pricing. The governments received a royalty usually stipulated as a fixed nominal amount per ton lifted, and that was the extent of their involvement in the petroleum industry.

The companies were able to exploit their control of production and of marketing of oil. If we disregard the era of the Standard Oil monopoly, the first collusive agreement covering the international market was made in 1928 [4]. In 1928, Standard Oil of New Jersey and Shell agreed to maintain market shares in foreign markets and in the acquisition of foreign oil interests, the "as is" - or "Achnacarry" - agreement. Jersey was a spokesman for all American exporting companies, which at that time

made serious attempts to form a U.S. Webb-Pomerene Export Association, a device by which a group of U.S. firms may join their export activities without violating U.S. antitrust legislation. As far as prices were concerned the high costs of the marginal U.S. wells, including many stripper wells, would determine prices everywhere in the world. Price was supposed to be equal to the U.S. Gulf price plus frieght, regardless of the actual origin of the oil.

The collaboration between American companies within the Webb-Pomerene framework collapsed, however, in 1930. The failure was due to incomplete coverage of all sources of supply in each particular market. In the U.S. it was difficult to control output due to widespread ownership and anti-trust. In Europe, Russian and Rumanian producers caused problems. There was, however, no evidence of price warfare or retaliation following the collapse of the agreement.

In 1930 a new agreement was signed with detailed penalties for over- and under-trading. This agreement controlled the European markets even if Russian and Rumanian producers still caused problems. In 1932 Rumania entered into a tentative agreement. An attempt to incorporate the Russians failed.

The 1930 "as is" was declared to be applicable to all countries out-side the U.S. A "Draft of Principle" in 1934, of "Utmost Confidence," arming the arrangement with supply quotas, distribution quotas and fines for over-trading extended formally the coverage of the agreement to the whole world.

The uncontrolled producers were in the U.S., Mexico, Russia, and Rumania. The disruptive ability of this outside fringe was limited. As early as 1952 the U.S. was a net importer, Mexico was unimportant, and Russia and Rumania had disappeared behind the iron curtain. The non-competitive price level previously established survived even if no formal agreement is recorded beyond 1945 [4].

Before World War II the U.S. Gulf was the only area in which there was to some extent free trade in crude oil. The notion of posted price originated from the fact that buyers of crude in the gulf area publicly stated the prices at which they were willing to buy crude. The Gulf price, being a proxy for the open market price, was used as a basis for determining the price of curde being charged elsewhere. The posted price of crude oil in the Middle East was determined by deducting transportation cost from the port of departure to the U.S. Gulf from the posted price in the U.S. Gulf. The posted price was also used as a tax-reference price. The companies paid royalties and taxes on the basis of the posted price, even if the price at which oil could be sold in the market place was below the posted price, which has been the case since the early 1950's.

2.3 The Second Generation

The earlier concession agreements gave exclusive rights to the exploitation of petroleum in enormous areas. These rights were given on terms which appeared unfavorable to the producer countries when they became

aware of the market value of their petroleum. The agreements created monopolies for the concessionaires, with the accompanying animosity which this provoked. The agreements also tended to transfer a country's oil policy making from the legal governmental powers to the oil companies. The traditional concessions, held almost exclusively by the eight major international oil companies, were increasingly regarded as derogatory to the national honor. In a world of rising nationalism the concession agreements in their original form could not survive. In some countries the concession regime was simply terminated by nationalization of the oil industry. Mexico nationalized its oil industry in 1938. Iran followed in 1951 [8]. The petroleum expertise available in the producing countries was, however, very limited. A reasonable compromise between the emphasis on national sovereignty and the efficiency of the oil operations was therefore a revision of the existing concession agreements in favor of the producing country.

With the exception of Venezuela no exporter country had developed petroleum expertise by the end of World War II when the era of decolonization began and the third world got an opportunity to increase cooperation among themselves. Venezuela helped educate the producer countries by organizing an exchange of information and views on aspects of the oil industry and on oil policies. Venezuela also saw the opportunity for increased revenues if the producer countries could bargain with the oil companies on a joint rather than an individual basis. Venezuela promoted

vigorously these ideas during the 1950's. The Arab league which was formed in 1945 to provide the Arab oil producing countries with a formal institutional structure within which to develop further collaborative arrangements [2], did not, however, mature to the point at which it could have realistically taken over the oil industry.

It was the entering oil companies, the independents and the state oil companies, and not the producer countries themselves that eventually took the initiative to a revision of the earlier concession agreements. Venezuela was the originator of many of the new contractual concepts that were being introduced. The newcomers had to offer the host governments better terms than the majors in the competition for access to crude oil supplies. The non-competitive price level was sufficiently high to accomodate both the higher share being paid to the producer countries and the independents' required rate of return on capital invested.

This second generation of concession agreements has the following characteristics:

1. The agreement is valid only for a well-defined limited area for a limited period of time;
2. The agreement contains rules about relinquishment after the expiration of certain periods of time;
3. The agreement is split into a reconnaissance and a production phase;
4. An income tax of 50% is levied.
5. Higher royalties, often graded royalties. The calculation of royalties is made explicit in the agreement. The principle of royalty expensing is followed;

6. Other fees are clearly defined and fixed;
7. Fixed rules for working programs and additional investments;
8. Detailed rules for the solving of disputes, prefixed rules about arbitrage.

Table 2-2 indicates how royalty and income tax rates are used to produce a government take, the producer governments' per barrel revenues.

The 50-50 profit-sharing principle established in this second generation of concession agreements increased substantially the revenues of the producer countries. These agreements did not, however, give the producer countries access to the decision-making bodies. Pricing and lifting-schedules were still to be decided by the companies.

The entrance of new firms, in addition to increasing the bargaining power of the exporter governments, also increased the level of competition in the market place. The entering firms put a downward pressure on the price of oil. After a ten year period of nominal price stability, the difference between the posted price and the price at which oil could be sold in the market increased in 1959 to the extent that the companies unilaterally reduced the posted price, the tax reference price, and hence decreased the government take. The producing countries opposed the reduction, established OPEC and fixed a posted price of $1.80 which was 5 cents above the previous level.

2.4 Participation

Venezuela was still in the lead when the companies reduced prices in 1959. When the companies unilaterally reduced prices for the second time

in August 1959, Venezuela convinced the other oil exporting countries, and the Organization of Petroleum Exporting Countries was formed in September 1960. The exporting countries had demonstrated that their technical knowledge and skills as well as their power position enabled them to oppose unilateral price reductions by the companies. The main objectives of OPEC were to:

1. Assure a stabilization of oil prices in the international crude oil market;
2. Bring about a coordination of oil policies in the member states;
3. Assure a stable income to the producer countries, and an effective, economic, and continual flow of oil supplies to the consuming countries, and a just rate of return on the oil companies' invested capital.

OPEC managed to reverse the downward trend in nominal prices, but not in real terms. The real tax-paid cost of crude decreased by 28 per cent in the 1960's (assuming a "normal" rate of inflation of 4 per cent).

The entrance of new firms continued through the 1960's. In 1960, 21 independents were producing in the Middle East. In 1970, 54 independents and 13 national oil companies in addition to the 8 majors were producing in this area [3]. The "majors," however, still played the major role even if decreasingly so. The share of the seven largest companies in non-U.S., non-Communist world oil production decreased from 87.1% in 1953 to 70.9% in 1972 [3].

The independents, having access to fewer sources of crude and being financially weaker than the majors, were much more dependent on each producer country and thus also much more vulnerable to the actions of the

individual producer countries. As the majors did not supply the independents with crude when the independents were cut off from their source by some producer country, individual producer countries were able to obtain considerable concessions from the independents. The concessions granted by the independents were later used as a basis for negotiations with the majors.

Again it was the vulnerability of the independents and the consumer country controlled state companies that made these companies, rather than the producer governments, introduce the contractual concepts that gave the governments direct control over domestic oil operations, and a means by which they could themselves participate in these operations. The Italian state oil company ENI finalized the first "joint-venture" agreements with government participation in 1957 with the state companies in Egypt and Iran [8].

The characteristics of the typical "joint-venture" agreements with government participation are:

1. The government's authority as a government and the government's rights as a participant in the venture are clearly separated.
2. The "joint-venture" is assigned a concession on the same terms as any other company. The government-controlled company thus becomes a concessionaire through the "joint-venture."
3. The government-owned company is usually 100 percent owned by the government.
4. As a rule, participation is on a 50-50 basis.

5. The government-controlled company's risk is reduced through the principle of "carried interest." This means that the foreign company "carries" the interest of the government by assuming the entire economic risk until commercial discoveries are made.

6. When commercial discoveries are made, the government-controlled company generally has to pay in cash its part of the further costs associated with the future development of production facilities.

7. The government-controlled company takes out its share of the production in crude and may then sell the crude back to its partners or market the crude itself.

The government owned oil companies operating nationalized industries did not have ready access to world markets. The Government Oil Refining Administration was set up in Iraq as early as 1952. The Iraqi National Oil Company was not formed until 1964 to engage in all aspects of the industry, including sales overseas, later taking over exploration and production under a nationalization programme. In the years following the nationalization, the Iraqi oil industry stagnated, and it was not revived until 1973, when an agreement including compensation was reached with the majors [8]. Iran had a similar experience following the nationalization of the Iranian oil industry in 1951, a take-over that did not become a reality until 1973, when a long-term supply agreement was reached with the majors.

The lack of technical and managerial expertise in the exporting countries proved to be costly in terms of reduced oil activities. The need for assistance from the concessionary companies was therefore recognized.

An effort was made to find a working relationship that could meet the requirements of the private companies without involving an equity participation. Indonesia, after having nationalized the oil industry in 1960, introduced production-sharing contracts in 1966. A production-sharing contract entitles the companies to a fixed percentage of the crude oil produced to recover their exploration and production costs. The formal ownership of the reserves discovered is retained by the state company. A politically explosive issue is thereby avoided. Politically neutral is also the "service contract" or "entrepreneur contract" concept formulated by Venezuela in 1959 and implemented for the first time in 1966 in an agreement between the French state-owned company ERAP and Iran. Under such an agreement the foreign oil company operates as a contractor for the state-owned company. The discoveries made and the petroleum produced remain the property of the state. The foreign oil company, the contractor, will usually get no more than a long-term right to buy a pre-assigned part of the produced crude at a discounted price. ERAP's agreement with Iran and Iraq in 1968 gave the company a long-term right to buy at a discounted price. However, in the much more significant agreement in 1973 between the major Consortium companies in Iran and the National Iranian Oil Company, NIOC, no discounts were granted.

Some of the major Persian Gulf producers (Saudi Arabia, Abu Dhabi, and Qatar), rather than announce nationalization of the oil industry, purchased, "at a bargain price," [8] a 25 percent share in the concessionary companies in an agreement of January 1, 1973. The companies were

compensated on the basis of the book value of their assets only. Because none of the state companies was yet in a position to market oil on this scale, the governments required the oil companies to buy back the oil the governments obtained through the participation agreements at a price to be determined by the governments. The buy-back price has been considerably higher than the total tax paid cost of equity oil.

Since 1973 the governments' share of the production ventures has increased rapidly. Kuwait recently announced a 100 per cent "participation" which is in effect a complete nationalization of the industry [9]. The other producers in the Gulf and Nigeria are expected to follow the example soon. When the governments push for a 100 per cent interest in the operating companies, the price structure is likely to converge towards the buy-back price which would then become the price of crude.

It is still somewhat unclear how the companies will be compensated in the future, whether it will be through a discount on the price of crude, a fee to perform under a service or a management contract, or some production sharing arrangement. The producer countries will still need the services of the international oil companies for a number of years.

2.5 Pricing

The fast rising demand for imported oil in the latter half of the 1960's put a strain on the delivery system. The spot tanker rate increased steadily from 1967. In May 1970 the trans-Arabian pipeline (Tapline) was blocked by Syria [1]. The producing governments in North Africa exploited

their favorable location by demanding higher taxes. When the companies refused to pay the higher tax, Libya restricted output to force the companies to agree to its demands. The companies rushed to the spot tanker market to secure transportation from the Persian Gulf. The supply of tanker transport is very inelastic in the short run when the industry is already operating at capacity. The spot market rate consequently jumped dramatically, and the companies found it economically justified to agree to the Libyan tax increase.

President Gadaffi of Libya demonstrated the ability and the power of an individual producer country to dictate its own terms. His initial success and the continued strain on the delivery system encouraged President Gadaffi to push for better terms. President Gadaffi emerged as a price leader of the producer countries.

The companies tried to recapture their bargaining power by agreeing upon a strategy of industry wide bargaining. They figured that the weakest countries' need for a settlement would discipline OPEC as a whole. The companies wanted to put pressure on OPEC's "independents."

The exporting countries, however, opposed such industry wide bargaining. They wanted first an agreement for the Persian Gulf and then with this agreement as a precedent, negotiate agreements for the other producing areas. The Persian Gulf was in 1970 as today, the marginal source of petroleum in the world, and the producer countries of the Persian Gulf were therefore in the strongest bargaining position.

The issue of industry wide, as opposed to regional negotiations, brought company executives and OPEC officials to Teheran in February 1971. An agreement seemed impossible when OPEC launched a very risky venture. On February 3 the OPEC representatives presented the companies with an ultimatum. If no agreement was reached by February 15, the separate governments would enforce their terms by legislation, imposing a ban on shipments by any company that refused to conform [7]. The companies elected to meet the OPEC demands, which implied an immediate increase in the governments' take of about 33 cents, and acceptance of four additional phased increases in the posted price, on 1st June 1971, and on 1st January 1973, 1974, and 1975. With an agreement established for the Persian Gulf, agreements for Mediterranean and African crudes were reached in Tripoli in April.

The Teheran and Tripoli agreements constitute the first significant pieces of evidence that a cartel was organized and operating among the petroleum exporting countries of the world. Since then the OPEC countries have been trying to climb up along the demand curve to benefit from a monopoly or a joint profit maximizing price.

The October 1973 cutback of production and the following increase in prices may, however, be explained by a political as well as by an economic hypothesis. As the October 1973 events do certainly not contradict an economic hypothesis, it was decided that for the purpose of this study a focus primarily on economic behavior would be appropriate.

Whether intentionally or not, from an economic point of view the timing of the October 1973 cutback was excellent. Demand for petroleum imports were growing close to the 1962-1973 average of 7.5 percent per year. Partly due to production and price controls of natural gas and crude oil in the United States, large increases in imports of crude oil and petroleum products were required. For market clearning at the regulated (frozen) prices, imports would have had to increase by 2 million barrels per day in 1973 [6]. The U.S. was thus on a 20 percent annual increase in imports path in 1972-1973, very vulnerable to cut-backs, and thus easily convinced that higher prices were necessary.

When it was clear that the U.S. would not be able to respond to higher prices, at least not in the short run, no major consuming country would be able to respond. Neither Western Europe nor Japan have short-term alternatives to their petroleum imports. There was consequently room for a major increase in the price of crude.

The escalation of the cost of crude to the oil companies and of the level of government take over the last fifteen years is summarized in Table 2-1. The buy-back price, the buy-back percentage and hence also the average cost of crude for the period 01/01/74 - 07/01/74 was determined retroactively. The companies were producing oil in that period without having a clear idea of what they would have to pay for it. The intentions of the producing countries seem to have been to do away with the posted price system. The producer governments expected to sell their oil in the open market at a price which consisted of the $7 floor

and a company margin which was not well defined. It soon appeared, however, that the governments could not sell anything like their buy-back amounts, and hence forced the companies to take them. The ability of the companies to take the buy-back oil and resell it at a very high price showed the governments that they could raise the price. The producer countries thus went through an important learning process in the spring of 1974. OPEC demonstrated an impressive level of discipline in the same period, being able to increase the price significantly at a time when also excess capacity increased significantly.

The price of crude oil in the Persian Gulf, the base point, and a set of quality and transportation differentials determine the price other producers may charge for their crude. The way the producer countries determine what the companies shall pay for crude oil and the dramatic change in ther terms of production are demonstrated in Table 2.2. The posted price or the tax reference price, which is now being unilaterally determined by the producer countries, serves as a basis for determining the producer countries' per barrel revenues. The royalties being paid are calculated as a percentage of the posted price and are being expensed for income tax purposes. A per barrel income figure is determined by subtracting production costs and royalty payments from the posted price. This income figure is then used as a basis for calculating a per barrel income tax which today is 85% of this imputed income figure. The government's per barrel revenues on equity oil, that is, on the oil that the oil companies own according to the concession agreements, are hence equal

to the sum of the per barrel royalty and income tax. The cost of buy-back oil and the percentage of the total being bought back by the companies from the governments participating in operating ventures are additional instruments the producer countries can use to make the weighted cost of crude, that is the average per barrel cost of crude to the oil companies, equal to some target price. The tax legislation of the consumer countries makes it favourable for the oil companies to realize the profits of their integrated operations in the producer countries as the companies get a tax credit for the taxes being paid to the producer countries, and thus can partially eliminate tax liabilities elsewhere. The company margin used to calculate the transfer price of crude oil or the F.O.B. cost of crude in the Persian Gulf is thus a proxy for the companies' profit margin on their integrated operations.

It is likely that the tax rules applicable to oil companies will be changed to the effect that profits will be distributed more evenly on their downstream operations by removing the tax credits as they are formulated today. The emerging working relationship between the companies and the governments may imply that the rather arbitrary determination of the cost of crude as illustrated in Table 2-2, resulting from the myriad of contractual and concessionary agreements presently in operation, will be replaced by some single price-concept.

TABLE 2-1

THE COST OF CRUDE IN THE PERSIAN GULF

(Arabian Medium, 31 API, Ex. Ras Tanura)

Period	Posted Price	Government Take	Tax-Paid Cost	Buy-Back Price	% of Total Brought Back	Average Cost of Crude
1960-1965	1.80	0.82	0.92			
1966-1967	1.80	0.85	0.95			
1968-1969	1.80	0.88	0.98			
1/1-11/14, 1970	1.80	0.91	1.01			
11/15/70-2/14/71	1.80	0.99	1.10			
2/15-5/31/71	2.18	1.26	1.37			
6/1/71-1/19/72	2.28	1.32	1.43			
1/20/72-1/1/73	2.48	1.44	1.55			
1/1-3/31/73	2.59	1.51	1.62			
4/1-5/31/73	2.75	1.61	1.71			
June 1973	2.90	1.70	1.80			
June 1973	2.95	1.74	1.84			
August 1973	3.07	1.80	1.90			
1/1-10/15/73	3.01	1.77	1.87	2.80	20%	2.05
10/16-12/31/73	5.12	3.05	3.15	4.76	20	3.47
1/1-3/1/74	11.65	7.00	7.10	7.10	25	7.10
3/1-7/1/74	11.65	7.00	7.10	10.82	25	8.04
1/1-7/1/74	11.65	7.00	7.10	10.87	57	9.25
7/1-10/1/74	11.65	7.06	7.16	10.96	62	9.50
10/1-11/1/74	11.65	8.12	8.22	10.96	47	9.81
11/1/74-1/7/75	11.25	9.82	9.92	10.67	58	10.35
1/1/75 -	11.25	9.82	9.92	10.46	56	10.22

Sources: Business Week & Petroleum Economist & Financial Times

TABLE 2-2

CALCULATION OF THE F.O.B. COST OF CRUDE
IN THE PERSIAN GULF

	January 71	November
POSTED PRICE	$1.800	$11.251
Less production cost	0.10	0.10
Less Royalty	0.225	2.250
TAXABLE BASE	1.475	8.901
Income Tax	0.738	7.566
Royalty	0.225	2.250
GOVERNMENT TAKE (Equity Oil)	0.963	9.816
Production cost	0.10	0.10
TOTAL TAX PAID COST (Equity)	1.063	9.916
BUY-BACK PRICE	-	10.671
Companies' average cost:	-	
Equity oil	1.063	9.916
Buy-back oil	-	10.671
WEIGHTED AVERAGE	1.063	10.353
Typical company margin	0.35	0.35
F.O.B. COST OF CRUDE	1.413	10.703

January 1971: Royalty 12.5% Tax 50%

November 1974: Royalty 20% Tax 85%, Buy-back price 94.85% of posted price, 42.1% equity oil and 57.9% buy-back oil.

2.6 Summary and Conclusions

The "majors" completely dominated the international petroleum market up until 1950. The early concession agreements kept the involvement of the producer governments at an absolute minimum. The companies were able to exploit their market power by establishing and maintaining a non-competitive price level. The early concession agreements were increasingly considered to be offensive to the national pride. The agreements could not survive in a world of growing nationalism. The non-competitive price level induces smaller independent oil companies to establish themselves as integrated companies with access to equity crude. Nationalism also induced consumer countries to establish their own state oil companies to explore for and produce oil. The entering firms were able to obtain concessions by offering better terms to the producer countries. A second generation of concession agreements was based on the 50-50 profit sharing principle introduced by Venezuela. Venezuela was the only producing country that played an active role in the conceptualization and implementation of these concession agreements that helped all the producer countries reach their goal of higher revenues from the petroleum sector. The continued entrance of new firms during the 1950's and the 1960's and the vulnerability of the independents to the actions of individual producer countries induced the independents to introduce the concepts that would make it possible for the producer countries to reach their second goal, direct access to and control of the operating units. The 100%

"participation" agreements that have been introduced lately, which mean in effect that the industry has been nationalized, give the producer countries a control constrained by their level of technical and managerial expertise only.

The development of the contractual relationships can be summarized as done in Table 2.3, where the two major characteristics of the contractual concepts in their "pure" form are listed as well as their dates of introduction. Except for the 1st generation of concession agreements all the contractual concepts as listed in Table 2-3 are included in some form or another in the existing contractual relationships between the producer countries and the multinational oil companies.

The downward pressure on price resulting from the increased competition from the independents made the companies unilaterally decrease the posted price, the tax reference price, in 1959. Venezuela seized the opportunity to convince the producing countries of the need for an organizational counterpart to the oil companies, and OPEC was formed in September 1960. OPEC managed to reverse the downward trend in nominal prices, but not in real terms in the 1960's. OPEC seems to have had no significant impact on the market price of crude oil in the 1960's.

The tanker shortage that developed in 1970 and the resulting dramatic increases in the spot market rates, made it possible for President Gadaffi of Libya being located closer to the consumer markets to obtain more for Libyan crude. The continued strain on the delivery system and President Gadaffi's resulting continued success in convincing the companies to pay higher taxes made Gadaffi an ideological as well as a

TABLE 2-3

CHARACTERISTICS OF CONTRACTUAL CONCEPTS

	Date of Introduction	% Government Ownership	Government Share of Crude Oil "Profits" %
CONCESSIONS			
1st Generation	1880's	0	Nominal
2nd Generation	1948	0	50[1]
NATIONALIZATION	1938	100	60-100
"JOINT-VENTURE" PARTICIPATION	1957	50	75
SERVICE CONTRACTS	1966	100	75-100

[1] 58% with royalty expensing which was introduced in the Middle East in 1964

Sources: Petroleum Economist
Neil H. Jacoby Multinational Oil, pp. 108-110

price leader of the exporters. The cohesiveness and the confidence of the exporting countries increased dramatically following Gadaffi's success. In Teheran and Tripoli in 1971 OPEC was able to force its demands through as a cartel. The exporter countries had decided to collude to enforce their demands. The strength of the colluding group was not tested as the oil companies chose to avoid a confrontation by agreeing to the increase in government take.

The October 1973 cutback of production demonstrated the cohesiveness of the dominating Arab subset of OPEC. OPEC has since then also shown an impressive level of discipline by being able to live with a considerable excess capacity without cutting prices. President Gadaffi seems to have lost his leading role. Saudi-Arabia, Egypt, and Algeria tend to dominate the political stage, Algeria and Iran the role as price leaders. Two years after the embargo political pragmatism and economic development seem to dominate the decisions of the producing countries in the Middle East. This does not imply, however, that the relationship between the producer countries, especially in the Persian Gulf, does not have a major political ingredient affecting their oil policies, neither does it imply that one or more major producers will not again use their control over oil, volumes and prices, to gain political favors from the West.

The presently emerging contractual regime is giving the individual exporter governments control over production of oil. OPEC as an organization has, however, no instruments available to regulate prices and

production rates. Production programs or pro-rationing has been discussed but never implemented. OPEC is no more than a forum for discussions and for coordination of the price- and production policies of the individual exporting countries. Except for the threat of cut-off in Teheran and the October 1973 embargo, the producer countries have never made decisions affecting the rate of production on a joint basis. Even during the embargo period the production policies of all the OPEC countries were not perfectly coordinated. Iran being the most significant non-conformist increased production significantly while the Arab subset of OPEC restricted output (11). Since the first major tax or price increase, the producer countries have accepted the way the market place and the lifting schedules of the oil companies have allocated production and profits among the exporters. The producer countries have thereby been able to avoid confrontations over these critical issues. The recent accomplishments of the exporting countries cannot be explained by their experience in operating an oil industry. The experience of the countries that nationalized the oil industry (Algeria, Indonesia, Iran, Iraq, and Libya) is somewnat more advanced than the experience of the countries that followed a participation-path (Abu Dhabi, Kuwait, Nigeria, Qatar and Saudi Arabia). Venezuela, which has also decided to nationalize the oil industry, is the most experienced with respect to making decisions on prices and production rates. Even if the oil companies have demonstrated that it is possible to maintain

a non-competitive price level in the petroleum industry as long as the colluding agreement covers a sufficient share of total supplies, the lack of experience in coordinating production-rates, the lack of access to the final consumer markets, the heterogeneity of the producer countries, and the increasing government involvement in the marketing of crude, leading possibly to confrontations the exporters are not prepared to face, may make it difficult or impossible for the producer countries to agree on a common tax or price policy. To determine the extent to which these factors have affected the success and the longevity of cartel-like collusive arrangements, a review was made of the research findings on previous cartels as reported in Chapter 3. The success of the exporters in sticking to an increasing price in the light of the level of excess capacity has, however, been so impressive that they may be reluctant to or careful about changing the present market- and company-determined system of allocating production and profits. This system may be considered fair and just as long as there is no evidence that the companies deliberately try to divert the way the marketplace ranks the competitiveness of the various countries' crudes.

The oil companies are not yet powerless. They provide a service for which there is no institutionalized organizational substitute. In the foreseeable future, the oil companies will still be indespensable to an orderly growth of production and distribution in the international oil industry. This is true not only because of their technical and logistics

capacity, but more importantly, because the companies constitute total systems wherein all of the various parts are integrated and attuned to one another. The significance of their logistics capacity was demonstrated during the embargo, when the companies were able to partially divert supplies, thereby reducing the effect on the primary targets of the embargo, the Netherlands and the U.S.[11].

The oil companies will probably continue to be the target of both producer and consumer disatisfaction. From the perspective of the producer countries, collusion between the oil companies and the consumer countries seem to be a fact. The companies did reduce prices in 1959 and in real terms also in the 1960's. During the last year the oil companies have been accused by the consumer countries of colluding with the producer governments. To the extent that any company owns petroleum reserves, such a company shares the interests of OPEC in high world market prices for crude oil.

The companies are severely constrained, however, in their ability to resist producer government initiatives, even if the oil companies are an important component of the mechanism for raising and supporting international oil prices.

CHAPTER 3
THE EXPERIENCE OF PREVIOUS INTERNATIONAL COMMODITY CARTELS

3.1 Introduction and Summary

The Teheran and Tripoli agreements of 1971 between the oil exporting countries and the oil companies constituted the first significant pieces of evidence that a cartel was being operated by the oil exporting countries. The price-making power of OPEC was clearly demonstrated in the fall of 1973 and in 1974. The average price of crude in the Persian Gulf increased by 505% between October 15, 1973 and November 1, 1974. As long as the OPEC countries can agree on a joint market strategy they can take advantage of their monopoly power and enjoy monopoly profits. A cartel is however, an unstable unit even from a theoretic point of view. The market solution resulting from explicit collusion among oligopolists cannot be uniquely determined. The OPEC countries are also a rather heterogenous group of countries. To learn about the efficiency and longevity of cartels, a review was made of the research findings on the efficiency and the longevity of international cartel agreements.

The economics and political science literature contains more than 50 studies of the operation of cartels in the trade of international commodities. Agreements have been formed by companies and countries in commodities as far ranging as tin and tea; these agreements have lasted for varying lengths of time, and have had varying degrees of success in curtailing production and raising prices to consuming countries. The research

literature has documented cartel "success" and has provided a number of reasons why some cartels have worked better than others. Here we review and compile research results in a way which should indicate central factors in the operation of workable versus unworkable cartel agreements.

Although there have been numerous cartels in almost every commodity in international trade, only a small number of these price-controlling organizations have been studied in detail. Of those studied, even a smaller number have been analyzed sufficiently completely to make it possible to tell the difference between cartel success or failure. We have found evidence on 51 cartel agreements in 18 industries. These constitute two samples from which we draw conclusions on the factors determining the success or failure of cartels.

Cartel success or "efficiency" has been defined in terms of the ability of the organization to raise price at least 200% above the unit costs of production and distribution. If the cost to the highest cost member of the cartel at the margin were $1.00 per ton then the cartel would be efficient if it raised prices to $3.00 per ton and kept them there for a significant period of time.

The review indicates that of the 51 significant cartel organizations reported, only 19 ahcieved price controls which raised the level of charges to consumers significantly above what they would have been in the absence of agreements. But even the efficient cartels did not seem to last very long. Cartels were able to raise prices for four years or more, where concentration of production was high, demands inelastic, the cartel's

market share was high, the membership had cost advantages over outsiders, and governments did not get involved in the operations of the cartel.

If OPEC were to follow the pattern set by the 19 earlier "efficient" cartels, then it would likely have a 4 to 6-year duration. The primary source of breakdown would likely be the uncontrolled additions of supply from the "fringe" of OPEC countries (Iraq, Indonesia, Nigeria) or from the non-member countries.

3.2 Cartel Characteristics

The information available on international cartel agreements is not sufficient for rigorous empirical hypothesis testing. The studies made on cartels differ significantly in terms of their level of detail and research focus. From a theoretic point of view all important aspects of a cartel agreement were not covered in the studies that have been reviewed. For the purpose of this study we therefore constructed two samples out of the 51 cartel agreements on which we had enough information to judge whether the cartel agreement had been successful or not. To identify the most important factors determining the "efficiency" and longevity of cartel agreements each cartel was summarized along a number of dimensions. Due to the anecdotal and/or vague nature of the data, we have been limited to a very tight range of response, often to binary representation. On the cartels belonging to sample 1 we had sufficient data to describe the cartels along 17 dimensions. Sample 2 consists of cartels on which we had sufficient data to code 5 dimensions only. The dimensions are intended to describe as completely as possible the known occurrences of

Dimension 5. If short-term substitutes for a commodity exist, the value of 1 is assigned; if no substitutes exist, 0 is assigned to the commodity.

Dimension 6. The existence of long-term substitutes is treated the same as for dimension 5.

Dimension 7. If governments were involved in the cartel agreement, a value of 1 is assigned; otherwise a value of 0 is assigned.

Dimension 8. The length of survival of the formal agreement in years.

Dimension 9. If the cartel members' share of total prodiction in the industry is above 75 percent, a score of 2 is assigned; if the cartel members share is between 50 and 75 percent a score of 1 is assigned. A score of 0 is assigned if the share is below 50 percent.

Dimension 10. If the cartel members are responsible for more than 75 percent of total exports in the international export/import market, a score of 2 is assigned. A score of 1 indicates that the cartel members export between 50 and 75 percent of the total; a value of 0 is assigned if the cartel members export less than 50 percent of that particular commodity.

Dimension 11. This dimension is included to test whether industries learn over time, that is if the number of previous attempts to organize a cartel influence the success of later attempts to organize. The score is equal to the particular cartel's number in this sequence of attempts.

