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International Oil Supplies and Demands

Energy Modeling Forum

Stanford University

Preface

The Energy Modeling Forum (EMF) was established in 1976 at Stanford University to provide a structural framework within which energy experts, analysts, and policymakers could meet to improve their understanding of critical energy problems. The eleventh EMF study, "International Oil Supplies and Demands", was conducted by a working group comprised of leading international oil analysts and decisionmakers from government, private companies, universities, and research and consulting organizations. The EMF 11 working group met four times in 1989 and 1990 to discuss key issues and analyze international oil markets.

This report discusses indepth the issues and results studied by the working group. It suplements the major conclusions appearing in the previously released summary report, which is also reproduced in this volume. Inquiries about the study and these reports should be directed to the Energy Modeling Forum, 406 Terman Center, Stanford University, Stanford, CA 94305 (telephone: 415-723-0645).

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EMF's Senior Advisory Panel continues to offer valuable advice on topics as well as comments and suggestions for improving EMF reports. We would also like to acknowledge Kenneth Ellis, Edith Leni, Pamela McCroskey, Dorothy Sheffield, and Susan Sweeney for their assistance in the production of this report.

This volume reports the findings of the EMF working group. It does not necessarily represent the views of Stanford University, members of the Senior Advisory Panel, or any organizations providing financial support.

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Senior Advisory Panel

The Energy Modeling Forum (EMF) seeks to improve the usefulness of energy models by conducting tests of models in the study of key energy issues. The success of the Forum depends upon the selection of important study topics, the broad involvement of policymakers, and the persistent attention to the goal of improved communication. The EMF is assisted in these matters by a Senior Advisory Panel that recommends topics for investigations, critiques the studies, guides the operations of the project, and helps communicate the results of the energy policymaking community. The panel is not responsible for the results of the individual EMF working group studies.

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EXECUTIVE SUMMARY

Since the mid-1980s the world economy has increased its dependence on oil supplies from the Persian Gulf. The oil price response to the Iraqi invasion of Kuwait in August 1990, and the ensuing war between Iraq and allied forces underscore the world's vulnerability to future oil price shocks, given the long-run trend towards increased dependence upon oil from this region.

The eleventh Energy Modeling Forum (EMF) working group met four times over the 1989-90 period to compare alternative perspectives on international oil supplies and demands through 2010 and to discuss how alternative supply and demand trends influence the world's dependence upon Middle Eastern oil. Proprietors of eleven economic models of the world oil market used their respective models to simulate a dozen scenarios using standardized assumptions. From its inception, the study was not designed to focus on the short-run impacts of disruptions on oil markets. Nor did the working group attempt to provide a forecast or just a single view of the likely future path for oil prices. The model results guided the group's thinking about many important longer-run market relationships and helped to identify differences of opinion about future oil supplies, demands, and dependence.

Dependence Upon Middle Eastern Oil

The results from a number of different models and scenarios led to several key conclusions about the world's dependence upon Middle Eastern oil:

• Dependence upon Middle Eastern oil will grow in the future, despite widely different views on the future levels of prices, supplies, and demands. This growing dependence will increase the exposure of the world economy to the substantial insecurity of oil supplies that has been so characteristic of this region.

• The share of oil imports will rise quickly in many major energy-consuming countries. Even with steadily higher oil prices, about two of three barrels consumed within the United States are likely to be imported by 2010.

• While oil production and consumption in the Non-OPEC countries are moderately sensitive to oil prices, this growing dependence upon Middle Eastern oil supplies probably cannot be halted or reversed even if oil prices within the oil-consuming nations were to be greatly increased through taxation or other incentives. For this reason, policies for limiting oil imports are likely to be insufficient for eliminating or containing this dependency. Policy measures may also need to include oil stockpiles, monetary and federal tax policies for stabilizing the economy, and other measures to help the economy adapt to future price shocks caused by instability in oil supplies.

Oil Demands and Supplies

These conclusions about dependency are robust across a range of alternative demand and supply projections. Major conclusions about differences in demand and supply trends include:

• After many years of changing energy prices, fluctuating economic growth and shifting government policy, there is little agreement about how these factors will affect the rate of increase in future demand. While projected oil demand in the market economies is virtually stagnant or growing very modestly by 2000 in some models, it grows briskly in others. Although the wide range in projections is disconcerting, the existence of fundamentally different views can be expected. Analysts assign different values to demand responses to price, economic growth, and technical change. They must draw these values from a limited historical experience containing several sharp shifts in trends for price, economic growth, and oil quantities.

• Projections at the higher end of the spectrum hold that oil demand will grow proportionally with economic growth if oil prices remain unchanged. In addition, they indicate rising oil intensity over the next five years because recent prices (after adjusting for inflation and excluding the price spike during the Iraqi invasion of Kuwait) have been below previous prices during the 1970s and early 1980s. Since oil demand adjusts only gradually to price changes, the price declines during the late 1980s will continue to stimulate oil demand growth during the 1990s.

• Conversely, demand projections at the lower end show continued improvements in oil efficiency even without higher oil prices. They also project little additional stimulus to future demand resulting from the price declines of the 1980s.

• After many years of changing oil prices, fiscal policies of oil-producing countries, and regulatory regimes, there is little agreement about how these factors will influence the level of future oil supply. There is agreement that U.S. supplies will fall regardless of price assumptions because new reserves will be increasingly more expensive. Outside the United States, resource costs appear to be less important than institutional constraints such as infrastructure, taxation, and government ownership of oil-producing enterprises. Projected supplies in these less mature regions either grow or remain relatively stable. Given data constraints and the immense political and economic uncertainty in the USSR, the study has not addressed the potential for net Soviet oil exports. While the bleak economic and political outlook portend declining oil exports over the next few years, a favorable resolution of these conditions could make the USSR an important source of additional world oil supplies in the longer term.

• When oil prices are held constant at $19 (all prices are in 1990 U.S. dollars) over the 1989-2010 period, the projected supply and demand levels in all models reveal strong pressures for OPEC members to either expand production rapidly or increase prices. The median result calls for OPEC to expand production by 5.2% per annum between 1990 and 2000 to meet the oil demand generated by world economic growth of about 2.9% per annum. Many oil analysts think that OPEC would not increase production so quickly, requiring higher prices to reduce world demand and increase production outside OPEC. Over the next decade, a combination of factors could reduce the call on OPEC, and hence the pressure for higher prices, below the range estimated here. It becomes much more difficult to sustain this price path through the next two decades, requiring either significantly less cooperation among OPEC members or very early development of inexpensive unconventional oil supplies at prices substantially below those considered likely today.

Oil Prices

In addition, while the study placed much less emphasis on projecting what the future oil price would be, the group emphasized two conclusions about market-clearing oil prices:

• Projected market-clearing oil prices, determined by the interaction of supply and demand conditions, rise over time in all models, although at substantially different rates. Two distinct sets of price paths are evident. Low demand growth and expanding OPEC output keep prices in several models along a low-growth track, increasing to the low $20s by 2000 and to about $30 by 2010. Substantially higher oil prices result when either demand growth is more rapid or OPEC output is constrained to 37 MMBD or less. The latter limit reflects a combination of economic and political conditions including: declining net income (discounted) at higher production levels, limited ability to absorb additional oil revenues, and a reluctance to sell more of a "patrimonial resource".

• In combination with the previous discussion of the flat price scenarios, these results suggest that oil prices are unlikely to remain consistently below $20 per barrel over the next two decades. At the higher end, it is unlikely that the long-run sustained oil price path over the next decade will exceed the 1981 peak of $55 (in 1990$) during the second oil price shock. Within this wide range, uncertainty about external factors like world economic growth, oil supply and demand responses to prices and economic growth, and political developments in oil-producing and oil-consuming countries can lead to a number of plausible outcomes.

Further Work Needed

In the study, existing models of the world oil market were used to quantify certain key relationships important for understanding this market and to highlight major areas of agreement as well as differences. By providing a consistent framework for evaluating a number of important factors, the models have been very useful for advancing the group's discussion and for revealing the implications of various oil supply and demand trends for future oil prices and dependence upon OPEC supplies. However, even after many years of energy policy debates, several research and modeling issues remain open. The working group identified four critical areas where a revival of research and modeling would be particularly useful for improving the state of analysis of world oil markets:

• The most critical challenge to future modeling appears to be ways to represent the cartel's long-run output decision. Decisions about when and by how much the cartel will expand capacity need to be linked to the market conditions being determined elsewhere in the model. Extensions to incorporate the possibility of rivalry within OPEC and its impact on long-run capacity decisions should also be encouraged.

• Another critical concern is to resolve the disparate views on future trends in oil use efficiency. Additional study is needed to separate the effects of current prices from past prices and other nonprice factors such as technological progress or shifts in the economy's composition of goods and services. Furthermore, while oil demand growth is expected to be concentrated in the developing countries, poor data often prevent careful analyses of their energy production, use, and balance-of-payment constraints.

• Many existing models focus on oil only, giving limited attention to interfuel substitution issues. Environmental policies and more abundant natural gas supplies can alter substitution opportunities, perhaps dramatically changing the oil market picture. Some expanded capability to handle these issues will become increasingly important.

• Analyses of world oil market conditions are severely limited by the unavailability of reliable data on the cost of producing oil in major supply regions outside the United States. Moreover, the role of technology and the effect of producing-country tax policies in enhancing future oil supplies are poorly understood.

INTRODUCTION

Since the mid-1980s the world economy has increased its dependence on oil supplies from the Persian Gulf. After several years of stagnating world economic growth and oil demand, oil use rose sharply beginning with the oil market collapse in 1986. At the same time, oil production outside the Middle East stabilized after expanding significantly during the first half of the decade.

The oil price response to Iraqi invasion of Kuwait in August 1990, and the ensuing war between Iraq and allied forces, demonstrated the inherent instability of an oil market so dependent upon relatively inexpensive supplies from the Persian Gulf. Even though most of the 4.3 million barrels per day (MMBD) of lost Iraqi and Kuwaiti production was replaced with surge production from other countries, prices rose sharply in the weeks after the August invasion, with spot prices reaching $40 per barrel in October when fears of expanded military conflict intensified. This crisis underscores the world's vulnerability to future oil price shocks, given the long-run trend towards increased dependence upon oil from this region.

Study Background

This report summarizes the key results of the eleventh Energy Modeling Forum (EMF) study, henceforth referred to as EMF 11, focusing on international oil supplies and demands through 2010. In May 1989, the EMF commenced this study to compare alternative perspectives on supply and demand issues and to discuss how alternative supply and demand trends influence the world's dependence upon Middle Eastern oil. How rapidly will world oil demand grow? Will supplies outside OPEC increase, stabilize, or decline? What are the long-run implications of these demand and supply trends for the world's dependence on oil from OPEC member countries and particularly from the Persian Gulf? And do these trends make us more or less concerned about possible future oil disruptions?

From its inception, the study was not designed to focus on the short-run impacts of disruptions on oil markets. Other analytical frameworks would have been chosen had short-run oil market dynamics been the primary interest.

Nor did the working group attempt to provide just a single view of the likely future path for oil prices. For one thing, the key conclusions about the growing dependence upon Middle Eastern oil do not depend upon the oil price outlook. Moreover, three oil shocks and two major price collapses within two decades show the perils of oil price forecasting. There exists considerable uncertainty about the basic economic forces influencing the oil demand and supply conditions that determine oil prices. Moreover, the market outcome is critically dependent upon how these economic forces interact with a set of highly unpredictable political factors. While these problems limit the usefulness of precise price forecasts, they increase the value of probing the range of possible market outcomes in order to understand how basic economic forces lead to alternative oil market conditions.

Organization of Summary Report

After a brief description of the general approach, the models, and the scenarios, the report summarizes the main conclusions. In analyzing the results, the report begins with a comparison of the projected supply and demand trends when all models use a common oil price path. Then, the response of supply and demand to alternative oil price paths is considered. Finally, these findings are integrated to explain the factors determining differences in the market clearing oil price projected by the models.

Table 1. Models in EMF Study

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*Organization listed for identification purposes. Models and results do not necessarily represent official view of listed organization.

APPROACH

As in previous EMF studies, the research was conducted by an ad hoc working group of more than 40 leading analysts and decisionmakers from government, industry, academia, and other research organizations. In the EMF process, the working group pursues the twin goals of (1) improving the understanding of the capabilities and limitations of existing energy models and (2) using these models to develop and communicate useful information for energy planning and policy. A key objective is to foster an improved dialogue between the developers and potential users of world oil models.

The EMF 11 working group met four times over the 1989-90 period to develop a study plan with a set of carefully selected scenarios, analyze model results and supporting research, and develop key conclusions and insights. Proprietors of 11 economic models of the world oil market used their respective models to simulate a dozen scenarios using standardized assumptions. The model results guided the larger group's thinking about many important market relationships and helped to identify differences of opinion about future outcomes.

Models

The 11 world oil models used in this study are listed in Table 1 with the name of the working group representative and affiliated organization. Since the modelers used EMF standardized assumptions for prices, economic growth, and cartel capacity, these projections are not forecasts of the particular organizations. Moreover, the institutional affiliation listed in Table 1 is given to identify the model rather than to indicate an official modeling framework of a particular organization.[1] This caveat applies particularly to BP America, WOMS, and the Federal Reserve Bank of Dallas, as well as the various university models.

OIL MARKETS AFTER THE PERSIAN GULF CRISIS

The scenarios in this study were specified and finalized prior to Iraq's invasion of Kuwait and the ensuing Persian Gulf war. The working group met for a fourth and final time, one month after the initial invasion, to review the major conclusions of the analysis. During this meeting, the group extensively discussed the usefulness and limitations of these models and projections, in light of the Persian Gulf crisis.

The invasion underscored the difficulty of anticipating when political events will disrupt oil markets. Once the disruption occurred, moreover, oil prices were influenced by such short-run factors as inventory building in anticipation of how hostilities would be resolved. The world oil models used in this study focus upon the longer-run economic conditions influencing oil supply and demand and are therefore not appropriate for studying the timing of disruptions and their near-term effect on oil prices.

At the same time, models such as those used in this study were useful for establishing that the spiraling oil prices in response to the crisis were well above levels that were consistent with long-run economic conditions in 1990. The combination of slack oil market conditions with substantial oil replacement potential from other countries indicated that oil prices would soon return to their lower levels. While oil prices surpassed $40 per barrel on some days during 1990, the average oil price for the year was about $23 per barrel, a level only slightly higher than the average projected 1990 level in the market-clearing scenario in this study. The group was confident that prices would return to their lower levels after the uncertainty about war outcomes was resolved, and they did.

The Persian Gulf crisis of 1990 is also likely to have some long-lasting impacts on the oil market. Will increased western military presence in the Persian Gulf enhance the security of oil investments in the region? Has the crisis strengthened the political position of the monarchial states, who have traditionally sought lower prices, or ultimately the more populist regimes, who have tended to adopt more aggressive pricing policies? While the models will not help to resolve the uncertainty in these geopolitical issues, they provide an essential framework for understanding the economic implications of different Middle Eastern policy regimes on the world oil markets. Any effort to reconsider oil markets after the invasion of Kuwait must include a thorough analysis of the same supply and demand issues discussed in this study.

The models were developed to prepare long-run projections of oil prices, oil production, and oil consumption and to study changes in these variables under alternative scenarios. They incorporate the behavior of three distinct types of decisionmakers: oil consumers, oil producers outside the cartel, and oil producers within the cartel. Most models report prices and supply-demand balances annually and focus exclusively on world oil markets.[2] Alternative fuel prices and interfuel substitution are not explicitly represented. Instead, competing fuel prices in the future are assumed to change with oil prices as they have in the past. The response of oil demand to changes in these other fuel prices is also based upon historical experience.

In these models, oil consumers respond to Gross Domestic Product (GDP), energy-saving trends in technology or economic structure (if present), and oil prices. Shifts in the economies' structures are seldom incorporated explicitly, because each region's economy is represented as one aggregate sector. The response of oil producers outside the cartel is governed by assumptions about trends in resource depletion and technology in addition to oil prices. By basing parameter values on historical experience, most models assume that past regulatory policies will be continued into the future. Some models may adjust these responses to reflect expected changes in regulation and fuel substitution.

Table 2. Scenarios in EMF Study

Predetermined Price Path Scenarios:

1. Flat Oil Price (with Base GDP Path)
2. Rising Oil Price (with Base GDP Path)
3. 1989 IEO Price
4. Flat Oil Price with High GDP Path
5. Flat Oil Price with Low GDP Path
6. Rising Oil Price with High GDP Path
7. Rising Oil Price with Low GDP Path
8. No Economic Growth (with Flat Oil Price)
9. No Economic Growth or Technological Time Trend (with Flat Oil Price)

Market-Clearing Price Scenarios:

10. Cartel Case (with Base GDP Path)
11. Cartel Case (with High GDP Path)
12. Competitive Case (with Base GDP Path)

In most models, the cartel's productive capacity is predetermined, based upon modeler judgment of a combination of economic and political constraints. The cartel sets a price based upon last period's price and rate of utilization of its capacity based upon a relationship that explains price movements somewhat better in the 1970s than in the 1980s. In this way, oil prices, production, and consumption are determined recursively; market conditions in one year influence those in the succeeding year.

Scenarios

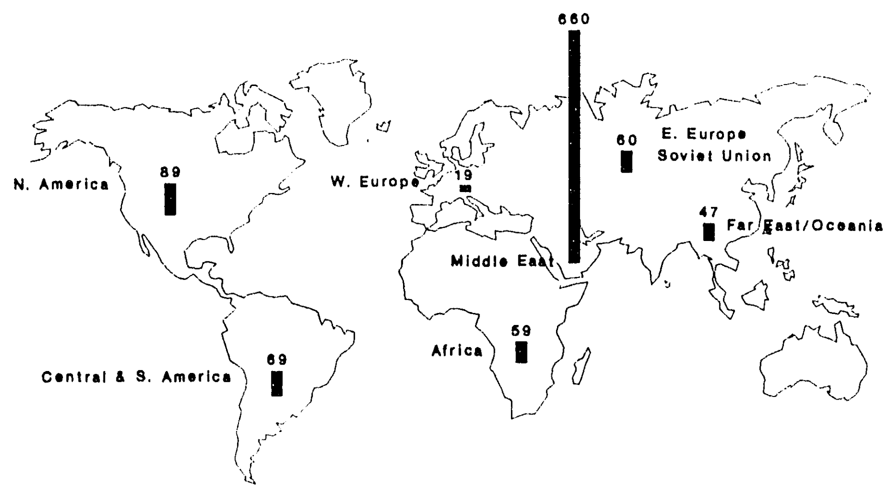
The working group considered a dozen scenarios, listed in Table 2, in which all modelers used the same input assumptions for economic growth and OPEC capacity. The first nine scenarios also specified a predetermined price path that was to be assumed by each modeler. Specific model assumptions about OPEC's behavior or responses to market conditions were not used in these scenarios. Instead, the oil-producing cartel is considered to be a passive participant, operating as a residual supplier of oil, meeting all oil demand that remains unsatisfied by non-OPEC production. Price and economic growth assumptions are discussed together with the major findings.

These first nine scenarios were developed to allow a standardized comparison of the projected supply and demand trends in various models across a wide range of reasonable oil price and GDP paths. They also help to interpret the results from three additional scenarios where supply and demand conditions, including OPEC production decisions, are allowed to determine a market-clearing oil price in each model.[3]

It should be emphasized that modelers were requested not to impose any shifts in government policies in running these cases. Many working group members thought that oil-importing countries would impose taxes and other conservation policies to limit their oil demands. Thus, the EMF scenarios should

Figure 1. World Crude Oil Reserves

January 1, 1990 (Billion Barrels)



Source: EIA, International Energy Annual, DOE/EIA-0219

be considered as revealing the pressures that would emerge under alternative oil price and GDP paths if no such policies were implemented.

The price trajectories in this study should be viewed as paths averaging over several decades. Almost surely, actual year-to-year prices will deviate from the long-run paths reflecting short-term shifts in market conditions. In addition, the study has not tried to anticipate future shifts in foreign exchange rates that could affect the price of oil in local currencies and ultimately the dollar-denominated price.

ALTERNATIVE PERSPECTIVES ON SUPPLY AND DEMAND TRENDS

The Growing Dependence Upon Persian Gulf Oil

Dependence upon Middle Eastern oil will grow in the future, despite wide differences in quantitative estimates of prices, supplies, and demands. Current oil reserves are heavily concentrated in the Middle East (Figure 1); furthermore, this oil is inexpensive to produce relative to oil in other regions.[4]

Many of the study's key findings can be summarized by discussing the results from one scenario--the 1989 IEO price case. Unless noted otherwise, the conclusions discussed here apply broadly to the other scenarios as well. This scenario was based upon the mid-price case in the Energy Information Administration's 1989 *International Energy Outlook (IEO)*. After dramatic declines in actual oil prices between 1981 and 1986, this scenario calls for the long-run, sustained oil price path to remain relatively flat in the high teens through the early 1990s, before rising to $30 a barrel by 2000 and to $39 a barrel by 2010. (All prices are in 1990 U.S. dollars.) This path shows the oil price path that can be sustained over the long run; prices in the short run can be either above or below this path. The market economies are assumed to grow at 2.9% per annum over the 1990-2010 period in this scenario, with higher economic growth (4.1% p.a.) outside the OECD countries. Finally, any additional policies to reduce oil demand in the major economies are not incorporated. While one might expect some demand reduction policies in the United States, other countries already have made considerable progress in shifting away from oil.

The median results[5] represented in Figure 2 highlight the growing dependence upon OPEC and the Persian Gulf[6] found in all models. After leveling out during the 1980s, oil consumption in the market economies begins to rise, with much of this growth occurring within the developing countries (particularly, in the Pacific Rim). Oil production outside OPEC member countries falls gradually through 2000 and more steeply during the initial decade of the next century. While production within the United States falls, production in other regions remains relatively stable in many models. The median result shows a very modest decline in non-OPEC production--a noticeable break in the upward trend observed for the 1980s. Despite the higher prices in later years, production declines because geologic depletion in mature areas offsets exploratory finds in new regions, technological progress, and improved economic incentives. As a result of gradually rising demand and falling or stable production outside the cartel, dependence upon OPEC and Persian Gulf sources grows throughout the next two decades. Increasing demand in a market with OPEC output growing only moderately, across a range of conditions, is the major explanation for gradually increasing oil prices over the longer run, such as with the 1989 IEO price path. If OPEC members in this scenario were to act simply as residual suppliers--producing whatever quantities to meet the excess demand not being supplied by non-OPEC production--their production (median result) would grow from 21.5 MMBD in 1988 to 36.7 MMBD by 2000 and to 43.2 MMBD by 2010. Moreover, the strong upward trend in OPEC production is robust across the models.

Rapidly growing OPEC production means that world oil production will increasingly be concentrated in the lower-cost regions, principally the Persian Gulf producers within OPEC. The percent of oil supplies for the market economies originating from OPEC countries (bottom of Figure 2) rises from 43% in 1988 to 58% by 2000. The Persian Gulf's market share also rises substantially from 27% in 1988 to 42% by 2000.

Growing dependence upon Persian Gulf oil will have major energy security implications, even for countries that import little or no oil. As the world's dependence upon this source increases, interruptions in the flow of oil from that region will cause larger oil price shocks. Past price shocks severely depressed economic activity in both energy-exporting and energy-importing countries.[7] A particular country's dependence upon oil imports does not necessarily change this outlook and is therefore less important from an energy security perspective.

These trends are based upon the assumption that OPEC members would become residual suppliers at the prices assumed in the 1989 IEO price path. In fact, OPEC could adopt several different strategies that would influence the oil price in significant ways. While there remains considerable uncertainty about OPEC's behavior, the EMF 11 results suggest strongly that OPEC's increasing market share will materialize, even in scenarios where it influences prices through cooperative behavior.

World Oil Demands

After many years of changing energy prices, fluctuating economic growth, and shifting government policy, there remains considerable uncertainty about how these factors will influence future oil demand. While oil demand in the market economies is virtually stagnant or growing very modestly by 2000 in

Figure 2. Median Results for 1989 IEO Price Path

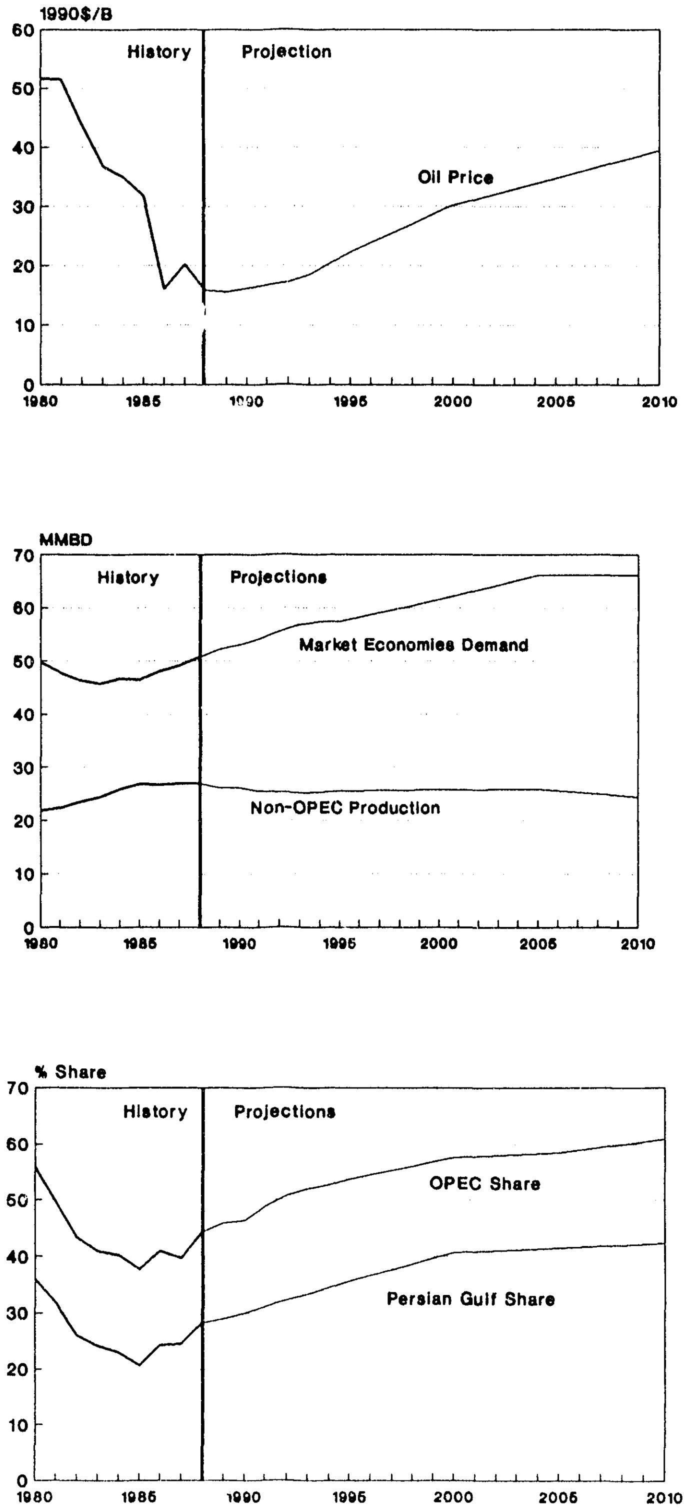
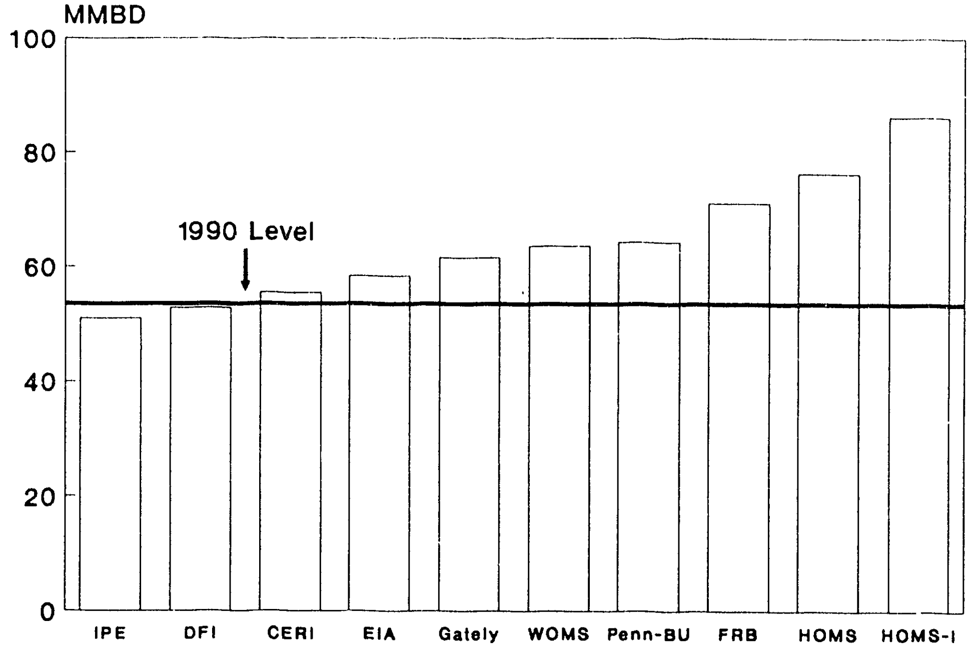


Figure 3. Market Economies Consumption in 2000 with 1989 IEO Price Path



some models (e.g., IPE and DFI shown at the left in Figure 3), it grows briskly in others (HOMS and FRB-Dallas, shown at the right in the same figure). By 2000, there exists a 30 MMBD difference in demand projections (Figure 3), despite the common oil price and economic growth assumptions.

While the wide range in projections is disconcerting, the existence of fundamentally different views can be expected. Oil demand projections incorporate the separate effects of several key factors: the current oil price, economic growth, technical change influencing oil demand independently of price, and past oil prices (since demand adjusts slowly to price). Analysts determine different values for the demand response to these factors, based upon a limited historical experience containing several sharp shifts in trends for price, economic growth, and oil quantities. In the 1950s and 1960s, GDP and oil demand grew at roughly comparable rates. Over the next decade, real oil prices rose sharply, causing oil demand to grow less rapidly than GDP in many countries. During the 1980s, oil consumption declined or grew very slowly, as other fuels displaced residual fuel oil in powerplants and major stationary industrial applications. The transportation sector, on the other hand, has remained almost totally dependent on gasoline and jet fuel for airplanes. Since 1986, total oil use has grown more rapidly during a period of widespread economic recovery and lower oil prices.

At the moment, it is uncertain whether the decoupling of oil use and economic growth in past periods will continue, and at what rate. Once residual fuel oil has been displaced in many applications, oil use trends will be heavily dominated by the growing transportation demand for gasoline and jet fuel. Moreover, there may be renewed reliance upon heavy fuel oil for new generating capacity and industrial installations in economies with severe capital constraints.

Projections at the higher end of the spectrum view that oil demand will be strongly stimulated by economic growth; a 1% increase in GDP results in a 1% increase in oil use in both HOMS and FRB-Dallas, if oil prices remain unchanged. Moreover, in the absence of higher prices, there exists no long-run trend towards more efficient energy use in these projections. While some new technologies save energy, other technologies and lifestyle changes use more energy.

Conversely, demand projections at the lower end show continued improvements in oil efficiency even without higher oil prices. Within this group, oil intensities (oil use per dollar of GDP) at the higher end are falling at approximately the same rate as they did in the late 1980s, while those at the lower end decline more rapidly, more in line with the experiences of the late 1970s.

Another surprising source of discrepancy between oil demand projections is the gradual effect of lower oil prices since 1986 on oil demand during the 1990s. Contributing to the higher demand projections of the first group is the belief that oil use will rise more rapidly than economic growth over the next five years because recent prices (after adjusting for inflation and excluding the price spike during the Iraqi invasion of Kuwait) have been below previous prices during the 1970s and early 1980s. Since oil demand adjusts only gradually to price changes, the price declines during the late 1980s will continue to stimulate oil demand growth during the 1990s. In contrast, there is little additional stimulus to future demand resulting from the price declines of the 1980s in the lower demand projections. The significance of this source of demand growth to some projections is demonstrated by the fact that there exists a 16 MMBD difference between projections as early as 1995.

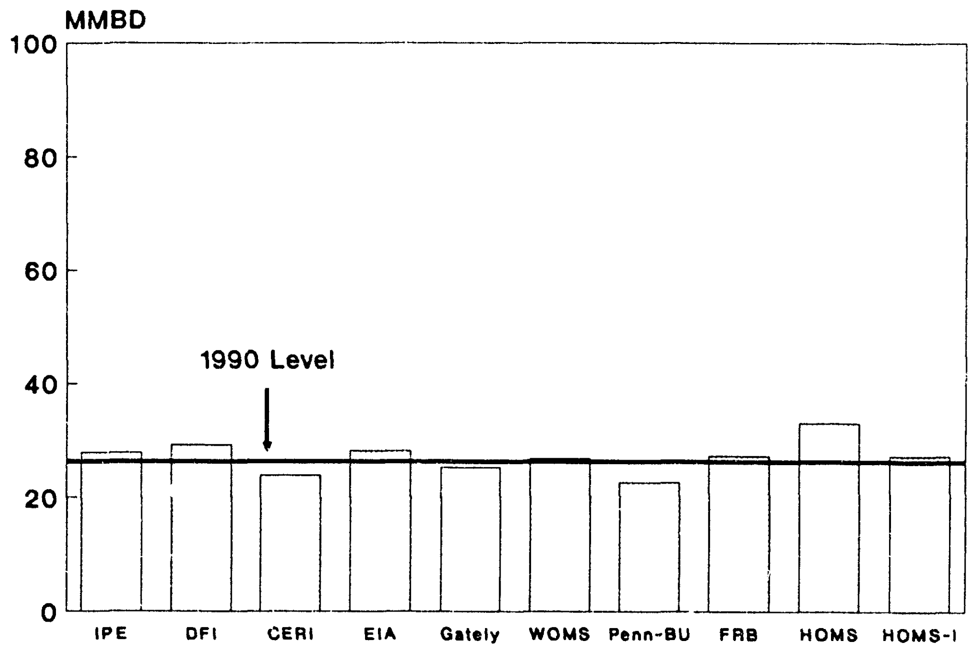
Non-OPEC Supplies

After many years of changing oil prices, fiscal policies of oil-producing countries, and regulatory regimes, there is little agreement about how these factors influence the level of future oil supply. Estimates of oil production outside OPEC (excluding the Soviet Union) under these same oil price assumptions are shown in Figure 4, which adopts the same vertical scaling as in Figure 3 as well as ordering of models, i.e., from lowest to highest total demand, moving from left to right. Differences in production are less pronounced than for the market economies demand. Production ranges from 24 to 32 MMBD by 2000; by 2010, the range widens considerably to 20-38 MMBD.

This smaller variation in production estimates does not reflect greater certainty in future oil supply than demand levels. Many models are based upon the same geologic resource base estimates and use similar assumptions about constraints on expanding future supplies, even though considerable uncertainty exists about both the resource base and these drilling constraints. Moreover, relative to the average projected level, the range in production estimates is not noticeably smaller than that in consumption. While projected oil demands grow over the period, projected non-OPEC supplies fall or remain stable for the most part.

Even after a decade of growth in non-OPEC supplies, most analysts anticipate future oil production from these areas to decline over the next decade. Higher resource costs and limits on expanding oil drilling in newer regions lacking a supporting infrastructure contribute to this decline in production. Non-OPEC production is highest in HOMS and FRB-Dallas, neither of which explicitly links its production estimates to resource

Figure 4. Non-OPEC Production in 2000
with 1989 IEO Price Path



estimates. Instead, production changes over time and with the oil price path, based upon responses that have been derived statistically from historical data.

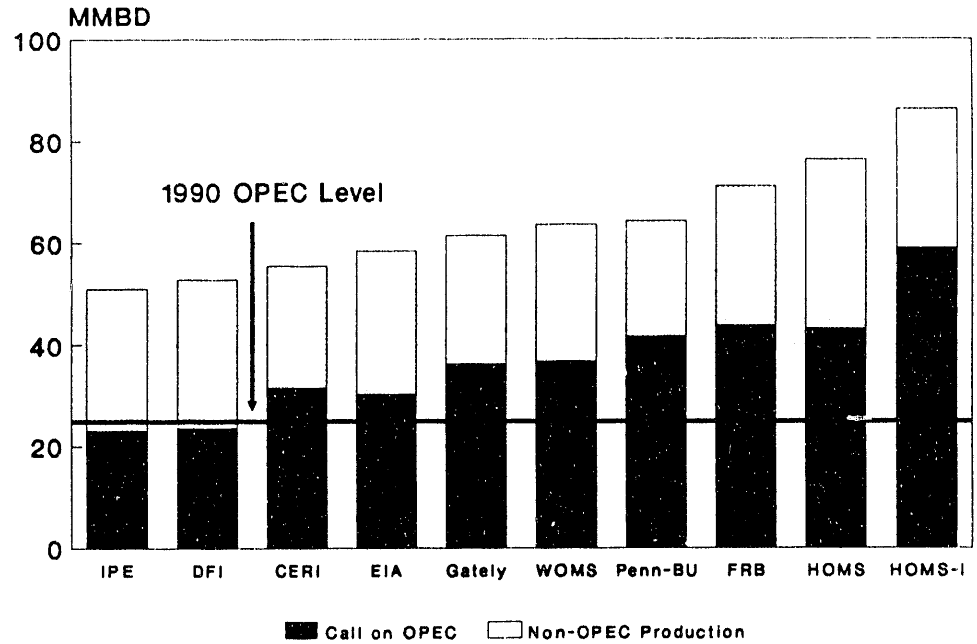
There is agreement that U.S. supplies will fall regardless of price assumptions because new reserves become increasingly expensive. By contrast, projected supplies in less mature regions outside the United States either grow or remain relatively stable. While oil exploration and discovery in these newer regions generally are less costly than in the United States, institutional constraints such as infrastructure, taxation, and government ownership of oil-producing enterprises often restrict oil-producing activity from expanding rapidly.

In general, analysis of supply decisions is hindered by inadequate information about the costs of various resources, the impetus for technological advancement in oil exploration and production, and the role of government intervention through changes in fiscal (tax) policies.

The Call on OPEC

Despite these substantial differences in supply and demand projections, there exists a consensus on the rising dependence upon OPEC oil during the next two decades. As a result of growing world demand and relatively flat (sometimes declining) non-OPEC production, the demand for OPEC oil increases strongly in virtually all models.[8] Figure 5 combines the information in Figures 3 and 4 to reveal the widening gap between total demand and non-OPEC production that must be met by OPEC members to keep prices along the 1989 IEO price path. OPEC's production of 21.5 MMBD in 1988 would need to grow to a range of 25-45 MMBD by 2000, depending upon the model. Currently more than 40 percent of the market economies oil demand originates in OPEC countries. The median share

Figure 5. Market Economies Supply Sources in 2000 with 1989 IEO Price Path



projected in the study rises to 56% in 2000 and 62% in 2010 in the 1989 IEO price case. Since market demands vary more across models than do non-OPEC supplies, differences in the call on OPEC will reflect differences in total demand more than in non-OPEC supply. Thus, the net call on OPEC in Figure 5 is some 50% higher for HOMS and FRB-Dallas, even though they indicated the highest non-OPEC production in the previous figure.

Growing U.S. Imports

A rising OPEC market share reflects greater dependence upon imports for meeting oil consumption in many major energy-consuming countries. These trends are likely to accelerate interest in policies for reducing oil imports, particularly in the United States where low world crude oil prices and low U.S. taxes on oil use have exacerbated the oil import outlook.

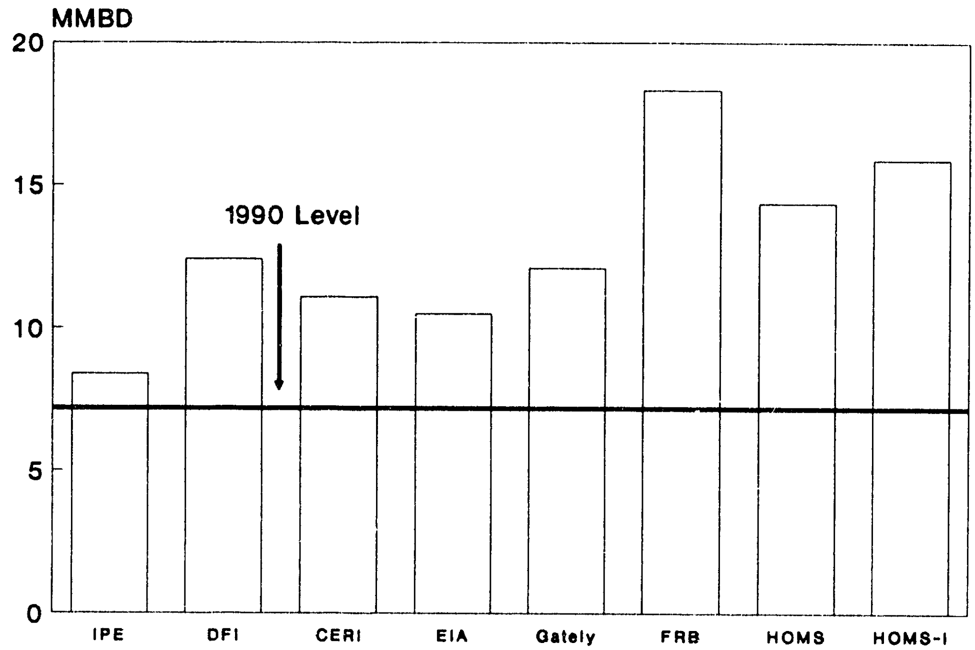
Despite a wide range of projections for U.S. oil production and consumption, there is agreement that U.S. imports will grow briskly over the next two decades. Oil imports rise from 6.9 MMBD in 1988 to a range of 8-18 MMBD by 2000 with the 1989 IEO price path (Figure 6). Imports tend to be higher in models projecting greater U.S. and world demand growth (on the right side of the figure) than with lower demand growth. In the 1989 IEO price case, slightly more than one of every three barrels consumed by the United States is imported beginning in 1988, but about two of three barrels consumed are imported by the end of the period, 2010.

ALTERNATIVE PRICE PATHS

Is $19 Oil Sustainable?

Why couldn't the sustained, long-run oil price path remain flat at about $19 (rising only with inflation) through the next two

Figure 6. U.S. Imports in 2000
with 1989 IEO Price Path

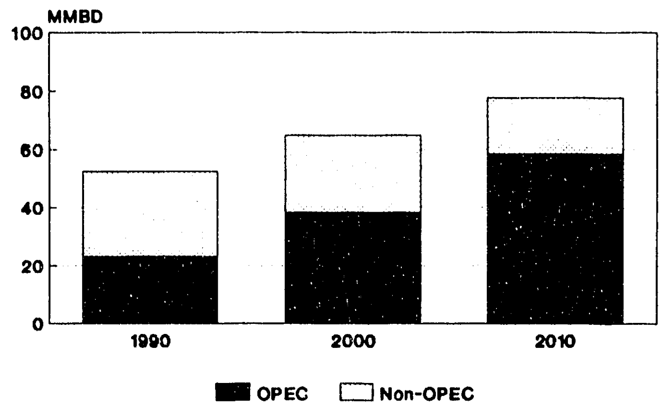


decades?[9] The long history of oil prices, dating back to early in this century, reveals no long-run trend towards rising prices after adjusting for inflation. Given that it has been just as likely for oil prices to decline as to rise in any given year, the current price may be the best estimate of the long-run trend given the extreme uncertainty about the market. Moreover, some analysts find that long-run resource costs are low enough and government policy is flexible enough to make this perspective a viable one.[10]

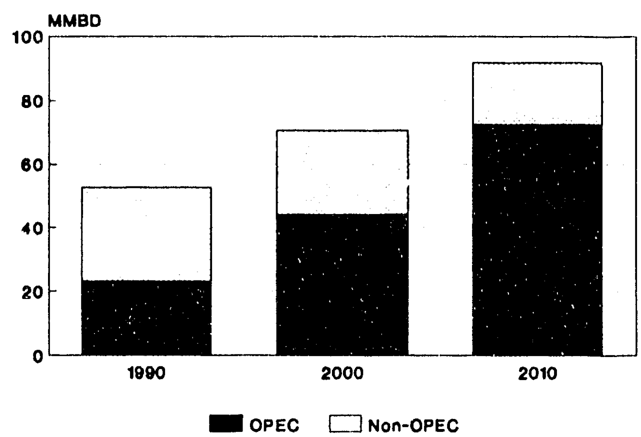
When oil prices are held constant at $19 over the 1989-2010 period, the projected supply and demand levels in all models reveal strong pressures for OPEC members to either expand production rapidly or increase prices. This conclusion holds for a very wide range of demand projections in the various models and applies to three different economic growth scenarios. If OPEC were simply to meet this demand at the $19 price, they would need to expand production rapidly, surpassing their peak production of 31 MMBD well before the end of century. If world economic growth is to keep pace with its recent trend (about 3% per annum), three out of four barrels consumed in the market economies would originate from OPEC by 2010.

The median results shown in Figure 7 for these three scenarios indicate substantially rising oil demands, modestly declining non-OPEC supplies, and rapidly growing dependence upon OPEC sources. Total market economies demand is shown as the sum of OPEC (the solid bar) and non-OPEC including net USSR exports (the light bar). Total demand in the base flat price case[11] grows from 52 to 63 MMBD over the next decade. Due to modestly declining non-OPEC production, OPEC production would need to expand to 38 MMBD. The call on OPEC in 2000 would fall to 33 MMBD if the market

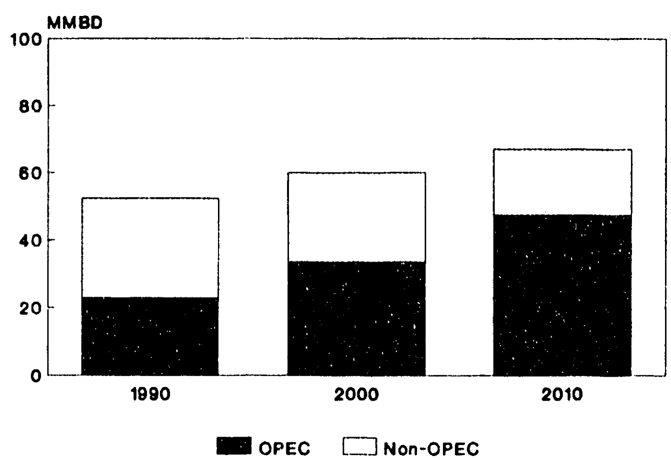
Figure 7. Production under Flat Price Case with Base GDP Path



... with High GDP Path



... with Low GDP Path



economies were to grow by 1 percentage point per year less (the low growth case); it would increase to 44 MMBD if these economies were to grow by 1 percentage point per year more. Expansions in OPEC supplies of 3.9, 5.2, and 6.7% per annum between 1990 and 2000 would be required in the low, base, and high GDP cases, respectively.

The sustainability of such an oil price path depends critically upon OPEC members' willingness to expand oil output. Oil productive capacity in the Middle East is relatively inexpensive and easy to expand. Indeed, even prior to the Iraqi invasion of Kuwait, announced expansions to OPEC capacity exceeded 10 MMBD.[12] With the resolution of the Gulf crisis, many oil-producing countries seem willing for the moment to expand their capacity. If these developments should result in OPEC's capacity expanding to more than 40 MMBD by 2000, they would accommodate the demands on OPEC in the flat price scenario in all but the higher economic growth scenario. By 2010, however, oil prices would be under strong pressure to increase in response to world economic growth of 2.9% per annum, unless OPEC capacity was expanded to well over 60 MMBD.

OPEC might not increase production so quickly, requiring higher prices to reduce world demand and increase production outside OPEC. Economic incentives might well constrain cartel oil production from reaching such levels. Rapid expansion of its production could depress oil prices sufficiently to reduce the cartel's profits.[13] Alternatively, OPEC's reluctance to supply additional oil could reflect a declining need for additional oil revenues for their internal investment, or a political resistance to depleting what they consider to be a "patrimonial" resource at "bargain" prices for the industrialized countries. The Energy Information Administration's *1989 International Energy Outlook*, for example, projected that OPEC capacity would not exceed 36 MMBD by 2000. Under these conditions, OPEC's productive capacity would be severely strained by 2000 in two of the three economic growth cases.

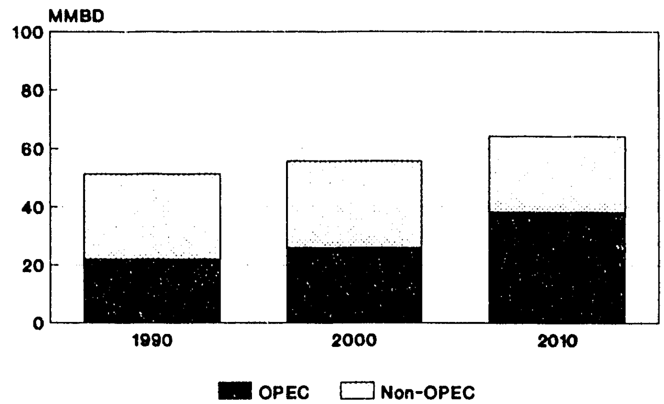
In summary, prices could be sustained at $19, but only with a program of aggressive capacity expansion by OPEC. In the absence of this acceleration in OPEC supplies, it becomes difficult to sustain this price path, particularly after 2000. Even over the next decade, maintaining the flat oil price path through 2000 would require some combination of lower economic growth, higher production of conventional oil in areas outside OPEC, early development of inexpensive unconventional oil supplies, and aggressive policies for reducing oil consumption by major consuming countries.[14]

And finally, long-run developments within the Soviet Union could affect the long-run oil price path. While the bleak economic and political outlook portend declining oil exports over the next few years, a favorable resolution of these conditions could make the USSR an important source of additional world oil supplies in the longer term. The combination of expanded oil production, aggressive energy conservation, or extensive fuel switching away from oil within the Soviet Union could result in substantial increases in oil exports from this region in the coming years, placing downward pressure on prices.

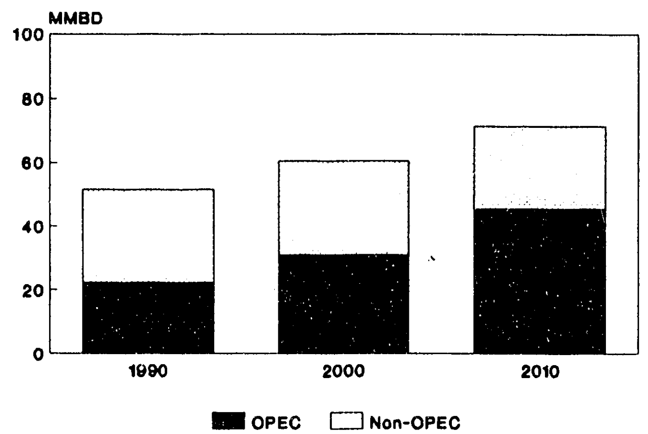
A Rising Price Path

Without rapid expansion of OPEC supplies, it can be expected that oil prices will increase from $19, augmenting non-OPEC production and reducing world demand and the call on OPEC estimated in the flat oil price case. Figure 8 shows the median projection for consumption, non-OPEC production, and the call on OPEC when oil prices are assumed to rise steadily from $19.50 to $39 through 2000 and remain at that higher level after 2000. Consumption

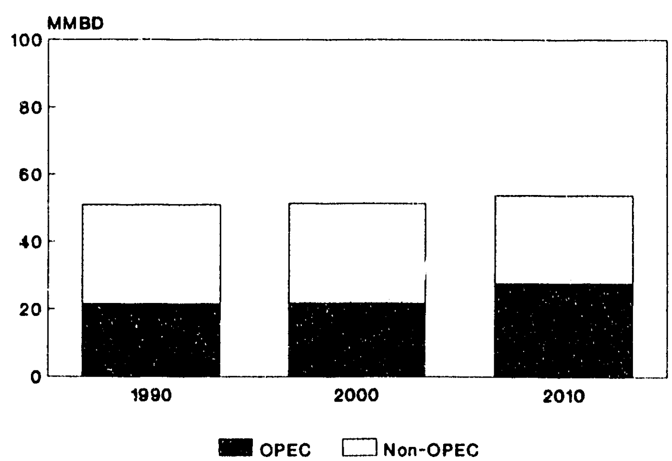
Figure 8. Production under Rising Price Case with Base GDP Path



... with High GDP Path



... with Low GDP Path



grows more slowly to 55 MMBD by 2000, while non-OPEC production remains relatively stable at 28 MMBD through the period. The higher prices significantly alter the call on OPEC, which falls from 38 MMBD in the flat price case to 26 MMBD in the rising price case by 2000. As a result, OPEC production increases by a relatively modest 1.7% p.a. through 2000 in the rising price scenario.

