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FUTURE WORLD OIL PRICES: MODELING METHODOLOGIES AND SUMMARY OF RECENT FORECASTS

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ABSTRACT

This paper has three main objectives. First, the various methodologies that have been developed to explain historical oil price changes and forecast future price trends are reviewed and summarized. Second, the paper summarizes recent world oil price forecasts, and, when possible, discusses the methodologies used in formulating those forecasts. Third, utilizing conclusions from the reviews of the modeling methodologies and the recent price forecasts, in combination with an assessment of recent and projected oil market trends, oil price projections are given for the time period 1987 to 2022.

The paper argues that modeling methodologies have undergone significant evolution during the past decade as modelers increasingly recognize the complex and constantly changing structure of the world oil market. Unfortunately, at this point in time a consensus about the appropriate methodology to use in formulating oil price forecasts is yet to be reached. There is, however, a general movement toward the opinion that both economic and political factors should be considered when making price projections.

Likewise, there is no consensus about future oil price trends. Forecasts differ widely. However, in general, forecasts have been adjusted downwardly in recent years. Further, an overall assessment of the forecasts and recent oil market trends suggests that oil prices will remain constant in real terms for the remainder of the 1980s. Real oil prices are expected to increase by between 2 and 3 percent during the 1990s and beyond. Forecasters are quick to point out, however, that all forecasts are subject to significant uncertainty.

1. INTRODUCTION

Between the years 1973 and 1982 the nominal price of oil on the world market increased by more than 1600 percent -- from $2.10 to $34.00 per barrel.[1] Further, the price increases were sudden and sharp, increasing from $2.10 to $9.60 per barrel between January 1973 and January 1974 and from $13.34 to $26.00 per barrel between January 1979 to January 1980. These price escalations -- both in terms of their size and their occurrence over a relatively short time period -- have caused, and continue to cause, significant impacts on economic activity, social structures, government programs, and international relations. These price escalations and their resulting impacts have also spawned a host of studies that espouse particular methodologies for explaining historical price changes, as well as for forecasting future price trends. Yet more than ten years after the start of the so called "Energy Crisis" there exists little consensus about how the world oil market functions and, more specifically, how world oil prices are determined. This is not an unexpected outcome, given the accuracy of previous forecasts. Further, the poor accuracy of previous forecasts is not altogether surprising, given that the modeling assumptions used in those forecasts did not reflect the unexpected -- and what most would argue were unpredictable -- market disruptions of 1973-74 and 1979-80. Work continues to study the structure of the world oil market and the mechanism by which oil

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[1] Price quotes are for Saudi Arabia light crude, the official marker crude for the Organization of Petroleum Exporting Countries (OPEC).

prices are determined. Work also continues to forecast oil prices using models with widely divergent underlying assumptions.

The purposes of this paper are threefold. First, the paper reviews and summarizes the various methodologies that have evolved to explain historical oil price changes and to forecast future price trends. Second, the paper summarizes the numerous world oil price forecasts that have appeared in recent years and identifies, when possible, the methodologies and underlying assumptions used in formulating those forecasts. Third, utilizing the conclusions drawn from the reviews of the modeling methodologies and the recent price forecasts, in combination with an assessment of recent and projected oil market trends, oil price projections are given for the time period 1987 to 2022.

Since the oil price shock of 1973, numerous theories and models have been developed that supposedly represent the functioning of the world oil market. In Chapter 2 these various views of the oil market are reviewed and categorized into three major groups -- economic models, political models, and models that combine aspects of the two approaches. Under each of these three main headings there is additional disaggregation to reflect different objective functions, structural assumptions about the world oil market, and so forth. Given the large number of oil models, it is not feasible -- nor necessarily productive -- to attempt to review each individual model. Rather, this review points out commonalities among the models and methodologies with the purposes of (1) suggesting the relevant players that determine the price of world oil, (2) suggesting the objective functions of those players, and

(3) suggesting the degree to which each of the players is able to manipulate the market to maximize or satisfy their objectives. Another important aspect of this review is the identification of the major parameters that have impacted, and can be expected to impact, world oil prices under the different methodologies. As will become apparent, there are numerous ways that the world oil market can be modeled. Further, each of those approaches have certain credibilities -- as well as handicaps -- in explaining historical oil price changes. However, different methodologies may suggest very different reasons why oil prices may have changed in the past and why prices may change in the future. Depending upon how one characterizes the world oil market, the implications for how future oil prices may change are quite different.

In Chapter 3 the numerous oil price forecasts that have been published in recent years are reviewed and summarized. In addition to reporting how different forecasters view future oil price trends, the chapter identifies, where possible, the modeling methodologies and assumptions about key parameters used to obtain the forecasts. Of particular importance are the sensitivities of the different forecasts to changes in major input parameters. An additional point of interest is how forecasts of mid-term and long-term oil prices have changed since the official oil price reduction of 1983.

In the final chapter the conclusions from Chapters 2 and 3 are used in combination with an assessment of current and projected oil market conditions to select high, medium, and low oil price projections for the time period 1987 to 2022. In addition to

selecting business-as-usual price paths -- i.e., paths for which the basic structure of the world oil market remains unchanged -- two price paths representing the breakup of the oil cartel and the occurrence of a significant oil supply disruption are discussed.

2. METHODOLOGIES TO EXPLAIN WORLD OIL PRICE BEHAVIOR

I. Introduction

This chapter reviews and summarizes the various methodologies that have been developed to explain historical world oil price changes and forecast future oil price trends. The methodologies are categorized into one of three broad groups -- (1) economic, (2) political, and (3) economic-political combinations. In addition to explaining how the different methodologies view the relevant players in the world oil market and the objective functions of those players (if any), the review identifies the major parameters relevant to each major methodology that are argued to have impacted, and are expected to impact, world oil prices.

However, before those methodologies are addressed in detail, a brief historical review of major developments in the world oil market is necessary to understand why particular methodologies have evolved. That review is presented in the next section.

II. A Brief Overview of Historical Changes in the World Oil Market

For our purposes the post-OPEC era of the world oil market can be divided into three time periods -- 1960-73, 1973-81, and 1981 to the present. An examination of each of these periods spells significant changes not only in the levels of world oil prices, but also for the relevant players and market structural conditions under which those players acted individually or as a group to determine or at least impact world oil prices.

A. The 1960-73 Time Period

The Organization of Petroleum Exporting Countries (OPEC) was formed in 1960 and consisted of five members -- Iran, Iraq, Kuwait, Venezuela, and Saudi Arabia. At the time of the formation of OPEC, the oil producing nations within OPEC, and the other oil producers that would later join the organization, had little power over production decisions within their own nations, and of course even less influence on world oil prices. During the 1950s and most of the 1960s the production and trade of oil from the (to become) OPEC countries was controlled to a great extent by the major international oil companies. World oil prices were generally below the $2.00 per barrel level and international oil companies held a very high equity interest in the crude production of the major OPEC producers. The taxes received by the producing countries from the production of a barrel of oil were very low.

The objectives of OPEC in its early years were rather unambitious as compared to later years. The producing countries attempted to (1) gain control over the level of production in their own countries, (2) change the tax system by which the producing countries received revenues from the major oil companies so as to increase the total revenues to the producing countries, and (3) gain greater equity interest in the production operations in their own countries. However, to a great extent the producing countries did not begin to effectively use their international power until around 1970. For example, in January 1970 the new radical Libyan government forced -- or threatened with nationalization -- the international oil companies operating within Libya to renegotiate

their oil prices. This event was probably most important in that it provided a rallying point for other oil producers and brought the realization that the producing countries had considerable power to impact the oil market. Later in 1970 both Algeria and Iraq won concessions from the oil companies over prices and investment plans. These events seemed to set off a series of successful price and benefit demands made by the producing countries.

The major point to note from the review of this period is that the major oil producing countries gained significant power in determining both the price and production of oil in their own countries and therefore became a new and powerful player in the determination of world oil prices. In other words, there was a change in (1) the relevant players in the determination of oil prices, (2) the feasible objectives of those players, and (3) the abilities of the different players to manipulate the market, or at least their segments of the market, to realize those objectives. Although the feasible objectives of OPEC remained limited -- compared to future standards -- the organization had become a power to be dealt with in the world oil market.

B. The 1973-81 Time Period

Between the years 1973 to 1981 the world oil market changed tremendously. Previous to the major events of 1973-74 the producing countries had attempted to obtain a larger share of the economic rents that had gone to either the international oil companies or to the treasuries of the consuming countries in the form of taxes. (Prices of petroleum products were much higher during the 1960s and early 1970s than could be accounted for by

crude prices. For example, prices for gasoline in Europe were in the $30.00 per barrel price range reflecting high domestic tax levels.) After 1973 the producing countries not only continued to transfer the wealth that was previously obtained by the oil companies and the governments of consuming countries, but also obtained additional wealth by directly increasing the price of crude to consuming countries.

The first major price jolt of the 1970s came in October 1973 when six major Persian Gulf producers -- Abu Dhabi, Iran, Iraq, Kuwait, Qatar, and Saudi Arabia -- agreed to raise the posted price of Saudi marker crude from $3.01 to $5.12 per barrel. Then in January 1974 the Organization of Arab Petroleum Exporting Countries (OAPEC) further raised the posted price of Saudi marker crude to $11.65 per barrel, reflecting more than a 380 percent increase in posted prices over the pre-October level. These huge price increases, of course, occurred during the time of the Arab oil embargo against oil sales to the United States and the Netherlands because of their support of Israel in the 1973 Arab-Israeli War. However, close investigation of that embargo shows that although approximately 98 percent of the oil from OAPEC producers was halted to the U.S., increased imports from other sources helped to mitigate the impacts of the embargo. One factor that helped reduce the impacts of the embargo on physical flows of oil was the fairly good control that the major oil companies retained over the distribution of world oil. While OAPEC oil could not be sent to embargoed countries (because of threats from the oil producing

countries), other oil could easily be rerouted to the U.S. and the Netherlands.

Simultaneously, several producers reduced production in response to the embargo. In October 1973 Saudi Arabia, Kuwait, Dubai, and Algeria cut production by over 5 percent. These same countries cut production by a minimum of 25 percent in November 1973, and both Abu Dhabi and Qatar came very close to these targets during the same time period. However, production cutbacks began to diminish in December. By January 1974 production cutbacks in these countries were only about 10 percent. Further, it is interesting to note that not all OPEC countries participated in the production cutbacks and some even increased production. For example, Libya, a major supporter of the embargo, met the OAPEC mandated 25 percent reduction only in November. Production actually increased by about 4 percent in Iran, Indonesia, and Nigeria. Therefore, the rather moderate production cutback was maintained for only about three months and was not shared equally by all OPEC members.

The period 1975 to 1978 was relatively tranquil as the world attempted to adjust to the huge price increases of 1973 and 1974. In nominal terms world oil prices continued to increase at between 5 and 10 percent per year, while in real terms the price of oil actually declined.

The second major jolt to world oil prices followed the start of the Iranian Revolution in late 1978. Oil exports from Iran were reduced in September 1978 and by December 1978 virtually all Iranian oil exports had halted. However, in terms of total free-world oil production, the Iranian Revolution did not result in

large production losses due to production increases in non-disrupted countries. While total free-world production was reduced by about 4.5 percent between December 1978 and January 1979, free-world production was very nearly back to its pre-disruption level by March 1979.

Therefore, as was the case in 1973-74, the disruption was not long term or severe. However, the oil price changes that resulted during this time period were severe. Between July 1978 and January 1981 the official price of Saudi light crude increased from $12.70 to $32.00 per barrel. Various arguments have been put forth to explain these huge escalations. Certainly, production reductions by Saudi Arabia during this time period contributed to the increases. Further, some have argued that between the disruption of 1973-74 and the Iranian Revolution of 1978 there was a major structural change in the role of the major oil companies in the production and distribution of oil from the OPEC countries. It is argued that less control over the distribution of available oil by the major oil companies led to increased competition for available oil on the spot market, drastically increasing spot prices, and eventually leading to official price escalations.

Whatever the underlying reasons for the price increases, some obvious market structural changes occurred during the 1973 to 1981 time period. First, OPEC, and the OAPEC countries in particular, gained tremendous market power as compared to the previous era. No longer was OPEC an organization that attempted to siphon off oil wealth that had previously gone to consuming countries and major oil companies. OPEC, or at least a subset thereof, was now the

leader of the world oil market with power to make production decisions, if not in fact to set oil prices. Second, the OPEC countries with their newfound oil wealth had begun ambitious development programs that not only changed the nature of their economic and social structures, but also demanded the continuation of large infusions of oil revenues if those programs were to continue. Third, the major oil companies had lost much of their ability to control the distribution of crude and in so doing had lost some ability to "smooth out" short-term and relatively minor supply disruptions. Finally, oil consumers and non-OPEC producers had begun the long adjustment process to the huge price increases of the 1970s and early 1980s.

However, the oil producing nations clearly maintained control of the world oil market, despite the facts that oil consumption was being reduced through capital replacement, factor substitution, etc., and non-OPEC production was on the rise. The relative power of the players in the determination of world oil prices had changed, and with that change came drastic escalations in world oil prices.