Dimension 12. Members are given a score of 1 if the cost differences within the cartel are less than 50 percent - that is, if the high-cost

producers produce at a cost no larger than 50 percent above the low-cost producers. Otherwise, the dimension is given a score of 0.

Dimension 13. The efficiency of the cartel refers to the ability to charge prices close to the monopoly price, i.e., if price is 200 percent of marginal cost or more. Otherwise, the score of 0 is assigned. This very rough indicator of cartel efficiency was applied because information on the location and slope of the demand curve and the location and slope of the marginal cost curve usually was not sufficient to allow calculation of the monopoly price.

Dimension 14. This dimension is given a score of 0 if the cartel members' potential time horizon is more than 1 year and a score of 1 if the time horizon is less than 1 year.

Dimension 15. The dimension is given the score of 0 if a cartel breakdown was not-market-related, i.e., due to government intervention, war, etc., and a score of 1 if the breakdown was market-related, i.e., due to the loss of markets to outsiders or the emergence of competition between cartel members'.

Dimension 16. This expands on no. 15 by assigning a value of 1 if the breakdown was market-related and due to external forces, i.e., non-member suppliers or consumer retaliation, and a value of 0 if the cartel broke down due to an internal conflict between the cartel members.

Dimension 17. This final measure further expands on the breakdown issue by assigning a value of 1 if the external forces were outside supply, i.e., non-member supplies, and a value of 0 if the response of

consumers or demand response constituted the external forces that caused the cartel breakdown.

3.2.2. Cartel Characteristics of Sample 2

This second sample was necessary because we did not have sufficient information to characterize the cartels along the full set of 17 dimensions shown above. The attributes of Sample 2, therefore, should be viewed as a quick summary, and are essentially a subset of the attributes of Sample 1.

Dimension 1. This refers to the length in years of the agreement, see no. 8 above.

Dimension 2. This attribute is similar but not identical to Dimension 1 of Sample 1 above. If the four-firm concentration ratio is more than 75 percent, a score of 2 is assigned. A 1 is given if between 50 and 75 percent. Concentration of less than 50 percent is designated as 0.

Dimension 3. Here we are referring to concentration within the cartel itself. See Dimension 9 of Sample 1 above.

Dimension 4. Cartel breakdown is analyzed as in Dimension 16 in Sample 1.

Dimension 5. Cartel efficiency is described as in Dimension 13 in Sample 1.

3.3 Sample 1

Sample 1 consists of the industries on which we were able to obtain information to assign a numerical value to the 17 dimensions defined

Table 3-1
CHARACTERISTICS OF "EFFICIENT" CARTELS
Sample 1

	Rubber	Mercury		Aluminum					
Year	1934	1928	1939	1901	1906	1912	1923	1929	1931
1. Concentration of Production	0	1	1	1	1	1	1	1	1
2. Concentration of Exports/ Imports	0	1	1	1	1	1	1	1	1
3. Demand Elasticity	0	0	0	0	0	0	0	1	1
4. Income Elasticity	1	1	1	1	1	1	1	1	1
5. Short-term Substitutes	0	0	0	0	0	0	0	1	1
6. Long-term Substitutes	1	0	0	1	1	1	1	1	1
7. Government Involvement	1	0	0	0	0	0	0	0	0
8. Length of Formal Agreement	6	8	10	5	2	2	3	4	5
9. Cartel Members' Share of Total Production	2	2	2	0	0	0	0	0	2
10. Cartel Members' Share of Exports/Imports	2	2	2	2	2	2	2	2	2
11. Number of Recorded Attempts to Set Prices	4	1	2	1	2	3	4	5	6
12. Cost Differences Among Cartel Members	0	1	1	1	1	1	1	1	1
13. Efficiency	1	1	1	1	1	1	1	1	1
14. Potential Time Horiaon of Agreement	0	0	0	0	0	0	0	0	0
15. Break-down Market Related	0	0	1	1	1	0	1	1	1

Table 3-1 (Continued)
CHARACTERISTICS OF "EFFICIENT" CARTELS
Sample 1

	Rubber	Mercury		Aluminum					
Year	1934	1928	1939	1901	1906	1912	1923	1929	1931
16. Break-down Externally	-	-	0	0	1	-	0	1	0
17. Break-down due to External Supply	-	-	-	-	1	-	-	1	-

Table 3-2
CHARACTERISTICS OF "INEFFICIENT" CARTELS
Sample 1

	Rubber	Tin			Sugar		
Year	1922	1929	1931	1935	1931	1937	1958
1. Concentration of Production	0	1	1	1	0	0	0
2. Concentration of Exports/ Imports	0	1	1	1	1	1	0
3. Demand Elasticity	1	0	0	0	0	0	0
4. Income Elasticity	1	1	1	1	1	1	0
5. Short-Term Substitutes	1	0	0	0	1	1	0
6. Long-Term Substitutes	0	0	0	0	1	1	1
7. Government Involvement	1	1	1	1	0	1	1
8. Length of Formal Agreement	6	2	3	2	4	2	3
9. Cartel Members' Share of Total Production	1	2	2	2	0	2	2
10. Cartel Members' Share of Exports/Imports	1	2	2	2	2	2	2
11. Number of Recorded Attempts to Set Prices	3	1	2	3	5	6	?
12. Cost Differences Among Cartel Members	0	0	0	0	0	0	1
13. Efficiency	0	0	0	0	0	0	0
14. Potential Time Horizon of Agreement	0	0	0	0	0	0	1
15. Break-down Market Related	1	1	1	1	1	0	0
16. Break-down Externally	1	0	0	0	1	-	-
17. Break-down due to External Supply	1	-	-	-	-	-	-

Table 3-2 (Continued)
CHARACTERISTICS OF "INEFFICIENT" CARTELS
Sample 1

	Steel				Tea	Copper	
Year	1926	1930	1931	1933	1933	1955	1964
1. Concentration of Production	0	0	0	0	0	1	1
2. Concentration of Exports/ Imports	0	0	0	0	0	1	1
3. Demand Elasticity	0	0	0	0	0	0	0
4. Income Elasticity	1	1	1	1	1	0	0
5. Short-Term Substitutes	0	0	0	0	1	1	1
6. Long-Term Substitutes	0	0	0	0	1	1	1
7. Government Involvement	0	0	0	0	0	1	1
8. Length of Formal Agreement	4	0.5	0.17	6	6	2	2
9. Cartel Members' Share of Total Production	0	0	0	2	1	0	2
10. Cartel Members' Share of Exports/Imports	1	1	1	2	2	0	2
11. Number of Recorded Attempts to Set Prices	?	?	?	?	?	?	?
12. Cost Differences Among Cartel Members	1	1	1	1	1	1	1
13. Efficiency	0	0	0	0	0	0	0
14. Potential Time Horizon of Agreement	0	0	0	0	0	0	0
15. Break-down Market Related	1	1	1	0	0	1	1
16. Break-down Externally	0	0	0	-	-	1	1
17. Break-down due to External Supply	-	-	-	-	-	0	0

The British colonies contained 72 percent of world capacity in 1922. The Dutch colonies contained another 25 percent of world capacity. The Dutch twice refused cooperation, but took advantage of the plan by increasing production. The British market share decreased from 67.5 percent in 1922 to 54.1 percent in 1927, whereas the market share of the Dutch colonies increased from 23.2 percent to 37.7 percent.

Outside production, internal rivalry, as well as the problems of timing of restrictions were the reasons for the failure of the Stephenson Plan.

The International Rubber Regulation Agreement of 1934 did, however, succeed in increasing prices so that the average producer, according to Stocking and Watkins, could enjoy a margin of 126 percent, and we judged the cartel to have been efficient, given the fact that the cartel lived with the threat of synthetic rubber.

British, Dutch, French, Indian and Siamese kept the agreement up until World War II, even though attacked by U.S. protests, which resulted in the organization of a semi-official resistance movement to conserve tires and use reclaimed rubber.

The consumption of rubber was assumed to be income-elastic.

2. Tin

Production of tin was dominated by a few governments in the Far East-Malaysia (Dutch), Thailand, Nigeria and the Belgian Congo. These producers tried to regulate tin prices, but our recorded attempts, 1929-1931, 1931-1935, and 1935-1937 were all failures due to lack of discipline and enforcement of the restrictive measures.

There was no satisfactory substitute for tin, even though there was some secondary recovery of tin from scrap. Tin was indispensible in armaments and we assumed that demand was inelastic as is also the case today, according to C. Fred Bergsten. The statement by Hexner that "production costs varied from mine to mine" is the basis for our assumption that costs differed by more than 50 percent.

3. Mercury

According to Hexner and Burrows, the price of mercury has been close to the monopoly price since 1928. Spain and Italy have completely dominated the production of this commodity for which no substitute exists. As mercury is also indispensible in armaments, price-elastic and income-elastic demand is assumed.

The cost difference between Spanish and Mexican producers is assumed to be above 50 percent. The cartel established in 1928 broke down in 1936 due to the Spanish War. It was reestablished in 1939 and then lasted until 1949 when it broke down due to internal problems. Since 1950 there have never been more than 3 years of disagreement among the major mercury producers of the world.

4. Aluminum

Originally due to patent rights, and later due to inter-corporate ties, the aluminum industry has been highly concentrated. The sequence of cartels, 1901-1906, 1906-1908, 1912-1914, 1923-1926, 1926-1930, and 1931-1936, all seem to have been successful in stabilizing the monopoly level of the previous period.

According to Donald H. Wallace, the elasticity of demand increased in the latter twenties due to the conversion of latent into effective demand through the development of new alloys and products. Aluminum became at this time a capable substitute for various alloys of iron, copper, and zinc in heavy-duty components. The aluminum industry was under-going a process of transition from a condition of limited markets to one of diversified markets. We therefore assumed that demand moved from the inelastic to the elastic segment of the demand curve in the late twenties.

Demand also seems to have been income-elastic in this period. The importance of technology should imply that cost differences were small. The capital-intensity of consumption seems to indicate that no short-term substitutes existed even if long-term substitutes did exist.

5. Steel

The first international steel cartel, 1926-1930, consisted of national steel cartels united in an association. The national steel cartels had government support, but was primarily of a private character.

This first cartel produced 30 percent of the world's output of steel and 66 percent of world exports. It collapsed, however, in 1930 due to internal problems. In 1930 a second international steel cartel experienced half a year of frustration. In 1931 a third cartel lasted for only two months. A fourth cartel that lasted from 1933 to 1939 had, according to Stocking and Watkins, some success in keeping prices higher than otherwise would have been the case and was also able to discriminate between customers. The price series does not, however, seem to support a judgment on the cartel as being efficient.

6. Tea

There have been a number of attempts to organize cartels in the tea industry. The International Tea Cartel from 1933 to 1939 was regarded as an interesting example of a collective marketing control established by trade associations with the cooperation of governments. The concentration in the industry was low. Demand was probably price inelastic as is the case today, according to C. Fred Bergsten. Demand also seems to have been income-elastic in the relevant period. Cost differences were most likely high. The War prompted the British Ministry of Food to take over the whole tea supply and fix prices according to the average price prevailing at the end of 1938. The price series seem to indicate that the cartel had no effect on prices.

7. Sugar (1864-1939)

The concentration in the sugar industry is low. In the export markets, however, the concentration is high due to common sales agencies. According to Stocking and Watkins, demand was price-inelastic prior to World War II. Demand seems to have been income-elastic in the same period.

In 1864, 1902-12, 1929, 1942, 1953, 1956 and 1958 cartel attempts in this industry are included in Sample 2. The first international sugar cartel we include in this sample is the so-called Chadbourne Agreement of 1931-1935, which was a private marketing control agreement, approved and enforced by the respective governments. Failure to restrict production efficiently and the rapidly increasing market share of outsiders made the

Chadbourne Agreement collapse. On the initiative of the League of Nations, a new international agreement was signed on May 6, 1937. It was a diplomatic treaty between 21 governments representing 85-90 percent of the world's sugar production and consumption. Prices were stabilized some 30 percent above the 1935-1936 average prices, and the cartel was accordingly judged to be inefficient. The agreement was disrupted by the War in 1939.

8. Sugar (1958-1961)

Today nearly 90 percent of the world's sugar is either consumed in the areas where it is produced or is marketed under a quota system. This means that a very small proportion of all sugar produced is freely traded in international markets. In the short-term, corn syrup and other sweeteners can be substituted for cane or beet sugar. The precise elasticity of demand is not well known, but it was judged to be inelastic in the near term.

Sugar trading receives protection from many government-backed commodity agreements. In the U.S. there is a U.S. Sugar Act. In Great Britain the comparable pact is the British Commonwealth Sugar Agreement. In 1958 an International Sugar Agreement (ISA) was negotiated between all of the large producing nations in order to stabilize the wide fluctuations in prices. This international agreement was not able to restrict fluctuations, but it did serve to prevent any further declines in average prices. The ISA broke up in 1961 because of growing difficulties between the U.S.

and its major sugar trading partner, Cuba. Until that time the U.S. had gotten 75 percent of its imports from Cuba. However, in mid-1961 the U.S. cancelled all international trade with Cuba and sought other sources of sugar elsewhere in Latin America. At the same time Cuba had huge supplies which had to be sold in other, non-U.S. markets. This instability in market conditions was enough to cause the ISA to crumble and world prices to fall.

9. Copper (1950-1970)

Most of the free world's copper supply is found in fewer than 7 countries and is refined by what is known as "the big eight" firms, for uses in electrical and other industrial processes. Quantitative estimates of the short-run elasticity of demand (between .21 and .48) have underscored that demand is relatively inelastic since not many short-run substitutes are available. In the long run (10 years or more), alternatives are more feasible and demand elasticity is relatively elastic (approximately 2.8). (Burrows, 1974.)

During the mid-1950's, and again in the mid-1960's, producers made attempts to influence the market price. These actions were generally taken with the full knowledge and cooperation of the respective governments. Chile, Peru, Zambia, and the Congo have been the most active in this regard and have formed a joint body, CIPEC, to promote their common interests. The initial price experiment (1955-1956) was undertaken by a Zambian producer who felt that he could appreciably affect the price of copper by imposing a ceiling on price. The unilateral attempt was

unsuccessful, however, in that the cooperation of other producing firms was not attained.

A second price experiment (1965-1966) found more support among the large producers, and consequently was far more successful from their perspective. In the two-year period, copper prices doubled as the "big eight," as well as smaller firms, temporarily agreed on common goals. After two years of steadily rising prices, agreement among producers faded as some began shading on prices. Explanations of the breakdown have noted that some of the less developed countries have vastly different time horizons than many of the private producers. For example, while Chile was interested in expoliting a short-run demand in elasticity, many of the private firms were much more conservatively inclined with an eye toward preserving long-run demand and discouraging the development of copper substitutes.

3.4. Sample 2

Sample no. 2 consists of the industries on which we were able to obtain information sufficiently detailed only to code the five dimensional cartel table defined above. The sources of information are identical to those of Sample no. 1. The influence of our personal judgment is, however, more severe on this sample than on the first sample. The results are shown in Table 3-3.

1. Wheat

In 1933 the first international wheat agreement was established by governments of wheat-producing and importing countries, without direct

Table 3-3
CHARACTERISTICS OF "EFFICIENT" CARTELS
Sample 2

	Copper		Quebracho			Sulfur	Potash	Phosphate Rock	Magnesium	Iodine	Diomonds
Year	1918	1929	1819	1926	1934	1934	1926	1933	1923	1878	1930
1.* Length of Formal Agreement	6	3	3	5	8	6	13	6	18	61	12
2.* Concentration of Production	2	2	2	2	2	2	2	0	0	0	2
3.* Cartel Members' Share of Total Production	2	2	2	2	2	2	2	2	2	2	2
4.* Break-down Externally (?)	0	1	0	0	0	1	1	1	1	1	1
5.* Efficiency	0	1	1	1	1	1	1	1	1	1	1

CHARACTERISTICS OF "INEFFICIENT" CARTELS
Sample 2

	Sugar							Wheat				Platinum		Salt Lake		Coffee		
Year	1864	1902	1929	1942	1953	1956	1958	1933	1942	1949	1959	1918	1931	1926	1930	1957	1958	1959
1.*	0	10	0	0	0	0	0	1	5	10	3	0	2	4	9	1	1	3
2.*	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2	2	2
3.*	0	0	0	2	2	2	2	2	1	1	2	2	2	0	0	1	1	2
4.*	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0
5.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

reference to private entrepreneurs or their organizations. The agreement broke down within a year due to disagreement over quotas and acreage reduction in addition to a very unfavorable price development. In 1942 Argentina, Australia, England, the U.S. and Canada established a new pool, limited in scope, but to be extended after the war. This plan collapsed, however, in 1947 when Argentina abstained.

The post-war international wheat arrangements have been for three-year periods. The 1949 wheat agreement was renewed in 1953 and 1956, then revised substantially in 1959 and renewed in 1962, which is the last year on which we have any information. Too weak jurisdiction over members has made these agreements inefficient.

2. Copper (1918-1940)

In 1918 a cartel was formed to liquidate the tremendous stocks of copper piled up as a result of the war and to regulate new production and exports. It was wholly American in membership. It represented 95 percent of the American production. The only outsider was Katanga, still in its infancy. The cartel was disbanded in 1924 after dissension arose between the companies with foreign properties and those with purely domestic properties. The cartel was successful in liquidating stocks without causing a sharp fall in prices, and also in regulating exports. It was consequently judged to have been efficient.

In 1926 Copper Exporters Inc. (a Webb-Pomerene association) was established. The company controlled 95 percent of the world's production of copper. The combined effect of the 1928-29 boom and cartel rationing sent prices upwards. The resentment against the cartel grew so strong, however, that a buyer's strike was called. From then until the dissolution of the cartel in 1932, with the enactment of the U.S. excise tax on copper, the power position of the cartel steadily declined. On the 1935-1941 international copper cartel information relating to world markets outside the U.S. is scarce.

3. Platinum

In 1918 several producers tried unsuccessfully to organize a cartel. In 1931, however, an agreement was signed, only to break down in 1933. Due to the fact that platinum is mainly a by-product and that palladium which is a substitute was not included, control of the market by the cartel seems to have been impossible.

4. Quebracho

Argentina and Paraguay have completely dominated this industry. In both countries the quebracho producers were organized in a government-sponsored cartel. In the periods 1919-1922, 1926-1931, and 1934-1946 (1946 being the last year on which we have information) these two national cartels operated jointly in the international market through establishing exclusive sales agencies, export quotas and uniform price policies. In 1942 the American agents were indicted for violation of anti-trust

regulations. As we have not been able to obtain additional information, this indictment (as well as a 1920-1939 price series) is the basis on which we have judged the cartels to have been efficient.

5. Sulfur

In 1838 the United Kingdom broke the Sicilian sulfur monopoly by sending gunboats. In 1934 a cartel was organized among the U.S. and Italian producers. The U.S. had at that time 80 percent, Italy 11 percent and Japan 6 percent of the world's production of crude sulfur. The cartel had complete control over export supplies and markets through the use of export quotas and uniform prices. According to Hexner, "Significant international agreements concerning sulfur are most characteristic of modern cartellization." U.S. anti-trust actions and some information on prices is the basis for judging the cartel to have been efficient up until World War II.

6. Sodium Sulphate (Salt Lake)

Important outsiders seem to have made life difficult for the cartels in this industry from 1926-1930 and 1930-1939.

7. Potash

Under strong pressure from the French and German governments, the potash exporters of these two countries formed a cartel in 1926. Germany was at that time responsible for about 60 percent and France for about 16 percent of the world's production of potash. Export prices were to be determined by production costs. American producers were, however, indicted in 1939 under the Sherman Act because of alleged cooperation in

price policies among themselves and with the European cartel. It was stated that this natural monopoly was abused by Germany and France. As export prices of potash were not published, the above-mentioned evidence is the basis for judging the cartel to have been efficient.

8. Phosphate Rock

World phosphate exports were regulated by an agreement established in 1933 and further amplified in 1934 and 1935. The agreement embraced the whole international market. The agreement is surrounded by a high degree of secrecy. From 1929 to 1939 phosphate prices tend, however, to support our judgment on the cartel as having been efficient.

9. Magnesite

In 1923 Czechoslovak and Austrian producers established a joint-stock sales company to regulate the international magnesite market. An "understanding" with American producers was also obtained. The large magnesite consumers were the shareholders of the magnesite companeis involved. In 1941 there was a U.S. Justice Department indictment for U.S. - European division of world magnesite markets. On this basis we judged the cartel to have been efficient.

10. Diamonds

Government licencing and monopoly support have helped monopolize the diamond industry. In 1930 a diamond trading company was established as the sole selling agency for 99 percent of African diamond production or 95 percent of world diamond production. The British government took over the company in 1942, after what is assumed to have been 12 successful years.

11. Coffee (1957; 1958; 1959-1962)

Coffee is primarily grown in Brazil, other Latin American nations, and Africa. Since World War II, world production has sharply increased, while simultaneously Brazil's market share has steadily declined. Production is almost universally undertaken in the less developed countries and as such represents a substantial amount of these countries' GNP. Due to chronic conditions of over supply, especially in Brazil, several exporting nations have periodically attempted to stabilize or bolster sagging coffee prices.

In 1957, and again in 1958, there were Latin American Coffee Agreements that were signed. Most Latin producers agreed to hold back a percentage of their harvests from the market with Brazil leading the charge with a 40 percent reduction. Neither agreement was successful in raising prices because African nations filled the gap with their own coffee.

In 1959 the African producers agreed to enter an International Coffee Agreement, in which there was 85 percent participation by world producers. The agreement set fixed export quotas which were based on 90 percent of past exports or 88 percent of estimated future exports. The agreement was renewed annually and was significant in that consuming nations were also included. The system has had the effect of providing a floor and increased stability for formerly volatile coffee prices.

3.5 Conclusions and Extensions

There are nine efficient and fourteen inefficient cartels in sample 1. Also, ten efficient and eighteen inefficient agreements make up sample 2. Therefore, of the 51 significant cartel organizations only 19 acheived price controls which raised the level of charges to consumers significantly above what they would have been in the absence of the agreements. The results for these two samples are summarized in Tables 3-4 and 3-5.

The efficient cartels did not seem to last very long. Although formal organizational agreements (to set up cartel management, for example) lasted longer in the efficient cartels, the average length of effective controls on price was not more than four to five years. The mercury cartel in the 1930's and 1940's, and the potash, magnesite, and diamond cartels of the 1930's, seem to have been able to control prices for as long as a decade, but these were not major products in international trade. The more important products, such as rubber in the 1930's or aluminum, copper or sulfur before World War II, experienced cartel longevity from one to four years.

There are a number of factors important in the longevity of the efficient cartel. Without these factors, it would seem to have been impossible for most cartel organizations to last for more than a few months.

1. Concentration of production was characteristic of the efficient cartel. Approximately 90% of the efficient cartels in sample 1 had concentration levels higher than 50% (the largest four firms had more than

Table 3-4
SUMMARY TABLE
Sample 1

	"Efficient"	"Inefficient"
A. Number of Cartels	9	14
B. Average Length of Formal Agreement (Years)	5	3.1
1. Concentration of Production (High:1, Low:0)	0.9	0.36
2. Concentration of Exports/Imports (High:1, Low:0)	0.9	0.5
3. Demand Elasticity (Elastic:1, Inelastic:0)	0.22	0.06
4. Income Elasticity (Elastic:1, Inelastic:0)	1	0.78
5. Short-Term Substitutes (No:0, Yes:1)	0.22	0.43
6. Long-Term Substitutes (No:0, Yes:1)	0.77	0.43
7. Government Involvement (No:0, Yes:1)	0.11	0.58
9. Cartel Members' Share of Total Prod. (Very high:2, High:1, Low:0)	0.9	1.14
10. Cartel Members' Share of Exp./Imp. (Very high:2, High:1, Low:0)	2	1.58
12. Cost Differences Among Cartel Members (High:0, Low:1)	0.9	0.58
14. Potential Time Horizons of Agreements (Long:0, Short:1)	0	0.08
15. Break-down (Non-market related:0, (Market-related:1)	0.66	0.70
16. If Market-related Break-down, Then (Externally:1, Internally:0)	0.33	0.30
17. If External Reason for Break-down, Then (Supply:1, Deman:0)	1	0.5

Table 3-5
SUMMARY TABLE
Sample 2

	"Efficient"	"Inefficient"
A. Number of Cartels	10	18
B. Average Length of Formal Agreement (Years)	8	2.7
2. Concentration of Production (Very high:2, High:1, Low:0)	1.6	0.55
3. Cartel Members' Share of Total Prod. (Very high:2, High:1, Low:0)	2	1.2
4. Break-down (Externally:1, Internally:0)	0.6	0.28

50% of total production or capacity to produce); but only 36% of the inefficient cartels had concentration levels this high. Similarly, the efficient cartels controlled a very high percentage of exports.

2. Demand conditions also strongly affected the chances that the cartel agreement worked well and lasted for a reasonable period of time. The summary tables show that the efficient cartels were characterized by inelastic demands (lack of sensitivity of quantities demanded to price changes), and that they also were characterized by the lack of short term substitutes in most cases (only 22% of the efficient cartels in the first sample had no long term substitutes); but this was also true of the inefficient cartels. The presence of ability to substitute other products in the long run may have limited both the length of life time and the efficiency of the agreement.

3. Government involvement made a difference in the success of the agreement. Government agencies were involved in the setting up of the organization of the cartel in almost 90% of the cases in which the cartel did work well. Although not much information was provided in the studies as to what the governments' activities were, it is presumed that at some stage political and diplomatic relations entered into the cartel organizations so as to break down the agreements.

4. Supply conditions differentiated efficient from inefficient cartels. Most of the successful cartels had as members one or two firms with production costs much lower than other firms, the lowest cost firms tending to "dominate" operation of the agreements. When cartels did break

down, it was mostly because of entry of additional suppliers or the expansion of supply by small firms outside the cartels' agreements (as shown by line 14 of the summary table for sample 1, Table 4).

In summary, there seem to be several important factors differentiating efficient from inefficient cartel agreements.

Cartels were able to raise prices for four years or more, where concentration of production was high, demands inelastic, and where few short term substitutes were available for the cartelized product. Governments were involved in breaking down agreements. Operating cost advantages and the presence of few outside sources of supply able to expand capacity were important for cartel success. These factors are shown in the summary table for sample 1, as those conditions of the 14 listed, for which the efficient cartel had significantly different values from the inefficient cartel.[1]

Much the same is shown by sample 2, because the concentration of efficient cartels is significantly higher than the inefficient. Also the cartel members' share of total production was much higher, and if cartel breakdown occurred, it was mostly because of entry into international markets by new firms.

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[1] By "significant difference" we mean a rough qualitative difference in the magnitude of the statistics between 0.0 and 1.0 in the two columns of the tables. For those six factors termed "significant" the differences in table values range from .32 to .66. Although there are smaller differences indicated by other factors, we chose to ignore them at this time because of small sample size and the highly qualitative nature of the values assigned between 0 and 1 between each cartel attribute.

There are further important dimensions not included in the findings from the earlier research studies. Indications scattered throughout the studies are that an important additional factor for cartel success or failure is tight control of distribution channels. The iodine cartel lasted more than 50 years as an organization without significant disruption, by making all iodine sales out of a single cartel association office in London (although there were no findings on the ability of this organization to raise unit price above unit cost). There are other examples in which additional elements of control seem to have followed from cartel supervision of distribution, but these are too scattered to lead to a research conclusion at this time. Similarly, the factor of the level of concentration among consumers seems to be important in some cases. Where there are only a few consumers and they are able to play one cartel member off against the other, then the efficiency of the cartel would appear to have been limited. But high buyer concentration was found only in very few cases and cannot be said to be a "finding" from the research analysis.

Probably the most important determinant of the longevity of a cartel agreement is the way production and profits are allocated among the cartel members. The unavailability of information on this aspect of a cartel agreement made it impossible to determine the level of conflict among the cartel members. Given the fact that the "efficient" cartel broke down more often due to the emergence of competition among the members rather than due to the response of non-members, the internal operating mechanisms of cartels have to be analyzed if we want to learn more about the stability of cartel-dominated markets.

The conslusions on important factors for cartels' success, and the summary tables themselves, are based upon the reading and evaluation of research materials in a wide variety of industries and cases. There is a strong element of personal judgment in the assigning of such attributes as "high concentration" or "lack of short term substitutes." It should be stressed that another review of this material might well establish somewhat different factors in the efficiency of agreements, or whether in fact an agreement was efficient or inefficient. But the overall impression that efficient cartels do not last very long would probably not be dispelled. Neither would the finding that high concentration, the presence of a dominant producer, and the lack of expansion by those outside the cartel, contribute very strongly to cartel price control over the 4 to 6-year lifetime of a typical organization.

3.6 Implications for OPEC

What do these factors tell us about the causes for the efficiency and longevity of the present day petroleum cartel? There have been petroleum cartels at an earlier time; the "as is" or "Achnacarry" agreement of the late 1920's to maintain output shares of American oil exporting companies collapsed in 1930 without having had a significant effect on European markets. Later similar agreements with quotas and fines did not collapse, but there is little or no evidence that tney had an appreciable effect on price levels before World War II. From 1945 to 1960 there were no formal agreements.

But prices were "high" in the sense that marginal production costs plus user charges could not have exceeded $1.00 per barrel, while prices were mostly centered around $2.00/barrel. The companies were hence about to maintain a non-competitive price level. Since the advent of the highly efficient OPEC cartel operation in the early 1970's, price-cost differences have increased to many times those expected from the earlier cartels.

The present day OPEC agreement has many of the characteristics found in the earlier cartels that were successful for limited time periods in other industries. The demands for final product are inelastic, and there are few short term substitutes for this product. Concentration within the cartel is substantial, and OPEC itself as an organization supplies about 90% of the total flow in international trade. The Arab subset of OPEC supplies 54% alone of the total international flow. There are substantial cost differences among firms, with the Persian Gulf producers having significant cost advantages and significantly greater capacity than the "fringe" of Southeast Asian, East African and South American countries.

The Teheran and Tripoli agreements in 1971 between the oil exporting countries and the oil companies may be considered as the first evidence of an efficient producer country petroleum cartel. Since then the producer countries have been able to successfully raise prices to a level that

makes OPEC the most efficient cartel in modern times. The OPEC countries have not, however, been able to agree on and stick to a formal system for sharing production among the member nations. As long as the OPEC members accept the way the major oil companies allocate the reductions in production and/or profits allocation systems makes, however, OPEC as vulnerable to emergence of internal compeition as the cartels that have been reviewed, even if the willingness to accept production cutbacks and to live with a hugh excess capacity has been impressive.

If OPEC were to follow the pattern set by the 19 earlier "efficient" organizations, then it would likely have a 4 to 6-year duration. The primary source of breakdown of price controls would likely be the significant additions of supply from either the "fringe" of OPEC members, or the non-member countries (in this case, the North Sea countries, Canada, and the United States) which by self-supply reduce the demands placed on the low cost Persian Gulf states.

CHAPTER 4

CARTEL THEORY AND ITS RELEVANCE TO THE INTERNATIONAL PETROLEUM MARKET

4.1 Oligopoly Theory

A cartel is a lable assigned to a group of suppliers that has entered into an explicit agreement to limit competition for mutual benefit. The circumstance under which this is feasible is when the number of suppliers of a particular good or service is "small," and each supplier is aware that his profits depend on the behavior of each other supplier in the industry. That is, when the market structure is oligopolistic. A cartel is an attempt to find a cooperative equilibrium in an oligopolistic market, and is thus a special case in oligopoly theory.