The rising price path represents an upper bound on oil prices over the next decade. While the call on OPEC lies in the 30-33 MMBD for four models, half the models show that OPEC members would be left with considerable excess capacity over this period. The median OPEC production is only 26 MMBD in 2000 or 74% of the 35 MMBD capacity limit used by EIA. Moreover, higher prices in the presence of low OPEC output would be a strong inducement for cheating on production quotas by cartel members. These pressures become very intense when rising oil prices are combined with low economic growth, conditions which keep the median OPEC production virtually constant through 2000 and only modestly higher than current levels by 2010.

The results from the flat and rising price paths help to determine the likely range of oil prices over the next decade. Flat oil prices below $20 imply very strong growth in OPEC production; rapidly rising prices exceeding $39/Bbl by 2000 require limited OPEC production in more than half the models. The 1989 IEO price path discussed previously lies between these two price paths over most of this period.[15]

Reducing Dependence Upon OPEC

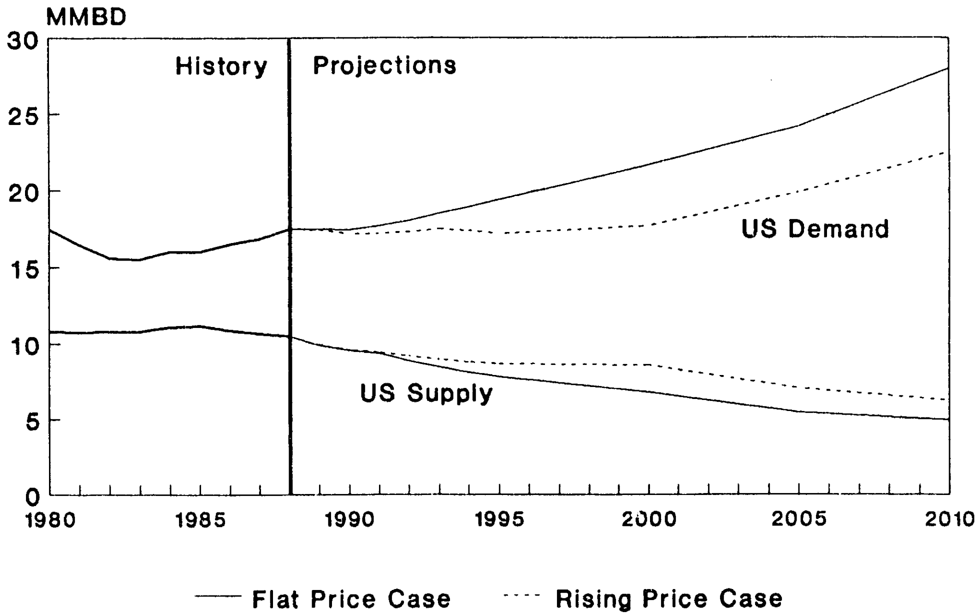
These results also demonstrate that while oil production and consumption are moderately sensitive to oil prices, large changes in oil prices are often required to alter significantly the dependence upon OPEC supplies. This finding is relevant to the effectiveness of policy intervention by non-OPEC countries to discourage oil consumption or encourage domestic production. Oil taxes increase the delivered price paid by consumers, oil subsidies increase the after-tax price received by producers, and oil import fees do both. Although mandated conservation measures (e.g., automobile efficiency requirements) do not increase delivered oil prices directly, they impose higher costs on consumers by requiring other inputs to be substituted for energy and hence can be viewed as an implicit tax on oil use.

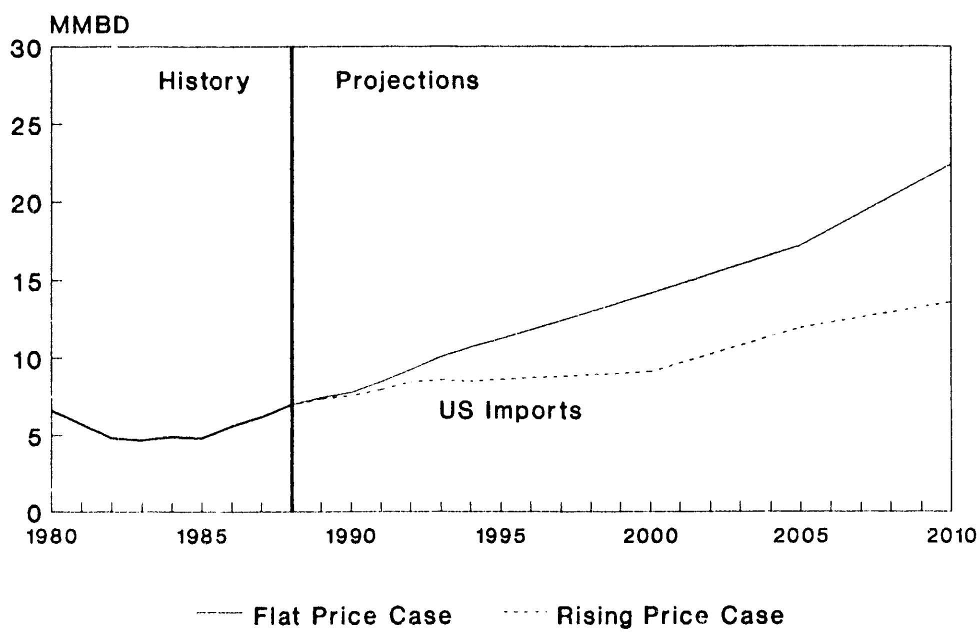
Figure 8 implies that aggressive policy intervention by non-OPEC countries would reduce but not reverse their dependence upon Persian Gulf oil supplies compared to no new policies. Moreover, the strategy would be less effective than depicted here if some countries did not adopt the oil tax or tariff. Countries that did not adopt these policies would probably face a world price that was even lower than before the policy's implementation, thereby stimulating demand in these regions.

It will be especially difficult to avoid increases in U.S. oil imports. Figure 9 compares the median U.S. oil consumption and production in the flat $19 case and in the rising price case (to $39 by 2000, flat thereafter). Higher prices clearly reduce oil consumption growth and slow the decline in oil production, but the need for imports grows. This happens despite a doubling in the U.S. price, which could increase due to a higher world oil price or to domestic U.S. policies that raise the price above world levels.

Thus, it will be difficult and costly to reduce imports enough to alter significantly the nation's exposure to oil imports or the insecurity of the world's oil supply. The removal of artificial barriers to domestic production and to energy conservation would clearly be desirable and would have beneficial effects. However, appropriate policy responses should also include efforts to help the econ-

Figure 9. Median U.S. Oil Demand, Supply, and Imports





omy adapt to future price shocks. Such strategies might include oil stockpiles and macroeconomic stabilization policies.

MARKET-CLEARING OIL PRICES

The previous figures revealed the call on OPEC resulting from a predetermined price path used by all modelers. The supply and demand conditions projected by the model did not influence the oil price path in these scenarios. In these estimates, OPEC was simply a passive producer, supplying all output left unmet by other producers, in order to keep prices along the assumed long-run, sustained price path.

We now ask a different question: would OPEC be willing to produce this amount and how would this output decision influence the market-clearing price in each model? Instead of fixing the price path and asking for the net demand for OPEC oil, the analysis now determines both the price and OPEC's production. In these scenarios, each model determines a unique market-clearing oil price path that balances the amount of oil supplied and demanded using some common assumptions about economic growth. It should be emphasized that these price paths result from standardized assumptions used by the modelers; their actual price projections based upon their own assumptions may well be different.

Two Views of Future Oil Prices

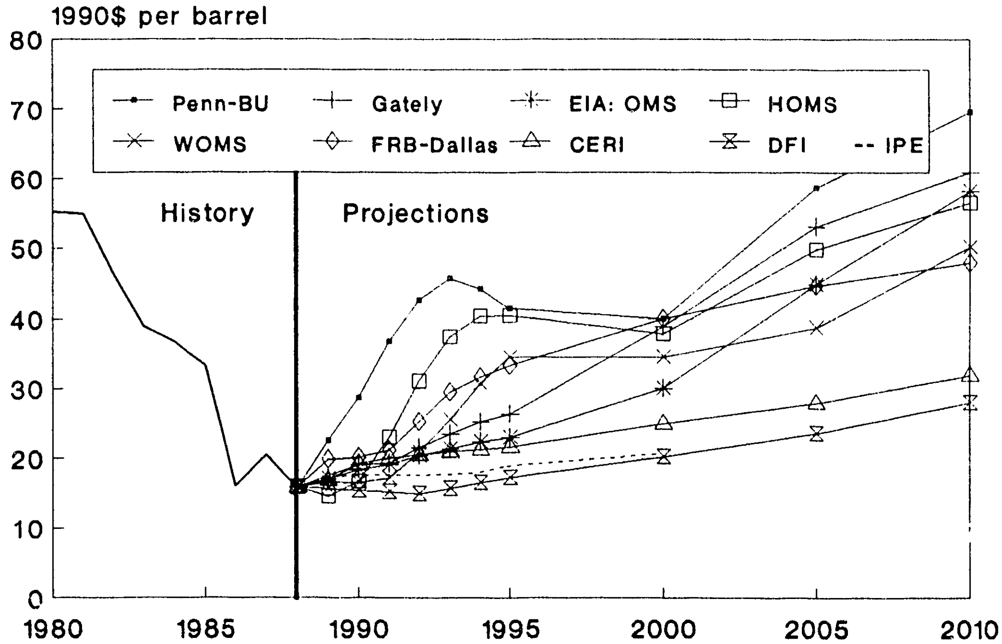
Figure 10 compares the oil price projections from each model when OPEC is assumed to exert some monopoly control, using the same economic growth assumptions as in the 1989 IEO price case discussed above (i.e., 2.9% per annum in the market economies).[16] All prices rise through the decade, but at considerably different rates. Six price paths generally lie above the 1989 IEO price path, while three others fall below it.

In combination with the previous discussion of the flat price scenarios, these results suggest that oil prices are unlikely to remain consistently below $20 per barrel over the next two decades. At the higher end, it is unlikely that oil prices will be sustained above the 1981 peak of $55 (in 1990$) reached temporarily during the second oil price shock. Within this wide range, uncertainty about external factors like world economic growth, oil supply and demand responses to prices and economic growth, and political developments in oil-producing and oil-consuming countries can lead to a number of plausible outcomes. Oil companies and energy policymakers should be prepared for a very wide range of oil prices. At the same time, our results also underscore that increased reliance upon Middle Eastern oil occurs regardless of the precise level of oil prices.

The emergence of two different general trends in the price path is clearly evident from this figure. Low demand growth and expanding OPEC output keep prices in CERI and DFI-CEC along a low-growth track, increasing to the low $20s by 2000 and to about $30 by 2010.[17] This path is representative of the median response in the July 1990 International Energy Workshop poll reported by Manne and Schrattenholzer (1990). Rapid demand growth coupled with constrained OPEC output translates into sharply higher prices reaching the $40-$55 range by 2010 in HOMS and FRB-Dallas.

Although demands grow much more slowly in the remaining projections--Penn-BU, OMS, WOMS, and Gately--constrained OPEC production eventually forces prices upward. Across all models, when OPEC output is below about 35 MMBD, prices are always considerably higher than $30 by 2010 in this scenario. Thus, low prices are associated with both low demand growth and expanded OPEC production. If either or both of these conditions do not hold, substantially higher prices result. Production outside OPEC could also contribute to price differences, but it varied by considerably less

Figure 10. Market-Clearing Price with Cartel



among models in this study than did total demand and OPEC production.

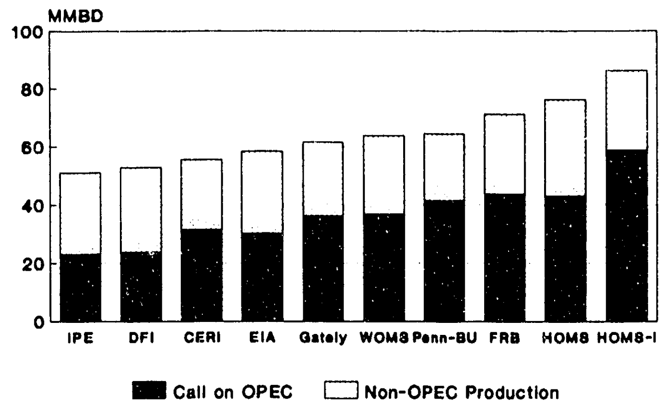
The expectation of some increase in oil price is similar to many earlier projections of oil prices made in 1980 and reflected in a previous Energy Modeling Forum study (1981). In hindsight, of course, these projections were very wrong, as oil prices fell dramatically.[18] A principal difference between projections is that the previous estimates were made at a time when inflation-adjusted oil prices were some three times their current levels. The current projections are based upon the premise that after almost a decade of lower oil prices, the incentives for increased production outside OPEC and for energy conservation measures have been weakened considerably.

Key Determinants of the Oil Price

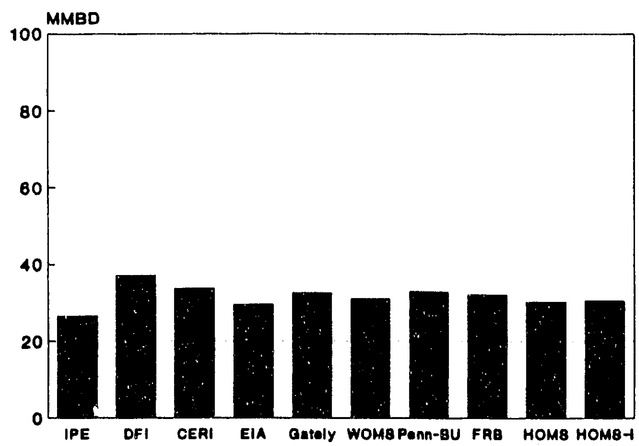
The critical role of world demand and OPEC production in influencing the market-clearing prices is shown in the three panels of Figure 11. The top panel duplicates the previous Figure 5. It emphasizes once again that high demands in the market economies in the 1989 IEO price case result in high calls on OPEC while low demands result in low calls on OPEC. When low calls on OPEC are combined with expanded OPEC capacity in the market-clearing price case (the middle panel), low oil prices result (the bottom panel). These conditions apply to the DFI-CEC and CERI projections, both of which anticipate OPEC production to exceed 33 MMBD over the next two decades.[19] As a result, there is less upward pressure on price, leading to relatively smaller increases in the oil price over the 1990-2010 period.

The remaining models tend to project either higher world oil demands (and hence, calls on OPEC) or lower OPEC production under market-clearing conditions or both.[20] Except for IPE, these models report higher oil price paths in the bottom panel. Prices

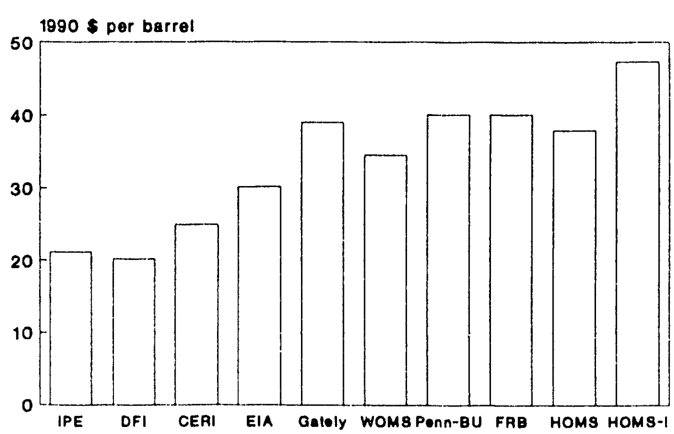
Figure 11. Higher World Demands and Higher Calls on OPEC



...or Constrained OPEC Production



...Lead to Higher Market-Clearing Oil Prices in 2000



remain relatively low in IPE, even with limited OPEC production, because demand barely grows while non-OPEC production falls very little in that model. With even modest oil demand growth, OPEC production would need to increase in this model to keep oil prices from rising.

The cartel's output was not constrained in DFI-CEC and CERI by limits on OPEC capacity (about 37 MMBD). In these models, OPEC production exceeds this limit, thus contributing to their lower price paths. Except for Gately,[21] the other models assume a capacity limit based upon the EIA's 1989 *International Energy Outlook.* This limit reflects one or more of the following economic and political conditions: declining net income (discounted) at higher production levels, limits on their use of additional oil revenues for internal investment, and a reluctance to sell more of a "patrimonial resource".

FUTURE DEMAND GROWTH

This study has emphasized the key role of oil demand in influencing OPEC's rising market share, the increasing U.S. dependence upon oil imports, and the future path of market-clearing oil prices. It is important to understand the reasons behind the differences in oil demand observed in the study.

Aggregate Oil Demand Projections

The models in this study determine aggregate oil demand on the basis of assumptions on the oil price, economic activity (GDP), and technological progress. For example, the effect of oil prices on oil consumption depends upon the change in oil price and the response of demand to price. This demand response represents an aggregate measure of the effects of many decentralized decisions, such as the purchase of energy-using equipment and the intensity of use of equipment in many different sectors. It increases over time to reflect the greater substitution opportunities as new equipment replaces old equipment. Although the oil price and GDP paths were standardized across models in nine scenarios, the responses to these variables may differ considerably because modelers determine different values for these effects.

It is understandable why modelers do not agree on the relative importance of different factors for explaining oil demand, even when they use the same oil prices and GDP paths. Energy analysts, policymakers, and planners must draw lessons about how these factors affect demand from a limited historical experience that includes several sharp shifts in oil market trends. Over the last three decades, oil demand has gone through three distinct stages. Prior to 1973, demand grew briskly while prices remained relatively stable at below $10 per barrel (1990$). During the 1970s and through 1985, demand was sluggish while prices remained high and economic activity slowed. In the last half of the 1980s, demand grew slowly at first but eventually recovered strongly while prices generally remained low and the economy expanded.

This situation provides no clear criteria for distinguishing the one "correct" explanation for the decoupling of oil demand and economic growth. For example, the slow growth in oil demand during the mid-1980s, coupled with low energy prices, can be explained as a gradual adjustment in energy demand in response to the high prices of the late 1970s through the early 1980s. Alternatively, the same conditions can be explained as a relatively low response to price and a gradual reduction in oil use through technological progress independent of oil prices.

Major Influences on Demand

A framework for explaining these differences in demand behavior can be used to separate the oil demand growth into several components:

(1) the "GDP growth" effect reflecting the influence of higher levels of economic activity;

(2) the "price" effect resulting from future changes in the price of oil;

(3) the "autonomous efficiency improvement" effect in which changes in oil use accrue over time and are unrelated to either price or GDP changes; and

(4) the "initial momentum" effect due to the fact that current oil demand has not adjusted completely to current and past oil prices.

The first two effects are relatively well known and are universally accepted by oil analysts. More GDP growth and lower oil prices stimulate oil demand growth. Analysts disagree, however, on the strength of these two responses. The remaining two effects require some elaboration.

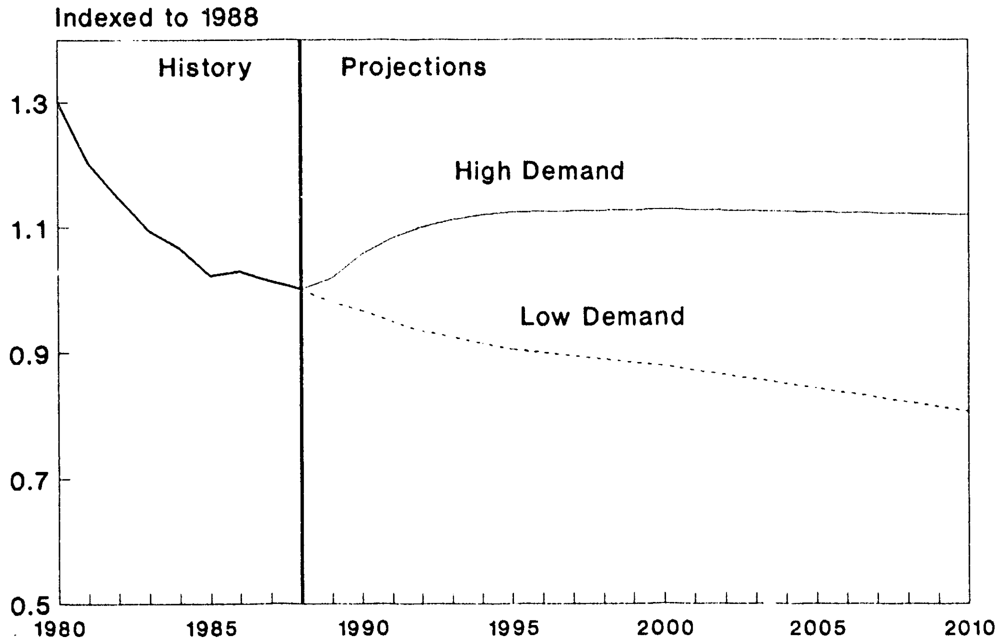
"Autonomous efficiency improvements" (AEI) refer to changes in oil use that are not motivated by oil price changes. For example, in 1967, Boeing introduced the 747 airplane, which yielded enormous fuel efficiency gains. Higher energy prices did not induce the adoption of this technology; the plane had been designed well before the oil price shocks of the 1970s for a variety of reasons. The gradual turnover in the fleet of airplanes that reduced this sector's oil intensity would have occurred regardless of what happened to oil prices.

Shifts in the economic structure away from energy-intensive sectors and products can also contribute to a long-run decline in oil use per unit of output in many developed countries. To the extent that the shifts are not induced by price changes, they can be considered as part of the autonomous efficiency improvement effect.

"Initial momentum" refers to the tendency of oil demand to either increase or decrease in the absence of future price or GDP changes and autonomous efficiency improvements. The major source of initial momentum is the incomplete adjustment of current oil demand to current and past oil prices. Since energy-using equipment is replaced only gradually, future oil demand will be adjusting to the current oil price, even if there are no future changes in the oil price. For example, in 1981 the momentum effect would have been negative; if price had stayed at its high 1981 level, the lagged effects of adjustments to previous price increases would have reduced demand, as more energy-efficient capital was adopted. By contrast, the decline in oil prices in 1986 pushed the real costs of many petroleum products below their levels over most of the last two decades. If these lower oil prices persisted indefinitely, there would be less incentive to pursue energy conservation in new investment than before. New equipment would become more energy intensive than the equipment installed previously, causing the economy's energy intensity to rise over the next several years. This would be a positive momentum effect. In other words, the lagged effect of past prices on future consumption means that oil demand changes even if there were to be no future change in oil prices or economic activity.[22]

These last two effects--autonomous efficiency improvements and initial momentum--can have a significant impact on future oil use per dollar of GDP (or oil intensity). The lower line in Figure 12 represents the lower demand path found for most models in this study when the inflation-adjusted oil price is held at its 1988 level over the next two decades. Oil intensity declines as tech-

Figure 12. OECD Oil-GDP Ratio in Flat Price for Two Different Demand Trends



nological progress and shifts in the economy's structure improve oil efficiency over time. Moreover, price declines prior to 1988 have little or no effect on future oil demand. Oil intensity continues its downward drift, although at a slower rate than in the early 1980s, immediately after the second oil price shock.

The upper line shows the higher demand projection of a few models for the same flat oil price path. Autonomous improvements in oil efficiency are absent in these projections. Moreover, they assume that the oil price declines in 1983 and 1986 begin to stimulate oil demand gradually as new energy-using equipment is purchased. In the absence of further oil price changes (after 1988), oil demand would eventually begin to increase faster than economic growth, as shown for the 1990-95 period in Figure 12.

There will be other effects on oil demand that fall outside these definitions and are considered part of the initial momentum effect in the decomposition of oil demand growth. Some regulations, such as the corporate average fuel-efficiency (CAFE) standards for automobiles in the United States, may require consumers to purchase more fuel-efficient vehicles than they would otherwise choose. Alternatively, reductions in oil use can also be achieved through interfuel substitution towards other fuels. If, for example, a relative abundance of natural gas depresses that fuel's price significantly below its historical relationship with oil prices, oil demand would fall even in the absence of oil price increases or autonomous efficiency improvements.[23]

Decomposition of Demand Growth

The causes for discrepancies in the projections for oil demand growth have been separated into the above four components, based upon the results from four different scenarios.[24] In each of the four scenarios, all modelers assumed the same oil price and

GDP paths. Hence, differences in the estimated price and GDP components reported in this section reflect differences in the responses of oil demand to the assumed changes in price and GDP.

Figure 13 summarizes this decomposition of the oil demand growth for the OECD countries over the 1988-2000 period in the 1989 IEO price scenario. The solid line indicates the total change in oil demand above its 1988 level of 37 MMBD. Total demand growth is comprised of four separate effects, some of which increase growth while others decrease it. The models are ordered according to total oil demand growth, with the lowest growth to the left and the highest growth to the right.

Major discrepancies exist among these demand projections. The rapid growth in the two HOMS and the FRB-Dallas projections are striking. OECD demand grows from about 37 MMBD in 1988 by 13-14 MMBD to 50 MMBD or more by 2000. At a minimum, an 8 MMBD gap separates this group from the other projections, in which demands grow by 5 MMBD or less to no more than 42 MMBD by 2000.[25]

The models showing the highest demand growth--Gately, WOMS, FRB-Dallas, HOMS, and HOMS-1--use demand responses to prices and economic growth that have been statistically derived from the historical experiences of the last several decades. While future demand responses emulate past ones in these models, projected demand trends can still differ from past ones, depending upon the assumed future conditions for the oil price and economic growth. In contrast, all of the remaining models except BP America use demand responses to these conditions that are based upon the modelers' judgement.[26]

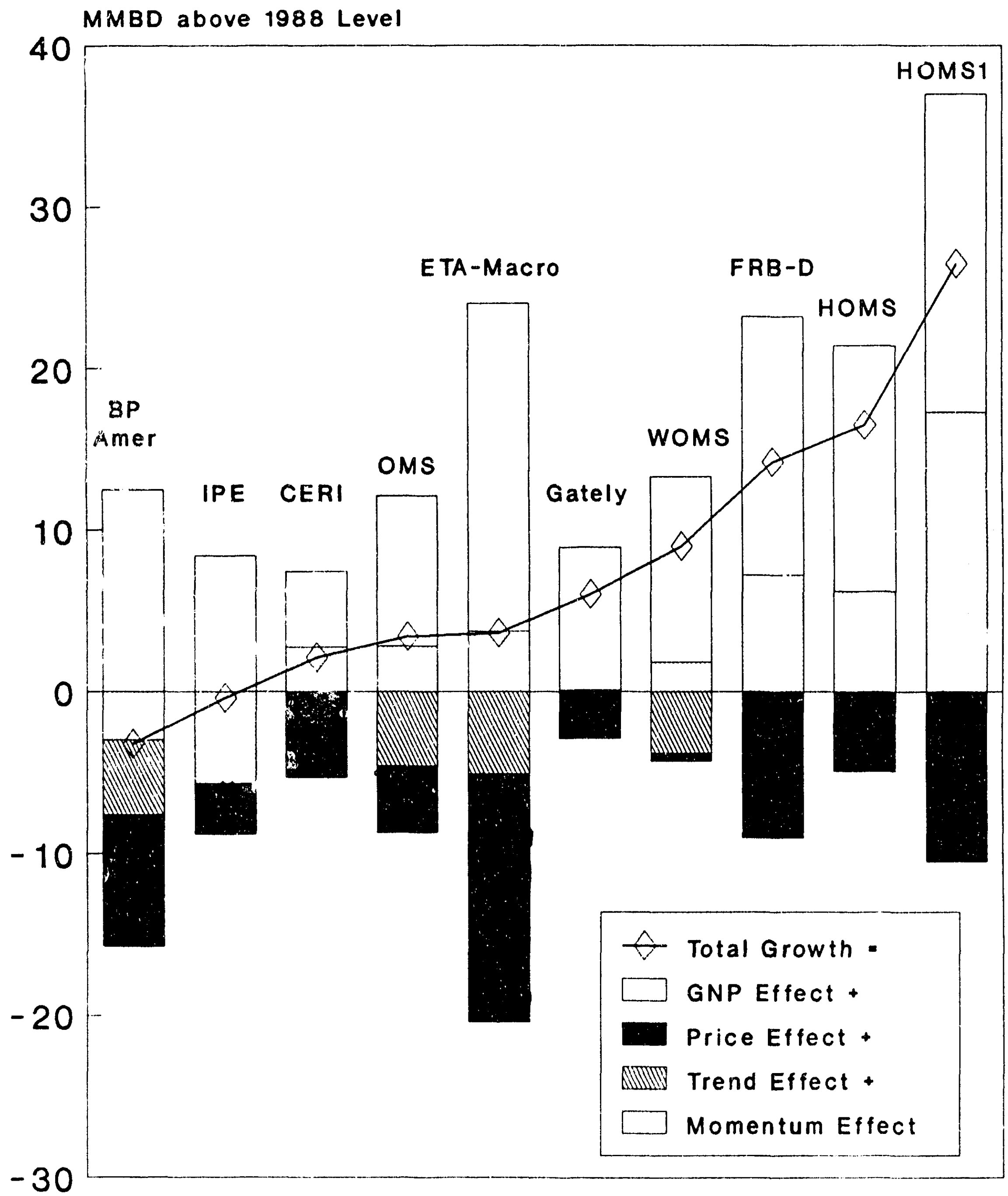
Interestingly, large discrepancies in oil demand projections for 2000 remain even after accounting for differences in the demand response to future oil prices. Across projections, the GNP effect varies the most, but the variation in the price and the initial momentum effects are also significant.[27] The contribution of the initial momentum effect is surprising and unexpected. As early as 1995, this effect accounts for about 5-6 MMBD of the 13 MMBD increase in total demand in HOMS and FRB-Dallas.[28] Even after five more years of economic growth, these momentum effects are large relative to the GDP effects for the OECD demand growth estimates shown in Figure 13. In these two models, they account for about 30 percent of the total growth in the flat price scenario (i.e., excluding the price effect).

Within each projection, the biggest component is the effect of higher GDP in stimulating oil demand, although the initial momentum and price effects are substantial in a few models. The price effect increases over time as energy-using equipment is replaced by more energy-efficient vintages, but the economic growth effect remains dominant, even over the longer 1988-2010 period.

HOMS and FRB-Dallas project long-run oil intensities as a function of the oil price only.[29] A one percent increase in the GDP level will result in a one percent increase in oil demand, if oil prices remain fixed at their 1988 level. There is no autonomous improvement in oil efficiency (labeled as "trend effect" in Figure 13) that operates independently of the oil price in these two models. While some new technologies save energy. other technologies and lifestyle changes may actually use more energy. Higher prices dampen but do not offset this larger demand growth.

The presence of autonomous improvement in oil efficiency keeps projected oil demands considerably lower in BP America, ETA-Macro and WOMS, even though all possess relatively large GDP effects. Moreover, the price effect is considerably larger in ETA-

Figure 13. OECD Demand Growth, 1988-2000: Decomposed into 4 Effects



Note: Growth in 1989 IEO Price Path

Macro than in other models. Without this price effect, its oil demand is comparable to the highest demands (HOMS and FRB-Dallas) in the flat price scenario. ETA-Macro focuses upon all energy forms. When oil prices rise, oil demand falls as: (1) the demand for all energy declines, and (2) as electricity replaces oil and other fossil fuels. In ETA-Macro, this first effect alone is comparable in size to the full effect of oil prices on oil demand in most of the other models, resulting in greater sensitivity to oil prices.

The remaining models--IPE, CERI, Gately and OMS--have relatively small GDP growth effects, in which oil consumption grows proportionately less than economic growth. This smaller GDP effect operates like the trend effect in the other models; oil efficiency improves over time (assuming some economic growth) even if oil prices do not increase from their 1988 levels. OMS also reports an additional autonomous trend towards increased oil efficiency that further reduces its projected growth in oil demand.

The initial momentum effect is pronounced in the HOMS and FRB-Dallas projections because long-run oil intensities in these models respond symmetrically to oil price increases and decreases. Moreover, oil intensities respond quite slowly to oil price changes. The model parameters indicate that much of the response to the recent lower oil prices had not occurred by 1988. Since the oil price is currently lower than it has been over much of the last 15 years, the initial momentum effect in most models causes oil demand to grow, i.e., it is positive. Even if there were no economic growth, under constant prices OECD demand would still have grown over 6 MMBD in HOMS and FRB-Dallas simply due to future demand adjustments to the current oil price level.

Incomplete adjustment to current and past prices plays a relatively minor role in most of the remaining models, accounting for at most 3 MMBD of demand growth by 2000.[30] The negative initial momentum component for two models (BP America and IPE) is not due to the incomplete adjustment of current oil demand to current prices, as in the other models. For example, continued automobile efficiency improvements are allowed in the BP America model regardless of the oil price path. This decline arises from policies for fuel efficiency standards on oil use and are unrelated to either price or autonomous efficiency improvements.

The historical experience of the 1970s and 1980s imposes certain restrictions on the nature of the oil demand response that are reflected in the model responses shown in Figure 13. First, large price effects are generally associated with large GDP effects, and small price effects with small GDP effects. A model with a large response to GDP and a small response to oil prices would have badly overestimated oil demand growth over the last two decades, given the actual oil price and economic growth trends over this period. Similarly, one with a small response to GDP and a large response to oil prices would have underestimated oil demand growth over this same period.

Second, the autonomous efficiency improvement effect is often absent in models displaying large price effects. Past reductions in oil demand intensity can be due to changes in price and other nonprice factors. When a model attributes a major role to price, there remains little additional improvement in energy efficiency to be explained by nonprice factors.

And third, large price effects are often associated with large initial momentum effects and vice versa. This is understandable because the initial momentum effect is itself a response to price changes from previous periods. If demand responds symmetrically to price increases and decreases, these two effects incorporate similar responses.[31]

FUTURE CHALLENGES FOR WORLD OIL MODELING

The working group has used existing models of the world oil market to quantify certain key relationships important for understanding this market and to highlight major areas of agreement as well as differences. By providing a consistent framework for evaluating a number of important factors, the models have helped to reveal the implications of various oil supply and demand trends for future oil prices and dependence upon OPEC supplies.

While the models have been very useful for advancing the group's discussion, they are not without their limitations. In many cases, the models reflect what we can quantify about the oil market. Their limitations are often indicative of limitations on our general understanding of oil markets themselves.

Basic Approach

Many world oil models emphasize long-run demand trends and responses to price and economic growth. Traditionally, they have been less developed on the supply side for understandable reasons. It has been more difficult to incorporate factors like the distribution of resources by cost category, the impetus for technological advancements in oil drilling, and producer-country tax and royalty policies. Similarly, both modelers and other oil experts have difficulties in articulating the cartel's long-run strategies on capacity expansion.

As a result, the models' projections are often driven by a few key assumptions: the rate of economic growth, an estimate of the recoverable resource base outside of the cartel, and the cartel's capacity path. With modest economic growth, oil prices will be projected to rise over the next two decades given the conventional view on trends in oil use efficiency, the non-OPEC resource base, and OPEC capacity.

The models were not developed for analyzing very short-run issues, such as energy shocks and energy security policies. These topics require information on monthly or quarterly rather than annual market conditions as well as rather extensive linkages between the oil market and the macroeconomy, incorporating both short-run and long-run effects. Other analytical frameworks have been developed for addressing these concerns.

Moreover, these annual projections seldom extend beyond 20 or 25 years, limiting the ability of these models to incorporate a range of longer-run considerations, such as the transition to alternative liquid fuels for transportation or the longer-run effects of environmental policy on world oil markets. Extending these projections even another 10 years may require some fundamental changes in model structure and data requirements to incorporate some of the technological, lifestyle, and other changes that are likely to emerge in a longer period. The longer time horizon may also highlight the need for models that have producers and consumers consider the impact of future conditions on current decisions.

Recommendations for Future Research

The working group identified four critical areas where further developments would be particularly useful for improving the state of analysis of world oil markets.

OPEC Capacity. The most critical challenge to future modeling appears to be ways to represent the cartel's long-run output decision. Decisions about when and by how much the cartel will expand capacity need to be linked to the market conditions being determined elsewhere in the model. (IPE and Penn-BU already incorporate some of these effects.) In their current form, most world oil models are critically dependent upon assumptions about the future path of OPEC capacity. Once target capacity levels are reached in these models, oil price projections become extremely sensitive to key input assumptions on economic growth and OPEC capacity. Another important dimension would be to incorporate the possibility of rivalry within OPEC and its impact on long-run capacity decisions.

Oil Demand Within and Outside the OECD Countries. Another critical concern is to resolve the disparate views on future trends in oil use efficiency. Additional study is needed to separate the effects of current prices from past prices and other nonprice factors such as technological progress or shifts in the economy's composition of goods and services. World oil modeling should also include efforts to differentiate the demand for oil as a transportation fuel and all other oil uses outside the transportation sector. In addition, most analysts expect oil demand growth to be concentrated in the developing countries. Poor data often prevent careful analyses of these regions, resulting in crude assumptions made about their demand responses to changing market conditions, often without explicit consideration of structural change in the economy and its impact on the transition from traditional to commercial energy. Moreover, few existing world oil models explicitly represent the interactions between energy use, energy production, capital formation, and international trade. As a result, balance-of-payment constraints on future commercial energy use are frequently ignored.

Interfuel Substitution. Many existing models focus on oil only, giving limited attention to interfuel substitution issues. They implicitly assume that other fuel prices move with oil prices and that interfuel substitution responses will be as they have been in the past. Environmental policies and more abundant natural gas supplies can alter both of these relationships, dramatically changing the oil market picture. Natural gas can be converted to close substitutes for oil, such as compressed natural gas and methanol to fuel vehicles. It can also be used to replace oil for power generation. While the models cannot incorporate all the technical and economic factors that may influence these decisions, some capability to handle these broader types of issues will become increasingly important.

Non-OPEC Resources and Supply. Analyses of world oil market conditions are severely limited by the unavailability of reliable data on the cost of producing oil in major supply regions outside the United States. Geologic estimates of the remaining resource base are useful but do not reveal the relative costs of exploring for and finding oil resources in different regions. Reliable drilling cost information is collected primarily for the United States but remains unavailable for other regions. This problem is compounded by the absence of a market mechanism and an effective pricing system within the Soviet Union, currently the largest oil-producing country in the world. And finally, the role of technology and the effect of producing-country tax policies in enhancing future oil supplies is poorly understood.

CONCLUSIONS

For what kind of world oil future should energy policymakers and corporate decision-makers be preparing and planning? Our results strongly suggest a wide range of possible outcomes. Some analysts see rapidly growing demand pushing up against limited OPEC capacity, conditions leading to rapidly rising oil prices later in this decade. Other analysts expect slower demand growth combined with increased OPEC willingness to produce oil, conditions leading to quite modest increments in the oil price. Over the next decade, oil prices in inflation-adjusted terms are unlikely to be sustained above 1981 peak levels temporarily reached during the second oil shock. Nor are they likely to fall below current ($19) levels for an extended period of several decades, unless the cartel disintegrates or unconventional oil becomes economic much sooner than is currently anticipated.

Despite the rather substantial differences in views on oil supplies and demands, there was agreement within the study on certain aspects of the oil market future. Fueled by greater demand growth, particularly outside OECD, oil production will need to expand significantly. As a result, production will be increasingly concentrated in the lower-cost regions of the Persian Gulf. This result applies across a wide range of possible future oil price paths or rates of growth in oil demand. A greater dependence upon these oil supplies will increase the impact of economic and political decisions within the Middle East on world economic growth. Moreover, increased demand for the cartel's oil will increase its market power, increasing the likelihood that coordinated strategies among cartel producers will be successful in keeping oil prices above those expected in a pure competitive environment.

Oil imports in many OECD countries will rise. This dependence will be more acute in the United States, where the combination of steady growth in oil use and falling domestic production is expected to increase the import share of total consumption from 38% in 1988 to 50%-60% by 2000 even with gradu ally increasing oil prices. If oil prices were to remain unchanged at about $19 (in inflation-adjusted terms), the United States would be importing about two of every three barrels consumed by the end of the century. Thus, the United States will be faced with either high prices and low imports or low prices and high imports; either way, the oil import bill as a percentage of total GDP will rise.

There remains considerable uncertainty about the future geopolitical environment in the Middle East in the aftermath of the war between Iraq and the allied forces. While the long-run implications of rising dependence upon Persian Gulf oil production are not yet fully understood, such trends are likely to thrust energy security concerns back before policymakers in many oil-consuming countries. There is likely to be more active consideration of policies that reduce the dependence upon oil, thereby limiting these economies' vulnerability to future oil price shocks. However, there are limits to how aggressively and how quickly the world economies can reduce their dependence upon Persian Gulf oil before import-reduction policies begin to impose large economic costs. While import-reduction policies should be pursued, they should also be supplemented with policies that help their economies adapt more easily to sudden energy price shocks. Examples of such "shock absorbers" include monetary and federal tax policies for stabilizing the economy, increased wage and price flexibility in their economies, and the building and use of oil stockpiles.

APPENDIX

Methodology for Decomposing Demand Growth

The four scenarios specified oil price and GDP paths that were to be used by all models. The cases included: (1) the 1989 IEO price case (with the baseline GDP path); (2) the flat price case (with baseline GDP); (3) the flat oil price path with no economic growth after 1988; and (4) the flat oil price path with no economic growth and no technical change unrelated to oil price changes. The price effect was measured as the change in oil consumption between the first two cases; the income effect was measured as the change in oil consumption between the second and third cases; and the autonomous efficiency improvement effect was measured as the difference between the third and fourth cases. The initial momentum effect was measured as the change in oil consumption between 1988 and 2000 in the fourth scenario. Algebraically, the growth in demand in the 1989 IEO price case equals the sum of these components:

$$\begin{aligned} D(t,IEO) - D(1988) = {} & D(t,IEO) - D(t,Flat) \\ & + D(t,Flat) - D(t,\Delta Y=0) \\ & + D(t,\Delta Y=0) - D(t,\Delta Y=\Delta T=0) \\ & + D(t,\Delta Y=\Delta T=0) - D(1988) \end{aligned}$$

where D is oil demand, t is year (e.g., 2000), and IEO, Flat, $\Delta Y=0$, and $\Delta Y=\Delta T=0$ refer to the four cases. The four right-hand terms are the price, GDP, autonomous efficiency improvement, and momentum effects, respectively. The sum of the last three effects equals the demand growth in the flat price case. BP America's price effect may be overstated slightly because it is for the rising price case rather than the 1989 IEO price case, which was not simulated for this model. Demands for DFI-CEC have not been decomposed, because they are the OMS projections by assumption. Penn-BU did not separate OECD demand from world demand.

ENDNOTES

1. Those interested in long-run energy and oil projections are referred to the semiannual polls conducted by the International Energy Workshop (IEW), as reported by Manne and Schrattenholzer (1989).

2. This general description does not apply to DFI-CEC and ETA-Macro, which report market outcomes every 5 or 10 years. Market participants in ETA-Macro seek the single best strategy for obtaining the most value (discounted) from their consumption of all goods and services over many years, rather than responding to current prices alone. Oil producers in DFI-CEC seek the single strategy for realizing the most net income (discounted). Both models assume that oil producers and/or consumers know future market outcomes with certainty (perfect foresight), have the flexibility to act on this knowledge, and are not influenced by other noneconomic objectives. In addition, there are other noteworthy exceptions to the general framework described in this section. BP America, ETA-Macro, and Penn-BU represent interfuel substitution opportunities explicitly; Penn-BU incorporates the effect of shifts in economic structure on oil demand; IPE and Penn-BU allow market conditions to influence OPEC capacity; and CERI and Gately choose OPEC production paths rather than capacity to represent OPEC's long-term investment strategy. Each model is described in Kress et al (1990). The responses of supply and demand to price and income changes inferred from various scenarios are presented in Huntington (1991).

3. The complete scenario input specifications are described in Huntington et al (1989).

4. The total resource base, including undiscovered resources yet to be classified as proven reserves, is less concentrated, but the Middle East still accounts for more than half.

5. Half the model projections lie above, and half below, the median value.

6. Total production is differentiated by OPEC and non-OPEC sources in this study because the models have reported production from OPEC countries as an aggregate. In discussing the issue of dependency, however, we have inferred Persian Gulf production from the scenario results as the difference between reported OPEC output and some external production estimates for other OPEC member countries. The latter were based upon some Energy Information Administration estimates in the *International Energy Outlook.*

7. This conclusion was reached in a previous Energy Modeling Forum study (1987).

8. Net USSR exports could become an important new supply source and represent a significant uncertainty in any oil market outlook. In the current study, however, these exports do not vary much across models and therefore do not contribute importantly to differences between models in the projected call on OPEC.

9. The flat oil price path was specified as \$18 in constant 1988\$, or \$19.44 in 1990\$ using a conversion factor of 1.08. To avoid the false impression of precision, we discuss the flat oil price trajectory in terms of a constant \$19 price in the remainder of the report.

10. Adelman (1986) argues against a long-run trend towards increasing costs. Oil prices will increase or decrease depending upon the relative strengths of competitive and monopolistic forces, but resource depletion will not push the long-run price trend upward. See also Lynch (1989).

11. The base flat oil price case assumed the same GDP growth rate as in the 1989 IEO price case.

12. As reported by Lynch (1990), Table 3, p.8.

13. Whether the cartel's net revenues would decline depends upon the response of world demand and of supply outside the cartel countries to price, which countries comprise the cartel, and what share of the total market these countries supply.

14. Many of these possibilities are discussed in greater depth in the forthcoming technical volume for the current EMF study.

15. This price path reaches the rising price path by 2010.

16. The study has not analyzed the important but difficult issue of which OPEC countries might constitute the oil-producing cartel. A high economic growth and a competitive case were also simulated. In the latter, oil prices were modestly lower than in the cartel case (e.g., by $10 per barrel) in some models and substantially lower, with levels ranging in the $10-$20 per barrel, in others. This scenario demonstrated that analysts had very different approaches for representing a competitive world oil market.

17. IPE joins this group through 2000, but does not project oil market conditions after 2000. The reasons for its lower price path are discussed later in the text.

18. A substantial portion of the error in projecting oil prices in this previous EMF study was due to external assumptions about economic growth and the non-OPEC oil resource base. World economic growth was slower and non-OPEC production higher than anticipated by many experts. Another important error was to overestimate the amount of demand-adjustment that had already been accomplished by 1980, in response to higher prices. These points have been addressed by Gately (1984, 1986) and are discussed briefly in the forthcoming technical volume for the current EMF study.

19. The expansion in OPEC production in these two models is more pronounced for 2010 than for 2000 (shown in Figure 11). The results for 2010 are discussed in the forthcoming technical report for this study.

20. Similar results are obtained for other years, e.g., 2010. While this simple explanation is extremely powerful for sorting through differences in projected prices, it requires certain caveats. Other factors that could affect prices include non-OPEC production levels for a common price path and the response of supplies and demands to price changes. For example, oil demands in HOMS-1 are much more sensitive to price increases than they are in Gately, at least for the range of prices below $55 (1990$), the 1981 peak. This factor places less upward pressure on prices in HOMS-1 and greater upward pressure on prices in Gately, as revealed in the bottom panel of Figure 11.

21. The Gately model used a production path that was selected on the basis of OPEC's net income position rather than an explicit capacity constraint.

22. Despite their apparent similarity, there is an important distinction between autonomous efficiency improvement and initial momentum. Oil demand reductions achieved through autonomous efficiency improvement are costless to the economy; other inputs are not required to substitute for the lower levels of oil use. Oil demand

reductions achieved through initial momentum (when current prices are high relative to past prices) do require the substitution of other inputs. The latter adjustments must be price induced, although the required price changes occur before the current year.

23. It appears appropriate to include these sources of oil demand changes in the initial momentum rather than the autonomous efficiency improvement effect, given the discussion in the previous endnote. The interfuel substitution effect is induced by a price change. While regulations do not explicitly raise prices, they implicitly raise the costs of oil use. Neither effect implies a costless shift towards less oil use.

24. See the appendix.

25. OECD demand grows to about 46 MMBD in WOMS.

26. Many of these models base some of their judgmental parameters, e.g., the response to price, upon statistical studies of past oil demand. However, in contrast to the first group of models, they do not derive all key parameters simultaneously from the same historical data set.

27. This conclusion is based upon standard deviations computed for each effect, excluding the alternative HOMS-1 results and setting the momentum effects for BP America and IPE to zero. As discussed later, the momentum effect for these two models is not due to incomplete adjustments to current and past prices. The GNP effects depend, of course, partly on the OECD economic growth rate (2.6% per annum); the variation in this effect among models will be greater for faster economic growth and less for slower economic growth.

28. Similar results hold for the decomposition of OECD oil demand growth between 1988 and 1995, although the relative importance of initial momentum decreases over time.

29. HOMS-1 does the same, except that in estimating the response to prices from historical experience, it allows for a one-time shift in oil intensity after 1980.

30. This estimate includes both OECD and non-OECD countries.

31. Not all models embrace the assumption of reversibility in the demand response to price changes. The Gately model is most explicit about assumed asymmetries in the demand response to price changes. Due to large capital costs, investment in energy-conservation measures is not undone when prices fall from previously high levels, so that demand would not increase very much. Nor does such investment need to be added back when prices begin to recover and rise again, so that demand would not decline very much. Indeed, the price effect for this model is relatively low, as seen from Figure 13. However, if prices were to exceed their historical maximum (which are not reached in the EMF scenarios), the price response would increase as new opportunities for investment in conservation would emerge.

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CHAPTER 2

INTERNATIONAL OIL SUPPLIES AND DEMANDS: AN ANALYSIS OF THE RESULTS

Chapter 2

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Chapter 2

INTERNATIONAL OIL SUPPLIES AND DEMANDS: AN ANALYSIS OF THE RESULTS

I. BACKGROUND OF STUDY

This paper reviews the detailed results of the eleventh Energy Modeling Forum (EMF) study focusing on international oil supplies and demands through 2010. It supplements the conclusions contained in the working group's summary report.

Models

The 11 world oil models used in this study are listed in Table 1 with the name of the working group representative and affiliated organization.[1] Since the modelers used standardized EMF assumptions for prices, economic growth, and cartel capacity, these projections are not forecasts of the particular organizations. Moreover, the institutional affiliation listed in Table 1 is given to identify the model rather than to indicate an official modeling framework of a particular organization. This caveat applies particularly to BP America, WOMS, and the Federal Reserve Bank of Dallas, as well as the various university models.