C. The 1981 to Present Time Period

Although throughout the 1970s the price of crude on the world market appeared to be downwardly rigid -- at least in nominal terms -- a series of events began around the first part of 1981 that suggested a reduction in the strength of OPEC in relation to non-OPEC oil producers and major consuming countries. In September 1980 fighting began between two OPEC members -- Iran and Iraq -- resulting in drastic reductions in exports from those countries.

Iranian exports decreased by about 1 million barrels per day -- Iraq's by about 3 million barrels per day. While the size of the disruption in percentage terms was about the same as that accompanying the Iranian Revolution -- about 4 to 5 percent of free-world production -- the impact on the price of oil was significantly less. There are several reasons prices did not escalate as during previous disruptions. Certainly, the record level of oil stocks at the outbreak of the war contributed to the calm. Further, the consumption of oil in the world market was decreasing as a result of a worldwide economic slowdown and as a result of the addition of more efficient fuel use capacity. For example, U.S. consumption of refined products decreased from a peak of 18.8 million barrels per day in 1978 to 15.3 million barrels per day in 1982. World consumption decreased from a peak of 65.1 million barrels per day in 1979 to 58.9 million barrels per day in 1982. In addition, non-OPEC producers had responded to the huge price increases of the 1970s by sharply increasing their own production levels. While total OPEC production decreased from a high of about 31 million barrels per day in 1979 to 17.3 million barrels per day in May 1984. production in non-OPEC, free-world countries increased from 17.6 to 21.5 million barrels per day during the same time period. In addition, the Soviet Union increased oil exports to the free world from 1.28 to 1.54 million barrels per day between 1980 and 1982.

The pressures exerted on OPEC's pricing structure by non-OPEC production increases and decreases in worldwide oil consumption resulted in an increasing discrepancy between official OPEC prices

and crude prices on the spot market. In response to these pressures OPEC met in March 1983 and announced a $5 reduction in their benchmark price from $34 to $29 per barrel. At the same meeting OPEC agreed to set an overall output ceiling for the organization at 17.5 million barrels per day, with the majority of the production constraints being borne by the major oil producers of the Persian Gulf.

While the actions taken by OPEC at the March 1983 meeting helped to stabilize oil prices and prevent further erosion of OPEC's powerbase, other problems threatened OPEC's future control of the world oil market. For example, to maintain the ambitious development programs begun by many of the oil producers in the 1970s, large inflows of oil revenues were needed. However, because of increased competition from non-OPEC producers, oil demand reductions, and the official OPEC price reduction, some development programs were threatened. These pressures resulted in increased competition among the OPEC members for oil sales. In recent years, pressures have been most severe in the OPEC countries with larger populations -- e.g., Iran, Iraq, Indonesia, Nigeria, and Venezuela. In addition, both Iran and Iraq have required large inflows of oil revenues to maintain their continuing war. According to a recent report (Chase Manhattan Bank, 1984) OPEC as a whole experienced an account deficit of $16.5 billion in 1982 and $21.5 billion in 1983.

As a result of these and other pressures, OPEC has in recent months experienced difficulty in maintaining its official production ceiling of 17.5 million barrels per day. In the last quarter of 1983 total OPEC production exceeded 19 million barrels

per day putting additional pressure on OPEC's official price structure. More recently, certain OPEC members have officially or in effect reduced their prices below the official price levels -- Nigeria, Iran, and Iraq being cases in point. Pressures on official OPEC prices from overproduction continue at the time of this writing. For example, price reductions by Norway and Great Britain have placed additional pressures on Nigeria which produces crude of a similar type.

Therefore, since 1981 there have been changes in the structure of the world oil market that have impacted world oil prices. Reactions by non-OPEC producers and oil demanders to the severe price increases of the 1970s forced both reductions in official OPEC prices and the imposition of production ceilings on OPEC members. As a result, oil revenue reductions have threatened development programs and in some cases government stability -- for example, the recent coup in Nigeria. Further, the threat of severe and sudden oil price escalations resulting from supply disruptions has diminished as productive capacity far exceeds production. Although to date the core members of OPEC -- mainly Saudi Arabia -- have maintained their base price of $29 per barrel by absorbing the majority of the necessary production reductions, several OPEC members continue to cheat in terms of both prices and production levels. The cohesion of OPEC in the post-1981 era has been shaken

and with that change have come significant reductions in world oil prices.[2]

Table 2.1 gives the historical changes in the official price of Saudi Arabian light crude and Nigerian crude from 1973 to the current time period. The prices of other crudes vary depending on their respective qualities.

III. Methodologies Developed to Explain and Forecast Oil Prices

The methodologies that have been developed to represent the functioning of the world oil market draw significantly from the modeler's discipline and his or her perception of history. At the risk of oversimplification, this section summarizes three main categories of models that have been used to explain historic world oil price changes and, in some cases, used to forecast future oil price trends. As stated earlier, an indepth account of each model will not be attempted because of the sheer number of models and because such an exercise would probably, for our purposes, contribute little to a better understanding of world oil price forecasts. Rather, models or methodologies are placed in one of the three major groups discussed above -- (1) economic models, (2) political models, and (3) economic-political combination models. Figure 2.1 gives a graphical representation of the disaggregation

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[2] Historical accounts of developments in the world oil market are available from numerous sources. See, for example, Deese and Nye (1981), Vernon (1976), Landis and Klass (1980), Bohi and Russell (1978), Curlee (1983), Johany (1980), and Griffin and Teece (1982). For more recent assessments of the world oil market and how recent trends may signal future changes in the structure of the market, see, for example, Bohi and Quandt (1984), Horwich and Weimer (1984), Weyant (1983), Kash, Fox, and Wilbanks (1983), and Curlee (1984).

Table 2.1. Official prices of Saudi Arabian light and Nigerian crude for selected dates (Nominal dollars per barrel)

TIME	SAUDI LIGHT	NIGERIAN
JANUARY 1973	$2.10	$3.10
DECEMBER 1973	$3.60	$5.84
JANUARY 1974	$9.60	$12.60
JULY 1974	$10.40	$11.85
JANUARY 1975	$10.46	$11.80
JUNE 1976	$11.51	$12.89
JUNE 1977	$12.70	$14.63
JULY 1978	$12.70	$13.87
JULY 1979	$18.00	$23.49
JULY 1980	$28.00	$37.02
JULY 1981	$32.00	$39.92
JANUARY 1982	$34.00	$36.52
MARCH 1983	$29.00	$30.00
JULY 1984	$29.00	$29.85

SOURCES: American Petroleum Institute (1984)
Central Intelligence Agency (1984)
Curlee (1983)

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JULY 1978	$12.70	$13.87
JULY 1979	$18.00	$23.49
JULY 1980	$28.00	$37.02
JULY 1981	$32.00	$39.92
JANUARY 1982	$34.00	$36.52
MARCH 1983	$29.00	$30.00
JULY 1984	$29.00	$29.85

SOURCES: American Petroleum Institute (1984)
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Curlee (1983)

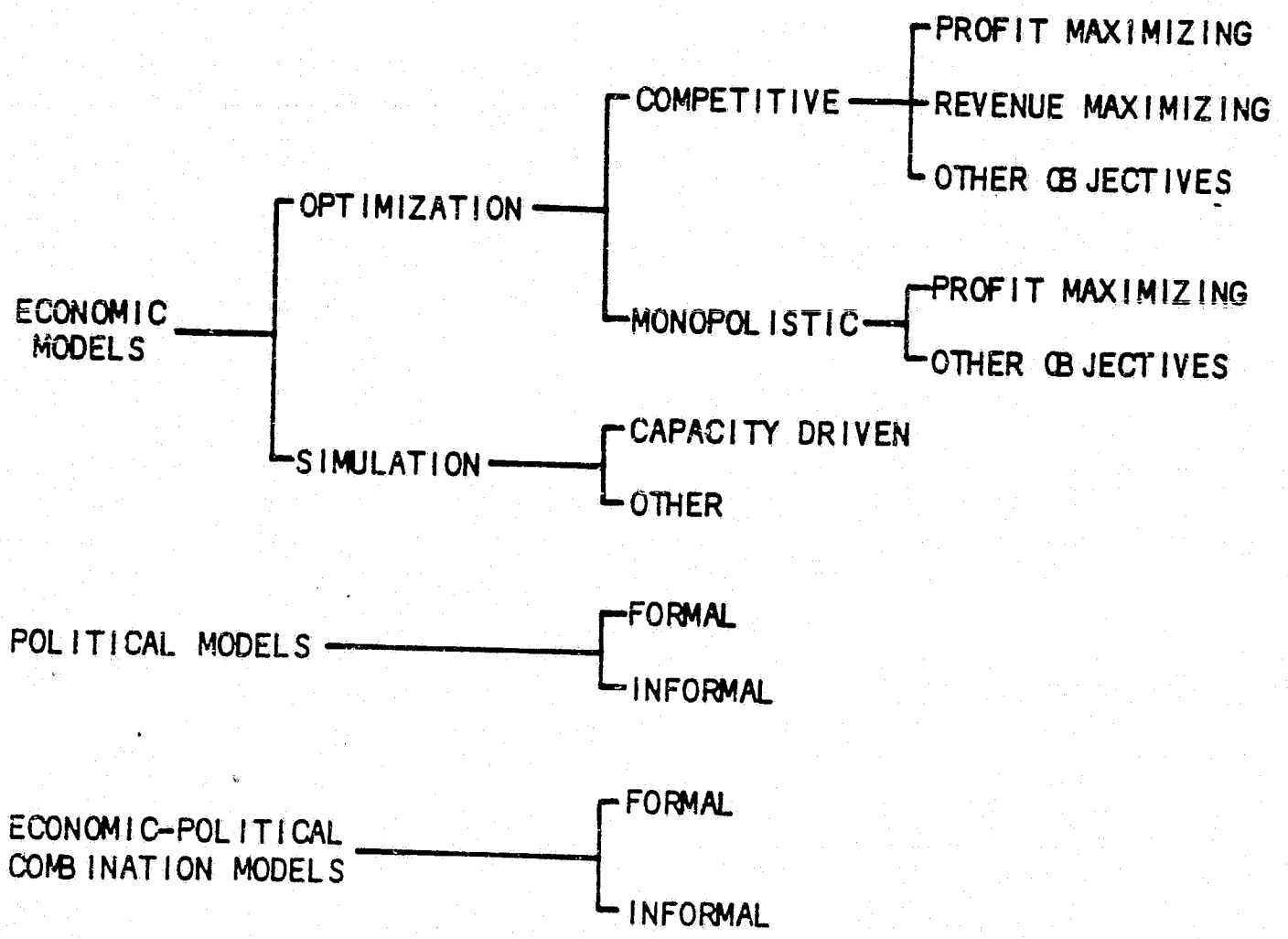

Fig. 2.1 Methodologies to forecast world oil prices

of the three major modeling types into various subcategories. The key market and non-market parameters that are hypothesized to impact oil prices under each group of methodologies are subsequently identified.

A. Economic Models

Economic models of the world oil market can be divided into two broad subgroups -- optimization models and simulation models. In optimization models some part of the oil market is assumed to have foresight of future market conditions and alters their production and/or pricing decisions to maximize some given objective function. For example, in many models the objective function is discounted profits. In simulation models price changes are assumed to be determined by some set of market or non-market parameters over which no explicit control is exercised by any subset of the oil market. For example, in many simulation models it is assumed that world oil prices are determined by the level of excess production capacity in the OPEC countries or a subset thereof (where the level of production capacity is set exogenously).

1. Optimization Models

The majority of the optimization models assume that OPEC, or a subset of OPEC, sets production in order to maximize the stream of discounted profits from the production of their oil reserves. The selection of the optimal production stream is dependent upon numerous parameters, the identification of which requires a brief review of the economics of depletable resources.

The depletable resources literature is based on the 1931 seminal article by Hotelling. In that article Hotelling describes how a resource owner with zero production costs will produce over time under both competitive and monopolistic market conditions. From elementary economics it can easily be shown that in a competitive market price will be equal to marginal cost. However, in the case of a depletable resource the marginal cost of the resource is not just the marginal cost of production. In essence the owner of a depletable resource is faced with the question of when to produce the resource. Therefore, in addition to the actual cost of production, the resource owner must also consider the opportunity cost of producing the resource today at the expense of not producing the resource tomorrow or, alternatively, producing tomorrow at the expense of not producing today. In the simplified case that Hotelling considered where production costs are zero and resources are fixed, it can be shown that the price of the depletable resource must rise at the rate of interest in a competitive market. Intuitively, this conclusion is obvious because in equilibrium the value of the resource in the ground must be equal to the value of the resource being produced. The owner of the resource has the option of producing the resource today and investing the payment for that resource at the market rate of interest, or the owner can leave the resource in the ground and have the value of the resource increase at the market rate of interest. In equilibrium the resource owner will be indifferent between the two choices.