Oligopoly theory is intended to help us understand the behavior of markets that are structurallywise located somewhere in between perfectly competitive markets and markets dominated by a single monopoly. The distance between these two extremes is huge, and there is consequently room for a number of theories to explain the infinite number of points between the two polar cases. The lack of success of the simple theories on the relationship between market structure and behavior, theories desinged to explain the whole continuum of possible market structures and behaviors, has given rise to a bewildering number of theories based on a priori behavioral assumptions built into formal models or on case-study information. The closer the market structure assumed or observed

is to one of the two polar cases the stronger and more plausible seem the conclusions. Conclusions with respect to the dark area in between the polar cases are more a common sense extension of the implication of the polar cases, rather than the outcome of a generally accepted, adequate theory of oligopoly. Excellent reviews of the state of the art of oligopoly theory are provided elsewhere [10,17].

Oligopolistic markets have provided a rich source of hypothesis to be explored in formal models by the mathematically inclined, or to be evaluated in case studies by patient empirically oriented researchers. The classis models of Cournot, Bertrand, Edgeworth, and von Stackelberg in which the reaction of each oligopolist to the action of each other oligopolist is specified, constitute the core of the formal models exploring the behavioral interdependencies between profit-maximizing firms. Bishop's [4] more recent work on the nature of oligopolistic warfare also explores the behavioral interdependencies between oligopolists. By disregarding the behavioral complexities within the existing oligopolistic market, the "limit-price" modelers simplify the world into "existing firms" and "potential entrants." Such a simplification makes it possible to focus on the interaction between the ways in which potential entrants perceive the response to entry by existing firms and the behavior of the existing firms. Harrod, Edwards, Bain, Sylos-Labini, Modigliani, and Bhagwati have among others developed this formal modelling approach. Work in this tradition by Gaskins, Kamien and Schwartz,

and Baron also includes an explicit treatment of uncertainty and of the dynamics of the entry process. The above mentioned "limit-price-model" simplification implies that this modelling approach should be regarded as belonging to the family of monopoly models, rather than being included in the portfolio of oligopolistic models.

The formal models have not, however, proven to be very useful to students of particular markets, and their existence seems to have had a negligible effect on applied research as exemplified by the research reviewed on the experience of international commodity cartels. The lack of applicability of formal models to the analysis of particular markets has given rise to more "story-telling" on oligopolistic markets than on any other subject in economic theory. Detailed studies of individual industries and firms, studies on how actual firms make actual decisions, have provided the basis for our insight into oligopolistic markets more than the formal models. The important characteristics of oligopoly behavior are not captured by the conventional models.

More recent efforts have been made to construct simulation models that incorporate elements of "story-telling" and of theoretical studies in one analytic framework [13, 16]. Such models may provide us with tools that possess some of the rigour of the formal modeling tradition without giving up the richness of the "story-telling" approach.

4.2 Cartel Behavior

The existence of OPEC as a formal organization to coordinate the oil policies of the member states, to stabilize the price of oil, and to assure a stable income to the producer countries makes it logical to focus on the kinds of explicit collusive agreements that are labeled cartel agreements.

The economic incentive to organize and operate a cartel is that each individual member of an industry can make larger profits by receiving an appropriate share of the industry-wide monopoly profits than by following any other market strategy. It is the benefits of being a member rather than the disadvantages of being a non-member that is the incentive to participate in a cartel.

Legal and political constraints may, however, make it impossible for a cartel to reach the monopoly solution, in which case a cartel will not necessarily be the profit-maximizing strategy for all suppliers in an industry.

The existence of a cartel agreement does not solve the problem of lack of a unique solution concept inherent in oligopolistic markets. The lack of a unique profit maximizing solution tends to make cartel agreements unstable. Contributing to the observed instability of cartels is the fact that in most countries collusive agreements constitute criminal conspiracy. In the international domain the sovereignty of the nation-state makes it impossible to legally enforce but also to

prosecute collusive agreements initiated by inter-government action. The cartel agreements of interest are consequently those that cannot be controlled by court-enforced sanctions. It is no trivial task to discourage individual cartel members from price cheating to capture additional sales and profits when threatening believable and punitive retaliation is the only means of enforcement.

The ease with which information about what rival firms are doing and what potential entrants might do is dependent on the number of firms in an industry, and the similarity of the firms, including similarity with respect to the perceptions of the present and to expectations about the future. The smaller are the costs associated with gathering information on the activities of rival firms, the smaller are the costs associated with enforcing a collusive agreement, and the greater will be the ability of a group of firms to behave as a single monopoly.

If the colluding group of firms is heterogenous, the demand for the industry's output is inelastic whereas the demand for any individual firm's output is highly elastic, and the marginal production costs are small compared to the cartel price, then there are considerable incentives for each individual member to engage in price cheating. The same set of characteristics provides also, however, strong incentives for a group of firms to form a collusive agreement. The logical implication of the different effects of the above-mentioned incentives on individual and on joint behavior should be a fluctuating market price. If the cartel is

reorganized every time cheating is detected, then the expectations of the individual firms would be to make "a fast buck" before being discovered, and then back to the old routine. Such a set of expectations would imply ever increasing fluctuations over time.

4.3 Cartel Management

The tasks of the managers of a cartel agreement are: (1) to design a pricing strategy that will maximize the profits of the membership, (2) to allocate production in the most efficient way, (3) to design a system for allocating joint profits in a "fair" way, and (4) to police the cartel agreement such that no one can chisel to his own benefit and to the detriment of some other cartel member.

For the purpose of this study we will primarily be concerned with the first three tasks. The fourth will be briefly considered to indicate the nature of this problem. The policing problem is a source of instability, and may as such be used as an argument in a "story" about cartel breakdown. The policing problem is, however, considered to be beyond the scope of the market characteristics that will be included in the model. The pricing problem and the possible systems for allocating production and profits will be explicitly included in the model.

A discussion of a cartel price as different from a monopoly price is reported in an article by MacAvoy and Orr (M & O) [14]. Because it is assumed in the model of this study that the "optimal" cartel price is the

"monopoly" price, a relatively detailed discussion of the M & O pricing-stragegy is included to demonstrate the "optimality" of the "monopoly" price as the cartel price.

It is my hypothesis that the reason for cartel breakdowns is the lack of appropriate systems for allocating production and profits. The center of attention when studying the stability of a cartel-dominated market should therefore be the division of profits. There are more profits to be shared by the members of an industry when the joint profit maximizing solution is chosen than in any other case. A separate section will therefore be devoted to a focus on possible ways to divide profits such that nobody will feel tempted to break the cartel policy for economic reasons. It is pointed out in the conclusion of the M & O article that "A determinate one-price joint profit maximum seems to be necessary to a 'general' analysis of the kind presented in this article." In the above-mentioned section an attempt at such a "general" analysis is made.

4.3.1 Policing

Stigler has stated [18]:

> "It is a well-established proposition that if any member of the agreement can secretely violate it, he will gain larger profits than by conforming to it. It is, moreover, surely one of the axioms of human behavior that all agreements whose violation would be profitable to the violator must be enforced ... Enforcement consists basically of detecting significant deviations from the agreed upon prices. Once detected, the deviations will tend to disappear because they are no longer secret and will be matched by fellow conspirators if they are not withdrawn ... The ease with which price-cutting is detected by rivals is decisive."

Stigler consequently formulated the policing of a collusive agreement as a problem in the theory of information. He defined perfect collusion to be "that no buyer changes sellers voluntarily. There is no competitive price-cutting if there are no shifts of buyers among sellers." On the basis of this definition and normal buyer behavior, Stigler has constructed a probabilistic model of the market share of the various cartel members. Significant deviations from expected market shares would then be an indication of price-cutting having taken place and such price-cutting would consequently be detected.

Stigler's approach to stabilizing a cartel is thus to closely supervise the market share of each participant to make it impossible to secretly violate the cartel agreement, thereby making cheating unprofitable and destroying the destabilizing expectations mentioned above.

4.3.2 Pricing

On the basis of a model of an industry assuming time lags in the flow of information, linearity of all relations, variable costs to be zero, and division of the market for a homogenous good equally among several sellers, M & O demonstrates that the optimal pricing strategy for the cartel in the presence of cheating is the following: "The cartel should set its price to yield maximum joint profit for the loyal members, given that a cheater is maximizing his own profits in the face of the cartel policy."

In the M & O analysis there are n+1 firms, and the market demand (in units per unit of time) is given by:

$$Q = (n+1)\alpha - (n+1)\beta P \quad \alpha,\beta>0 \tag{4.1}$$

when each firm charges the same price P. The demand for a cheater's output is given by

$$Q_1 = \alpha - \beta P + \gamma(P-P_1) \quad \gamma>\beta \tag{4.2}$$

and the loyal firms' demand is

$$Q_{-1} = n\alpha - n\beta P - \delta(P-P_1) \quad 0<\delta<\gamma \tag{4.3}$$

The resulting profit functions are respectively

$$\pi_c = P[n\alpha - n\beta P - \delta(P-P_1)]$$

and

$$\pi_1 = P_1[\alpha - \beta P + \gamma(P-P_1)]$$

and the reaction functions are given by the conditions

$$\frac{\partial \pi_c}{\partial P} = \frac{\partial \pi_1}{\partial P_1} = 0$$

which implies that

$$P_{10} = [\alpha + (\gamma - \beta)P]/2\gamma \tag{4.4a}$$

is the equation of the reaction of the cheater to the cartel price changes and

$$P_1 = [-n\alpha + 2(n\beta + \delta)P_0]/\delta \tag{4.4b}$$

is the reaction function of the cartel. M & O demonstrate that the intersection of the reaction functions results in two equilibrium prices that are positive, lower than the collusive price, and are stable according to the standard definition of stability.

The fact that we are discussing a homogeneous product implies that all suppliers of the product can charge no more than any other supplier if positive sales are to be obtained. This implies that the loyal firms and the cheater will have to end up charging an identical price. If the price they end up with is lower than the collusive price, everybody is worse off than in the initial market solution assuming that each firm again will supply the same share of the market, which seems likely given the symmetry of the firms. Any decision rule that results in a solution unfavorable to all firms is obviously not stabilizing. A return to the previously joint solution might take place or further competition might emerge. If the suppliers are differentiated by location then segmentation of markets is possible and the conclusion that all suppliers would charge the same price under joint profit maximization is due to the particular assumptions of M & O, namely that there are (n+1) identical firms in (n+1) identical markets. The market also has to be segmented for two groups of suppliers selling an identical product to charge different prices without nullifying the sales of either group. The general conclusion is, therefore, that the M & O interpretation of their cartel stabilizing strategy will not result in a stable cartel-dominated market.

The joint profit maximizing price, the "monopoly" price, is the "optimal" cartel price. The system for allocating production and profits should be designed to discourage cheating, as pointed out in the next section. A cartel should never fiddle with the price once the joint profit maximizing price-path has been reached.

4.3.3 Allocation of Production and Profits

The demand for an industry's output is

$$Q = Q(P) \tag{4.5}$$

The number of suppliers in this industry is fixed due to an absolute barrier to entry. The total cost, C, of producing the industry output depends on the level of output, Q, as well as the distribution of production, W, among the firms:

$$C = C(W,Q) \tag{4.6}$$

The joint profit-maximizing solution is that of a multi-plant monopolist, i.e., the price, quantity, and distribution of production resulting from equalizing marginal revenue with marginal cost in the plants being operated to produce the monopoly quantity. If an industry behaves like a multi-plant monopolist the level of profits generated will be large enough to compensate all the members sufficiently to make price cheating unattractive. If we stick to the rule that the loyal members of a cartel will choose the price and quantity that will maximize their profits as a price-taker, it is possible to design a system for division of profits that will

make the potential cheater's profits at least as large by sticking to the cartel policy as by behaving as a price-taker.

If we let π_i^* denote the profits of a cheater when behaving as a price-taker and the loyal firms reacted to the defection by maximizing profits, and π^* denotes the joint industry profits in the case of perfect collusion, the optimal system of division of profits, WP, is such that:

$$WP_i \ \pi^* \geq \pi_i^* \tag{4.7a}$$

or

$$WP_i \geq \frac{\pi_1^*}{\pi^*} \tag{4.7b}$$

This system of division of profits removes the economic incentive to chisel. It can easily be shown that the loyal firms of a cartel are always better off by compensating a potential cheater in this way than by letting him defect and then maximizing profits without him. If both the potential cheater and the loyal firms are better off under this profit sharing arrangement, everybody is better off. If we deonte the profits of the loyal firms in the presence of a cheater as π_{-i}^*, it is sufficient to demonstrate that the following inequality holds:

$$(1 - \frac{\pi_i^*}{\pi^*}) \ \pi^* \geq \pi_{-i}^* \tag{4.8a}$$

or

$$\pi^* - \pi_i^* \geq \pi_{-i}^* \tag{4.8b}$$

or

$$\pi^* \geq \pi_i^* + \pi_i^* \ . \tag{4.8c}$$

The inequality (4.8c) holds by definition of π^*. π^* was defined as the maximum profits that could be extracted from the industry. π^* is therefore at least as large as the total profits resulting from any other price/production combination. The implication is that the system of division of profits as defined above improves the lot of all cartel members from any other possible market strategy not involving stupidity on the part of some industry members. The economic incentive to breaking the collusive contract is therefore removed.

The general conclusion with respect to the use of price and quotas for stabilizing pruposes is that a cartel should focus on how to allocate monopoly profits to remove incentives to cheating and never fiddle with the joint profit maximizing price.

4.4 Conclusion

The focus of this study is on a particular market, the international petroleum market. The existing institutional environment of that market makes it plausible to focus on cooperative market solutions in general, and on possible cartel coalitions in particular. Given the state of the art of oligopoly models assuming cooperative market behavior, a simple monopoly model is the most plausible when describing the price behavior of a given colluding group. Conventional oligopoly models are not useful when dealing with the problem of which firms are likely to form a collusive agreement under which circumstances. A more detailed study, "story-telling," is needed to hypothesize which coalitions are likely to emerge under the different circumstances the industry may have to face. A

specific analysis of the membership of OPEC is needed to construct a plausible set of intracartel reaction functions. The way production and profits is allocated among the cartel membership is a good proxy for a measure of the desirability, and hence also of the feasibility of various cartel compositions.

The need to combine formal modelling aspects with informal "story-telling" makes a simulation model the most ambitious approach that can be made to the analysis of a particular market without sacrificing the empirical validity of the analysis.

CHAPTER 5

THE MODEL REPRESENTATION OF THE INTERNATIONAL PETROLEUM MARKET

The purpose of this study is to develop a framework for analysis of the likely degree of and the implications of non-competitive behavior to be observed in the international petroleum market. The focus of this study is therefore on the market strategies that may be pursued by the world's oil exporters on a joint or on an individual basis.

The shortcomings of formal models designed to analyze oligopolistic markets imply, as pointed out in Chapter 4, that the structure of a model designed to analyze a particular oligopolistic market should be flexible enough to combine features of formal modelling with informal "story-telling." As it is our intent to study the behavior of the market as it actually exists rather than calculating "efficient" or "optimal" patterns of market development, and because there are many time-dependent relations that are important to include, it was decided to develop a simulation model. A simulation model easily permits formulations of a number of exporter decision rules or exporter market strategies. The form of the relationships or of the equations of the model was chosen such that an explicit analytic expression for the market clearing price consistent with each combination of exporter strategies could be derived. No numerical or "optimizing" subroutines are therefore needed to solve for a market clearing price path. The structure of the model and the functional relationships are constructed to explore the implications of pricing behavior reflecting a monopolistic market structure, a competitive market

strategy, or any combinations of the two. The change in the set of decision rules being applied in each period makes the model evolutionary in the sence that the price behavior of the market may change from period to period.

There is a complex transportation network serving the international petroleum market. A number of different crude oil qualities and petroleum products are flowing in international trade. For the purpose of this study, however, it was decided that the costs in terms of increased model complexity would outweigh the benefits of gained insights by explicitly representing this transportation and products network. It was decided to treat oil as a homogenous product and to disregard the geographic location of exporters and importers. The international petroleum market is hence treated as a "bathtub," therefore the label the "bathtub" model.

5.1 The Importer Regions

The international petroleum market is presently the marginal source of energy in the world. The international price of petroleum determines the price that can be charged for all fuels, and hence also the quantity supplied of all other fuels. The demand facing the world's exporters is thus a residual demand. The "bathtub" model consists of such a residual demand framework.

In the model development we will deal with a group of net importers, denoted by the index i, and with a set of exporters, j. We define E_i^t as

total demand for energy in region i in year t, and let P be a vector of past and present energy prices. The relationship between the international price of petroleum and the total demand for energy in region i in year t can be then represented as

$$E_i^t = E_i\ (P,t). \tag{5.1}$$

The market share of oil, in region i in period t, M_i^t, is likewise a function of past and present prices in the international market,

$$M_i^t = M_i(P,t), \tag{5.2}$$

as is also the indigenous supply of oil in region i in year t, S_i^t, where

$$S_i^t = S_i(P,t). \tag{5.3}$$

The resulting demand for imports to region i in year t, D_i^t, is consequently

$$D_i^t = D_i(P,t) = E_i^t \cdot M_i^t - S_i^t \tag{5.4}$$

In the present version of the model the world is divided into four importing regions, i = 1, ··, 4. They are Western Europe, Japan, United States, and the rest of the world (not including USSR, Eastern Europe, and China which are included in the model as net exporters only).

The relationships defined in Equations 5.1 to 5.3 are complex. A simplification of these relationships is required to solve for the market clearing price and quantity even in the case of perfect competition. As we will focus on non-competitive market behavior, including monopoly behavior, in which case the first derivative of the residual demand

function together with the first derivative of the monopoly unit's total cost function will determine the market price, even more simplified versions of the relationships defined above are required. To be able to test a number of ways of structuring the behavioral characteristics of the various participants in the international petroleum market, approximations were made to the above relationships such that the system of equations representing the international market could be solved analytically rather than having to solve the system of equations by applying some more costly numerical method. A set of linear approximations to the regional oil/energy relationships was therefore constructed.

5.1.1 Price Expectations

An important characteristic of the oil/energy sector is the long lead times due to the capital intensity of the sector. That is, a number of periods is required to adjust the capital equipment of the oil/energy producing and consuming sectors to a significant change in price. The oil/energy producers and consumers will hence adjust their capital equipment to the market price they expect to prevail when the equipment will be on stream some time in the future. The sophistication of these investors may differ a great deal, and there is consequently room for a number of rules representing how expectations with respect to the future price level are formed. Given the state of the art of predicting the future and a strong desire to simplify as much as possible such expectations rules, the present price was chosen as a first approximation to the expected price. A more complex expression for the expected price is introduced in Sec.5.2.9.

If we define "the long-term" to be the number of periods required for a complete adjustment of the capital equipment of the oil/energy sector to a significant change in the price of oil/energy, then the postulated linear approximations and the assumption that the expected price is equal to the present price imply that the long-term relationships between the variables characterizing the oil energy sector and the past, current, and expected oil/energy price will be of a simple linear form with current price representing the price vector. The long-term total demand for energy in region i in year t, $\bar{E}_i^t$, (where the "bar" above a variable indicates its long-term value), is consequently:

$$\bar{E}_i^t = e\,1_i^t - e\,2_i p^t \qquad (5.5)$$

Equation (5.5) hence represents the quantity of energy that would have been consumed in a given year and at a given price if energy consuming equipment could have been adjusted instantaneously to any price level.

The price-slope coefficient, $e2_i$, was simply estimated by calculating the post-adjustment energy consumption level for two different price levels under identical assumptions about income and other effects, and then dividing the absolute difference between the consumption levels by the absolute difference between the two price levels thereby constructing a linear energy demand junction. The time-dependent intercept coefficient, $e1_i^t$, was estimated by calculating an initial intercept in a year in which the actual and the long-term market solution was assumed to

coincide (the actual and the long-term solution was assumed to coincide in 1973 at $3), and then extrapolating this initial intercept at a rate such that the level of long-term energy consumption would have increased at the rate of growth of the economy for a given price level. That is, an income elasticity of one is assumed when calculating the location of the long-term energy demand function in each period.

To get from the simplified long-term relationships to the short-term relationships, the short-term being one year, a process by which the market would move from one long-term equilibrium to another was assumed. This process was assumed to be completely described by the length and form of a distributed lags function. There is a number of distributed lags functions that are frequently used by economists. The reasoning behind the ten year moving average applied here is very simple. The cost of oil/energy has traditionally constituted only a fraction of total production costs. Even a significant increase in the cost of oil/energy will consequently not make existing plants and equipment instantaneously obsolete; a gradual process of replacement of depreciated assets with "energy-tuned" equipment is more likely to be observed. If we assume that a ten-year straight line depreciation rule is a plausible approximation to the average industry-wide way of depreciating and replacing assets, then a ten-year moving average is a plausible approximation to the process by which the economy will adjust itself to a significant change in the price of oil/energy.

In the non-oil energy sector and the oil-sector there is a number of short-, intermediate-, and long-term measures that will be made in response to a significant increase in the price of oil/energy. Secondary and tertiary recovery methods are applied to increase production from existing oil fields in the short term. Opening up of new coal mines and production from new oil fields following increased development drilling are expected in the intermediate term. Nuclear plants and new oil fields will come on stream in the longer term. We may therefore assume that the response process of the energy producing sector is similar in kind to the process of adjusting energy consuming equipment. The apparent similarities of the adjustment processes made another simplifying assumption plausible, namely that the same distributed lags function is a plausible approximation to the adjustment process of all the oil/energy related sectors. With the possible exception of Japan, all the regional units are sufficiently aggregated and the number of energy-related options in each region is sufficiently similar, even if the weights given to the various options may differ, that the same distributed lags function also apply to all the consumer regions. That is, the adjustment process of all sectors in all the regions is assumed to be identical.

5.1.2 Linear Market Relationships

By imposing an adjustment process linking the long-term to the short-term on the long-term demand for energy function, Equation (5.5), the following linear approximation to the relationship between past and present prices and the demand for energy in region i in year t emerges:

$$E_i^t = el_i^t - e2_i \sum_{k=t-K}^{t} \lambda^k p^k$$

$$\sum_{k=t-K}^{t} \lambda^k = 1. \qquad (5.6a)$$

K is the length of the adjustment process and the λ's are the annual weights of the adjustment process. The intercept of this linear relationship is assumed to grow such that energy consumption for a given price will grow at the rate of growth of the economy in region i, G_i^t.

$$E_2^t = el_i^{t-1} + E_i^{t-1} \times G_i^t - e2_i \sum_{k=t-K}^{t} \lambda^k p^k \qquad (5.6)$$

The same procedure was also used to construct short-term market share- and indigenous supplies- relationships, even if the intercepts of the latter two relationships were estimated differently from that of the total demand for energy. In the case of the market share relationship the fraction of oil in total demand for energy was also simply linearized. According to the studies made by OECD and FEA [2,8], the market share of oil is relatively insensitive to the price of oil within a fairly wide price range. The intercept of the linear market share relationship consequently dominates this relationship. A linear approximation to the relationship between past and present prices and the market share of oil does not have some of the properties we would expect from a market share

relationship. That is, if the price of oil fell to zero in a linear market share equation the market share of oil would not automatically converge towards one, and if the price of oil increased to infinity then the market share of oil would not converge towards zero. Given the insensitivity of the market share of oil to the price of oil within the price range we consider of most relevance from an empirical point of view ($4 to $15 in 1975 dollars), as indicated by the studies of OECD and FEA, the linear market share approximation seems to be a relatively costless simplification. The time-horizon of this study is 1990. In the longer-term we would expect the market share of oil to be more price sensitive and for a study of the longer-term implications of a change in the price of oil a linear approximation to the market share relationship would be inappropriate.

When an initial market share intercept, mO_i had been calculated according to the procedure outlined above in the text to Equation (5.5), then an exogenous growth rate, GM_i, was calculated by solving for the annual rate of change of the market share of oil in the 1972 to 1985 period consistent with OECD's $3 constant price of oil scenario. GM_i represents the expected trend in the market share of oil at continued low energy prices. This assumed growth rate thus tends to bias upwards the market share of oil for prices above $3. The long-term price effect was estimated as was $e2_i$ in Equation (5.5) and is incorporated in the slope $M2_i$. The linear approximation to the market share of oil in region i in year t is consequently:

$$M_i^t = mO_i(1+GM_i)^t - m2_i \sum_{k=t-K}^{t} \lambda^k p^k \qquad (5.7)$$

5.1.3 Indigenous Supplies

When a promising geological basin is discovered or when the price of oil suddenly increases we would expect the oil industry to go through three stages, the first being an intense exploration and development effort to get production facilities on stream. Once the production facilities are on stream, we would expect a higher level of production to be sustained for some years before the newly developed fields are being gradually depleted. If the higher price level results in a high rate of discoveries, aggregate production does not necessarily have to fall. In the linear approximation to the indigenous supply function, it was assumed that the price would affect the future level of plateau production in the various regions. It was further assumed that development and gradual starting up of new production facilities, the length of the plateau production period, as well as the rate of decline of production following the period of peak production could be represented by extrapolating the intercept at different exogenous rates over the three typical production stages. The initial equilibrium intercept, sO_i, is hence being extrapolated at a price-independent rate of change, d_i^t, dependent only on the stage in the production process at which the region is producing. The linear approximation to the short-term relationship between past and present prices and indigenous supplies in region i in year t is:

$$S_i^t = s0_i(1-d_i^t)^t + s2_i \sum_{k=t-K}^{t} \lambda^k p^k \qquad (5.8)$$

By summarizing the regional demand for imports, the residual demand facing the exporter in year t, D^t emerges as:

$$D^t = d_1^t + \sum_{k=t-K}^{t} [-\lambda^k x d_2^k x p^k + \lambda^k \times d_3 \times (p^k)^2] \qquad (5.9)$$

where

$$d_i^t = \sum_i [(e1_i^{t-1} + E_i^{t-1} x G_i^t)(m0_i(1+GM_i)^t) - s0_i(1-d_i^t)^t]$$

$$d_2^t = \sum_i [e2_i \times m0_i(1+GM_i)^t + (e1_i^{t-1} + E_i^{t-1} \times G^t) \times m2_i + \lambda 2_i]$$

$$d_J = \sum_i (e2_i \times m2_i)$$

The international market clearing price can then be determined from the accounting identity of Equation (5.10) below, stating that the price has to clear the market in the sense that at that price the level of exports in period t, S^t, is equal to the level of imports in the same period:

$$D^t = S^t \qquad (5.10)$$

As the focus of this study is on the behavioral options open to the world's exporters rather than the policies of the importer governments,

Equation (5.10) is given in its "pure" form. That is, no policy instruments are explicitly included in the equation representing the worldwide demand for imports. To incorporate and to assess the traditional importer country policy options like tariffs, quotas, consumer taxes, and producer subsidies, only minor modifications of the representation of the consumer regions are required.

5.2 The Exporters

The behavioral options open to the world's oil exporters are in the following represented by a set of pricing or production strategies that the exporters may choose to, or have to, follow on an individual or a joint basis. An explicit analytic expression for the market clearing price or quantity consistent with the various exporter strategies is deducted.

Two versions of the "bathtub" model have been constructed. To asses the significance of or the market implications of the behavior of some stable collusive combinations of exporter countries, a simple version of the "bathtub" model was constructed. In this simple version of the model one exporter unit only is explicitly represented. The composition of the exporting group may be changed, however, by transferring countries from the exporter unit to the unit representing the rest of the world's indigenous suppliers, or vice versa. Indigenous suppliers are assumed to behave

as price-takers. It is thereby possible to combine price-taker behavior on the part of some exporters with any of the below-mentioned strategies to be played by the other exporters even in this simple model version.

The heterogeneity of the exporting countries and the theoretical as well as empirical instability of oligopolistic markets imply that it is unlikely that all the exporters will follow the same strategy. A more complex version of the "bathtub" model, the cartel version, was therefore constructed to trace the evolution of the international petroleum market resulting from the changing behavior of the major exporter units. By allowing four exporter units to change decision rules in any given period, the cartel version of the "bathtub" model covers a very wide range of possible market solutions. A number of experiments could be performed, however, by using the simple model version. The simple model should therefore be considered a cost-saving version of the cartel model.

5.2.1 Static Perfect Competition

"Static Perfect Competition" means that the exporter unit behaves as a mypoic price-taker. That is, the exporter unit produces the quantity that equalizes marginal cost and the current price. The marginal cost function is the inverse of the competitive supply function. A linear approximation to the relationship between the competitive supply level from exporter j in period t, S_j^t, and past and present prices was constructed in the same way as the linear approximations to the supply functions indigenous to the regional consumer units.

$$S_j^t = s0_i(1-d_j^t)^t + s2_j \sum_{l=t-L}^{t} (\delta^l p^l) \qquad (5.11)$$

where $\sum_{l=t-L}^{t} \delta^l = 1$

To be able to write the expression for the market clearing price in a more compact form, we may simplify the expressions for residual demand and exporter supplies by incorporating all terms that do not involve the current price in a constant term. The constant term of the residual demand function in period t, DL^t, is consequently:

$$DL^t = d_1^t + \sum_{k=t-K}^{t-1} (-\lambda^k d_2^k p^k + \lambda^k d_3 (p^k)^2).$$

Equation (5.9) can then be written as:

$$D^t = D_L^t - \lambda^t d_2^t p^t + \lambda^t d_3 (p^t)^2 \qquad (5.9a)$$

By defining unsubscribed supply coefficients to represent aggregate exporter supplies, and by introducing an analogous constant term, SL^t,

$$SL^t = s0(1-d^t)^t + s2 \sum_{l=t-L}^{t-1} \delta^l p^l,$$

Equation (5.11) can be written in a compact form representing aggregate competitive exporter supplies

$$S^t = SL^t + \delta^t s2 p^t \qquad (5.11a)$$

By setting equation (5.9) equal to (5.11a) and solving the system with respect to p^t, the market equilibrating price in the case of static perfect competition, p_1^t, is found to be:

$$p_1^t = \frac{\lambda^t d_2^t + \delta^t s_2}{2\lambda^t d_3} - \sqrt{\left(\frac{\lambda^t d_2^t + \delta^t s_2}{2\lambda^t d_3}\right)^2 - \frac{DL^t - SL^t}{\lambda^t d_3}} \qquad (5.12)$$

5.2.2 Static Monopoly

The static monopoly strategy is to charge the price that will equalize the marginal revenue of the long-term residual demand function, $\overline{MR}^t$, with long-term marginal production costs, $\overline{MC}^t$. That is, the static monopolist disregards the form of the adjustment process of the consumer markets and also user cost. The monopolist does, however, exploit the inertia of the consumer markets by extrapolating the intercept of the residual demand function at the anticipated rate of growth of the economy K periods hence, where K is the number of periods needed for adjustment of the consumer markets, and then choosing the current price to be the price that equalizes marginal revenue and marginal cost in this enlarged future market. This pricing rule is labeled "static monopoly" because it is similar to the pricing rule a monopolist would follow in a market that adjusts instantaneously to a change in price and where there are no complications resulting from resource limitations. The "static monopoly" pricing rule defined here as well as the other decision rules specified in the following are not deducted from maximization on the part of the

exporter. The decision rules are plausible approximating rules given our knowledge of the objectives and of the likely behavior of the exporters. Actual revenue optimization would probably imply more exploitation of the inelasticity of the short-term demand function. That is, a higher price in the period following the monopolization of the market and then a decreasing price converging towards some long-term rising monopoly price-path would probably generate higher revenues than the monopoly-rules of this study. It is considered more likely, however, that the producer countries, in the case of continued collusion, will follow some pricing rule that will result in a smoothly rising price, rather than follow a pricing rule that will deliberately produce price fluctuations to maximize short-term gains or to discourage potential entrants into the oil/energy market.