Table 1. Models in EMF Study

Model	Working Group Contact*
EIA:OMS	Mark Rodekohr, Energy Information Administration
IPE	Nazli Choucri, Massachusetts Institute of Technology
ETA-MACRO	Alan Manne, Stanford
WOMS	Nicholas Baldwin, PowerGen, U.K.
CERI	Anthony Reinsch, Canadian Energy Research Institute
HOMS	William Hogan, Harvard, and Paul Leiby, Oak Ridge National Laboratory
FRB-Dallas	Stephen P.A. Brown, Federal Reserve Bank of Dallas
DFI-CEC	Dale Nesbitt, Decision Focus, Inc.
BP America	E. Lakis Vouyoukas, British Petroleum
Gately	Dermot Gately, New York University
Penn-BU	Peter Pauly, University of Pennsylvania and University of Toronto, and Robert Kaufmann, Boston University

*Organization listed for identification purposes. Models and results do not necessarily represent official view of listed organization.

[1]The approach and structure of each model is described in the paper by Kress et al (1991).

Scenarios

The working group considered the 12 scenarios listed in Table 2. Nine were developed to analyze differences in oil demand and supply projections based upon standardized assumptions for the oil price and economic growth.[2] Specific model assumptions about OPEC's behavior or responses to market conditions were excluded from these fixed-price-path scenarios. These results allow a standardized comparison of the projected supply and demand trends in various models across a wide range of reasonable oil price and GDP paths. They also help to interpret the results from three additional scenarios where supply and demand conditions, including OPEC production decisions, are allowed to determine a market-clearing oil price in each model.

It should be emphasized that modelers were requested not to impose any shifts in government policies in running these cases. Many working group members thought that oil-importing countries would impose taxes and other conservation policies to limit their oil demands. Thus, the EMF scenarios should be considered as revealing the pressures that would emerge under alternative oil price and GDP paths if no such policies were implemented. For its part, the oil producer cartel is considered to be a passive participant in the fixed price path scenarios, operating as a residual supplier of oil, meeting all the oil demand that remains unsatisfied by non-OPEC production.

Table 2. Scenarios in EMF Study

Predetermined Price Path Scenarios:

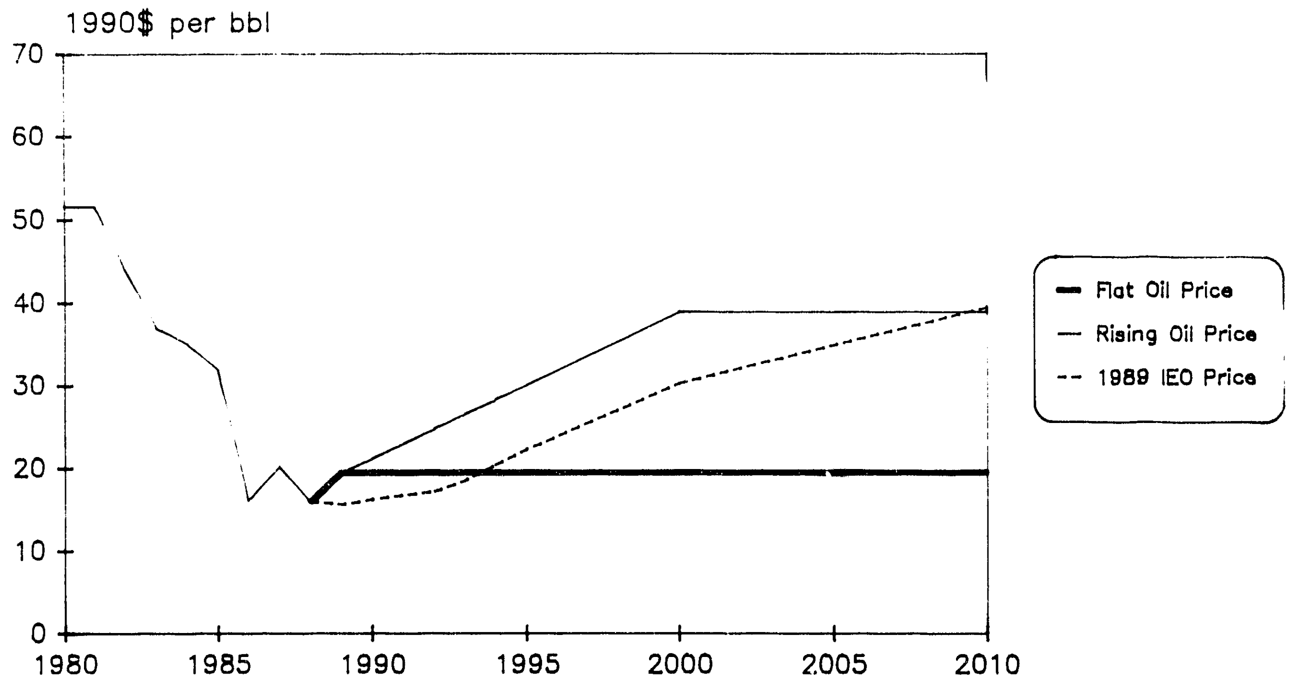
1. Flat Oil Price (with Base GDP Path)
2. Rising Oil Price (with Base GDP Path)
3. 1989 IEO Price
4. Flat Oil Price with High GDP Path
5. Flat Oil Price with Low GDP Path
6. Rising Oil Price with High GDP Path
7. Rising Oil Price with Low GDP Path
8. No Economic Growth (with Flat Oil Price)
9. No Economic Growth or Technological Time Trend (with Flat Oil Price)

Market-Clearing Price Scenarios:

10. Cartel Case (with Base GDP Path)
11. Cartel Case (with High GDP Path)
12. Competitive Case (with Base GDP Path)

[2]The complete scenario input specifications are described in Huntington et al (1991).

Figure 1. Refiners' Acquisition Cost for U.S. Oil Imports



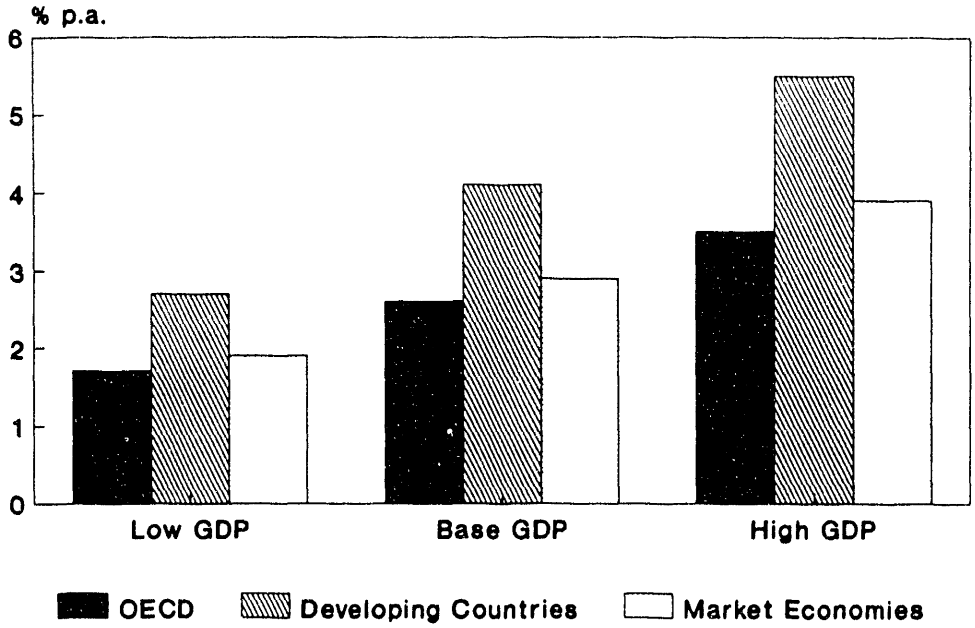
The price trajectories in this study should be viewed as paths averaging over a long period of several decades. Almost surely, actual year-to-year prices will deviate from these long-run paths reflecting short-term shifts in market conditions. In addition, the study has not tried to anticipate future shifts in foreign exchange rates that could affect the dollar-denominated price of oil.

A flat oil price case assumed that the U.S. refiner acquisition cost for imported oil rises from about $16.00 in 1988 to $19.50 per barrel in 1989 (all prices are in 1990$)[3] and remains at that level through 2010. A rising oil price case assumed that this oil price rises gradually to $39 per barrel by 2000 and remains at that level through 2010. A third fixed price path scenario adopted the U.S. Energy Information Administration's (1989) mid-case price outlook from their 1989 International Energy Outlook. As shown in Figure 1, the 1989 IEO price path rises gradually at first, reaching $30 per barrel by 2000, and ending at $39 per barrel by 2010. For most of the 1990-2010 period, this price path lies between the flat and rising price paths.

Differing views on the future path for oil prices made it difficult to develop a consensus or preferred oil price forecast to serve as a base case. Many of the available published oil price forecasts, however, share the EIA's view of soft prices early in the 1990s, followed by rising prices

[3]Oil prices in the study were originally expressed in 1988$, which have been multiplied by 1.08 and rounded to the nearest fifty cents to approximate 1990$. Thus, the 1988 price of $14.70 converts to $15.88. Oil prices in the original flat price scenario were held constant at $18 (or $19.44 in 1990$). Prices in the rising price scenario reached a maximum of $36 (or $38.88 in 1990$).

Figure 2. Economic Growth Assumptions, 1990-2010



later in the forecast horizon. Such a price path results from the combination of growing oil demand, stimulated by low oil prices in the early years and modest economic growth, and limited supply expansion in the absence of price increases. While some forecasts are higher and others are lower than the EIA projections, the group thought that this price path (as reported in the 1989 IEO and since updated) was a useful benchmark for comparing oil production and consumption estimates.

In all three scenarios, the gross domestic product (GDP) of the market economies is assumed to grow by 2.9% per year between 1988 and 2010, with higher economic growth (4.1% p.a.) outside the OECD countries. These base economic growth assumptions, shown by the middle set of bars in Figure 2, are essentially those used by the Energy Information Administration in their 1989 International Energy Outlook's mid-price case mentioned above.[4]

The next four scenarios probe the effect of alternative economic growth assumptions combined with either the flat or rising price paths. The base GDP assumptions were lowered by about 1 percentage point to represent a low-growth path and raised by the same amount for a high-growth path. These alternative GDP growth assumptions are summarized in Figure 2.

During the study, participants became aware of the paramount importance of world demand projections to oil market outcomes. As a result, the group specified two additional scenarios, assuming a fixed price path, in order to diagnose differences in the oil demand projections in the other scenarios. One of these cases assumed flat oil prices with no economic growth; the other assumed the combination of flat oil prices, no economic growth, and no

[4]The EMF economic assumptions include some late-year revisions to the EIA assumptions.

autonomous efficiency improvements in oil efficiency that accrue over time and are unrelated to the oil price.

The last three scenarios listed in Table 2 specify that each modeler incorporate OPEC behavior to determine a market-clearing oil price path. The first two market-clearing price cases assume that OPEC can exert some monopoly power and influence price through their production strategies. They differ only in their GDP assumptions. The third market-clearing price case simulates competitive conditions where monopoly power is absent. The results of the market-clearing price scenarios are discussed in Sections 7 and 9.

Organization of the Report

This study offers a wide range of views on future oil supplies, demands, and prices. Since it is unlikely that any scenario's assumptions will all prove to be correct, it is more important to understand the reasons for these differences among results than to focus on the forecasted trends themselves. Reflecting this point, the report seeks initially to explain differences in oil demand and supply projections based upon standardized assumptions for oil price and economic growth. The analysis then shifts to cases in which each model determines a market-clearing price, based upon standardized assumptions about economic growth.

The next section highlights the key findings of the study. Emphasis is placed upon the 1989 IEO price case because many of the major discrepancies and commonalities observed for this scenario can be found in the other scenarios as well. Section 3 discusses several cases with a fixed price path in order to provide a perspective on the conditions necessary to prevent inflation-adjusted oil prices from rising. Sections 4 through 7 explain the reasons for the observed differences in OECD demand, non-OECD demand, non-OPEC supply, and OPEC production. Section 8 discusses the role of government intervention by oil-importing countries. Section 9 integrates the discussion on differences in supply and demand projections from previous sections to provide a framework for explaining the oil price results in the study. It contains a concluding summary of the conditions leading to a low (or high) oil price world.

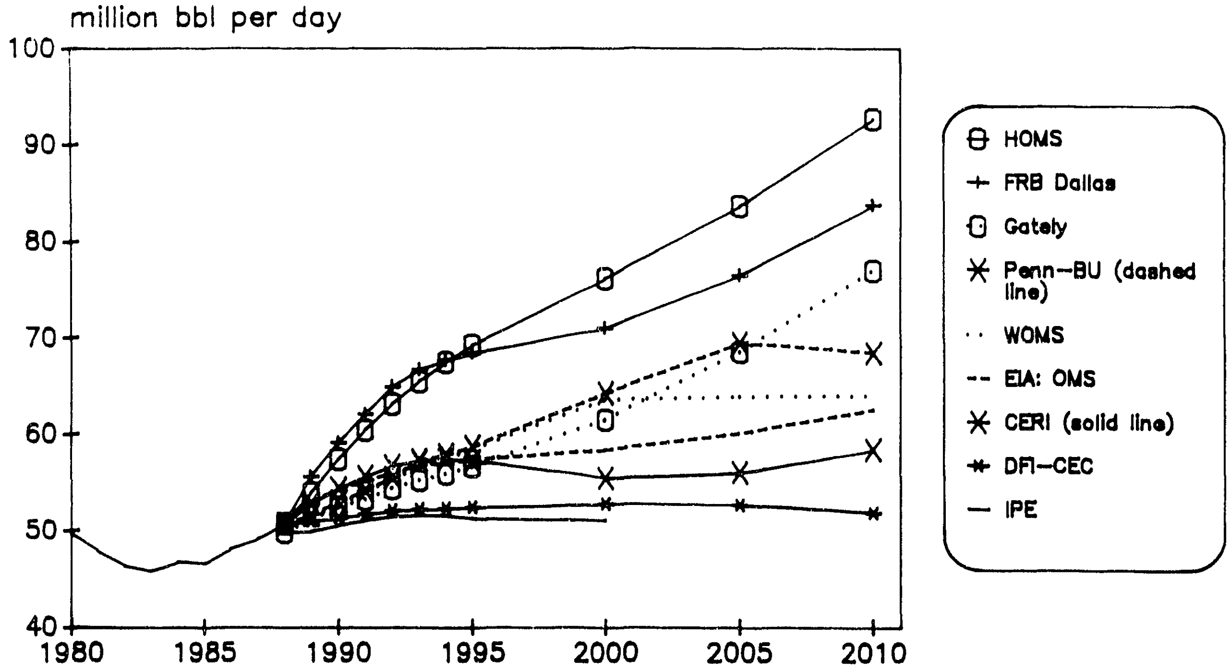
II. ALTERNATIVE PERSPECTIVES ON SUPPLIES AND DEMANDS

Many of the study's key findings can be summarized by discussing the results from one scenario--the 1989 IEO price case. Unless noted otherwise, the conclusions discussed here apply broadly to the other scenarios as well. The figures in this section reveal the key trends reported for each model, in contrast to the comparison of the level in the year 2000 that was presented in the summary report.

World Oil Demands

After many years of changing energy prices, fluctuating economic growth and shifting government policy, there is little agreement about how these factors will influence the rate of increase in future demand. Figure 3 plots for each model the projected oil demand for the market economies in the 1989 IEO Price case over the 1988-2010 period. While in several

Figure 3. Market Economies' Consumption With 1989 IEO Price Path



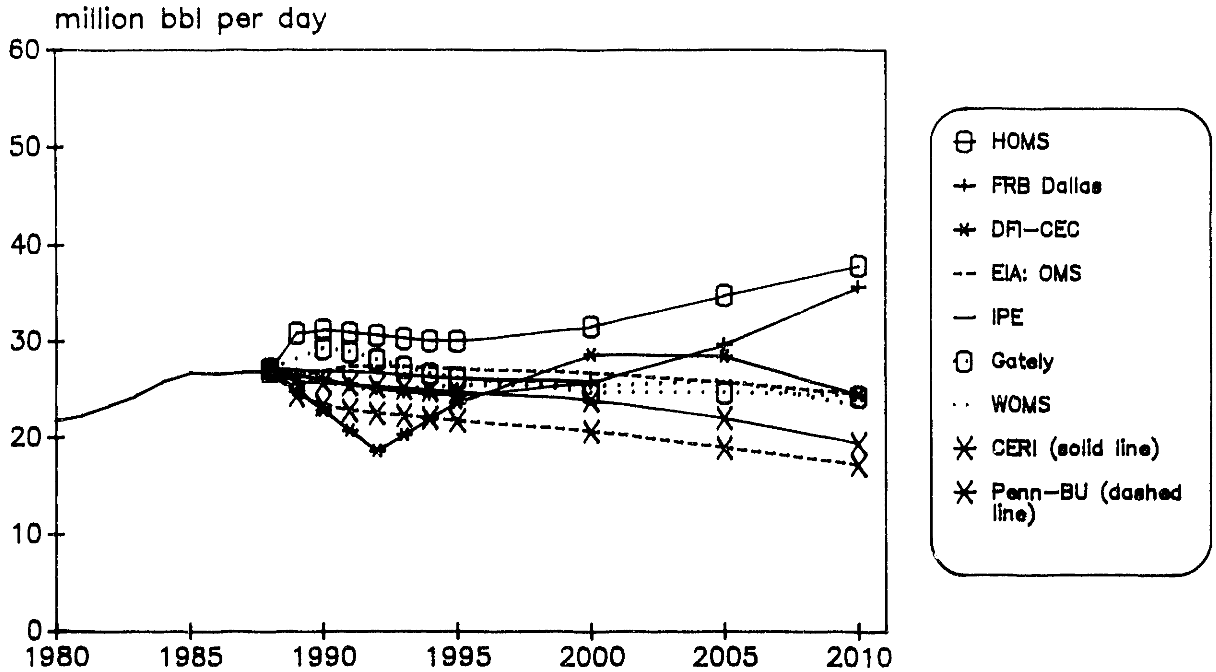
models oil demand is virtually stagnant (IPE and DFI-CEC) or growing very modestly (CERI and OMS), it grows briskly in others (HOMS and FRB Dallas). As early as 1995, there exists an 18 MMBD difference in demand projections, despite the common oil price and economic growth assumptions.

Projections at the higher end of the spectrum are based upon a belief that oil demand will be strongly stimulated by economic growth and that there will be no autonomous improvements in energy efficiency (unrelated to price). Additionally, this view anticipates rising oil intensity (oil use per $ of GDP) over the next five years because recent prices (before the Iraqi invasion) have been below previous prices during the 1970s and early 1980s. Conversely, demand projections at the lower end envision little additional stimulus into the future from past price decreases, continued improvements in energy efficiency despite lower oil prices, and relatively modest increases in demand due to economic growth.

Non-OPEC Supplies

After many years of changing oil prices, fiscal policies of oil-producing countries, and regulatory regimes, there is little agreement about how these factors will influence the level of future oil supply. While these differences are significant, they are not as large as those for world oil demand. Figure 4 plots for each model the projected Non-OPEC oil supply in the 1989 IEO price case over the 1988-2010 period. All but two models show a very modest decline in Non-OPEC production--a noticeable break in the upward trend observed for most of the 1980s. Despite the higher prices in later years, production declines because decreases in the mature U.S.

Figure 4. Non-OPEC Production With 1989 IEO Price Path



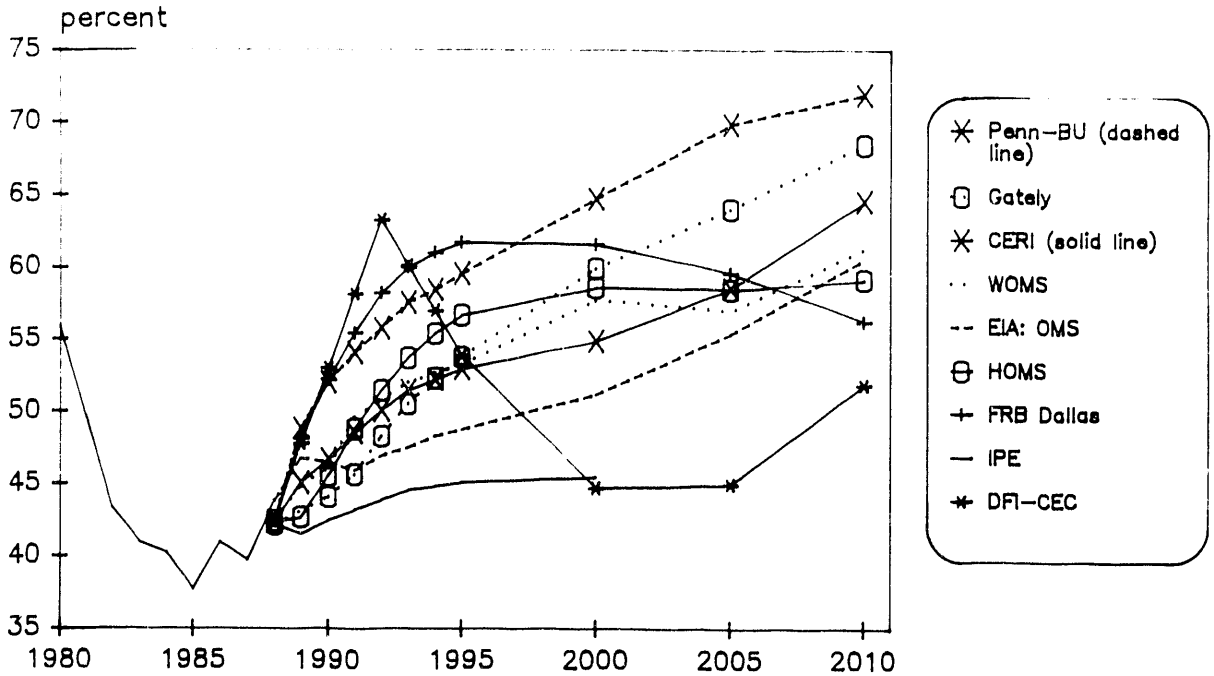
region more than offset any increases in the newer regions outside the United States. Within the United States, resource depletion dominates any technological progress, resulting in declining U.S. production in all models. In two models (HOMS and FRB Dallas), the higher prices in this scenario allow significantly more Non-OPEC production outside the United States in later years. Total non-OPEC production across the various models ranges from 20 to 32 MMBD by 2000; by 2010, the range widens dramatically to 17-38 MMBD.

The uncertainty in any supply projection is obviously very great, given the range of results displayed in Figure 4. Analysis of supply decisions is hindered by inadequate information about a number of factors: the costs of various resources, the impetus for technological advancement in oil exploration and production, and the role of government intervention through changes in fiscal (tax) policies. Some of these factors are considered in Section 6.

OPEC's Rising Market Share

Despite these substantial differences in supply and demand projections, there exists a consensus that dependence upon OPEC oil will rise during the next two decades. As a result of growing world demand and relatively flat (sometimes declining) Non-OPEC production, the demand for OPEC oil increases strongly in virtually all models. If OPEC members in this scenario were to act simply as residual suppliers--producing whatever quantities are needed to meet the excess demand not being supplied by Non-OPEC production--their production would grow from 21.5 MMBD in 1988 to 31.6 MMBD by 1995, 33.6 MMBD by 2000, and 42.3 MMBD by 2010 (averages for all models). These future production levels represent increases of 5.6, 3.8,

Figure 5. OPEC Share of World Production (ex USSR) With 1989 IEO Price Path



and 3.1 % per annum from the 1988 level. The rate of change in required OPEC production decreases through time as prices rise. Although the results from an individual model can deviate substantially from these averages (as was the case with the demand and supply projections shown in Figures 3 and 4), the strong upward trend in OPEC production is robust across the models.

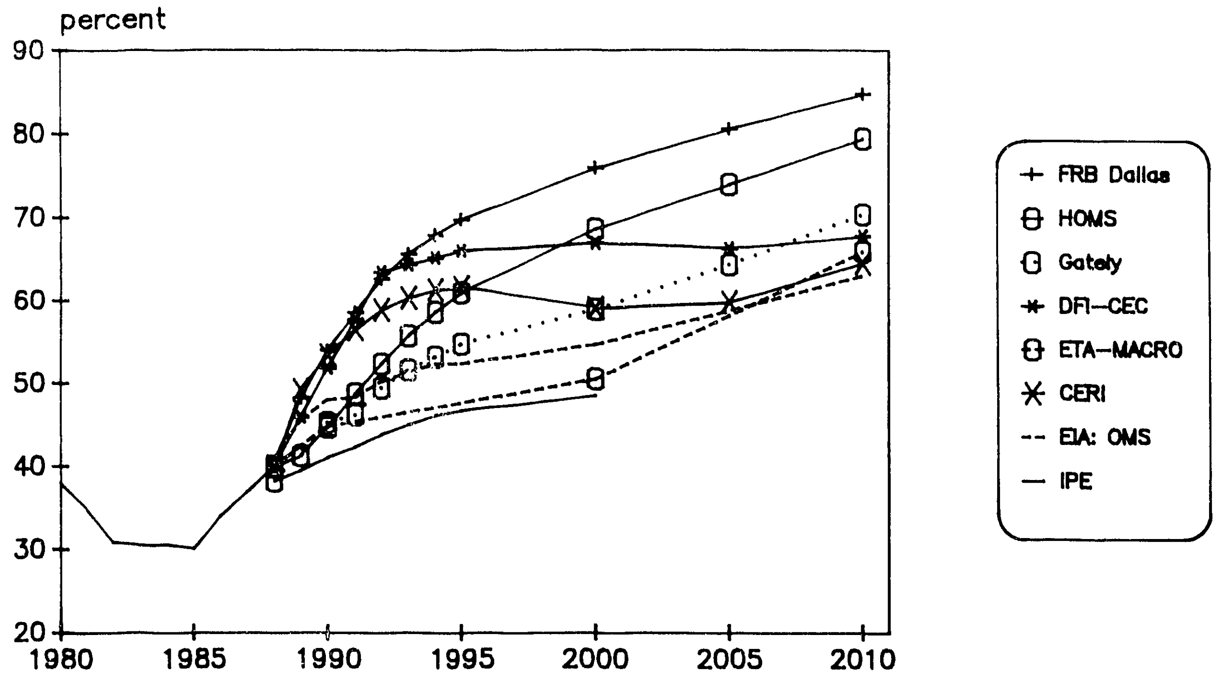
Rapidly growing OPEC production means that world oil production will increasingly be concentrated in the lower-cost regions, principally the Gulf producers within OPEC. The percent of oil supplies for the market economies originating from OPEC countries (Figure 5) rises from 43% in 1988 to above 50% before 2000 in most models. OPEC's share climbs to about 50-60% in most models by 2000 and to about 55-70% by 2010.

These trends are based upon the assumption that OPEC members would become residual suppliers at the prices assumed in the 1989 IEO price path. In fact, OPEC could adopt several different strategies that would influence the oil price in significant ways. While there remains considerable uncertainty about OPEC's behavior, the EMF 11 results suggest strongly that OPEC's increasing market share will materialize, even in scenarios where it influences prices through cooperative behavior. Section 7 considers some of these possible strategies in greater depth.

Growing U.S. Oil Imports

Despite a wide range of projections for U.S. oil production and consumption, there appears to be agreement that U.S. imports will grow briskly over the next two decades. On average across models, oil imports rise from 6.9 MMBD in 1988 to 11 MMBD by 2000 and to 15 MMBD by

Figure 6. U.S. Import Share of Consumption With 1989 IEO Price Path



2010. The annual oil import bill associated with these import levels grows from $37 B (billion) in 1988 to $114 B by 2000 and to $200 B by 2010. As a percent of U.S. GNP, these oil import bills are 1.8% and 2.5% in 2000 and 2010, respectively, as compared to 0.8% in 1988.

In the 1989 IEO price case, slightly more than one of every three barrels consumed by the United States is imported beginning in 1988, but about two of three barrels consumed are imported by the end of the period, 2010. The increasing dependence upon foreign oil is emphasized in Figure 6, where all models show the import share rising above its 1988 value of 38%. By 2000, imports account for one-half to three-fourths of total oil consumption in virtually all models, with many of the projected shares clustering in the 60-70% range by 2010.

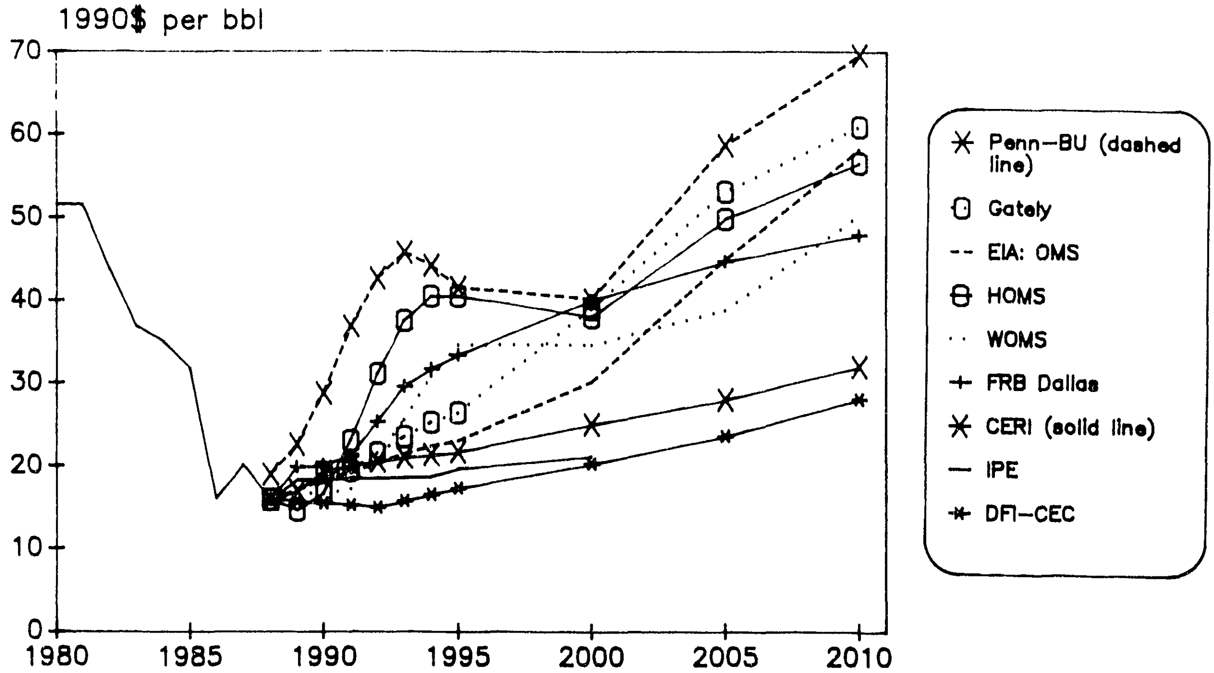
The share of OECD oil consumption attributable to imports also rises, although not as precipitously as for the United States. These trends would return energy security concerns to the policy forefront in major oil-consuming countries, an issue that is addressed in Section 8.

Higher Future Oil Prices

In several scenarios, market-clearing oil prices were determined that balanced the amount of oil supplied and demanded for the particular model and assumptions about economic growth. When oil prices are determined endogenously with OPEC exerting market control, oil prices are uniformly higher than 1988 levels. The rate of increase, however, varies significantly across models.

Figure 7 compares the oil price projections from each model when OPEC is assumed to exert some monopoly control, using the same economic growth assumptions as in the 1989 IEO price case discussed above. The new price paths show increasing prices, as in the assumed 1989

Figure 7. Market-Clearing Prices With Cartel



IEO price path, although differences among models are significant. By 2000, five price paths are above the $30 assumed in that earlier scenario, while four other price paths are at or below that level. The emergence of two distinct sets of price paths is clearly evident from this figure. The DFI-CEC, IPE, and CERI projections lie well below the others, rising gradually to about $30 by the end of the horizon. The other projections show strong upward pressure on oil prices, which reach $50 and higher by 2010.

Many factors can contribute to the differences in price paths shown in Figure 7, but two conditions are particularly noteworthy. Both DFI-CEC and CERI project relatively slow growth in world oil demand even with lower oil prices. They also anticipate OPEC production to exceed 35 MMBD over the next two decades. As will be discussed in Section 9, this combination of conditions places these models in the lower-price "camp" in this figure.

The assumption that OPEC exerts some monopoly control over prices through its production strategies was dropped in the market-clearing case under competitive conditions. As expected, oil prices were lower than under cartel conditions and remained flat for two models in the competition case. In addition, the group considered the impact of higher economic growth. Detailed consideration of both cases, however, must await Sections 8 and 9.

There are many other possible scenarios that could influence future oil prices. Rather than consider each in detail, the working group chose to analyze carefully the factors influencing demand and supply conditions--important drivers of these price forecasts. As an example, the next section focuses on the conditions that would be necessary to keep oil prices from rising.

III. IS $19 OIL SUSTAINABLE?

Three EMF 11 scenarios held real oil prices constant at about $19 per barrel, the level prevailing at the start of the study.[5] The base flat oil price case assumed the same GDP growth rate as in the 1989 IEO price case. The alternative scenarios represent a high GDP case (GDP 30 for market economies grows by about 1 percentage point higher) and a low GDP case (GDP grows by about 1 percentage point lower).

The projected supply and demand levels for the flat oil price paths indicate that, in the absence of a significant expansion in oil supply, oil prices are not likely to remain flat over the next two decades. Table 3 summarizes the trends for OECD demand, Market Economies demand, Non-OPEC production, and the residual call on OPEC production in the three scenarios based upon the flat oil price path. Although the table reports medians[6] only, these scenarios also produced the same wide range of results observed for the 1989 IEO price case. All scenarios imply substantially higher oil demands, modestly declining non-OPEC supplies, and rapidly growing dependence upon OPEC sources. Many, but not all, oil analysts think that OPEC will not increase production so quickly, requiring higher prices to reduce world demand and increase production outside OPEC.

In the flat oil price case shown in the upper rows, oil consumption in the market economies, which include the less developed countries (LDCs), grows by about 2% per year, with a somewhat slower growth in the developed OECD countries. Non-OPEC production would decline modestly through 2000 (from 27 to 25 MMBD), falling more precipitously during the initial decade of the next century. The residual call on OPEC production would climb rapidly to 38 MMBD by 2000 and to 58 MMBD by 2010. Demand for OPEC production at the flat price would increase by 5.2% p.a. between 1990 and 2000. If OPEC were simply to meet this demand at the $19 price, three out of four barrels consumed in the market economies would originate from OPEC member countries by 2010.

In the projections immediately below those results in Table 3, the higher GDP path would accentuate these trends by raising world oil demand, increasing the call on OPEC to 44 MMBD in 2000 and to 72 MMBD in 2010. The lower GDP path would reduce significantly the level of OPEC production to 33 and 47 MMBD by 2000 and 2010, respectively. These results are highlighted in Table 4, which is based upon the estimates shown in Table 3.

These results indicate the strong pressures that would build upon OPEC producers. If world economic growth maintains its recent rate (about 3% per annum), OPEC would need to expand its production rapidly, surpassing its peak production rates of the 1970s early in the next

---

[5]Adelman (1986) argues against a long-run trend towards increasing costs. Oil prices will increase or decrease depending upon the relative strengths of competitive and monopolistic forces, but resource depletion will not push the long-run price trend upward. To avoid the false impression of precision, we discuss the flat oil price trajectory in terms of a constant $19 price (rather than $19.50) in the remainder of the paper.

[6]Half the projections lie above and half fall below the reported median value.

Table 3. Consumption, Production, and Call on OPEC (MMBD) with Flat Oil Price Path, 1990-2010

(Median Results)

	1990	2000	2010	Annual Change 1990-2000	Annual Change 2000-2010
Flat Oil Price					
Consumption					
OECD	37.7	45.1	55.6	1.8%	2.1%
Market Econ	52.1	63.4	77.2	2.0%	2.0%
Production					
Non-OPEC	27.1	25.0	18.7	-0.8%	-2.9%
USSR Exports	2.2	1.5	0.6	-3.8%	-8.8%
OPEC	23.1	38.2	58.4	5.2%	4.3%
OPEC Share	43.8%	60.8%	76.0%		
Flat Price with High GDP					
Consumption					
OECD	38.1	47.4	62.4	2.2%	2.8%
Market Econ	52.5	68.7	93.7	2.7%	3.2%
Production					
Non-OPEC	27.2	25.0	18.7	-0.8%	-2.9%
USSR Exports	2.2	1.5	0.7	-3.8%	-7.3%
OPEC	23.2	44.2	72.4	6.7%	5.1%
OPEC Share	44.4%	64.8%	79.8%		
Flat Price with Low GDP					
Consumption					
OECD	37.6	42.1	47.2	1.1%	1.2%
Market Econ	51.9	58.8	67.6	1.3%	1.4%
Production					
Non-OPEC	27.1	25.0	18.7	-0.8%	-2.9%
USSR Exports	2.2	1.5	1.0	-3.8%	-4.0%
OPEC	22.9	33.5	47.2	3.9%	3.5%
OPEC Share	43.1%	56.6%	69.6%		

Notes:

1) Reported OPEC production is the actual median estimate. It will not be exactly equal to the difference between the median market economy consumption and the sum of the median non-OPEC production and net Soviet exports. Similarly, the reported market share for OPEC is a median estimate.

2) Not all models report all variables or regions. The apparent faster demand growth in OECD than in market economies for the 2000-2010 period in the flat price scenario reflects the fact that ETA-Macro did not report market economies consumption, while Penn-BU did not report OECD consumption.

Table 4. Call on OPEC (MMBD) With Flat Oil Prices

(Medians)

As reported in Table 3:	2000	2010
High Growth	44.2	72.4
Base Growth	38.2	58.4
Low Growth	33.5	47.2
With Flat Non-OPEC Production:*		
High Growth	42.1	64.0
Base Growth	36.1	50.0
Low Growth	31.4	38.8

----

*These estimates have been computed by subtracting the change in Non-OPEC production between 1990 and 2000 (or 2010) from the call on OPEC, as they are reported in Table 3.

century. These residual demands would quickly exceed the 37 MMBD limit on OPEC capacity that many analysts[7] believe will operate for either economic or political reasons. Additional production might not be justified on economic grounds because OPEC's revenues could fall with more production if world demands and Non-OPEC supplies are sufficiently responsive to price. Even if economic considerations did not inhibit such expansion, however, many oil analysts believe that political constraints would deter OPEC members from providing 75% (with 2.9% economic growth) to 80% (with 3.9% economic growth) of the world oil supply in 2010. Such political resistance might stem from the reluctance to deplete a "patrimonial" resource at "bargain" prices for the industrialized countries or from the inability to absorb additional oil revenues.

For this reason, a flat $19 oil price could be sustained over the next twenty years only under certain conditions. Aside from a complete collapse of OPEC cooperation, these conditions include slower world economic growth, continued strong growth in Non-OPEC supplies, sharp cost reductions and early development of unconventional oil supplies, or aggressive policies for reducing oil consumption by major consuming countries.

The estimates in Table 4 suggest that slower world economic growth (to about 2% per annum) would make the flat oil price case more likely, particularly through the end of the century. OPEC would be required to increase its production only to 33.5 MMBD by 2000, an annual increase of 3.9%. After 2000, however, OPEC production would be required to expand

[7]This capacity limit was assumed in the market-clearing scenarios of this study, based partly upon the previously mentioned Energy Information Administration (1989) projection.

to 47 MMBD by 2010. Few analysts believe that OPEC members would want to expand their production by this much in order to keep prices constant.

Robust oil production outside the Middle East was an important force in depressing oil prices during the 1980s. If Non-OPEC output could be maintained at its 1990 level, instead of declining, OPEC would need to produce 2.1 MMBD less by 2000 and 8.4 MMBD less by 2010. The effects of these greater production levels on the call on OPEC in the three flat price scenarios are summarized in the bottom half of Table 4. By 2010, OPEC would need to produce as much as 50 MMBD if oil production outside OPEC were to stabilize at 27 MMBD in the absence of increases in real oil prices and the market economies were to grow by 3% per year. Once again, the conditions for 2000 are not implausible, although many analysts do not believe them to be the most likely. Beyond 2000, the flat price outlook is considerably harder to support, unless economic growth also slows at to about 2% per year.

Within the Soviet Union, the combination of expanded oil production, aggressive energy conservation, or extensive fuel switching away from oil within the Soviet Union could result in substantial increases in oil exports from this region in the coming years. Considerable uncertainty exists about this possibility, which depends upon the confluence of several critical conditions, including political stability, meaningful price reform, and economic vitality. In addition, early development of inexpensive unconventional oil supplies could affect the markets within this time period, although most analysts see these newer supplies being either limited or remaining relatively costly through 2010.

Finally, countries outside OPEC could aggressively adopt policies and strategies for reducing oil use or increasing domestic production, thereby reducing the call on OPEC below those levels shown in Table 3. Taxes or subsidies affect oil quantities by changing the oil price paid by consumers or received by producers. Mandated conservation measures (e.g., automobile efficiency requirements) can be viewed as an implicit tax because the required substitution of other inputs for energy imposes higher costs on consumers. Large changes in explicit or implicit prices are required to significantly alter supply and demand trends outside OPEC, as will be discussed below.

Lacking these alternative conditions, it can be expected that oil prices will increase from $19, augmenting non-OPEC production and reducing world demand and the call on OPEC estimated in the flat oil price case. Table 5 shows the median projection for consumption, production, and the call on OPEC when oil prices rise gradually from $19.50 to $39 through 2000 and remain at that higher level after 2000. Higher prices significantly alter the call on OPEC, which falls from 38 MMBD in the flat price case to 26 MMBD in the rising price case by 2000. For comparison with the previous results, Table 5 also reports supply and demand levels for this alternative price path with high and low GDP assumptions.

The results from the flat and rising oil price cases also illuminate the potential for policy intervention by Non-OPEC countries to reduce their dependence on OPEC oil. A very large oil

Table 5. Consumption, Production, and Call on OPEC (MMBD) with Rising Oil Price Path, 1990-2010

(Median Results)

	1990	2000	2010	Annual Change 1990-2000	Annual Change 2000-2010
Rising Oil Price					
Consumption					
OECD	37.5	35.9	40.5	-0.4%	1.2%
Market Econ	51.4	55.5	60.4	0.8%	0.8%
Production					
Non-OPEC	27.1	28.1	25.2	0.4%	-1.1%
USSR Exports	2.2	1.5	0.8	-3.8%	-6.1%
OPEC	21.9	26.0	38.2	1.7%	3.9%
OPEC Share	42.1%	46.7%	57.6%		
Rising Price with High GDP					
Consumption					
OECD	37.5	40.7	47.1	0.8%	1.5%
Market Econ	51.8	58.3	71.2	1.2%	2.0%
Production					
Non-OPEC	27.2	28.1	25.2	0.3%	-1.1%
USSR Exports	2.2	1.5	0.7	-3.8%	-7.3%
OPEC	22.3	30.9	45.6	3.3%	4.0%
OPEC Share	43.0%	51.4%	63.7%		
Rising Price with Low GDP					
Consumption					
OECD	37.2	34.6	35.1	-0.7%	0.1%
Market Econ	51.0	51.3	54.0	0.1%	0.5%
Production					
Non-OPEC	27.1	28.1	25.2	0.4%	-1.1%
USSR Exports	2.2	1.5	1.0	-3.8%	-4.0%
OPEC	21.6	21.8	27.6	0.1%	2.4%
OPEC Share	41.3%	41.8%	51.9%		

Notes:

1) Reported OPEC production is the actual median estimate. It will not be exactly equal to the difference between the median market economy consumption and the sum of the median non-OPEC production and net Soviet exports. Similarly, the reported market share for OPEC is a median estimate.

2) Not all models report all variables or regions. The apparent faster demand growth in OECD than in market economies for the 2000-2010 period in the rising price scenario reflects the fact that ETA-Macro did not report market economies consumption, while Penn-BU did not report OECD consumption.

consumption tax imposed by all oil-consuming countries would significantly reduce the demand for OPEC oil and may make a flat producer price path of $19 sustainable over a period of several decades. Similarly, large subsidies of similar magnitude would augment oil supplies outside the cartel, indicating a smaller reduction in the net demand for OPEC oil.

Based upon the estimates in Tables 3 and 5, Table 6 suggests that large changes in policy instituted across many countries are required to appreciably alter the call on OPEC when crude oil prices remain constant. The first row reproduces the estimated call on OPEC from the flat price case shown in Table 3, while the second row shows the effect of combining the oil consumption estimates in the rising price case with the Non-OPEC oil production estimates in the flat price case. The demand-reduction policy, therefore, is assumed to gradually increase the delivered price of oil by $19.50 after 10 years (in 2000), while keeping crude oil prices constant.[8] With the baseline GDP assumptions, the market economies' demand for oil in 2000 would fall from 63 MMBD in the flat price case (Table 3) to about 55 MMBD after the tax (Table 5). This reduction of about 8 MMBD in world demand would lower the call on OPEC from 38 MMBD in the flat price case to 30 MMBD in the demand reduction case. By 2010, the call on OPEC would rise only to 41 MMBD in this case rather than the 58 MMBD in the flat price case.

The third row of Table 6 is based upon the supply increases achieved by moving from the flat to the rising price case. It can represent the effect of an aggressive producer subsidy program, gradually reaching about $19 per barrel by 2000, instituted in all producing countries outside OPEC. Non-OPEC production in 2000 would be more than 3 MMBD higher than in the flat oil price case, requiring OPEC to produce 35 rather than 38 MMBD to meet demand in the flat price case. These subsidies would augment Non-OPEC production by 6.5 MMBD in 2010, calling for a smaller increase in OPEC's production--to about 52 MMBD--to meet demand in the flat price case.

The estimates shown in Table 6 suggest that the demand-reduction policy reduces the call on OPEC more effectively than does the supply-augmentation policy. This difference occurs because non-OPEC production represents only a small share of total demand, particularly in the later years. The proportional impact of higher prices on oil production and consumption are more comparable to each other. On average, a doubling of the oil price causes about a 40% increase in Non-OPEC production and a similar 40% decrease in consumption in the market

[8]A large oil tax would be absorbed partly by oil consumers and partly by oil producers. This discussion assumes that the cartel would absorb the tax only to the extent that producer prices, excluding the tax, would remain constant along the flat price path. Thus, if in the absence of a tax, producer prices would rise to $28 by 2000, producers would be absorbing $8.50 ($28-$19.50) and consumers would be absorbing $11 ($39-$28). Alternatively, the analysis asks how much the cartel would need to produce to keep crude oil prices from rising while still meeting world oil demand after the tax. The subsidy discussed in the next paragraph is treated analogously.

Table 6. Call on OPEC (MMBD) Under Assumed Policy Conditions

(Medians Results)

	2000	2010
Flat Price (No Policy)†	38.2	58.4
Aggressive Policies* for:		
Reducing Demand	30.3	41.6
Augmenting Supply	35.1	51.9

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†As reported in Table 3.

*These estimates have been computed by subtracting the change in oil consumption in the market economies (or the difference in Non-OPEC production for the supply-augmentation policy) due to the higher oil price path from the call on OPEC reported in the first row.

economies by 2010 in the various models.[9] Nevertheless, the results do correctly emphasize that it will become increasingly more difficult to alter dependence upon OPEC with policies that operate on the supply side alone, given the declining share of production outside OPEC.

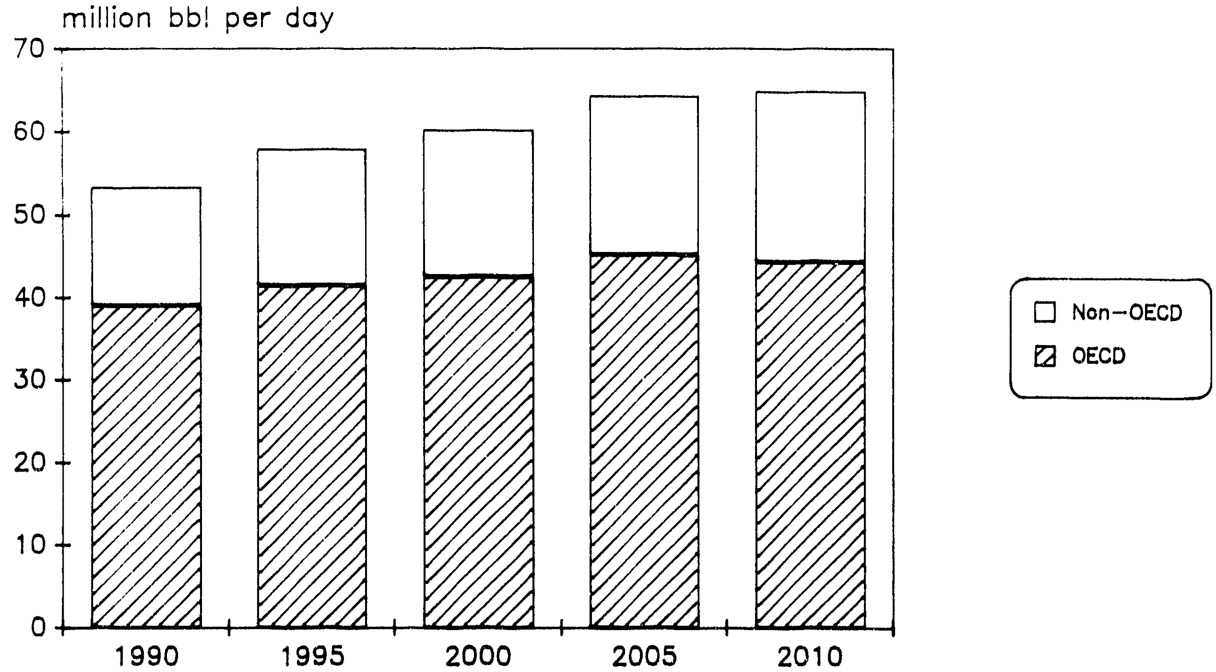
Both the supply and demand-oriented policies considered here are very aggressive, placing a wedge of more than $19 between the world and domestic prices. Moreover, many countries would need to implement similar policies to have the impact described here. Since many countries already have higher taxes and lower oil intensities than does the United States, such policies would be more burdensome for them. Countries that did not adopt these policies would face a lower world price, which would stimulate demand and reduce supply in these regions. While such policies can be expected to reduce the world oil price (exclusive of taxes and subsidies), they would need to be both large and broadly applied to keep the crude oil price from rising under the baseline conditions described in this study.

IV. FUTURE OECD DEMAND GROWTH

The remaining sections examine the supply and demand trends in more depth, beginning with an analysis of the factors contributing to differences in the demand projections across models. With respect to the regional composition of demand, all projections are consistent with the median results, displayed in Figure 8, revealing the increasing importance of oil consumption in the developing countries outside the OECD in the total market. Over the next decade, the developing countries' oil use grows by 2.2% per year while OECD's increases by 0.7% per year under the assumptions of the 1989 IEO price case. During the 2000-2010 period, oil use in these

[9]See Huntington (1991). The median estimates in Tables 3 and 5 imply a 35% decrease in consumption and a 43% increase in production when percent changes are expressed as logarithmic difference, which is appropriate for large changes in prices and quantities.