In the case of a monopoly that controls the resource base, it can be shown that the monopolist (under the same simplifying assumptions given above) will maximize profits when marginal revenue, which will be less than price, rises at the market rate of interest. This is a straightforward extension of the argument for the competitive case with the addition of the profit maximizing condition for monopolists -- i.e., profits are maximized when marginal revenue is equal to marginal cost. An interesting extension of the monopoly argument shows that the monopoly -- facing a demand function with price elasticity other than unity -- will produce less and price higher in the first time periods of production and will produce more and price lower in the later time periods of production as compared to a competitive market. The monopoly thus promotes resource conservation.

Since Hotelling's seminal article, numerous papers have extended this basic methodology to account for some of the simplifying assumptions made by Hotelling -- for example, by including positive and increasing resource production costs, accounting for the possibility of reserve additions, or including a backstop technology or good that would replace the resource in question at some backstop price. Depending on which assumptions are relaxed, the analysis can become quite complicated.

Again at the risk of oversimplification, the major parameters that determine the price of the depletable resource under profit maximizing conditions can be categorized in a few groups. The major parameters of concern are (1) the size of the resource base, (2) the rate of interest or the discount rate, (3) the backstop

price, (4) the long-run and short-run price elasticity of demand and supply of the resource, (5) the rate of world economic growth and how that growth translates into changes in demand for the resource, and (6) the speed at which the market adjusts to changes in market prices and economic activity.

In the mid 1970s the economics profession generally modeled the world oil market by assuming that OPEC or the core countries within OPEC -- i.e., countries such as Saudi Arabia that have vast and low-cost reserves as compared to other OPEC countries -- effectively cartelized the market. It was assumed that by restricting production these producing countries could in effect set the price of world oil such that their discounted profits were maximized. Supposedly, once the oil cartel gained control of the oil market in the early 1970s, production and pricing decisions were made by the producing countries so as to move from the previous competitive price and production trajectories to the higher-priced and lower-production trajectories dictated by monopolistic profit maximization. Models that fall into this category include Pindyck (1978), Kalymon (1975), Cremer and Weitzman (1976). Gately, Kyle, and Fisher (1977), and Singer (1982). There are also numerous models that are variations of the basic monopolistic profit maximizing approaches. Hnyilicza and Pindyck (1976), Eckbo (1976), and the Salant/ICF Model (see EMF, 1982) address the inherent problems faced by any cartel that arise from bargaining over pricing and production decisions. Because of varying economic and social concerns in different countries within the cartel, different members will have different perceptions about

which production and price paths are optimal. These models use game theory to study bargaining within the cartel and identify side payments that may be necessary to maintain the cohesion of the cartel.

In contradiction to the methodologies discussed above, numerous modelers have argued that one does not necessarily have to assume that OPEC or a subset of OPEC acts as a monopolistic profit maximizer to explain historic oil price increases or to forecast future price trends. MacAvoy (1982) has argued that the price increases of 1973-74 were unavoidable even under competitive conditions, given the very tight oil markets that had resulted from very low historic oil prices.

Some modelers argue that the drastic historical price changes can be explained within a competitive market in which the control of the resource base shifted from international oil companies to the oil producing countries. For example, Johany (1980) has argued that the price increases of the early 1970s were a natural result of the transfer of the property rights to oil from the multinational oil companies to the producing countries. It can be argued that the international oil companies made decisions based on a high discount rate previous to the early 1970s because of fears of expropriation. Once property rights were transferred to the producing countries, their lower discount rates naturally translated into lower levels of production and higher oil prices.

Another variant of the competitive argument is based on the ability of the producing countries to absorb the revenues from their oil sales. This is the basic approach taken in Teese (1982),

Cremer and Salehi-Isfahani (1980), Mead (1979), and Ezzati (1976). These models in effect argue for a backward bending supply curve for the major oil producing countries. The higher the oil price goes, the less the major producing countries produce because they have no ability to utilize the increased revenues. This position has been criticized on the basis that the producing countries must assume that oil in the ground is worth more that "money in the bank." The proponents of this position counter this criticism by arguing that investments made by producing countries in consuming countries are always subject to threats of expropriation, thus decreasing the relative value of "money in the bank."

Other variations of the competitive framework also exist. Blitzer, Meeraus, and Stoutzesdyk (1975) argue that the major producing countries attempt to satisfy the dual objectives of the maintenance of market share and high current revenues. In the ETA/Macro Model (see EMF-6, 1982), the basic objective is to maximize the discounted utility of oil consumption in OECD (Organization of Economic Cooperation and Development) countries. Oil prices are a function of OECD imports. In the Kennedy-Nehring Model (see EMF-6, 1982) it is assumed that the competitive non-OPEC conventional oil producers have perfect foresight and act to maximize discounted profits. OPEC production is determined exogenously.

2. Simulation Models

The majority of models used today to forecast world oil prices do not employ the optimization approach discussed above. Rather, simulation models -- which do not directly assume that a subset of

the oil market manipulates oil production or prices to satisfy some objective -- are used to forecast oil prices and other key oil market parameters.

These simulation models often employ a simplistic methodology in determining world oil prices -- as compared to the optimization approaches discussed above. The most common assumption about oil price determination is that prices rise when capacity utilization in the OPEC countries rises above some prescribed level -- usually about 85 percent. At some capacity utilization level below 85 percent the price of oil is assumed to decline. The level of OPEC production capacity is usually an exogenous input. Models that fall within this category include Gately (1983), Levy (1974), OMS (DOE, 1983), OILMAR (see EMF-6, 1982), DRI (1983), WOIL (see EMF-6, 1982), Braden (1981), Gately, Kyle, and Fisher (see EMF-6, 1982), Opeconomics (see EMF-6, 1982), and Oiltank (see EMF-6, 1982).

There are also models that have variations of this basic theme. For example, the International Petroleum Exchange (IEP) Model (see EMF-6, 1982) explicitly considers the actions of the multinational oil companies in its simulation. Prices react to changes in the reserves to production ratio, production costs, and exogenous royalties. The IEP is the only simulation model reviewed in which the production capacity of OPEC is not set exogenously.

The key parameters that determine world oil prices are usually the same in simulation models as in optimization models -- i.e., oil reserves, interest rates, backstop price, economic growth, adjustment rates, and short-run and long-run supply and demand elasticities. Econometric approaches are used to identify how

these parameters -- in addition to OPEC capacity utilization -- have been related to historical oil price changes. Assumptions about how these key parameters may change in future years allows the modeler to project future oil price trends.

Simulation models can be criticized on the grounds that the major determinant of oil prices -- OPEC capacity utilization -- is usually assumed to be exogenous.[3] Because of this "oversimplification," it can be argued that most simulation models are more adept at forecasting how oil market parameters other than price may react to future price changes, rather than actually forecasting world oil prices.

B. Political Models

Some modelers have made the implicit assumption that political factors dominate economic criteria in determining the price of oil in the world market. To some extent it can be assumed that political goals within the major producing countries are compatible with wealth maximizing goals. However, it has been argued that often economic goals -- e.g., wealth or revenue maximization -- must be, and are, sacrificed to obtain both internal and external political objectives. In these cases, it can be argued that formal or informal political models can best suggest why prices have changed historically and how oil prices may change in the future.

Two political models are reviewed briefly here. In Moran (1982) it is argued that the political decisions of Saudi Arabia --

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[3]Curlee (forthcoming) argues that the quality of the existing data on current and projected OPEC and non-OPEC production capacity is poor, thus placing empirical projections from these models in question.

the assumed OPEC leader -- will have a significant influence on future world oil prices. This informal model argues that Saudi Arabia attempts to maximize its own political objectives in its oil production decisions, while being constrained by potential hostile pressures both internally and externally. Moran presents a detailed description of the probable political objectives of the numerous political groups within Saudi Arabia that may have influence over future energy policy decisions. Moran thus presents a model of how differing internal political objectives -- including wealth maximization on the part of some power centers in Saudi Arabia -- can interact to determine oil production decisions that do not conform to any of the criteria specified in the economic models discussed above.

In a more formal model by Saaty and Gholamnezhad (1981) a methodology called "analytic hierarchies" is used to formulate a political model of the world oil market that takes a more global perspective.[4] Several political factors are considered, including the degree of instability in the Persian Gulf Region, the intensity of the Arab-Israeli conflict, and the increased influence of the Soviet Union in the Middle East. Several "economic-technological" factors are also considered within the political framework, including strategies of the consuming countries to influence oil consumption, excess-oil-production capacity, the influence of the international financial institutions, oil discovery rates, and development of alternative energy sources.

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[4]The "analytic hierarchies" approach is not explained in great detail by the authors. For a detailed description of that approach see Saaty (1980).

C. Combination Models

In recent years there has been a growing perception among many modelers of the world oil market that the mechanism by which world oil prices are determined is far more complicated than that represented in either economic or political models. This realization has followed the poor predictive abilities of both economic and political modeling approaches. The frustration felt by modelers is best explained by two quotes from one of the foremost researchers in the field, Robert Pindyck. Pindyck was one of the first authors to model OPEC as a monopolistic wealth maximizer. Pindyck's confidence in this approach is reflected in his 1979 paper. "So far OPEC has done more or less the same thing, and to the extent that it continues to do so, economic maximization should provide a reasonable basis for explaining and forecasting the price of oil" (page 175). However, in a publication by Pindyck in 1982 he reassesses the worth and predictive capabilities of "models that describe 'economically rational' price formation by the OPEC cartel" (page 175). "I will argue that improved models might be useful for examinig various theoretical and empirical issues in the behavior of oil markets, but that they are not needed, and would not be very useful, for predicting world oil prices" (page 176). "It seems to me that from a theoretical point of view, models of OPEC oil pricing have reached a practical limit as tools of analysis. As far as empirical predictions of oil prices are concerned, some of these models have already exceeded that limit" (page 179).

Modeling methodologies have therefore evolved to incorporate the realization that future oil prices are very uncertain and difficult to predict. On the one hand, some modelers have adopted simplistic "rules of thumb" to forecast oil prices -- such as the assumption used in most simulation models that oil prices are a function of the degree to which OPEC production capacity is utilized.

On the other hand, some modelers have (1) attempted to incorporate political factors into their economic approaches or (2) have opted for informal methodologies that implicitly include economic and political criteria. An example of the first type is a model by Daly, Griffin, and Steel (1982). In that model OPEC supply responses are modeled on the basis of actual and potential reserves, absorptive capacity, and political constraints. The modeling approach -- which employs a basic economic approach constrained by perceived political realities -- was used to assess the stability of the OPEC cartel given different price paths. Examples of the second type are Pindyck (1982) and Weyant (1983). In these papers no formal models are constructed. Rather, projections of future market conditions are based on intuitive judgments based on the authors' perceptions of economic and political realities.

IV. Conclusions

Several conclusions can be drawn from this review of methodologies designed to explain and forecast world oil price changes. First, the roots of the various approaches are in the modelers' disciplinary perspectives and perceptions of historical

events in the world oil market. As has been reviewed, the world oil market has gone through many structural changes in the past two decades. Depending on the time period that is being modeled, the particular methodology that is required may differ. Second, the methodologies have evolved during the past decade. This evolution has come as a result of the poor predictive capabilities of previous models and because there has been a realization that the structure of the oil market -- including the relevant players, the objective functions of the players, and the abilities of the players to manipulate the market to maximize those objectives -- has changed. Finally, and most importantly for our purposes, there is no consensus about what methodology should be used to forecast future world oil prices. To some extent there has been a movement toward a consensus that prices will be determined by both economic and political factors. Beyond that there is less than complete agreement about the particular modeling approach that should be used. However, it is generally agreed that different modeling methodologies may lead to significantly different oil price forecasts.[5]

Whatever the conceptual problems that remain in the area of oil price forecasting, there is no shortage of price forecasts from which to choose and evaluate. A review of the recent oil price forecasts and their underlying assumptions is the subject of the next chapter.

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[5] For more information on the different methodologies that have been developed to forecast world oil prices see, for example, Sweeney (1983), Belcer (1981), Griffin and Teese (1982), and Gately (1984).

3. WORLD OIL PRICE FORECASTS

1. Introduction

The purpose of this chapter is to review and summarize recent mid- to long-term world oil price forecasts. As was the case in the previous chapter, the large number of oil market models and forecasts prevents a detailed discussion of each forecast. Rather, the various forecasts are summarized and, where possible, categorized according to the modeling types and major model parameters discussed in the preceding chapter. Of particular interest are the variations in the forecasts caused by changes in the key parameters. In addition, the forecasts are discussed in terms of the dates the forecasts were made. A key question is whether the most recent oil price forecasts -- those completed after the official oil price reduction of 1983 -- differ significantly from earlier forecasts. Because of the large number of forecasts available, only those completed after 1980 are considered in this review.

A direct comparison of different price forecasts is difficult for several reasons. In many cases only the forecast is given. The assumptions about key model parameters, and in some cases the basic modeling methodology, are often not given. Further, because the modeling methodologies and assumptions about key parameters differ so widely in some cases, it is impossible to pinpoint why price forecasts differ.