The construction of a set of plausible decision rules on the basis of some knowledge of the objectives of the market participants rather than deduce the decision rules on the basis of a theory of profit-maximizing behavior is the major distinction between the "behavioral" approach made in this study and the traditional studies of the behavior of market participants. The inexistence of a theory of profit maximizing behavior in oligopolistic markets, and the number of plausible decision rules that might be observed in such markets make a "behavioral" rather than a rigorously formal approach more useful.

The quadratic residual demand function of Equation (5.9) and the monopoly's marginal cost function of the form of the inverse of Equation

(5.11) imply that an equation of third degree would have to be solved to find the price at which marginal revenue is equal to marginal cost. To avoid this problem, Equation (5.9) was linearized in the following way. (The "bar" signifies that it is the long-term version of Equation (5.9) that is being considered. That is, no lags are included).

$$\begin{aligned} \bar{D}^t &= d_1^y - d_2^t p^t + d_3 (p^t)^2 = d_1^t - (d_2^t - d_3 p^t) p^t \\ &\simeq d_1^t - (d_2^t - d_3 p^{t-1}) p^t = d_1^t - d_4^t p^t \\ \bar{D}_L^t &= d_1^t - d_4^t p^t \end{aligned} \tag{5.13}$$

As d_3 is small and as p^{t-1} is close to p^t on the "static monopoly" price-path or any other "smooth" path, the approximation is fairly accurate. The empirical estimation of d_3 shows as reported in Chapter 6 that d_3 is less than .04. The linear residual demand function, $\bar{D}_L^t$, is to be extrapolated K periods according to the "static monopoly" pricing rule. The resulting marginal revenue of the long-term extrapolated residual demand function is consequently:

$$\overline{MR}^t = d_1^{t+K} - 2 d_4^t p^t \ . \tag{5.14}$$

The long-term version of the competitive supply cure is of the form:

$$S^t = s1^t + s2 p^t \ . \tag{5.15a}$$

By taking the inverse of this relationship and keeping in mind that quantity is formulated as a function of price rather than price as a

function of quantity, the following expression for long-term marginal production costs can be deducted:

$$\overline{MC}^t = \frac{s_1^{t+K} x d_4^t}{s_2} - \frac{d_1^{t+K} x d_4^t}{s_2} + \frac{(d_4^t)^2}{s_2} \; p^t \qquad (5.15)$$

By solving for the price that equalizes equations (5.14) and (5.15), the "static monopoly" price is found to be:

$$p_2^t = \frac{d_1^{t+K} - \frac{s_1^{t+K} x d_4^t}{s_2} + \frac{d_1^{t+k} \; x \; d_4^t}{s_2}}{2d_4^t + \frac{(d_4^t)^2}{s_2}} \qquad (5.16)$$

5.2.3 Income Stabilization

Income stabilization simply means that the exporters will supply a quantity, S_3^t, such that the resulting income is equal to some target revenue level, I^t.

$$S_3^t = \frac{I^t}{p^t} \qquad (5.17)$$

By combining equations (5.9) and (5.13), the short-term linearized residual demand function may be written as

$$D_L^t = DL^t - \lambda^t d_4^t p^t. \qquad (5.9b)$$

The market price resulting from equalizing equations (5.12) and (5.9b) is consequently

$$p_3^t = \frac{DL^t}{2\lambda^t d_4^t} - \sqrt{\left(\frac{DL^t}{2\lambda^t d_4^t}\right)^2 - \frac{I^t}{\lambda^t d_4^t}} \qquad (5.18)$$

5.3.4 Production Stabilization

The exporters may decide to produce some fixed quantity in a given period or decide on a fixed production path over time, D^{*t}. Supply S_4^t is then:

$$S_4^t = D^{*t} \qquad (5.19)$$

With a fixed supply path the quadratic demand function of Equation (5.9) can be used without causing analytical problems when determining the market price. The resulting market equilibrium price is

$$p_4^t = \frac{d_2^t}{2d_3} - \sqrt{\left(\frac{d_2^t}{2d_3}\right)^2 - \frac{DL^t - D^{*t}}{\lambda^t d_3}} \qquad (5.20)$$

5.2.5 Target Pricing

When the group of exporters decide on a common pricing strategy over time, this strategy is labeled "target pricing." The target price path, TP^t, may be any price path on which consensus has been reached. The production strategy that goes along with target pricing is to produce whatever the market will take at the target price without worrying about how actual production is allocated among the exporters.

When the price is exogenously determined to be TP^t, then the market equilibrating quantity is:

$$S_5^t = DL^t - \lambda^t d_2^t TP^t + \lambda^t d_3 (TP^t)^2 \qquad (5.21)$$

Neither the desired income-path of the income stabilizing strategy, the desired production-path of the production stabilizing strategy, nor the desired price-path of the target pricing strategy are determined inside the model. They are not a result of any analysis within the model.

5.2.6 Exhaustible-Resource Competition

The exporters may try to aniticpate all future prices for their non-renewable resource by estimating the price they will obtain for the last unit of the resource, and then determine their present production such that the price today is the net present value equivalent of the ultimate price [6.7]. The ultimate price is defined to be the price of the "backstop technology," PB, which is the cost of producing a substitute product resting on a very abundant resource base. If we define r as the discount factor, then the net present value equivalent of the backstop technology price is uniquely determined if we can determine the number of periods until exhaustion takes place. That a resource base has been exhausted at a given price means that the marginal cost of extracting an additional unit from the resource base is higher than the given price. The resource base is therefore a function of the backstop technology price.

Determining the number of periods until exhaustion, N, implies solving analytically the following equation with respect to T, the exhaustion date:

$$R = \sum_{t}^{T} D^t dt \qquad (5.22)$$

where R is the level of recoverable reserves consistent with a backstop technology price of PB and D^t is the quantity consumed at any point in time, given the fact that the price charged is the net present value equivalent of the backstop-technology price. The simplest and most naive way of determing N would be to divide R by D°, the initial level of consumption. This procedure implicitly assumes a perfectly inelastic demand for the resource, and a zero income elasticity. The elasticity assumptions of this study are different from zero. An attempt was therefore made to construct an expression for N that would reflect non-zero elasticity assumptions. The problems we have to face to arrive at an analytic expression for N when demand grows with time and is also price responsive can be illustrated by formulating the problem using the continuous version of the simplified long-term linear demand function of Equation (5.13) as a short-term demand function. That is, instantaneous adjustment of the market is assumed. Demand, D^t, is then a linear function of price in the following way:

$$D^t = \alpha_1 e^{\beta t} - \alpha_2 p_1^t \qquad (5.23)$$

where α_1 and α_2 are appropriately adjusted versions of d_1 and d_4 in Equation (5.13), and β is an assumed rate of market growth. p^t is defined to be

$$p^t = PB\ e^{-r(T-t)}, \quad \text{and}$$

$$N = T-t.$$

Equation (5.22) then becomes:

$$R = \int_{t}^{T} \alpha_1 e^{\beta t} - \alpha_2 p \beta e^{-r(T-t)} dt \qquad (5.24)$$

Equation (5.24) can be solved numerically, but it does not seem to be possible to deduct an explicit analytic expression for N or T-t even in this over-simplified case.

As stated earlier, the simulation framework being constructed here is based on explicit analytic expressions for all endogenous variables. Approximating "behavioral" decision rules have been constructed to keep the model framework simple. More complex sub-routines to optimize or to solve numerically some segment of the model have been replaced by these "behavioral" decision rules. The same procedure has been followed to get around the Equation (5.24) problem. By assuming that all the "exhaustible-resource competitors" expect the same rate of growth of the economy, agree on the income elasticity of demand as well as on the price-elasticity of demand, and also expect the market price to grow at the rate of interest as the price is expected to follow the path of the net present value equivalent of the back-stop technology price, then all competitors will expect the market to grow at the same rate if it is also assumed that the market price initially was equal to the net present value equivalent of the back-stop technology. The expected rate of growth of the market, EG, is simply a function of the elasticity of income, I, the expected rate of growth of the economy, G_E, the price elasticity, E, and the rate of interest, r, as price

will increase at the rate of interest on the expected price path,

$$EG = I \times G_E + E \times r. \tag{5.25}$$

The assumption that the expectations of all competitors with regard to the four variables on the right hand side of Equation (5.25) are identical, will produce an expected growth rate as can be illustrated in a simple example. If the competitive suppliers expect the economy to grow at a rate of 5% per year, assume an income elasticity of one, a rate of interest of 10%, and a price-elasticity of -0.1, then they would expect that quantity consumed in each period to increase by 4%.

The expected growth rate of the quantity consumed, EG, can be used to solve for the number of periods until exhaustion. N was determined from the following set of equations:

$$R = \sum_{i=t}^{N} D^0(1+EG)^t \tag{5.26a}$$

$$R = D^0\left[\frac{(1+EG)^N-1}{EG}\right] \tag{5.26b}$$

$$N = \frac{LOG\left[\frac{EG \times R}{D^0}+1\right]}{LOG(1+EG)} \tag{5.26c}$$

The resulting market price is:

$$p_6^t = \frac{PB}{(1+r)^{Nt}} \tag{5.27}$$

How good N^t is an approximation to the number of periods until exhaustion depends on the level of reserves compared to present production, the price-path prior to the p_6^t - path, and how fast the market will adjust to a new price path.

5.2.7 Exhaustible-Resource Monopoly

Under static monopoly the optimal price and production is determined by equalizing marginal revenue and current marginal production costs. Under exhaustible-resource monopoly the net present value equivalent of the ultimate price is substituted for current marginal production costs. That is, the monopoly price and production are determined by equalizing marginal revenue and the net present value equivalent of the backstop technology price, which is a plausible approximation to the Hotelling-condition in the monopoly case, namely that the difference between marginal revenue and marginal cost shall grow at the rate of interest [6], when marginal production costs are "close" to zero.

The number of periods until exhaustion was again estimated assuming an expected rate of market growth determined by the net effect of the growth of the economy and the increase in price resulting from the increased size of the market and by the fact that the shadow price of the resource which is substituted for current marginal production costs is assumed to grow at the rate of interest. It is further assumed that the elasticity of demand in the monopoly case is equal to minus one. In the simple static monopoly case with zero marginal costs then the monopoly price is determined such that the elasticy of demand at the monopoly price is minus one. This does

not hold in the case of positive marginal costs or on the Hotelling monopoly path. But it is a fair approximation to the elasticity of demand also in the latter two cases as long as marginal costs are small or the number of periods until exhaustion is large. If marginal costs are small or the number of periods until exhaustion is large then the monopolist's cost conditions are close to the zero cost case from which the minus one elasticity assumption is deducted.

From these assumptions the monopolist's expected growth of consumption, MG, can be estimated in the case of "exhaustible-resource monopoly pricing" by determining the net change in quantity consumed in each period, resulting from the income effect and the price effect on the monopoly price path. Equation (5.26c) then becomes

$$N = \frac{LOG[\frac{MG \times R}{D^0} + 1]}{LOG(1+MG)} \qquad (5.28)$$

The monopoly price resulting from the equalization of marginal revenue and the monopoly net present value equivalent of the ultimate price is:

$$p_7^t = \frac{d_1^t + [PB/(1+r)^{Nt}] \times d_4^t}{2 \times d_4^t} \qquad (5.29)$$

In the present versions of the model the monopoly price is chosen to be the higher price of the static monopoly price and the exhaustible-resource monopoly price. The exhaustible-resource monopoly price would be higher than the static monopoly price if the net present value of the back-stop technology price, the present opportunity cost of the resource, is higher

than marginal production costs. The price reflecting the higher opportunity cost is thus chosen as the monopoly price. The upper limit of the monopoly price is the price of the backstop technology.

5.2.8 Cartel Pricing

The world's exporters are not a very homogenous group. A model intended to identify and analyze the implications of various oil exporter strategies should therefore be able to incorporate and deal with this heterogeneity. The cartel version of the "bathtub" model allows individual exporters and exporter sub-groups to follow different strategies. The oligopolistic structure of the international petroleum market necessitates an explicit representation of the various strategies that might be designed to allocate production and income among the major oil exporters.

The lack of a unique solution concept for oligopolistic markets necessitates more assumptions than in either the competitive case or in the monopoly case to solve for an equilibrating price. There is no uniquely rational behavior that can be specified for an individual oligopolist, since the most profitable behavior for one seller depends on the response of the others. The fact that oligopolists fully recognize their mutual dependence is not sufficient for a unique solution. A unique solution or an equilibrating price implies that expected and actual outcomes are identical. Expectations play a crucial role in oligopolistic markets. To simulate the behavior of price in an oligopolistic market it is therefore necessary to specify the expected and actual reaction of all other oligopolists to one oligopolist's behavior. With three or more oligopolists

the possible relevance of coalitions among some subgroups constitutes a major complication. The number of possible coalitions increases rapidly with the number of individual oligopolists. To narrow down the range of possible market solutions the OPEC-cartel is collapsed into three individaul units and two aggregate units. The individual units are unit one, U_1, consisting of Iraq, Nigeria, Indonesia, and Gabon; unit two, U_2, consisting of Iran, Algiers, Venezuela, and Ecuador; and unit three, U_3, consisting of Saudi Arabia, Kuwait, UAE, and Libya. The reasoning behind the selection of these units is indicated in Section 6.4. The two aggregate units are unit four, U_4, consisting of U_1, U_2, and U_3; and unit five, U_5, consisting of U_2 and U_3. All other exporters are included in a separate unit, the competitive exporter fringe.

The demand for cartel output in period t, RD^t, is the difference between the worldwide demand for imports in period t, D^t, and what the exporter fringe can or wants to supply in period t, SE^t.

$$RD^t = D^t - SE^t \tag{5.30}$$

The exporter fringe may also follow non-pricetaker strategies like income or production stabilization, but it is assumed that the fringe will not participate in any explicitly colluding agreements. The composition of the above-mentioned units may, of course, be altered. For the sake of simplicity in the presentation, and to avoid pretending that the possible market solutions defined below are not dependent on the composition of the units, the compositions of the units will not be changed in the following.

All the above-mentioned characteristics of the exporter group as a whole apply to each exporter subunit, and hence also to the exporters that may form a collusive agreement to extract a monopoly rent. There are, however, additional characteristics of each cartel member that may or may not influence the location and the stability of a cartel determined market solution. The production capacity of unit j in period t, C_j^t, which is a function of past and expected prices, P, development and production costs, MC_j, time, t, and any cartel policy on prorationing of capacity, cc,

$$C_j^t = C_j\ (P, MC_j,\ t,\ cc) \tag{5.31}$$

is likely to influence the behavior of cartel unit j.

The production allocated to unit j in period t, Q_j^t, which is a function of the total demand for cartel output in period t, RD^t, and the cartel-determined quota-system in period t, W^t,

$$Q_j^t = Q_j\ (RD^t,\ W^t) \tag{5.32}$$

as well as the associated production profits, and the income requirements of unit j, are major determinants of the desirability of the cartel solution or of the strength of the disintegrating forces working on the cartel. The income requirements of unit j, IR_j^t, are simply assumed to be a function of time, t.

$$IR_j^t = IR_j\ (t) \tag{5.33}$$

5.2.8.1 Quotas

Production and profits may be allocated in a number of ways. The quota-systems described below have been chosen on the basis of what might be acceptable to the OPEC-membership and on the basis of what economic theory says about the way production and profits should be allocated among a colluding group.

The simplest possible way of allocating production and profits is to decide on an historic base year, and then fix the future market shares at the base year level. If we denote the base year 0, then an historic quota system, WH, implies that cartel member j will be allocated the following market share:

$$WH_j = \frac{Q_j^0}{RD^0} \tag{5.34}$$

Production profits are retained by the individual members. That is, no side-payments are being made.

The fact that some OPEC countries have a high need for income may make plausible a quota-system based on the income requirements of the membership. That is, the market share allocated to producer j in period t when based on income requirements, WF_j^t, is proportional to his relative share of total cartel income requirements in period t, IR_c^t.

$$WF_j^t = \frac{IR_j^t}{IR_c^t} \tag{5.35}$$

If the cartel could allocate production as a multi-plant monopolist, then production should be allocated such that the marginal cost of producing each cartel member's last unit, MC_j^t, was equalized, and equal to the marginal revenue of the cartel as a whole, MR_c^t. WE_j^t is determined such that

$$MC_j^t = MR_c^t \quad = 1,2,3. \tag{5.36}$$

In this multi-plant scenario profits are allocated according to the economic power of each unit as defined in Section 4.2.2 and in Equation (5.37) below. If we denote the total profits of the colluding group in period t by π_c^t, and the total profits of unit j as an outside price taker assuming the remaining cartel members maximize joint profits by π_j^t, then a system of allocation of total cartel profits consistent with the economic power of each member, WP^t, would imply that unit j would receive the following share of total profits:

$$WP_j^t = \frac{\pi_j^t}{\pi_c^t} \tag{5.37}$$

As defined in equation (5.37), the "economic power" quotas will not necessarily add to one. These quotas do not apply to all cartel members. They are assumed to be administered by the dominant producer(s) as a way of bribing non-dominant producers to adhere to the cartel policies. The dominant producer(s) will thus keep the residual monopoly rent left over after compensations have been paid. The "economic power" quotas may also be used as a proxy for a "fair" allocation of production when side-payments

are not feasible.

The dominant producer may also choose to invest in the cartel countries in which the gap between the income requirements of the country and the income from oil exports is the widest. As the foreign investment program of the dominating producer is designed to increase cartel stability, a foreign investment quota-system, WI, based on the difference between the income requirements based quotas and the "economic power" based quotas has been designed.

$$WI_j^t = WF_j^t - WP_j^t \qquad (5.38)$$

Under such an internal transfer of funds system, each producer country will receive investable funds in proportion to its income requirements. Neither the "economic power" quotas nor the investments quotas apply to all cartel members, and neither will the consequences add to one. Both quota systems are designed to increase the attractiveness of cartel membership to the producers that might behave differently.

5.2.8.2 Price-Strategies

Each cartel unit has a separate "monopoly" price, p_j^t, to propose as the "optimal" cartel price, p_c^t. The various "monopoly" prices are calculated as was the "monopoly" price described above. Each "monopoly" price is consequently a function of the backstop technology price, PB, the residual demand function facing the cartel, RD, the expected production quota, W_j, the expected growth rate of production, MG_j, the level of reserves, R_j, the

cost conditions, MC_j, the discount factor relevant to unit j, D_j, and time, t.

$$p_j^t = p_j\ (PB,RD,W_j,MG_j,R_j,MC_j,D_j,t) \tag{5.39}$$

The cartel price, p_c^t, is a function of the various units' "monopoly" price.

$$p_c^t = p_c\ (p_1^t,\ldots,p_5^t) \tag{5.40}$$

The number of possible cartel prices increases rapidly with the number of alternative quota-systems and the number of cartel units. Even this simplified representation of four possible quota-systems and of five cartel units implies that fourteen different cartel prices might theoretically emerge.

5.2.9 Uncertainty in Oligopolistic Markets

The lack of a unique solution concept in oligopolistic markets and the resulting theoretical as well as empirical instability of such markets make it naive to expect the present price to be the price that will prevail in the future. It is consequently more realistic to assume that the existing and potential participants in an oligopolistic market will adjust their capital-intensive production and/or consumption equipment to some weighted average of the prices that would emerge under the most likely market strategies to be observed. Define this weighted average of the most likely future prices to be the expected value of the distribution of future prices E(P). If we further define the most likely future prices to be P_n,n=1,..., N and still let the actual price be P, then the expected value of the

future price distribution in period t can be defined as in the following equation:

$$E^t(P) = \sum_{n=1}^{N} \alpha_n P_n^t + \beta p^t \qquad (5.41)$$

$$\sum_{n=1}^{N} \alpha_n + \beta = 1$$

Depending on the weights, α_n, $E^t(P)$ can be higher, smaller, or equal to the present price.

It was assumed above that the monopoly strategy was to equalize the marginal revenue of the long-term residual demand function with long-term marginal production costs. The price-term in the long-term residual demand function was the expected price. That is, the monopolist was charging the "optimal" expected price.

If we assume that p_7^t of Equation (5.29) is the "optimal" expected price, and that the other price options are numbered one to six, then the price that should be charged in period t, p^t, to make the expected price in period t, $E^t(P)$, equal to P_7^t can be found by rearranging the following identity:

$$E^t(P) \equiv \sum_{n=1}^{6} \alpha_n p_n^t + \alpha_7 p_7^t + \beta p^t \qquad (5.42)$$

$$p_7^t \equiv \sum_{n=1}^{6} \alpha_n p_n^t + \alpha_7 p_7^t + \beta p^t$$

$$p^t \equiv p_9^t \equiv \frac{p_7^t(1-\alpha_7) - \sum_{n=1}^{6} \alpha_n p_n^t}{\beta}$$

Because of the problems involved in estimating the coefficients of equation (5.41), the α's and the β's, we will be restricted to a set of judgemental values for these coefficients. The price/quantity effect of uncertainty may, however, be demonstrated through the simple procedure outlined above.

This pricing strategy implies that the monopolist exploits the uncertainty inherent in the oligopolistic market structure. The fact that non-cartel market participants expect the cartel to fall apart or fear the reaction of the cartel if they should adjust their capital-equipment to the current cartel price allows the cartel to charge a higher price than otherwise would have been the case. If the cartel should fall apart then the other market participants might change their expected price only slightly, which implies further "punishment" for the cartel-members in terms of a smaller market share than would have been the case in a deterministic and competitive world.

CHAPTER 6

ANALYTICAL UNITS, DATA, AND THE FRAMEWORK OF THE STUDY

6.1 Introduction

The primary objective of this modelling effort is to establish the implications of various exporter strategies for the future price of oil in the international market. Because of the uncertainty associated with most econometric and engineering studies of the price-responsiveness of oil/energy markets, the model was also designed to be able to assess the sensitivity of the future price of oil to various coefficient or parameter values, however estimated. The uncertainty surrounding the traditional studies of the oil/energy markets results from the fact that the present level of prices is far outside the range of previous experience. Rather than allocating considerable time to determine point estimates of the various coefficients, a model structure has been designed in which the implications of the whole range of likely values for a given coefficient can be assessed. To simplify the presentation of the model and its features, a set of coefficients estimated on the basis of OECD and FEA projections [6,8,10], as well as on the basis of the projections of other private and public institutions have been chosen as a base case. The base case coefficients are hence estimated from the projection made in the above-mentioned studies rather than directly from historic observations. The studies by OECD and FEA were designed to trace out the implications for the world's energy markets of changes in the price of crude oil in the Persian Gulf, the cartel price, which is the focus of this study.

By assuming that the margin between the Persian Gulf price and the price paid by the final consumer would stay constant in absolute terms at the 1972 level, the net change in the future price to the final consumer of oil/energy resulting from a given change in the price of crude oil in the Persian Gulf could easily be calcualted. Once the net change in the price to the final consumer was established, the resulting net change in quantity consumed could be established by applying the elasticity-figures resulting from numerous studies of particular oil/energy markets. The OECD and FEA studies are based on "what-if-a-price-of-$X-would-prevail-up-to-1985" scenarios. Both studies disregard uncertainty. The scenarios cover, however, a sufficiently broad range to indicate the responsiveness of the world's oil/energy markets to changes in the price of crude oil in the Persian Gulf. The responsiveness of the world's oil/energy markets to the Persian Gulf price is the basis for picking the "most desirable" price-scenarios from the exporters' point of view.

The constant mark-up assumption, or the assumption that the margin between the price in the Persian Gulf and the price to the final consumer will stay constant in absolute terms is conservative. Even if the transportation costs and company profits have come down slightly, and refinery and marketing costs have increased only modestly, the level of taxation has changed drastically in most parts of the world since 1972 [4]. The coefficients estimated and the results given in the following do not include price induced consumer country energy policies and should therefore be regarded as indicating how markets would behave without consumer government interference.

Based on the forecasts of numerous public and private institutions, estimates of the potential price-responsiveness of the competitive exporter fringe, the non-OPEC producers and exporters, have been made. The assumptions underlying these estimates are made explicitly in the following. The reasoning behind the selection of presumingly behaviorally homogenous exporter sub-units is also made explicit, as are the assumptions underlying the calculations of the various coefficients and parameters characterizing the exporter sub-units.

6.2 The Consumer Regions

In the "bathtub" model the world is divided into four consumer regions. They are Western Europe, Japan, United States, and the rest of the world (not including USSR, Eastern Europe, and China). The linear relationships representing the consumer regions in the "bathtub" model were estimated on the basis of the forecasts made by OECD, FEA, and other public and private institutions [7,8,9,10,11]. The procedure followed by these institutions to predict the future consumption of energy is the following:

(1) Extrapolate the amount of energy spent in a base year (1972 or 1973) at the assumed rate of growth of the economy to some target year (most often 1980 or 1985). That is, a "long-term income elasticity" of one is implicitly assumed.

(2) Reduce the amount extrapolated to the target data by a percentage equal to an assumed "long-term demand elasticity" times the percentage change in the price of energy from the base year to the target year.

As the "long-term elasticity of demand" represents the ultimate effect of a gradual process in which the price effect "works" itself into the market, the above-mentioned procedure implies that the reduction in the quantity consumed in each of the periods of adjustment to the new price level is disregarded. If a yearly elasticity of income of one is assumed and the growth of the economic activity is assumed to be a proxy for income then the growth rate should be applied to the amount of energy actually consumed in each of the adjustment years. We may define the "long-term elasticity of demand" to be the certeris paribus, ultimate percentage change in quantity consumed resulting from a given percentage change of price in a perfectly deterministic world. I have defined the quantity subject to change as the initial quantity rather than the target year quantity at the initial price. This implies that the absolute number of units of reduction will be lower than what the OECD-FEA procedure indicates. Only in the case of no income effects are the two procedures identical. By incorporating the income effect, the price effect, as well as the length and distribution of the adjustment lags, the level of energy consumption in the target year as well as the intermediate years can be estimated as an explicit function of the above mentioned variables.

By defining the quantity subject to change as the initial rather than the target year quantity at the initial price, the price-responsiveness of demand in a linear framework is scaled down. If we assume that the initial quantity was X_0, that the initial price was P_0, that at the initial price

consumption was growing at G% a year and that it has been estimated that at a new price P_T then the quantity in some target year, T year hence, will fall to X_T, then information of this estimate would imply the following price-responsiveness, or price scope:

$$\frac{X_0(1+G)^T - X_T}{P_T - P_0} \quad . \tag{6.1}$$

When assuming the same price-responsiveness in relative terms affecting the initial level of consumption only, that is that initial consumption will fall to a level X_{P0} such that

$$\frac{X_{P0}}{X_0} \doteq \frac{X_T}{X_0(1+G)^T}$$

or

$$X_{P0} = \frac{X_T}{(1+G)^T} \tag{6.2}$$

Then the price-scope calculated from the absolute changes will be smaller

$$\frac{X_0 - \frac{X_T}{(1+\ )^T}}{P_T - P_0} \quad . \tag{6.3}$$

The price-slope (6.1) is consequently $(1+G)^T$ greater than the price-slope (6.3). By scaling down the price-responsiveness of the studies by OECD and FEA in this way the price-responsiveness assumed in this study may be considered to be very modest. The procedure by which the OECD and FEA

estimates was scaled down makes it simple to understand the price-assumptions underlying the simulations reported in the following as well as to change the price-slope assumptions for further simulations in a consistent and readily understandable manner.

To avoid kinked demand functions and discontinuous marginal revenue functions in a model basically designed to calculate price-paths over time consistent with different sets of objectives of the oligopolists deminating the international petroleum market, energy demand functions, market share functions, and functions of indigenous supplies were linearized over the $3-$9 price range (in 1972 dollars). The price refers to the price per barrel of oil F.O.B. the Persian Gulf.

Table 6.1 presents the coefficients of the consumer regions including the cases in which some share of the group of exporters is included in the indigenous supply-function of the rest of the world. The supply assumptions of the OPEC-members are the "optimistic set" as indicated in Table 6-7 of Section 6-4. The origin of the coefficients is indicated in Table 6-2 summarizing the mathematical representation of the consumer regions. The parameter values common to all the consumer regions are listed in Table 6-3. Table 6-4 lists the assumed projections of supply of oil in the countries included in the rest of the world's indigenous supplies.

CONSUMER REGION	KEY COEFFICIENT VALUES	ANNUAL GROWTH AND DECLINE RATES 73 74 75 76 77 78 79 80-85 85-90
United States	el_{1972}=38.143 e2=0.8 m0 = 0.526 m2=0.023 gm= 0.0127 s0 = 7.788 s2=1.233	G^t: 0.043 -0.02 0.01 0.04 0.04 0.05 0.05 0.04 0.04 d^t: .037 → 0
Western Europe	el_{1972}=25.37 e2=0.44 m0 = 0.678 m2=0.025 gm=0.0057 s0 = 0.24 s2=0.028	G^t: 0.051 0.02 0.02 0.04 0.05 0.06 0.05 0.05 0.05 d^t: -0.0487 → 0
Japan	el_{1972}= 7.303 e2=0.22 m0 = 0.783 m2=0.01 gm=0.0016 s0 = -0.048 s2=0.02	G^t: 0.081 -0.03 0.01 0.04 0.04 0.06 0.07 0.06 0.06 d^t: 0.056 → 0
"Rest of the World"	el_{1972}=18.363 e2=0.43 m0 = 0.604 m2=0.001 gm=0.0014 $s0^2$ = 3.928 $s2^2$=0.658 $s0^3$ = 3.928 $s2^3$=2.758 $s0^4$ = 8.065 $s2^4$=5.058	G^t: 0.059 0.02 0.03 0.04 0.05 0.05 0.05 0.05 0.05 d^{t2}:-0.1628 → 0 d^{t3}:-0.1628 → 0 d^{t4}:-0.1012 → 0

[1]Supply from the North Sea is included in indigenous supplies "Rest of the World"
[2]Includes all non-OPEC producers and exporters
[3]Includes all non-OPEC plus Indonesia, Iraq, Nigeria, and Gabon
[4]Includes 3 plus Iran, Algiers, Venequela, and Ecuador

TABLE 6-1
COEFFICIENTS OF IMPORTER REGIONS

TABLE 6-2

REPRESENTATION OF IMPORTER REGIONS

Total demand for energy in Region i in Year t, E_i^t (Equation 5.6):

$$E_i^t = e1_i^{t-1} + E_i^{t-1} x G_i^t - e2_i \sum_{k=t-K}^{t} \lambda^k p^k$$

Market share of oil in Region i in Year t, M_i^t (Equation 5.8):

$$M_i^t = MD_i(1+GM_i)^t - M2_i \sum_{k=t-K}^{t} \lambda^k p^k$$

Indigenous supplies of oil in Region i in Year t, S_i^t (Equation 5.9):

$$S_i^t = s0_i(1-d_i^t)^t + s2_i \sum_{k=t-K}^{t} \lambda^k p^k$$

TABLE 6-3

PARAMETERS OF IMPORTER REGIONS

Length of Lag Structure: 10 years

Distribution of Lags: $\lambda^{t} = 0.05$ $\lambda^{t-1} = 0.1$ $\lambda^{t-2} = 0.1$

$\lambda^{t-3} = 0.1$ $\lambda^{t-4} - 0.1$ $\lambda^{t-5} = 0.1$

$\lambda^{t-6} = 0.1$ $\lambda^{t-7} = 0.1$ $\lambda^{t-8} = 0.1$

$\lambda^{t-9} = 0.15$

Price of Back-stop Technology:

1. $15.00 - The "simple" model version
2. $16.00 - The "cartel" version

TABLE 6-4

INDIGENOUS PRODUCTION "REST OF THE WORLD" MMB/D

	1973	1980	
		$3	$9
Trinidad & Tobago	0.164	0.20	0.24
Argentina	0.418	0.60	0.24
Bolivia	0.047	0.07	0.10
Colombia	0.199	0.30	0.40
Chile	0.032	0.05	0.05
Peru	0.069	0.10	0.14
Egypt	0.167	0.17	0.20
Syria	0.099	0.20	0.25
Sinai	0.106	0.10	0.10
Turkey	0.066	0.07	0.07
Angola	0.154	0.16	0.20
Tunisia	0.083	0.09	0.10
Congo	0.040	0.04	0.04
Australia	0.419	0.40	0.45
Others & LNG	0.715	0.715	0.715
	2.778	3.265	3.855

Sources: Petroleum Economist, Petroleum Encyclopedia 1974, Oil & Gas Journal, Various Public & Private Institutions.