Figure 8. Sources of Consumption in 1989 IEO Price Case
(Median)



two regions grows by 1.5% and 0.6% per year, respectively.[10] Faster assumed economic growth rates and less responsiveness to price among the developing countries appear to account for most of these differential growth rates in oil consumption.[11]

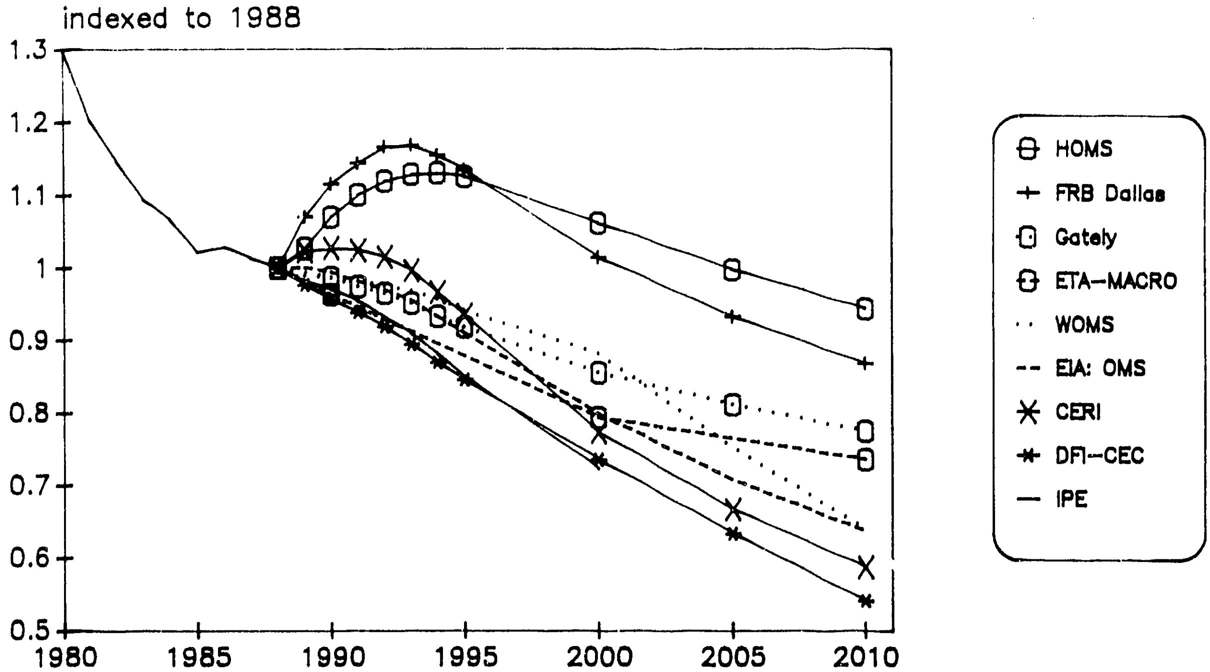
This section explores the causes of discrepancies in OECD demand growth projection, while the subsequent one focuses upon the projections for the developing countries.[12] The section begins by comparing the oil-GDP ratios for the various models for two different oil price paths: the flat and 1989 IEO price trajectories. These trends reinforce the earlier finding of a wide

[10]For consistency, these estimates have been derived from median results for all models that report both OECD and market economies consumption. ETA-Macro and Penn-BU results have been excluded for this reason. Also, IPE's results are excluded because their projections end in 2000.

[11]The estimates of elasticities inferred from a comparison of scenario results reveal a similar income elasticity of about 0.8 in the two regions. The inferred price elasticity averages -0.47 for developed countries and -0.30 for the developing countries. These estimates are explained in Huntington (1991).

[12]Most models focus on the demand for crude oil, but some consider the demand for different petroleum products. Most, but not all models, assume that the prices of other fuels rise with oil prices based upon the historical relationship among fuel prices. And finally, the models track oil demand at different levels of regional and end-use aggregation. All of these factors can cause discrepancies in oil demand projections.

Figure 9. OECD Oil-GDP Ratio With 1989 IEO Price Path



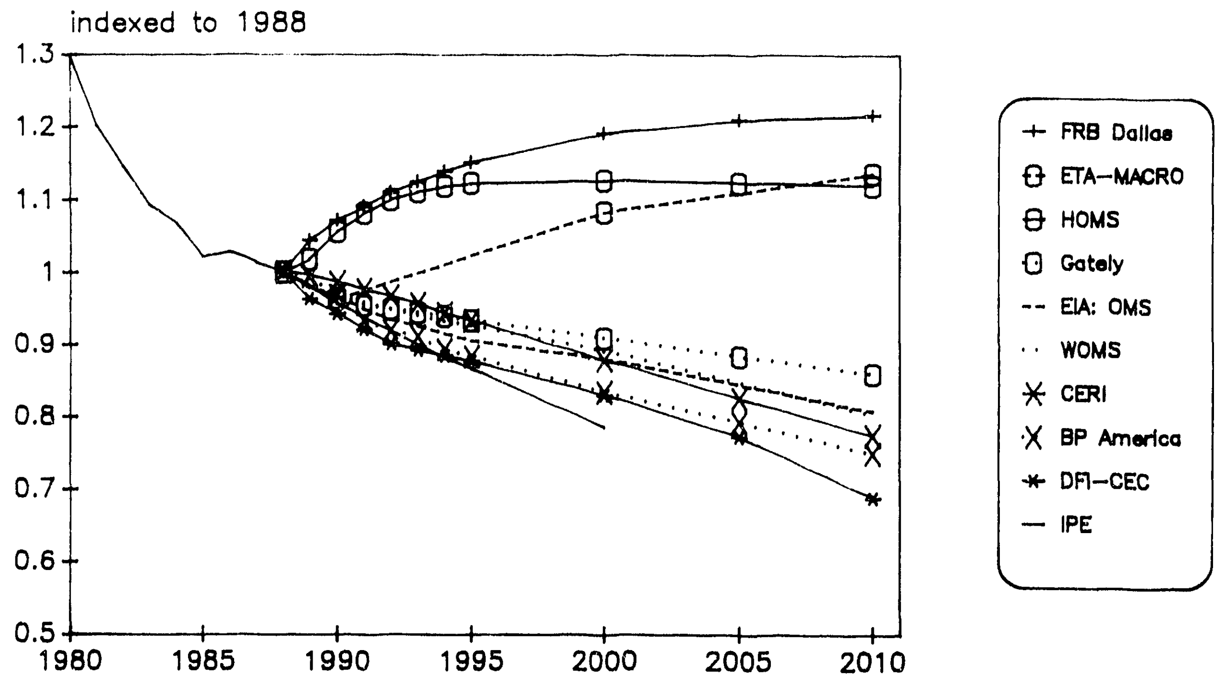
range of demand projections in the 1989 IEO price case introduced in Figure 3. Next, the major influences on OECD oil demand are discussed, after which the projected OECD oil demand growth is decomposed into four major effects. Finally, the role of oil prices in reducing OECD oil demand in the various models is examined.

Oil-GDP Ratios Under Two Price Paths

In most models OECD oil demand does not grow as rapidly as GDP, regardless of the oil price path, causing the oil-GDP ratio to continue its post-1973 decline. Figure 9 shows that the oil-GDP ratio in most models declines under the 1989 IEO price assumptions. By 2010, the oil intensity (indexed to 1 in 1988) declines by 20-40%, or by 1.0% to 2.3% p.a. in these models. Two projections (HOMS and FRB Dallas), however, show oil intensity rising over the early 1990s before falling after 1995. This behavior in the early years explains much of the difference among demand levels being projected for later years and will be discussed extensively below.

The oil-GDP ratio continues to decline in six of the nine models under the flat price scenario shown in Figure 10. By 2010, the oil intensity falls by 10-30%, or by 0.5% to 1.6% p.a. in these six projections. Among the remaining models, HOMS and FRB-Dallas reveal initial increases and then small declines in oil intensity with the 1989 IEO Price Path, as shown in Figure 9. They now show an increasing oil intensity with the flat oil price path. Revealing a significantly larger response to price than in the other models, ETA-Macro joins this group. Thus, the oil demand response to price is a second factor important for explaining differences

Figure 10. OECD Oil-GDP Ratio With Flat Price Path



among projected oil demand intensities and levels, and this effect is also discussed extensively below.

Major Influences on OECD Demand[13]

A framework for explaining these differences in demand behavior can be used to separate the oil demand growth into several components:

(1) the "GDP growth" effect reflecting the influence of higher levels of economic activity;

(2) the "price" effect resulting from future changes in the price of oil;

(3) the "autonomous efficiency improvement" effect in which changes in oil use accrue over time and are unrelated to either price or GDP changes; and

(4) the "initial momentum" effect due to the fact that current oil demand has not adjusted completely to current and past oil prices.

The first two effects are relatively well known and are universally accepted by oil analysts. More GDP growth and lower oil prices stimulate oil demand growth. Analysts disagree, however, on the strength of these two responses. The remaining two effects require some elaboration.

"Autonomous efficiency improvements" (AEI) refer to changes in oil use that are not motivated by oil price changes. For example, in 1967, Boeing introduced the 747 airplane, which yielded enormous fuel efficiency gains. Higher energy prices did not induce the adoption of this

[13]This section also appears in the summary. It is reproduced here because the analysis is critical to understanding the differences in demand projections.

technology; the plane had been designed well before the oil price shocks of the 1970s for a variety of reasons. The gradual turnover in the fleet of airplanes that reduced this sector's oil intensity would have occurred regardless of what happened to oil prices.

Shifts in the economic structure away from energy-intensive sectors and products can also contribute to a long-run decline in oil use per unit of output in many developed countries. To the extent that the shifts are not induced by price changes, they can be considered as part of the autonomous efficiency improvement effect.

"Initial momentum" refers to the tendency of oil demand to either increase or decrease without any further changes in price or GDP changes or autonomous efficiency improvements. A major source of initial momentum is the incomplete adjustment of current oil demand to current and past oil prices. Since energy-using equipment is replaced only gradually, future oil demand will adjust to the current oil price, even if there are no further changes in the oil price. For example, in 1981 the momentum effect would have been negative; if price had stayed at its high 1981 level, the lagged effects of adjustments to previous price increases would have reduced demand, as more energy-efficient capital was adopted. By contrast, the decline in oil prices in 1986 pushed the real costs of many petroleum products below their levels over most of the last two decades. If these lower oil prices persisted indefinitely, there would be less incentive to pursue energy conservation in new investment than before. New equipment would become more energy intensive than the equipment installed previously, causing the economy's energy intensity to rise over the next several years. This would be a positive momentum effect. In other words, the lagged effect of past prices on future consumption means that oil demand changes even if there were to be no future change in oil prices or economic activity.[14]

There will be other effects on oil demand that fall outside these definitions and are considered part of the initial momentum effect in the decomposition of oil demand growth. Some regulations, such as the corporate average fuel-efficiency (CAFE) standards for automobiles in the United States, may require consumers to purchase more fuel-efficient vehicles than they would otherwise choose. Alternatively, reductions in oil use can also be achieved through interfuel substitution towards other fuels. If, for example, a relative abundance of natural gas depresses that fuel's price significantly below its historical relationship with oil prices, oil demand would fall even in the absence of oil price increases or autonomous efficiency improvements.[15]

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[14]Despite their apparent similarity, there is an important distinction between autonomous efficiency improvement and initial momentum. Oil demand reductions achieved through autonomous efficiency improvement are costless to the economy; other inputs are not required to substitute for the lower levels of oil use. Oil demand reductions achieved through initial momentum (when current prices are high relative to past prices) do require the substitution of other inputs. The latter adjustments must be price induced, although the required price changes occur before the current year.

[15]It appears appropriate to include these sources of oil demand changes in the initial momentum rather than the autonomous efficiency improvement effect, given the discussion in the previous endnote. The interfuel substitution effect is induced by a price change. While

Decomposition of Demand Growth

The causes for discrepancies in the projections for oil demand growth have been separated into the above four components, based upon the results from four different scenarios.[16] In each of the four scenarios, all modelers assumed the same oil price and GDP paths. Hence, differences in the estimated price and GDP components reported in this section reflect differences in the responses of oil demand to the assumed changes in price and GDP.

Figure 11 summarizes this decomposition of the oil demand growth for the OECD countries over the 1988-2000 period in the 1989 IEO price scenario. The solid line indicates the total change in oil demand above its 1988 level of 37 MMBD. Total demand growth is comprised of four separate effects, some of which increase growth while others decrease it. The models are ordered according to total oil demand growth, with the lowest growth to the left and the highest growth to the right.

Major discrepancies exist among these demand projections. The rapid growth in the two HOMS and the FRB-Dallas projections are striking. OECD demand grows from about 37 MMBD in 1988 by 13-14 MMBD to 50 MMBD or more by 2000. At a minimum, an 8 MMBD gap separates this group from the other projections, in which demands grow by 5 MMBD or less to no more than 42 MMBD by 2000.[17]

The models showing the highest demand growth--Gately, WOMS, FRB-Dallas, HOMS, and HOMS-1--use demand responses to prices and economic growth that have been statistically derived from the historical experiences of the last several decades. While future demand responses emulate past ones in these models, projected demand trends can still differ from past ones, depending upon the assumed future conditions for the oil price and economic growth. In contrast, all of the remaining models except BP America use demand responses to these conditions that are based upon the modelers' judgement.[18]

Interestingly, large discrepancies in oil demand projections for 2000 remain even after accounting for differences in the demand response to future oil prices. Across projections, the GNP effect varies the most, but the variation in the price and the initial momentum effects are

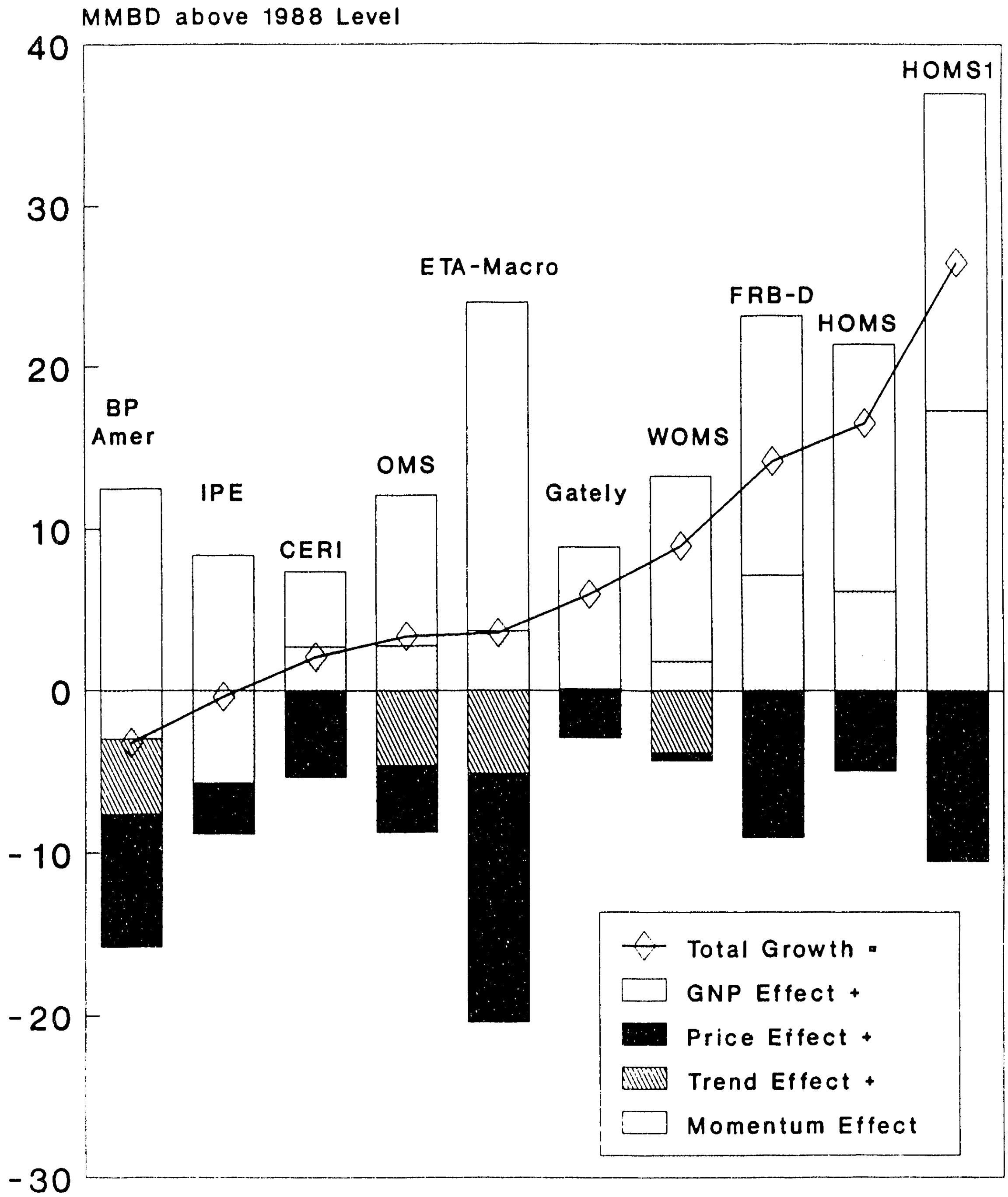
regulations do not explicitly raise prices, they implicitly raise the costs of oil use. Neither effect implies a costless shift towards less oil use.

[16]See Appendix A.

[17]OECD demand grows to about 46 MMBD in WOMS.

[18]Many of these models base some of their judgmental parameters, e.g., the response to price, upon statistical studies of past oil demand. However, in contrast to the first group of models, they do not derive all key parameters simultaneously from the same historical data set.

Figure 11. OECD Demand Growth, 1988-2000: Decomposed into 4 Effects



Note: Growth in 1989 IEO Price Case

also significant.[19] The contribution of the initial momentum effect is surprising and unexpected. As early as 1995, this effect accounts for about 5-6 MMBD of the 13 MMBD increase in total demand in HOMS and FRB-Dallas.[20] Even after five more years of economic growth, these momentum effects are large relative to the GDP effects for the OECD demand growth estimates shown in Figure 11. In these two models, they account for about 30 percent of the total growth in the flat price scenario (i.e., excluding the price effect).

Within each projection, the biggest component is the effect of higher GDP in stimulating oil demand, although the initial momentum and price effects are substantial in a few models. The price effect increases over time as energy-using equipment is replaced by more energy-efficient vintages, but the economic growth effect remains dominant, even over the longer 1988-2010 period. HOMS and FRB-Dallas project long-run oil intensities as a function of the oil price only.[21] A one percent increase in the GDP level will result in a one percent increase in oil demand, if oil prices remain fixed at their 1988 level. There is no autonomous improvement in oil efficiency (labeled as "trend effect" in Figure 11) that operates independently of the oil price in these two models. While some new technologies save energy, other technologies and lifestyle changes may actually use more energy. Higher prices dampen but do not offset this larger demand growth.

The presence of autonomous improvement in oil efficiency keeps projected oil demands considerably lower in BP America, ETA- Macro and WOMS, even though all possess relatively large GDP effects. Moreover, the price effect is considerably larger in ETA-Macro than in other models. Without this price effect, its oil demand is comparable to the highest demands (HOMS and FRB- Dallas) in the flat price scenario. ETA- Macro focuses upon all energy forms. When oil prices rise, oil demand falls as: (1) the demand for all energy declines, and (2) as electricity replaces oil and other fossil fuels. In ETA-Macro, this first effect alone is comparable in size to the full effect of oil prices on oil demand in most of the other models, resulting in greater sensitivity to oil prices.

The remaining models--IPE, CERI, Gately and OMS--have relatively small GDP growth effects, in which oil consumption grows proportionately less than economic growth. This smaller GDP effect operates like the trend effect in the other models; oil efficiency improves over time

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[19]This conclusion is based upon standard deviations computed for each effect, excluding the alternative HOMS-1 results and setting the momentum effects for BP America and IPE to zero. As discussed later, the momentum effect for these two models is not due to incomplete adjustments to current and past prices. The GNP effects depend, of course, partly on the OECD economic growth rate (2.6% per annum); the variation in this effect among models will be greater for faster economic growth and less for slower economic growth.

[20]Similar results hold for the decomposition of OECD oil demand growth between 1988 and 1995, although the relative importance of initial momentum decreases over time.

[21]HOMS-1 does the same, except that in estimating the response to prices from historical experience, it allows for a one-time shift in oil intensity after 1980.

(assuming some economic growth) even if oil prices do not increase from their 1988 levels. OMS also reports an additional autonomous trend towards increased oil efficiency that further reduces its projected growth in oil demand.

The initial momentum effect is pronounced in the HOMS and FRB-Dallas projections because long-run oil intensities in these models respond symmetrically to oil price increases and decreases. Moreover, oil intensities respond quite slowly to oil price changes. The model parameters indicate that much of the response to the recent lower oil prices had not occurred by 1988. Since the oil price is currently lower than it has been over much of the last 15 years, the initial momentum effect in most models causes oil demand to grow, i.e., it is positive. Even if there were no economic growth, under constant prices OECD demand would still have grown over 6 MMBD in HOMS and FRB-Dallas simply due to future demand adjustments to the current oil price level.

Incomplete adjustment to current and past prices plays a relatively minor role in most of the remaining models, accounting for at most 3 MMBD of demand growth by 2000.[22] The negative initial momentum component for two models (BP America and IPE) is not due to the incomplete adjustment of current oil demand to current prices, as in the other models. For example, continued automobile efficiency improvements are allowed in the BP America model regardless of the oil price path. This decline arises from policies for fuel efficiency standards on oil use and are unrelated to either price or autonomous efficiency improvements.

The historical experience of the 1970s and 1980s imposes certain restrictions on the nature of the oil demand response that are reflected in the model responses shown in Figure 13. First, large price effects are generally associated with large GDP effects, and small price effects with small GDP effects. A model with a large response to GDP and a small response to oil price increases would have badly overestimated oil demand growth when oil prices were rising over the last two decades, given the actual oil price and economic growth trends. Similarly, one with a small response to GDP and a large response to oil prices would have underestimated oil demand growth over this same period.

Second, the autonomous efficiency improvement effect is often absent in models displaying large price effects. Past reductions in oil demand intensity can be due to changes in price and other nonprice factors. When a model attributes a major role to price, there remains little additional improvement in energy efficiency to be explained by nonprice factors.

And third, large price effects are often associated with large initial momentum effects and vice versa. This is understandable because the initial momentum effect is itself a response to price changes from previous periods. If demand responds symmetrically to price increases and decreases, these two effects incorporate similar responses.[23]

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[22]This estimate includes both OECD and non-OECD countries.

[23]Not all models embrace the assumption of reversibility in the demand response to price changes. The Gately model is most explicit about assumed asymmetries in the demand response to price changes. Due to large capital costs, investment in energy- conservation measures is not

Further Discussion: Differences Among Models

The pattern of demand effects in Figure 13 reflects to some extent the different approaches used to determine the response of oil demand to various factors. Some modelers estimate these responses directly from statistical analyses of the historical experience of the last several decades. Others judgmentally select parameters for these responses, based partly upon past statistical studies by other analysts.

Both versions of HOMS and FRB Dallas are based upon explicit statistical modeling of the demand response to oil prices and GDP based upon available historical data. None represent any oil efficiency improvements over time because each modeler found no evidence for oil-saving technological progress. Thus, these models attribute the decline in oil demand since 1973 to higher prices and to the fact that demand adjusts only gradually to price changes. Correspondingly, their price effects are relatively large. The main HOMS results show a lower response to price because a one-time permanent change in the oil intensity level is assumed to occur in 1980. Thus, some of the decline in oil intensity is attributed to this structural change in oil demand rather than to higher prices, although an ongoing AEI effect accruing each year is still absent in this versions of HOMS. And finally, past prices are remembered strongly and quickly in these models. With relatively low prices in 1988, consumers shift to more energy-intensive options because they expect future prices to remain below their historical average.

The price and income responses of WOMS are similarly based upon historical data, but with a technological trend imposed showing less oil use over time. As more of the demand decline since 1973 is attributed to technological change, price has a smaller role in this model. In addition, demand adjusts to price changes much more slowly than in the other models. Thus, demand in 2000 is still being stimulated to a greater degree by the decline in oil prices assumed in the early years of the 1989 IEO price path.

The Gately model represents a third approach to estimating the price and income responses from historical data. While no explicit AEI effect is included, economic growth has a proportionately smaller impact on oil demand, i.e., demand grows by less than 1% for every 1% increase in GDP. This decoupling of oil demand and economic growth is especially true in Japan and Europe but does not hold for the developing countries. In addition, the demand response to falling prices today is assumed to be less than that to rising prices in the past.[24]

The demand response to price and GDP are not explicitly estimated from historical data in the other models, although they are calibrated to be representative of estimates available from a long line of statistical studies on energy demand. Except for ETA-Macro, these models show

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undone when prices fall from previously high levels, so that demand would not increase very much. Nor does such investment need to be added back when prices begin to recover and rise again, so that demand would not decline very much. Indeed, the price effect for this model is relatively low, as seen from Figure 13. However, if prices were to exceed their historical maximum (which are not reached in the EMF scenarios), the price response would increase as new opportunities for investment in conservation would emerge.

[24]See the previous footnote.

GDP stimulating oil demand by proportionately less than the change in GDP. These same models have price effects less than those for HOMS and FRB Dallas discussed above, although the OMS and CERI price effects are comparable to HOMS1.

V. FUTURE DEMAND GROWTH OUTSIDE THE OECD

Energy demand in the developing countries is expected to grow more rapidly than within the OECD due to higher projected economic growth rates, the movement from subsistence to commercial energy forms, and the increased demand for energy-using equipment. The oil projections in this study follow these general trends for all energy, with oil demand growing more rapidly outside than within the OECD. These trends assume that these countries are able to finance higher oil import bills while simultaneously importing the capital to maintain economic growth. Although the financing issue has not been addressed by the working group, it deserves additional attention using more disaggregated analyses of individual countries.

This section discusses the oil demand growth in the study for countries outside the OECD. After a brief discussion of energy in the development process, it compares the various projections for the oil-GDP ratios outside the OECD countries. The EMF results are also compared with some disaggregated oil and energy demand projections recently prepared by Lawrence Berkeley Laboratory (LBL). As was done for OECD demand in the previous section, this section also decomposes the projected oil demand growth in the various models into the same major components. This section concludes with several observations about the possible effect of the economic transformation in the Soviet Union and East Europe on world oil markets.

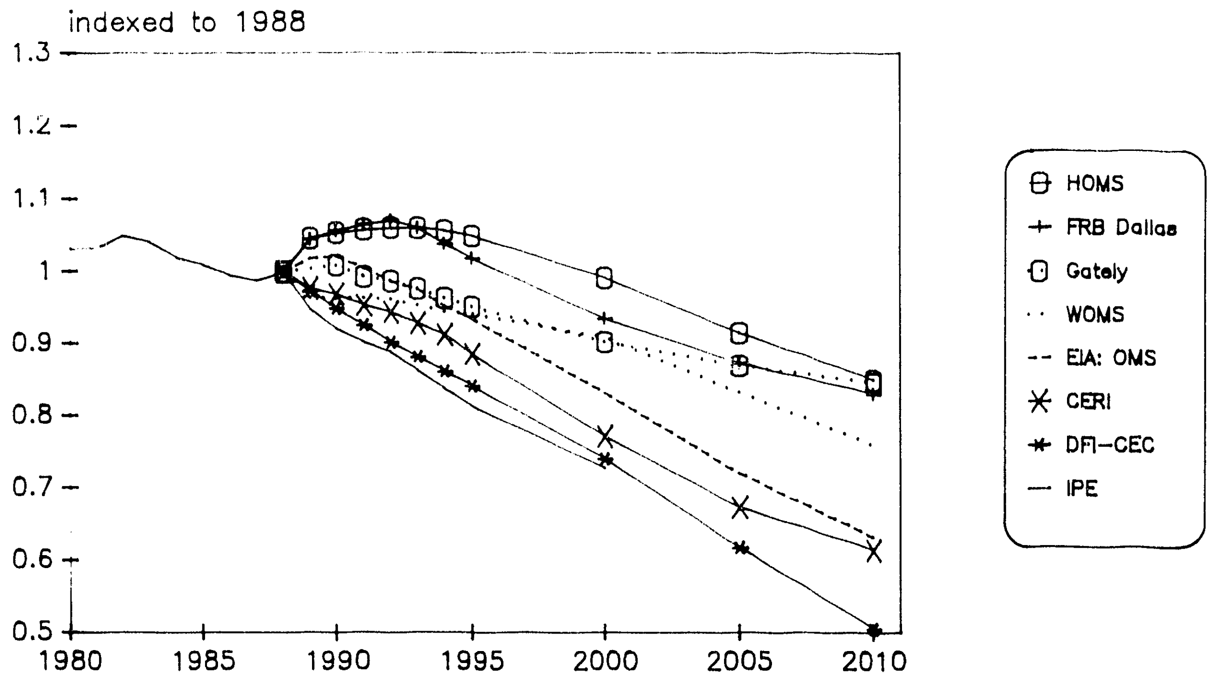
Economic Development and Energy

Most of the world's population live in countries undergoing a transformation in economic production and living standards. Market activity is replacing subsistence production, population is rushing into cities from rural areas, and ownership of vehicles and energy-using appliances is expanding. These economies are shifting towards industries producing basic raw materials that are also very energy intensive, e.g., steel, aluminum, cement, etc. By themselves, these trends portend increasing dependence upon fuels and power, particularly commercial energy. Imported oil in these countries, however, may be limited by several factors.

The capacity to import capital constrains this economic transformation in many developing countries retarding both economic growth and energy development. It represents a critical link to rising labor productivity and standards of living. It also figures prominently in the country's ability to produce domestic energy and consume energy efficiently. For the most part, capital will be imported from abroad and paid for by a country's exports.

Some developing regions are also a promising source of future energy supplies that could replace oil. The penetration of alternative fuels such as natural gas and coal may "back out" significant amounts of oil use in some sectors. The speed and extent of this replacement, however, is uncertain. Natural gas may often be limited by the very large required investment

Figure 12. Non-OECD Oil-GDP Ratio With 1989 IEO Price Path



in infrastructure. Coal use may increasingly face a contentious future as concerns about air quality and global greenhouse gases mount.

These transformations are already well underway in some developing economies while they are relatively nascent in others. Thus, it is inappropriate to view these nations as a single entity faced with the same economic and energy challenges. A diverse mixture of economic conditions and responses can be expected in these economies over the next several decades.

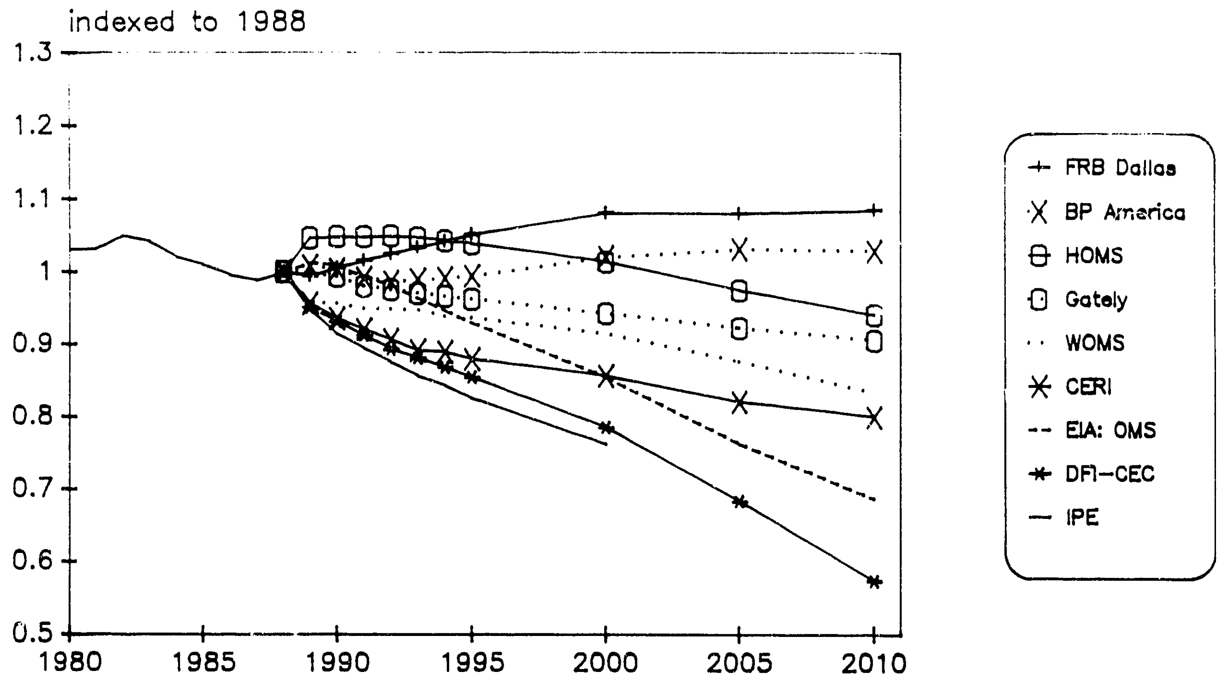
Oil-GDP Ratios Under Two Price Paths

Few models project Non-OECD oil demand to continue its historical trend of growing as fast as GDP, even with flat oil prices. In fact, the projected decline in oil intensity is comparable to that for the OECD developed countries in many cases.

The resulting decline in the oil-GDP ratio is shown in Figure 12 for all models under the 1989 IEO price assumptions. By 2010, the oil intensity (indexed to 1 in 1988) declines by almost 40%, or by 2.3% p.a. in two models--OMS and CERI--and even more in DFI-CEC. The others show a more modest decline from 15-25%, or 0.8-1.2% p.a., in the oil intensity through 2010.

The pattern of oil-GDP ratios is more diverse for the flat price case in Figure 13. FRB Dallas and BP America show the oil intensity in developing countries with a modest upward trend over the next two decades. The others all show long-term declines, albeit at different rates, ranging by 2010 from 5% (or 0.2% p.a.) to 30% (1.6% p.a.) for HOMS and DFI-CEC, respectively.

Figure 13. Non-OECD Oil-GDP Ratio With Flat Price Path



Comparison of EMF and LBL Projections

As with OECD demand, the oil market models included in this study relate the aggregate oil use in all developing countries to oil prices, GDP, and perhaps autonomous efficiency improvements. Severe data limitations generally prevent the analysis from differentiating oil demand by different regions or major countries or from including many of the important structural changes occurring within these societies.

The working group included several members who have made very detailed studies of energy demand in the developing countries. Based upon their research, the EMF working group was able to probe the potentially important role of oil demand outside OECD through a comparison of the EMF results with a more detailed, disaggregated assessment of energy demand. The latter demand study was conducted by the Lawrence Berkeley Laboratory (LBL), in support of some analysis of the impacts of climate change policies.[25]

There are several steps in developing such "bottom up" estimates of energy demand. First, the assumed GDP for each country is disaggregated by major sector, e.g., agriculture, transportation, industry, etc. Second, sectoral activity levels, such as output of raw materials, automobile and truck use, and household appliance ownership, are chosen to be consistent with the income level derived from the assumed economic growth rates. Third, estimates of energy efficiency within each sector are developed based upon the technical potential for achieving

[25]Sathaye et al (1989) discuss this study in detail. See Imran and Barnes (1990) for another useful source on demand projections for the developing countries.

energy savings and the rate at which new equipment is introduced. Fourth, sectoral fuel demand is computed as the product of separate estimates for sectoral activity or appliance ownership levels and the energy intensity within that sector. For example, gasoline demand for automobiles is calculated as the product of vehicles per capita, annual travel per vehicle, average fleet efficiency and total population. Each of the first three components are linked separately to income and prices for fuels and appliances. These sectoral demands are then aggregated to determine economywide fuel demands.

Table 7 summarizes the results from the LBL projections for three cases: a rapidly changing world (RCW), a slowly changing world (SCW), and a policy case labeled Intergovernmental Panel on Climate Change (IPCC). In addition to faster economic growth, the rapidly changing world assumes faster penetration of energy-using appliances (which increases the economy's energy intensity) but also greater end-use energy efficiency (which reduces the economy's energy intensity). Thus, the scenario could show either rising or falling energy intensity, depending upon the relative strengths of these two trends. Assumptions on GDP growth rates in the rapidly changing world scenario were changed to conform with the EMF scenarios. Oil price assumptions were already comparable to the EMF's 1989 IEO price case.

LBL estimated demands for two separate years--2000 and 2025. For comparison with the EMF results, a level for 2010 was interpolated from the demands for the two years reported. In Table 7, their aggregate energy and oil demand projections have been converted to intensities--e.g., oil or energy use per $ of GDP--and expressed as an index where 1985=1.000.

The oil-GDP ratio in the LBL study declines by 40-50% by 2010 in the first two scenarios. The detailed, "bottom-up" LBL estimates of oil intensities, therefore, are within the range of the aggregate EMF projections for the 1989 IEO price case, although at the lower end. In Figure 12, the LBL results would be indistinguishable from the DFI-CEC projections. The greater gains in aggregate oil efficiency in the LBL assessment, relative to the remaining models, may reflect improved oil efficiency in new energy-using equipment and vehicles, a slowing in the penetration of appliance ownership even though incomes rise, or both. The LBL results also reveal a continued shift from oil use to other energy forms, as indicated by the slower decline in energy intensities shown in the last row for each scenario in Table 7.

Decomposition of Non-OECD Demand Growth

Following the approach in Section 4, the oil demand growth outside OECD can be decomposed into "initial momentum", "GDP growth", "autonomous efficiency improvement" (AEI), and "price" components. The results of this decomposition for the 1988-2000 period are compared across models in Figure 14, which orders the models as they were in Figure 11, from lowest to highest growth in OECD demand. BP America and Gately reveal stronger non-OECD than OECD demand growth, due principally to a larger GDP effect, and hence appear to be "out of order" in Figure 14.

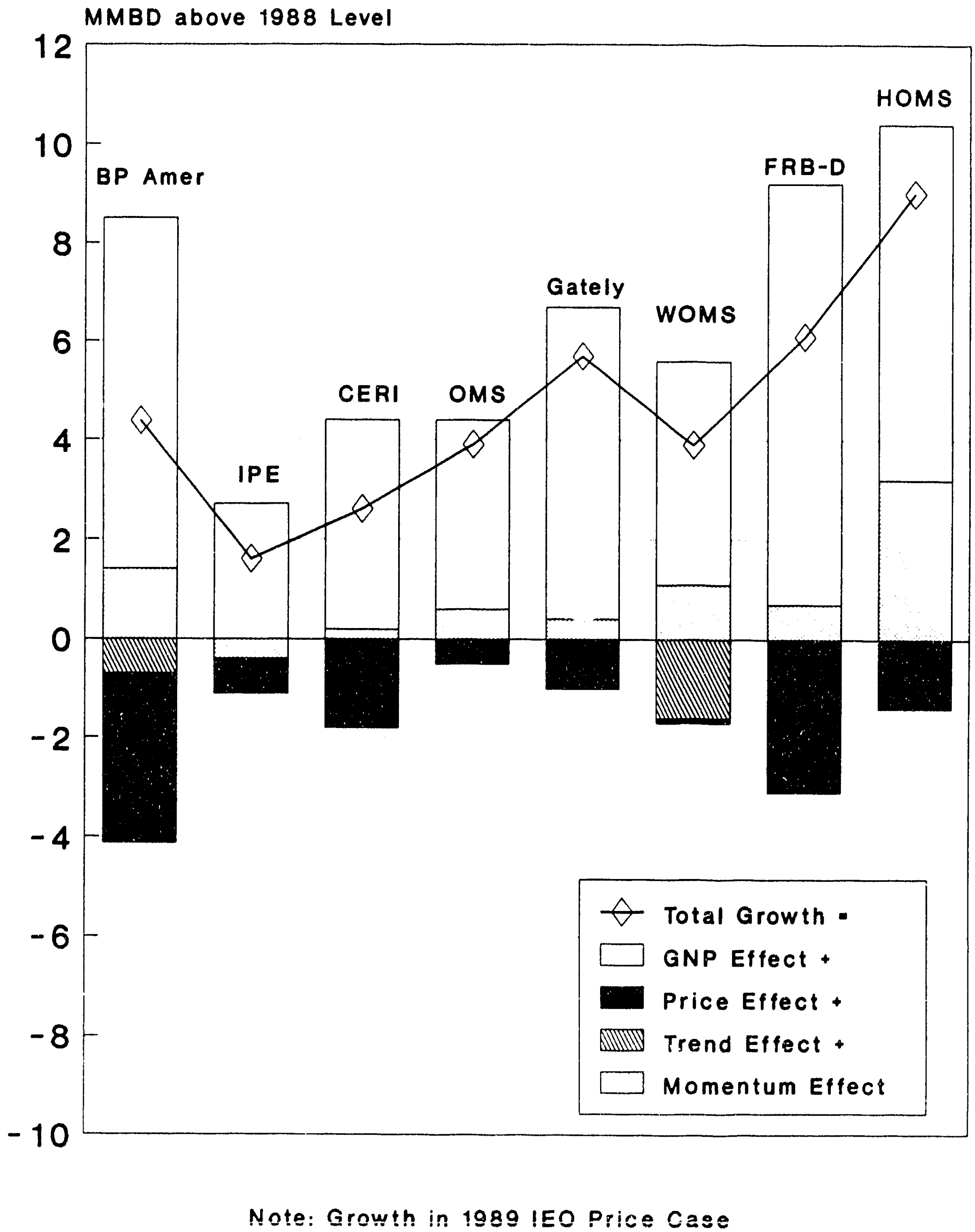
Table 7. Oil and Energy Intensities for Developing Countries from Lawrence Berkeley Laboratory Study

	Energy units=EJ/year				Growth Rate (%p.a.)	
	1985	2000	2025	2010 (interp.)	1985 -2000	2000 -2025
Rapidly Changing World:						
GNP (index)	1.000	1.992	5.844	4.7%	4.4%	
Oil	26.9	40.8	76.9	2.8%	2.6%	
Energy	67.9	121.8	315.5	4.0%	3.9%	
Intensities						
Oil	1.000	0.762	0.489	0.653	-1.8%	-1.8%
Energy	1.000	0.901	0.795	0.858	-0.7%	-0.5%
Slowly Changing World:						
GNP (index)	1.000	1.581	3.003		3.1%	2.6%
Oil	26.9	35.4	49.2		1.8%	1.3%
Energy	67.9	99.7	173.5		2.6%	2.2%
Intensities						
Oil	1.000	0.661	0.313	0.522	-2.7%	-2.9%
Energy	1.000	0.737	0.437	0.617	-2.0%	-2.1%
Intergovernmental Panel on Climate Change scenario:						
GNP (index)	1.000	1.880	4.553		4.3%	3.6%
Oil	26.9	50.0	101.0		4.2%	2.8%
Energy	67.9	131.0	317.0		4.5%	3.6%
Intensities						
Oil	1.000	0.933	0.642	0.817	-0.5%	-1.5%
Energy	1.000	0.969	0.799	0.901	-0.2%	-0.8%

Note: Estimate for 2010 is calculated as a simple, linear interpolation between 2000 & 2025 (for comparison with EMF 11 results).

The relative importance of the various components in explaining differences in Non-OECD oil demand growth are similar to the conclusions derived for the OECD countries in the previous section. HOMS and FRB-Dallas show the highest growth in Non-OECD demand by 2000 in the flat oil price case. They combine some initial momentum from past prices with an above average GDP growth effect. CERI and WOMS have relatively low demands in 2000 because the GDP growth effect is relatively small. The AEI trend effect is present for Non-OECD demand if it was present for OECD demand (Figure 11 in Section 4). Similar results hold for the decomposition of OECD oil demand growth between 1988 and 1995.

Figure 14. Non-OECD Demand Growth, 1988-2000: Decomposed Into 4 Effects



The highest projection (HOMS) in 2000 is about 7.5-8 MMBD greater than the lowest projection (IPE) in either the 1989 IEO price or flat price case. This range is about comparable to the OECD range (after excluding HOMS1) when each region is standardized for the level of oil consumption. The price effect is important for BP America and FRB-Dallas but remains relatively minor for the other models. In general, Non-OECD oil demand is less sensitive to price than is OECD demand.

Economic Transition in the Soviet Union and Eastern Europe[26]

The transformation of the Soviet Union and Eastern Europe from centrally planned to more market-oriented economies accelerated dramatically in 1989 and 1990. The Soviet Union is now adopting policies that may lead towards a market economy at the same time that economic performance is deteriorating rapidly and the political structure is disintegrating. In Eastern Europe market reforms are already being introduced, with varying intensity. The economic relationship between the Soviet Union and its former allies is being restructured. These changes will affect Soviet oil exports as well as East European imports, and thus the world oil market. However, domestic developments in these countries are characterized by fundamental uncertainty, making it difficult to analyze trends in oil trade from this region.

Problems in data availability and reporting have prevented energy supply and demand trends within these economies from being included in analyses of energy trends in market economies. Since the world oil models used in this study are based upon traditional data collection efforts, the models do not incorporate interactions between energy trends in the former eastern bloc countries and those in the market economies. The exogenous treatment of the former is likely to change significantly as information becomes more readily available.

The models maintain a world supply-demand balance through an exogenous assumption for net oil exports from the Soviet Union. In this study, most modelers adopted the EMF default assumption that called for net oil exports to decline gradually from about 2.4 MMBD in 1988 to about 1.0 MMBD by 2010. Such a scenario represents one of many possible outcomes. It assumes continued decline in Soviet oil production and small increases in Soviet oil consumption as modest economic growth more than offsets efficiency improvements in energy use.

In the future, the evaluation of world oil market trends will require the separate analyses of the Soviet Union, Eastern Europe, and China rather than treating them as one block for centrally planned economies. A key issue for the Soviet Union will be the extent to which foreign investment and efficiency improvements can reverse the recent oil production declines. As for energy consumption, there are considerable opportunities for improving efficiency both in terms of the economy's structure and in major energy-using industries. Meaningful price reform, however, is necessary for achieving these efficiency improvements on both the supply and demand side. At the moment, such reform is hindered by a number of institutional barriers and hence is very uncertain. While these trends suggest declining oil exports, foreign exchange needs may

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[26]Arild Moe contributed significantly to this section. For further discussion, see Moe (1991).

dictate Soviet oil export policies in important ways as well. In today's confusing economic and political situation in the USSR, it seems reasonable to expect a significant decline in Soviet oil exports in the coming years. Initially, most of the reduction will be in the trade with East European countries. A reduction from a total level of 3.7 MMBD in 1989 down to around 2.0 MMBD in the mid 1990s is not unlikely. However, in the event of a successful economic transformation, entailing considerable progress in energy conservation, Soviet oil exports could rebound in the second half of the 1990s. At this stage, Soviet export levels could become more sensitive to price developments than in the past, because new production capacities will be increasingly costly and a reformed economic system is likely to transmit price information to producers.

As Eastern Europe becomes more fully integrated with Western Europe, energy use will rise in tandem with continuing economic reform. Increasing crude oil imports from the Middle East are the most likely source of the additional energy supplies required. Recent events do not appear to have altered China's commitment to coal for powering its economy, rather than use other fuels like oil.

VI. NON-OPEC PRODUCTION

Oil production outside OPEC rose during the 1960s and 1970s as the total oil market expanded; it continued its steady growth through the 1980s, despite contracting world oil demand during much of the decade. Within the Non-OPEC region, however, the U.S. share has been declining. U.S. production has been relatively flat over the last several decades, with a noticeable decline in the last several years.

This section discusses the study's results for oil production outside the OPEC member countries. It begins by reviewing the basic approaches used in this study for preparing supply estimates. Next, estimates of the cumulative production over the 1988-2010 period are discussed within the context of the total resource base estimated recently by the U.S. Geological Survey. After a review of the supply trends both within and outside the U.S., the influence of price upon supply is considered. This section closes with a brief discussion of some recent estimates of the costs of unconventional oil from a recent National Academy of Sciences study on this subject.

Aggregate Oil Production Estimates

World oil models determine aggregate oil production outside OPEC on the basis of assumptions about the oil price and the effect of increased drilling on resource costs (depletion). In CERI, DFI-CEC, and ETA-Macro, the interest rate earned on financial assets is another variable influencing oil exploration and production. Additionally, the estimates may also informally incorporate the effect of taxation, advancements in geological knowledge and drilling technology, and infrastructure constraints on the rate of expansion in productive capacity in newer regions. All models consider U.S. production separately from the remaining Non-OPEC regions, and several disaggregate the latter into major supply regions.

All models embody a supply response to price. Most include a price elasticity that increases over time, reflecting the long lead times required to adjust oil exploration and production to changed economic incentives. This parameter is estimated from historical data in Penn-BU, WOMS, CERI, HOMS, FRB-Dallas, and BP America; it is determined judgmentally in the remaining models.

Producers are assumed to have perfect foresight on future market conditions in two models, DFI-CEC and ETA-Macro. Producers maximize oil income (revenues net of costs, appropriately discounted) over all years in DFI-CEC; they maximize the discounted value of aggregate economic consumption over all years in the ETA-Macro. The response to price in these models results directly from this optimizing behavior by producers. Higher prices increase the amount of oil that is ultimately recoverable at market prices. However, producers also consider the relative gains from delaying production until future time periods; thus, the rate of price increases, relative to extraction costs and the return on financial assets, also is important.

The treatment of resource depletion varies across models. OMS and Gately incorporate depletion in their reference series, before adjustments for price variations are introduced. The reference series incorporates the modeler's judgement about the resource base, finding rates, and drilling cost as well as any binding infrastructure constraints. These judgements often are based upon more detailed analysis of resource conditions. IPE adopts a similar approach in which an assumed depletion factor is used to adjust its reference series for cumulative oil discoveries.

HOMS and FRB-Dallas use statistical analysis to estimate the change in production over time from historical data, holding price incentives constant. The resulting time trend effect is assumed to hold for the future. It includes the net effect of infrastructure constraints on expansion in relatively undiscovered regions, technological progress, and resource depletion. In the simplest case, responses to both price and time are estimated from historical data. The resource base is not explicitly represented, and changes in country-specific taxes and other governmental policies are excluded.

Some analysts have been more explicit about the time factor, using a specific representation of the depletion effect known as the "Hubbert curve". Initially, resources become increasingly less costly to find as the industry realizes significant cost reductions in its expansion in a relatively new region. Ultimately, however, depletion sets in and increases costs. The ultimate recoverable resource base, as estimated either from geologic studies or by statistical curve fitting, enters explicitly into this formulation. This approach can also be adapted to include other key factors, such as oil prices, political factors, and country-specific regulations (e.g., the Texas Railroad Commission's prorationing that limited production in the United States.) In this study, CERI, Penn-BU, WOMS, and BP-America use this general methodology.

The two models employing optimizing behavior (DFI-CEC and ETA-Macro) specify explicit resource cost curves which indicate the amount of oil that can be ultimately recovered at each price level. Thus, resource depletion is explicitly represented in these frameworks through the shape of these curves. While ETA-Macro also imposes some constraints on the rate at which these resources can be found and developed, DFI-CEC assumes that all resources are producible once the market price covers the incremental cost of extracting the barrel.

Cumulative Production and the Resource Base

As indicated by the previous discussion, most models operate with an explicit or implicit resource limit on cumulative oil production. In DFI-CEC and ETA-Macro, an explicit resource cost curve for each region relates the amount of cumulative oil resources that could be profitably recovered at different prices. In CERI, Penn-BU, WOMS, and BP America, oil production declines as total cumulative production in a region approaches an explicit limit representing the total resource base that is ultimately recoverable. Resource constraints are introduced implicitly in OMS and Gately through their reference production series and in IPE through its depletion multiplier. Only HOMS and FRB-Dallas project oil production without any resource base constraints on cumulative production.