Because of these problems the available forecasts are grouped into three categories. The first contains what may be termed "expert judgment" in that often no rigorous mathematical model is

used to make the forecasts, or if a formal model is used the forecast itself has been "flavored" with the forecaster's own subjective views of the market situation. Often these forecasts do not give specific price projections, but rather project general price trends. This class of forecasts contains predictions based on the informal economic-political methodologies described in the preceding chapter, as well as informal economic and political models. The second category contains forecasts that are derived from formal mathematical models. Many forecasts in this category give the basic methodology and values of the major input parameters used to obtain the forecasts. In some cases the forecasts are tested for their sensitivities to changes in some or the key parameters. The third category contains surveys of numerous individuals and groups that periodically make price forecasts. These forecasts are based on formal mathematical models, expert judgment, and/or combinations of the two approaches. However, the surveys do not give sufficient information about the inputs to the individual forecasts to make detailed comparisons of the individual forecasts.

II. Forecasts Based on Expert Judgment

As is obvious from the preceding chapter, there are a variety of approaches to modeling the world oil market. Likewise, there are numerous positions about future market trends. In this section the discussion of those positions and forecasts begins with a review of several quotes from individuals well noted in the field:

> "...(S)o long as the OPEC nations maintain the current system of production control, the system is unstable in the upward direction, and a price hike is almost guaranteed at any time

unless the core nations take active roles toward preventing it. For these reasons, I would expect still higher (real) prices in the 1980's despite weak demand" (Adelman, 1982. page 54).

"OPEC will continue to have power over price, especially in the short term, and its power will increase when its capacity utilization increases. But, over the longer term, taking ten-year or twenty-year averages, OPEC's market power will be constrained by the underlying price-responsiveness of demand and of non-OPEC supply, for oil and alternative energy sources" (Gately, 1984, page 1113).

"Considering that OPEC has yet to demonstrate that it has the wherewithal to delimit competitive output expansion, two decades of constant real prices is a strong possibility -- in the absence of a supply disruption of significance" (Teece, 1982. page 86).

"In the long run, the desire of the Saudis to avoid the vulnerability that the mere existence of huge export capability brings -- vulnerability to consumer government pressures to use it, vulnerability to producer government pressures to let it lie idle -- exercises a great dampening effect on capacity plans for the kingdom, irrespective of what huge reserves and low discount rate might indicate. ...(T)he analysis of Saudi decision-making presented here suggests a more pessimistic view of oil prices (pessimistic from the point of view of energy consumers) than the economic optimization approach for any given set of assumptions about supply and demand for energy" (Moran, 1982. page 116).

"It may be assumed ... that OPEC's pricing policy in the 1980s will be more sensitive to market conditions than it was in the 1970s. If this is so, OPEC real prices will not rise significantly over the next nine years. If this assumption is wrong oil prices could continue to rise significantly for only a limited period before the organizations's price structure would collapse under the onslaught of consumer conservation and producer competition" (Lichtblau, 1982. page 143).

"While there remains a high degree of uncertainty about future world oil prices, most of the uncertainty concerns not whether real prices will rise, but rather how rapidly they will increase. ... The overall real price trend will be upward" (James Sweeney as quoted in Daly, Griffin, and Steele, 1982. page 145).

"Eventually, the upward pressure on oil demand caused by increases in economic activity could more than offset the downward pressure resulting from the dwindling adjustment to the 1979-1980 pr'ce increase. ...The slack world oil market may persist for two or three more years, but is unlikely to last much longer" (Weyant 1984. pages 393-394).

"The results of this paper suggest that the Iranian political upheavals of 1978-79 and the subsequent doubling of crude oil prices may well have defined the limits of OPEC's monopoly power. A long run real price path significantly greater than $32 per barrel seems likely to evoke large supplies of synthetic fuels, coupled with substantial conservation effects -- events which, taken together, make such a price path unlikely" (Daly, Griffin, and Steele, 1982. page 173).

"(I)t would probably be reasonable to assign a 2 to 4 percent real rate of growth to future oil prices as part of a 'most likely' forecast. But at the same time it must be remembered that the confidence interval around that forecast is extremely wide, perhaps as large as 50 to 100 percent. What should really matter in terms of the decision of energy producers and energy consumers is not the 'best guess' forecast, but the fact that the uncertainty around that forecast is considerable" (Pindyck, 1982. page 179).

"(T)he authors in this volume believe that the world economy has by no means fully responded to the 1973-74 price shock, let alone the 1979 shock" (Griffin and Teece, 1982, page 208).

"(T)he target revenue model suggests that substantial downward price movements are likely in the event of a prolonged soft market" (Griffin and Teece, 1982. page 211).

"The consensus of the authors appears to be that if a large price hike occurs in response to some political disruption, it will not be sustainable in the long run, unless such political upheavals permanently take appreciable capacity out of production" (Griffin and Teece, 1982. page 212).

"At most, after 1990 I would expect a real increase of 1 percent per year in oil prices after the $34 price is attained" (Netschert, 1983, page 141).

"If OPEC operates as a revenue-maximizing cartel, it will lower nominal oil prices to the $25-29/bbl range and allow inflation to reduce real oil prices in 1986 to the $20-23/bbl range" (Roumasset, Isaak, and Fesharaki, 1983, page 193).

"Unlike the situation in the 1970s, when the interest of exporting and importing countries seemed to be diametrically opposed, it now appears that OPEC and the importing countries will both lose if prices rise. ...Consequently, it is reasonable to imagine that most OPEC members will recognize their self-interest in stable prices in coming years" (Bohi and Quandt, 1984, page 18).

"If these models and scenarios correctly represent world oil futures, we can expect the real price of oil to decline or remain stagnant for several years and then to rise significantly..." (EMF-6, 1982. page 92).

"Whether from operations within OPEC or those in an open market, world crude oil price should remain constant or increase at most by one or two percentage points each year during the 1980s" (MacAvoy, 1982. page 78).

"The OPEC countries ...-- Algeria, Indonesia, Nigeria, Venezuela, and Ecuador -- will advocate large oil price increases during the 1980s because of their need for oil revenues and because of their limited role as exporters in the long term. ...Saudi Arabia and UAE have an economic incentive to block increases -- which would bring the oil price above ... the price at which substitutes to OPEC oil will start being introduced ... or the price at which the value of OPEC's financial surpluses will begin to depreciate..." (Aperjis, 1982. page 125).

While the review of these forecasts by industry experts does not lead to any definite conclusions, it does suggest a movement toward a consensus on several points. First, the predominant view is that real oil prices will not increase or decrease significantly during the remainder of the 1980s. In the 1990s and beyond real prices are expected to increase moderately, but should not be subject to the drastic price increases observed in the 1970s. Drastic price jumps are not seen to be in the interest of either oil consumers or OPEC. Second, the prevailing view is that OPEC will continue to maintain a significant degree of control over the oil market, but to a lesser degree than in the 1970s. This restraint on OPEC's power will result from the continuing adjustments of oil consumers and non-OPEC oil producers to the drastic price escalations of the 1970s. Third, there is a general consensus that the impacts of supply disruption, such as those of the 1970s, may result in short-term price jumps, but those jumps would probably not be maintainable over the long run. Finally, while price forecasts do not diverge as widely as they have in the

past, there is still a recognition and a warning that world oil price forecasts contain a great deal of uncertainty.

III. Forecasts Based on Formal Models

In this section numerous price forecasts that have resulted from formal mathematical models are reviewed. The sources of these forecasts vary widely -- from academic institutions, to government agencies, to private firms. In addition, the forecasts vary in terms of the year they were published and in terms of the modeling methodology used. At least one sample of each of the formal methodologies discussed in the previous chapter is represented. In some cases only one observation -- i.e., one forecast -- was available. In other cases there are as many as four observations from a particular model.

The review of forecasts presented here certainly does not represent all available forecasts. The review does, however, give a sampling of different modeling types, forecast years, and forecasting institutions. Further, this review does not lead to definitive statements about how and why forecasts vary due to differences in underlying assumptions and parameter specifications. Some broader general conclusions can, however, be drawn. In the following subsection the forecasts are presented and discussed in terms of their general modeling methodology, date of publication, and, where possible, the specific model used. That review is followed by a discussion of how changes in some of the key modeling parameters have been shown to impact some of the forecasts.

A. The Forecasts

To help in our assessment of the forecasts, the price projections are arranged according to different parameters in different tables. Table 3.1 presents the forecasts arranged by the year the forecast was published. While the price projections are given in terms of constant dollars for each individual forecast -- as given in the referenced source -- the different forecasts have not been adjusted to reflect a base-year constant dollars in this table. In Table 3.2 the forecasts are again arranged by year published, but all price projections have been converted to constant 1981 dollars.[6] Forecasts are arranged by modeling type and by the organization making the forecasts in Tables 3.3 and 3.4, respectively. In Table 3.5 the forecasts are arranged by their projected 1990 price level.

An overview of all the forecasts shows that oil prices -- in constant 1981 dollars -- are projected to be between $17.12 and $50.73 per barrel in 1985 (with a median of $25.46), between $19.56 and $64.00 per barrel in 1990 (with a median of $36.65), between $24.57 and $59.62 dollars per barrel in 1995 (with a median of

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[6] All prices have been adjusted by the U.S. GNP deflator. While the use of a U.S. price deflator is satisfactory to adjust oil prices to a base year from a U.S. perspective, it may not be appropriate in adjusting world oil prices to a base year. Because of significant changes in the exchange rates among different currencies, it is not clear that adjusting prices by a U.S. deflator will give accurate real price changes for the world market. For example, Huntington (1984) has argued that while the real price of oil went down in the U.S. between 1981 and 1982, the real price went up in several other OECD countries -- e.g., Italy, Japan, France, and the United Kingdom -- due to exchange rate variations.

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Table 3.1. A summary of oil price forecasts arranged by year published

Organization or Model	Source of Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
OPE DOE	OPE	1980	NA		43					1980
DOE/OPPA[a]	DOE/OPPA	1981	NA	46	55		74			1982
MITRE[a]	MITRE	1981	NA				76			1982
Satty & Ghol.	Satty & Ghol.	1981	Political	41.06	44.86					
Bohi	Bohi	1982	Combination	20.2						1972
ETA Macro	EMF-6	1982	Comp Opt		50.6		80.2	64.1	68.9	1981
Kennedy-Nehring	EMF-6	1982	Comp Opt		56.8		77.5	71.4	71.4	1981
Salant ICF	EMF-6	1982	Mono Opt		55.5		71.3	88.8	106.1	1981
WOM	Marshalla	1982	Mono Opt	31.53	35.91	38.85	42.17		56.66	1982
Foster[a]	Foster	1982	NA	34	38		49			1982
SHCA[a]	SHCA	1982	NA	53.8	66.5		103.4			1982
Gately	EMF-6	1982	Simulation		52.9		71.7	71.3	93.8	1981
IPE	EMF-6	1982	Simulation		37.2		54.6			1981
OILMAR	EMF-6	1982	Simulation		64		86.8	120.2	127.3	1981
OILTANK	EMF-6	1982	Simulation		63		92.1	129.7	152.3	1981
OMS	EMF-6	1982	Simulation		46.1					1981
Opeconomics	EMF-6	1982	Simulation		39.7		41.5			1981
WOIL	EMF-6	1982	Simulation		47.8		69.6	81.8	69.1	1981
Singer[b]	Singer	1983	Mono Opt	17.8	21.9	27.4	32.2			1980
SHCA[c]	SHCA	1983	NA	26.3	27.09	32.34	37.5	50.39	64.48	1983
Texaco[d]	Texaco	1983	NA	27	28	29	30			1982
Devarajan et al	Devar. et al	1983	Simulation	32.8						
DRI WOM	DRI	1983	Simulation	30.09	36.1	44.12	51			1981

Table 3.1. (continued)

Organization or Model	Source of Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
OMS High	EIA	1983	Simulation	34	48					1982
OMS Low	EIA	1983	Simulation	21	28					1982
OMS Mid	EIA	1983	Simulation	25	37					1982
Roumasset et al	Roumas et al	1983	simulation	17.12	19.56		25.47			1981
SHCA[c]	SHCA	1984	NA	26.3	27.9	32.5	40	60	80	1983
DRI[d]	DRI	1984	Simulation	27.5	25	28				1984
OMS High	EIA	1984	Simulation	30.53	45.64	65.89				1983
OMS High Draft	EIA	1984	Simulation	30	40	55				1984
OMS Low	EIA	1984	Simulation	22.44	29.16	36.54				1983
OMS Low Draft	EIA	1984	Simulation	24	25	30				1984
OMS Mid	EIA	1984	Simulation	26.52	36.65	50.49				1983
OMS Mid Draft	EIA	1984	Simulation	27.92	30	40				1984

[a]As reported in Foster, Burton and Hampeter (1983).

[b]Singer points out that these are not oil price forecasts, but rather reflect the prices that would be charged by a profit maximizing oil cartel.

[c]As reported in Alaska Power Authority (1984).

[d]Interpreted fro a graphical presentation.