6.3 The Exporter Fringe

The existing and potential producers and exporters of the world that are not assumed to join an international cartel agreement, and which may become important non-cartel sources of supply, are included in a separate unit, and the potential level of supplies of these countries, if they would behave as price-takers, are listed in Table 6-5. Brunei-Malaysia and Mexico might conceivably join an international cartel agreement. In light of their recent independent behavior, a first approximation to their future roles is independent market participants possible following non-competitive market strategies like income or production stabilization thereby indirectly supporting the cartel. Greece, India, and Zaire are minors in a world context. They are included, however, because their potential may be significantly higher than indicated in Table 6-5. The sensitivity of the future price of oil to assumptions about the level of supply from these sources should be assessed. Even if the Brazilian projections may be considered high, the overall estimate of total non-OPEC exporter supplies is in the conservative range.

6.4 OPEC Sub-Units

The above mentioned selection of consumer or importer regions follows the traditional pattern of analysis of international markets. The composition of the exporter fringe seems plausible given the present configuration of OPEC. The membership of OPEC is, however, very heterogenous, and depending on the set of dimensions that are chosen to characterize the individual member countries, very different "homogenous" units may be defined

TABLE 6-5

PRODUCTION OF NON-OPEC EXPORTERS MMB/D

	1973/74	1980		1985	
		$3	$9	$3	$9
United Kingdom	0.002	2.4	2.8	3.5	4
Norway	0.032	1.4	1.6	2.2	2.5
Canada	1.798	2	2.2	1.8	2.3
China[1]	0.090	2	2.6	2	2.6
USSR & Eastern Europe[1]	0.740	0.8	1	1	1.4
Brunei-Malaysia	0.320	0.7	1	0.7	1
Greece	0	0.06	0.06	0.18	0.18
Brazil	0.169	0.75	1	0.75	1
Mexico	0.465	1.5	2	1.5	2
India	0.148	0.2	0.2	0.2	0.2
Zaire	0	0.025	0.025	0.025	0.025
	3.764	11.84	14.49	13.86	17.21

NON-OPEC EXPORT COEFFICIENTS

$S0 = 3.003$ $S2 = 0.558$

$d_{1973-1980} = -25.36$ $d_{1980-1985} = -3.7$ $d_{1985-1990} = 0$

lag structure: $\delta^{t} = 0.2$; $\delta^{t-1} = 0.2$; $\delta^{t-2} = 0.2$; $\delta^{t-3} = 0.2$; $\delta^{t-4} = 0.2$

[1]Includes net exports only. China produced 0.860 MMB/D in 1973. USSR & Eastern produces 8.389 MMB/D.

Sources: Petroleum Economist, Petroleum Encyclopedia 1974, Oil & Gas Journal, Various Public & Private Institutions.

	End 1974 Reserves[1]	1974 Rate of Deplet[2]	73/74 cng in rate of depletion	73/74% change in production	74 prodctn over end 74 capacity	74 oil incme per capita $[3]	Embargo Behavior[4]	Location[5]
Saudi Arabia	173,100	0.018	-9.25	11.6	0.75	3600	E	PG
Kuwait	81,400	0.011	-24.696	-15.7	0.75	11434	E	PG
UAE Qatar	45,900	0.017	-29.817	5.24	0.73	6203	E	PG
Libya	26,600	0.021	-30.857	-28.1	0.64	4193	E	N-PG
Iran	66,000	0.033	-5.76	3.3	0.93	694	N-E	PG
Venezuela	15,000	0.0-2	-16.348	-11.6	0.92	1149	—	N-PG
Algeria	7,700	0.049	-9.395	-5.7	0.90	308	E	N-PG
Ecuador	2,500	0.022	-45.000	-29.8	0.48	98	N-E	N-PG
Indonesia	15,000	0.034	-25.202	4	0.84	35	N-E	N-PG
Iraq	35,000	0.020	-12.503	-2	0.76	805	-	N-PG
Nigeria	20,900	0.039	4.483	9.7	0.95	124	-	N-PG
Gabon	1,800	0.036	-1.515	17.2	0.89	1300	N-E	N-PG
TOTAL	490,900	0.023	-14.818	-0.6	0.81	415A 1198B		

Notes 1,2,3,4, & 5 above are referred to on the following page.

SELECTION OF OPEC SUB-UNITS

TABLE 6-6

NOTES TO TABLE 6-6

1. End 1974 reserves in millions of barrels
   Source: M.S. Crandall World Oil Study, MIT Energy Laboratory

2. Annual production divided by end 1974 reserves.

3. Assuming the export price is the relevant value of domestic consumption and applying the population figures from the International Petroleum Encyclopedia 1974.
   A.. OPEC average
   B.. Average without Nigeria and Indonesia

4. The countries that actively participated in the 1973 embargo have been assigned an E in this column. The countries that significantly increased production during the embargo have been assigned a N-E in this column, and the countries that were close to neutral have not been assigned anything.

5. PG means that the country has its most significant export terminals in the Persian Gulf. N-PG means that important export terminals are also located elsewhere.

Columns one and two, "End 1974 Reserves" and "1974 Rate of Depletion, indicate the economic power of the various countries. A low rate of depletion indicates a high potential for expansion. A low rate of depletion and a high reserve level imply that the potential expansion of output could be substantial relative to the size of the market, and also that a smaller expansion could be implemented at a modest cost. The ability to expand output at a low cost is a measure of the economic power of a producer country. The 1974 level of depletion indicates in addition to the production history of the country also the bargaining ability and power of the country as well as the relative emphasis on current as opposed to future revenues. Columns three and four, "73/73% Change in Rate of Depletion" and "73/74% Change in Production," indicate a country's willingness to produce below the potential to support the price level, the responsiveness of a country's reserve level to an increase in the price of oil, as well as the accomodations that will probably have to be made to keep the cartel together. Column five, "74-Production Over End 74-Capacity" is a proxy both for the short-term market power of the individual OPEC members, and for the willingness and the ability of the countries to restrict current output, as well as for the bargaining ability and bargaining power of the member countries.

There is a number of dimensions that may be defined to characterize the financial and political aspects of each country [2,3,5]. The financial and political aspects are for the purpose of this study, however, summarized in two dimensions only. Column six, "74 Oil Income Per Capita" is an indicator of the financial position of each country. Higher per

capita oil income signifies a lower need for present versus future revenues, a lower discount factor, higher financial reserves vis-a-vis import requirements and a greater ability to survive production cutbacks. As the October 1973 embargo is the only event affecting the international petroleum market that clearly involved political considerations, the behavior of the OPEC-membership during the embargo is used as a proxy for the political attitude of each country and for the political homogeneity of OEPC as a whole. Column seven, "Embargo Behavior" is an index of the producer countries' willingness to conform to joint political actions when there are substantial economic gains to be obtained along with the political gains, but when the distribution of the economic gains may be influenced by the behavior of the individual producer countries. The last column, "Location," indicates the ease with which the price/production policies of the membership can be supervised. The further away from the dominant producers of the Persian Gulf a country is located, the more difficult it is to supervise its policies and to detect deviations from the joint policies, and the stronger is the incentive for the country to cheat. "Location" is a proxy for the ease with which the quality and transportation differentials as well as the credit terms of a country can be supervised.

From Table 6-6 it may be argued that OPEC consists basically of three different member categories. A first category consists of countries that could expand output substantially relative to the size of the international petroleum market but know that the market could accomodate their increased output only at a lower price. This category constitutes the "hard core"

of the cartel. A second category consists of countries that are presently producing close to their potential, and that have a strong need for current income. The members of this category are the "price pushers" within the cartel. They want to continue their present rate of production and prefer a higher to a lower price. A third category includes the countries that have smaller reserves than the members of the cartel core, have a strong need for current income, but are producing at a lower rate of depletion than the "price pushers." The members of this category, the "expansionist fringe," are small relative to the market and would like to get a somewhat larger share of the market without having to reduce the price. That is the "expansionist fringe " would like the other members to accomodate them with a higher market share at the expense of these other members.

The "hard core" of the cartel, which was denoted unit three, U_3, in Section 5.2.8, consists of the countries that have the largest recoverable reserves of oil, produce at the lowest rate of depletion, have the highest level of excess capacity, have the highest financial surplus level, and have demonstrated an ability to work together within a colluding agreement. The OPEC-countries that fit this characterization are Saudi-Arabia, Kuwait, UAE & Qatar, and Libya.

The"price pushers" which were denoted unit two, U_2, in Section 5.2.8, consists of the countries that produce at the highest level of depletion, have the lowest level of excess capacity, and have a strong need for current income. Iran, Venezuela, and Algeria may be included in this category.

The "expansionist fringe" or unit one, U_1, consists of the countries that produce at an intermediate rate of depletion, expanded production the faster in 1973/74, have a high need for current income, did not participate in the embargo, and do not have their major export terminals in the Persian Gulf. Indonesia, Iraq, and Nigeria fit the characteristics of the "expansionist fringe."

Ecuador and Gabon are not very significant in this context. The strong expansion of production in Gabon in 1973/74 made Gabon a candidate for the "expansionist fringe," U_1. Ecuador's level of excess capacity was a decisive factor when including Ecuador among the "price pushers," U_2. Gabon's ability to further expand production may be limited, and Ecuador's level of excess capacity was not due to voluntary output reductions only, which implies that the two countries could both be accomodated elsewhere. The results of any analysis will not be significantly affected by such a change in status.

Even if Libya has relatively small recoverable reserves, the fact that Libya was the price-leader of OPEC from 1970-73, participated wholeheartedly in the embargo, and has also absorbed a significant share of the drop in the demand for imports made Libya a candidate for the cartel core. There is still room for considerable expansion in Iran, the level of recoverable reserves is substantial and the present rate of depletion is in the intermediate range. Iran did, however, expand production significantly [13] during the embargo and was producing close to capacity in 1974. Iran's need for current income also makes Iran less likely to play

the role of the residual supplier with the cartel core. The size of Iran's supplies vis-a-vis the international petroleum market makes it unlikely that Iran would expect other OPEC members to accomodate increased Iranian supplies, which leaves the "price pusher" role as the most likely for Iran to play in the future as in the recent past.

Iraq's low rate of depletion, high need for current income, non-participation in the embargo, and Mediterranean export terminals as well as the suspicion that recoverable reserves in Iraq are twice as high as those indicated in Table 6 are the factors that determined Iraq's membership in the "expansionist fringe." It is considered unlikely that Iraq will be willing to keep production at the present low level.

For the purpose of simulating the "simple" model version, the model having one exporter group only, an "optimistic" competitive supply function was estimated for each of the OPEC sub-units and these were then aggregated to serve as supply-functions for the relevant coalitions of sub-units. These supply estimates are considered optimistic because they assume that a supply level of one-tenth of the 1974 proven recoverable reserves could be sustained if the exporters behaved as price-takers and the price was $9 (in 1972 dollars). A reserves to production ratio of ten may be considered optimistic, but the assumption that the level of recoverable reserves will not continue to increase as a result of the four-fold increase in the price of crude oil may be considered pessimistic, as may also the assumption that the end 1974 production capacity is a proxy for the $3 competitive supply level. The "optimistic" case is therefore rather modestly optimistic, even if it is more optimistic than the supply assumptions underlying the simulations of the "cartel" version, namely that a

reserve to production ratio of twenty only would be sustainable at a price of $9.

The coefficient values of the linear supply functions of the exporter coalitions of the "simple" model version are listed in Table 6-7. The marginal cost functions can be found by taking the inverse of the assumed competitive supply functions.

When estimating the competitive supply functions of the OPEC-sub-units for the purpose of running the full cartel version of the "bathtub" model, the end-1974 level of capacity was still assumed to be the $3 competitive supply level, but the $9 competitive supply level was assumed to be only half the level assumed in Table 6.7 as a current recoverable reserves to production ratio of twenty rather than of ten was assumed.

There is a bewildering number of estimates of OPEC's present level of assets abroad and of OPEC's total imports over the last two years. To project the income requirements of the OPEC sub-units, which are represented as a time-dependent equation only,

$$IR_j^t = IRO_j\ (1+IG_j^t)^t,$$

where IRO_j is an initial constant and IG_j^t is the rate of growth of OPEC-subunit j's income requirements in year t, 1974 total OPEC imports of $35 billion was assumed to be a plausible figure. This figure was broken down into estimates of the total imports figures of the OPEC-subunits on the basis of information published by the Petroleum Economist and First National City Bank [12,5]. The projected total imports path is used as a

proxy for the income requirements of the OPEC countries. The coefficients of the cartel version is listed in Table 6-8.

There is a great deal of uncertainty associated with the coefficients listed above. Our limited experience with high-priced oil and with the implementation of ambitious industrialization programs in the oil exporting countries, makes a discussion based on explicitly stated assumptions the most ambitious analysis of what will happen in the international petroleum market that can realistically be undertaken.

TABLE 6-7
"OPTIMISTIC" EXPORT SUPPLIES

COALITION	KEY PARAMETER VALUES
All OPEC Countries	S0 = -10.122 S2 = 15.97 d^t: 73-90 0 R^1 = 489 100
OPEC minus Indonesia, Iraq Nigeria and Gabon	S0 = -10.122 S2 = 13.87 d^t: 73-90 0 R^1 = 418 200
Saudi-Arabia, Kuwait, UAE and Libya	S0 = -14,535 S2 = 11.57 d^t: 73-90 0 R^1 = 327 000

COMMON PARAMETER VALUES

Discount Factor:	10%
Expected Market Growth:	3%
No Lag Structure	

[1] Reserves in million barrels of oil

TABLE 6-8

"PESSIMISTIC" EXPORT SUPPLIES

UNIT	KEY PARAMETER VALUES
U_1: Iraq,	SO = 4.679 S2 = 0.587
Indonesia,	d^t: 73-90 0
Nigeria, Gabon	R^1 72 700
	IRO^2 = 5763 $IG_{1973-1980}$ = 20 $IG_{1980-90}$ = 10
	NB^3 = 1 AO^4 = -4400
U_2: Iran, Venezuela,	SO = 10.57 S2 = 0.215
Algeria, Ecuador	d^t = 73-90 0
	R^1: 91 200
	IRU^2 = 7542 $IG_{1973-1980}$ = 20 $IG_{1980-90}$ = 10
	NB^3 = 1 AO^4 = -1690
U_3: Saudi Arabia,	SO = 7.675 S2 = 4.167
Kuwait,	d^t: 73-90 0
URE & Qatar,	R^1: 327 000
Libya	IRO^2 = 8269 $IG_{1973-90}$ = 10
	NB^3 = 0.5 AO^4 = 11800

COMMON PARAMETER VALUES

Discount Factor	10%
Expected Market Growth	3%
Lag Structure: $\delta^t = 0$ $\delta^{t-1} = 0.25$ $\delta^{t-2} = 0.25$	
$\delta^{t-3} = 0.25$ $\delta^{t-4} = 0.25$	
Return on Financial Assets Abroad: 5%	

[1] Reserves in million barrels of oil
[2] Income requirements in million dollars
[3] Net back factor in dollars per barrel
[4] 1973 level of assets abroad

CHAPTER 7
RESULTS OF "BATHTUB" MODEL SIMULATIONS

To illustrate the nature of the model described in Chapter 5, and how this model combines aspects of formal modelling with informal "story-telling" to identify the likely evolution of price and trade pattern over time in a particular oligopolistic market, a set of "stories" or of simulations of the simple version and of the "cartel" version of the model is presented. The "stories" were constructed from cartel theory, from the empirical evidence on previous commodity cartels, and from the special characteristics of the individual exporters.

7.1 The Simple Version

In the simple version of the "bathtub" model the world is represented by four price-taking importer regions - Western Europe, the United States, Japan, and the rest of the world (not including the USSR, Eastern Europe, and China) - and one exporter unit. The simple version was designed to assess the significance of possible coalitions of exporter countries. The composition of the exporter coalitions can be changed by transferring countries from the exporter unit to the unit representing the rest of the world's indigenous suppliers, or vice versa. This version is labeled "simple" because all the exporters in the exporter unit are assumed to follow the same market strategy as opposed to the "cartel" version in which the exporters may follow different market strategies.

The linear relationships of this simple version as described in Chapter 5 were simulated with the coefficient and parameter values of Tables 6-1, 6-3, 6-5, and 6-7 of Chapter 6. The simple version is hence

simulated assuming the "optimistic" competitive supply response from the OPEC countries as mentioned in the text to Table 6-7. The "optimistic" competitive supply response implies that marginal production costs of the OPEC countries under the various "monopoly" scenarios of the simple model are assumed to be lower than in the case of the "pessimistic" supply response underlying the cartel model simulations.

In the "optimistic" case it was assumed that if the price of crude oil had increased to $9 in a competitive world then the Persian Gulf producers could have supplied a quantity equal to one tenth of the end 1974 proven recoverable reserves on an annual basis. In the "pessimistic" case, however, it was assumed that a $9 competitive price would sustain a level of production of only one twentieth of the end 1974 proven recoverable reserves, once production equipment had been adjusted to that price. That the supply response is smaller in the pessimistic case reflects the implicit assumption that marginal production costs would rise faster in that case. Marginal production costs in both the "optimistic" and the "pessimistic" case, constructed such that at the 1974 level of production marginal production costs in the model are $2.50, way above the marginal cost figures reported elsewhere ($0.10 - $0.70). The reason is that marginal production costs in this study were estimated or deducted from a hypothesis of what the supply-response of the various producer countries would be if they would leave OPEC to behave as "price-takers" rather than directly from figures on production costs. The fact that marginal production cost is the inverse of the competitive supply function implies that

if the hypothesized competitive supply response to a significant price increase is small then marginal production costs rise fast, which implies that the slope of the linear marginal cost relationship assumed here will be steep.

We are concerned with constructing a competitive supply/marginal cost relationship that is a plausible approximation to the competitive supply curve in a competitive world and to the marginal cost curve in a monopolistic world, because we are concerned with the implications of both modes of behavior. The competitive supply/marginal cost relationship is common to both modes of behavior.

The "pessimistic" case was constructed because it was hypothesized that it would be more realistic than the "optimistic" case if some OPEC-members should leave for the price-taking fringe. That is, the "optimistic" case implies an "unreasonably" large supply-response in the case that an OPEC member would leave OPEC. The "pessimistic" case is a scaled-down version of the "optimistic" case. As it would be simple to draw conclusions about the impact of the two cases on the results from both model versions, and to avoid duplication of results, the two models were being simulated assuming a different case for the purpose of demonstrating the nature of the models and their results.

In the tables and figures included below, some actual (in 1972 dollars) price- and quantity-scenarios (in millions of barrels per day) resulting from simulating this simple version of the "bathtub" model are described. The notation of these tables is identical to the notation used above. The column headings have the following meanings:

E - World consumption of energy
O - World consumption of oil
D - World imports of oil
P - The price per barrel of oil in the Persian Gulf

"MOBA" is the name of the simple version. MOBA followed by a figure indicates the number assigned to that particular simulation of "MOBA."

7.1.1 The "Bathtub" Compared to the OECD-Predictions

To make explicit the effect on world oil/energy consumption of the more modest growth assumptions made in this study, the OECD economic growth scenario (OECD 1974) is simulated in the $3- and $9- case. OECD assumed in its study on future consumption of oil/energy that the U.S. GNP would grow at a rate of 4.3% (0.043) from 1973-80 and at 4% (0.04) from 1980-85; Western Europe would grow at a rate of 5.1% (0.051) from 1973-80 and at 5% (0.05) from 1980-85; and Japan would grow at a rate of 8.1% (0.081) from 1973-80 and at 7.4% (0.074) from 1980-85. This high-growth scenario was further supplemented by assuming that "the rest of the world" would grow at a rate of 5.9% (0.059) from 1973-90. These growth assumptions are far above those of this study as indicated in Table 6-7 above, as the more recent projections taking account of the present recession are incorporated here.

Table 7-1 and Figure 7-1 summarize the OECD growth scenario assuming a $3 and a $9 price per barrel of oil in the Persian Gulf. Under the cost assumptions of the world's exporters (in this case the exporter unit is OPEC) of Table 6-7 above, the OECD consumption and import figures in the $3 case are not feasible. To produce the 1985-level of imports of

73.32 MMB/D as indicated in the $3 OECD case a minimum price of $5.18 is required.

By comparing the OECD-high growth scenarios with those of Table 7-2, in which the growth assumption of Table 6-7 have been applied, the net effect of the different growth assumptions becomes clear. Even the "post-recession" growth-scenario gives an infeasible imports quantity in the $3 case, in the sense that under the assumed cost conditions the imports quantities of the $3 "post-recession" scenario from 1985 and onwards cannot be exported at such a low price even when assuming perfect competition. A minimum price of $3.26 is required to sustain a 1985 production of 61.23 MMB/D. In Figure 7-2 the OECD and "post-recession" scenarios are plotted. The difference is substantial. In the $9- case OECD-growth assumptions imply a 1990 level of OPEC- production of 66.42 MMB/D whereas the "post-recession" growth assumptions imply a 1990 level of OPEC-production of only 50.44 MMB/D.

The price-responsiveness of oil imports assumed in this study is a scaled down version of the price-responsiveness estimated by OECD and FEA as pointed out in section 6.2. In Figure 7-2 the 1980 and 1985 projections of demand for OPEC oil at a $9 price made by OECD[1] are included. The $9 OECD level of OPEC production is 25.4 MMB/D in 1980 and 27.2 MMB/D in 1985. Use and output of oil by centrally planned economies are assumed to net out by OECD, which is a more conservative assumption than the net exports from

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[1] p. 114 Volume II, Energy Prospects to 1985 OECD 1974

these countries assumed in this study, as indicated in Table 6-5. At a $9 price Table 6-5 projects a level of net exports from centrally planned economies of 3.6 MMB/D in 1980 and 5 MMB/D in 1985. If we add these figures to the OECD growth scenario of Table 7-1, then the net effect of the more modest price-responsiveness assumptions of this study appears as (30.79 + 3.6 - 25.4) or 8.99 MMB/D in 1980 and (40.30 + 5 - 27.2) or 18.1 MMB/D in 1985. The more modest growth assumptions of this study imply a projected reduction in consumption of oil compared to the OECD case of 7.4 MMB/D in 1980 and of 10.64 MMB/D in 1985, as is evident from comparing Tables 7-1 and 7-2. The difference between the OECD projections and the projections of this study in 1980 is due to a more modest price-responsiveness of 8.99 MMB/D to be offset by higher net exports from the centrally planned economies of 3.6 MMB/D and more modest growth assumptions of 7.4 MMB/D. In 1985 the difference in price-responsiveness is 18.1 MMB/D in exports, in exports from USSR and China is 5 MMB/D, and in growth is 10.64 MMB/D.

7.1.2 OPEC Breakdown

From Table 6-6 of Chapter 6 the end-1974 production capacity of the OPEC-countries appears as being approximately 38 MMB/D. The $9 post-recession scenario of Table 7-2 ($9 in 1972 dollars, which would be about $11.70 in 1975 dollars), indicates that OPEC's daily production might fall as low as 25 MMB/D on an average annual basis as early as 1979. Even if OPEC managed to keep the cartel discipline of April 1975, in which month

TABLE 7-1

OECD ECONOMIC GROWTH SCENARIO

At an Oil Price of $3 per Barrel (MOBA40)

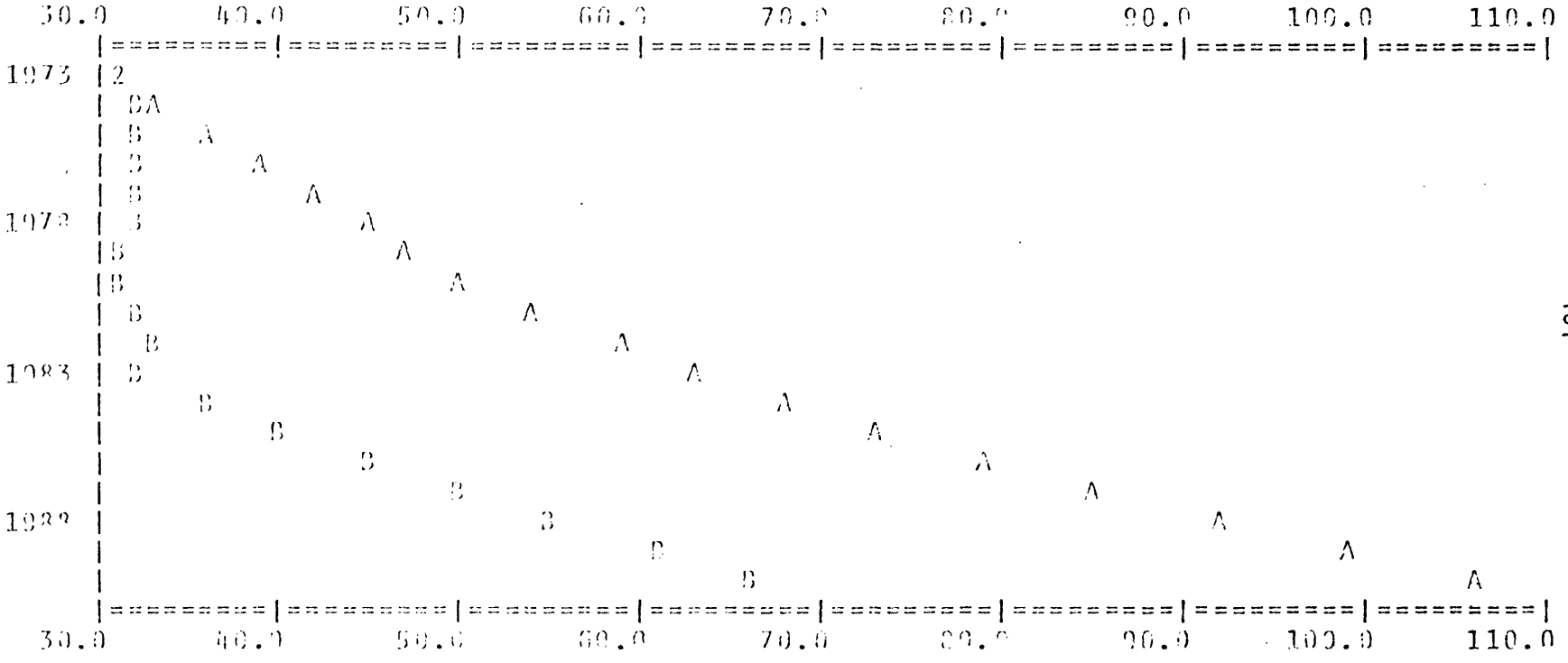
1973	87.6178	48.0746	30.7838	3.
1974	92.3583	52.8555	33.4819	3.
1975	97.1434	55.3975	36.2132	3.
1976	102.187	58.017	38.999	3.
1977	107.504	62.8232	41.7376	3.
1978	113.11	66.5278	44.5046	3.
1979	119.021	70.6433	47.3518	3.
1980	125.255	74.8031	49.2567	3.
1981	131.557	79.3811	54.1004	3.
1982	138.101	84.0117	58.5089	3.
1983	145.175	88.8762	63.2517	3.
1984	152.527	94.0204	68.1365	3.
1985	160.239	99.4789	73.3232	3.
1986	168.422	105.252	79.0061	3.
1987	177.089	111.364	85.2082	3.
1988	186.263	117.835	91.8798	3.
1989	195.962	124.688	99.0321	3.
1990	205.621	131.944	105.788	3.

At an Oil Price of $9 per Barrel (MOBA41)

1973	87.6178	48.0746	30.7838	3.
1974	91.7915	51.2941	32.1498	3.
1975	95.4124	53.0746	32.1453	3.
1976	99.2383	54.939	32.6825	3.
1977	103.257	56.894	31.7389	3.
1978	107.563	58.9468	31.6834	3.
1979	111.982	61.105	31.3147	3.
1980	116.707	63.3705	30.7681	3.
1981	121.439	65.6348	31.0867	3.
1982	126.422	67.9409	32.6823	3.
1983	131.133	69.6483	32.3602	3.
1984	137.736	73.7327	36.2146	3.
1985	144.719	78.1854	40.2957	3.
1986	152.072	82.7932	44.6133	3.
1987	159.816	87.6673	49.2176	3.
1988	167.972	92.8143	54.1246	3.
1989	176.563	98.3414	59.3517	3.
1990	185.614	104.239	64.9107	3.

Figure 7.1

DEMAND FORECASTS AT $3 AND $9 PRICES
UNDER OECD GROWTH SCENARIO



OPEC Production in Millions of Barrels Per Day

Symbol Scale Name
A $3 Per Barrel (MOBA40)
B $9 Per Barrel (MOBA41)

TABLE 7-2

"POST-RECESSION" GROWTH SCENARIO

At an Oil Price of $9 per Barrel (MOBA42)

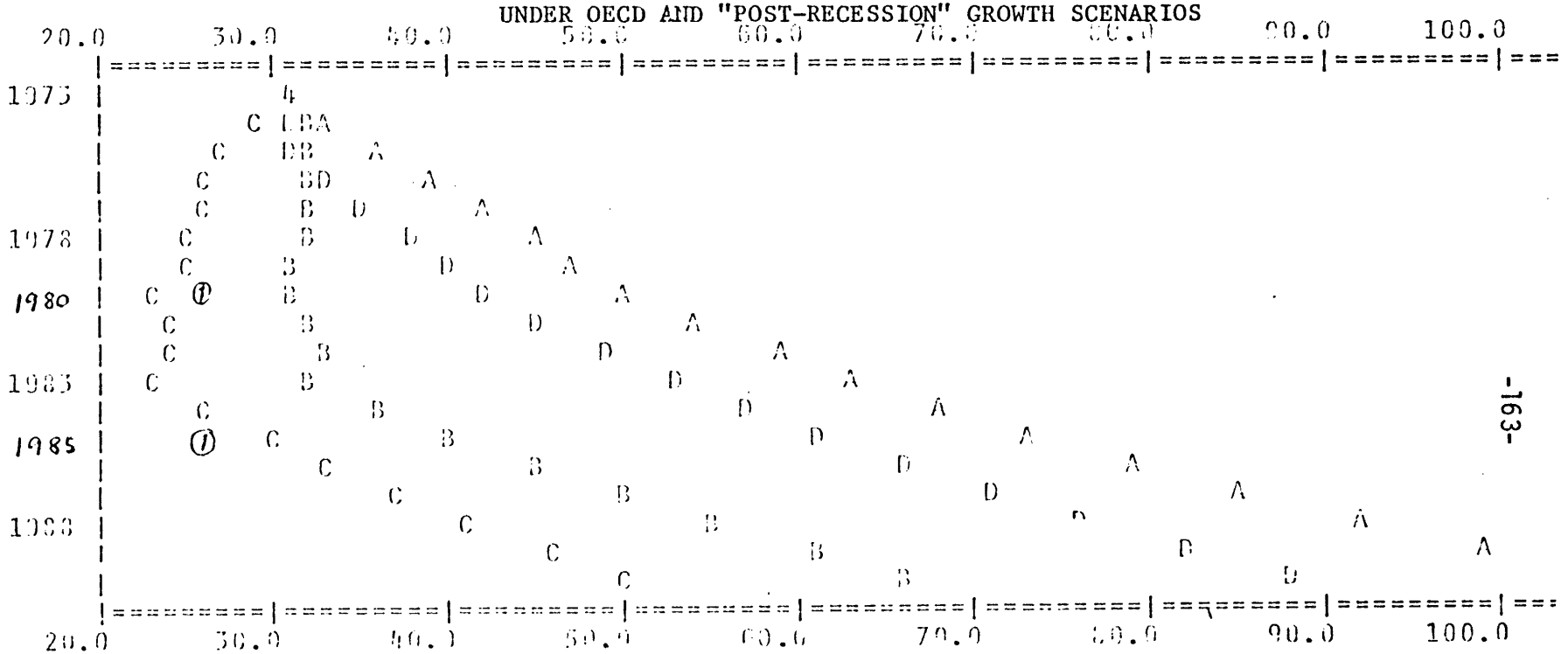
1973	87.3178	48.2746	30.7838	3.
1974	87.1569	48.4799	28.3267	3.
1975	87.5171	46.2905	27.3512	3.
1976	88.8837	49.2870	26.4311	3.
1977	92.3026	50.6180	25.6814	3.
1978	96.3573	52.5124	25.2539	3.
1979	100.505	54.5407	24.5504	3.
1980	104.703	55.9772	23.3888	3.
1981	107.791	57.0743	23.7361	3.
1982	111.037	59.446	24.1384	3.
1983	115.223	62.5628	25.2045	3.
1984	120.018	65.950	26.4149	3.
1985	126.27	67.4400	29.6501	3.
1986	132.192	71.1595	33.5609	3.
1987	136.597	75.9555	37.2656	3.
1988	144.007	79.1005	41.4006	3.
1989	151.708	83.5012	45.2015	3.
1990	158.345	88.2305	50.4408	3.