In Table 8, the cumulative Non-OPEC production through 2010 is reported for each model in 5 different scenarios. (The two endogenous price cases are discussed more fully in Section 9.) These estimates also include an adjustment for the minimum amount of oil that must be in the ground in 2010 to maintain production in that year. This adjustment equals production in 2010 multiplied by 8---the working group's estimate of the minimum reserves-to-production ratio. This estimate is considered a lower-bound benchmark for post-2010 oil production because it conservatively assumes that production declines each year as one-eighth of the remaining reserves are extracted.

Most estimates of cumulative production appear to lie within the U.S. Geological Service's mode estimate of 400 billion barrels for the total resource base including proved reserves as well as undiscovered resources.[27] This conclusion holds as well for the three models (OMS, Gately, and IPE) that represent the resource base implicitly. The two models lacking any resource base constraint (HOMS and FRB-Dallas) implicitly are operating with a more optimistic resource assessment. Cumulative production in these two models approaches the 400 billion barrels estimate in most scenarios, exceeding that level in HOMS for two scenarios. These levels could be achieved if higher prices, technological advancements in drilling, and more learning about the nature of oil discoveries effectively expanded the total pool of recoverable resources, beyond the levels estimated in current geologic studies.

The U.S. Geological Service's estimates are based upon detailed evaluation of the total resource base by region that includes current reserves as well as undiscovered recoverable resources. The USGS researchers make implicit assumptions about the economic environment by estimating the amount of oil that would be recoverable at current market prices. Resources are not disaggregated by cost, however, thus requiring considerable modeler judgment if these

[27]The USGS world estimates are discussed in Masters et al (1990).

Table 8. Non-OPEC

Implied Minimum Resources*
Including NGLs
(billions of barrels)

	Flat Price	Rising Price	1989 IEO Price	Market Clearing Price
Penn/BU	212	241	241	241
CERI	239	263	255	248
Gately	246	307	288	323
BP America	262	321		
WOMS	263	295	281	295
DFI/CEC	270	343	288	215
OMS	277	304	294	305
FRB Dallas	295	363	335	373
HOMS	340	420	383	446
Average	267	318	296	306

*Production to 2010 plus 8 times the final production rate to approximate minimum final reserves. The IPE results have been excluded. They extend through 2000 and hence are not comparable to the other results for cummulative production.

Estimated remaining 1988 resources including proven reserves given current technology and oil prices: mode of 400 billion bbl, fifth and ninety-fifth percentiles of 351 and 480 billion bbl respectively. Based on individual country resource estimates by Masters et al (1987) combined by assuming lognormality and independence of resource distributions.

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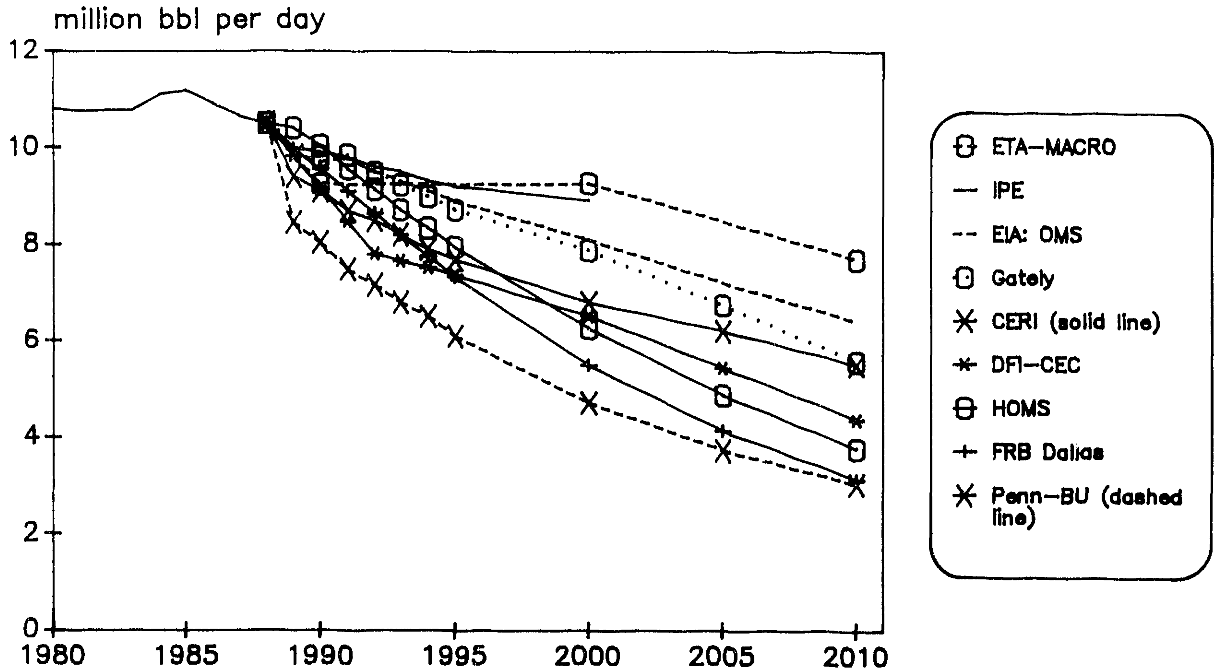
estimates are to be used to conduct market analyses.[28] Dramatic improvements in technology are also excluded in these assessments.

Non-OPEC Supply Trends

The projections in this study, for the most part, depict flat or declining levels of Non-OPEC supply over the next several decades, particularly after 1995. The decline is milder in the presence of the higher prices in the 1989 IEO price case, but it exists. These projected trends contrast with the growth in Non-OPEC oil supplies through 1985 and are more in line with their stable levels in a market environment of lower oil prices since then.

[28] From other sources, detailed cost estimates for different depths and pool sizes are available primarily for the United States; public information about the other producing regions in the world is scarce and often unreliable.

Figure 15. U.S. Production With Flat Price Path



U.S. Supply Trends

Virtually all of this future decline occurs in the United States. All models show U.S. production declining from its 1988 level of 10 MMBD in all scenarios, although at different rates. In the flat price case results depicted in Figure 15, U.S. production ranges from 4 to 9 MMBD in 2000 and from 2 to 8 MMBD in 2010. The highest projection (ETA-Macro) exceeds that of the lowest projection (Penn-BU) by 6 MMBD in 2010. This range, relative to the mean for all models, is comparable to that for total Non-OPEC supply. Apparently, greater knowledge and information about U.S. resources and costs, compared to that for other Non-OPEC regions, does not reduce the uncertainty about future supply conditions for this region.

Comparing across models, pessimism about U.S. supplies is not directly linked with pessimism about total Non-OPEC supply. The U.S. production declines for HOMS and FRB-Dallas are more pronounced after 20 years than for all the other models except Penn-BU. However, these two models revealed higher total Non-OPEC supply in Figure 4 than did the others. These two models share the same approach, in which oil production is related directly to price and time without an explicit link to the oil resource base.

Despite the substantial differences among results, the expected decline in U.S. production is not questioned. The United States is a mature region, where much of the inexpensive oil resources have already been discovered. Producers in the United States must continue to find and develop more costly resources, if they are to maintain current production levels. In the absence of higher prices or shift in government policy, production will decline sharply as resource depletion shifts costs upward. These reductions in oil production will be partially offset by improvements in oil drilling technology that reduce costs.

Supply Trends Outside the United States

The U.S. trends contrast sharply with the other regions outside OPEC and the USSR. Figure 16 compares the changes in production during the 1988-2000 period for the U.S. (top panel) and all other Non-OPEC regions (bottom panel) under the assumptions of both the flat and rising price paths. U.S. production declines from its 1988 level of 10 MMBD regardless of the oil price path. The remaining Non-OPEC production increases from its 1988 level of 16 MMBD when oil prices rise but reveals a more mixed result when prices are flat. Changes in other Non-OPEC production over the 1988-2000 period are generally small, less than 2 MMBD for six of the nine models. Except for HOMS and DFI-CEC, increasing production outside the U.S. does not offset declining U.S. supplies for this period, thus explaining declining total Non-OPEC production.

Other Non-OPEC regions (outside the USSR) are less well explored than the U.S., where many major fields have already been found and explored, and the technology often is sophisticated and expensive. In these less mature areas, the oil industry's expansion is likely to lead to better geologic information and to the adoption of technologic innovations that have been proven elsewhere. Production can be expanded in many of these regions without increasing costs through resource depletion.

Some of these other countries have attractive resources, but institutional and other constraints keep production rates below these levels justified by resource costs alone. Despite favorable oil prices in the 1970s and early 1980s, some resources outside the United States were not exploited rapidly.

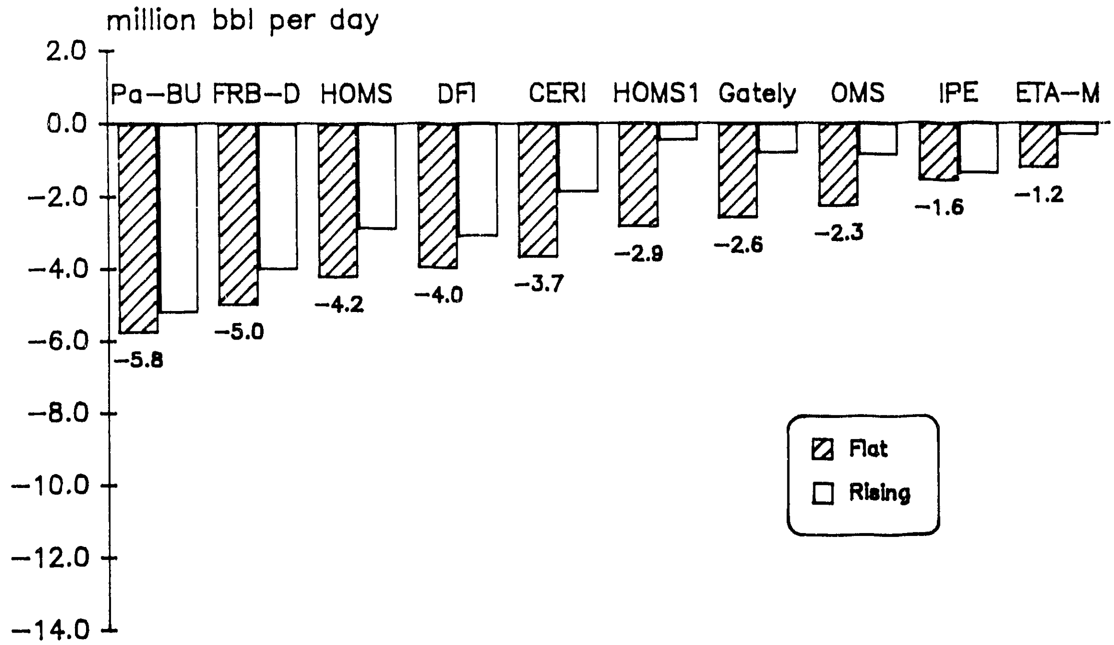
These limits on resource development partly reflect the fact that a rapid increase in oil drilling activity can impose large costs. Rapid expansion requires an expensive infrastructure, which may be an impediment in some regions that are politically risky. Slower expansion may be preferred because it can be sustained by a smaller amount of fixed capital for a longer period.

Institutional constraints also limit rapid resource development. Oil resources in some important producing countries are owned and developed by state oil companies, e.g., PEMEX in Mexico. These companies often have other political objectives that may conflict with economic considerations. Additionally, changes in tax regimes have influenced decisions, by offsetting sudden changes (particularly declines) in oil prices in an effort to stabilize production.

The Influence of Price

This figure also emphasizes the relatively modest effect of higher prices on projected oil production both inside and outside the United States. Declines in U.S. production are more gradual in the rising price than in the flat price case, but the production declines in the two cases usually differ by less than 2 MMBD by 2000 (top panel). Outside the United States, production is also greater with the higher 1989 IEO price path (bottom panel) in all models.

Figure 16. Change in U.S. Production, 1988-2000



... and Change in Other Non−OPEC Production (ex. U.S.)

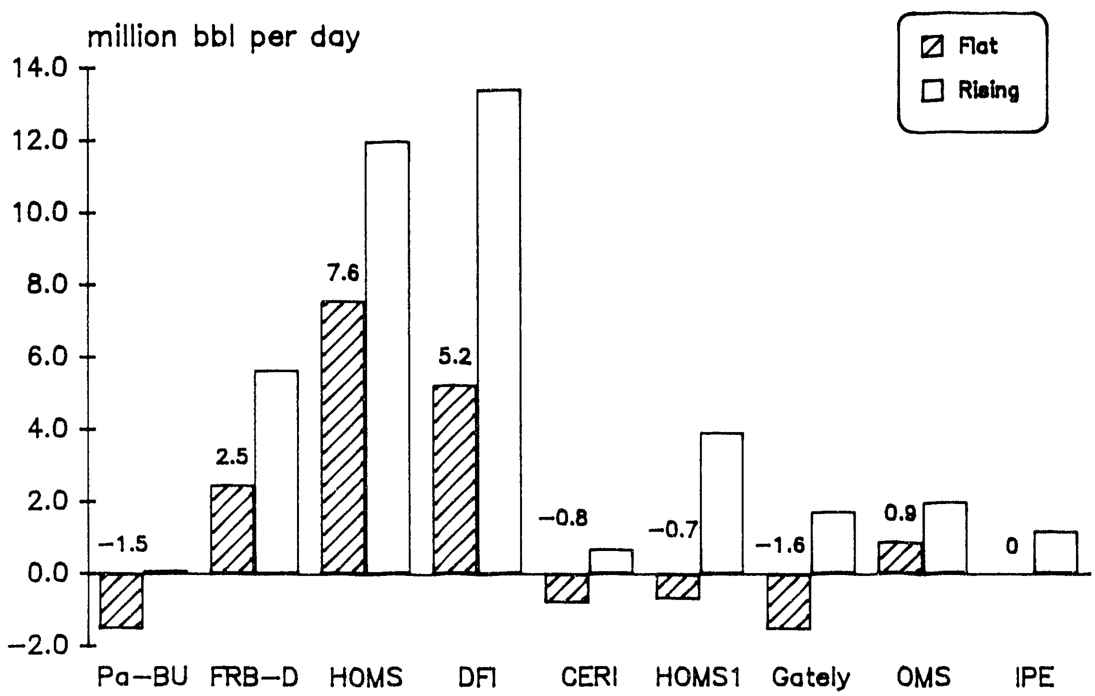
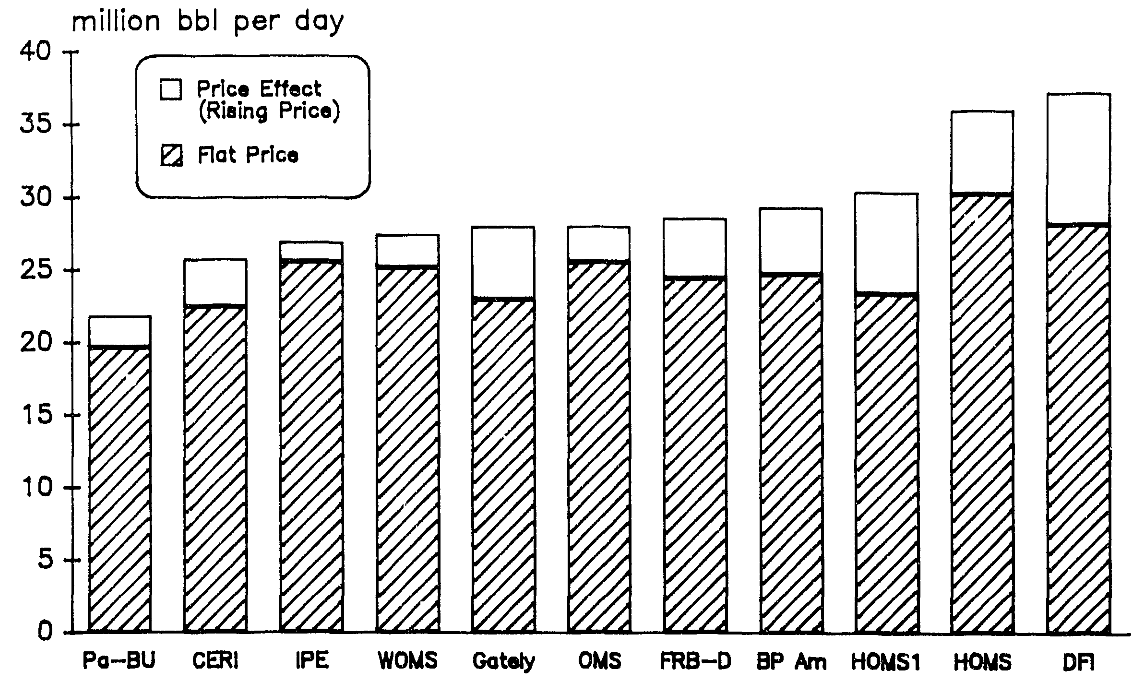


Figure 17. Total Non-OPEC Production, 2000



The relatively modest impact of the 1989 IEO price path on total Non-OPEC oil supplies is shown in Figure 17. Production in 2000 with flat prices is represented by the diagonal bar; the incremental effect of the rising price path on the 2000 production level is shown by the clear bar. Non-OPEC production responds very gradually to higher prices over time. Even after 20 years, production increases by 4% or less in most models for every 10% difference in oil price by 2010.

Despite the lower oil prices of the 1980s, incentives for expanding oil output have remained. Producer costs have proven to be much more flexible than anticipated by many analysts, expanding in tight markets and compressing in slack ones. In an effort to protect market share during slack markets, governments have responded by relaxing their demands for royalty payments and taxes. The markets for drilling equipment and other inputs have similarly been subjected to boom-and-bust cycles. In addition, production has shifted sharply away from the expensive oil in mature resource basins of the United States and towards less expensive basins in other regions.

Prospects for Unconventional Oil Supplies

If oil prices should continue to increase, unconventional supplies of oil would begin to enter the market and could significantly reduce the use of conventional oil in many end-use applications. Such new supplies include tar sands, oil shale, methanol or middle distillates from coal, gas, or wood, and ethanol from corn. While this potential is widely recognized, there exists considerable uncertainty and disagreement about the appropriate price range for making these alternatives economic on a large scale. Some participants thought that large amounts of unconventional oil supplies would be forthcoming before 2010 at prices well under the $39 price in the higher price path. A more prevalent view was that prices would need to be at this level or higher in order to induce the large amounts of substitute supplies that would place a cap on oil prices.

Representative of this latter view are the cost estimates in Table 9 for various technologies for producing unconventional liquid supplies. These estimates were recently prepared by the U.S. National Research Council (1990), which devoted considerable effort to estimating costs across technologies using a consistent set of assumptions. The analysis focuses upon U.S. sources of alternative liquid fuels, although it would be useful to extend the same careful analysis to other sources outside the U.S., e.g., Canadian tar sands. The results indicate that large quantities of tar sands, compressed natural gas, and direct liquefaction of coal can be expected at about $40 per barrel or less (1990$), although some of these technologies have not yet been demonstrated.

Many of these technologies have long lead times before they can produce large supplies of alternative fuels. During the transition, it is possible for oil prices to rise above the crude-oil-equivalent cost figure listed in Table 9 for a number of years. These cost estimates will "cap" oil prices only after production has greatly expanded. On a project basis, companies will realize revenues only after a number of years. Thus, they will invest only if they expect prices to reach these minimum costs and remain there long enough to recoup their investments. In the second column, a target price has been computed for each technology that would be necessary to have the private sector commit large funds to essentially risky projects. These calculations suggest that unconventional supplies would become important sources somewhere in the $40-$50 range.[29]

The National Research Council study focused on liquid supplies from domestic U.S. sources, with natural gas priced at $5/Mcf (1988$). Projects based upon remote foreign supplies of natural gas could be much more competitive if the price of these foreign sources remained lower than $5 over the long term. For each of the four technologies based upon natural gas, an investment trigger price has been calculated for natural gas costs of $1/Mcf and $3/Mcf. Since capital costs may be higher overseas, the trigger prices in Table 10 are shown for the original estimate of capital costs (for the United States), 25% higher capital costs, and 50% higher capital costs. For comparison, the U.S. trigger prices are included in this table as well. The results indicate that under the most favorable conditions (very inexpensive long-term gas supplies and no increased capital costs), compressed natural gas and methanol from natural gas could become available at costs in the lower $20 range. The costs of these two technologies appear to be more sensitive to natural gas prices than capital costs, over the range considered in this table.

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[29]Douglas Robinson prepared these estimates as well as those reported in Table 10. See Appendix B for a discussion of the methodology.

Table 9. U.S. Availability of Alternative Liquid Fuels
Ranked by Investment Trigger Price
(1988$/Bbl)

Technology	Cost*	Investment Trigger Price	Constraints	State of Technology**
Tar Sands, Solvent Extraction	28	29	Supply Limit of 200 M bopd	No Demonstration
Compressed Natural Gas as Auto Fuel	33	38	Some supply limit, demand limit	Commercial
Direct Liquefaction of Coal	38	41	Unlimited supply and demand	No Demonstration
Methanol from Undergrnd. Coal Gasification	44	44	Unlimited supply, lag on demand	No Demonstration
Tar Sands, Pyrolysis	41	45	Supply limit of 200M bopd	No Demonstration
Oil Shale Mining	43	46	Unlimited supply and demand	No Demonstration
Methanol from Natural Gas	45	53	Some supply limit, lag on demand	Commercial
Methanol from Gas from Coal	53	57	Unlimited supply, lag on demand	Demonstrated
Gasoline from Coal by Mobil's MTG	62	66	Unlimited supply and demand	Demonstrated
Midl. Dist. from Nat. Gas By Shell's MDS	58	67	Some supply limit, unlimited demand	No Demonstration
Gasoline from Nat. Gas by Mobil's MTG	60	69	Some supply limit, unlimited demand	Commercial
Ethanol from Corn	66	76	Supply limit	Commercial
Methanol from Wood	73	81	Some supply limit, lag on demand	Demonstrated

*Estimated by National Research Council (1990). That study focused solely upon U.S. sources of alternative liquid fuels. The EMF working group did not attempt to extend coverage of the cost estimates to other world regions, where significant opportunities for replacing conventional oil exist as well.

**Refers to US technology. Some may be more advanced outside the U.S.A.

oil prices are determined by supply and demand conditions rather than being simply assumed. We

Table 10. Investment Trigger Prices for Selected Liquid Fuels Technologies Based Upon Alternative Assumptions for International Natural Gas Prices

(1988$/bbl)

		$1/Mcf			$3/Mcf		
Technology	U.S. Base Case	No Additional Capital Costs	25% Additional Capital Costs	50% Additional Capital Costs	No Additional Capital Costs	25% Additional Capital Costs	50% Additional Capital Costs
Compressed Natural Gas as Auto Fuel	38	23	24	24	32	33	34
Methanol from Natural Gas	53	24	26	28	39	41	43
Midl. Dist. from Natural Gas by Shell's MDS	67	26	29	31	47	50	53
Gasoline from Natural Gas by Mobil's MTG	69	30	34	37	50	54	58

These investment trigger prices do not reflect the higher transportation costs associated with remote natural gas.

VII. OPEC

The study projects a growing call on OPEC production for the several price paths considered. This growth was particularly sharp with a flat $19 oil price. Will OPEC simply meet this call at this price or will it push prices higher? This issue raises the role of prices in balancing supply and demand conditions. To address this concern, we consider several scenarios in which will refer to these cases as "endogenous" price paths rather than the "exogenous" or assumed paths of the previous sections.

This section discusses the OPEC behavior represented in the two endogenous price scenarios in which OPEC members were assumed to set prices as a cartel. After considering alternative perspectives on OPEC's long-run capacity expansion decision and its price-setting behavior, the section reviews the key features of the several endogenous price scenarios examined in the study. Next, the results from a high growth cartel case are studied to show how different assumptions about OPEC's behavior lead to dramatically different results concerning the response of price and OPEC production to more robust economic growth. This section closes with a comparison of OPEC's revenue outlook for several key scenarios as a means to develop further insights into the economic incentives facing OPEC under different conditions.

OPEC's Capacity Decisions

Decisions about expanding OPEC output are critical for understanding future oil market conditions. And yet, considerable uncertainty exists about OPEC behavior. OPEC members have very diverse interests, as was evident in the recent developments leading to the Iraqi invasion of Kuwait. Some members seek higher prices through constrained cartel production, while others want lower prices and increased output. These countries appear to be guided by a blend of political and economic objectives, and this balance differs among members according to their preferred pricing strategy. Their collective behavior oscillates between coordinated strategies for restricting production and competitive rivalry among members. In such an environment, the ability to hold the cartel together is not assured and is likely to fluctuate with changing market conditions. If cooperative behavior should fail completely and competitive pressures prevail, prices would be set by the resource costs[30] in that region, about which there is some uncertainty.

Adding new capacity will be economically profitable for OPEC or a subgroup of its members when the additional revenues exceed the extra costs of augmenting supplies. OPEC's revenues will be determined by the residual demand for its oil, comprised of world demand minus supply from outside member countries. While additional oil production by the cartel will lower oil prices, OPEC producers will raise revenues if OPEC quantities increase faster than prices fall. The more price sensitive are world demand and non-OPEC supply, the more responsive to price changes will be the demand for OPEC oil. In addition, when OPEC's market share is small,

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[30]Included within these costs would be a "user cost", the cost of using oil today rather than holding it for some future period.

modest changes in world consumption and Non-OPEC production will have proportionately larger impacts on OPEC quantities. As with any investment, the economic incentives will also depend upon the timing of revenues and costs and the rate of return on nonpetroleum assets.

OPEC members are likely to consider other factors in their capacity decisions as well. They may be quite uncertain about future oil market conditions and the responses of various segments of the oil market to price changes. The risks of being wrong in their assessment may induce them to choose capacity expansion paths other than one based purely on the economic incentives described above, or they may shift their plans as they gain new information about market conditions.

There may also be a reluctance to produce above a certain level in any year because higher production levels might subject these governments to the criticism that they were giving away a "patrimonial" resource. Alternatively, OPEC countries may have difficulty in absorbing the additional oil revenues from increased exports, i.e., investing the proceeds productively either within their domestic economy or abroad.

For many of these reasons, most world oil models assume a path for OPEC capacity over time, based upon judgmental factors reflecting a combination of political and economic conditions. For these models, the study design recommended a limit on OPEC capacity that rises to 37 MMBD over the next two decades for the scenarios in which market-clearing prices were determined. In Penn-BU, capacity is added if it increases the net present value of the cartel's net income stream.

While determining the precise capacity limits can be difficult, these considerations represent the kind of judgment that must be made in order to project future oil prices. Such judgment need not be so aggregate. Some analysts have resorted to a "bean counting" approach in which a subjective assessment of each producer's objectives and capabilities results in a "target" capacity for each country.[31] The net effect is the same; investment in new capacity is determined separately from the interplay of market forces in these models.

The DFI-CEC, CERI and Gately models do not have explicit capacity constraints. DFI-CEC assumes that new capacity will be added if it is economic. In essence, there is no distinction between adding capacity or increasing output; capacity constraints simply do not operate in this framework. The latter two models assume an OPEC production path, which in the case of Gately, is chosen exogenously on the basis of the cartel's economic incentives.

OPEC Price Setting Behavior

Once capacity is determined, OPEC output in any one year is set by the interaction between demands, Non-OPEC supplies, and OPEC capacity. In any year, a call on OPEC capacity is calculated as the residual between world demands and non-OPEC supplies at the prevailing oil price. Prices play a pivotal role in allocating existing OPEC capacity. When the call on OPEC pushes production above some critical rate of capacity utilization, e.g., 80% of capacity, the

[31]See Feld, Kreil, and Rodekohr (1991) for a discussion of this approach.

models project that oil prices will rise. This relationship, based upon historical experience, explains price movements during the 1970s better than during the 1980s.[32] The higher price reduces the call on OPEC by decreasing consumption and increasing Non-OPEC supplies in the next period. Alternatively, when the call on OPEC falls sufficiently to push capacity utilization below this critical rate, price is reduced, resulting in a greater call on OPEC in subsequent periods.

OPEC sets prices quite differently in the DFI-CEC model. As in the other models, it faces a net oil demand curve comprised of the residual between world demand and non-OPEC supply. Rather than meeting the current call on its production and changing its price (depending upon capacity utilization rates), it will adopt a production path, and with it a pricing strategy, that will maximize the present value of profits over time under the assumption that it has perfect knowledge and certainty about the future. The analysis explicitly considers the tradeoff between producing oil now or waiting until future periods. OPEC producers are assumed to (1) know with certainty what future prices and market conditions will be in all future years and (2) have the capacity to change their production quickly to take advantage of this information. This contrasts with the OPEC behavior in the other analytical frameworks, which view these producers as searching imperfectly for a target price in an environment of considerable uncertainty.

Market-Clearing Price Scenarios

The market-clearing (endogenous) price scenarios are patterned after the fixed (exogenous) price path cases---flat, rising, and 1989 IEO price. The main difference between these two sets of scenarios is how OPEC is represented. In the fixed price paths, OPEC was a residual supplier meeting any excess demand at the given price. In the market-clearing price cases with OPEC as a cartel, modelers allowed OPEC to adjust its price in response to oil market conditions. It should be emphasized that the label "cartel" signifies some degree of market control by OPEC members rather than as a pure monopoly case in all but the DFI-CEC model.

Two scenarios were run with the same OPEC cartel assumptions but with two different world GDP paths--the baseline (used for the 1989 IEO price case) and the high GDP growth paths discussed in Section 3. A comparison of the two cases reveals the sensitivity of oil prices and quantities to higher economic growth under cartel conditions.

A third scenario explores the effect of a competitive market structure, using the same baseline GDP growth rates for each region that were used in the 1989 IEO price case. OPEC members in this case are assumed to be competitive producers who individually do not influence prices with their separate production decisions. The study did not impose any rules or provide guidelines for representing the competitive market structure, leaving it to the individual modeler to implement these conditions in the most appropriate way given the model's structure. Competitive markets are believed to set price equal to the actual resource costs of the incremental (or next) oil barrel. And yet, there is a very large uncertainty about the actual

[32]See Powell, (1990).

resource costs for oil produced in the OPEC region. This situation led to little standardization on OPEC supply conditions in this case and to a very wide range of projected price paths.

OPEC Capacity and Oil Prices

The OPEC capacity constraint in most models significantly influences the long-run price path. When the call on OPEC output pushes production up near its capacity, prices must rise. Since oil consumption and production (outside OPEC) are only modestly sensitive to price over the first few years, prices must rise strongly to remove the pressure on OPEC capacity.

The effect of higher economic growth rates operates in a similar fashion in most models. Limited OPEC capacity forces the higher potential oil demand resulting from additional economic growth to be met mostly by rising prices rather than by increased oil quantities. If instead, cartel producers could anticipate this economic growth and found it profitable to increase production, the response to higher growth would be to expand capacity. Under these conditions, upward pressure on prices would be substantially less.

Both types of responses are observed in the top portion of Figure 18, which compares the percent increase in OPEC production in the high GDP cartel case relative to the production in the cartel case (with base GDP assumptions). All but two models indicate very little movement in OPEC production. The exceptions are DFI-CEC and IPE. The former assumes that OPEC is constrained only by its resource costs and its desire to maximize its profits as a cartel over time. Given the response of supply and demand to price in the model and OPEC's share of production, it is profitable for OPEC to expand production.

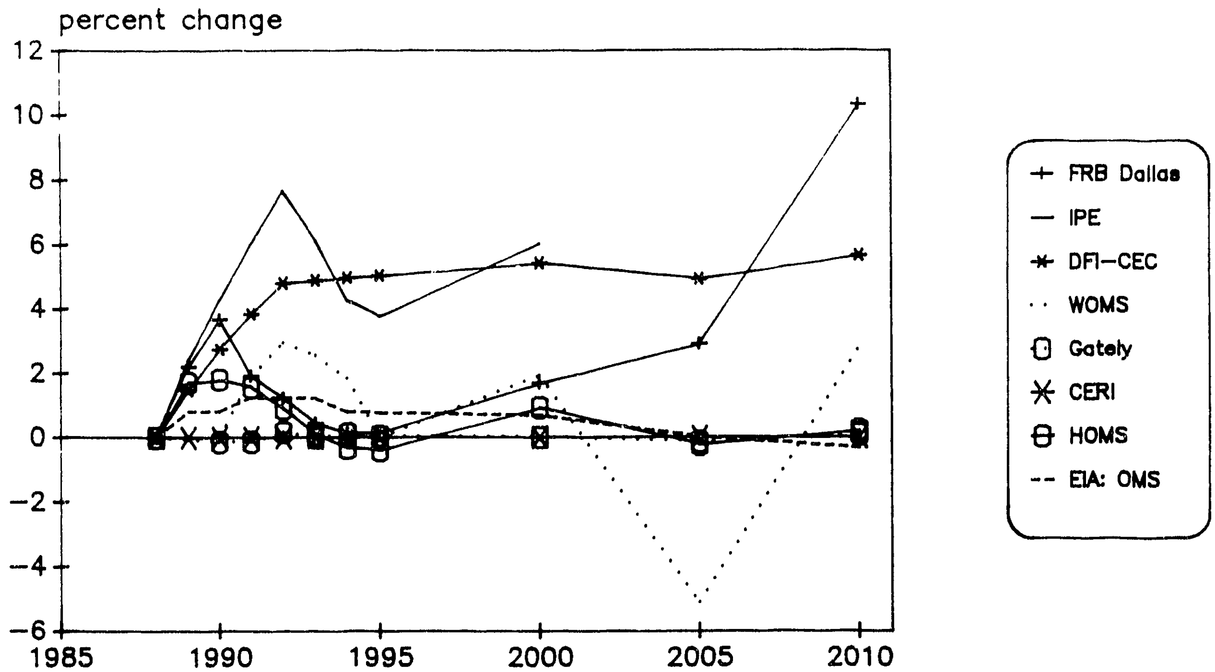
The percent price increases resulting from the higher GDP path are shown in the bottom panel of that same figure. All models except DFI-CEC reveal sharp upward price swings in response to the higher oil demand generated by faster economic growth. The price path for DFI-CEC is relatively invariant to shifts in economic growth because cartel producers can increase oil output at very little incremental cost and are not constrained by capacity considerations. While increases in OPEC production (top panel) are large for IPE, its price also increases sharply (bottom panel). Thus, this model should be categorized with the other models, showing a proportionately larger price than production response.

OPEC Revenues

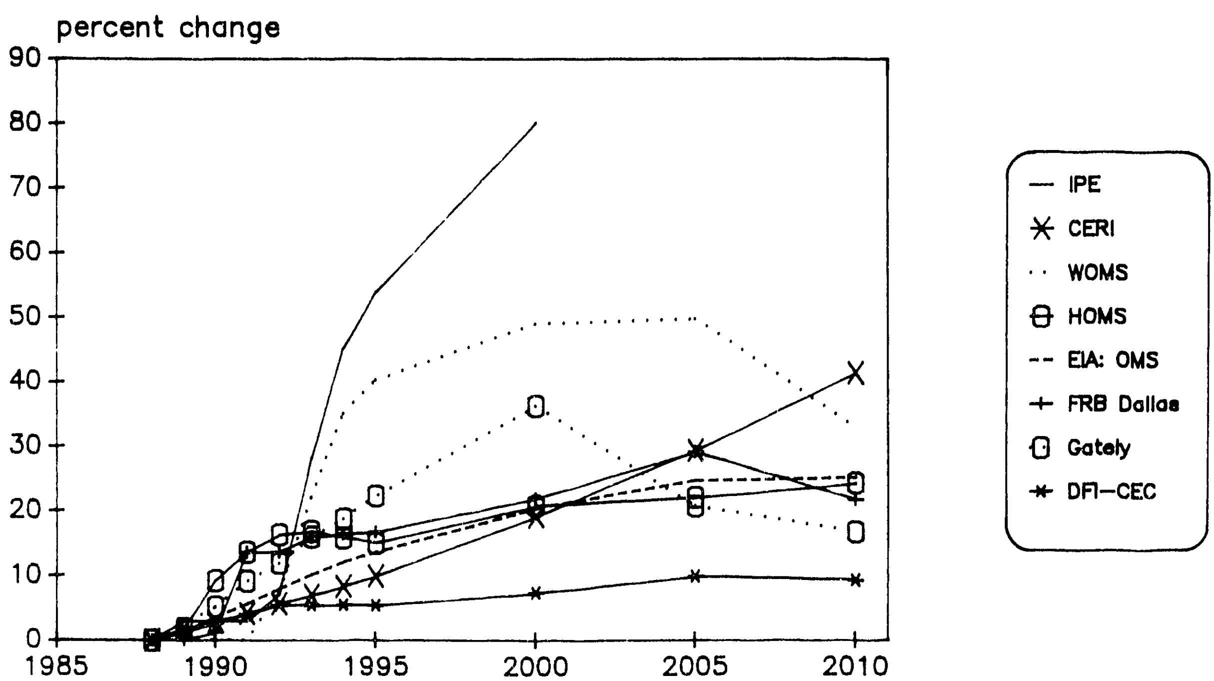
OPEC's decision to invest in capacity expansion will depend partly upon political considerations and partly upon its economic incentives to do so. How are OPEC's economic incentives affected by different pricing strategies? If the revenue streams are similar across a range of price paths, the economic criteria in selecting a pricing strategy will be relatively minor, opening the opportunity for member countries to weigh political objectives more strongly in their oil strategies. If, on the other hand, differences in the revenue stream are large, OPEC members sacrifice considerable economic profits when they fail to exercise control over the market.

Over the price paths considered, the EMF results suggest that there are substantial economic gains for OPEC from higher prices. The price increase more than offsets any reduction

Figure 18. Effect of High Growth on OPEC Production



... and on the Oil Price



in OPEC's production. OPEC net revenues were calculated and discounted to represent net present values for the different scenarios. An after-tax, inflation-adjusted discount rate of 6% was used. In the first three columns of Table 11, OPEC's discounted revenues in the rising price case (reaching $39 by 2000) exceed those in the flat price case ($19 through 2010) by $1 trillion or more in most models. The rising price revenue streams are often 25-45 percent more than their flat price counterparts.[33] The discounted revenues in the 1989 IEO price case are comparable to those in the rising price case. DFI-CEC reports the smallest gain from restricted output and higher prices. As will be discussed in Section 9, this model also projects market-clearing prices lower than most other models when OPEC retains control over the market.

Higher prices in the rising price case reduce the demand for OPEC oil but not by enough to reduce revenues. Estimates of the price sensitivity of the demand for OPEC oil, inferred from a comparison of the rising and flat price scenarios, confirm that quantities fall proportionally less than prices increase in all models except DFI-CEC.[34]

In the last two columns of that same table, the DFI-CEC and FRB-Dallas results show little economic gain from OPEC acting as a cartel compared to its members acting competitively. Both models show stronger demand and supply sensitivity to price than in many other models, causing the net demand for OPEC oil to be responsive to price as well. The Gately and OMS results indicate the largest increase in discounted revenues from cartelization, reflecting the much lower oil prices under competitive conditions, simulated by these models, as will be discussed in Section 9. Lower supply and demand responses to price also contribute to this result.

VIII. GOVERNMENT INTERVENTION BY OIL-IMPORTING NATIONS

Growing oil consumption and constant or declining production outside OPEC increase the dependence on OPEC and especially the Persian Gulf in all scenarios and all models. In 1988, OPEC members supplied 38% of the oil used in the market economies. In the 1989 IEO price case, the median projected share of total supplies to the market economies originating from OPEC members rises to 58% by 2000 and to about 61% by 2010. Within the U.S., imports are expected to rise sharply and the import bill to more than double. Moreover, oil prices will tend to be volatile, and future oil price shocks are quite likely. These conditions are likely to raise considerable concern within major oil-consuming countries and to encourage policymakers to adopt more aggressive strategies for limiting oil use and imports.

This section discusses the effects of policies to limit oil imports through reducing oil consumption or augmenting domestic oil production. It focuses on U.S. oil policy, but many other important oil-consuming countries face similar situations as well. Trends in U.S. oil import levels and the associated import bills are discussed initially. The section then considers three policy

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[33]These estimates exclude the depressing effect of higher prices on GDP but this omission is unlikely to invalidate the results. Most analysts believe that steadily higher oil prices have a relatively mild impact on long-run economic growth. See Hickman et al (1987).

[34]See Appendix C for the individual estimates for each model.

Table 11. Present Value of OPEC Production

1988 to End of Life
(billions of 1990 dollars at 6% real)

	Fixed Price Path			Market-Clearing Price Paths	
	Flat Price	Rising Price	1989 IEO Price	Competitive	Cartel
DFI/CEC	$3,248	$3,753	$4,302	$4,123	$4,280
OMS	$3,905	$5,220	$5,167	$3,617	$5,885
BP America	$3,976				
WOMS	$4,037	$5,396	$5,528	$4,608	$6,037
CERI	$4,092	$5,075	$5,216	$3,861	$4,894
Gately	$4,320	$6,314	$6,088	$2,876	$7,407
Penn/BU	$4,368	$6,258	$6,229	$6,640	$7,783
HOMS	$5,016	$6,663	$6,733		$6,966
FRB Dallas	$5,285	$6,503	$6,559	$6,480	$6,709
Average	$4,250	$5,648	$5,728	$4,601	$5,947

Present values are to mid-1988. IPE and ETA-Macro are excluded.

The IPE model reports production only to 2000.
ETA-Macro includes OPEC in the "Rest of World" region.

Based on estimated remaining 1988 resources of 724 billion bbl. (mode). For years after 2010, the 2010 price was used. The 2010 production rate was used to play-out remaining resources at a constant reserve-to-production ratio.

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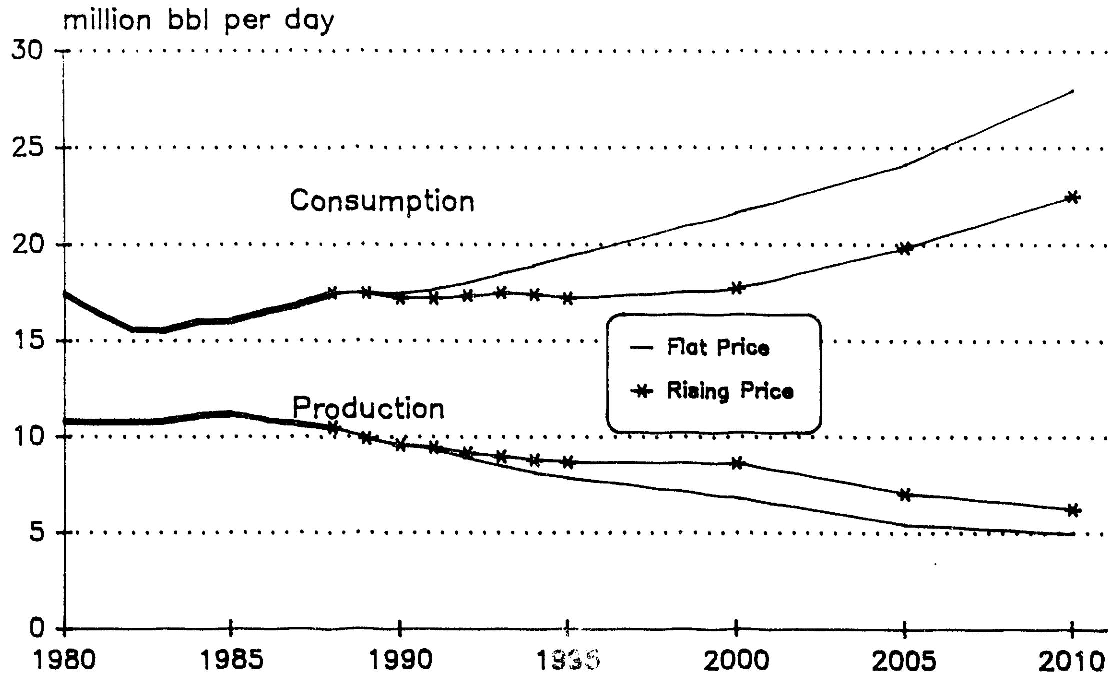
rationales for limiting oil imports--energy security, limiting the cartel's market power, and improving a trade imbalance--before discussing several policy options. The section concludes by briefly considering efforts to reduce oil consumption as part of an overall strategy for improving the environment.

Growing U.S. Imports

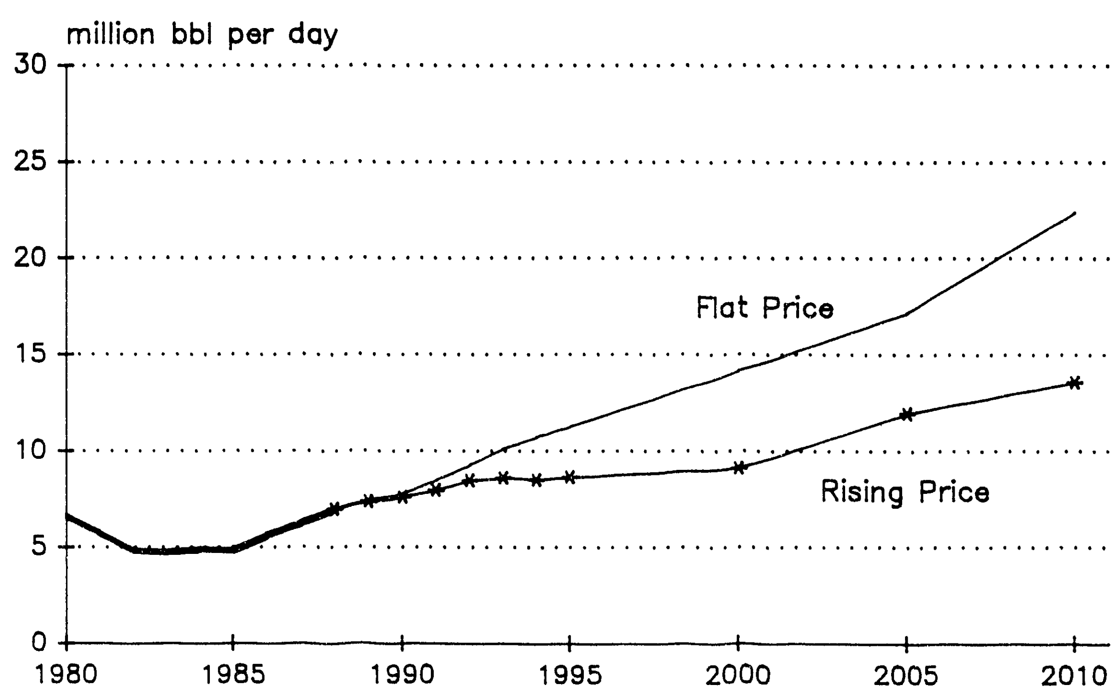
Regardless of oil price path, U.S. oil imports are likely to grow significantly over the next twenty years. The nature of the problem is revealed clearly in the median model results plotted in Figure 19. Even with rising prices, U.S. oil consumption is expected to grow and U.S. domestic production to decline. As a result, U.S. imports increase steadily throughout the period.

By 2000, the price in the 1989 IEO price case is $30 per barrel, or more than 50% higher than in the flat price scenario. And yet, U.S. imports are reduced by only about 2.6 MMBD or 18%. These results underscore the difficulty of achieving significant reductions in oil imports. Large domestic oil price increases, either through market forces or a domestic tariff on imports,

Figure 19. Median U.S. Consumption and Production



and Median U.S. Imports



would be required to significantly alter the outlook for U.S. oil import dependence.[35]

If produced by market forces rather than domestic policies, either of these price paths would lead to substantially higher U.S. oil import bills, which grow from a 1988 level of $37 B to a median level of $120 B (1988$) by 2000 and to $179 B by 2010 in the rising price case (top panel of Figure 20). The flat oil price path would reduce the median oil import bill only modestly, to $93 B by 2000 and to $ 147 B by 2010, because lower prices are offset by higher import volumes.

These trends increase the relative importance of oil imports in the U.S. economy. In recent years, the U.S. oil import bill, as a percentage of real GNP, has fluctuated from 0.3% in 1972 to 2.8% in 1980 in recent years. More recently, it has been about 0.8% in 1988. By 2010, the median import bill rises to 2.1% of total GDP in the rising price case and to 1.7% in the flat price case (bottom panel of Figure 20).

Energy Security

The political risks and instability of supply in the Middle East will remain the principal threat to oil-consuming countries. The increasing dependence of world oil consumers on the Persian Gulf makes shocks more likely and increases the economic consequences of disruptions. The policy toward energy imports should be guided more by these concerns than by the economic consequences of increasing monopoly power among cartel producers or about the effects of a rising oil import bill on the trade deficit.

A nation's dependence upon oil imports does not necessarily constitute an energy security problem. Oil can be easily traded between regions. During a disruption, a country may lose some oil but always has access to other supplies, although at a higher price. All countries will experience the same price shock regardless of the source of its oil. More critical is the percentage of world oil consumption that originates in regions, such as the OPEC member countries located in the Persian Gulf, that historically have been viewed as insecure sources of oil supply. In this study, the Persian Gulf's share of the oil market climbs steadily and strongly in all scenarios. Policy should focus on instruments that reduce the world economies' dependence upon these supplies rather than simply a particular country's dependence on oil imports.

Increased Costs of U.S. Oil Imports

The EMF results indicate rising oil prices over the long run for most models. These higher prices represent a transfer of wealth from U.S. residents to foreign oil producers within the cartel, who control oil prices above competitive levels. Each barrel of imported oil requires more U.S. exports to be sold abroad; less U.S. economic output is available for use by domestic residents.