Table 3.2. A summary of oil price forecasts arranged by year published
(In constant 1981 dollars)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
OPE DOE	OPE	1980 NA			47.02					1981
DOE/OPPA[a]	DOE/OPPA	1981 NA		43.37	51.86		69.77			1981
MITRE[a]	MITRE	1981 NA					71.66			1981
Satty & Ghol.	Satty & Ghol.	1981	Political	41.06	44.86					1981
Bohi	Bohi	1982	Combination	39.41						1981
ETA Macro	EMF-6	1982	Comp Opt		50.6		80.2	64.1	68.9	1981
Kennedy-Nehring	EMF-6	1982	Comp Opt		56.8		77.5	71.4	71.4	1981
Salant ICF	EMF-6	1982	Mono Opt		55.5		71.3	88.8	106.1	1981
WOM	Marshalla	1982	Mono Opt	29.73	33.86	36.63	39.76		53.43	1981
Foster[a]	Foster	1982	NA	32.06	35.83		46.2			1981
SHCA[a]	SHCA	1982	NA	50.73	62.7		97.5			1981
Gately	EMF-6	1982	Simulation		52.9		71.7	71.3	93.8	1981
IPE	EMF-6	1982	Simulation		37.2		54.6			1981
OILMAR	EMF-6	1982	Simulation		64		86.8	120.2	127.3	1981
OILTANK	EMF-6	1982	Simulation		63		92.1	129.7	152.3	1981
OMS	EMF-6	1982	Simulation		46.1					1981
Opeconomics	EMF-6	1982	Simulation		39.7		41.5			1981
WOIL	EMF-6	1982	Simulation		47.8		69.6	81.8	69.1	1981
Singer[b]	Singer	1983	Mono Opt	19.46	23.95	29.96	35.21			1981
SHCA[c]	SHCA	1983	NA	23.79	24.51	29.26	33.93	45.59	58.35	1981
Texaco[d]	Texaco	1983	NA	25.46	26.4	27.34	28.29			1981
Devarajan et al	Devar. et al	1983	Simulation	30.93						1981
DRI WOM	DRI	1983	Simulation	30.39	36.1	44.12	51			1981

Table 3.2. (continued)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
OMS High	EIA	1983	Simulation	32.06	45.26					1981
OMS Low	EIA	1983	Simulation	19.8	26.4					1981
OMS Mid	EIA	1983	Simulation	23.57	34.88					1981
Roumasset et al	Roumas et al	1983	simulation	17.12	19.56		25.47			1981
SHCA[c]	SHCA	1984	NA	23.79	25.25	29	36.19	54.29	72.39	1981
DRI[d]	DRI	1984	Simulation	24.13	21.94	24.57				1981
OMS Low	EIA	1984	Simulation	20.31	26.39	33.06				1981
OMS Mid	EIA	1984	Simulation	23.99	33.17	45.69				1981
OMS High	EIA	1984	Simulation	27.62	41.3	59.62				1981
OMS Low Draft	EIA	1984	Simulation	21.06	21.94	26.32				1981
OMS Mid Draft	EIA	1984	Simulation	24.5	26.33	35.11				1981
OMS High Draft	EIA	1984	Simulation	26.33	35.11	48.27				1981

[a]As reported in Foster, Burton and Hanpeter (1983).

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Table 3.3. A summary of oil price forecasts arranged by modeling type
(In constant 1981 dollars)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
Gately	EMF-6	1982	Simulation		52.9		71.7	71.3	93.8	1981
IPE	EMF-6	1982	Simulation		37.2		54.6			1981
OILMAR	EMF-6	1982	Simulation		64		86.8	120.2	127.3	1981
OILTANK	EMF-6	1982	Simulation		63		92.1	129.7	152.3	1981
OMS	EMF-6	1982	Simulation		46.1					1981
Opeconomics	EMF-6	1982	Simulation		39.7		41.5			1981
WOIL	EMF-6	1982	Simulation		47.8		69.6	81.8	69.1	1981
Devarajan et al	Devar. et al	1983	Simulation	30.93						1981
DRI WOM	DRI	1983	Simulation	30.09	36.1	44.12	51			1981
OMS High	EIA	1983	Simulation	32.06	45.26					1981
OMS Low	EIA	1983	Simulation	19.8	26.4					1981
OMS Mid	EIA	1983	Simulation	23.57	34.88					1981
Roumasset et al	Roumas et al	1983	Simulation	17.12	19.56		25.47			1981
DRI[a]	DRI	1984	Simulation	24.13	21.94	24.57				1981
OMS High	EIA	1984	Simulation	27.62	41.3	59.62				1981
OMS High Draft	EIA	1984	Simulation	26.33	35.11	48.27				1981
OMS Low	EIA	1984	Simulation	20.31	26.39	33.06				1981
OMS Low Draft	EIA	1984	Simulation	21.06	21.94	26.32				1981
OMS Mid	EIA	1984	Simulation	23.99	33.17	45.69				1981
OMS Mid Draft	EIA	1984	Simulation	24.5	26.33	35.11				1981
Satty & Ghol.	Satty & Ghol.	1981	Political	41.06	44.86					1981
OPE DOE	OPE	1980	NA		47.02					1981
DOE/OPPA[b]	DOE/OPPA	1981	NA	43.37	51.86		69.77			1981

Table 3.3. (continued)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
MITRE[b]	MITRE	1981 NA					71.66			1981
Foster[b]	Foster	1982 NA		32.06	35.83		46.2			1981
SHCA[b]	SHCA	1982 NA		50.73	62.7		97.5			1981
SHCA[c]	SHCA	1983 NA		23.79	24.51	29.26	33.93	45.59	58.35	1981
Texaco[a]	Texaco	1983 NA		25.46	26.4	27.34	28.29			1981
SHCA[c]	SHCA	1984 NA		23.79	25.25	29	36.19	54.29	72.39	1981
Salant ICF	EMF-6	1982 Mono Opt			55.5		71.3	88.8	106.1	1981
DM	Marshalla	1982 Mono Opt		29.73	33.86	36.63	39.76		53.43	1981
Singer[d]	Singer	1983 Mono Opt		19.46	23.95	29.96	35.21			1981
TA Macro	EMF-6	1982 Comp Opt			50.6		80.2	64.1	68.9	1981
Kennedy-Nehring	EMF-6	1982 Comp Opt			56.8		77.5	71.4	71.4	1981
Bohi	Bohi	1982 Combination		39.41						1981

[a]Interpreted from a graphical presentation.

[b]As reported in Foster, Burton and Hanpeter (1983).

[c]As reported in Alaska Power Authority (1984).

[d]Singer points out that these are not oil price forecasts, but rather reflect the prices that would be charged by a profit maximizing oil cartel.

Table 3.4. A summary of oil price forecasts arranged by organization making forecast (In constant 1981 dollars)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
Bohi	Bohi	1982	Combination	39.41						1981
Devarajan et al	Devar.et al	1983	Simulation	30.93						1981
DOE/OPPA[a]	DOE/OPPA	1981	NA	43.37	51.86		69.77			1981
DRI WOM	DRI	1983	Simulation	30.09	36.1	44.12	51			1981
DRI[b]	DRI	1984	Simulation	24.13	21.94	24.57				1981
ETA Macro	EMF-6	1982	Comp Opt		50.6		80.2	64.1	68.9	1981
Fostser[a]	Foster	1982	NA	32.06	35.83		46.2			1981
Gately	EMF-6	1982	Simulation		52.9		71.7	71.3	93.8	1981
IPE	EMF-6	1982	Simulation		37.2		54.6			1981
Kennedy-Nehring	EMF-6	1982	Comp Opt		56.8		77.5	71.4	71.4	1981
MITRE[a]	MITRE	1981	NA				71.66			1981
OILMAR	EMF-6	1982	Simulation		64		86.8	120.2	127.3	1981
OILTANK	EMF-6	1982	Simulation		63		92.1	129.7	152.3	1981
OMS	EMF-6	1982	Simulation		46.1					1981
OMS High	EIA	1983	Simulation	32.06	45.26					1981
OMS High	EIA	1984	Simulation	27.62	41.3	59.62				1981
OMS High Draft	EIA	1984	Simulation	26.33	35.11	48.27				1981
OMS Low	EIA	1983	Simulation	19.8	26.4					1981
OMS Low	EIA	1984	Simulation	20.31	26.39	33.06				1981
OMS Low Draft	EIA	1984	Simulation	21.06	21.94	26.32				1981
OMS Mid	EIA	1983	Simulation	23.57	34.88					1981
OMS Mid	EIA	1984	Simulation	23.99	33.17	45.69				1981
OMS Mid Draft	EIA	1984	Simulation	24.5	26.33	35.11				1981

Table 3.4. (continued)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
OPE DOE	OPE	1980	NA		47.02					1981
Opeconomics	EMF-6	1982	Simulation		39.7		41.5			1981
Roumasset et al	Roumas et al	1983	Simulation	17.12	19.56		25.47			1981
Salant ICF	EMF-6	1982	Mono Opt		55.5		71.3	88.8	106.1	1981
Satty & Ghol.	Satty & Ghol.	1981	Political	41.06	44.86					1981
SHCA[a]	SHCA	1982	NA	50.73	62.7		97.5			1981
SHCA[c]	SHCA	1983	NA	23.79	24.51	29.26	33.93	45.59	58.35	1981
SHCA[c]	SHCA	1984	NA	23.79	25.25	29	36.19	54.29	72.39	1981
Singer[d]	Singer	1983	Mono Opt	19.46	23.95	29.96	35.21			1981
Texaco[b]	Texaco	1983	NA	25.46	26.4	27.34	28.29			1981
WOIL	EMF-6	1982	Simulation		47.8		69.6	81.8	69.1	1981
WOM	Marshalla	1982	Mono Opt	29.73	33.86	36.63	39.76		53.43	1981

[a]As reported in Foster, Burton and Hampeter (1983).

[b]Interpreted from a graphical presentation.

[c]As reported in Alaska Power Authority (1984).

[d]Singer points out that these are not oil price forecasts, but rather reflect the prices that would be charged by a profit maximizing oil cartel.

Table 3.5. A summary of oil price forecasts arranged by projected 1990 price level (In constant 1981 dollars)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
MITRE[a]	MITRE	1981	NA				71.66			1981
Bohi	Bohi	1982	Combination	39.41						1981
Devarajan et al	Devar. et al	1983	Simulation	30.93						1981
Roumasset et al	Roumas et al	1983	Simulation	17.12	19.56		25.47			1981
DRI[b]	DRI	1984	Simulation	24.13	21.94	24.57				1981
OMS Low Draft	EIA	1984	Simulation	21.06	21.94	26.32				1981
Singer[c]	Singer	1983	Mono Opt	19.46	23.95	29.96	35.21			1981
SHCA[d]	SHCA	1983	NA	23.79	24.51	29.26	33.93	45.59	58.35	1981
SHCA[d]	SHCA	1984	NA	23.79	25.25	29	36.19	54.29	72.39	1981
OMS Mid Draft	EIA	1984	Simulation	24.5	26.33	35.11				1981
OMS Low	EIA	1984	Simulation	20.31	26.39	33.06				1981
Texaco[b]	Texaco	1983	NA	25.46	26.4	27.34	28.29			1981
OMS Low	EIA	1983	Simulation	19.8	26.4					1981
OMS Mid	EIA	1984	Simulation	23.99	33.17	45.69				1981
DM	Marshalla	1982	Mono Opt	29.73	33.86	36.63	39.76		53.43	1981
OMS Mid	EIA	1983	Simulation	23.57	34.88					1981
OMS High Draft	EIA	1984	Simulation	26.33	35.11	48.27				1981
Foster[a]	Foster	1982	NA	32.06	35.83		46.2			1981
DRI WOM	DRI	1983	Simulation	30.09	36.1	44.12	51			1981
IE	EMF-6	1982	Simulation		37.2		54.6			1981
Opeconomics	EMF-6	1982	Simulation		39.7		41.5			1981
OMS High	EIA	1984	Simulation	27.62	41.3	59.62				1981
Satty & Ghol.	Satty & Ghol.	1981	Political	41.06	44.86					1981

Table 3.5. (continued)

Organization or Model	Source or Model	Date of Source	Model Type	1985	1990	1995	2000	2010	2020	Year Constant Dollars
OMS High	EIA	1983	Simulation	32.06	45.26					1981
OMS	EMF-6	1982	Simulation		46.1					1981
OPE DOE	OPE	1980	NA		47.02					1981
WOIL	EMF-6	1982	Simulation		47.8		69.6	81.8	69.1	1981
ETA Macro	EMF-6	1982	Comp Opt		50.6		80.2	64.1	68.9	1981
DOE/OPPA[a]	DOE/OPPA	1981	NA	43.37	51.86		69.77			1981
Gately	EMF-6	1982	Simulation		52.9		71.7	71.3	93.8	1981
Salant ICF	EMF-6	1982	Mono Opt		55.5		71.3	88.8	106.1	1981
Kennedy-Nehring	EMF-6	1982	Comp Opt		56.8		77.5	71.4	71.4	1981
SHCA[a]	SHCA	1982	NA	50.73	62.7		97.5			1981
OILTANK	EMF-6	1982	Simulation		63		92.1	129.7	152.3	1981
OILMAR	EMF-6	1982	Simulation		64		86.8	120.2	127.3	1981

[a]As reported in Foster, Burton and Hanpeter (1983).