At an Oil Price of $3 (MOBA43)

1973	87.3178	48.8746	30.7838	3.
1974	87.7038	49.2146	30.6431	3.
1975	88.2277	50.4984	31.3151	3.
1976	92.7967	53.6564	33.1084	3.
1977	96.9796	56.0238	35.1352	3.
1978	102.102	58.66	37.6568	3.
1979	107.465	63.5438	39.052	3.
1980	112.402	66.8078	41.8715	3.
1981	117.78	70.0207	45.408	3.
1982	123.248	74.5219	49.1032	3.
1983	129.018	78.5111	52.9668	3.
1984	135.063	82.8046	57.0044	3.
1985	141.396	87.3202	61.2346	3.
1986	148.031	92.1269	65.6712	3.
1987	154.984	97.1181	70.3624	3.
1988	162.268	102.387	76.2309	3.
1989	169.901	107.946	81.7206	3.
1990	177.899	113.808	87.8525	3.

FIGURE 7.2

DEMAND FORECASTS AT $3 AND $9 PRICES
UNDER OECD AND "POST-RECESSION" GROWTH SCENARIOS



OPEC Production in Millions of Barrels per Day

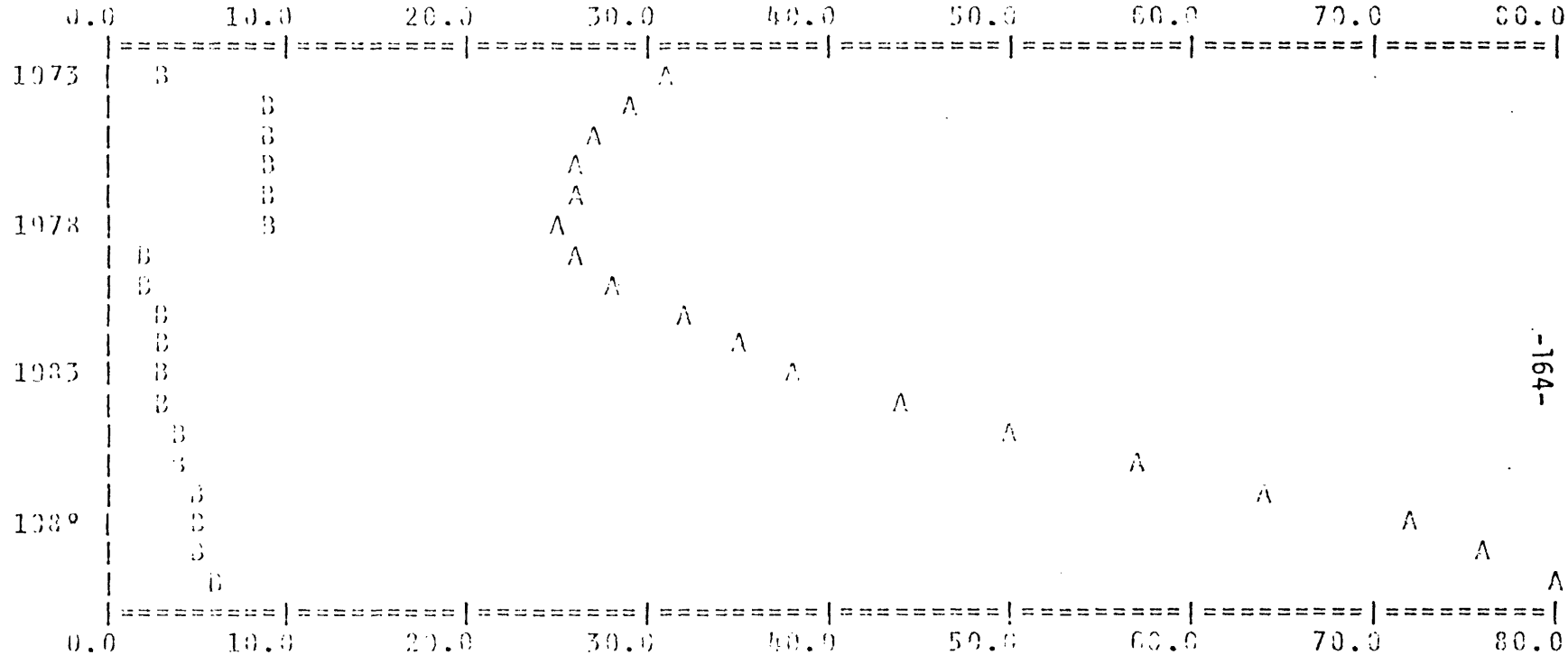
SYMBOL SCALE NAME

A OECD Growth Scenario at $3 per barrel (MOBA40)
B OECD Growth Scenario at $9 per barrel (MOBA41)
C "Post-Recession" Growth Scenario at $9 per barrel (MOBA42)
D "Post-Recession" Growth Scenario at $3 per barrel (MOBA43)

[1]OECD: Energy Prospects to 1985 OECD 1974.

FIGURE 7.3

PRICE AND PRODUCTION PATTERN IN THE CASE OF OPEC BREAKING DOWN IN 1979



SYMBOL SCALE NAME

A OPEC Production in Millions of Barrels Per Day

B The Price in $ per Barrel of Crude Oil in the Persian Gulf

the OPEC countries produced at a rate of 25,888 MMB/D[1] only, no international commodity cartel has managed to live with such a huge excess capacity (see Chapter 3). It may therefore be prudent to question OPEC's ability to live with an excess capacity of about 35% of the presently existing total productive capacity in the period from 1974 to 1985. The fact that the OPEC-countries are still adding to the level of productive capacity will increase the strain on cartel discipline even further.

In Table 7-3 and Figure 7-3 a scenario is therefore constructed in which the cartel manages to keep a constant price in real terms from 1974 to 1979 and then collapses in 1979, and the static competitive price emerges in the same year. The long adjustment period of demand accounts for the slow pick-up of OPEC sales and production. The conservative assumptions underlying the OPEC competitive supply functions account for the apparently high price level that emerges when the cartel breaks down in 1979 in Table 7-3. The 1979 price is the long-term marginal production cost of supplying the 1979 level of production of 26.16 MMB/D within the OPEC countries. The price level in 1979 is equal to the long-term static competitive price level, and the fact that marginal production costs when producing from an already developed field are smaller than the marginal production costs when additional capacity has to be developed to produce an additional unit is disregarded. The cost functions of the model include both production and development costs independently of the level of productive capacity, which implies that the price level in the case of OPEC

[1] Petroleum Intelligence Weekly, 5/26/75, pg. 11

TABLE 7-3

CARTEL BREAK-DOWN IN 1979 (MOBA44)

	E	O	D	P
1973	87.8173	48.7746	30.7838	3.
1974	87.1560	48.4799	29.3267	0.
1975	87.5171	48.2805	27.3512	0.
1976	89.8837	49.2276	26.4311	0.
1977	92.8926	50.6109	25.6614	0.
1978	96.6573	52.5124	25.0539	0.
1979	101.153	55.3017	26.1913	2.28687
1980	105.382	58.8542	28.2144	2.41816
1981	111.022	62.5371	31.731	2.68010
1982	116.26	66.3119	35.4064	2.85937
1983	121.146	69.4745	37.7739	3.01172
1984	127.013	74.0023	44.078	3.41707
1985	134.926	80.429	50.3851	3.79297
1986	142.202	86.1046	57.0295	4.21484
1987	149.741	91.9237	63.7343	4.64844
1988	158.102	98.8469	72.1001	5.17578
1989	165.045	103.143	75.4077	5.37891
1990	172.209	107.598	79.037	5.65672

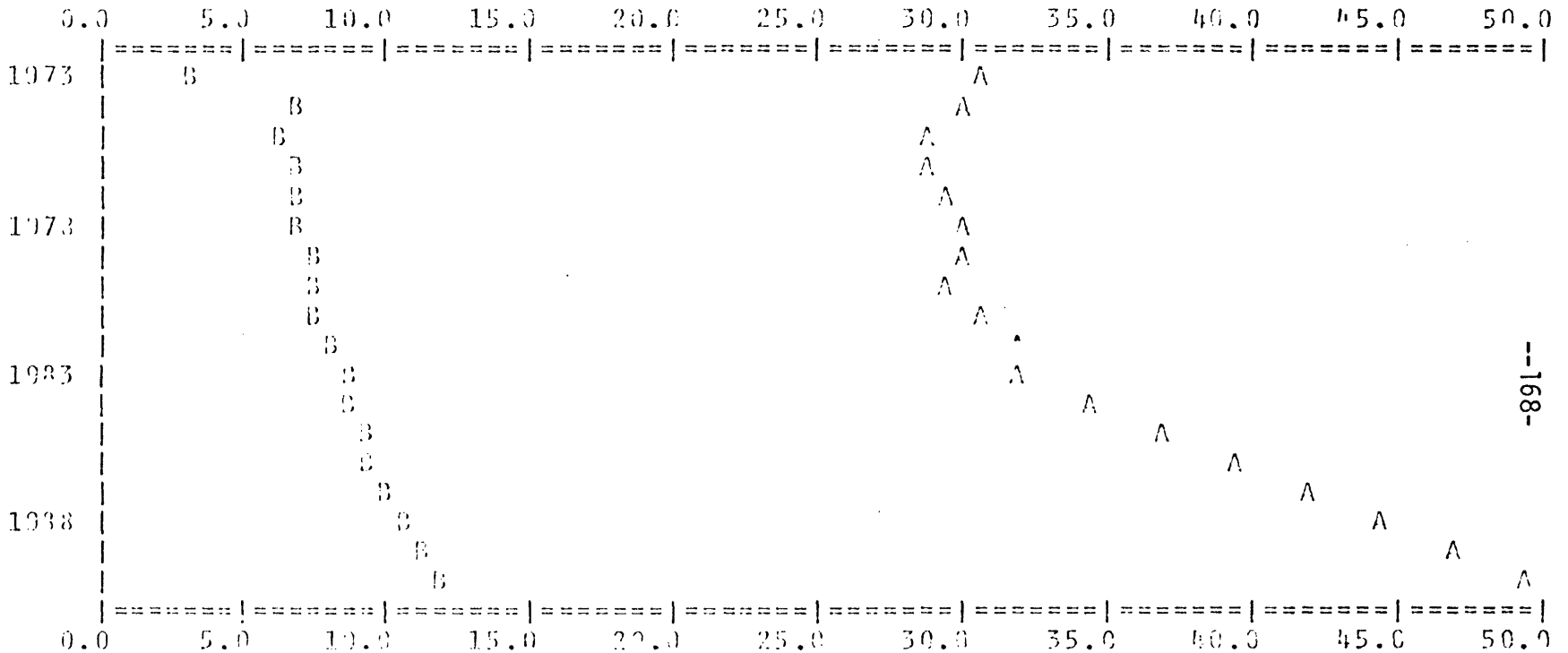
TABLE 7-4

OPEC - "MONOPOLY" PRICING (MOBA45)

	E	O	D	P
1973	87.8173	48.8746	30.7838	5.
1974	87.357	48.7301	30.7782	6.00209
1975	88.1006	49.007	28.8236	6.36751
1976	91.2281	50.721	26.9082	6.70364
1977	94.416	52.5088	28.2239	6.97367
1978	98.7302	55.0064	28.7695	7.11433
1979	103.332	57.454	29.3655	7.29499
1980	107.919	59.502	29.8316	7.42007
1981	111.153	61.7707	30.7347	7.75209
1982	115.421	63.9492	31.7529	8.0003
1983	119.459	65.8542	31.8124	8.44991
1984	124.773	68.8182	34.4022	8.80502
1985	130.894	71.791	36.629	9.10824
1986	135.677	74.9056	38.2103	9.5712
1987	141.457	78.0745	41.7852	10.0666
1988	147.485	81.3264	44.3328	10.631
1989	153.722	84.8276	46.8732	11.2169
1990	160.15	87.8875	49.4313	11.8221

FIGURE 7.4

OPEC "MONOPOLY" PRICE AND PRODUCTION



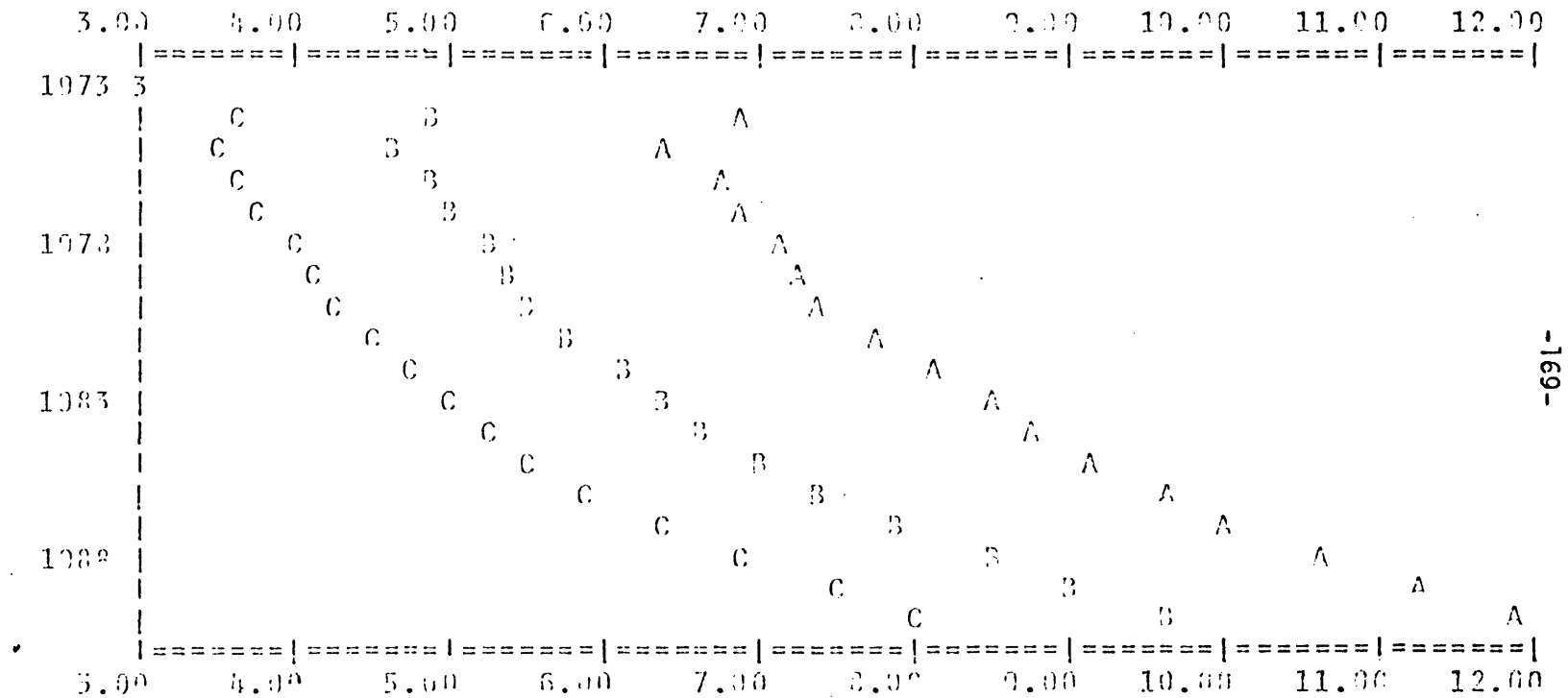
SYMBOL SCALE NAME

A OPEC Production in Millions of Barrels Per Day

B OPEC Price of Crude Oil in $ Per Day

FIGURE 7.5

OPEC AND OPEC SUB-UNIT "MONOPOLY" PRICES



Price Per barrel of crude oil in the Persian Gulf in 1972 dollars.

SYMBOL SCALE NAME

A OPEC "monopoly" price (MOBA45)

B OPEC without Indonesia, Iraq, Nigeria, and Gabon "monopoly" price (MOBA46)

C Saudi Arabia, Kuwait, UAE, and Libya "monopoly" price (MOBA47)

breakdown might fall even further to the marginal production costs of producing from existing facilities.

7.1.3 OPEC "Monopoly" Prices

If OPEC would follow a joint profit maximizing strategy, the OPEC-"monopoly" price/quantity path should emerge. In Table 7-4 and Figure 7-4 the price/quantity path of an OPEC-monopoly strategy is indicated. The monopoly price is the higher of the static monopoly price and the exhaustible-resource monopoly price defined in Chapter 5. Even when the ultimate level of recoverable reserves is assumed to be equal to the end-1974 level of recoverable reserves only, the back-stop technology price is assumed to be $15, and the appropriate discount factor 10%, then the exhaustible-resource monopoly price is smaller than the static monopoly price all the way to 1986. In 1987 the exhaustible-resource monopoly price is $0.08 higher and in 1990 $0.61 higher than the static monopoly price. That is, the opportunity cost of oil as measured by the net present value equivalent of the backstop price is smaller than marginal production costs in the period from 1974 to 1986.

The OPEC-"monopoly" price of Table 7-4, the joint profit maximizing price resulting from perfect collusion among the OPEC members is far below the present price level. The reason for this discrepancy may be that the OPEC-members have a different notion of what is in their best interest, or that the bargaining power of some individual member is so strong as to divert the joint price away from the joint profit-maximizing price to a level consistent with profit-maximizing behavior on the part of some individual member only.

It may also be noted that OPEC's present price appears to be consistent with exploitation of the short-term elasticity of demand, and that the price under such an hypothesis would be expected to come down to the longer-term monopoly level. The "bathtub" model as it stands today is not, however, designed to identify these shorter-term aspects of a recently monopolized market.

One purpose of the "cartel" model discussed below is to identify the desired price- and production paths of the individual OPEC members and thus also to reveal the extent to which the desired market solution of some OPEC member dominates OPEC policies. However, an initial impression of the "desires" of the individual OPEC members may be obtained also from the simple model, as demonstrated below.

The heterogeneity of the OPEC countries implies that each member may define a different "OPEC-monopoly price" dependent on each country's anticipated share of OPEC production and on the costs of producing that share of the total. By disregarding the regional relationships between producer and consumer countries, and by constructing marginal cost functions for each OPEC member consistent with Table 6-7 of Chapter 6, each OPEC country's "OPEC-mopoly price" may be identified in the simple "bathtub" model. The residual demand facing a country j in period t, D_j^t, as a member of OPEC, may simply be represented as the anticipated share of total OPEC production, W_j^t.

$$D_j^t = W_j^t \times D^t \qquad (7.1)$$

TABLE 7-5

The 1972 desired OPEC price in 1972 and 1975 dollars

	ALGERIA	VENEZUELA	OPEC
1975-dollars	9.3	10.86	8.27
1972-dollars	7.15	8.35	6.37

In Table 7-5 the desired "OPEC-monopoly price path" is indicated for Algeria, Venezuela, and for OPEC as a whole. Algeria and Venezuela were picked because they had the highest rate of depletion or had the lowest reserves to production ratio as indicated in Table 6-6. A low reserves to production ratio implies that a country is closer to its own resource limit, and therefore may be interested in switching to the back-stop price at an earlier date.

It was further assumed that Algeria and Venezuela would be assigned a production quota equal to the two countries' share of OPEC's 1975 production. The desired price of the three exporter units in 1975, in 1972 and 1975 dollars (assuming an accumulated rate of inflation since mid-1972 of 30%) is listed in Table 7-5.

The fact that the current price is so close to Venezuela's desired OPEC-price tends to strengthen Venezuela's image as the "expert" among the oil producers and as an internal "price pusher." The reason for Venezuela's higher desired price is that the end-1974 level of recoverable reserves, which is used as a proxy for ultimate recoverable reserves, is small compared to current production such that the opportunity cost of oil in Venezuela as measured by the net present value of the back-stop price is substantial. The net present value equivalent of the back-stop technology price is significantly higher than static production costs in the Venezuelan case.

There is reason to doubt some of the OPEC-members' willingness to adhere to jointly determined quota policies even if OPEC were ever to be

TABLE 7-6

OPEC SUB-UNIT "MONOPOLIES"

OPEC without Indonesia, Iraq, Nigeria and Gabon (MOBA46)

	E	O	D	P
1973	87.8178	48.8745	24.5139	3.
1974	87.5412	48.9654	23.7935	4.83281
1975	88.7039	49.7857	23.1800	4.84393
1976	91.0194	51.8013	23.7898	4.87585
1977	95.0349	54.2715	24.4750	5.02807
1978	100.438	57.2727	25.4328	5.22004
1979	105.182	60.231	26.143	5.38392
1980	109.631	62.9858	26.8747	5.50931
1981	114.055	65.8083	27.8418	5.78492
1982	119.046	68.6769	28.3214	6.07259
1983	123.097	71.5309	30.0076	6.36709
1984	127.355	74.817	32.7139	6.66991
1985	134.905	78.2102	34.0166	6.98093
1986	140.865	81.7306	37.4688	7.52021
1987	146.959	85.3069	39.0329	7.82269
1988	155.288	88.9864	42.3589	8.46591
1989	159.852	92.6927	44.7864	9.01422
1990	166.635	96.4304	46.8639	9.57287

Saudi Arabia, Kuwait, UAE, and Libya as the "Monopolist"(MOBA47)

	E	O	D	P
1973	87.8178	48.8745	13.3882	3.
1974	87.6882	49.1334	12.7137	3.50158
1975	88.8082	50.2708	12.7729	3.50382
1976	92.5227	52.8771	13.0561	3.68158
1977	96.558	55.439	13.2825	3.78877
1978	101.584	58.8141	17.3211	3.95329
1979	106.628	62.1739	18.4836	4.11881
1980	111.385	65.3456	19.5089	4.24033
1981	116.334	68.6093	21.7182	4.48289
19	121.472	71.9519	23.835	4.73137
1983	126.752	75.3046	25.592	4.98777
1984	132.407	78.848	28.8543	5.25266
1985	138.245	82.6348	30.2416	5.52656
1986	144.327	86.444	32.8942	5.82781
1987	150.636	90.3276	35.867	6.41768
1988	157.189	94.3088	37.2094	6.91215
1989	163.988	98.3552	39.2755	7.44111
1990	171.031	102.453	41.1021	7.9799

able to design and implement a pro-rationing system. If some OPEC-countries are expected to increase production to a level such that marginal production costs are equal to the OPEC-determined "monopoly" price rather than stick to some "fair" market share, then these OPEC-members may be considered as price-takers, and the relevant "monopoly" unit may be defined to be OPEC minus these price-takers, some sub-unit of OPEC. The simple "bathtub" model was consequently simulated assuming that two OPEC-subunits would play the "monopoly" role.

In Table 7-6 MOBA46 describes the "monopoly" price/quantity path resulting from throwing Indonesia, Nigeria, Iraq, and Gabon into the indigenous supply function of the "rest of the world," and letting the remaining OPEC-countries follow a "monopoly" strategy. MOBA47 indicates the price/quantity path resulting from letting Saudi Arabia- Kuwait, UAE, and Libya only play the "monopoly" game, when everybody else is a price-taker. In Figure 7-5 the price-paths resulting from the monopoly behavior of the three units are plotted.

All OPEC countries have reduced production somewhat, but not everybody has reduced output to the same extent, which implies that the "optimal" price from the dominant unit's point of view should recognize "price-taker" tendencies and would probably lie somewhere in between the price paths of MOBA45 and MOBA46.

These simulations indicate that the present price is consistent with an hypothesis of "price pusher" influence. As the economic sophistication of the dominant unit (Saudi Arabia, Kuwait, UAR, and Libya) increases over time, a shift downwards in price may be expected even if OPEC should survive as a colluding unit.

7.1.4 The Effect of Uncertainty

The uncertainty associated with the future price of oil may make the level of excess capacity associated with a market price of $9 smaller than otherwise would have been the case. A number of private and public institutions have predicted a drop in the price of oil in the late seventies or early eighties due to the anticipated flow of oil from non-OPEC producers and exporters as well as the emergence of some intra-cartel competition. The effect of expected prices different from actual prices is demonstrated in the "bathtub" model by constructing an expected price, E(P), different from the actual price, P. In the scenario described in Table 7-7 (MOBA48) it is assumed that the expected price is a weighted average of the actual price and a $6 price.

$$E^t(P) = 0.5 \times 6 + 0.5 + p^t \ .$$

The actual price is kept constant at $9. The market will consequently adjust to an expected price of $7.5. By comparing this scenario with the $9 scenario in which actual and expected prices coincided (MOBA42), as done in Figure 7-6, the quantity of world imports is kept at a significantly higher level over the time-horizon of the model in the case of the expected price being lower than the actual price. The difference in the 1974-1985 period is possibly large enough to save the cartel from collapsing due to an inability to allocate the necessary reductions in output.

If OPEC should try to exploit the fact that the expected price is different and lower than the monopoly price of the previous scenarios, the price charged in each period would be P in Table 7-8, whereas the expected

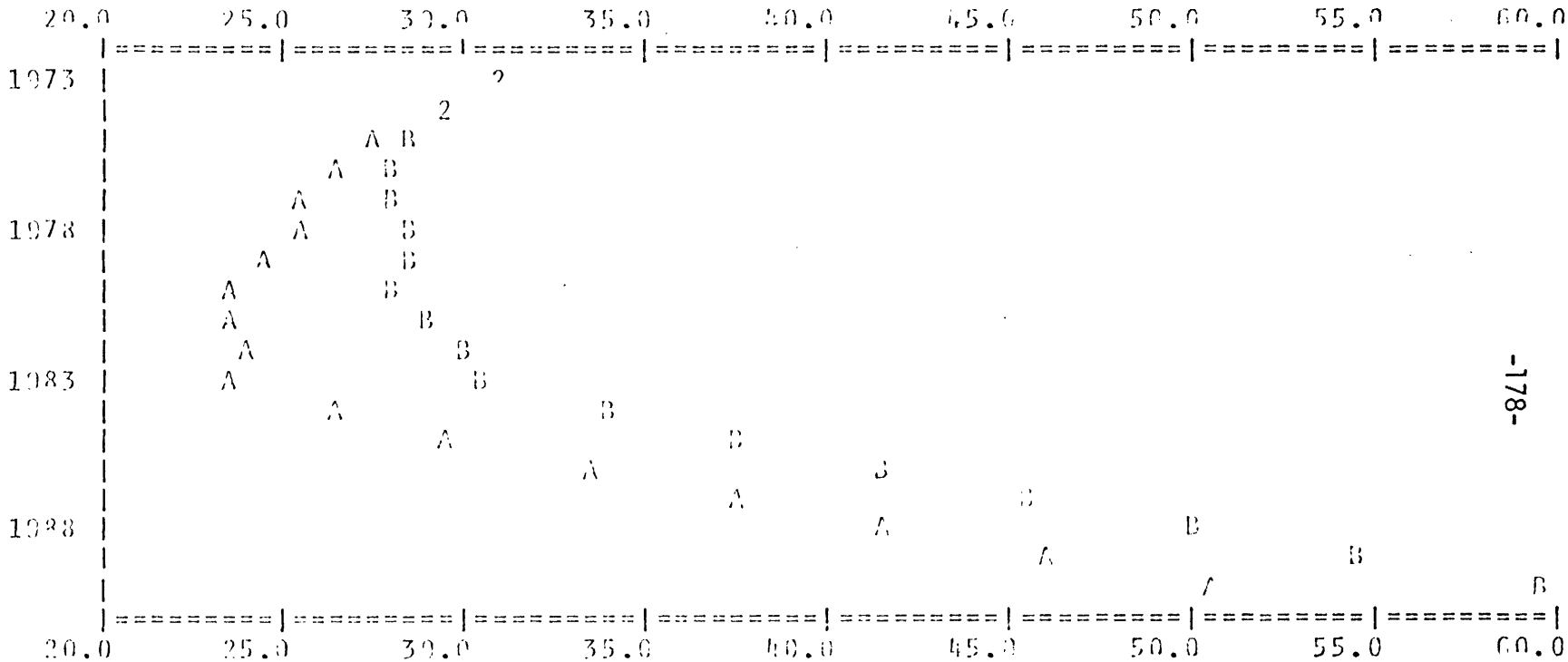
TABLE 7-7

EXPECTED PRICE
DIFFERENT FROM ACTUAL PRICE (MOBA48)

	E	O	D	E(P)	P
1973	87.8178	48.8746	39.7838	3.	3.
1974	87.2986	48.6528	29.645	7.5	0.
1975	87.0447	48.8028	28.3008	7.5	0.
1976	88.612	52.1757	26.8484	7.5	0.
1977	93.8468	51.8935	27.954	7.5	0.
1978	98.041	54.2812	28.2516	7.5	0.
1979	102.244	53.4774	28.8	7.5	0.
1980	106.[illegible]	58.5833	27.8954	7.5	0.
1981	110.278	60.743	28.9861	7.5	0.
1982	114.585	63.0223	30.1862	7.5	0.
1983	118.672	64.8458	30.4758	7.5	0.
1984	124.229	66.4438	33.2282	7.5	0.
1985	130.052	72.1937	37.3125	7.5	0.
1986	136.152	76.1466	41.2654	7.5	0.
1987	142.544	80.3143	45.4331	7.5	0.
1988	149.24	84.7227	49.8405	7.5	0.
1989	156.257	89.4038	54.5217	7.5	0.
1990	163.609	94.3391	59.455	7.5	0.