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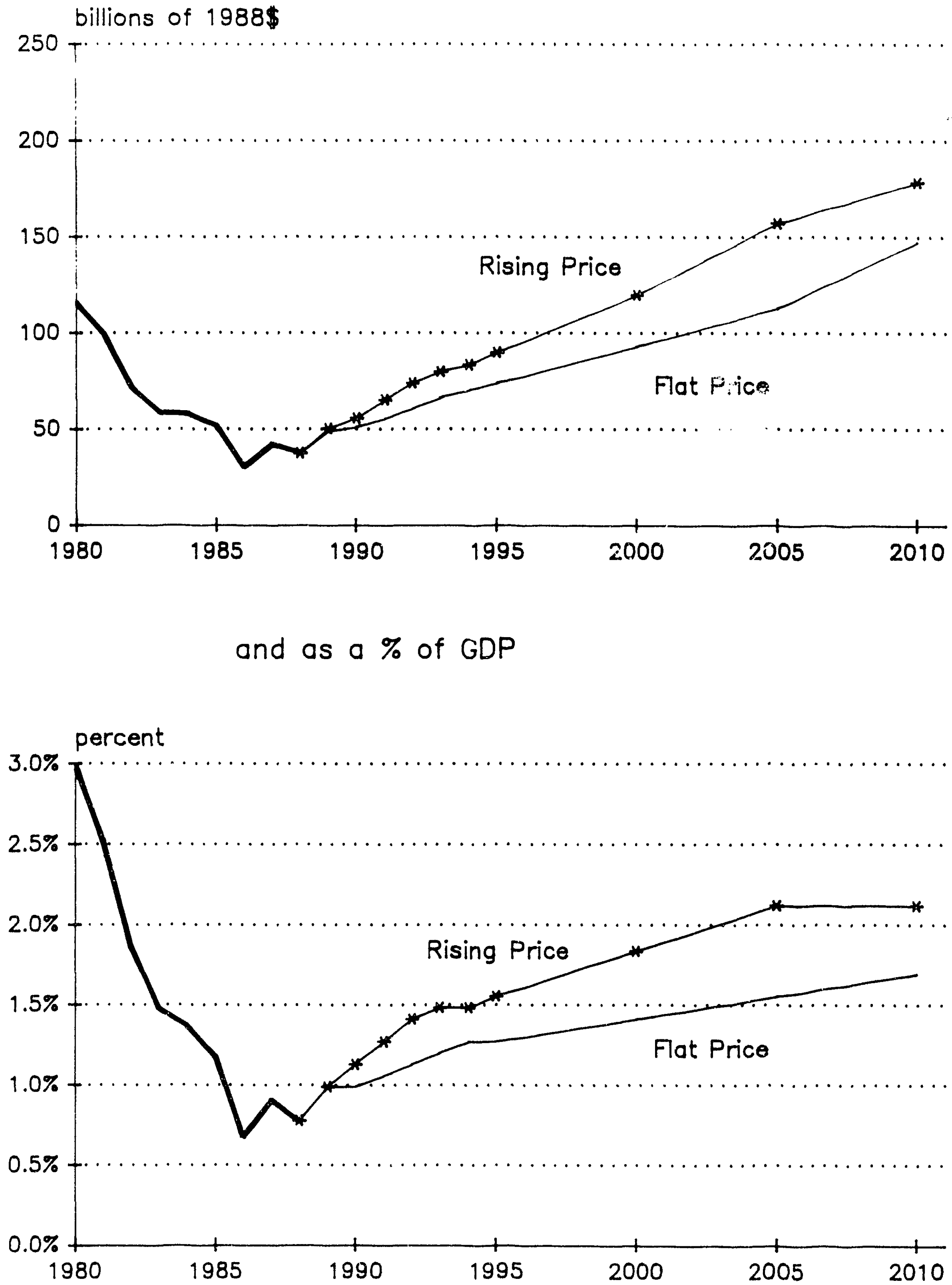
[35]U.S. import-reduction programs are likely to be large enough to reduce the world oil price. In this case, a higher tariff than discussed here would be needed to raise delivered oil prices to the required levels. It should also be noted that mandated reductions in oil consumption through efficiency standards and similar policies would impose costs that could be viewed as an implicit price increase to oil consumers.

Figure 20. Median U.S. Oil Import Bill



This transfer represents a real cost because the nation must produce more goods and services to maintain the same level of aggregate consumption.

A more contentious issue, not addressed by the working group, is whether the United States should adopt policies to reduce these wealth losses. As a large oil consumer, the United States may be able to affect world oil prices by reducing its oil use. As an example, suppose that a 1 MMBD reduction in U.S. oil use lowered world oil prices by $1 per barrel. The dollar savings would be realized over all remaining barrels imported. If U.S. imports fell from 7 MMBD (its 1988 level) to 6 MMBD, the wealth gain for the U.S. would be $6 MM per day ($1 x 6 MMBD). Each barrel saved would reduce the wealth transfer by $6 ($6 MM per day/1 MMBD).

This savings is sometimes referred to as the market power component of the oil import "premium".[36] The existence of a premium justifies going beyond free-market prices in reducing oil imports. A nation should be willing to adopt policies for reducing oil imports, provided that the costs of such strategies were below $6 per barrel, using the above example. The premium does not, however, argue for the use of any particular policy instrument such as a tariff or mandated energy efficiency standards. Other factors must be considered. Tariffs or taxes have the advantage of decentralizing the oil-savings decisions, allowing the higher domestic oil price to allocate the oil-savings to those sectors that can implement such reductions most easily. However, tariffs may be viewed by other countries as protectionist, thereby generating tariffs on other commodi t aded internationally. Implementation may also be a problem if some "friendly" oil-producing countries are exempted from the tariff.

One key issue is whether and by how much oil prices would fall. Cartel oil producers could refuse to accept lower prices, although they would be sacrificing oil income in the immediate period.[37] If they have the flexibility and foresight to consider the returns from future market conditions, however, cartel producers might respond to the lower demand by removing oil from today's market and selling it in more profitable markets in the future. Such shifts in production would tend to increase oil prices in the near term, dampening the effect of demand-reduction policies on oil prices. Moreover, reducing oil imports will affect the full gamut of goods andservices that are traded internationally. The simple example above considers only what happens in the oil market. Reduced wealth for world oil producers will affect their demand for goods and services that could affect the prices of U.S. exports either positively or negatively. If cartel revenues were invested heavily in other countries, for example, oil-reduction policies could reduce the world supply of capital and savings, thus retarding economic growth in countries heavily dependent upon foreign capital.

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[36]The oil import premium has been extensively discussed in the energy economics literature, including the previous Energy Modeling Forum (1981) study on world oil markets.

[37]This statement assumes that cartel producers were maximizing income before the introduction of the policy.

The U.S. Oil Import Bill

Would not this growing oil import dependence worsen the nation's current trade balance? Could U.S. exports of all goods and services grow fast enough to allow rapid oil import growth of this magnitude? Such concerns appear misplaced for the most part.

The imbalance in the nation's current trade accounts reflects an imbalance at the macroeconomic level rather than at the level of any one industry. When a nation's private savings fall short of meeting both private investment and net public borrowing (i.e., the government's deficit), its residents must borrow funds from abroad. Foreign purchases of U.S. assets essentially displace foreign purchases of U.S. goods and services, resulting in exports declining relative to imported goods and services. Reducing oil imports does not necessarily alter this basic imbalance in the nation's savings rate. As a result, such policies are likely to alter the composition of the nation's current trade deficit--fewer oil imports and more nonpetroleum imports--without changing its aggregate level.

For similar reasons, total U.S. exports are unlikely to constrain future oil imports. Rising oil imports will mean either a decline in the non-oil import bill or an increase in the total volume of U.S. exports. Exports may have to grow more rapidly than the U.S. economy as a whole, but should still be able to support the rising oil import bill.

Policies for Limiting Oil Imports

Large oil-importing countries have available a range of policy instruments for reducing oil prices and their exposure to price shocks. Options include oil taxes or import tariffs, mandated efficiency standards on energy equipment, subsidies to domestic oil producers, oil stockpiles, and fiscal and monetary policies for stabilizing the economy. All but the last two involve limiting oil import levels. But how easily can imports be reduced?

It is quite expensive to reduce imports to levels that would substantially alter oil imports and the security of world oil supply. If oil prices followed the flat price path of $19 over the next decade, Table 12 shows that U.S. imports would grow from 7.0 MMBD in 1988 to a range of 9.0-22.9 MMBD in 2000 (the first column), depending upon the model. With the higher prices in the rising price scenario, U.S. oil imports in 2000 would be lower, but would still increase above 1988 levels in all but one model (ETA-Macro). As shown in the second column of this table, they would range from 5.5 to 15.0 MMBD. The last two columns indicate that the higher prices reduce oil imports with proportionately similar impacts on U.S. consumption and production in most models.

Under certain conditions, the results of the rising price path can be viewed as being policy induced. Suppose that in an environment of flat $19 world oil prices through the decade, U.S. policymakers sought to reduce imports through gradual implementation of an oil import fee, reaching $19 per barrel in 2000.[38] If the fee had no effect on the world oil price, the price for

[38]Alternatively, the policy could be a tax on total U.S. oil consumption combined with a subsidy to domestic producers. The two types of policies are analytically similar.

Table 12. US Imports in 2000 with Flat and Rising Oil Price Paths

	US Imports, 2000 (MMBD)			Pct Change in	
	Flat	Rising	Change	Demand	Supply
EIA: OMS	13.2	8.2	-5.0	-17.8%	17.3%
Gately	14.0	10.0	-4.0	-10.1%	22.6%
IPE	9.0	7.8	-1.2	-5.6%	2.2%
ETA-Macro	19.3	5.5	-13.8	-45.3%	9.7%
CERI	14.3	8.0	-6.3	-21.7%	26.5%
HOMS	16.2	11.7	-4.5	-14.2%	21.2%
FRB Dallas	22.9	15.0	-7.9	-24.5%	18.0%
DFI-CEC	13.6	10.5	-3.1	-11.2%	13.3%
HOMS-I	19.7	10.0	-9.7	-26.7%	31.3%
Average	15.8	9.6	-6.2	-19.7%	18.0%

both U.S. producers and consumers would follow the higher prices assumed in the rising price case. The U.S. oil import levels in the rising price case shown in the table would be representative of the levels that would prevail under such a fee.

These estimates underscore that efforts to limit oil imports to current levels or lower would require a large import fee, higher than a gradually imposed levy reaching $19 per barrel by 2000. More rapid implementation of the tariff would reduce dependence upon the cartel, but may hurt short-run economic growth more. Moreover, if the fee should cause the world oil price to fall, the U.S. price would be lower because it equals the world price plus the fee. As a result, dependence upon OPEC would be higher than those reported for the rising price case, and the fee would provide less protection to the economy during a disruption. Of course, lower world oil prices would provide direct economic benefits for the U.S. under stable oil market conditions. For this reason, policymakers face a dilemma. Oil imports and dependence upon insecure supplies will increase, but efforts to limit oil imports will be difficult and costly. This situation raises the importance of policy options that increase the economy's ability to adapt to price shocks.

If oil stockpiles have been built over the years and made available during a disruption, the release of oil can damp the spike in oil prices. The effectiveness of stockpile releases in reducing economic losses depends upon the response of oil supplies and demands to price, which have been analyzed in this study. The value of stockpiles lies in their capacity to reduce sharply price shocks for all countries during a disruption, not in their replacing physical barrels of oil in any particular country releasing the stockpile.

Government fiscal (spending and tax) and monetary policies are also important for stabilizing the economy during a disruption. Many macroeconomic stabilization policies, however, are effective at offsetting either losses in output or inflation; few politically acceptable policies are appropriate for fighting the twin damages of oil disruptions--lost economic output and higher prices for goods and services. This dilemma has prevented major oil-consuming countries from relying extensively upon such policies during previous oil shocks.

Environmental Policies

Many countries are considering environmental policies that would impose strict controls on future energy use. In an effort to improve air quality, many countries are considering aggressive policies to switch the vehicle fleet from oil to compressed natural gas, methanol, and other alternatives. If successful, such policies could reduce the future demand for oil significantly. Global concerns about greenhouse gases are also likely to influence the fuel mix, although the implications for oil are unclear. While oil's carbon content is less than coal's, it is greater than that of natural gas.

Although the study did not address these issues, it does provide a framework for understanding basic factors influencing oil supply and demand that should be useful for future studies of these problems. The issue of autonomous efficiency improvements and the link between energy use, price, and economic growth--issues discussed at length with respect to the oil market in this report--will be critical to resolving the question of how future environmental policy will affect the energy sector and the economy. Based partially upon the findings of this study, a new EMF working group (EMF 12) currently is addressing the economic and energy sector impacts of policies for reducing greenhouse gas emissions.

Any policies that reduce oil demand will tend to depress the before-tax price of oil. Some of the factors already discussed, including oil producers' willingness to absorb price reductions, will determine the extent to which this price would fall. In addition, the degree of coordination among countries will be a significant influence. If, for example, only the developed market economies impose a tax on oil for environmental reasons, the delivered price of oil for the developing countries would fall. While taxes would discourage oil consumption in the developed countries, the lower oil price (untaxed) in the developing countries would increase oil consumption. The efficacy of the tax for reducing global emissions diminishes as more countries are excluded from the policy and as the emissions standards in the excluded countries are more lax.

IX. IMPLICATIONS FOR WORLD OIL PRICES

Despite a range of projected supply and demand conditions, there is a consensus in the study that a $19 price path is unsustainably low in the long-run. Demand growth at current prices would outpace supply expansion, placing upward pressure on prices over the long run. While there is no "iron law" that oil prices must rise, the set of conditions needed for oil prices to remain at $19 on a sustained basis over the next two decades, discussed in Section 3, appear less likely than those producing higher prices. Nevertheless, within the projections done for this study, several very different oil futures have been offered. While the study expects future prices to rise, there are considerable differences among models and scenarios in the rate of increase.

This section explains the differences in projected oil price paths when the price in each model is allowed to change in response to market conditions.[39] After explaining how supply and demand interactions lead to price movements, the discussion focuses initially upon the range of prices in the market-clearing price case. Next, the effect of assuming competitive OPEC producers is analyzed, and the resulting range of price projections is discussed. Finally, the conditions leading to an increased likelihood of either low or high prices are summarized.

The Implications of Market-Clearing Prices

The fixed price path scenarios were useful for examining how oil consumption and production in the different models responded to the same assumptions about the oil price and GDP paths. The market-clearing price scenarios analyzed in this section allow the oil price to change in response to differences in supply and demand conditions. While it is more difficult to explain differences in model responses under these conditions, the results from these new scenarios provide a more comprehensive account of how the various models represent world oil markets.

The different responses of oil production and consumption to alternative oil price paths remain relevant for explaining differences in the results from the new scenarios. But now, differences in the underlying supply and demand conditions also contribute importantly to the different price paths. For example, when demand conditions lead to relatively high oil consumption over a range of prices, there will be greater upward pressure on the market-clearing price. The higher price will encourage additional oil production and reduce oil consumption until a new supply-demand balance is achieved. The responses of supply and demand to changes in price will help govern the extent to which prices need to rise. The lower the price responsiveness of supply and demand, the greater the price increase needed to clear the market.

These interactions make it difficult to probe the market-clearing price scenarios by examining these cases alone. As a result, we adopt a two-step approach. Initially the supply and demand conditions are compared across models but with the same oil price path, e.g., the 1989 IEO price scenario. This initial step allows a more meaningful comparison of the results obtained from the market-clearing price case, where oil prices are responding to different market conditions in the manner described above.

Prices in the Market-Clearing Price Case

Two "camps" were identified in the oil price projections for the market-clearing price case shown in Figure 7 of Section 2. Prices are lowest in the DFI-CEC and CERI results, moving to only $15-$20 per barrel by 2000 and to $20-$25 per barrel by 2010. Prices in the other models rise much more sharply, clustering in the $25-$35 range by 2000 and in the $40-$55 range by 2010.

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[39]Appendix D briefly considers the problems with forecasting oil market conditions during the 1980s.

Table 13. 2010 Oil Price (1990$/B): Market-Clearing Price Case

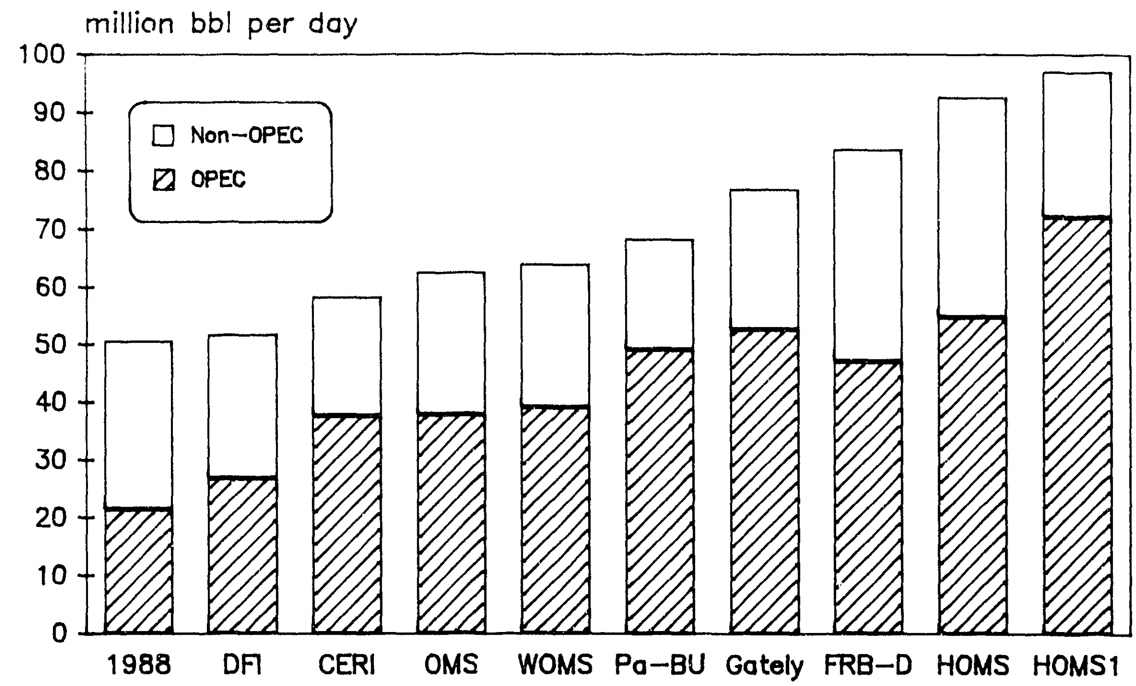
OPEC PRODUCTION IN MARKETING-CLEARING CASE	WORLD DEMAND GROWTH IN 1989 IEO PRICE CASE	
	> 1.2% p.a.	< 1.2% p.a.
< 35 MMBD	HOMS $56 FRB-Dallas $48	EIA:OMS $58 WOMS $50
> 35 MBD	Penn-BU $70 Gately $61	CERI $32 DFI-CEC $28

Note: Oil prices are influenced by factors other than world demand growth and OPEC production. See text.

The low-price "camp" is characterized by both lower world demands and higher OPEC production than in the other models. Table 13 summarizes these results by categorizing the models by world oil demand growth and OPEC production. The two rows differentiate models by the maximum OPEC production level in any year (below or above 35 MMBD). The two columns differentiate models by the growth rate in world oil demand (above or below 1.2% p.a.) when all models use the same 1989 IEO price path. Each model is shown with its price in 2010. The two representatives of the low-price "camp"--CERI and DFI-CEC--appear in the lower, right-hand box, where both OPEC production exceeds 35 MMBD and demand grows slower than 1.2% p.a. Because other factors will also influence oil prices, one should not attribute differences in oil prices between boxes in Table 13 as being due to world oil demand growth and OPEC production alone.

This conclusion can also be seen by decomposing world oil production into OPEC and Non-OPEC sources, first for the 1989 IEO price case with its pre-determined price path, and then forthe market-clearing price case. Figure 21 shows OPEC and Non-OPEC production for each model in the 1989 IEO price case. World demand for each model is represented by the height of the two stacked bars together. The models have been ordered by world demand, from highest to lowest, moving from left to right. HOMS1 has the highest demand as well as call on OPEC production. HOMS and FRB-Dallas combine relatively high demands with relatively optimistic

Figure 21. OPEC and Non-OPEC Production in 2010 With 1989 IEO Price Path

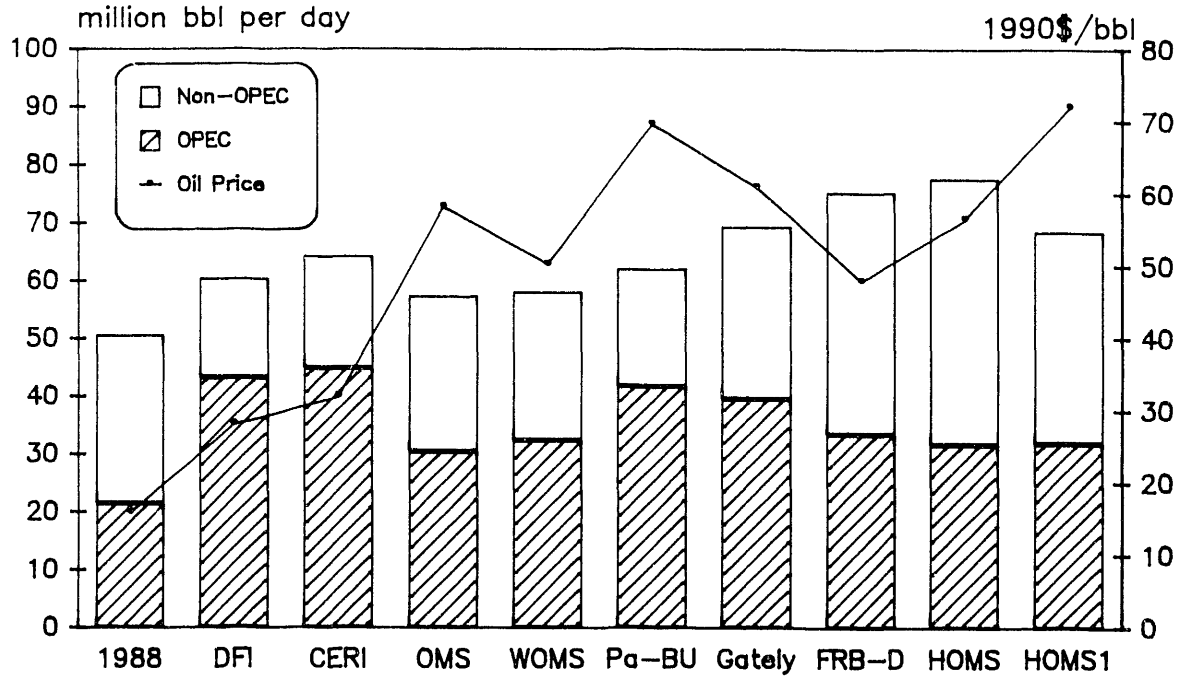


outlooks for Non-OPEC supply. DFI-CEC and CERI have the smallest demands as well as some of the smaller calls on OPEC production. Note that world consumption and Non-OPEC production estimates in this figure have been standardized on price, the 1989 IEO price path.

Next consider the same kind of figure for the market-clearing price case (shown in Figure 22), where each model now determines a different price in 2010 indicated by the line in the figure. The big change between the two scenarios occurs with the CERI and DFI-CEC results. Whereas most models show less OPEC production in the market-clearing price case than in the 1989 IEO price case, these two models show more OPEC output, indicating that the predetermined price path in the 1989 IEO price case was too high. OPEC members in this case are willing to sell more than is the call on OPEC in the 1989 IEO price case. OPEC sales expand sharply as they accept prices lower than the 1989 IEO price path. At the same time, the quantity of world oil consumed in the cartel case remains lower than in many models, despite the fact that oil prices are lower in the two models. (Recall that their demands, standardized by price, were the lowest of all the models; the models are ordered as they were in Figure 21.)

Models that show either a low world demand or high OPEC production, but not both, do not project low prices. OPEC production in Gately's market-clearing price case (Figure 22) is roughly comparable to the CERI and DFI-CEC results. Its price is some $25 higher, however, because it has higher oil demands (Figure 21) when all models use the same 1989 IEO price path. Likewise, world demands in OMS and WOMS are not much different than in the two low-price

Figure 22. OPEC and Non-OPEC Production and Oil Price in 2010
With Market-Clearing Cartel Conditions



models when all models use the same 1989 IEO price path, but the corresponding OPEC productions in the market-clearing price case are substantially smaller for these two models.

Reasons for lower demand conditions were extensively discussed in Sections 4 and 5 and include a lower demand response to GDP, continued autonomous efficiency improvements in oil use, and the absence of a lagged effect of past oil price changes (just prior to 1989) on oil demand. Differences in OPEC production were examined in Section 7. CERI and DFI-CEC are two of the three models revealing that OPEC members gained little or no additional discounted net revenue from higher oil prices. With relatively low OPEC markets shares, world demand and Non-OPEC supply sensitivity to price cause OPEC revenues to be relatively unchanged when prices increase.

In addition to world demands and OPEC production, several other factors influence the range of prices for the models shown in Figure 22. While HOMS and FRB-Dallas have some of the highest demands, their 2010 prices, $52 and $44, respectively, are lower than in the Gately model. This result is due to their relatively more optimistic outlooks on Non-OPEC supply (Figure 17). The Gately model produces a higher price ($56) than either of these two models partly because Non-OPEC supplies are less. A contributing factor is its substantially smaller demand response to price, which requires larger price increases to balance supply and demand in the market-clearing price case.

OPEC as Competitive Producers

Most world oil models are structured in a way that view OPEC as an imperfect competitor that can set prices on the basis of tightness in the oil market rather than simply taking the prevailing market price path as given. This approach is not suitable for examining oil markets when OPEC members act competitively. Under these conditions, prices will be driven down towards OPEC's resource cost, about which there is some uncertainty. Thus, when the working group specified a competition case, it was well recognized that the modelers were being asked to run a scenario that is not often analyzed. While the results must be evaluated very carefully for this reason, the additional scenario proved to be useful for thinking about how markets might change under such conditions.

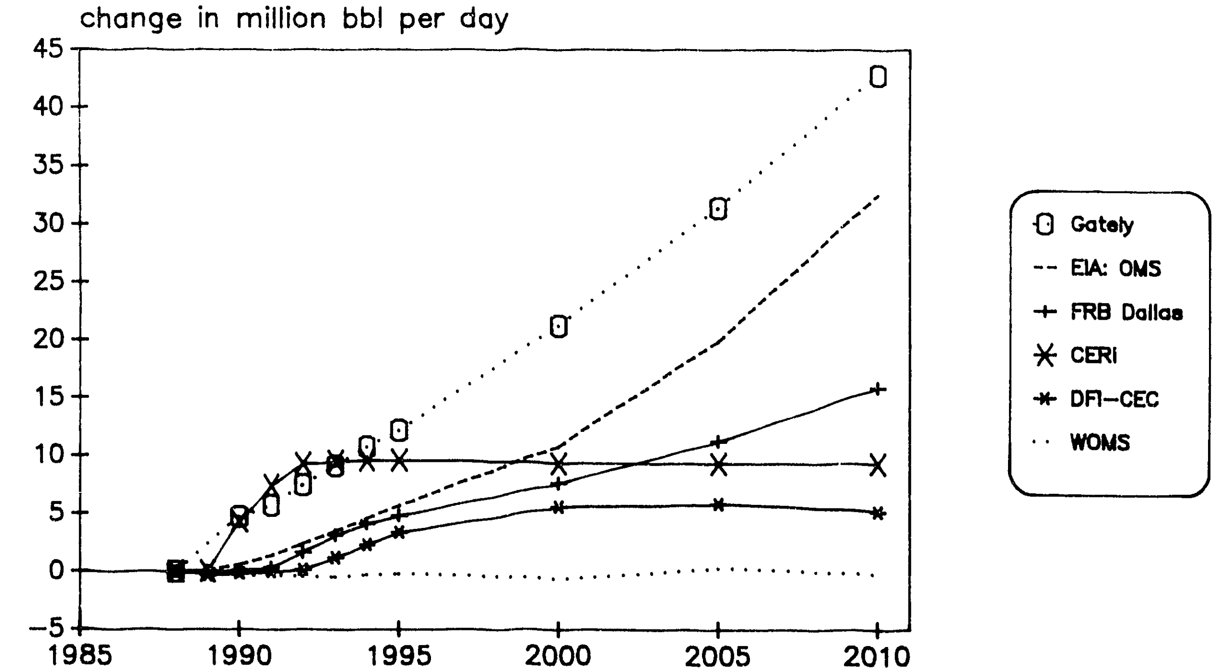
While oil prices were consistently below their cartel levels, the results ranged considerably across models. As might be expected, the differences in oil price paths often reflected the alternative ways in which competitive conditions were represented. For this reason, it is more appropriate to consider these two cases as indicating alternative views on the extent of control exerted by OPEC rather than as two extreme states of the world--pure monopoly and perfect competition.

In WOMS and FRB-Dallas, competition was simulated simply by allowing OPEC to produce much closer to its capacity before the market experienced rising prices. The same fixed path of OPEC capacity was used in the market-clearing price case assuming cartel conditions (hereafter, referred to as the cartel case in this section). This path was invariant to changing market conditions. These assumptions appear to represent limited competition because capacity itself is still being constrained. As a result, except for FRB-Dallas in the later years, OPEC production does not change very much between the competitive and cartel conditions, as confirmed by the change in OPEC output (in MMBD) shown in Figure 23's top panel.

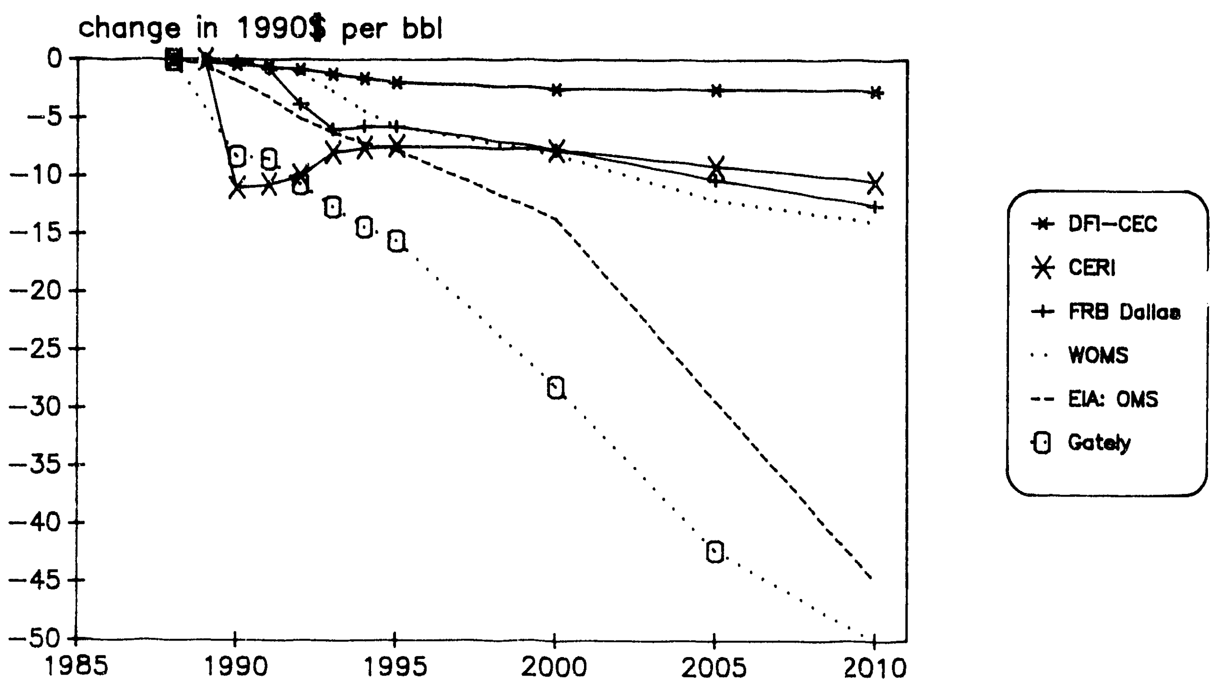
The OMS and Gately models adopted a very different approach by removing OPEC capacity constraints altogether. Assumptions about the long-run incremental cost of additional oil production in the Middle East were substituted for the pre-determined OPEC capacity constraints used in the market-clearing price case under cartel conditions. While there is great uncertainty about this assumption, the results are indicative of the dramatic effect of competitive conditions in the oil market. Competitive prices in these models fluctuated between $12 to $15 in OMS and were assumed fixed at $10 through 2010 in the Gately model. The removal of OPEC capacity constraints produced much higher OPEC production than in the other models, reaching about twice its level in the cartel case.

CERI uses a fixed path for production rather than capacity. In the competitive case, they assumed a higher trajectory of OPEC production based upon judgmental factors. Relative to the cartel case, OPEC production increased by the same proportional amount as in the Gately model in the early years (top panel of Figure 23). While the production increase in later years was considerably less than Gately's, it remained generally higher than those for the first set of models.

Figure 23. Effect of Competition on OPEC Production



... and on the Oil Price



The OPEC production path for DFI-CEC results from changing OPEC's rule of reaching its objective of maximizing profits. In the cartel case, prices are set to maximize discounted profits given that OPEC can influence price through its production decisions. In the competition case, profits are maximized by assuming that prices are not influenced by OPEC's decisions but instead are determined by the balancing of aggregate oil resource supply and demand conditions. The very modest change in OPEC production that results from this change (the top panel of Figure 23) emphasizes that OPEC has very little market power under the conditions simulated by DFI-CEC for the cartel case discussed previously. If OPEC were to raise prices higher than in the cartel case, it would lose revenues because of the combined effect of reduced world oil consumption and increased oil output by other producers.

Competitive Oil Prices

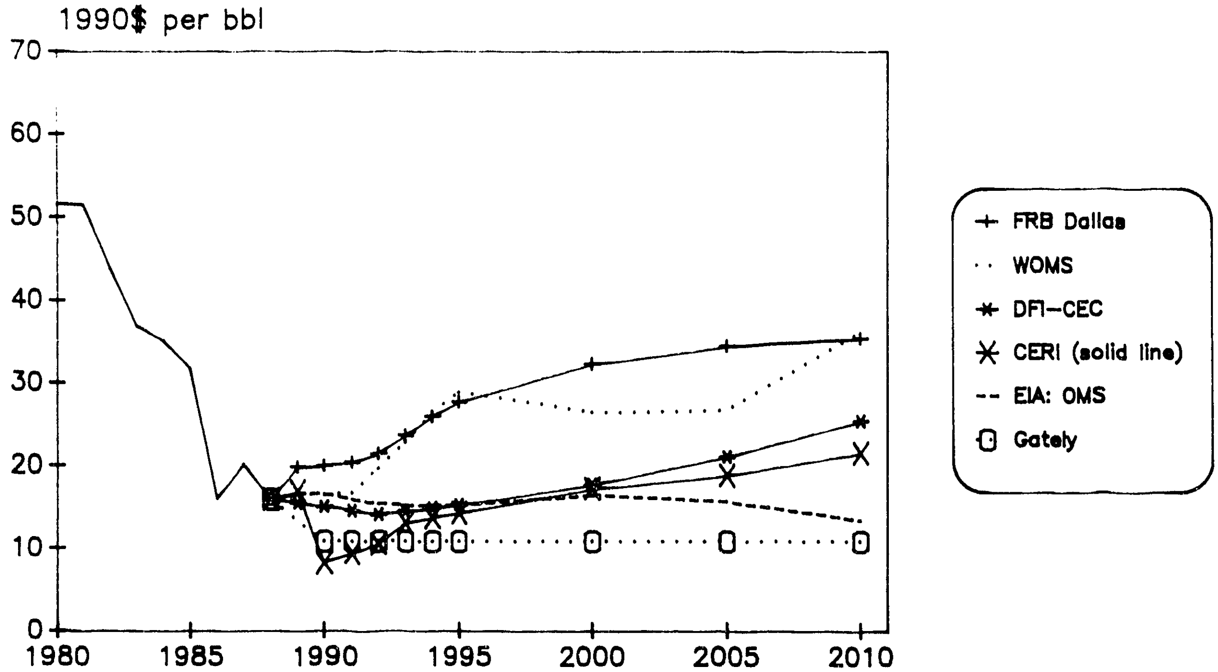
As a result of these changes, oil prices in the competitive case (the bottom panel of Figure 23) are about $5 lower than their cartel levels in DFI-CEC and $10 lower in all others except Gately and OMS. The large price decreases observed for Gately and OMS indicate that OPEC's resource costs of producing more oil are relatively low while its market power is considerable. This view contrasts sharply with the DFI-CEC simulations, which suggest higher economic costs associated with OPEC production (setting prices under competitive conditions) but noticeably less monopoly power.

The oil price paths resulting from the competitive case (Figure 24) cover a rather wide range. Gately and OMS portray flat or declining prices over the next two decades. The two models in the low-price camp in the cartel case (Figure 7)--CERI and DFI-CEC--report in the $15 range in 2000 and in the $20 range in 2010, compared to $20 and $25, respectively, for the same two years in the cartel case. Competitive case prices rise to the $25-$30 range between 2000 and 2010 for the remaining models and are only marginally lower than their cartel levels in 2000 ($30-$35), although the gap between the two cases widens by 2010 ($30 compared to cartel prices ranging from $40-$55).

Conditions for a Low (or High) Oil Price World

In summary, let us characterize the low-price world by what has been learned about supplies, demands, and their interaction. The world economies grow modestly, not exceeding their recent historical rate of about 3% per year. Furthermore, oil demand grows noticeably slower than GDP, even without any further increases in oil prices. The continued decline in oil intensity may be due to a combination of technological progress, accelerated interfuel substitution towards other fuels like natural gas, and continued shifting in economic structure away from energy-intensive goods and services. In addition, OPEC demonstrates a willingness to expand production well beyond the 37 MMBD capacity constraint found in many official forecasts, such as the Energy Information Administration's *International Energy Outlook*. In the absence of a competitive market, this expansion requires that OPEC can increase its cartel profits by selling

Figure 24. Market-Clearing Prices With Competition



more oil and that it is not constrained by internal pressures to save its "patrimonial" resources for future generations.

While these conditions are the most critical ones for a low price world in this study, a set of contributing factors can also be identified. Despite declining U.S. production, total production outside OPEC does not fall, even without further price increases. Technological advances in oil exploration, development, and production offset any cost increases due to resource depletion. Furthermore, if prices do rise, e.g., due to higher economic growth, supply is modestly responsive, thus requiring a smaller price increase to restore the supply-demand balance. Likewise, there are widespread opportunities to substitute other fuels, labor, and capital for oil use in the event of oil prices increases. And finally, oil-importing countries implement policies that restrict oil use, either through direct taxation or mandated efficiency standards.

A high-price world would be more likely under the opposite conditions. For example, it might develop from a combination of more rapid economic growth, less autonomous oil efficiency improvement, and a reluctance by OPEC to expand output much beyond the 35-40 MMBD range. Such a world would also be more likely if non-OPEC supply and world demand over the long run were significantly less responsive to increases in price than they had been to price increases of the 1970s.

APPENDIX A

Methodology for Decomposing Demand Growth

The four scenarios specified oil price and GDP paths that were to be used by all models. The cases included: (1) the 1989 IEO price case (with the baseline GDP path); (2) the flat price case (with baseline GDP); (3) the flat oil price path with no economic growth after 1988; and (4) the flat oil price path with no economic growth and no technical change unrelated to oil price changes. The price effect was measured as the change in oil consumption between the first two cases; the income effect was measured as the change in oil consumption between the second and third cases; and the autonomous efficiency improvement effect was measured as the difference between the third and fourth cases. The initial momentum effect was measured as the change in oil consumption between 1988 and 2000 in the fourth scenario. Algebraically, the growth in demand in the 1989 IEO price case equals the sum of these components:

$$
\begin{aligned}
D(t,IEO) - D(1988) = {} & D(t,IEO) - D(t,Flat) \\
& + D(t,Flat) - D(t,\Delta Y=0) \\
& + D(t,\Delta Y=0) - D(t,\Delta Y=\Delta T=0) \\
& + D(t,\Delta Y=\Delta T=0) - D(1988)
\end{aligned}
$$

where D is oil demand, t is year (e.g., 2000), and IEO, Flat, $\Delta Y=0$, and $\Delta Y=\Delta T=0$ refer to the four cases. The four right-hand terms are the price, GDP, autonomous efficiency improvement, and momentum effects, respectively. The sum of the last three effects equals the demand growth in the flat price case. BP America's price effect may be overstated slightly because it is for the rising price case rather than the 1989 IEO price case, which was not simulated for this model. Demands for DFI-CEC have not been decomposed, because they are the OMS projections by assumption. Penn-BU did not separate OECD demand from world demand.

APPENDIX B

Methodology for Estimating Trigger Prices for Unconventional Oil Technologies

By

Douglas R. Robinson

This appendix summarizes information about the cost and availability of synthetic liquids from U.S. sources. Table 9 in the text presents the costs, investment trigger prices, constraints on resource supply and demand, and states of development for each technology. The primary source of information for this summary is a National Research Council study (1990) on alternative liquid fuels.

The Council's cost estimates presented here were prepared using a 10% real discount rate. The estimates of production volumes are based on constraints on process inputs and consumption of outputs. The state of the technology is classified as commercial, demonstrated, or no demonstration as described by the Council's study.

The investment trigger price is an estimate of the oil price which will prompt investment in capacity for a particular technology. The basic idea behind the trigger price is the existence of a required minimum price for building synthetic fuel plants under considerable uncertainty. In general, there would be no capacity installed for a new synthetic fuel technology until the price of oil significantly exceeds the cost of production.

The analysis is based on an analysis by Pindyck (1991) that introduces a method for valuing and deciding when to start a project that can later be shut-down if revenues are too low. Intuitively, the method incorporates a balancing of the potential loss if investment is made too soon (and oil prices fall) with the loss of present value if the project is delayed too long.

The underlying assumptions of the analysis include a fixed capital investment (I) to be followed by per barrel operating costs (c) once production begins. The revenues from the sale of synthetic fuel will depend on the price of oil. Future oil prices are assumed to be distributed log normally with the current oil price as its mean and a standard deviation of 20% per year. The discount rate for petroleum cashflows is assumed to be 3.5% higher than the expected rate of future price increase; this differential is denoted by δ. The risk-free interest rate (r) is assumed to be 3% real per year.

The following formulas determine the price at which investment should be made (P*). P* is the solution to:

$$\frac{A(\beta_1-\beta_2)}{\beta_1}(P*)^{\beta_2} + \frac{(\beta_1-1)}{\delta\beta_1}P* - \frac{c}{r} - I = 0$$

where

$$A = \frac{r - \beta_1(r - \delta)}{r\delta(\beta_1 - \beta_2)} c\,(1-\beta_2)$$

$$\beta_1 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{[\frac{r-\delta}{\sigma^2} - \frac{1}{2}]^2 + \frac{2r}{\sigma^2}}$$

$$\beta_2 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} - \sqrt{[\frac{r-\delta}{\sigma^2} - \frac{1}{2}]^2 + \frac{2r}{\sigma^2}}$$

This derivation of this formula is included in the paper by Pindyck.

The relationship between total cost and the trigger price depends on the relative share of capital and operating costs in the total cost. The trigger price is also affected by the correlation between the operating cost and the price of oil.

These same formulas were used to prepare the sensitivity analysis of the costs of selected gas-based technologies to alternative assumptions about natural gas prices and capital costs that appear in Table 10 in the text.

APPENDIX C

Inferred Price Elasticities of the Call on OPEC

Table C-1 reports estimates of the price elasticity of the demand for OPEC oil, inferred from a comparison of the rising and flat price scenarios using the same approach described in Huntington (1991). These elasticities are the ratio of the percentage decline in quantity and the percentage increase in price between the two scenarios for the same year. They are an increasing function of the price elasticities of market economies demand and Non-OPEC supply and a decreasing function of OPEC's share of the market.

Except for DFI-CEC, the price elasticities are uniformly below unity, implying that there are revenue gains from restricting output below the levels that would be produced with flat oil prices. The elasticities do not often increase much over time, despite the tendency for the elasticities of supplies and demand of particular regions to increase, because OPEC's market share is also expanding. Thus, increasing dependence upon the cartel will provide incentives for the cartel to restrict output and raise prices. The price elasticities are lowest in the high GDP case because OPEC's market share is highest. Other things being equal, therefore, higher economic growth will lead to higher prices.

Table C-1
Inferred Price Elasticities of the Call on OPEC

Elasticities with Base GDP:

	2000	2010
DFI-CEC	-1.249	-0.842
HOMS-I	-0.853	-0.988
BP America	-0.849	
CERI: WOMM	-0.829	-0.702
FRB-Dallas	-0.776	-1.035
HOMS	-0.638	-0.794
EIA: OMS	-0.565	-0.611
Gately	-0.453	-0.449
WOMS	-0.421	-0.739
IPE	-0.411	
Penn-BU	-0.382	-0.535
Average	-0.675	-0.744

Elasticities with High GDP:

	2000	2010
DFI-CEC	-1.156	-0.769
HOMS-I	-0.794	-0.907
BP America	-0.732	
CERI: WOMM	-0.765	-0.633
FRB-Dallas	-0.711	-0.878
HOMS	-0.574	-0.674
EIA: OMS	-0.531	-0.566
Gately	-0.414	-0.389
WOMS	-0.384	-0.654
IPE	-0.256	
Penn-BU	-0.385	-0.548
Average	-0.609	-0.669

Elasticities with Low GDP:

	2000	2010
DFI-CEC	-1.390	-0.920
HOMS-I	-0.925	-1.097
BP America	-1.025	
CERI: WOMM	-1.000	-0.868
FRB-Dallas	-0.862	-1.295
HOMS	-0.722	-0.977
EIA: OMS	-0.615	-0.669
Gately	-0.500	-0.531
WOMS	-0.477	-0.869
IPE	-0.749	
Penn-BU	-0.347	-0.494
Average	-0.783	-0.858

Note: Elasticities are inferred from rising and flat price cases using the same GDP growth assumptions.

APPENDIX D

Oil Price Forecasting During the 1980s: What Went Wrong?

It is easy to be critical of the dismal past track record of oil forecasters. Even putting aside the price shocks of 1979-80 and 1990, which few people anticipated, the errors in forecasting a shock-free decade were large.

A previous EMF study (1981) contained projections done in 1980 that showed the inflation-adjusted oil price, after a period of flat or mildly declining prices during the early to mid-1980s, rising from its 1980 level over the next several decades. The projections were representative of others that were done at that time as well as what a number of nonmodeler experts were saying as well. Indeed, the inaccurate forecasts based upon world oil models stem from basic political and market uncertainties that at the same time misled a wider community of oil-market watchers using informal judgement rather than models.

What did go wrong with the "conventional wisdom" of 1980, including nonmodeling market watchers as well as modelers? This question can not be easily answered for nonmodelers, because they are seldom explicit about their assumptions that underlay their market assessment. A revisit to the EMF projections referenced above, however, helps to identify several key factors.[40] While definitive answers will depend upon which expert's story is examined, several factors predominate.

Actual economic growth rates were below the assumed rates during the first half of the 1980s. If the oil market projections had been based upon actual economic growth rates, readers of the earlier EMF report would have been struck by a very noticeable decline in projected oil prices during most of the 1980s. Oil price forecasters are usually reluctant to exercise much control over the macroeconomic inputs, although such assumptions are often critical to the forecast.

Further, the price projections would have been lower (and closer to actual history) if the modelers had not listened to the "conventional wisdom" of nonmodeling supply experts and had instead incorporated more optimistic outlooks for Non-OPEC supplies, more in line with the actual 1980 experience. And finally, some errors may have resulted in the EMF study from other inputs agreed to by the working group, such as an underestimate of the amount of demand reduction yet to be achieved, in response to the price increases of the 1970's.

While the inputs to the scenarios examined in that earlier study were clearly a culprit, there are reasons for suspecting that improvements in model specification are warranted as well. Some specific recommendations are made in the summary report. These points are not intended to discredit the models but rather to move modelers, model-funders, and model-users in the direction of improving them.

[40]Gately (1984,1986) provides a useful review of the errors in projecting oil prices in the EMF study. Porter (1991) focuses on the non-OPEC supply projections from the EMF study.

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Chapter 3

EMF 11 REVISED SCENARIO DESIGN

Hillard Huntington, Douglas Robinson, and Andrea Kress*
November 15, 1989

At the September meeting in Cambridge, the EMF 11 working group agreed to consider five new scenarios in addition to the original seven first-round scenarios for comparing model results. This paper lists the scenarios and discusses the input assumptions and the outputs to be reported for these 12 cases.

Modelers are asked to recheck their first-round results to ensure that their oil price and GDP assumptions correspond to the explicit assumptions outlined in this paper. Assumptions about oil prices, GNP growth rates, and OPEC capacity are also contained in the EMF diskette (at the bottom) for reporting results.

SCENARIOS

Nine of the scenarios specify the world oil price and economic growth rates exogenously. The intent of these cases is to facilitate discussions about different perspectives on international supplies and demands and their implications for the call on OPEC supplies under these conditions. Specific model assumptions about OPEC's behavior or responses to net demand for OPEC oil are excluded from these scenarios. By understanding differences among models in these scenarios, the working group should be better prepared to examine other scenarios that include assumptions about OPEC behavior in later rounds.

Modelers are requested to run the following 12 scenarios:

(1) Flat World Oil Price with Baseline GDP. Oil prices remain constant at $18 per barrel (1988 dollars) from 1989 to 2010. GDP for the Market Economies grows 2.9% per annum between 1990 and 2000.

(2) Rising World Oil Price with Baseline GDP. Oil prices double from $18 to $36 per barrel (1988 dollars) between 1989 and 2000 and remain constant thereafter. World GDP grows 2.9% per annum between 1990 and 2000.

(3) Flat World Oil Price with High GDP. Oil prices remain constant at $18 per barrel (1988 dollars) from 1989 to 2010. World GDP grows 3.9% per annum between 1990 and 2000.

*Energy Modeling Forum.

(4) Flat World Oil Price with Low GDP. Oil prices remain constant at $18 per barrel (1988 dollars) from 1989 to 2010. World GDP grows 1.9% per annum between 1990 and 2000.

(5) Rising World Oil Price with High GDP. Oil prices double from $18 to $36 per barrel (1988 dollars) between 1988 and 2000 and remain constant thereafter. World GDP grows 3.9% per annum between 1990 and 2000.

(6) Rising World Oil Price with Low GDP. Oil prices double from $18 to $36 per barrel (1988 dollars) between 1988 and 2000 and remain constant thereafter. World GDP grows 1.9% per annum between 1990 and 2000.

(7) Cartel case with Baseline GDP (endogenous). Oil prices are determined endogenously by incorporating OPEC production decisions and equating crude oil supply and demand. OPEC is assumed to operate as a cartel. World GDP grows 2.9% per annum between 1990 and 2000. EIA estimates of OPEC capacity are assumed for those models that do not determine OPEC investment decisions endogenously.

(8) Flat Oil Price with No Growth. Oil prices remain constant at $18 per barrel (1988 dollars) from 1989 to 2010. World GDP and population are maintained at 1988 levels.

(9) Flat Oil Price with No Growth or Time Trend. Oil prices remain constant at $18 per barrel (1988 dollars) from 1989 to 2010. World GDP and population are maintained at 1988 levels. Any energy efficiency trend explicitly linked to time is eliminated.

(10) Competitive Case with Baseline GDP (endogenous). Oil prices are determined endogenously by incorporating OPEC production decisions and equating crude oil supply and demand. OPEC is assumed to behave competitively. Each modeler is requested to specify explicitly how such behavior was represented in their model. World GDP grows 2.9% per annum between 1990 and 2000.

(11) Cartel Case with High GDP (endogenous). Oil prices are determined endogenously by incorporating OPEC production decisions and equating crude oil supply and demand. OPEC is assumed to operate as a cartel. World GDP grows 3.9% per annum between 1990 and 2000. EIA estimates of OPEC capacity are assumed for those models that do not determine OPEC investment decisions endogenously.

(12) "Conventional Wisdom" Oil Price with Baseline GDP. Oil prices follow the EIA Middle case, rising to $27 per barrel (1988 dollars) by 2000 and to $37 by 2010. GDP for the Market Economies grows 2.9% per annum between 1990 and 2000.

INPUT ASSUMPTIONS

The Energy Information Administration (EIA) of the U.S. Department of Energy has sent each modeler the following information:

(1) a diskette with the OMS model and baseline exogenous assumptions;

(2) an OMS Users' Manual;

(3) a copy of the International Energy Annual, 1989 that provides historical data relating to international oil markets;
(4) a copy of the International Energy Outlook, 1989 that discusses the EIA's assumptions and projections of world oil markets; and
(5) a copy of the Annual Energy Outlook, 1989 that discusses the EIA's assumptions and projections of U.S. energy markets.

The EIA assumptions referenced in this section refer to those contained on the OMS disk and are the baseline assumptions discussed in item #4 above.