[b]Interpreted from a graphical presentation.

[c]Singer points out that these ar not all price forecasts, but rather reflect the prices that would be charged by a profit maximizing oil cartel.

[d]As reported in Alaska Power Authority (1984).

$33.06), between $25.47 and $97.50 per barrel in 2000 (with a median of $62.10), between $45.59 and $129.70 per barrel in 2010 (with a median of $71.40), and between $53.43 and $152.30 per barrel in 2020 (with a median of $71.90). Caution must, however, be advised in interpreting these results. All forecasts do not give price projections for the same time periods. Generally, fewer projections are available for years further into the future.

Some general conclusions can, however, be drawn from the review of these forecasts. First, price forecasts do not seem to vary consistently according to modeling type. Projections vary significantly within the modeling types for which several forecasts are given. For example, projections for 1990 using simulation models range from a high of $64.00 per barrel for a 1982 forecast to a low of $19.56 per barrel for a 1983 forecast. Further, forecasts published during 1982 as a result of the Energy Modeling Forum's EMF-6 report on world oil prices -- in which the simulation approach was used -- varied between $37.20 and $64.00 per barrel. It is interesting to note, however, that the forecasts based on monopolistic optimization tend to be relatively lower -- especially in the more distant future -- than forecasts using competitive optimization and simulation models. The reader may recall from the previous chapter that economic theory suggests that although a monopoly will set prices higher than competition would dictate at the beginning of the production of the fixed resource, a monopoly or a cartel will eventually set prices lower than would exist in a competitive market as resources are depleted.

Second, there does appear to be a significant difference between forecasts published during the 1981-82 and 1983-84 time periods. A review of Tables 3.2 and 3.5 shows that forecasts have in general been revised downward in the 1983-84 time period. Table 3.4 shows how forecasts from specific models have changed over time. For example, base projections published by Data Resources, Inc. in 1984 were much lower than those published in 1983 -- from $44.12 down to $24.57 dollars per barrel for 1995. Forecasts published by the Energy Information Administration (within the U.S. Department of Energy) using the Oil Market Simulation (OMS) Model have been revised downward since the official OPEC price reduction of 1983. EIA's medium case projections for 1990 have changed from $34.88 per barrel in 1983 to $26.33 per barrel in 1984.[7] The high and low EIA forecasts have also been revised downward from $45.26 to $35.11 per barrel and from $26.40 to $21.94 per barrel, respectively. As can be seen from Table 3.4, projections by Sherman H. Clark Associates (SHCA) have been lowered drastically since 1982. For example, SHCA projected in 1982 that oil prices would be $97.50 per barrel in 2000. In 1984 that projection has been revised downward to $36.19 per barrel in constant 1981 dollars.

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[7]Note that the most recent EIA forecast given in the tables is a draft and thus cannot be considered an official EIA forecast.

B. Sensitivities of Forecasts to Changes in Key Parameters

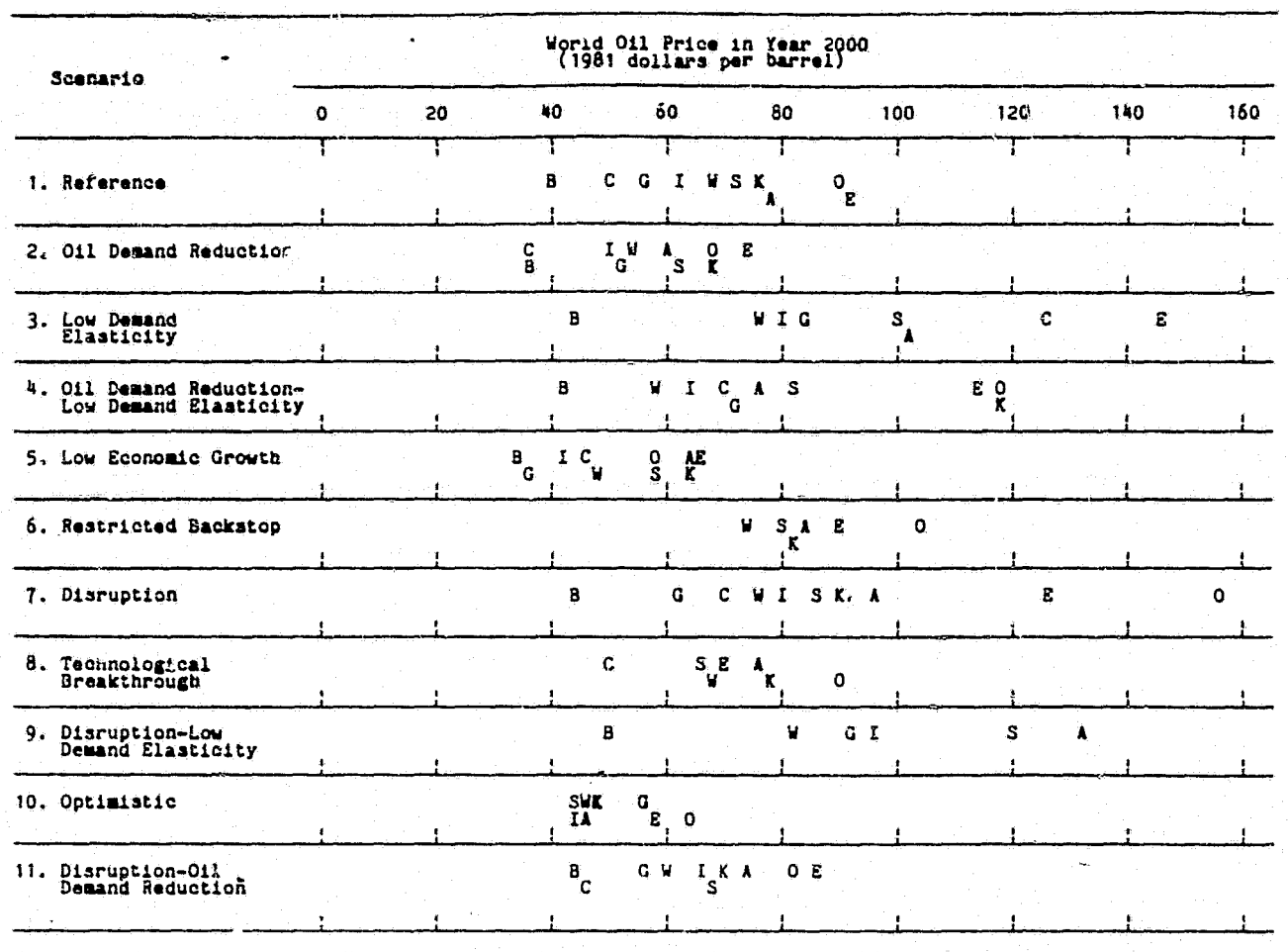
There is not sufficient detail given in the above discussed forecasts to complete a formal sensitivity study of the results. Ideally, one would like to test the sensitivities of different modeling types to changes in the key parameters. However, in most cases the published forecasts give only minimal information about the key parameter values. Many parameter values are not given. Further, in many publications there are several scenarios presented; however, the different scenarios represent changes in several parameters, not just one. It is therefore not possible to determine how the forecasts vary because of a change in a particular parameter.

As a result, this subsection will concentrate only on the publications that have reported how forecasts from a particular model or a group of models vary due to changes in the major parameters. Two publications are the focus of this subsection -- the Energy Modeling Forum's EMF-6 report and a book edited by Griffin and Teece (1982). The discussion is further limited to the major parameters that influence the forecasts of optimization and simulation models discussed in Chapter 2 -- i.e., oil demand price elasticity, GNP growth, oil demand income elasticity, interest rates, the backstop price, and the level of OPEC production capacity. Table 3.6 gives the different scenarios used in the EMF-6 study. Figure 3.1 summarizes how the oil price forecasts for 2000 from each of the ten simulation and optimization models used in that study varied, given the major parameter changes as represented by the different scenarios.

Table 3.6 Scenario assumptions used in the EMF-6 study

Scenario	Demand Reduction	Long-run Primary Energy Demand Elasticity	Economic Growth Rate	OPEC Production Capacity	Nonconventional Energy Supply
1. Reference	None	Oil: -0.6, energy: -0.4	See Table A-3	34 MMBD	$60/bbl: limited quantities (Appendix B)
2. Oil Demand Reduction	20 MMBD by 2020				
3. Low Demand Elasticity		-0.375, -0.25			
4. Oil Demand Reduction-Low Demand Elasticity	20 MMBD by 2020	-0.375, -0.25			
5. Low Economic Growth			2/3 of reference rates		
6. Restricted Backstop					50% of reference limits
7. Disruption				24 MMBD from 1985 on	
8. Technological Breakthrough					$40/bbl; increased limits
9. Disruption-Low Demand Elasticity		-0.375, -0.25		24 MMBD from 1985 on	
10. Optimistic	20 MMBD by 2020			gradual increase 40 MMBD in 1987	$40/bbl; increased limits
11. Disruption-Oil Demand Reduction	20 MMBD by 2020			24 MMBD from 1985 on	
12. High Oil Price					

Source: EMF-6 (1982, page 102)



Models: G = Gately, I = IEES-OMS, C = IPE, A = ETA-MACRO, K = Kennedy-Nehring, O = OILMAR, E = OILTANK, W = WOIL, S = Salant-ICF, B = Opeconomics

Note: For all models other than IEES-OMS and IPE, the average of prices between 1995 and 2005 is given. For IEES-OMS, the 1995 price is presented; for IPE, averages between 1995 and 2000 are presented. Several projections are higher than $160/bbl and thus do not appear above. These include: for the low demand elasticity scenario, Kennedy-Nehring ($175) and OILMAR ($177); for the disruption-low demand elasticity scenario, OILTANK ($184), IPE ($198), Kennedy-Nehring ($217), and OILMAR ($417).

Fig. 3.1. Sensitivities of EMF-6 price forecasts.

Source: EMF-6 (1982, page 49)

1. Long-Run Oil Price Elasticity of Demand

There has long been a controversy about the appropriate long-run oil price elasticity to use in oil price forecasts. In the EMF-6 study a base elasticity of -0.6 was used. In other scenarios the price elasticity was reduced to -0.375. As can be seen from Figure 3.1, this change resulted, as we might expect, in large increases in the forecasts for the year 2000. In the base case, prices range from about $40 to $95 per barrel in constant 1981 dollars. The price elasticity reduction increases that range to about $45 to $145 per barrel.

The base price elasticity used in most papers in Griffin and Teece (1982) is significantly higher at about -0.75. Daly, Griffin, and Steele (1982) study the implications of a -0.365 demand elasticity on OPEC's stability and conclude that under the lower elasticity -- and given a $32 real price path -- OPEC's production increases to 38.3 million barrels per day in 2000 as compared to 22.2 at the higher elasticity. OPEC's stability is thus more stable at the lower elasticity and therefore higher oil price paths are more likely.

In a sensitivity study by Salant (1982) the price elasticity of demand was reduced from -0.5 to -0.4 with the result that the optimal price for a profit maximizing cartel increases by 7 % in 1980. The price difference between the two paths increases gradually over the entire forecasted period -- 1980 to 2050 -- given the elasticity reduction.

2: GNP Growth

There appears to be less disagreement about the assumed rate of GNP growth. The EMF-6 study assumed annual GNP growth rates of approximately 3% in the OECD countries and 5% in the oil-importing developing countries through the year 2000. Other forecasts used approximately the same rates. For example, Data Resources, Inc. used a GNP growth rate of about 3% for seven of the large OECD countries in its Autumn 1984 publication. The Energy Information Administration also used a 3% growth figure in its May 1984 publication. The papers in Griffin and Teece (1982) assume OECD economic activity will grow at between 3% and 3.5% between now and the year 2000. During recent decades real GNP growth has been about 4%, with significantly faster growth in the 1960s as compared to the 1970s. There may be more divergence on how GNP growth will translate into increased oil consumption. In most of the models used in the EMF-6 study, it was assumed that growth in oil demand would be roughly proportional to the growth in GNP. In the papers in Griffin and Teece it was assumed that roughly a 1% increase in GNP will result in a 0.75% increase in oil demand.[8]

In the EMF-6 study the base case economic growth was reduced by 33% in one scenario. Figure 3.1 indicates that most of the

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[8]The implications of economic growth will differ depending on the type of country in which the growth occurs. Most forecast that growth in less developed countries will result in larger increases in oil demand than in developed countries. For more on this subject, see the EMF-6 report or Griffin and Teece (1982).

forecasts were moderately sensitive to the lower growth assumption.[9]

3. Oil Supply Price Elasticity

Belder (1981) contains a summary of the OECD oil supply price elasticities contained in the models that were a part of the EMF-6 study. That summary is reproduced in Table 3.7 Elasticities ranged from -0.241 to 1.162. Belder concludes that the differences in the assumed supply price elasticities had a significant impact on the EMF-6 forecasts.