FIGURE 7.6

WORLD IMPORTS AT A $9 ACTUAL PRICE AND DIFFERENT EXPECTED PRICES



SYMBOL SCALE NAME

A Actual Price Equal to Expected Price (MOBA42)

B Actual Price Different From Expected Price (MOBA48)

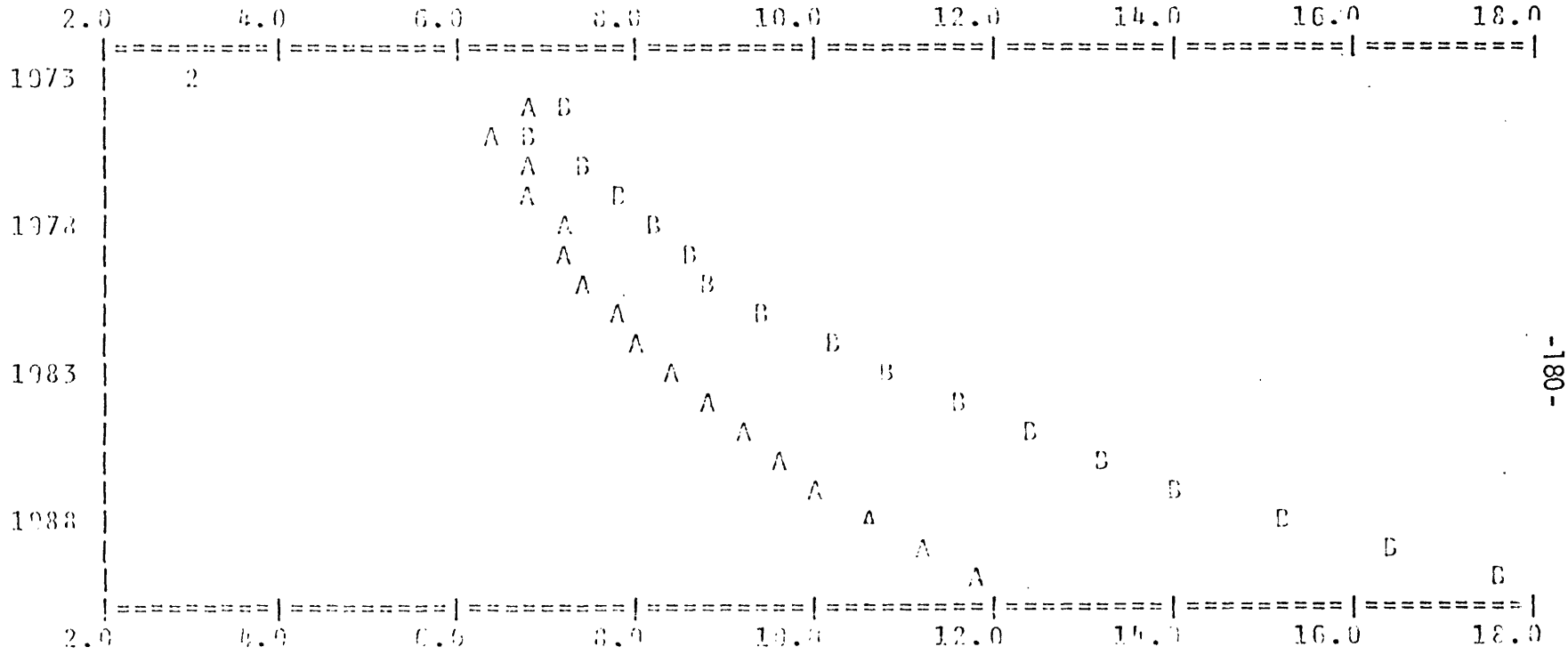
TABLE 7-8

OPEC EXPLOITING MARKET UNCERTAINTY (MOBA49)

	E	O	D	E(P)	P
1973	87.679	48.0801	30.444	4.5	3.
1974	87.3054	46.366	29.1503	6.64377	7.29754
1975	87.8224	48.7467	28.2339	6.41617	8.85934
1976	90.7074	50.35	28.3842	6.80363	7.58606
1977	94.1447	52.252	28.0151	6.87229	7.74579
1978	98.4568	54.701	28.1525	7.11109	8.22219
1979	102.736	57.0705	28.330	7.20121	8.58249
1980	106.706	59.2111	28.0206	7.41031	8.85261
1981	110.827	61.3925	30.0073	7.74657	8.49313
1982	114.238	63.3501	30.7086	8.09103	10.1938
1983	119.402	65.6445	31.2039	8.44216	10.8843
1984	124.643	68.7385	34.3772	8.78706	11.5853
1985	129.974	71.7302	36.5795	9.16962	12.3919
1986	135.55	74.841	38.1554	9.58345	13.1209
1987	141.337	78.013	41.7336	10.0373	14.0745
1988	147.363	81.2694	44.3529	10.6079	15.2157
1989	153.597	84.5754	46.9471	11.1918	16.3837
1990	160.012	87.8887	49.4007	11.7954	17.5909

FIGURE 7-7

OPEC "MONOPOLY" PRICE UNDER DIFFERENT ASSUMPTIONS ABOUT PRICE EXPECTATIONS



SYMBOL SCALE NAME

A OPEC "monopoly" price when expected price = actual price (MOBA45)

B OPEC "monopoly" price when expected price = 0.5 x $6 + 0.5×actual price (MOBA49)

price would be E(P) of Table 7-8. The expected price is as defined above half way between $6 and the actual price. The expected price in the monopoly case (MOBA49) is equal to the actual price in the "normal" monopoly case (MOBA45), because under the monopoly strategies defined in Chapter 5, the monopolist is assumed to maximize revenues with respect to the expected price, and because the monopolist is assumed to have perfect information with respect to the probability distribution determining the expected price.

The actual price of the two scenarios is plotted in Figure 7.7. Exploiting the uncertainty as represented by the weights of the expected price formula makes it possible for the cartel to profitably charge a substantially higher price than a stable monopoly would have been able to do.

7.2 The Cartel Version

From the simulations of the simple "bathtub" model, or from the "stories" that were being told by simulating that model, some of the critical aspects of the future international petroleum market emerge. A most critical aspect is the extent to which the exporting countries can agree on joint as opposed to individual strategies. The composition of the colluding group of exporters determines directly the level of the "monopoly" price. The uncertainty associated with the composition of and the stability of the most likely colluding groups determine to a large extent the response of the world's energy markets to the pricing-strategies that may

be pursued by the various colluding groups and thereby also the "joint-profit maximizing price" as perceived by the exporters.

To be able to focus on the likely composition of and the stability of collusive exporter groups, it is necessary to consider the collusive agreements from the point of view of the individual exporters. The stability of a collusive agreement depends on the desirability of the agreement to the individual members. A model that can tell "stories" about the desirability of various collusive arrangements to the individual participants is therefore needed to consider the stability question. The cartel version of the "bathtub" model is designed to tell "stories" about the possible reaction of individual exporter units to various collusive arrangements. In the simple model version the world is collapsed into two groups of market participants, the importers and the exporters. All the members of each group follow the same market strategy, even if the composition of the two groups can be changed to demonstrate the significance of likely exporter coalitions. The forces working on the coalitions, or the incentives to form coalitions, cannot be explicitly discussed within the framework of the simple model. By dividing the world into one importer group and four exporter units, the level of conflict within various coalitions of the exporter units may be explicitly discussed. The level of conflict depends on how close the actual joint market strategy of the colluding group is to the joint strategy considered most favourable by the individual exporters. The level of tolerance for internal conflict depends on the attractiveness of the individual market strategies open to the members relative to the outcome of the actual joint market strategy.

In the "cartel" model some joint and individual market strategies are compared from the point of view of the individual exporters. Criteria have been defined that indicate the attractiveness of various market strategies to the exporters. By allowing non-colluding exporters to follow non-competitive market strategies, the contribution of such individual non-competitive strategies to the maintenance of a non-competitive price level over time may be assessed.

In the following pages some results from simulating the cartel model, some cartel "stories" are presented. The composition of the individual exporter units and the reasoning behind the selection of these units are as indicated in Section 6.4. The logic behind the form and content of the various cartel-arrangements is indicated in Section 5.7.8.

The notation used in the following is analogous to the notation of Chapters 5 and 6. The index of the cartel units, j, runs as follows:

j = 1 The "expansionist fringe," consisting of Iraq, Nigeria, Indonesia, and Gabon.

j = 2 The "price pushers," consisting of Iran, Algeria, Venezuela, and Ecuador.

j = 3 The "cartel core," consisting of Saudi Arabia, Kuwait, UAE, and Libya.

j = 4 All of OPEC

j = 5 OPEC without the "expansionist fringe."

SE = Supplies from the competitive exporter fringe.

Q_j = Supplies from cartel unit j.

IN_j = Production income and financial income to cartel unit j.

IR_j = Income requirement of cartel unit j.

W_j = Production quota of cartel unit j.

Additional notation used to tell the various "cartel stories" will be explained as we move along.

7.2.1 Historic Quotas

Cartel-theory cannot give us the necessary and sufficient conditions for a cartel-dominated market to remain stable over time. It is possible, however, to sumulate a cartel-dominated market, to assume a stable price, and then to demonstrate what such a stable path would imply for each cartel member in terms of some critical factors. It is thereby possible to demonstrate the minimum level of discipline each cartel member must live with, and this may be used as a proxy for the necessary conditions for any stable price-path to be observed.

In the simulation labeled cartel 8 (Table 7-9) some of the implications of a constant price in real terms of $9 (in 1972 dollars or approximately $11.20 in 1975 dollars) and of cartel-production being allocated over time as it was in 1973 for each of the cartel members are discussed. Cartel 8 is hence a breakdown of the implications of the scenario labeled MOBA42 in Table 7-2 for each of the exporter units, and thus analagous to the exercise made by FEA (FEA 1974) to indicate the kind of pressure that OPEC would have to sustain to keep a $9 price level (in 1972 dollars).

An important aspect of the pressure that will build up, is the level of excess capacity with which the cartel will have to live. The present level of productive capacity, approximately 38 MMB/D, is far above

expected production in the years to come. As there is no system of prorationing of capacity within OPEC, and the present price level is far above the cost of installing additional capacity in the producer countries, the producers may be expected to increase their existing capacity. There is, however, a number of individual and joint capacity strategies that may be designed by the producers. To indicate the potential level of capacity, and hence also of excess capacity, it was assumed that the exporters will develop a level of productive capacity equal to their supply potential in a $9 competitive world. The supply potential or the competitive supply level given a $9 price was determined assuming the coefficient and parameter values of Table 6-8.

In 1973 the "expansionist fringe" produced 17.4% of tbtal OPEC-production, the "price-pushers" produced 35% of the total, and the "cartel core" produced the remaining 47.6%. In Table 7-9 the production of the four individual exporter units and the excess capacity of the three individual cartel units and of OPEC as a whole are listed. It is unlikely that the OPEC-countries will develop a production capacity equal to the supply-potential. The level of excess capacity as defined in Table 7-9 does, however, point to an important aspect of the strain to which OPEC might become subject.

In Table 7-10 the income associated with oil production and with holding claims on foreign countries, the import requirements and the accumulated holdings of assets abroad, of each of the individual cartel units are listed. The projected import requirements are simply a function of

time. The coefficients of these time-dependent functions are listed in Table 6-8, as is also the initial level of assets abroad for each of the cartel units. Non-petroleum exports are disregarded, which implies that the projections made beyond 1985 are very inaccurate. It may take ten years before non-petroleum exports become significant.

Table 7-10 is stated in constant 1972 dollars. It is implicitly assumed that the rate of inflation of oil prices will equal the rate of inflation of import prices to the OPEC-countries, which may tend to bias the import-requirements downwards and the level of accumulated assets abroad upward, as the higher rate of imports inflation may blow up the import requirements. According to Middle East Economic Survey, the import price index rose on the average for each OPEC-country by 26.3% in 1974 (up from 10.3% in 1973 and 1.1% in 1972), or substantially faster than any worldwide index of inflation that might be used as a yardstick for indexing of oil prices.

Even under the optimistic assumptions of this scenario, by 1990 OPEC holdings abroad will on the average have reached the zero-level again, even if there are substantial individual differences. As it appears from Table 7-10, the "expansionist" fringe will run a deficit as early as 1978, and the "price-pushers" will run a deficit already in 1980. The "cartel core" will not run a deficit in the simulation period. From Table 7-9 it is apparent, however, that the "cartel core" will bear most of the burden of the excess capacity as defined above.

There are a number of "stories" that can be told about why some cartel member would or would not like the $9 stable price- and quota-path described. In the following some of the "stories" we consider plausible in terms of what we might expect the individual cartel members to suggest as common policy and how the other cartel members might react to these suggestions will be explored. The "stories" are put together or constructed on the basis of cartel theory, the empirical evidence on international commodity cartels in general, as well as on the basis of the specific characteristics of the OPEC-countries as outlined in Section 6.4.

7.2.2 Financial Quotas

The "expansionist" fringe of OPEC, Indonesia, Iraq, Nigeria, and Gabon has a high need for income, and on an average per capita basis the level of oil income is small both in absolute terms and compared to the rest of OPEC. These countries may therefore be reluctant to accept any reduction in output that would not instantaneously give higher export revenues, and they may become very hard pressed economically as well as politically when the level of income falls short of their income requirements as defined above, which might happen in early 1978 as indicated in Table 7-10. A possible reaction given their own financial situation as well as the financial surpluses of the "cartel core," would be to propose a quota-system based on the income requirements of the cartel members as defined in Section 5.2.8. Such a quota-system would significantly

TABLE 7-9

PRODUCTION AND EXCESS CAPACITY IN MMB/D RESULTING FROM A $9 PRICE AND HISTORIC QUOTAS (CARTEL 8)

PRODUCTION

	Competitive Exporter Fringe	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	4.6285	5.10304	10.2507	13.9518
1975	5.02766	4.77066	9.01427	13.9754
1976	7.13933	4.57954	9.21171	12.5279
1977	8.84373	4.30703	9.04459	12.9206
1978	10.0221	4.26427	8.57755	11.6355
1979	13.1325	4.862	8.17069	11.1121
1980	15.1993	3.86543	7.77528	10.5746
1981	15.5655	3.98499	8.01534	10.9013
1982	15.8556	4.11346	8.27421	11.2529
1983	16.3001	4.05201	8.15052	11.0848
1984	16.7796	4.50504	9.06471	12.5729
1985	17.2146	5.15004	10.3774	14.1132
1986	17.2146	5.80317	11.673	15.8753
1987	17.2146	6.48263	12.505	17.2089
1988	17.2146	7.20371	12.505	21.6019
1989	17.2146	7.96705	12.505	25.3109
1990	17.2146	8.77522	12.505	29.1521

EXCESS CAPACITY

	OPEC	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	8.5204	1.33037	0.956804	0.22415
1975	17.8151	2.54003	1.92325	13.3511
1976	20.4186	3.62146	2.44629	21.1431
1977	34.0212	4.08447	3.3379	26.8086
1978	43.1377	5.00775	5.32744	33.5125
1979	44.3001	5.0	5.33431	34.8058
1980	45.4208	5.00057	4.72071	34.6036
1981	44.7451	5.07708	4.40035	34.8767
1982	44.3044	5.84853	4.23079	33.925
1983	44.3575	5.00009	4.3544	34.0032
1984	41.2315	5.50005	3.80028	32.0052
1985	37.0353	4.80206	2.12782	31.0347
1986	34.2934	4.15083	0.851955	29.3026
1987	30.3805	3.47033	0	26.0201
1988	28.2443	2.75828	0	23.4831
1989	21.8522	1.99405	0	18.0581
1990	17.2127	1.18077	0	16.0259

TABLE 7-10

FINANCIAL IMPLICATIONS OF A $9 PRICE AND HISTORIC QUOTAS (CARTEL 8)

(Figures in Millions of 72-dollars)

	"EXPANSIONIST FRINGE"		"PRICE PUSHERS"	
	Income	Import Requirements	Income	Import Requirements
1974	13212.9	8200.	30173.8	10060.3
1975	13940.2	9958.70	35140.1	13632.0
1976	14136.3	11059.5	34624.1	15030.1
1977	15751.1	14340.7	34478.6	18760.2
1978	15558.2	17208.8	34515.	22520.2
1979	14570.7	20659.5	33452.7	27024.3
1980	13614.3	24720.6	32375.1	32429.1
1981	13452.4	27259.6	33220.7	35672.
1982	13201.2	29884.5	34023.4	38239.1
1983	12155.1	32932.9	33323.2	43163.
1984	12045.2	36831.2	33720.	47479.3
1985	11815.3	39899.2	32207.7	52227.2
1986	11639.7	43699.1	35192.6	57449.2
1987	14114.7	48299.1	27342.1	63194.7
1988	13953.2	53119.	25540.5	69514.1
1989	11333.4	58439.2	23351.3	76465.4
1990	8895.14	64273.2	20695.6	84111.2

	Accumulated Assets Abroad		
	"Expansionist Fringe	"Price Pushers"	"Cartel Core"
1974	8240.80	10533.4	43385.1
1975	14329.	21079.2	75304.2
1976	18514.7	32834.2	105500.
1977	19095.1	47576.6	130350.
1978	18040.2	60371.5	149132.
1979	11070.2	74805.7	163022.
1980	812.91	84751.6	220121.
1981	-12087.4	93398.2	246757.
1982	-20770.7	87030.4	273730.
1983	-58506.5	77230.8	299451.
1984	-73034.4	68491.2	328042.
1985	-80028.3	54471.7	350330.
1986	-122248.	32214.4	383515.
1987	-162423.	-3358.18	431475.
1988	-202508.	-47302.3	474443.
1989	-249835.	-100717.	521570.
1990	-304084.	-164133.	571726.

increase the market-share of the "expansionist" fringe and the "price-pushers" as can be seen from Columns Two and Four of Table 7-11. But even such a significant increase in market share would only marginally postpone the point in time when oil and financial income would fall short of the rapidly increasing income requirements of these countries. The income difference under the two scenarios is, however, substantial as appears from Figure 7-8.

The "cartel core" is subsidizing the other cartel members under the financial quota-scenario. The rate of depletion of the "cartel core's" reserves drops to a level fifty percent lower than in the historic quota-scenario as is indicated in Figure 7-9, even if the market share of the "price-pushers" drops fairly rapidly after 1985 and the market shares of the "expansionist" fringe decreases after 1986 due to capacity constraints and an expanding market (Table 7-11). The number of periods the "cartel core" has to wait to sell lost current output makes the net present value of the additional future cash-flow associated with selling "oil in the ground" so insignificant that the additional current income of the non-core members represents an income transfer, a side-payment, from the cartel core to the other members approximately equal in magnitude to the net gain of the non-core members. The cartel core may be reluctant to a subsidy that significant, which implies that the cartel core may react by proposing an alternative price/quota system.

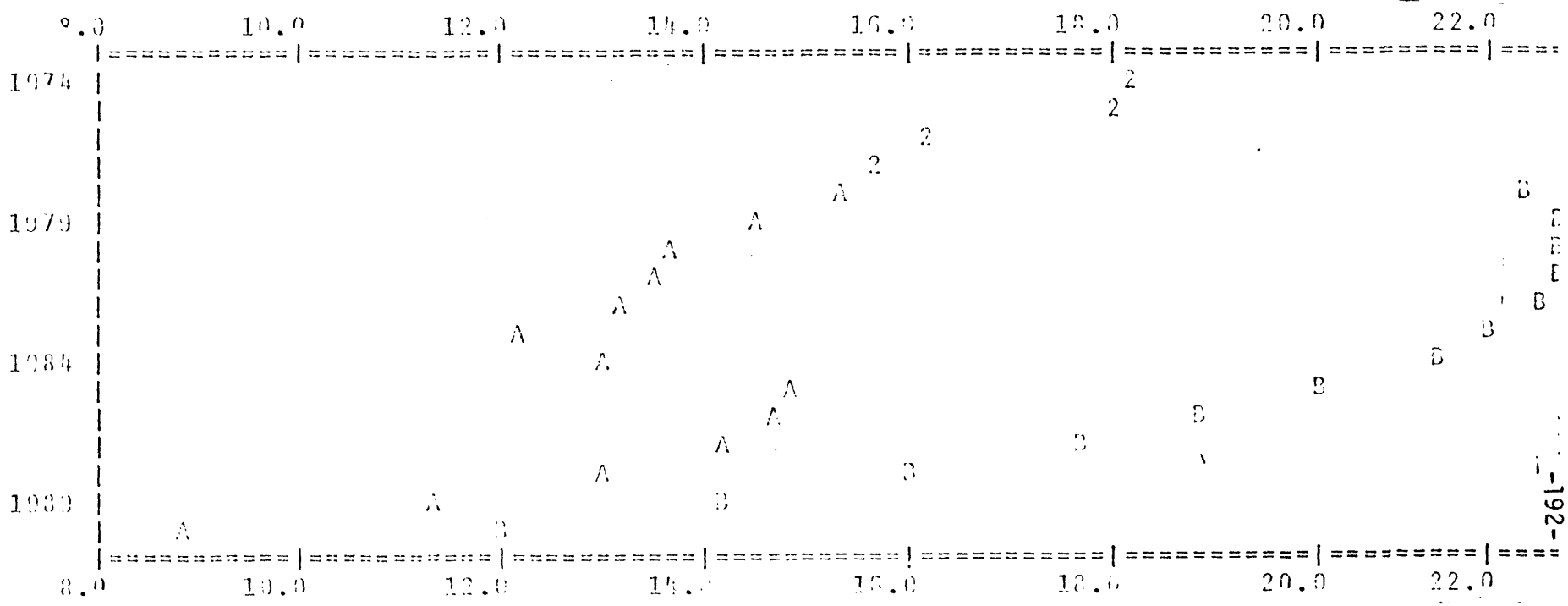
Table 7-11

FINANCIAL QUOTAS (CARTEL 9)

	"Expansionist Fringe"		"Price Pushers"	
	Quota	Production	Quota	Production
1974	0.174	5.16004	0.35	10.2587
1975	0.174	4.77066	0.35	9.01427
1976	0.174	4.57054	0.35	8.31171
1977	0.174	4.39703	0.35	8.04459
1978	0.319466	7.75572	0.614142	10.1495
1979	0.323734	7.56751	0.623653	9.80712
1980	0.330695	7.34943	0.632764	9.61389
1981	0.330695	7.57353	0.632764	9.91103
1982	0.330695	7.81783	0.632764	10.2368
1983	0.330695	7.79183	0.632764	10.0779
1984	0.330695	8.73461	0.632764	11.4388
1985	0.330695	9.085	0.621750	12.505
1986	0.323687	9.362	0.374895	12.505
1987	0.287380	9.362	0.335040	12.505
1988	0.240604	9.362	0.302048	12.505
1989	0.217545	9.362	0.273078	12.505
1990	0.197532	9.362	0.247050	12.505

FIGURE 7.8

INCOME TO THE "EXPANSIONIST FRINGE" UNDER AN HISTORIC AND A FINANCIAL QUOTA SYSTEM



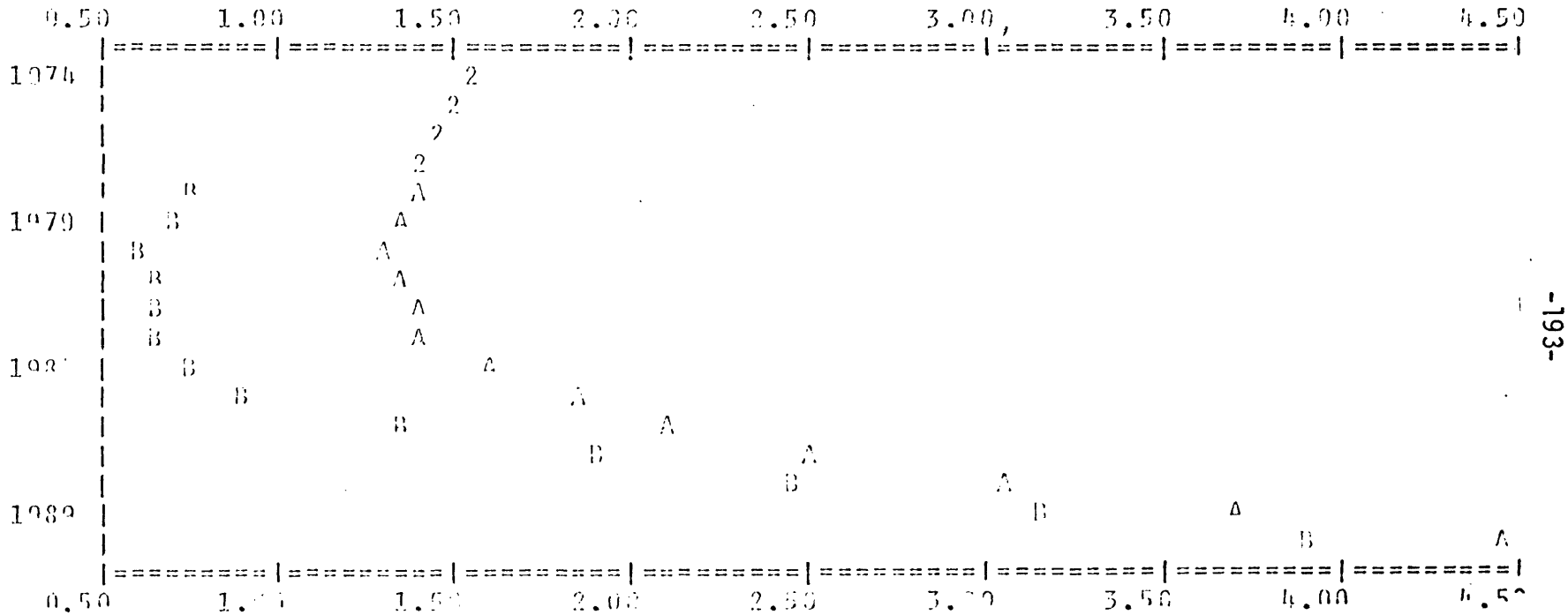
SYMBOL SCALE NAME

A Income under Historic Quota System (Cartel 8)

B Income under Income Requirements Based Quota System (Cartel 9)

FIGURE 7.9

RATE OF DEPLETION OF "CARTEL CORE'S" RESERVES UNDER HISTORIC- AND "FINANCIAL" QUOTAS



Current Production as a Percentage of Current Proven Recoverable Resources

SYMBOL SCALE NAME

A Rate of Depletion under Historic Quotas (Cartel 8)

B Rate of Depletion under Income Requirements Quotas (Cartel 9)

7.2.3 "Price-Pusher" Dominance

If it is considered unfair to fiddle with the historic market-shares, then the price might be used to increase the revenues of the cartel as long as the current price is below the monopoly price. By agreeing to a joint pricing-strategy that is "optimal" from the "low-reserve base," "high need for income" countries but too high for the low-cost, "extensive reserve base" countries, a side-payment system across time is in effect being implemented. If therefore the cartel core would object to a quota-system based on income requirements, the non-core members might propose a pricing strategy that would contain such a time-dimensional side-payment system.

In the simulation labeled cartel 10 in Table 7-12 it was assumed that the financial quota system would survive only for a year (1978), and that the OPEC pricing strategy desired by the "price-pushers," Iran, Venezuela, Algeria, and Ecuador, would be implemented in 1979 along with the historic quotas of cartels. Even if the "optimal" 1979 price is below $9, the "optimal" price increases fast enough to significantly alleviate the financial problems of the non-core members as appears from comparing the income columns of Tables 7-10 and 7-12. The pricing-strategy of Cartel 10 (Table 7-12) is incomewise more favourable to the non-core members than the financial quota-system of cartel 9. The rate of depletion of the cartel-core's reserves is also substantially higher under the historic quota system than under the financial quota system, even if it is still low, which may make the "price-pusher" strategy more acceptable to the cartel-core.

TABLE 7-12

"PRICE-PUSHER" PRICE AND HISTORIC QUOTAS (CARTEL 10)

	PRODUCTION MMB/D			
	Competitive Exporter Fringe	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	4.6285	5.10004	10.2587	13.0518
1975	5.62766	4.77060	9.01427	13.0754
1976	7.13999	4.57054	8.21171	12.5279
1977	8.84373	4.30703	8.84459	12.0280
1978	10.8221	7.75572	10.1495	[illegible]
1979	13.1350	4.08325	8.21344	11.1703
1980	15.1626	3.80360	7.85225	10.8701
1981	15.5443	4.39102	8.94884	10.9478
1982	15.999	4.05575	8.15011	11.095
1983	16.5333	3.86237	7.76013	10.566
1984	17.1483	4.2145	8.47745	11.5203
1985	17.8965	4.51357	9.07993	12.3475
1986	18.2308	4.03398	8.72353	13.224
1987	18.569	5.12702	10.3131	14.0258
1988	18.916	5.41159	10.8854	14.8041
1989	19.2714	5.68102	11.2682	15.3249
1990	19.6365	5.78748	11.6415	15.8324

	Market Price ($1972)	Income "Expansionist Fringe"	Income "Price Pushers"
1974	0.	10218.2	36173.3
1975	0.	10040.9	35149.1
1976	0.	10136.3	34024.1
1977	0.	15731.1	34470.3
1978	0.	22407.	39002.1
1979	3.52453	14277.6	32429.
1980	8.00712	14076.5	32068.
1981	9.57523	14737.5	35333.1
1982	10.1500	15191.4	37508.8
1983	10.7512	14571.1	37589.5
1984	11.3451	16000.3	42160.8
1985	11.9409	17275.1	46629.9
1986	12.5072	20330.3	51743.8
1987	13.2621	21410.3	56876.5
1988	13.959	22415.6	61284.4
1989	14.6101	22890.6	62811.7
1990	15.2962	23380.6	62449.8

7.2.4 "Cartel Core" Dominance

It may also be assumed that the sophistication of the OPEC decision-makers, including those of the cartel core, will increase over time, and that such a radical proposal as the financial quota-system might trigger an adjustment of OPEC policies to some economic realities. Such an adjustment might, of course, take place even without any prior radical proposals.

The economic realities may be perceived to be OPEC's monopoly position and the economic power of the individual cartel members. OPEC may therefore choose to follow a joint profit-maximizing pricing-strategy, and to allocate production and profits according to the "economic power" quotas as defined in Sections 5.2.8 and 4.2.2. An "economic power" quota system implies that each non-core cartel member is assigned a production quota such that the particular member makes at least as much profit as a cartel member as he would have made as an outside price-taker. The cartel thereby minimizes the compensation a cartel member will want to adhere to the policies of the cartel. The cartel core, being the dominant producer, allocates the profits and keeps the residual rent under this scenario.

Such a scenario is simulated in Cartel 11, and some of the implications are listed in Table 7-13. It appears from Table 7-13 that the historic quotas are not very different from the "economic power" quotas. The "expansionist fringe" would gain some, and the "price-pushers" would lose some compared to the historic quotas. The cartel core would consequently be able to increase production only marginally compared to the historic case.

TABLE 7-13

"ECONOMIC POWER" QUOTAS (CARTEL 11)

	Market Price ($ 1972)	"Expansionist Fringe" Quota	"Expansionist Fringe" Production	"Price Pushers" Quota	"Price Pushers" Production
1974	0.	0.174	5.10004	0.35	10.2587
1975	0.	0.174	4.77066	0.35	9.61427
1976	0.	0.174	4.57054	0.35	9.21171
1977	0.	0.174	4.39703	0.35	8.84459
1978	0.	0.316466	7.75572	0.414142	10.1405
1979	0.10381	0.201493	4.7457	0.282453	6.66787
1980	0.5209	0.192529	4.50786	0.285707	6.69955
1981	0.03514	0.190374	4.48557	0.278583	6.56417
1982	0.25571	0.188443	4.5702	0.271472	6.58384
1983	0.78088	0.186572	4.40682	0.264599	6.24966
1984	10.209	0.184763	4.34538	0.257894	6.06587
1985	10.8477	0.18299	5.23202	0.251553	7.19248
1986	11.1302	0.18115	5.64814	0.244874	7.035
1987	11.0142	0.179586	6.04665	0.23852	8.03009
1988	12.1174	0.177858	6.45302	0.232348	8.64744
1989	12.0152	0.176073	6.7577	0.226383	8.69356
1990	13.1519	0.174333	7.05713	0.220635	8.93147

	"Expansionist Fringe" Income	"Expansionist Fringe" Import Requirements	"Price Pushers" Income	"Price Pushers" Import Requirements
1974	18212.8	8298.	36173.8	10368.5
1975	18040.8	9058.79	35140.1	13032.9
1976	18136.3	11050.5	34824.1	15639.1
1977	15731.1	14348.7	34478.0	18798.9
1978	22407.	17208.8	38982.1	22520.2
1979	17477.7	20850.5	27191.5	27024.5
1980	15035.4	24780.9	26628.9	32429.1
1981	15883.9	27250.6	27522.9	35072.
1982	16023.2	29984.5	28283.7	38239.1
1983	15454.0	32982.0	27480.9	43163.
1984	16514.5	36281.2	28783.9	47479.3
1985	19441.3	39909.2	31788.7	52227.2
1986	20428.4	45000.1	33880.7	57449.8
1987	21267.2	48280.1	36035.3	63194.7
1988	22032.9	53119.	38892.6	69514.1
1989	22411.	58430.9	39329.5	76465.4
1990	22923.8	64273.9	40361.7	84111.9

Both the "expansionist fringe" and the cartel core is better off under this scenario than under the historic scenario. The "expansionist fringe" should be close to indifferent between the "economic power" scenario and the "price pusher" scenario as indicated by the income columns of Tables 7-12 and 7-13. The "price pushers" are, however, worse off in the latter than in the former case. The overall implications of the "economic power" scenario would make it attractive to OPEC.