Oil Prices. The nine exogenous price scenarios specify three world oil price paths as indicated in Table 1. All scenarios should begin in 1988 with an actual price of $14.70 for the refiners acquisition cost of U.S. oil imports. The three price paths are:

(1) Flat World Oil Price. The refiners acquisition cost of U.S. oil imports is maintained at $18 per barrel (1988 dollars) from 1989 to 2010.
(2) Rising World Oil Price. The refiners' acquisition cost of U.S. oil imports rises to $19.50 (1988 dollars) per barrel by 1989 and increases linearly to $36 per barrel (1988 dollars) by 2000. This is an increase of $1.50 per barrel per year. Real oil prices remain flat from 2000 to 2010.
(3) "Conventional Wisdom" World Oil Price. A reported in the EIA middle case, the refiners' acquisition cost of U.S. oil imports rises to $27 per barrel (1988$) by 2000 and to $37 per barrel (1988$) by 2010.

Modelers using a different oil price variable should adjust their series to correspond to the above series. EIA will provide historical data on different world oil prices.

GDP Growth Rates. These scenarios specify three world GDP growth rates as indicated in Table 2. These GDP cases are:

(1) Baseline GDP. Regional GDP growth rates are those provided by the Energy Information Administration in the disk with the OMS model. These growth rates correspond to the base case in the EIA's International Energy Outlook.
(2) High GDP. The GDP growth rate of each region is increased by one-third (33%) above the baseline GDP growth rate, resulting in world GDP growth rate being 1% higher. Thus, if region X grows by 6 percent per year in the baseline, its economy grows by 8 percent, not 7 percent (1% p.a. higher), in this scenario.
(3) Low GDP. The GDP growth rate of each region is reduced by one-third (33%) below the baseline GDP growth rate, resulting in world GDP growth rate being 1% higher. Thus, if region X grows by 6 percent per year in the baseline, its economy grows by 4 percent, not 5 percent (1% p.a. lower), in this scenario.

Table 1: Exogenous Oil Price Cases
(1988 $ per barrel)

Year	Flat	Rising	"Conventional Wisdom"
1988	14.70	14.70	14.70
1989	18.00	19.50	14.40
1990	18.00	21.00	15.00
1991	18.00	22.50	15.50
1992	18.00	24.00	15.90
1993	18.00	25.50	17.10
1994	18.00	27.00	18.90
1995	18.00	28.50	20.60
1996	18.00	30.00	22.50
1997	18.00	31.50	24.25
1998	18.00	33.00	25.88
1999	18.00	34.50	26.91
2000	18.00	36.00	28.00
2001	18.00	36.00	29.20
2002	18.00	36.00	30.16
2003	18.00	36.00	30.94
2004	18.00	36.00	31.61
2005	18.00	36.00	32.35
2006	18.00	36.00	32.93
2007	18.00	36.00	33.68
2008	18.00	36.00	34.52
2009	18.00	36.00	35.46
2010	18.00	36.00	36.50
2020			42.00
2030			46.00

Endogenous GDP Changes. When simulating the three oil price paths, modelers are asked not to change GDP growth rates, unless their model has an explicit feedback effect relating changes in GDP to changes in the oil price.

Real Interest Rates. Modelers requiring an interest rate should assume a 6 percent rate, after taxes and adjusted for inflation (i.e., real).

Table 2: Exogenous GDP Growth Rate Cases

(% change per annum)

	1988 Level**	1988	1989	1990 to 2000	2001 to 2002	2003 to 2005	2006 to 2010
Base GDP							
U.S.	3425	4.4	3.2	2.5	2.4	2.4	2.6
Canada	346	5.0	3.2	3.0	2.9	2.9	2.8
Japan	1456	5.9	4.0	3.1	3.1	3.1	3.1
Europe	4467	3.5	2.7	2.4	2.6	2.6	2.6
NODCs	1989	2.9	2.9	4.0	4.3	4.3	4.2
OECD*	9694	4.2	3.1	2.6	2.6	2.6	2.7
Market Economies*	11,638	4.0	3.1	2.8	2.9	3.0	3.0
High GDP							
U.S.		4.4	4.3	3.3	3.2	3.2	3.5
Canada		5.0	4.3	4.0	3.9	3.9	3.7
Japan		5.9	5.3	4.1	4.1	4.1	4.1
Europe		3.5	3.6	3.2	3.5	3.5	3.5
NODCs		2.9	3.9	5.3	5.7	5.7	5.6
OECD*		4.2	4.1	3.5	3.5	3.5	3.6
Market Economies*		4.0	4.1	3.7	3.9	4.0	4.0
Low GDP							
U.S.		4.4	2.1	1.7	1.6	1.6	1.7
Canada		5.0	2.1	2.0	1.9	1.9	1.9
Japan		5.9	2.7	2.1	2.1	2.1	2.1
Europe		3.5	1.8	1.6	1.7	1.7	1.7
NODCs		2.9	1.9	2.7	2.9	2.9	2.8
OECD*		4.2	2.1	1.7	1.7	1.7	1.8
Market Economies		4.0	2.1	1.9	1.9	2.0	2.0

*Provided for modelers that require assumptions for aggregate regions.

**GDP Levels (1980$) are provided for modelers' reference. Based upon data provided by EIA from WEFA Outlook, Oct. 1989. NODC level equals OTHER (as reported on OMS diskette) minus Australia and New Zealand. Europe includes Australia and New Zealand. Market Economies excludes OPEC, for which there is no separate EIA growth rate.

Table 3: Assumptions for OPEC Capacity
(million barrels per day)

Year	OPEC Capacity (MMBD)
1988	28.2
1989	29.0
1990	29.0
1991	29.0
1992	29.3
1993	30.1
1994	30.9
1995	32.1
1996	32.9
1997	33.6
1998	34.1
1999	35.0
2000	35.3
2001	35.5
2002	35.7
2003	35.8
2004	36.0
2005	36.1
2006	36.3
2007	36.4
2008	36.6
2009	36.7
2010	36.9

OPEC Capacity/Production Path. In the exogenous price scenarios, OPEC is assumed to be a swing producer, meeting all unsatisfied demand at the exogenous oil price. In the endogenous oil price scenarios (#7, 10, and 11), modelers requiring an OPEC capacity projection should use EIA's assumption as contained on their OMS disk (reproduced in Table 3). Modelers who set OPEC oil quantities rather than capacity should contact the EMF for a corresponding OPEC production path.

Backstop Costs. Modelers requiring a backstop cost in their endogenous scenario should assume $54 per barrel (1988 dollars). Note that this backstop cost is not the price of the least costly alternative to conventional oil but the price at which alternative sources become infinitely available.

Table 4: Regions to be Reported

	Oil Consumption	Oil Production	Oil Imports	% Change in GDP
United States (US)	X	X	X	X
OECD	X	X	X	X
Non-OPEC Developing Countries (NODCs)	X	X	X	X
Market Economies (Mkt Econ)	X	X		X
OPEC		X		
Total Non-OPEC		X		
Centrally Planned Economies (CPEs)			X Exports	

Notes: EMF diskette reports updated 1988 values for oil consumption, production, and imports, as provided in new OMS diskette from EIA. OECD includes US, Canada, Japan, and Europe, plus an adjustment for Australia and New Zealand. Non-OPEC developing countries equals Other minus Australia and New Zealand. Total Non-OPEC excludes CPE exports.

Other Assumptions. Where possible, please use EIA's projections on their OMS disk for any other exogenous assumptions. Please contact the EMF staff (telephone: (415) 723- 0645) if you need additional inputs or would like to discuss any assumptions.

OUTPUTS

For the next EMF 11 working group meeting in March, modelers are free to report results for whatever variables and regions they think are illuminating. For the purposes of the standardized model comparisons developed by the EMF staff, modelers are requested to report only certain variables and aggregate regions that all or most modelers report.

The following variables for the aggregate regions shown in Table 4 should be reported to the EMF:

Price--Crude oil price (refiner acquisition cost of U.S. imports in 1988$/barrel);
Cons.--Crude oil consumption including NGLs (millions of barrels per day);
Prod.--Crude oil production including NGLs (millions of barrels per day);
Impt.--Crude oil net imports including NGLs (millions of barrels per day); and
GDP --Gross Domestic Product (percent change per annum).

In reporting output to the EMF, modelers are requested to:

- print data to a Lotus 1-2-3 file on a double-sided, double-density diskette included with this scenario design;
- use the data report template provided by EMF that specifies the scenario, region, and variable;
- report data where available for each year from 1988 to 2010;
- indicate missing data with blanks;
- use the updated 1988 values (incorporating the most recent revisions) given on the diskette provided by EMF as a guide for ensuring that you are reporting the same concept;
- report crude oil volumes in millions of barrels per day; and
- report crude oil prices as the U.S. refiner acquisition cost for imported oil in 1988 dollars per barrel.

All scenarios are to be reported in one LOTUS worksheet. A copy of the Lotus template for reporting the results from scenario #5 is shown in Table 5. The scenario is identified in terms of oil price trend (Rising) and GDP path (High) in the first column. The requested variable is indicated in the second column (see variable list above for abbreviations) and the region in the third column (see Table 4). The EIA 1988 data are shown next, followed by a blank area for reporting results for each year through 2010 (only 1991 is shown in the table). Please disregard but do not delete the hidden columns A through D; they represent EMF codes.

Modelers are also asked to report, in their transmittal letter, estimates of the remaining oil resources by region in their scenarios. Modelers are requested to return the diskette with the results by January 26, 1990, in order that the data can be processed and analyzed in time to have some preliminary analyses available for the working group before the March 1990 meeting. Please send the diskette to:

Hill Huntington
Energy Modeling Forum
406 Terman Center
Stanford University
Stanford, CA 94305-4022

Finally it is recommended that the complete simulation results be stored on disk or tape, in case it becomes necessary at a later date to retrieve additional information for scenario interpretation.

Table 5: EMF Template for Reporting Results

Worksheet Name: TEMPLATE.WK1

Example: Scenario #5
Rising Oil Price, High GDP

Price	GDP	Var.	Region	1988	1989	1990	1991
Rising,	High	Price		14.7			
Rising,	High	Cons.	U.S.	17.5			
Rising,	High	Cons.	OECD	36.9			
Rising,	High	Cons.	NODCs	10			
Rising,	High	Cons.	Mkt Econ	50.7			
Rising,	High	Prod.	U.S.	10.5			
Rising,	High	Prod.	OECD	17.6			
Rising,	High	Prod.	NODCs	9.5			
Rising,	High	Prod.	Non-OPEC	27			
Rising,	High	Prod.	OPEC	21.5			
Rising,	High	Prod.	Mkt Econ	48.5			
Rising,	High	Impt.	U.S.	7			
Rising,	High	Impt.	OECD	19.3			
Rising,	High	Impt.	NODCs	0.5			
Rising,	High	Expt.	CPEs	2.4			
Rising,	High	GDP	U.S.	4.4%			
Rising,	High	GDP	OECD	4.2%			
Rising,	High	GDP	NODCs	2.9%			
Rising,	High	GDP	Mkt Econ	4.0%			

Note: Worksheet contains twelve (12) scenarios.

Chapter 4

COMPARISON OF THE STRUCTURE OF INTERNATIONAL OIL MODELS

Andrea Kress, Douglas Robinson, and Kenneth Ellis*

January 1991

INTRODUCTION

The Energy Modeling Forum is comparing the responses of 11 world oil models (listed in Table 1) in its study on International Oil Supplies and Demands (EMF 11). This paper describes the salient structural features of these models to help potential model users better understand how projections are developed from such systems. The discussion is primarily qualitative, although key quantitative information, such as elasticities, are reported where available and are presented in Tables 1 and 2.

TWO BASIC APPROACHES

There are two fundamentally different approaches for modeling the world oil markets: recursive simulation and intertemporal optimization (P. Beider, 1981). The principal distinguishing feature is their assumption about the degree to which decisionmakers know where future prices will move.

Recursive Simulation Models

Recursive simulation models solve for market supply-demand balances one year at a time. Figure 1 shows a prototype model of this type. Non-OPEC supplies from market economies are governed by assumptions about technological advances, resource depletion, and by past and current oil prices. Net exports from the Soviet Union, Eastern Europe, and China are assumed without an explicit analysis of oil supply and demand conditions in those regions. World oil demand is influenced by assumptions about GNP and autonomous energy efficiency improvements and by past and current oil prices. The residual demand unsatisfied by non-OPEC sources is met by OPEC production. OPEC producers then set the next year's price on the basis of how much OPEC productive capacity is utilized to meet world oil demand during the current year, often referred to as an OPEC price reaction function. Higher capacity utilization rates produce larger price changes. OPEC capacity levels are usually set exogenously. See appendix A for a discussion of the price reaction function and the supply equations. In many cases, a model will include additional factors. For example, some models explicitly incorporate the effects of

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Table 1

Summary of EMF 11 Supply Models

Features	OMS	IPE	ETA MACRO Global 2100	Penn/BU	WOMS	CERI	HOMS	FRB Dallas	DFI/CBC	BP America *	Gately
Model Type 3/18/90 11:28 PM	Recursive Simulation	Recursive Simulation	Intertemporal Optimization	Recursive Simulation	Recursive Simulation	Recursive Simulation	Recursive Simulation	Recursive Simulation	Intertemporal Optimization	Recursive Simulation	Recursive Simulation
Perfect Foresight	No	No	Consumers and Producers	No	No	No	No	No	Yes	No	No
Supply Model Regional Aggregation	U.S., Canada, Europe, Japan, OPEC, other World Outside of Communist Area (WOCA), net Centrally Planned Economies (CPEs)	Gulf, OECD, Non-Gulf LDC producers	U.S., Other OECD, Soviet Union + Eastern Europe, China, Rest of World (ROW)	OPEC, CPEs, and eight non-OPEC regions	OPEC, N. America, other non-OPEC, Centrally Planned Economies (CPEs)	OPEC, 16 Non-OPEC Producers	U.S., non-U.S./non-OPEC, OPEC	U.S., non-U.S./non-OPEC, OPEC	Core OPEC, other OPEC, CPE, LDC, U.S., Canada, other OECD	Iran/Iraq, other OPEC Gulf, other OPEC, non-OPEC	U.S., Canada, Europe, Japan, OPEC, other World Outside of Communist Area (WOCA), net Centrally Planned Economies (CPEs)
Price Determination In Endogenous Simulations	OPEC price reaction function in response to previous year's capacity utilization	Depends on Gulf countries' taxes, production costs, and oil company markup. Markup is determined by capacity utilization and other factors	Exogenous price paths only	Dependent upon OPEC capacity utilization, OPEC market share, oil stocks, and other factors	OPEC price reaction function in response to previous year's capacity utilization	Clears markets given OPEC output	OPEC price reaction function in response to previous year's capacity utilization	OPEC price reaction function.	Core OPEC set price to maximize the present value of their reserves given discount rate	OPEC's share in WOCA demands, OPEC's capacity utilization	Judgementally selected OPEC output path, with market clearing prices
OPEC Productive Capacity	Exogenous	Endogenous based on expected future demand through investment	OPEC production is included in the ROW region. Production capacity in all regions is endogenous	Exogenous	Exogenous	No explicit capacity	Exogenous	Exogenous	Endogenous given price path	Exogenous	Exogenous
Production Decision in Cartel Model	Fills residual demand from non-OPEC regions. Next year's price is based on capacity utilization	Fills residual demand from non-OPEC regions. Limited by capacity.	ROW sector meets residual demand subject to region-specific upper bound constraints on imports/exports	Fills residual demand from non-OPEC regions	Fills residual demand from non-OPEC regions. Next year's price is based on capacity utilization	Specified exogenously	Fills residual demand from non-OPEC regions. Next year's price is based on capacity utilization	Fills residual demand from non-OPEC regions. Next year's price is based on capacity utilization	Intertemporal optimization by all producers to maximize profits	Gulf OPEC exogenous. Other OPEC affected by financial pressures.	Exogenous OPEC output
Production Decision in Competitive Model	Produces at 95% of capacity. Price clears the market.		N. A.	OPEC produces more than the diff. between WOCA demand and non-OPEC prod. Extra quantity exogenous variable.	Produces at 95% of capacity. Price clears the market.	Specified exogenously				N. A.	Price set at $10
Non-OPEC Producers Price Influence on Conventional Supply	Deviation from base DOE price/production series using price elasticities	Deviation from base series using price elasticites for OECD. LDCs produce to clear market	Via intertemporal optimization to maximize discounted utility of consumption	Deviations from Hubbert curve based on price, oil/gas ratio, and political events	Deviations from Hubbert curve based on price	Reserve additions based on oil price, interest rates, and reserve life	Supply determined by econometric relationship to current prices, past output, and time trend	Supply determined by econometric relationship to current prices, past output, and time trend.	Via intertemporal optimization to maximize discounted profits given prices	Deviations from three benchmark series based on Hubbert and other information.	Deviation from base DOE price/production series using price elasticities
Depletion	Handled implicity in DOE base series	Depletion multipliers adjust base production series for cumulative production	Constant production - reserve - resource ratios, with option to delay additions	Depends on cumulative production through Hubbert-type analysis	Depends on cumulative production through Hubbert-type analysis	Explicit model of reserve additions and production functions	Handled implicitly in time trend	Handled implicitly in time trend	Resource cost curves	Handled in benchmark series	Handled implicity in DOE base series
Explicit Resource Base	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
Backstop Production	No backstop	In the U. S.	Yes	None	None	Yes, Canada only	None	None	Backstop production after 2000	Yes	No backstop
Centrally Planned Economies	Exogenous	Exogenous	Endogenous	Net export exog., macro-models edog.	Exogenous	Exogenous	Exogenous	Exogenous	Exogenous	Exogenous	Exogenous
Modeler	Mark Rodekohr	Nazli Choucri	Alan Manne	R. Kaufmann/P. Pauly	Baldwin/Prosser	Anthony Reinsch	Hogan/Leiby	Stephen Brown	Dale Nesbitt	Lakis Vouyoukas	Dermot Gately

* Model and results do not necessarily reflect BP America's corporate views.

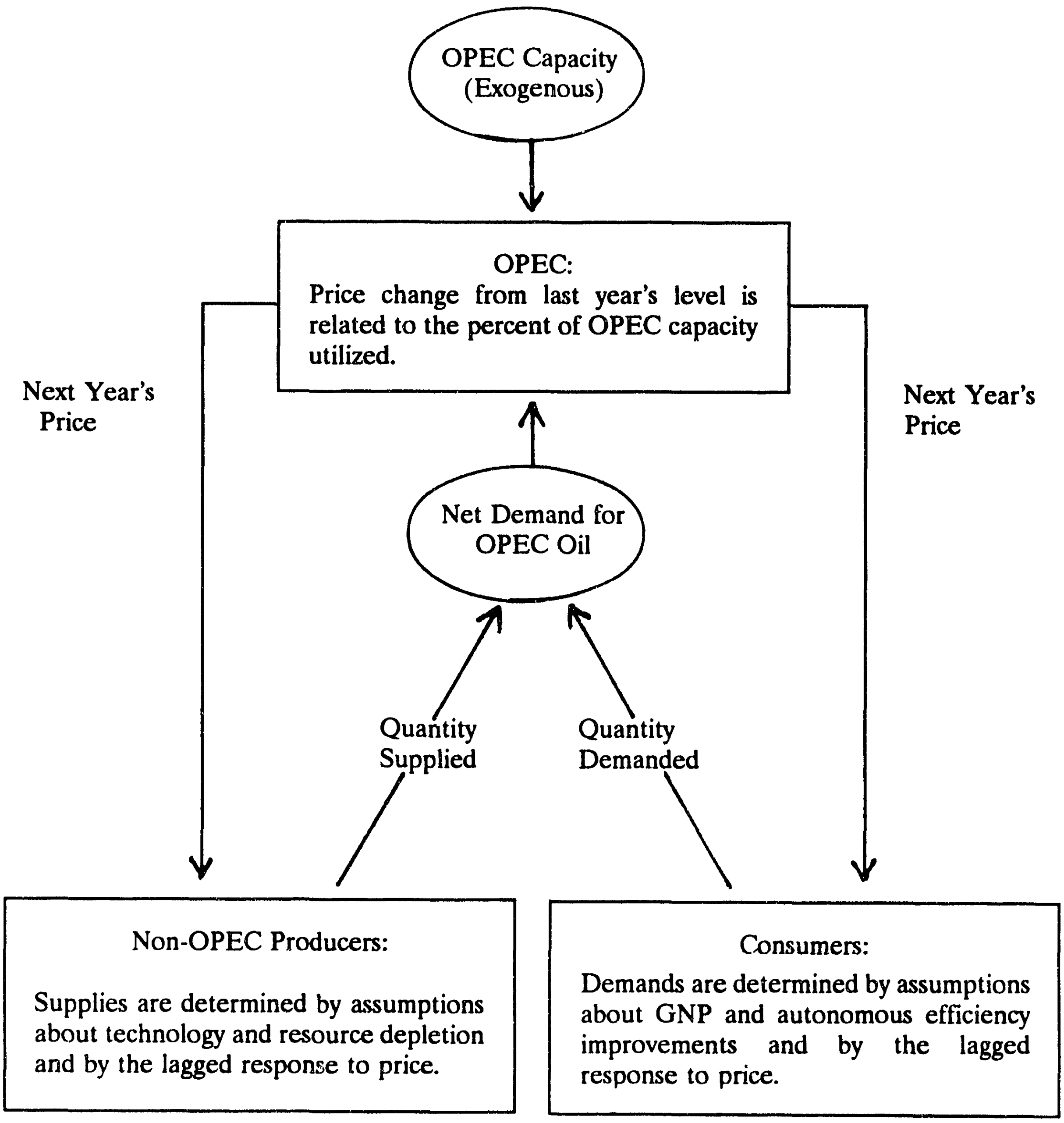
Table 2

Summary of EMF 11 Demand Models

Features	OMS	IPE	ETA MACRO Global 2100	Penn/BU	WOMS	CERI	HOMS	FRB Dallas	DFI/CEC	BP America *	Gately
Model Type 3/18/90 11:20 PM	Recursive Simulation	Recursive Simulation	Intertemporal Optimization	Recursive Simulation	Recursive Simulation	Recursive Simulation	Recursive Simulation	Recursive Simulation	Intertemporal Optimization	Recursive Simulation	Recursive Simulation
Perfect Foresight	No	No	Consumers and producers	No	No	No	No	No	Producers	No	No
Demand Model Regional Aggregation	U.S., Canada, Europe, Japan, OPEC, other World Outside of Communist Area (WOCA)	U.S., W. Europe, Japan, Can-Aus-NZ, Middle East - OPEC, Non-M.E. OPEC, Other LDCs	U.S., Other OECD, Soviet Union + Eastern Europe, China, Rest of World (ROW)	OECD, OPEC non-OPEC LDCs, Centrally Planned Economies (CPEs)	OECD, WOCA, LDCs	U.S., Canada, Japan-AUS-NZ, W. Europe,OPEC, Non-OPEC LDCs, CPEs	U.S., Canada, other OECD, Japan, OPEC, other WOCA	U.S., Japan, Canada, U.K. W. Germany, France, Italy	U.S., Japan-Aus-NZ, LDC, CPE, other OECD	OECD, LDC's	U.S., OECD, Europe, Other OECD, OPEC, Other LDC (non-CPE)
Consumers Direct Price Influence on Demand	Via crude-price elasticities	Via crude-price elasticities	Via intertemporal optimization to maximize discounted utility of consumption	Via crude price elasticities (?)	Via crude price elasticities	Via product price elasticities	Via crude price elasticities	Via crude price elasticities	Via crude price elasticities	Via composite energy price elasticities and oil product prices relative to prices of competing fuels in each sector	Via elasticities for resid and non-resid. Responsiveness depends on price relative to max. past price
Short Run Elasticity For Gasoline	Upward Price: -0.07 Downward Price: -.06 (crude oil)			No explicit elasticities	WOCA: -0.04 OECD: -0.045 (crude oil)	OECD: -0.1 LDC: -0.0975 OPEC: -0.075	-0.135 (crude oil)	U.S. -.09, Canada -.04, Japan -.11, Other OECD -.13, Other WOCA -.22		OECD -0.12	Varies by region: -0.1 to -0.3
Long Run Elasticity For Gasoline	Upward: -0.64 Downward: -0.47	Crude oil: -0.3	Elasticity of substitution between energy and other inputs equals 0.4 in OECD	No explicit elasticities	WOCA: -1 OECD: -1.875 (crude oil)	OECD: -0.5 LDC: -0.65 OPEC: -0.50	-0.9 (crude oil)	U.S. -.56, Canada -.60, Japan -.68, Other OECD -.49, Other WOCA -.41	-0.5 (crude oil)	OECD -0.45	Varies by region: -0.1 to -0.3
Energy-GNP Feedback	One-parameter feedback in OMS	Oil prices influence growth of demand	Aggregate nested CES production functions by rgn.; interfuel sub. between electric & non-electric	Joint determination of oil prices and real income	None	None	Yes, changes in GNP determined by oil price feedback effect	None GNP exogenous	None	None	Two parameter feedback: level and change in oil price
Non-Price Related Technical Change	Yes. Calculate a reference demand time series that excludes price and income effects.	Yes. There is conservation even with constant prices. The conservation term also depends on lagged price and inversely on economic growth.	Autonomous energy efficiency improvement of 0.5% per annum in OECD.	No time trend.	Time dependent conservation term, set to 0 for EMF runs.	No time trend.	No time trend.	No.	Demand curve exogeneous based on EIA data.	Yes. Depends on sector. For transport sector, road m.p.g. improves 1% per year	Set to zero
Interfuel Substitution	Implicit in own-price elasticities.	Implicit in conservation term. Substitute availability is determined by expected oil prices and exogeneous substitute prices.	Explicit capital/labor tradeoff with energy. Explicit oil/gas tradeoff with electricity.	Interfuel substitution handled in detailed macroeconomic model	Implicit in own-price elasticities.	Implicit in own-price elasticities.	Implicit in own-price elasticities.	Implicit in own-price elasticities.	Same as EIA	Yes. Explicit through relative price of oil. Also, fuel switching occurs if oil prices break through imposed thresholds.	Implicit in own-price elasticities.
Shifts in the Economy	Implicit in the reference demand series described above.	Implicit in the conservation term.	1-sector model. Income elasticity equals one	Shifts in the economy handled in detailed macroeconomic model	Implicit in price and income elasticities. Short- and long-run income elasticities equal 1.0 for OECD and WOCA.	Implicit in price and income elasticities. Short- and long-run income elasticities less than 1.0 for OECD and WOCA.	Implicit in price and income elasticities. Short- and long-run income elasticities equal 1.0 for OECD and WOCA.	Not included. Tested for this variable and found it insignificant. Income elasticity of one.	Same as EIA	No.	Implicit in price and income elasticities
Effects of Past Price Changes	Koyck lag demand equation.	Five-year adjustment to price	None, except for initial benchmarking.	Past prices effect current demand through capital stock	Koyck lag demand.	Koyck lag demand.	Koyck lag demand.	Polynomial distributed lag function	Same as EIA	Depends on sector.	Residual: Koyck lag. Non-resid: distributed lag on max. past price
Modeler	Mark Rodekohr	Nazli Choucri	Alan Manne	R. Kaufmann/P. Pauly	Baldwin/Prosser	Anthony Reinsch	Hogan/Leiby	Stephen Brown	Dale Nesbitt	Lakis Vouyoukas	Dermot Gately

* Model and results do not necessarily reflect BP America's corporate views.

Figure 1. Generic Representation of Recursive Simulation Models



alternative fuel prices (e.g., natural gas) or shifts in economic structure away from energy-intensive sectors. In addition, several models include the influence of exchange rates on supply and demand decisions through their effects on the real price of oil expressed in local currencies.

OPEC price reaction functions can also be more complex than that indicated in Figure 1. OPEC capacity is determined endogenously in the IPE model, as higher expected future oil demand increases investment in productive capacity. The IPE price reaction function also includes OPEC's reserve-to-production ratio, extraction costs, and royalties.

The recursive models generally provide a richer representation of oil demand than supply conditions. (IPE is a notable exception.) The availability of data on key demand influences--energy prices and GNP--explains much of the emphasis on oil demand. Responses to GNP and energy prices are based (explicitly or implicitly) on historical data. However, they can be adjusted to include other factors judged to be important by the modeler. Comparable information is not available to adequately represent many of the relevant factors (technological advances, resource depletion, and country-specific taxation policies) considered important for determining oil supply.

The difficulties of modeling OPEC decisionmaking are well known. Both political forces and market structure (cartel versus competition) can substantially influence production levels. Although recursive simulation models (except for IPE) adopt a very simplistic representation of OPEC, the resulting OPEC price reaction functions have (until recently) conformed to observed short-run market outcomes since 1973.

Hence the demand equations lie at the core of most recursive simulation models. Estimates of non-OPEC production are subtracted from these demand projections to derive a net demand for OPEC. As this net demand pushes up against OPEC capacity (set exogenously), prices are increased to reduce future net demands through lower world oil demands and higher non-OPEC production. The models focus on oil demand trends and short-run pricing behavior; long-run supply considerations are either ignored (e.g., OPEC capacity) or represented in very rudimentary fashion.

<u>Intertemporal Optimization Models</u>

Optimization models assume the following: 1) that oil producers and/or consumers know what future prices will be in all relevant years (i.e., they have perfect foresight), and (2) that the players have the capacity to change their production or consumption path to take advantage of this information. Thus, for example, non-OPEC producers will choose a production path that maximizes the present value of their oil profits. If future profits (appropriately discounted) promise a greater return than current profits, producers will have incentives to delay oil extraction until later years. As production is shifted toward later periods, future prices will fall and current prices will rise until the incentives for delayed extraction disappear. In equilibrium, net profits should rise with the real interest rate on capital assets.

When a group of "core" producers operates like a cartel, it has the added incentive of exploiting its monopolist position. As in the recursive models, it faces a net oil demand curve comprised of the residual between world demand and non-OPEC supply. However, the core in the optimization model realizes that its production path influences oil prices. Rather than meeting the current call on its production and changing its next year price (depending upon capacity utilization rates), it will adopt a production path and pricing strategy that will maximize the present value of profits over time. Economic criteria are unabashedly the driver in this model, whereas the OPEC price reaction function of the recursive model may have some political criteria or other constraints embedded in its empirically-based response. In the recursive models, the cartel makes decisions in a very uncertain market environment in which the optimal production path is unknown.

Actual implementation of the perfect foresight assumption can differ depending upon which decisionmakers have the information. Therefore, it is preferable to consider these models separately rather than to discuss a generic optimization model, as was done in the case of the recursive models.

Details of the representation of supply and demand in each of the 11 models are given in the sections below.

SUPPLY MODELS

Oil Market Simulation (OMS) Model

The Oil Market Simulation (OMS) model is a Lotus spreadsheet created by the Energy Information Administration to test alternative price verses OPEC production capacity scenarios. Production from Non-OPEC regions is forecasted using price elasticities to capture deviations from Department of Energy base series. OPEC behavior is modelled using a price reaction function. The price change from last year is set in response to OPEC's capacity utilization (filling all residual demand) this year. This model and its underlying assumptions serve as the basis for inputs to many of the other models used in the EMF 11 study.

OPEC is modelled as filling all demand not met by non-OPEC supplies or exogenously specified exports from Centrally Planned Economies. OPEC sets the price change for the current year based on a comparison between the current year's capacity utilization (capacity specified exogenously) and a target utilization.

The OMS models non-OPEC regions using a DOE baseline projection that is corrected for deviations in price from the DOE projection using elasticity and lag parameters for five different regions -- United States, Canada, Europe, Japan, and other World Outside of Communist Area. This approach is explained in Appendix A. The base projections are based on a mixture of detailed country analysis, statistical study and judgement.

The short run price elasticity for non-OPEC supplies increases with time. The lag in supply response, current oil price and last year's supplies are the only factors that can change the baseline projection of non-OPEC supply.

The non-OPEC oil demand and supply parameters were estimated using projections published by the Energy Information Administration. Domestic projections are made with the Intermediate Future Forecasting System. The supply and demand elasticities and lag parameters are estimated to fit the EIA's base case projections and their sensitivities.

Gately

The model developed by Dermot Gately of New York University forecasts oil production for exogenous price scenarios or for market clearing prices with exogenously specified OPEC production. Production is modeled as coming from the United States, Canada, Europe, Japan, OPEC, other-World-Outside-of-communist-area, and net exports from Centrally Planned Economies. There is no treatment of backstop production.

The non-OPEC region does not have an explicit resource base. Production is based on a base DOE price/production series which implicitly handles depletion. Deviations from the base production series is done with elasticities.

For the competitive scenario, two different price paths were submitted. In one case the price of oil was set exogenously at $10 per barrel throughout the period. In the second case the price of oil began at $10 and increased gradually over time, at the assumed rate of interest, following the Hotelling principle for competitive market conditions.

International Petroleum Exchange Model (IPE)

The International Petroleum Exchange model focuses on the international flows of capital and the balance of payments. Supply is modeled for OECD, Middle East OPEC, and other-LDC producers. In all regions, the resource base is explicitly specified. Price is based on the capacity utilization of Persian Gulf countries and other factors.

The projected production from the OECD region is an aggregation of detailed estimates for the United States, Western Europe, Japan, and Canada-Australia-New Zealand. For Canada-Australia-New Zealand, production is equal to the minimum of 95 percent of capacity or total demand. It is assumed that policies in those countries preclude net exports. U. S. production is determined by price and depletion effects, modifying initial production series; Western Europe production is also determined by price and depletion effects, modifying a production series which increases to show the effect of the North Sea coming on-line in the 1970s; Japan production is set at zero.

For most of the other-LDCs, production is modeled as being 90 percent of capacity. Mexican production is determined directly from a base series, modified by a price elasticity.

ETA - MACRO / Global 2100

Alan Manne developed the ETA - MACRO/Global 2100 model to examine long run implications of policy decisions such as a carbon emissions tax. The model focuses on energy supply and demand through electric and non-electric sectors. For EMF 11, the model was run to forecast oil supply and demand in response to exogenous price paths.

Supply regions are U. S., other-OECD, the Soviet Union-Eastern Europe, China, and the rest of the world (including OPEC). Production capacity for each region is determined endogenously using perfect foresight with regard to future demand and oil prices to maximize discounted utility of aggregate economic consumption. The resource base is explicitly specified to be consistent with Masters et al. [1987]. Production is a fixed fraction of reserves. The rate at which resources are converted to reserves depends on the optimal level of investment in capacity and is limited by a fixed fraction of the remaining resources.

Backstop production is modeled from coal or shale-based synthetic fuels and other higher cost sources such as biomass-based fuels.

This is the only model with endogenous estimation of production in centrally planned economies.

Penn/BU

The oil model in Penn/BU is broken into five conceptual blocks: a macroeconomic block, a supply block, a demand block, a price block, and an OPEC capacity block. Oil consumption and real oil prices are used by the supply block to calculate production from non-OPEC and OPEC producers. The price block calculates oil prices based on OPEC behavior, OPEC capacity and rates of capacity utilization, and oil shocks. The OPEC capacity block calculates additions to OPEC capacity based on "decision rules" such as the net present value of the revenue stream. The following sections describes the supply blocks in greater detail.

The Supply Block. The supply block calculates output from four sources: non-OPEC nations, OPEC nations, and exogenously specified net exports from centrally planned economies and natural gas liquids. OPEC production is the difference between oil demand and all other non-OPEC sources.

The supply block calculates non-OPEC oil supply with a new methodology that combines the curve fitting technique developed by Hubbert (1962, 1967) with the econometric models pioneered by Fischer (1964). The combined model simulates the finite supply of oil explicitly by representing the effects of physical changes in the resource base that are not reflected fully by price along with an econometric analysis of the deviations from the bell shaped curve.

Combining the curve fitting technique with an econometric model is a two stage process (see Kaufmann, n.d.) In the first stage, data for cumulative production are fit to a logistic curve with a method developed by Hubbert. The first difference of the logistic curve yields an estimate for the annual rate of production. This is Hubberts's well known bell shaped curve for the production cycle of a non-renewable resource. Hubbert argues that the logistic function and its bell shaped derivative embody the physical features of oil formation, distribution, and discovery, that determine the quantity of oil ultimately discovered and the rate at which it is produced.

Because the physical characteristics of the oil resource base do not determine production completely, the new method also incorporates the effects of economic and political variables. In the second stage, the differences between the actual rates of production and the rates of production that are predicted by the bell shaped production curve are used as a dependent variable in an OLS model in which economic and political factors serve as independent variables. These variables include real oil prices (corrected for exchange rates), pro-rationing by the Texas Railroad Commission, and the collapse in the Mexican economy.

A two step grid search procedure is used to identify both the logistic curve and the econometric model that account for historical variations in the rate of production. The methodology is used to estimate equations for eight non-OPEC regions: Alaska, lower-48 United States, Canada, Mexico, non-OPEC South America, Western Europe, non-OPEC Africa, and non-OPEC Asia.

The Price Block. The price block calculates the price of oil based on variables that are calculated endogenously and specified exogenously. These variables include OPEC behavior, capacity utilization by OPEC, and oil shocks. The effect of these variables on the price of oil is estimated econometrically from historical data. The equation accounts for much of the variation in oil prices between 1974 and 1988 and satisfies all of the usual criteria for statistical significance.

The OPEC Capacity Block. As described above, capacity utilization by OPEC affects oil prices. Capacity utilization by OPEC is determined by two variables, the demand for oil from OPEC, which is calculated endogenously by the supply block, and OPEC's level of operable capacity. For some EMF 11 scenarios, OPEC capacity was specified explicitly. In other cases, OPEC capacity additions can be determined endogenously using a present value rule. Each year the change in present value caused by a capacity addition is used to decide if capacity should be added in that year. The present value calculation is based on price and OPEC production forecasts (both with and without additions) over a five-year planning horizon.

CERI -- WOMM

Anthony Reinsch's Canadian Energy Research Institute model focuses on the discovery and development process in non-OPEC regions. OPEC production is exogenously specified in all scenarios as is natural gas liquids production and exports from Centrally Planned Economies. Backstop production from Canadian sources only is considered.

There are 16 non-OPEC production regions: Canada, U. S., Mexico, Brazil, Argentina, Colombia, Peru, Trinidad, Egypt, Angola, India, Malaysia, Australia, Other Middle East, North Sea, and Western Europe. For each region, reserves are added from a geologically estimated ultimate potential resource base at a rate dependent upon oil price, interest rates, and reserve life. The success of drilling activity is modeled by means of a Hubbert-type curve, i.e. as a function of cumulative exploratory effort. See discussion of Penn-BU model for explanation on Hubbert-curve approach Production of reserves is driven by region-dependent decline rates.

Non-conventional crude production includes the Beaufort Sea and Eastern Offshore Canada, as well as tar sands ($26 per barrel).

Harvard Oil Market Simulation model (HOMS)

As implemented for the EMF 11 exercise, non-OPEC supply is modeled from U. S. and non-U. S./non-OPEC sources using a model derived through econometric analysis. The supply from these two regions is dependent upon current prices, past output, and a time trend that implicitly handles depletion. The long run supply elasticities are about .6 for both regions. The HOMS model can also be implemented such that a DOE baseline projection is corrected for deviations in price from the DOE projection using elasticity and lag parameters for five different regions. CPE exports and capacity are modeled exogenously. At 80% capacity utilization, prices hold steady.

William Hogan and Paul Leiby provide an extensive discussion of their non-OPEC supply models. In HOMS, output is a function of current prices, past output and a time trend representing technological improvements and resource depletion. It uses a Koyck lag model with the price variable being a six year moving average. In the United States, aggregate production is a function of the average wellhead price, incorporating the effects of wellhead price controls. U. S. refiners acquisition cost is the price for the rest of the non-OPEC production.

The parameters used imply that both the U. S. and other non-OPEC producers have a slow response to price changes, but the long-run price elasticities are similar, 0.58 for the U.S. and 0.65 for other non-OPEC countries. The time trends modeling depletion and technological change show that long-run additions to production at constant prices decline 5.2% per year in the U.S. and increase a statistically insignificant 0.4% per year for other non-OPEC producers. At the same prices in the DOE baseline, the HOMS yields substantially more total non-OPEC production than the DOE base line.

For EMF 11, William Hogan and Paul Leiby made available a second supply model that is very similar in style to OMS. The non-OPEC supply regions are the United States, Canada, other OECD, Japan, and other WOCA.

HOMS uses DOE non-OPEC supply projections with adjustments for prices that deviate from the baseline assumption. Supply responds slowly to changes in prices relative to the baseline price path.

FRB Dallas

Stephen Brown of the Federal Reserve Bank of Dallas has developed a model for estimating oil production based on econometric analysis of non-OPEC regions (the United States and other non-OPEC) and a price reaction function for OPEC. Net exports from Centrally Planned Economics correspond to DOE assumptions. Unconventional sources of liquids are not modelled.

As with the OMS model and others, the FRB Dallas model projects OPEC production through the use of a price reaction function. OPEC's productive capacity is specified exogenously and corresponds to the standard EMF assumptions. The fraction of this capacity that is utilized in any year determines the following year's price. OPEC is assumed to have a target capacity utilization below which it lowers prices and above which it raises prices.

Oil production equations for the U.S. and non-OPEC/non-U.S.-market-economies are based on econometric analysis of production's relationship to current price, past prices, past output, and a time trend. Although this style of modeling does not include geologic information, depletion is represented in the time trend. The trend for the U.S. reduces supply over time for a steady state price. Conversely, the function for the non-OPEC/non-U.S. market economies includes a time trend variable that increases supply over time for a steady-state price.

DFI/CEC

The Decision Focus Incorporated/California Energy Commission model is an intertemporal optimization framework in which producers have perfect foresight concerning oil prices. Demand is calibrated to OMS results. Both OPEC and non-OPEC producers use their knowledge of future oil prices to maximize their discounted future profits from oil production. Each sector has a resource-cost-curve that provides marginal cost information for the profit maximization decision. In addition to foresight, the OPEC core members use market power to influence prices in their profit maximization. Since the objective is discounted profit maximization, interest rates are critical in production rate determination and price.

OPEC is divided into a core and non-core (price takers) with its overall market power depending on the size of the core. As with non-OPEC regions, OPEC's capacity and production decisions are driven by its cost curves. OPEC members maximize their present value profits using foresight (core uses its market power, non-core does not). The core takes the behavior of consumers, non-core OPEC and non-OPEC into account to set price.

Non-OPEC production regions are Lower-48 United States, Alaska, U.S. Enhanced Oil, Canada, Other OECD, LDCs, and exogenously specified exports from Centrally Planned Economies (2 million barrels per day). Each region is represented by a resource cost curve that specifies the availability of oil at each given total cost (exploration, development, and production).

Robert Marshalla and Dale Nesbitt (DFI/CEC modelers) find that interest rate expectations are a key determinant of oil price and production. Lower interest rates tend to cause high current oil prices since producers will be more likely to defer production. Market power of OPEC depends on the difference between gross demand (consumption) and aggregate supply by non-cartel producers. Although not always true, net OPEC demand is quite elastic under EMF 11 assumptions, and such elasticity impedes the market power of OPEC. Net demand is affected by gross demand and non-OPEC supply, and both are important.

The model includes a large number of unconventional fuel sources which can come on line after the year 2000 at prices above $57 per barrel. These include oil shale, tar sands, coal liquefaction, and biomass liquids from various regions . A resource cost curve is input for each depletable resource activity. This gives the cumulative future resources that could be added to reserves as a function of marginal cost.

WOMS

The World Oil Market Simulation (WOMS) model was developed by Nick Baldwin and Richard Prosser to model non-OPEC oil production through the use of Hubbert-type analysis. OPEC production is modeled using a price reaction function. Exports from Centrally Planned Economies are specified exogenously. Unconventional sources of liquids were not modeled.

For the cartel scenarios of EMF 11, price is determined by the fraction of OPEC capacity utilized in the prior period. The annual percentage change in real prices is -24% + 4.7%/(1 - Capacity Utilization) where capacity is exogenously specified to match EIA assumptions. This function implies that below an 80% capacity utilization OPEC will lower oil prices.

For the competitive-OPEC scenario, OPEC members were assumed to ignore all quotas and produce at 95% of capacity.

Production from North America and other-non-OPEC is modeled by applying Hubbert analysis to the supply process. See the Penn-BU model for a discussion of this. The current period production projected by the resource-based Hubbert curve is modified based on current and past oil prices (adjusted for exchange rates), past period Hubbert projections, and past period oil production. The North American resource base is estimated by a search for the value that best explains past production (ultimate production of 256 billion barrels); that for non-OPEC/non-North America is chosen based on judgement (ultimate of between 250 and 400 billion barrels).

BP America

For EMF 11, the BP America model is used to project production in response to the flat and rising oil price scenarios. Exogenous supplies of oil are specified for Iran/Iraq (to 1995) and exports from Centrally Planned Economies. Endogenous production is modeled for non-Gulf-OPEC, non-OPEC, and unconventional supplies. Gulf-OPEC fills residual demand.

Other-OPEC productive capacity is specified exogenously with the level of production affected by financial pressures.

Non-OPEC production is projected from three benchmark series based on Hubbert curves and other information. See the Penn-BU model for a discussion of this. These series represent depletion of an explicit resource base. Production responds to price through deviations from these base series.

The model can be used for endogenous price determination. For this type of simulation, OPEC's share of World-Outside-of-Communist-Area demands and OPEC's capacity utilization influence price.

The BP America model and results are the product of Lakis Vouyoukas and do not necessarily reflect BP America's corporate views.

DEMAND MODELS

OMS

Like most of the EMF 11 models, EIA-OMS uses a Koyck-lag constant elasticity demand function. This function forecasts demand for some time period t given the following quantities: a reference demand time series (which excludes price and income effects), the forecasted and reference prices in period t, price and income elasticities, the lag coefficient, and a feedback elasticity. This last component is a measure of how energy prices affect GNP growth. Non-price driven technical change is reflected in the reference demand time series based on off-line analysis. Interfuel substitution and sectoral shifts in the economy are represented implicitly via the reference demand series.

Gately

The Gately model disaggregates oil demand in each region into two components: residual fuel oil and all other petroleum products. Residual fuel oil is used primarily by electric utilities; its demand has fallen sharply since 1978, due to fuel-switching. Other petroleum products are used primarily in transportation, residential, and commercial sectors; its demand has increased, but more slowly than before the two major price increases. The demand function for residual fuel is a constant-elasticity Koyck lag equation. For other products, a cubic polynomial distributed lag based on whether prices are above or below the Maximum Historical Price (MHP) is used.

The Gately model includes two-parameter feedback from oil prices to GNP growth to incorporate both long-run and short-run effects. The GNP growth rate is a function of both the level and the change in oil prices.

The demand response to price is asymmetric: price changes in either direction which leave the price below the Maximum Historical Price have a lower elasticity (-.1 to -.3) than price changes above the MHP (-.7 to -1.2). The larger price elasticities were not used in any EMF 11 scenario.

Non-price related efficiency improvements were not included in the EMF 11 runs. Interfuel substitution and temporal shifts in the economy are treated only implicitly.

IPE

The IPE model calculates consumer demand by adjusting a reference series based on the 1974 OECD demand projections. The base series is adjusted by endogenously-determined oil prices and exogenously set prices of alternative energy sources. The base series is adjusted through the use of two multipliers: one for oil prices and one for alternative energy prices. Each factor includes an exponent, analogous to an elasticity, which represents the impact on oil demand of changes in oil prices or of changes in alternative source availability. The impact of price changes on demand is spread out over a five-year period. Non-price related conservation is incorporated in the model. Price changes are "remembered" in that they continue to affect demand for many years. Conservation also varies inversely with economic growth. Shifts in the economy are included in this conservation term.

ETA-MACRO

The ETA-MACRO model is an intertemporal optimization model in which both consumers and producers have perfect foresight. In each period, consumers maximize their discounted utility of aggregate economic consumption taking into account depletion of exhaustible resources and accumulation of capital from previous periods. Consumers also anticipate future energy scarcities and environmental restrictions. The model includes an autonomous (non-price-related) energy efficiency improvement of 0.5% per year. Two tradeoffs are explicitly represented with elasticities of substitution: capital/labor vs. energy inputs, and electric vs. non-electric energy demand. A one-sector model of the non-energy economy is used; therefore shifts in the economy to less energy-intensive industries are not modeled explicitly. Such shifts can be incorporated through the autonomous efficiency improvement parameter.

Penn-BU

The Penn-BU model interfaces with a detailed world macroeconomic model (Project LINK) in which the level of economic activity is calculated separately for 79 countries based on exogenous and endogenous variables such as population, productivity, capital formation, etc. Economic activity is disaggregated by industrial sector, and oil prices are an important determinant of economic activity in many sectors. The levels of economic activity forecast for each nation are coordinated via an international trade matrix which ensures that global economic production equals consumption. Oil demand is calculated from individual nations' demands and the international trade matrix. The individual nations' demands are calculated from the forecast for economic activity and oil prices. Shifts in the economy are represented via the disaggregation of economic activity in the macroeconomic model.

CERI

In contrast to many EMF 11 models, CERI models the effect on demand of product prices instead of crude oil prices. Product demand is determined using a Koyck-transformed, constant-elasticity equation which includes the refined product price, forecasted regional economic growth, and previous changes in product demand. Product and regional price elasticities were based on the econometric literature. No non-price related technical change is included in the model. Sectoral shifts in the economy and interfuel substitution are represented in the model only through price and income elasticities. However, short- and long-run income elasticities are less than 1 for both OECD and Market Economies, indicating that as GDP increases, oil consumption increases by less than a proportional amount. These elasticities therefore suggest that a smaller share of GDP is generated from energy-intensive industries as the economies grow.

HOMS

The HOMS demand equation is a linear Koyck-lag function in demand intensity. The long-run demand intensity is either linear or log-linear (constant elasticity) in price. Base GNP growth is exogenous. There is a feedback effect of oil prices on GNP -- that is, oil price affects demand both directly (through the crude-oil price elasticity) and indirectly (by affecting GDP level which in turn enters the demand equation).

The model does not represent any non-price related conservation. HOMS is an oil-only model and interfuel substitution is modeled implicitly in the current oil price and price elasticities. Sectoral shifts in the economy are also represented only implicitly. The income elasticities for WOCA (Market Economies) and OECD are 1.0, indicating that the share of GDP from oil-intensive industries does not change as the economy grows. The linear form of demand does include a large one-time shift in long-run intensity targets which was estimated from post-1980 data and applied to forecast years after 1980. This shift corresponds to a permanent reduction in the oil intensity of new equipment.

<u>FRB Dallas</u>

The FRB Dallas model represents market economies' oil demand as a function of price, expected prices and GDP. Expected prices are modeled as a polynomial distributed lag of past changes in price. The model's representation of demand is adapted from an econometric analysis of OECD oil demand and from Carol Dahl's survey (1991) of oil demand elasticities for LDC's.

Oil demand is estimated separately for four regions within the OECD. The demand in each region is estimated as a function of GDP and a polynomial distributed lag of price. Estimated price elasticities for each region are given in the "Summary of Demand Models" table. The GDP elasticity of oil demand was not found significantly different from 1.0 for the OECD countries. This elasticity was set at 1.0 for all five regions modeled.

Econometric tests were performed with data for the four OECD regions to look for indication of autonomous efficiency improvements, asymmetric responses to price movements and sectoral shifts in the economy over time. No significant effects were found. The model runs performed for EMF 11 include no representation of these phenomena.

<u>DFI</u>

The DFI model incorporates an exogenous demand curve based on EIA projections.

<u>WOMS</u>

Oil demand in the WOMS model is determined using a Koyck-lag function including GDP, lagged GDP, crude oil price and lagged oil demand. International exchange rates and non-price related conservation are also explicitly included in the demand function. Conservation is incorporated exogenously by adjusting the demand projection by a linear trend set to reach a target level by given year. For the EMF runs this level was 0 in the year 2000.