In Griffin and Teece (1982), which generally contains lower price projections than the EMF-6 study, the authors conclude that "(t)he principal differences between the views presented here and the Stanford's Energy Modeling Forum appear to stem from assumptions about OPEC's behavior and the non-OPEC supply response. ...The differences are not principally due to the price elasticity of demand assumptions..." (page 214). In addition to believing that the supply possibilities in the non-OPEC countries are greater than the EMF-6 models assume, the papers in Griffin and Teece argue that the assumed OPEC production capacity of 34 million barrels per day is "excesively conservative." "(I)f OPEC production reached 38.3 (million barrels per day) in the year 2000, reserves to

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[9] Belder (1981) contains an analysis of why the different models in the EMF-6 project produced different price forecasts given the same input assumptions. Belder concludes that alternative assumptions about non-OPEC supply price responsiveness greatly influence the divergence in price forecasts. Belder also concludes that "(t)he inclusion of a feedback effect, in which higher oil prices reduce the economic growth of the oil importing nations, is significant in moderating the magnitude of price changes" (page 3).

Table 3.7. OECD oil supply elasticities: EMF-6 models

Models		1985	1990	1995	2000	2005	2010	2015	2020	Average
IEES/OMS	(1)	0.026	0.377	0.455						0.283
	(2)	0.033	0.319	0.197						0.183
	(3)	0.056	0.256	0.425						0.249
IPE	(1)	0.0	0.0	0.157	0.083					0.060
	(2)	0.023	0.046	0.119	0.138					0.082
	(3)	0.017	0.106	0.042	0.105					0.068
Salant/ICF	(1)	-3.591	-0.798	0.115	0.509	-2.814	4.723	2.049	2.225	0.302
	(2)	-1.540	-1.201	-0.621	-0.863	0.284	0.718	0.552	0.742	-0.241
ETA-MACRO	(1)	0.713	0.439	0.271	0.569	1.911	0.954	2.628	1.745	1.154
	(2)	0.0	1.114	1.521	0.317	∞	5.304	1.129	-1.251	1.162
	(3)	0.0	0.232	0.561	0.876	0.746	0.801	0.779	0.783	0.598
WOIL*	(1)	0.007	0.035	0.157	0.318	0.529	1.107	4.402	-2.903	0.457
	(2)	0.009	0.027	0.280	0.166	0.392	0.468	0.604	0.371	0.290
Kennedy/ Nehring	(1)	0.089	1.308	0.542	0.841	-1.053	∞	∞	∞	0.505
	(2)	-0.191	-0.194	-0.193	-0.099	0.090	0.318	0.263	0.245	0.029
OILTANK	(1)	0.052	1.568	0.858	0.358	-0.085	-0.270	-0.484	-0.405	0.199
	(2)	0.037	0.290	0.688	0.103	-0.101	-0.253	-0.257	-0.175	0.042
	(3)	0.114	1.101	0.599	0.047	-0.303	-0.483	-0.491	-0.307	0.035
Opeconomics	(1)	0.0	0.0	0.0	0.0					0.0
	(2)	0.0	0.0	0.0	0.0					0.0
OILMAR*	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: (1) = Reference and Oil Demand Reduction scenarios
(2) = Reference and Low Elasticity scenarios
(3) = Reference and High Price scenarios
* = U.S. elasticities
∞ = constant prices but a nonzero supply difference between scenarios; these cases are not included in the averages

Source: Beider (1981, page 28)

production ratios in the Cartel Core would not be appreciably different than in 1980" (page 215). In the EMF-6 study it was shown that the simulation models structured around an OPEC capacity utilization rule gave significantly lower price forecasts when the capacity level was increased from 34 to 40 million barrels per day. See Figure 3.1.

4. Interest Rates

The assumed interest rate or discount rate can -- as discussed in Chapter 2 -- have a significant impact on the optimal price level set by a profit maximizing producer of a depletable resource. In a paper by Marshalla and Nesbitt (1984) the sensitivity of changing the discount rate on the optimal price path of a profit maximizing oil cartel is assessed. In the case of this particular study, a change in the assumed real discount rate altered the optimal price path less in more distant time periods than in the near term. Under the assumption that the cartel is composed of all OPEC countries, a decrease in the discount rate from 6% to 2% increases the optimal cartel price from $26.33 to $36.25 per barrel in 1987, from $32.42 to $40.37 per barrel in 1997, and from $49.36 to $50.63 per barrel in 2022.

5. The Backstop Price

The EMF-6 study contained one scenario in which a perfect substitute for crude oil becomes available in the year 1996 at a cost of $48 per barrel in 1981 dollars -- see scenario 8 in Figure 3.1. As can be seen from Figure 3.1, this particular technological

breakthrough did not result in sharply different price reductions from either the simulation or optimization models.

IV. Surveys of Oil Price Forecasts

Recently an informal group known as the International Energy Workshop (IEW) was formed to collect and compare the most up-to-date, long-term forecasts of world oil market trends. The group sends out periodic surveys to numerous contributors who provide statistics on crude-oil prices, GNP growth, primary energy consumption and production, and electricity generation. The respondents do not provide information about their modeling approach, the basic underlying assumptions of their forecasts, and so forth. The surveys do, however, obtain responses from all sectors that forecast market conditions -- e.g., government agencies, private firms, academia, individual energy consultants, and world organizations. Numerous countries are represented. Typically, the contributors provide only a base case scenario; however, in some cases contributors will provide, for example, high, medium, and low cases. Projections are given for the years 1990. 2000. and 2010.

In this section the results of two recent IEW surveys are reviewed. The results of the 1983 survey are given in a paper by Manne and Schrattenholzer (1984). The results of a more recent IEW poll completed in July 1984 were given in a presentation by Alan Manne at the November 1984 meetings of the International Association of Energy Economists. Table 3.8 contains summaries of those surveys.

In the IEW surveys all price projections are given in terms of index numbers where 1980 equals to 100. Note that in Table 3.8 the IEW results have been converted to constant 1980 dollars per barrel for Saudi Arabian light crude. The CIA (1984) reports that the average price for Saudi Arabian light crude in 1980 was $28.67 per barrel.

As can be seen from the table, the median and mean forecasts have been revised downward from 1983 to 1984 by about $3 to $4 per barrel for all forecast years. According to the latest IEW survey, the median forecasts for 1990, 2000, and 2010 are $27.81, $36.73, and $46.66, respectively, in real 1980 dollars. The range of forecasts continues to be high, with some forecasters predicting drastic real price reductions and some predicting drastic price rises.

Table 3.8. Results of the 1983 and 1984 IEW surveys

	NUMBER OF RESPONSES	MEDIAN RESPONSE	MEAN RESPONSE	STANDARD DEVIATION	RANGE
FORECAST YEAR 1983 SURVEY					
1990	68	$31.54	$31.90	$7.94	$63.93-$20.34
2000	61	$42.43	$41.28	$10.55	$68.80-$17.77
2010	24	$50.17	$49.63	$14.74	$76.26-$14.34
FORECAST YEAR 1984 SURVEY					
1990	57	$27.81	$29.11	$7.69	$63.93-$20.07
2000	54	$36.73	$37.69	$9.92	$62.50-$18.64
2010	16	$46.66	$47.54	$15.74	$76.26-$15.77

4. CONCLUSIONS

"Energy forecasting is a hazardous occupation. Virtually any projection is doomed to be incorrect" (Manne and Schrattenholzer, 1984, page 48).

1. Introduction

The purposes of this paper have thus far been to (1) review the different modeling approaches that have been developed to explain historical oil price changes and forecast future price trends, and (2) review, interpret, and criticize price forecasts that have resulted from these methodologies. In this concluding chapter we review the conclusions that can be drawn from Chapters 1, 2, and 3 in regard to these general purposes and address the degree to which there exists a consensus on modeling approaches and price forecasts. In addition, this chapter presents a subjective assessment of future oil market trends based on the conclusions drawn from previous chapters. Of particular interest is how market structural changes -- resulting from both economic and political pressures -- may impact future oil prices. Finally -- and again drawing on conclusions from previous chapters -- this chapter contains this author's subjective judgment of oil price trends for the 1987 to 2022 time period. In addition to providing high, medium, and low price trajectories for "business-as-usual" market conditions -- conditions in which the basic structure of the world oil market remains relatively unchanged -- the implications of a severe oil supply disruption and a futher breakdown of OPEC's cohesion on oil prices are also considered.

II. A Summary of Conclusions from Previous Chapters

A review of the conclusions from the previous chapters is in some ways difficult, because one of the main thrusts of those chapters is that after more than a decade of intensive study of the world oil market there is little consensus about the way prices are formed -- which is, of course, in itself a major conclusion. However, in a more positive vein there are several general conclusions that can be drawn from a review of the history of the oil market, the models to represent that market, and the forecasts from those models.

The overriding conclusion is that in all three areas -- i.e., the market, the models, and the forecasts -- there has been significant evolution within the past decade. A review of the structural changes in the oil market since the late 1960s shows drastic and continual changes in the relevant players that have significant control over the pricing mechanism, the relevant objectives of those players, and the abilities of those players to manipulate the market to realize those objectives. During the 1970s the major producing countries gained significant control over production decisions within their own countries and thus gained significant control over oil prices. In the early 1980s that control began to decline as non-OPEC producers increased production and major consuming countries reduced consumption in response to the drastic price escalations of the 1970s. In addition, the objectives of the players -- particularly, but not exclusively, the major producers -- may have changed over time as political objectives outweighed wealth maximizing goals and as demands for

oil revenues became increasingly important to ambitious development programs. Political decisions within some consuming countries also led to structural changes -- for example, the removal of oil price controls in the United States.

There has been an equally impressive evolution in the ways the market has been modeled. During the early 1970s models largely followed disciplinary lines, with variations within each discipline to account for different perceptions of the structure of the oil market. To a great extent these models were built by economists who typically used very rigid orthodox theoretical approaches to represent a market that was, in fact, undergoing great structural change. Very elaborate mathematical models arose to represent how a monopolistic producer would produce or set prices to maximize discounted profits. However, the sophistication was based largely on the theoretical and empirical refinement of a rather simplistic underlying objective function -- wealth maximization. Economists in large part ignored the fact that major oil producing countries are not subject to the same kind of forces that a competitive or even monopolistic producer faces within a capitalistic market environment -- i.e., the threat of takeover when profits are not maximized. From this realization arose what may be termed "sufficing" models that adopted alternative objectives, such as meeting a minimal revenue requirement.

The decision to employ producer objectives other than wealth maximization resulted in models that more closely resembled the real-world oil market; however, it also opened a whole new set of issues. If profit maximization is not necessarily an objective

that the major producers will follow, or will eventually be forced to follow because of market pressure, what objective should be used? It is at this point that many modelers realized that political objectives play a major role in the production and pricing decisions of many producers and should be explicitly or implicitly included in any model of the world oil market. The ways political considerations were included differed. In some models political constraints were imposed on an otherwise economic wealth maximizing approach. In other models the political process was tantamount to or exceeded all economic market forces. Some modelers opted for informal models that implicitly contained economic and political considerations.

Therefore the major conclusions to be drawn from more than a decade of modeling the world oil market is that the oil market is continually evolving and world oil models must continually evolve to more closely represent that market. One can also conclude that the general thrust of future models will be to empl- an interdisciplinary modeling approach to address the co economic-political questions or to use a simplistic rule of thumb in forecasting prices, such as setting prices as a function of an exogenously specified OPEC capacity utilization level.

In addition, there is an increasing realization that any forecast of world oil prices is highly uncertain. The general trend is to deemphasize specific point projections and concentrate more on the probable range of future prices. Although recent forecasts of oil prices for the next 30 years are generally down by $3 to $5, reflecting the recent official OPEC price reduction, the

variation in the forecasts remains high. The median response of recent forecasts is that in real terms oil prices will remain flat until about 1990. Between 1990 and 2010 the median forecast is that real prices will increase by between 2 and 3 percent yearly.

III. A Subjective Assessment of Future Market Trends

Given the various caveats discussed in the above section, this section discusses the current oil market environment and presents this author's own subjective assessment of future market conditions. At the time of this writing the oil market continues to be "soft" and many industry officials predict further price cuts. In an effort to support its $29.00 base price, OPEC recently agreed to cut its production ceiling from 17.5 to 16 million barrels per day, with the major producing countries accepting the majority of the cuts. However, oil companies continue to put pressure on OPEC and non-OPEC producers to make price concessions as official prices continue to exceed prices on the spot market. For example, pressures on producers of North Sea oil -- i.e., Norway and the United Kingdom -- place indirect pressure on Nigeria which produces crude of a similar type. Nigeria's well publicized revenue needs make price concessions more probable in the event of a North Sea price reduction and thus continues to threaten the pricing structure of OPEC.