OPEC could, however, do a little better by allocating production and profits as a multi-plant monopolist as defined in Section 5.2.8. Cartel 12 (Table 7-14) represents such a multi-plant monopoly scenario. A negative financial compensation means that the production income resulting from Unit j's allocated production is higher than Unit j's share of total cartel profits as determined by the "economic power" quotas. The investment subsidy is the "cartel core's" investment in Unit j to make Unit j's investable funds equal to a level consistent with a quota system based on income requirements.

Under this scenario production is allocated in the most efficient way. That is, marginal production costs are equal in all cartel units at the allocated level of production. It is thereby possible to obtain an efficiency premium over and above the "economic power" quota-system, as is illustrated in Figure 7-10 in terms of the income of the cartel core in the two cases.

The marginal cost functions of the "bathtub" model are linear. The coefficients determining the location and slope of the marginal cost relationships were estimated on the basis of an assumed expansion as

indicated in Section 6.4. This implies that for the countries that could only marginally expand production under an assumed increase in the competitive price level, the marginal cost curve would be very steep. This implies again that in the same countries the marginal costs would be assumed to fall very rapidly if the countries should produce short of capacity. The effect of the linear marginal cost relationships is that countries having a steep marginal cost curve and producing short of capacity will be allocated a share of monopoly production that is biased upwards. This bias explains the "price-pushers" high share of monopoly production.

Linear marginal cost relationships also imply that average cost is equal to marginal costs at a production level 50% of the current production level, as can be seen by integrating the linear marginal cost relationship to find total costs and then by dividing by quantity to get average cost. In the case of a negative average cost when deducted from the linear marginal cost relationship, a kinked average cost curve was assumed to avoid the negativity problem. A flat constant average cost minimum was assumed up to the point where average costs consistent with the marginal cost relationship becomes positive. Under competitive supply assumptions the linear relationships imply that average cost is implicitly assumed to be half the competitive price. As the average cost of producing from existing capacity is only a fraction of the cost of adding new capacity, which is the relevant cost concept in a competitive world, the above-mentioned linear relationships will tend to bias downwards the "economic power" quotas as defined in Sections 4.2.2 and

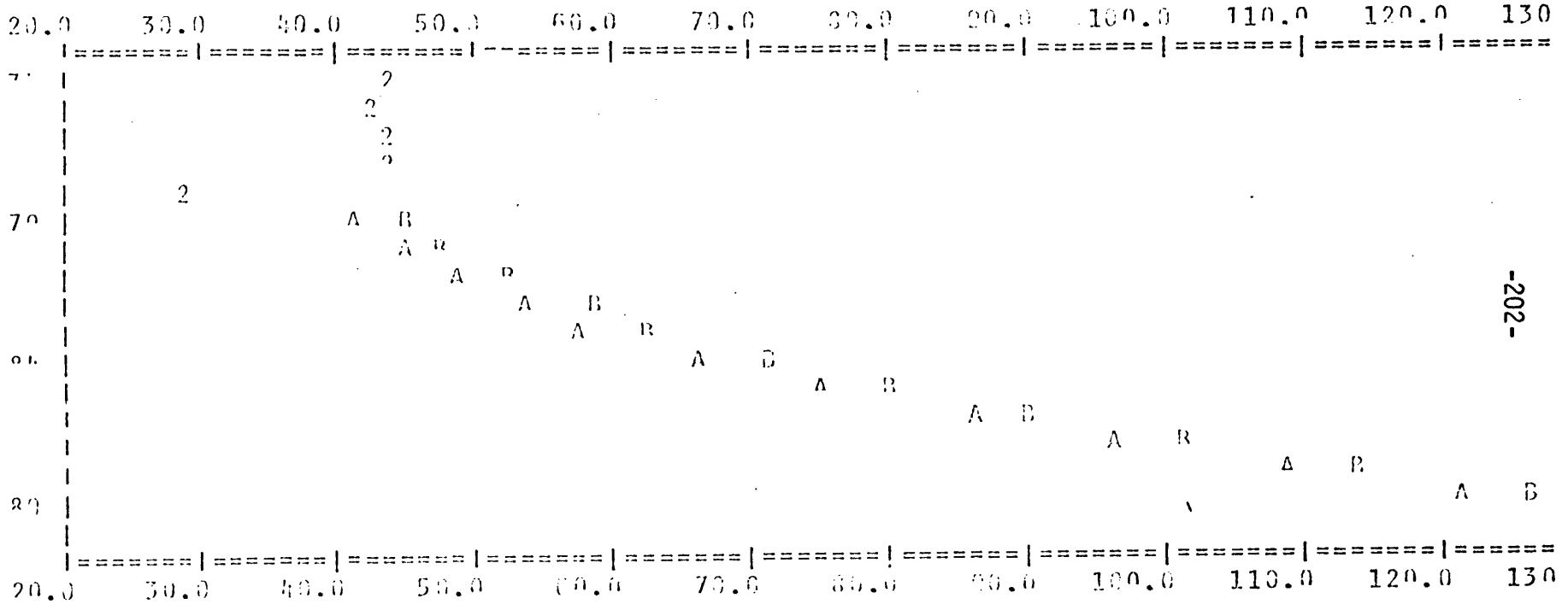
TABLE 7-14
"MULTI-PLANT MONOPOLY" (CARTEL 12)

	"EXPANSIONIST FRINGE"		"PRICE PUSHERS"	
	Quota	Production	Quota	Production
1974	0.174	5.10004	0.35	10.2587
1975	0.174	4.77966	0.35	9.61427
1976	0.174	4.57954	0.35	9.21171
1977	0.174	4.30703	0.35	8.84459
1978	0.316486	7.75572	0.414142	10.1405
1979	0.201815	4.75323	0.440041	10.5972
1980	0.212891	4.62575	0.467793	10.9257
1981	0.201782	4.75435	0.460778	10.5070
1982	0.1994	4.83593	0.458203	10.6275
1983	0.201574	4.70128	0.418700	10.9001
1984	0.193287	5.00004	0.406400	10.7128
1985	0.187065	5.3486	0.378252	10.8153
1986	0.181345	5.05422	0.353403	10.9272
1987	0.179604	5.05288	0.327422	11.0366
1988	0.172345	6.26586	0.306715	11.1512
1989	0.169459	6.50745	0.292686	11.2397
1990	0.166821	6.75302	0.279877	11.5290

	FINANCIAL COMPENSATION TO:		INVESTMENT SUBSIDY TO:	
	"Expansionist Fringe"	"Price Pushers"	"Expansionist Fringe"	"Price Pushers"
1974	0.	0.	0.	0.
1975	0.	0.	0.	0.
1976	.	0.	0.	0.
1977	0.	0.	0.	0.
1978	0.	0.	0.	0.
1979	-24.7559	-12107.5	9159.40	10153.
1980	-1540.52	-13006.9	10033.8	11294.6
1981	-257.573	-14399.5	11770.	12941.3
1982	-988.199	-14915.9	12725.	14429.3
1983	-1373.62	-13862.8	13199.1	15397.4
1984	-878.445	-15473.3	15903.3	17908.
1985	-493.931	-14424.7	16015.5	20029.
1986	-24.020	-13340.9	18804.5	20604.3
1987	397.070	-12300.5	19655.5	18719.5
1988	812.397	-11367.6	19417.1	18777.
1989	1078.72	-10975.	19822.	18630.6
1990	1343.89	-10597.9	20275.5	18516.8

FIGURE 7.10

EFFICIENTY-BONUS



SYMBOL SCALE NAME

A "Cartel Core's" Income under "Economic Power" Quotas (Cartel 11)

B "Cartel Core's" Income under Multi-plant Monopoly Allocation of Production (Cartel 12)

5.2.8. The profits of a cartel unit as an outside price-taker will be biased downwards.

These biases, even if substantial in the multi-plant allocation of production case, are not considered of sufficient importance to make the linear relationships unfit in a model intended to explore the implications of some plausible exporter strategies. Once the implications of some exporter strategies have been evaluated in this simplistic framework, more sophisticated functional relationships may be introduced. Due to the computational problems involved when formulating more sophisticated relationships, and the resulting dramatic increase in the costs of simulating a "bathtub"-type model, the introduction of more complex relationships is considered to be beyond the scope of this study.

7.2.5 OPEC Cracks

None of the above-mentioned cartel-scenarios allow the expansionist fringe to earn enough on its oil production to cover the imports bill for the period beyond 1978. It may be politically infeasible for the "expansionist fringe" to produce at a level short of full capacity when at the same time there is a shortage of funds. The other members of OPEC may recognize the fringe's inability to restrict production according to an OPEC-designed quota-system, and choose a pricing strategy accordingly. That is, the other members of OPEC recognize the "expansionist fringe's" inability to behave differently from a price-taker. The "price-pushers" and the cartel core may conseqeuntly try to maximize joint profits under the assumption that the "expansionist fringe" will behave as a price-

TABLE 7-15

OPEC WITHOUT "THE EXPANSIONIST FRINGE" (CARTEL 13)

PRODUCTION MMB/D

	Competitive Exporter Fringe	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	4.6285	5.10004	10.2507	13.0518
1975	5. [illegible]	4.77086	9.61427	13.0754
1976	7.13060	4.57054	9.21171	12.5279
1977	8.04373	4.30703	8.84459	12.0286
1978	10.8221	7.75572	10.1405	[illegible]
1979	13.024	8.962	4.66125	[illegible]
1980	15.0012	9.07671	3.90382	[illegible]
1981	15.2002	9.46743	4.25724	[illegible]
1982	15.4835	9.31043	4.523	11.1618
1983	15.0154	9.01515	4.41822	12.200
1984	16.2002	9.46624	5.05080	12.4352
1985	16.683	9.7034	5.59382	14.7351
1986	17.1143	9.95203	6.12840	16.0801
1987	17.3566	10.200	6.0312	16.7328
1988	17.6066	10.4754	7.1076	21.4287
1989	17.9351	10.7523	7.41426	24.0356
1990	18.1327	11.0390	7.65056	25.8438
				27.3829

	Market Price ($ 1972)	Income "Price Pushers"	Import Requirements "Price Pushers"	Rate of Depletion "Cartel Core"
1974	0.	36173.8	10060.5	0.015554
1975	0.	35149.1	13032.9	0.014702
1976	0.	34024.1	13330.1	0.013777
1977	0.	34472.6	10760.9	0.013087
1978	0.	38899.1	22520.2	0.007742
1979	7.05504	16178.5	27824.3	0.011656
1980	7.57303	15047.1	38429.1	0.011088
1981	7.93818	13758.6	35072.	0.013581
1982	8.3507	17302.7	30250.1	0.015188
1983	8.76689	10010.	43163.	0.0156
1984	9.18089	18307.8	47479.5	0.018933
1985	9.62441	19050.2	50227.2	0.02107
1986	10.1016	21134.7	57449.8	0.025690
1987	10.5025	22558.6	63194.7	0.028553
1988	11.0771	24103.6	69514.1	0.034200
1989	11.5835	24282.7	72465.4	0.037871
1990	12.0995	24261.1	84111.9	0.04226

taker and produce at capacity. Cartel 13 (Table 7-15) consists of a scenario in which the "expansionist fringe" is assumed to follow a price-taker strategy from 1979 and beyond, and the production and profits of the monopoly unit, the "price pushers" and the cartel core, are allocated according to the economic power quotas of Sections 4.2.2 and 5.2.8. The resulting market price in 1979 is $1.14 below the joint profit maximizing price of OPEC as a whole, as can be seen by comparing the market price columns of Tables 7-13 and 7-15. The 1979 income of the "price-pushers" is approximately $27.1 billion in the joint OPEC case with "economic power" quotas, Table 7-13, as opposed to only about $16.2 billion in the case presented in Table 7-15 also with "economic power" quotas.

Allocating production and profits of the sub-OPEC monopoly unit as a multi-plant monopolist would only marginally improve the income position of the "price-pushers." The level of excess capacity of the "price-pushers" is also high as a result of the "expansionist fringe" following a price-taker strategy, as can be seen by comparing the 1979 figures of production of the "price-pushers" in Tables 7-15 and 7-16. Beyond 1978 the "price-pusher" production column of Table 7-16 indicates the full capacity of the "price-pushers." A likely response of the "price-pushers" may therefore be to follow the example of the "expansionist fringe," and produce at capacity as a price-taker. The immediate effect of such a move by both the fringe and the "price-pushers" is very dramatic, as is apparent from production figures of the "cartel core" in Table 7-16. Table 7-16 lists some of the implications of the cartel core maximizing profits alone. Even if the "optimal" cartel core price is substantially

Table 7-16

THE "CARTEL CORE" ALONE (CARTEL 15)

PRODUCTION MMB/D

	Competitive Exporter Fringe	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	4.6985	5.10004	10.2587	13.3518
1975	5.82736	4.77006	9.71427	13.0754
1976	7.13000	4.57954	9.21171	12.5279
1977	8.24373	4.39703	8.84459	12.0286
1978	10.8221	7.75572	10.1405	6.89206
1979	12.048	9.062	12.585	1.74216
1980	14.8628	9.47084	12.3273	2.03885
1981	14.9207	9.10204	12.1205	5.17045
1982	15.6775	.527	12.8703	7.21457
1983	15.2807	8.51173	11.9738	8.47069
1984	15.5475	8.79524	12.1777	11.9445
1985	16.247	9.03092	12.164	14.0058
1986	17.4702	9.28556	12.2572	18.3174
1987	18.7205	9.54755	12.3532	21.5802
1988	17.0815	9.81091	12.455	25.516
1989	17.248	10.1033	12.5567	27.2247
1990	17.5201	10.3978	12.6646	29.2256

INCOME

	Market Price ($ 1972)	"Cartel Core"	"Price Pushers"	"Expansionist Fringe"
1974	0.	43337.9	33173.6	10212.9
1975	0.	43024.9	33140.1	10040.9
1976	0.	43223.	34024.1	10136.3
1977	0.	43476.1	34470.0	10731.1
1978	0.	20445.4	39002.1	22447.
1979	5.00300	11071.1	14062.2	8432.12
1980	6.55214	15303.7	19615.9	12926.3
1981	6.7072	19682.2	21802.2	13705.5
1982	7.20413	26614.1	24247.1	14000.5
1983	7.82530	31136.2	26012.2	15726.6
1984	8.35810	41421.2	28225.	16000.2
1985	8.50057	51247.4	27400.5	16381.2
1986	9.00845	59403.2	28631.8	16674.6
1987	9.49183	74269.9	30521.4	16800.5
1988	9.00202	89060.8	28285.8	16854.0
1989	10.5036	98804.7	25603.3	16892.9
1990	11.0327	110857.	24667.0	16872.

lower than the OPEC-subunit "monopoly" price of Table 7-15, the fact that the "price pushers" can throw in a substantial level of productive capacity makes the 1979 income of the "price pushers" higher in the cartel-core case than in the Cartel 13- scenario of Table 7-15. In the longer term the income of the "price-pushers" as price-takers converges against the income level of Table 7-15 in accordance with the definition of the "economic power" quotas.

The dramatic effect on the production level of the cartel core might also result in a price-war emerging. A price-war could even push the price close to a zero level.

7.2.6 Re-establishment of OPEC

In the industries which structure is most favourable for collusive arrangements, there has been a number of attempts to re-establish a collusive agreement once an agreement has fallen apart. Chapter 3 gives ample evidence on this aspect of "oligopolluted" industries. There have always been considerable short-term incentives to re-establish a non-competitive price level, even if in the longer term the non-competitive price level often induced more entry than anticipated to the detriment of the colluding firms.

Also in the case of an OPEC break-down there would be considerable incentive to re-establish a collusive arrangement. The difference between the income of the cartel core when maximizing profits alone (Cartel 15) and when re-establishing OPEC (Cartel 16) is more than $35 billion in 1981. The "price-war price" of Table 7-7 indicates the short-term market price if all cartel members threw their full productive capacity on the market

TABLE 7-17

RE-ESTABLISHMENT OF OPEC (CARTEL 16)

PRODUCTION MMB/D

	Competitive Exporter Fringe	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	8.9285	5.10004	10.2587	13.0513
1975	5.02726	4.77066	9.61427	13.0754
1976	7.13009	4.57054	9.21171	12.5279
1977	8.94373	4.30703	8.84459	12.1286
1978	10.8221	7.75572	10.1405	8.00200
1979	12.8502	8.002	12.505	2.21405
1980	14.6768	8.2108	12.2331	4.0702
1981	14.7201	5.15077	7.38832	14.9972
1982	14.9717	5.35345	7.74985	15.2224
1983	15.4503	5.10652	7.31456	15.2308
1984	15.0513	5.00842	7.08504	16.0004
1985	17.0007	5.00545	8.10974	18.2702
1986	17.7401	0.84023	8.43401	19.823
1987	17.0240	0.05502	8.03748	21.0330
1988	18.1064	7.22159	8.43125	24.0288
1989	18.4565	7.18551	8.22213	24.4551
1990	18.7203	7.05837	8.0150	24.5418

	Market Price	"Price-War Price"
1974	0.	0.055262
1975	0.	0.224699
1976	0.	-0.340013
1977	0.	-0.000405
1978	0.	-1.35222
1979	3.04106	-1.31038
1980	4.07524	-0.317006
1981	8.50885	-0.100284
1982	9.22584	-0.018659
1983	9.88884	-0.174401
1984	10.2240	0.170883
1985	10.6773	0.301625
1986	11.1031	0.856220
1987	11.8526	1.32245
1988	12.1530	2.15796
1989	12.667	2.11022
1990	13.1948	1.82818

in any given year. Even if a negative price is not feasible, a negative price indicates that in the case of a short-term price war, the price could theoretically fall to a level very close to zero. If a price-war price level rather than the long-term competitive equilibrium price level emerged following an OPEC-breakdown, then the incentive for re-establishment would be even stronger. The emergence of a long-term competitive equilibrium price in case of OPEC breakdown is based on the assumption that if price should fall below this level there would be a strong enough speculative demand for oil that the price would be forced back to the long-term competitive price level.

The confidence of the OPEC-countries in running a collusive arrangement might get a serious crack in case of a break-down. Lack of confidence might make future collusive arrangements even more unstable, and we would expect to observe a fluctuating price level due to a "breakdown-re-establishment-cycle." One such cycle is included as an illustration in Table 7-17, the market price "cycling" from $9 in 1978 to $3.94 in 1979 and up to $9.50 in 1981.

7.2.7 Income Stabilizing Exporter Fringe and Uncertainty

Some of the governments of the countries we have assigned to the competitive exporter fringe have expressed concern over the sheer magnitude of their expected oil export revenues. High export revenues may, if they were to be absorbed immediately in the local economy, cause inflation only. Production ceilings have consequently been constructed to adjust future production to a level of income that the governments believe

the local economies can absorb. The reasoning is thus along the lines of the income stabilization strategy of Section 5.2.3.

The implication of a competitive exporter fringe behaving as on a backward bending supply curve is that the monopoly unit can disregard the exporter fringe and choose a monopoly price with respect to the demand for world imports, D^t, which is higher than the monopoly price with respect to world residual imports, RD^t. By substituting Equation (5.12) for SE^t in Equation (5.30), and taking the first derivative of the revenue function associated with Equation (5.30), the implication above becomes obvious,

$$\frac{\partial(RD^t x p^t)}{\partial p^t} = \frac{\partial((D^t-[I^t/p^t])p^t)}{\partial p^t} = \frac{\partial(n^t x p^t)}{\partial p^t} - \frac{\partial I^t}{\partial p^t} = \frac{\partial(D^t x p^t)}{\partial p^t}. \quad (7.2)$$

If we assume that the competitive fringe had anticipated an income level consistent with a $9 price and production at capacity, and that they would reduce production according to Equation (5.17) if the price moved above this level, then OPEC could raise price almost 20% higher in the second half of the "breakdown-re-establishment-cycle" as pointed out in Table 7-18 than otherwise would have been the case, as indicated in Table 7-17.

The dramatic jump in demand for cartel output following the re-establishment of OPEC in 1981, the OPEC-column of Table 7-18, is caused by the competitive fringe's reduction in output following the price increase in the same year. The income stabilization strategy of the competitive fringe will greatly increase the attractiveness of a joint OPEC "monopoly" pricing strategy, increasing both the price- and production level of the

TABLE 7-18

OPEC AND AN "INCOME STABILIZING" FRINGE (CARTEL 18)

PRODUCTION MMB/D

	OPEC	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	28.5050	5.13402	10.3271	14.9448
1975	27.8755	4.85035	9.75044	13.2688
1976	27.2005	4.7501	9.55401	12.8045
1977	26.8728	4.87551	9.48477	12.7805
1978	26.7284	8.48677	11.4983	7.91325
1979	24.7587	8.909	12.505	8.28976
1980	25.6881	9.17918	12.2183	4.5006
1981	29.7182	5.90636	7.91689	18.3329
1982	31.8457	5.80612	7.98957	17.973
1983	31.0309	5.85203	7.47288	17.3091
1984	33.091	5.97825	7.79124	19.5856
1985	35.0692	6.27955	8.45882	20.7838
1986	37.1479	6.59761	8.34201	22.2077
1987	39.1328	6.90214	8.56667	23.2538
1988	42.1456	7.36163	9.03754	25.7486
1989	41.5267	7.1041	8.70308	25.0295
1990	39.8007	6.85095	8.1693	24.8484

	"Market Price"
1974	0.
1975	0.
1976	0.
1977	0.
1978	0.
1979	.99525
1980	4.73104
1981	12.0153
1982	11.3588
1983	12.1402
1984	12.5049
1985	13.0739
1986	13.5488
1987	14.0309
1988	14.5919
1989	15.0224
1990	15.5247

TABLE 7-19

"INCOME STABILIZING" FRINGE AND UNCERTAINTY (CARTEL 19)

PRODUCTION MMB/D

	OPEC	"Expansionist Fringe"	"Price Pushers"	"Cartel Core"
1974	29.565	5.14431	10.3477	14.072
1975	28.1058	4.88041	9.83704	13.379
1976	27.7185	4.8232	9.70103	13.194
1977	27.4105	4.77281	9.58646	13.051
1978	27.4128	8.67523	11.3528	7.384
1979	24.6806	9.962	12.505	2.213
1980	24.337	9.18742	12.2127	2.937
1981	32.1362	7.63641	6.05977	18.44
1982	31.8358	7.53124	5.96657	18.337
1983	31.8104	7.84267	6.11464	17.853
1984	33.0808	8.7714	6.75141	17.558
1985	34.8650	9.7471	7.38275	17.735
1986	37.7404	10.7560	8.45094	17.552
1987	38.5595	11.7844	8.7754	18.000
1988	40.7780	13.0250	9.44992	18.302
1989	41.6193	13.9008	9.93165	17.788
1990	41.7854	14.6015	10.2719	16.912

	Market Price	Expected Price	"Price-War Price"	Long-Term Competitive Price
1974	0.	9.07585	1.01632	3.45247
1975	0.	9.50385	0.377444	2.71260
1976	0.	8.5094	-0.003953	3.00892
1977	0.	8.7536	-0.3649	3.20801
1978	0.	8.04517	-0.854045	3.45492
1979	3.67407	6.90116	-1.31064	3.67407
1980	4.2037	7.50051	-1.13685	4.2037
1981	14.031	11.5793	0.965602	4.53597
1982	13.8635	11.4778	0.652003	4.30967
1983	14.8680	12.115	0.220511	4.25030
1984	15.3721	12.5628	0.180827	5.18077
1985	16.3507	13.0617	0.260000	5.53082
1986	17.0858	13.5335	0.300472	5.91023
1987	17.0133	14.0135	0.67586	6.35730
1988	18.5595	14.5006	1.0082	6.80007
1989	19.3003	14.9962	1.12063	7.25971
1990	20.0656	15.4980	1.02455	7.72808

OPEC-countries, and consequently, the income level of these countries.

If the non-cartel market participants adjust their consumption- and production-equipment to an expected price level that is below the price currently charged by the cartel, then such behavior will have a price effect similar to that of an income stabilizing exporter fringe. That is, the cartel can charge a higher price and will be able to produce a larger quantity than otherwise would have been the case.

In Table 7-19 a scenario is listed, Cartel 19, that adds uncertainty as defined in Section 5.2.9 to the income stabilizing case of Cartel 18 in Table 7-18. It is assumed that the expected price, $E(P)^t$, is a weighted average of the long-term competitive price, PC^t, the stable price-path, \$9, the back stop technology price, \$16, and the joint OPEC price $p4^t$, and the OPEC subunit prices of the "price-pushers" and the cartel core, $p5^t$, and of the "cartel core" alone, $p3^t$, as well as the current price, p^t, in the following way;

$$E(P)^t = 0.1xPC^t+0.1x16+0.1xP4^t+0.1xP5^t+0.1xP3^t+0.4xP^t + 0.1 \times 9$$

The expected price of Table 7-19 is approximately equal to the actual price of Table 7-18, (which it is supposed to be) except for the slight disturbance of the higher expected price in the two breakdown years. The actual price of Table 7-19 is more than 20% higher than the actual price of Table 7-18. The quantity of Table 7-19 is also larger than that of Table 7-18 due to the decreased production of the income stabilizers associated with the higher actual price.

The tendency of some countries to behave as income stabilizers, and the energy market participants' unwillingness to commit themselves to capital equipment reflecting the current price may help stabilize the OPEC cartel and also help sustain a price level even higher than the current level.

7.3 Conclusion

7.3.1 The International Petroleum Market

The structure of the international petroleum market is oligopolistic. The lack of a unique solution concept for oligopolistic markets makes a bewildering number of price levels plausible outcomes of the oligopolists' market strategies. There is no uniquely rational behavior that can be specified for an individual ologopolist, since the most profitable behavior for one seller depends on the response of the others. When the product is relatively homogenous, as is crude oil, the demand for the industry's product is inelastic whereas the demand for any single supplier output is highly inelastic, as is also the case for oil , then the range of possible price outcomes is even broader. In such a case the incentive to organize a cartel as well as the incentive to chisel is large. But even the most successful cartels tend not to survive for more than four to six years.

The lack of a uniquely rational behavior for an oligopolist makes it difficult to formulate formal models for oligopolistic markets. The "bathtub" model is therefore a simulation model of a flexible nature. The

form of the relationships constructed is simple enough to assure that an analytic expression for the market equilibrating price can be deducted under the various combinations of market strategies to be observed.

The cost conditions and the price-responsiveness assumed in this study are "pessimistic" in the sense that they tend to bias the monopoly or the collusive price upwards. The fact that the end 1979 proven recoverable reserves are used as a proxy for ultimately recoverable reserves also biases the collusive price upwards. The opportunity cost of oil as measured by the net present value equivalent of the back-stop technology price will thereby be biased upwards.

The major determinants of the future of the international petroleum market, as they emerge from the "stories" told by simulating the two versions of the "bathtub" model, are the composition and the cohesiveness of the colluding exporter group , the degree of non-price-taking behavior on the part of the non-colluding exporters, as well as the perceived level of uncertainty with respect to the future level of price in the Persian Gulf. Given the theoretical and empirical instability of cartel-dominated markets, the heterogeneity of the OPEC countries, as well as the incentives to chisel at a cartel determined price level and to establish a cartel at a competitive price level, the general conclusion is that the future price of oil is likely to fluctuate, and that the magnitude of the fluctuations will be determined by the composition of the colluding group, the degree of non-competitive exporter behavior, and the level of uncertainty in the market.

The price range in any given year is likely to increase over time. The most likely 1975-1985 price range as projected under conservative price-responsiveness assumptions is $4 to $15 in 1972 dollars. The mean of the distribution of expected price outcomes is in the upper half of this range due to the considerable incentives to re-establish OPEC in the case of a break-down.

The OPEC countries will have to learn to live with a considerable level of excess capacity. It seems unlikely that OPEC production will reach more than 80% of the existing capacity of J8 MMB/D in the 1980-1985 period. The lack of systems for allocating productive capacity within OPEC may make the level of excess capacity even higher.

7.3.2 The "Bathtub" Model

The uncertainty with respect to the kind of behavior that will be observed in the international petroleum market, and the desire to evaluate a number of market strategies within the same model framework led to the simple structure of the "Bathtub" model. To be able to perform a number of experiments inexpensively, linear approximations, allowing an analytic expression for the market clearing price to be deducted, were constructed to the relationships we know are much more complex. As part of the National Science Foundation project "Analysis of the World Oil Market," more complex relationships will be introduced in the "Bathtub" model by attaching sub-routines to perform a piecewise linearization of the appropriate relationships or to solve numerically for the market clearing price when the relationships constructed do not allow an analytic

expression for the market clearing price to be deducted. By attaching optimizing sub-routines more cartel strategies may also be added. The "optimal" short-term exploitation of a newly monopolized market may be deducted from an optimizing sub-routine. Such sub-routines seem to indicate that the "optimal" price path implies a higher price in the initial rather than in the later years. The approximations to the"long-term monopoly price" in the "bathtub" model do not capture these short-term aspects of monopoly-pricing. Short-term exploitation of market power will most likely imply a higher price in the initial years and a lower price in the later years than the "bathtub" "Monopoly" price path under the same assumptions about the expected price.

The linearity assumed introduces biases in the calculations of the various quota systems. A more realistic representation of production costs would most likely increase the production share of the cartel core in the monopoly case, and also increase the level of joint profits. The composition of the three cartel units has been kept constant. Both the composition of the above-mentioned three cartel units and the number of and the characteristics of the cartel units may be changed to produce a number of additional intra-cartel scenarios. A number of additional "stories" may therefore be told to explore for necessary and sufficient conditions for cartel stability.

The major consumer countries, the importer regions, were assumed to behave as price-takers. Consumer country policies have affected the success of international commodity cartels. By introducing traditional

consumer-country policies like tariffs, quotas, taxes, and subsidies some likely necessary and sufficient conditions for cartel stability may be identified under these more complex circumstances. Such consumer country policies will be introduced in the "bathtub" model in the immediate future as part of the above-mentioned world oil project.

Even if there is ample room for improvements of the "bathtub" model in terms of a more realistic representation of the international petroleum market in a world energy market context, the major determinants of the future of the international petroleum market and the relative significance of these determinants as identified in the existing versions of the "bathtub" model are not expected to change. The major determinants of the future of the international petroleum market are the composition and the cohesiveness of the colluding exporter group; the degree of non-price-taking behavior on the part of the non-colluding exporters, as well as the perceived level of uncertainty with respect to the future level of price in the Persian Gulf.

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