However, one must be careful to distinguish between short-term market signals and probable long-term market possibilities. In the long term three widely divergent price paths are possible. First, the oil producing countries may "weather the current storm" and maintain their pricing cohesion, if not their current $29.00 base

price. The strength of OPEC is largely dependent on the ability of Saudi Arabia to absorb the necessary production cuts to maintain their desired price. Second, demands for revenues in the major producing countries may force production levels that are incompatible with current prices, or the major producers may be forced to "police" members of OPEC and non-OPEC producers by allowing prices to fall, at least temporarily. A significant price reduction of this type could alter the world price trajectory for a period of decades. Third, political turmoil in the Persian Gulf area that results in the long-term disruption of crude from Saudi Arabia and other large Persian Gulf producers could cause drastic escalations in price, such as those observed in the 1970s. Most oil analysts agree that such a disruption, even during soft-market conditions, would result in severe price increases.

The most probable of these three broad scenarios is the first -- i.e., the present basic structure of the market will remain intact. It is generally felt that the benefits to be received by oil producers from maintaining the current structure are large enough to prevent OPEC and non-OPEC producers from entering a "price war" that could significantly reverse the price escalations of the 1970s. Over the longer term, it is generally agreed that OPEC will increase its share of the oil market as non-OPEC reserves dwindle and world economic growth -- especially in the developing countries -- causes significant increases in world oil consumption. Financial reserves within the major producing countries, such as Saudi Arabia, should be sufficient to allow production reductions that will prevent an "all-out price war."

This does not mean, however, that the probabilities of the other two extreme scenarios are infinitesimally small. In another paper by this author (Curlee, 1984), it is argued that the current pressures being exerted on the structure of the world oil market increase the probabilities of both further, and possibly severe, oil price reductions and severe price increases, as compared to the more stable market conditions of recent years. On the one hand, revenue pressures in the more populous producing countries may lead to political unrest that may result in the current governments of those countries being replaced. An example of these political pressures is the recent coup in Nigeria. In order to increase revenues, some countries within OPEC may elect to increase production with or without the approval of OPEC. There is evidence that this is happening currently. If this occurs, more pressure will be placed on the major producing countries to reduce their levels of production. There are, however, limits below which even the major producing countries cannot be expected to reduce production. Chase Manhattan Bank (1984) projects that OPEC's current-account deficit will increase to $16 billion in 1985 from a level of $15 billion in 1984. Although the major core members of OPEC -- i.e., Saudi Arabia, Kuwait, United Arab Emirates, and Qatar -- have about $300 billion in foreign assets, it is clear that they could not be drawn down significantly without some degree of internal turmoil. In the event that the core OPEC members no longer police their production limits, severe price reductions are possible. These downward pressures on price would be further increased if Iran and Iraq end their war and resume production at

pre-war rates. OPEC as a whole has the ability to increase production by about 8 million barrels per day over their June 1984 levels, given their current available production capacity.[10]

On the other hand, the internal political pressures resulting from unmet revenue needs could result in violent conflict within and among the producing countries. Any violent confrontation involving the major producers of the Persian Gulf area would probably result in severe price increases. In the event of the loss of all Persian Gulf production capacity, total OPEC capacity would be reduced from 34.840 to 11.725 million barrels per day. Production losses would be about 11.630 million barrels, based on June 1984 production levels. Given that with the loss of the Persian Gulf producers, OPEC excess-production capacity is only about 3.220 million barrels per day and little excess capacity exists in non-OPEC countries -- with the possible exceptions of Mexico and Canada -- significant panic and price increases could be expected in the world oil market. The exact price increases that would result are virtually impossible to predict. This type of disturbance represents a worst case scenario.

Of course, concluding that the most likely scenario is one in which there is no drastic change in market structure only marginally reduces the problem of forecasting prices. Within this broad scenario there are numerous unknowns that may greatly impact oil prices. However, drawing upon the opinions of numerous industry experts, some general conclusions can be drawn. First,

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[10] The CIA (1984) reports that as of September 1984 total available OPEC production capacity was 26.175 million barrels per day. Production in June 1984 was 18.215 million barrels per day.

there is significant evidence that neither non-OPEC suppliers nor major consuming countries have fully adjusted to the drastic price increases of the 1970s. This continued adjustment will tend to dampen the demand for OPEC oil, at least throughout the remainder of the 1980s. Second, estimates of economic growth are relatively low which suggests that major oil demand increases will not result from increased economic activity. However, even if growth exceeds the current projections, recent work by Daly, Griffin, and Steele (1982) suggests a long-run oil demand elasticity of only about 0.75 with respect to economic activity. A key unknown, however, is how economic growth in developing countries will translate into increases in oil consumption. Third, the level of OPEC production capacity does not appear to be a binding constraint in either the mid or long term. Huge levels of excess capacity currently exist and there appear to be few reasons that OPEC could not, or would not, increase production capacity should the need arise in the long term. Fourth, various experts suggest that it is not in the interest of OPEC to desire large price increase because of the likely responses of non-OPEC suppliers and oil consumers to those increases. Because of these reasons it is most likely that real oil prices will remain constant throughout the remainder of the current decade.

However, due to resource depletion in non-OPEC countries and in some OPEC countries, real price increases are inevitable eventually. Further, once the world oil market becomes "tighter" in the late 1980s and early 1990s, there is an increasing probability of short-term price spikes resulting from temporary

supply disruptions. There is a growing consensus, however, that price spikes resulting from temporary supply disruptions will not result in drastically different long-run price trends because those higher prices are not in the interest of the major producers. Taking the opinions of the various experts into account, real price increases of about 2 percent per year appear to be most probable.

IV. Future Oil Prices

Figure 4.1 gives oil price forecasts for the time period 1987 to 2022 in five year intervals under the assumption that there are no significant market disturbances. The base case forecast is computed under the assumption that real oil prices remain constant in 1984 dollars throughout the remainder of the decade. Prices for the remainder of the forecast period are assumed to increase by 2 percent per year in real terms. The high and low projections are, admittedly, reached in an ad hoc way. If selecting a most likely base case from the numerous forecasts discussed in Chapter 3 is risky, selecting a probable range around that base is dangerous. In order to share that danger -- or at minimum have some stated reason for selecting a range -- the standard deviations of the forecasts from the most recent International Energy Workshop were used. The high projections for the years 1987 and 1992 were obtained by adding one standard deviation from the 1990 IEW forecasts to the base case results. The low projections were obtained by subtracting one standard deviation from the base case. The high and low projections for the years 1997 and 2002 were obtained by adding and subtracting one standard deviation from the

Table 4.1. Oil price projections
1987 to 2022
(In constant 1984 dollars per barrel)

Year	Base	Low	High
1987	$29.00	$21.00	$37.00
1992	$30.00	$22.00	$38.00
1997	$33.00	$23.00	$43.00
2002	$37.00	$27.00	$47.00
2007	$41.00	$25.00	$56.00
2012	$45.00	$29.00	$61.00
2017	$49.00	$34.00	$65.00
2022	$55.00	$39.00	$70.00

Note: Rounded to the nearest dollar

forecasts for the year 2000. All remaining high and low projections were obtained using the standard deviation from the IEW projections for the year 2010.

It is all but impossible to project how prices might change under the two extreme scenarios discussed in the above section. In the case of a "price war" in which OPEC countries increase production sharply in an attempt to increase revenues, world prices could drop sharply -- into the $15 to $20 price range. Possibly the more important question for consumers and producers within the United States is, however, the degree to which the U.S. government would allow prices to drop. It is most probable that a tariff or quota would be set so that U.S. investments in oil production and use technologies that depend on relatively high oil prices would not become instantly outdated. The tariff or quota would be done in the name of -- and could be argued for on the basis of -- reducing future U.S. vulnerability to events in the world oil market. Real domestic prices below the $21 per barrel level might face significant opposition. In 1984 dollars the world price of oil was about $21.75 before the price escalation following the Iranian Revolution.

Likewise it is very difficult to predict how the market would react to a large and prolonged disruption of Persian Gulf oil. In the EMF-6 report the models used in that study were exercised under the assumption that a permanent but unanticipated reduction in OPEC capacity of 10 million barrels per day would be initiated in 1985 while the world oil market is projected to be "soft." Figure 4.1 shows how the various models responded to the scenario. For each

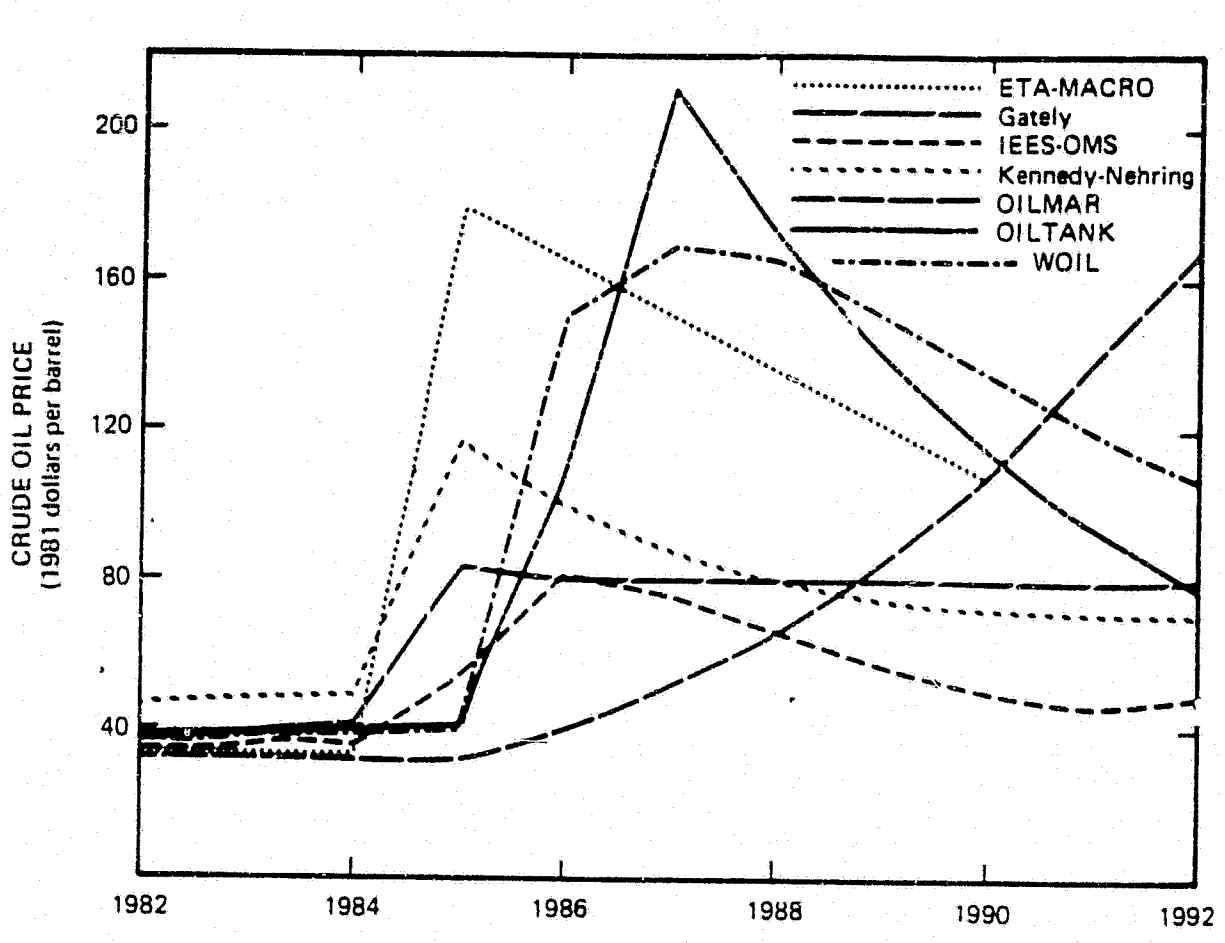

Fig. 4.1. EMF-6 price projections given a permanent 10 million barrel per day capacity reduction.

Source: EMF-6 (1982, page 58)

one million barrel per day reduction in capacity, the models -- with the exception of one -- projected that prices would increase by between $5 and $12 dollars per barrel. As can be seen from the figure, the impacts of the disruption over the long term vary significantly from model to model. Once again, this extreme scenario represents a worse case with a small probability of occurrence.

V. Final Conclusions

The dominant conclusions from this paper concern not what we know about the functioning of the world oil market, but rather what we do not know and how what we do not know can influence our perceptions of future market trends. In some senses, we as students of oil markets have asked as many questions as we have answered about how oil prices are formed. Further, there is an increasing recognition that the answers to the questions, as well as the relevant questions, are constantly changing as oil analysts track a constantly moving target. Methodologies developed to study past market changes and suggest future market directions have evolved as modelers identify and begin to study the extremely complicated set of parameters that determine oil prices. But foremost, oil forecasters increasingly recognize the vulnerability of their trade to conceptual and empirical uncertainties. Users of forecasts are increasingly warned that projections reflect specific assumptions about the structure of the oil market and the key market parameters that are dictated by the use of a particular methodology. If history has not necessarily made forecasters of oil prices more accurate, it has made them wiser.

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