Demand is estimated as relatively insensitive to price in the short run (Market Economies short-run elasticity = -0.04) and relatively sensitive in the long run (Market Economies long-run elasticity = -1). The lags are extremely long: it is estimated that half of the price-change induced capital stock adjustment takes 17 years for the Market Economies and 29 years for the OECD countries.

Sectoral shifts in the economy and interfuel substitution are not represented explicitly in the model. However, short- and long- run income elasticities for OECD and Market Economies are equal to 1, indicating no significant shift toward a less energy-intensive economy.

BP America

The influence of price changes on demand in the BP America model is calculated using a aggregate energy price elasticity and the relative prices of oil products and competing fuels in each sector. Three sectors are represented in the OECD demand calculation: transportation, power generation, and other uses. For non-OECD demand a one-sector model is used. The effects of past price changes on demand and non-price related technical change also vary by sector.

Energy-GNP feedback is not represented in the model, nor are shifts in the economy over time to less energy-intensive industries. Interfuel substitution is explicitly represented through the relative prices of competing fuels. Additional fuel switching occurs in the model if oil prices surpass exogenously set thresholds.

APPENDIX A

In the recursive simulation models, OPEC, using its monopoly power, sets the price of oil by adjusting its production capacity utilization. The price of oil follows the price reaction function

$$\frac{[P(t)-P(t-1)]}{P(t-1)} = a + \frac{b}{[1-\textit{expected capacity utilization during } t-1]}$$

The proportional increase in oil price rises nonlinearly as capacity utilization rate decreases. Since the intercept a is negative, there exists a target utilization rate where oil prices tend to neither rise nor fall.

The short-run supply equation for each particular region in OMS and other models using reference projections is

$$s(t) = m(t) * P(t)^{e(t)}, * s(t-1)^{a}$$

e(t) is the short-run price elasticity and a is the lag coefficient. Price and supply are valued with respect to a reference value. Thus, supply is a log-linear weighted average of the previous periods supply and the response to current prices. A similar equation applies to determining oil demand per dollar of GNP, where the parameter a is negative.

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Chapter 5

INFERRED DEMAND AND SUPPLY ELASTICITIES FROM A COMPARISON OF WORLD OIL MODELS

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INTRODUCTION

Analyses of oil markets frequently depend upon a relatively small set of important parameters governing the response of oil supplies and demands to prices and economic growth. Analysts must assign these parameter values from a limited historical experience that includes several sharp shifts in oil market and economic trends. As a result, one finds a range of plausible parameter values being used by oil policy analysts that can often lead to quite different perspectives on oil market trends and the effectiveness of various policies to reduce dependence upon insecure oil supplies.

This paper summarizes the responses of oil supply and demand to prices and income in 11 world oil models that were compared in a recent Energy Modeling Forum (EMF) study. In May 1989, the EMF commenced a study of international oil supplies and demands (hereafter, EMF 11) to compare alternative perspectives on supply and demand issues and how these developments influence the level and direction of world oil prices. In analyzing these issues, the EMF 11 working group relied partly upon results from 11 world oil models, using standardized assumptions about oil prices and gross domestic product (GDP). During the study, inferred price elasticities of supply and demand were derived from a comparison of results across different oil price scenarios with the same GDP growth path. Inferred income elasticities of demand were derived from a comparison of results across different economic growth scenarios with the same oil price path. Together, these estimates summarize several important relationships for understanding oil markets.

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The next section provides some background on the EMF study and on general trends in the scenarios of interest that help to understand the results. The following sections explain the derivation and qualifications of the inferred estimates, report the results, and summarize the key conclusions.

THE EMF STUDY

Purpose and Approach

The eleventh Energy Modeling Forum study analyzed the factors determining the long-run trends in the international oil market over the next two decades. Such issues included the growth in world oil demand, the prospects for supplies outside OPEC, and the long-run implications of these demand and supply trends for the world's dependence on oil from OPEC member countries and particularly from the Persian Gulf. From its inception, the study was not designed to focus on the short-run impacts of disruptions on oil markets. Nor did the study attempt to provide just a single view of the likely future path for oil prices.

As in previous EMF studies, the research was conducted by an ad hoc working group of more than 40 leading analysts and decisionmakers from government, industry, academia, and other research organizations. In the EMF process, the working group pursues the twin goals of: (1) improving the understanding of the capabilities and limitations of existing energy models and (2) using these models to develop and communicate useful information for energy planning and policy.[1] The group is guided in the pursuit of these goals by a set of design principles: (1) a model user orientation maintained by active user involvement in the development of the study; (2) a comparison of the capabilities and limitations of many models rather than a detailed evaluation of a single model; (3) an issue focus that directs and guides the study by applying the models to an important energy problem; (4) broad participation by a number of people in selecting the topic, forming the working group, analyzing the results, and disseminating key findings; and (5) decentralized analysis of scenarios by proprietors familiar with the individual models.

The group met four times over the 1989-90 period--prior to the Iraqi invasion of Kuwait--to develop a study plan with a set of carefully selected scenarios, analyze model results and supporting analysis, and develop key conclusions and insights. Eleven economic models of the world oil market were run by their proprietors at their home institutions using standardized assumptions for 12 different scenarios. These results were reported to the EMF staff and formed the basis of the group's indepth comparison of alternative perspectives on the world oil market.

Scenarios and Models

Only six of the 12 scenarios are analyzed in this paper. They were developed to analyze differences in oil demand and supply projections based upon standardized assumptions for the oil

[1]The EMF process and key findings from previous studies have been discussed extensively in several papers, e.g., see Huntington et al (1982).

price and economic growth. Specific model assumptions about OPEC's behavior or responses to market conditions are excluded from these scenarios. These results help to interpret the results from scenarios where supply and demand conditions, including OPEC production decisions, are allowed to determine oil prices endogenously in each model. Three cases assume a flat oil price path with different GDP growth assumptions--low, base, and high. Another three cases use the same three economic growth assumptions with a rising oil price path.[2]

The models in the study were developed to prepare long-run projections of oil prices, oil production, and oil consumption and to study changes in these variables under alternative scenarios. They incorporate the behavior of three distinct agents: oil consumers, oil producers outside the cartel, and oil producers within the cartel. Oil consumers respond to Gross Domestic Product (GDP),[3] energy-saving trends in technology or economic structure (if present), and oil prices. The response of oil producers outside the cartel is governed by assumptions about trends in resource depletion and technology in addition to oil prices. In most models, the cartel's productive capacity is exogenous, based upon modeler judgment of a combination of economic and political constraints.[4] The cartel sets a price based upon last period's price and rate of utilization of its capacity. In this way, oil prices, production, and consumption are determined recursively; market conditions in one year influence those in the succeeding year.

The main model features of interest to the elasticity estimates in this paper are summarized in Table 1.[5] Most are simulation models that determine oil prices recursively in the manner described above. ETA-Macro and DFI-CEC are optimization models that endow oil producers and/or consumers with perfect foresight. The first assumes that both oil producers and consumers maximize the discounted utility of total consumption of all goods and services; the latter assumes that producers maximize total discounted oil profits. These models require explicit assumptions about resource cost curves--the amount of recoverable resources ultimately available at different prices.

The table also compares the models in terms of periodicity, horizon (last year in the projection), number of supply and demand regions, and whether the supply and demand

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[2]The other six scenarios included three based upon an exogenous oil price path and three in which market-clearing prices were determined by each model. See Huntington et al (1989) for more information on the assumptions in all 12 scenarios.

[3]Shifts in the economies' structures are seldom incorporated explicitly, although a macroeconomic model linked to the Penn-BU model contains such detail.

[4]Capacity is endogenous in Penn-BU, IPE, and ETA-Macro. DFI-CEC uses an OPEC resource curve directly without any capacity constraint.

[5]This table is based upon a comparison of model structures reported by Kress et al (1990). Beider (1982) also provides a very useful comparison of similar modeling approaches used in a previous EMF study, including the distinction between recursive simulation and intertemporal optimization approaches.

Table 1. Key Features of Models

	OMS	IPE	ETA-MACRO#	PENN/BU	WOMS	CERI	HOMS	FRB DALLAS	DFI-CEC	BP AMERICA	Gately
Model Type	Recursive Simulation	Recursive Simulation	Intertemporal Optimization	Recursive Simulation	Recursive Simulation	Recursive Simulation	Recursive Simulation	Recursive Simulation	Intertemporal Optimization	Recursive Simulation	Recursive Simulation
Perfect Foresight	No	No	Producers and consumers	No	No	No	No	No	Producers	No	No
Periodicity	Annual	Annual	10-years	Annual	Annual	Annual	Annual	Annual	5-Years	Annual	Annual
Horizon	2010	2000	2100	2010	2010	2010	2010	2010	2032	2010	2010
Regions -Supply -Demand	7 6	3 7	5 5	10 5	4 3	17 7	3 6	3 7	7 5	4 2	7 5
Parameters -Supply -Demand	Judgment Judgment	Judgment Judgment	Judgment Judgment	Econometric Econometric	Econometric Econometric	Econometric Judgment	Econometric Econometric	Econometric Econometric	Judgment Judgment	Econometric Econometric	Judgment Ecometric
Participating Modeler	Mark Rodekohr	Nazli Choucri	Alan Manne	Robert Kaufmann and Peter Pauly	Nicholas Baldwin and Richard Prosser	Anthony Reinsch	William Hogan and Paul Leiby	Stephen P.A. Brown	Dale Nesbitt	Lakis Vouyoukas	Dermot Gately
Organization*	U.S. Energy Information Administration	M.I.T.	Stanford University	University of Pennsylvania & Boston University	PowerGen	Canadian Energy Research Institute	Harvard	FRB-Dallas	Decision Focus, Inc.	BP America	New York University

* Organization of individual (s) who developed and exercised the model during the study. Listed for identification purpose. Model and results do not necessarily reflect organization's views.

This version of ETA-Macro is also called Global 2100.

parameters are direct econometric estimates or are determined judgmentally based upon a reading of the available literature on energy demand responses. The institutional affiliation listed in Table 1 is provided to identify the model and not to indicate an official modeling framework of a particular organization. This caveat applies particularly to BP America, WOMS, and the Federal Reserve Bank of Dallas, as well as the various university models.

Most models report prices and supply-demand balances annually and focus exclusively on world oil markets. Alternative fuel prices and interfuel substitution are not explicitly represented but instead are implicitly incorporated through the own-price elasticity for oil.[6] (This assumes that both the relationship between oil and other fuel prices and the potential for interfuel substitution will remain the same as in the past.) An exception to this general paradigm, ETA-Macro focuses on the interactions between electricity, fossil fuels, and the economy in the very long run, embodying specific parameters for substitution between energy and nonenergy inputs as well as for substitution within energy between electricity and fossil fuels.

Demands and Supplies with the Flat Price Path

The EMF 11 working group considered several very different sustained, long-run paths for the world oil price. Current oil prices (December 1990) have been driven far above these assumed paths by the Iraqi invasion of Kuwait and could become quite volatile with military conflict. Eventually, however, many analysts expect that once the situation is resolved, market forces will return oil prices to substantially lower prices. Thus, these price trajectories should be viewed as establishing a reasonable range for the long-run, sustained path over the next several decades.

A flat oil price case assumes that the US refiner acquisition cost for imported oil rises from $14.70 in 1988 to $18 per barrel in 1989 (all prices are in 1988 $) and remains at that level through 2010. A rising oil price case assumes that this oil price rises gradually to $36 per barrel by 2000 and remains at that level through 2010. In both scenarios, GDP for the market economies is assumed to grow by 2.9% p.a. through the period, with higher economic growth (4.1% p.a.) outside the OECD countries. In both the flat and rising price scenarios, OPEC is considered to be a residual supplier of oil, meeting all the oil demand that remains unsatisfied by non-OPEC production.

It should be emphasized that modelers were requested not to impose any shifts in government policies in running these cases. Many working group members thought that oil-importing countries would impose taxes and other conservation policies to limit their oil demands. Thus, the EMF scenarios should be considered as revealing the pressures that would emerge under alternative oil price and GDP paths if no such policies were implemented.

Table 2 summarizes the trends for OECD demand, Market Economies demand, Non-OPEC production, and the residual demand for OPEC oil in the three scenarios based upon the flat oil

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[6]BP America and Penn-BU are exceptions. For the latter, interfuel substitution is incorporated in a detailed macroeconomic model linked to the world oil model.

Table 2. Consumption, Production, and Call on OPEC (MMBD) with Flat Oil Price Path

(Model Averages)

Flat Oil Price

	1990	2000	2010	%change (p.a.) '90-'00	%change (p.a.) '90-'10
Consumption					
OECD	38.3	46.9	58.1	2.0%	2.1%
Mkt Econ	52.6	66.3	85.6	2.3%	2.5%
Production					
Non-OPEC	28.5	25.5	20.7	-1.1%	-1.6%
CPE Exports	1.9	1.1	0.6	-5.4%	-5.3%
Call on OPEC	22.2	39.7	64.3	6.0%	5.5%
OPEC Share	42.3%	59.9%	75.1%		

Flat Price with High GDP

	1990	2000	2010	%change (p.a.) '90-'00	%change (p.a.) '90-'10
Consumption					
OECD	38.8	51.0	68.1	2.8%	2.9%
Mkt Econ	53.2	72.6	102.5	3.2%	3.3%
Production					
Non-OPEC	28.5	25.6	20.7	-1.1%	-1.6%
CPE Exports	1.9	1.0	0.4	-6.2%	-7.1%
Call on OPEC	22.8	46.1	81.3	7.3%	6.6%
OPEC Share	42.9%	63.4%	79.4%		

Flat Price with Low GDP

	1990	2000	2010	%change (p.a.) '90-'00	%change (p.a.) '90-'10
Consumption					
OECD	37.9	43.0	49.7	1.3%	1.4%
Mkt Econ	51.9	60.5	71.8	1.5%	1.6%
Production					
Non-OPEC	28.5	25.5	20.6	-1.1%	-1.6%
CPE Exports	1.9	1.2	0.8	-4.6%	-4.0%
Call on OPEC	21.6	33.8	50.4	4.6%	4.3%
OPEC Share	41.5%	55.9%	70.1%		

Note: The results are averages for all models that report all components in table. ETA-Macro is excluded from the averages in this table because it did not report market economies consumption and Non-OPEC production in the study. Penn-BU is excluded because it did not report OECD consumption. IPE results are included for 1990 and 2000 but are unavailable for 2010.

price path.[7] The alternative scenarios represent a high GDP case (GDP for market economies grows by about 1 percentage point higher) and a low GDP case (GDP grows by about 1 percentage point lower). Although the table reports model averages only, there exists a wide variation in results across models in these scenarios.

The projected supply and demand levels for the flat oil price paths reveal the strong pressure for OPEC members to either expand production rapidly or increase prices. All scenarios imply substantially higher oil demands, modestly declining non-OPEC supplies, and rapidly growing dependence upon OPEC sources. With the baseline GDP assumptions shown in the upper rows, OECD oil consumption would grow from 38 MMBD in 1990 to 47 MMBD by 2000 and to 58 MMBD by 2010. Consumption by the market economies, which includes the less developed countries (LDCs), would grow even more rapidly, reaching 86 MMBD by 2010. Non-OPEC production would decline modestly through 2000 (to 25 MMBD), falling more precipitously during the initial decade of the next century. The call on OPEC production resulting from these above trends would climb rapidly to 40 MMBD by 2000 and to 64 MMBD by 2010. Demand for OPEC production with the flat price would increase by 6.0% p.a. between 1990 and 2000. If OPEC were simply to meet this demand at the $18 price, dependence upon OPEC sources would quickly increase to 70% or more by 2010.

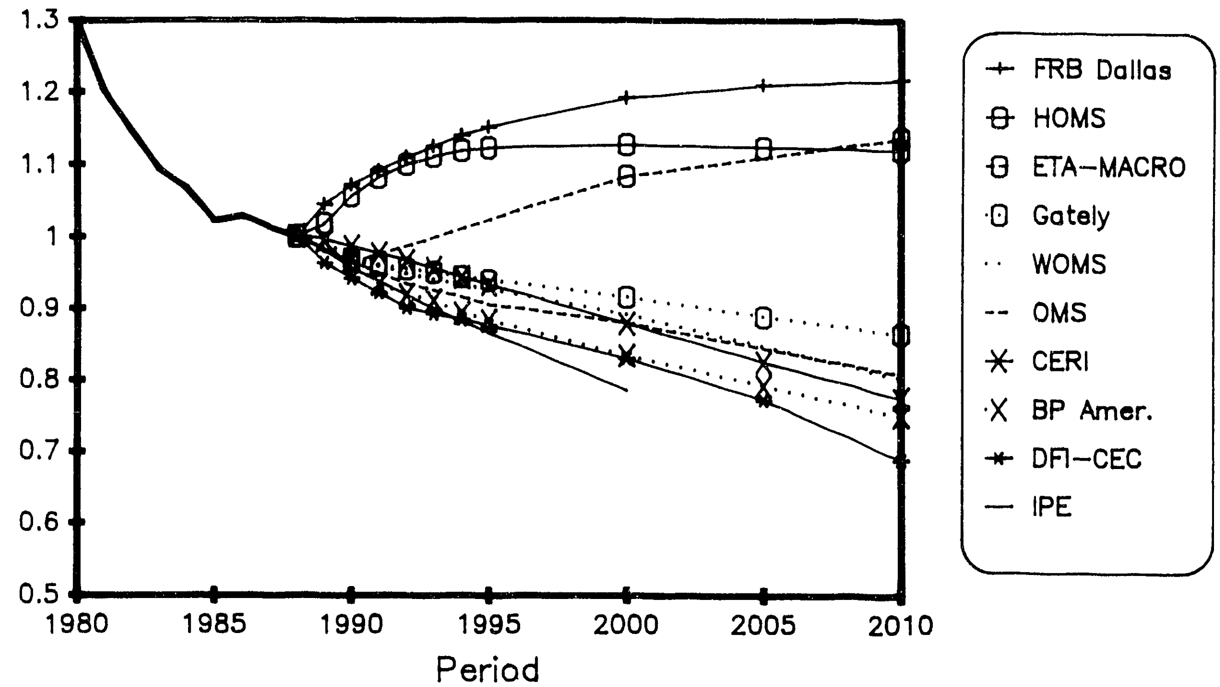
In the projections immediately below these results in Table 1, the higher GDP path would accentuate these trends by raising world oil demand, increasing the call on OPEC to 46 MMBD in 2000 and to 81 MMBD in 2010. The lower GDP path would reduce significantly the level of OPEC production to 34 and 50 MMBD, respectively, for these two years. This second scenario would still require a 4.6% per annum growth in OPEC production over the next decade.

Although not shown in this table, differences in demand projections among models dominate differences in production outside OPEC. In 2000, demand in the market economies varies by more than 30 MMBD across models, while non-OPEC supply varies by about 7 MMBD. Thus, variations in demand have a critical effect on the different calls on OPEC observed in the various models.

The range of demand projections is emphasized quite dramatically in Figure 1, which shows the oil-GDP ratio for the OECD countries continuing its historical decline of the last two decades in six of the nine models under the flat price scenario. By 2010, the oil intensity falls by 20-25%, or by 1.0% to 1.3% p.a. Three models--HOMS, ETA-Macro, and the Federal Reserve Bank (FRB) of Dallas--show the oil intensity as initially rising before leveling out with the flat oil price path. All three models assume that oil demand grows 1% for each 1% increase in economic output, holding energy prices constant. The other models assume further declines in oil intensity with future economic growth. Both HOMS and FRB Dallas are based upon explicit econometric modeling of the demand response to oil prices and GDP. Neither represents any oil efficiency

[7]Reflecting traditional data-collection procedures, the models (except ETA-Macro) exclude oil supplies and demands in the Soviet Union, Eastern Europe, and China. Net exports from these regions are an assumption.

Figure 1. OECD Oil-GDP Ratio With Flat Price (1988 = 1)



improvements over time because neither modeler found evidence for oil-saving technological progress. ETA-Macro uses demand responses that are based upon a reading of the available econometric evidence, but allows for oil efficiency improvements of 0.5% p.a.[8]

Demands and Supplies with the Rising Price Path

Table 3 shows the average projection for consumption, Non-OPEC production, and the call on OPEC when oil prices rise gradually from $18 to $36 through 2000 and remain at that higher level after 2000. For comparison with the previous results, Table 3 also reports supply and demand levels for this alternative price path with high and low GDP assumptions.

Lower calls on OPEC result in the three scenarios based upon the rising oil price path than in those based upon a flat oil price path. The average net demand with the baseline GDP reaches only 25 MMBD in the rising price case by 2000, compared to 40 MMBD in the flat price

[8]A more comprehensive decomposition of these differences is reported in Energy Modeling Forum (1990). This decomposition separates the OECD oil demand projections for each model in the flat price case into several components: the response to GDP changes; the momentum caused by past price changes which continue to influence demand decisions through a lagged adjustment process; and autonomous energy efficiency improvements (AEEI) that accrue over time and are unrelated to either future or past price changes. The momentum effect contributed importantly to the higher demand projections of HOMS and FRB-DALLAS, particularly in the early years. AEEI includes shifts in economic structure away from energy-intensive sectors as well as the emergence of new technologies and processes introduced for reasons other than price.

Table 3. Consumption, Production, and Call on OPEC (MMBD) with Rising Oil Price Path

(Model Averages)

Rising Oil Price

	1990	2000	2010	%change (p.a.) '90-'00	%change (p.a.) '90-'10
Consumption					
OECD	37.7	38.8	44.3	0.3%	0.8%
Mkt Econ	51.7	55.9	67.0	0.8%	1.3%
Production					
Non-OPEC	28.2	29.8	28.2	0.5%	-0.0%
CPE Exports	1.9	1.1	0.6	-5.3%	-5.2%
Call on OPEC	21.6	25.0	38.2	1.5%	2.9%
OPEC Share	41.8%	44.8%	57.0%		

Rising Price with High GDP

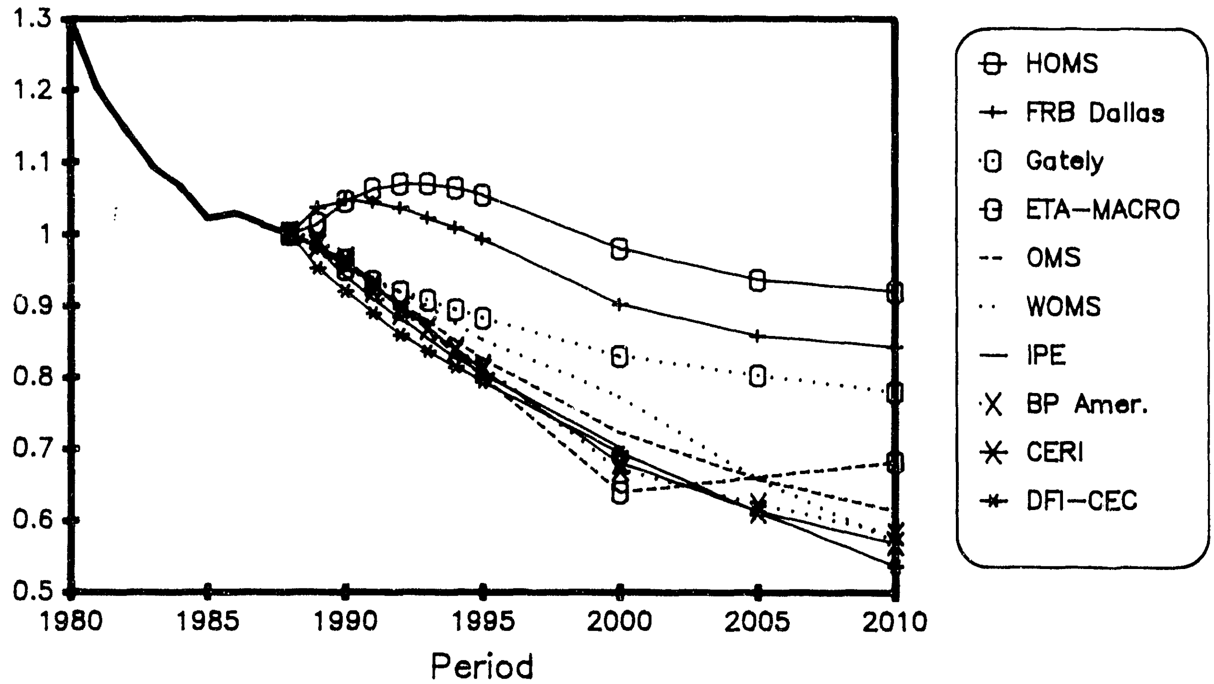
	1990	2000	2010	%change (p.a.) '90-'00	%change (p.a.) '90-'10
Consumption					
OECD	38.1	42.4	51.9	1.1%	1.5%
Mkt Econ	52.3	61.4	80.1	1.6%	2.2%
Production					
Non-OPEC	28.2	29.8	28.2	0.6%	-0.0%
CPE Exports	1.9	1.0	0.4	-6.1%	-7.2%
Call on OPEC	22.3	30.6	51.5	3.2%	4.3%
OPEC Share	42.5%	49.8%	64.3%		

Rising Price with Low GDP

	1990	2000	2010	%change (p.a.) '90-'00	%change (p.a.) '90-'10
Consumption					
OECD	37.2	35.3	37.9	-0.5%	0.1%
Mkt Econ	51.0	50.7	56.2	-0.1%	0.5%
Production					
Non-OPEC	28.2	29.7	28.1	0.5%	-0.0%
CPE Exports	1.9	1.3	0.9	-4.1%	-3.4%
Call on OPEC	20.9	19.7	27.1	-0.6%	1.3%
OPEC Share	40.9%	38.9%	48.2%		

Note: The results are averages for all models that report all components in table. ETA-Macro is excluded from the averages in this table because it did not report market economies consumption and Non-OPEC production in the study. Penn-BU is excluded because it did not report OECD consumption. IPE results are included for 1990 and 2000 but are unavailable for 2010.

Figure 2. OECD Oil-GDP Ratio With Rising Price (1988 = 1)



case. As a result, OPEC production increases by a relatively modest 1.5% p.a. through 2000 in the rising price scenario.

As expected, the rising price path encourages more non-OPEC production than in the flat price scenarios. The mean estimate calls for a relatively stable production path of 28 to 29 MMBD through the period. Meanwhile, oil demand in the market economies grows noticeably slower than with flat prices. Flat OECD consumption and moderately increasing demands for the market economies and for OPEC production result when high oil prices are combined with low economic growth.

Figure 2 shows that the oil-GDP ratio declines under the rising price assumptions for all but two models. By 2010, the oil intensity (indexed to 1 in 1988) declines by 30-40%, or by 1.6% to 2.3% p.a. The exceptions are HOMS and FRB-Dallas, both of which reveal oil intensities by 2010 that are not much lower than those in 1988. During the early 1990s in these models, oil intensity increases in response to the price declines of the 1980s. Later in the period, oil intensities begin to fall as future oil prices move higher.

ETA-Macro's oil intensity trend is substantially different with rising than with flat oil prices. With higher prices, it follows the pattern set by most models and declines throughout the period. This trend contrasts sharply with the oil intensity trends for the rising oil price case (Figure 1), where ETA-Macro joined HOMS and FRB-Dallas in showing rising or flat oil-GDP ratios through 2010. The sharp swing in this model from a falling intensity in the rising price case to a rising intensity in the flat price case reflects a strong demand response to price, as will be discussed in the next section on inferred estimates of price elasticities.

ELASTICITY ESTIMATES

The general oil supply and demand trends associated with the several rising and flat price scenarios were discussed above. In this section we report some elasticity estimates that summarize the responses of oil supplies and demands to changes in price and income based upon these scenarios. Price elasticities of oil supply and demand for each model are derived implicitly from a comparison of the quantity and price results from the rising and flat price scenarios. Inferred elasticities are computed as the ratio of the percent difference in the quantity demanded or supplied between the two scenarios and the percent difference in the crude oil price in the same year. GDP levels are held constant across these two scenarios. Income elasticities of oil demand for each model are derived implicitly from a comparison of the quantity and GDP results from the flat and the high GDP (with flat price) cases. They are computed as the percent difference in oil quantity between the two scenarios, divided by the percent difference in GDP levels in the same year. Oil prices are held constant across these two scenarios.

Uses and Qualifications

These estimates are quite useful for understanding the pressure on long-run oil prices to change in response to shifts in shifts in supply and demand conditions. For example, the mean results in Table 2 indicated rising oil demand with limited expansion in oil supplies outside OPEC with a flat oil price path. If OPEC producers also limit oil supplies, market pressures would push oil prices upward over the long run--a result that is evident in the endogenous oil price scenarios that the participating modelers ran during the study. How much prices would increase depends partly upon the size of the supply and demand shifts and partly upon the response of supply and demand to price. Limited price sensitivity requires larger increases in oil prices to re-establish an oil market equilibrium after the supply and demand shifts. Thus, price elasticities of supply and demand play an important role in shaping long-run oil price projections from any particular model.

These estimates also help elucidate how different production strategies influence the income of cartel producers exercising monopoly control. While cartel producers may have other objectives, income is likely to remain an important criteria in their decisionmaking. In any particular year, reduced cartel production will generate additional revenue if prices rise proportionately more than the cartel's output declines. Again, prices will tend to increase more with a given reduction in cartel output when world consumers and other producers outside the cartel are less sensitive to price and when the cartel's market share is greater. Ignoring extraction costs that are likely to be minimal, income for the period would be maximized when the net demand for cartel output possesses a unitary price elasticity. Income over the planning horizon, of course, would also depend upon the timing of revenue receipts and the cartel's discount rate.

Elasticity estimates are also useful for evaluating the effects on oil markets of various policies introduced in major oil-consuming countries to reduce imports and prices. Taxes on petroleum consumption will have a smaller impact on domestic national wealth when price-induced substitution away from oil is more extensive. Moreover, taxes will have a greater depressing effect on world oil prices, and hence a smaller impact on domestic prices (including the tax), when domestic demands are more price sensitive and supplies and foreign demands are less price sensitive.

While the inferred elasticities are quite useful summaries of the responses for each model, they must be interpreted carefully. Oil demand adjusts slowly to price as the capital stock turns over so that the complete adjustment to price (i.e., the long-run response) is not observed for many years. This problem is compounded by the fact that higher oil prices are phased in gradually over 12 years in the EMF rising price scenario. In most models, consumers are assumed to consider current (and past) prices, but not to look ahead at future prices. Thus, for over half the period, demand decisions are being made on the basis of prices below $36, the price level used in estimating the inferred elasticity for 2000 and beyond. By overstating the price change upon which decisions are made, the inferred elasticities will be understating the true elasticity. Finally, we should note that the elasticities need not be constant in all relevant price ranges, but may in fact depend upon the price level.

It should be emphasized that the EMF 11 estimates are for crude oil and not for petroleum product price elasticities. When refinery margins and taxes remain relatively stable in dollars per barrel, delivered product prices will change proportionately less than crude oil prices. Under these conditions, the crude price elasticity will be smaller, being approximately equal to the product price elasticity times the ratio of the crude to product prices. Such conditions appear to apply to U.S. oil markets. Given current prices within the U.S., crude elasticities are approximately one-half product elasticities.

P[illegible]sticities of Demand

[illegible]able 4 reports the average price elasticities of demand inferred from the EMF scenarios for the United States, OECD, non-OECD countries, and all market economies. The table contains estimates for the demand response after the first, tenth, and twentieth years.[9]

The results reveal several conclusions. First, the responses for the U.S. appear quite similar to those for all OECD countries. Price elasticities are approximately -0.1 after the first year, rising to -0.4 or -0.5 after 20 years of adjustment in the capital stock. Second, these estimates appear comparable to several recent econometric studies that have estimated the demand response to crude oil price changes in the U.S. (shown at the bottom of the table). It is not surprising that the Brown & Phillips estimates are similar because those estimates are precursors

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[9]The choice of initial year (1989 or 1990) depends upon how the price change was implemented in each model. The 10th and 20th-year estimates were calculated from results for 2000 and 2010, respectively.

Table 4. Inferred Crude Oil Price Elasticities of Demand

(Average Model Responses)

	1-YR	10-YR	Long-Run/ 20-YR
U.S.	-.10	-.33	-.44
OECD	-.12	-.34	-.47
Non-OPEC LDCs	-.11	-.21	-.30
Market Economies	-.10	-.26	-.38
Estimates from Other Studies on U.S. Demand:			
Crude Oil			
Gately-Rappoport (1988)	-.07	-	-.38
Brown-Phillips (1989)[a]	-.11	-	-.56
Gasoline			
Dahl (1986)[b]	-.29	-	-1.02

Notes: Elasticities are derived from the EMF rising and flat oil price scenarios. See text for derivation and qualifications.
[a] 1-quarter elasticity equals -.08.
[b] Survey of other studies. Average 1-quarter elasticity is -.13.

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to the FRB Dallas model being used in EMF 11. Also, shown in this table are the means reported by Dahl in her survey of U.S. gasoline demand studies. The first-year and long-run responses of -0.29 and -1.02, respectively, correspond roughly to crude oil price elasticities of -0.15 and -0.50, given recent crude oil and U.S. refined product prices. And third, the estimated price elasticities are lower outside than within the OECD. It should be emphasized, however, that the modeling of oil demand in the developing countries is very rudimentary given the existing data for these regions. Since much less effort has been expended to estimate oil demand parameters for these countries, one must be cautious in drawing conclusions from these estimates.

Estimated price elasticities are reported for each model in Appendix Table A.1. For the most part, long-run elasticities cluster in the -0.3 to -0.5 range for US and OECD demand. ETA-Macro and an alternative version of HOMS (HOMS-1) have substantially higher long-run price elasticities in the -0.8 range, while Gately and IPE reveal considerably smaller than average responses.

The higher response in HOMS-1 directly reflects the alternative assumptions used to estimate oil demand from historical data. This version assumes that all declines in oil intensities over the last two decades can be attributed to higher oil prices operating with a considerable lag as the capital stock is replaced. The version reported as HOMS[10] in the EMF study assumes that the structure of oil demand was permanently altered in 1980, resulting in a one-time improvement in oil use efficiency independent of the oil price. Thus, part of the price effect in HOMS-1 is attributed to other causes in HOMS.

The higher price response in ETA-Macro may depend upon its focus on all energy rather than oil alone, as in the other models. This model explicitly incorporates the interfactor substitution between energy and nonenergy inputs as well as interfuel substitution between oil and other energy forms. In addition, the model's substitution response to various prices is not estimated directly from historical data but instead is set judgmentally based upon a reading of estimates from other studies.

The lower price response in the Gately model results from assumed asymmetries in the demand response to price changes. Due to large capital costs, investment in energy-conservation measures is not undone when prices fall from previously high levels, so that demand would not change very much. Nor does such investment need to be added back when prices begin to recover and rise again, resulting in very little decline in demand. However, if prices were to exceed their historical maximum (which are not reached in the EMF scenarios), the price response would increase as new opportunities for investment in conservation would emerge.

Income Elasticities of Demand

Table 5 reports the average inferred income elasticities of demand for the United States, OECD, non-OECD developing countries, and all market economies. The table contains estimates for the demand response after the first, tenth, and twentieth years.

The mean long-run elasticities for these models lie in the 0.8-0.9 range for all regions. This result suggests some improvement in oil efficiency in these economies over time even without higher oil prices, because oil consumption grows more slowly than economic output. As reported in the appendix, however, the inferred income elasticities differ widely across models. Income elasticities in the range of unity are found for both versions of HOMS, FRB-Dallas, WOMS, BP-America, and ETA-Macro.[11] The 20-year income elasticities for the remaining models average 0.6 for both the OECD countries and market economies.

Most models with a unitary income elasticity also revealed a trend effect towards declining oil intensity that is unrelated to changes in either past or future oil prices or income.[12] These

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[10]The HOMS modelers do not prefer one specification over the other. The choice of which version to use as the main HOMS entry in the EMF study was arbitrary.

[11]ETA-Macro assumes an income elasticity of unity but did not run the scenarios that would reveal an inferred income elasticity. Its responses are not reported in the appendix tables.

[12]This information was ascertained by comparing two separate scenarios based upon the flat oil price path that (a) eliminated any economic growth, and (b) eliminated both any economic growth and any time trend towards improved oil efficiency independent of oil prices.

Table 5. Inferred Income Elasticities of Demand

(Average Model Response)

	1-YR	10-YR	Long-Run/ 20-YR
U.S.	.87	.85	.86
OECD	.88	.86	.88
Non-OPEC LDCs	.78	.88	.92
Market Economies	.72	.81	.85
Estimates From Other Studies of US Demand			
Crude Oil			
Gately-Rappoport (1988)[a]	.60	-	-
Brown-Phillips (1989)[b]	1.13	-	-
Gasoline			
Dahl (1986)[c]	.47	-	1.38

Notes: Elasticities are derived from the EMF High GDP (with Flat Prices) and Flat Price Scenarios.

See text for derivation and qualification.

[a] Estimated from annual data, 1949-85. Long-run income elasticity equals the first-year elasticity.

[b] Estimated from quarterly data, 1972:1-1988:1. Long-run income elasticity equals the first-year elasticity.

autonomous improvements in oil efficiency incorporate the adoption of newer more energy-efficient technologies or processes for reasons other than oil prices. In addition, the trend includes shifts in the economic structure away from energy-intensive industries. As a result, these models joined the group of models with income elasticities below one in projecting oil demand to grow less rapidly than economic growth, even with constant oil prices. Only FRB-Dallas and HOMS (both versions) incorporate a unitary income elasticity without any autonomous improvements in oil efficiency. These two models also indicate the highest demand projections in the EMF scenarios specifying exogenous oil price paths.

Finally, the first-year elasticities are virtually the same as the long-run or 20-year responses for all regions. The appendix reveals that most models follow this trend of relatively constant income elasticities over time. Exceptions are CERI and Penn-BU, in which both price and

Table 6. Inferred Crude Oil Price Elasticities of Supplies
(Average Model Response)

	1-YR	10-YR	Long-Run/ 20-YR
U.S.	.05	.24	.40
OECD	.05	.25	.43
Non-OPEC			
Total	.03	.21	.40
Excluding US	.02	.20	.38

Notes: Elasticities are derived from the EMF rising and flat oil price scenarios. Mean response excludes DFI-CEC, an intertemporal optimization model. See text for derivation and qualifications.

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income responses become stronger over time.[13] The Dahl survey of U.S. gasoline demand (mentioned previously) provides some evidence that income elasticities are larger in the long run than the short run, although the 1.38 long-term estimate can be consistent with the EMF-11 estimates only if other petroleum products are quite income inelastic.[14] The other two studies included in the bottom of Table 5 incorporate an instantaneous adjustment to the long-run income elasticity. They reflect the two alternative views depicted in the EMF estimates. The Gately-Rappoport study reports income elasticities of about 0.6 while the Brown-Phillips study estimates an elasticity that is not significantly different from unity.

Price Elasticities of Supply

Price elasticities of supply for the non-OPEC regions were calculated from the rising and flat price scenarios in a procedure analogous to the one used for the price elasticities of demand discussed previously. The percent difference in quantity produced between the two cases is divided by the percent difference in crude oil prices. Results for 1, 10, and 20-year responses appear in Table 6.

Price elasticities of supply begin a little lower than their demand counterparts (Table 4) but increase over time until the two elasticity estimates are roughly comparable after 20 years. Long-run price elasticities of supply average about 0.4 in each of several regions for which

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[13]The Penn-BU results cause the average income elasticities for the market economies in Table 5 to rise slightly. This model did not report consumption for other regions. Table 5 is based upon averages that exclude IPE and DFI-CEC in order to emphasize the time pattern of the response. DFI-CEC did not report short-run results, and IPE's horizon extends only through 2000.

[14]The surveyed studies generally did not control for the number of drivers. Gately (1990) argues that incorporating this effect would lower the income elasticity by nearly one-half.

responses could be calculated. Long-run responses for total non-OPEC production range from 0.16 (CERI) to 0.64 (HOMS-1), as reported in the appendix. The pattern of the DFI supply elasticity deserves special consideration. Suppliers in the model optimize production over time to maximize discounted profits. In the rising price case, suppliers have incentives to withhold production and extract oil in later years when profits (after discounting) become more attractive. As a result, this model predicts less production in most regions for the rising than for the flat price case in the early years and substantially greater production in the later years.[15]

CONCLUSIONS

The EMF scenarios were designed to analyze international oil supply and demand trends under alternative market conditions. While they were not specified explicitly to reveal precise estimates of the relevant elasticities, the scenarios do offer a unique opportunity to examine the approximate responses embodied in some of the major world oil models used for policy and planning purposes. This information is likely to be of considerable interest to policy analysts and to other world oil modelers.

From this comparison of scenario results, we conclude that the average price elasticity of demand (measured at the crude oil level) in these models is about -0.1 in the short run (after the first year), about -0.3 in the intermediate run (after 10 years), and about -0.4 in the long run (after 20 years). Most long-run estimates lie between -0.3 and -0.5, although several estimates fall either above or below this range.

The evidence on income elasticities is far more diverse. For the most part, the models incorporate the full demand adjustment to income within the first year of a change in GDP. The average estimate of 0.8 for all models is deceiving. Half of the models anticipate no further improvements in oil efficiency as the economy grows, unless oil prices move higher. This result is summarized by an inferred income elasticity of unity for these models. The remaining models show improvements in oil efficiency resulting from future economic growth, reflected by an inferred income elasticity of about 0.6. In addition, several models incorporate an autonomous long-run trend towards oil-saving goods, technologies, and processes, independent of price and income changes. The income effect and the potential for autonomous energy efficiency improvements are particularly fruitful areas for future research on energy demand.

Like their demand counterparts, the price elasticities of supply outside OPEC increase over time as the full adjustment to price changes is incorporated. The average crude oil price elasticity of supply is well below 0.1 in the short run (after the first year), about 0.2 in the intermediate run (after 10 years), and about 0.4 in the long run (after 20 years). Most long-run estimates lie between 0.2 and 0.5, although several estimates fall either above or below this range.

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[15]The model would view the assumed rising and flat oil price paths as being dynamically inconsistent because producers can earn a higher discounted profit in one time period than in another. This factor explains the wide swings in production observed for this model in response to the two exogenous oil price paths.

APPENDIX TABLES

Table A.1. Price Elasticity of Demand Inferred from Rising and Flat Price Cases

United States	1st Year	1995	2000	2005	2010
OMS (EIA)	-0.071	-0.232	-0.283	-0.327	-0.327
Gately	-0.137	-0.146	-0.154	-0.163	-0.171
IPE	-0.039	-0.078	-0.084		
ETA-MACRO			-0.870	-0.778	
CERI	-0.139	-0.296	-0.353	-0.419	-0.440
HOMS	-0.074	-0.162	-0.224	-0.287	-0.308
FRB Dallas	-0.088	-0.323	-0.405	-0.502	-0.537
DFI-CEC	-0.177	-0.171	-0.186	-0.184	
HOMS-I	-0.140	-0.341	-0.456	-0.630	-0.737
Average	-0.098	-0.219	-0.333	-0.359	-0.436
OECD					
OMS (EIA)	-0.130	-0.215	-0.285	-0.360	-0.396
Gately	-0.137	-0.151	-0.160	-0.171	-0.181
IPE	-0.104	-0.161	-0.164		
ETA-MACRO			-0.783		-0.761
CERI	-0.164	-0.311	-0.370	-0.431	-0.446
HOMS	-0.111	-0.205	-0.269	-0.332	-0.354
FRB Dallas	-0.101	-0.326	-0.404	-0.498	-0.531
DFI-CEC		-0.217	-0.258	-0.338	-0.362
WOMS	-0.063	-0.179	-0.208	-0.366	-0.490
BP America	-0.034	-0.181	-0.317	-0.349	-0.368
HOMS-I	-0.205	-0.439	-0.547	-0.713	-0.804
Average	-0.117	-0.238	-0.342	-0.395	-0.469
Non-OPEC LDCs					
OMS (EIA)	-0.106	-0.096	-0.122	-0.170	-0.199
Gately	-0.104	-0.130	-0.144	-0.163	-0.178
IPE	-0.144	-0.133	-0.153		
CERI	-0.126	-0.306	-0.388	-0.494	-0.535
HOMS	-0.098	-0.193	-0.232	-0.292	-0.328
FRB Dallas	-0.228	-0.318	-0.347	-0.386	-0.400
DFI-CEC		-0.098	-0.125	-0.175	-0.191
WOMS	-0.045	-0.071	-0.083	-0.138	-0.178
BP America	-0.058	-0.181	-0.255	-0.329	-0.357
HOMS-I	-0.102	-0.192	-0.232	-0.291	-0.326
Average	-0.112	-0.172	-0.208	-0.271	-0.299

(Table A.1 Continued)

Market Economies	1st Year	1995	2000	2005	2010
OMS (EIA)	-0.094	-0.167	-0.224	-0.288	-0.318
Gately	-0.131	-0.139	-0.147	-0.158	-0.165
IPE	-0.104	-0.143	-0.148		
Penn-BU	-0.013	-0.149	-0.158	-0.243	-0.313
CERI	-0.151	-0.298	-0.360	-0.431	-0.450
HOMS	-0.098	-0.190	-0.244	-0.305	-0.329
FRB Dallas	-0.139	-0.323	-0.388	-0.464	-0.490
DFI-CEC		-0.181	-0.219	-0.288	-0.309
WOMS	-0.025	-0.149	-0.171	-0.299	-0.396
BP America	-0.046	-0.181	-0.295	-0.342	-0.364
HOMS-I	-0.179	-0.362	-0.450	-0.579	-0.648
Average	-0.098	-0.208	-0.255	-0.340	-0.378

Notes:
FRB Dallas, WOMS, and BP America did not report for Non-OPEC LDCs. Their estimates have been derived as the difference in the responses for the market economies and OECD.

DFI-CEC's demand response to price was calibrated to first-round OMS results in this study.

Estimate for 1st year is for the year in which the initial demand response is observed--1990 for OMS, Gately, IPE, and BP America, and 1989 for all others. ETA Macro's demand response begins after 1990, i.e., in 1991, but is reported for every ten years only. Non-OPEC LDC response begins in 1990 for WOMS.

Table A.2. Income Elasticities of Demand Inferred From High GDP (with Flat Price) and Flat Price Cases

United States	1st Year	1995	2000	2005	2010
OMS (EIA)	0.601	0.711	0.731	0.756	0.769
Gately	0.875	0.918	0.936	0.944	0.946
IPE	1.199	1.048	0.972		
CERI	0.626	0.493	0.462	0.503	0.486
HOMS	1.000	1.000	1.000	0.994	1.000
FRB Dallas	1.099	0.968	0.972	0.975	0.991
DFI-CEC		0.646	0.693	0.723	0.627
HOMS-1	1.000	0.984	0.982	0.987	0.995
Average	0.914	0.846	0.844	0.840	0.831
ex. IPE & DFI	0.867	0.846	0.847	0.860	0.864
OECD					
OMS (EIA)	0.801	0.604	0.568	0.594	0.593
Gately	0.751	0.764	0.774	0.782	0.798
IPE	1.397	1.140	1.079		
CERI	0.376	0.371	0.403	0.440	0.458
HOMS	1.000	0.969	0.973	0.976	0.978
FRB Dallas	1.000	0.984	0.974	0.982	0.996
DFI-CEC		0.572	0.605	0.645	0.559
WOMS	1.000	0.980	0.991	1.006	0.996
BP America	1.111	1.249	1.248	1.257	1.262
HOMS-1	1.000	0.969	0.973	0.988	0.991
Average	0.937	0.860	0.859	0.852	0.848
ex. IPE & DFI	0.880	0.861	0.863	0.878	0.884
Non-OPEC LDCs					
OMS (EIA)	0.694	0.508	0.560	0.570	0.598
Gately	0.834	0.849	0.891	0.916	0.944
IPE	1.221	0.989	0.854		
CERI	0.770	0.478	0.610	0.649	0.710
HOMS	1.000	1.000	0.994	0.996	0.997
DFI-CEC		0.377	0.390	0.379	0.325
HOMS-1	1.000	1.000	0.994	0.996	0.997
FRB Dallas	1.000	1.045	1.062	1.043	1.054
WOMS	0.701	1.020	0.991	0.976	1.021
BP America	0.201	0.744	0.934	1.012	1.045
Average	0.825	0.801	0.828	0.838	0.855
ex. IPE & DFI	0.775	0.830	0.880	0.895	0.921

(Table A.2 Continued)

Market Economies	1st Year	1995	2000	2005	2010
OMS (EIA)	0.401	0.508	0.522	0.549	0.565
Gately	0.779	0.840	0.872	0.895	0.914
IPE	1.000	1.044	0.975		
Penn-BU	0.223	0.395	0.337	0.378	0.400
CERI	0.446	0.417	0.517	0.575	0.620
HOMS	0.900	0.902	0.929	0.933	0.948
FRB Dallas	1.000	1.029	1.033	1.043	1.055
DFI-CEC		0.523	0.557	0.572	0.495
WOMS	0.900	0.980	0.991	1.000	1.004
BP America	0.889	1.101	1.188	1.221	1.240
HOMS-1	0.900	0.902	0.922	0.928	0.937
Average	0.744	0.786	0.804	0.809	0.818
ex. IPE & DFI	0.715	0.786	0.812	0.836	0.854

Notes:

Responses were not reported for ETA-Macro. Elasticity equals 1 by assumption.

Estimates are approximate due to rounding of results reported to EMF staff. Estimated elasticities in the range of 0.95 through 1.05 are not distinguishable from unity.

In the BP America model, which has an explicit industrial structure, oil plays the role of swing fuel in the industrial and power generation sectors. The model is calibrated around an average expected economic growth and any growth above that, as in the High GDP Case, is treated as unexpected and generates a disproportionate increase in oil demand. The explicit expected income elasticities within the model are actually significantly below 1 for the OECD regions.

DFI-CEC's demand response to income was calibrated to first-round OMS results in this study.

Estimate for first year is for the year in which the initial demand response is observed--1991 for WOMS, 1990 for Gately, CERI, and Penn-BU, and 1989 for all other models. This response was not available for DFI-CEC, which reports every five years.

FRB Dallas, WOMS, and BP America did not report for Non-OPEC LDCs. Their estimates have been derived as the difference in the responses for the market economies and OECD.

Table A.3. Price Elasticities of Supply Inferred from Rising and Flat Price Cases

United States	1st Year	1995	2000	2005	2010
OMS (EIA)	0.117	0.149	0.230	0.306	0.340
Gately	0.045	0.186	0.294	0.453	0.577
IPE	0.000	0.024	0.032		
ETA-MACRO			0.134		0.215
Penn-BU	0.000	0.119	0.165	0.188	0.162
CERI	0.137	0.291	0.339	0.313	0.195
HOMS	0.012	0.159	0.281	0.440	0.522
FRB Dallas	0.013	0.137	0.239	0.382	0.475
DFI-CEC		0.028	0.180	0.377	0.500
HOMS-I	0.089	0.280	0.400	0.563	0.662
Average	0.052	0.168	0.235	0.378	0.394
OECD					
OMS (EIA)	0.070	0.119	0.163	0.233	0.256
Gately	0.052	0.186	0.294	0.453	0.577
IPE	0.000	0.015	0.069		
ETA-MACRO			0.187		0.290
Penn-BU	0.000	0.117	0.167	0.222	0.224
CERI	0.075	0.200	0.287	0.310	0.246
HOMS	0.086	0.295	0.423	0.597	0.701
DFI-CEC		-0.011	0.308	0.536	0.654
HOMS-I	0.076	0.294	0.422	0.596	0.699
Average	0.051	0.175	0.252	0.402	0.428
Non-OPEC Total					
OMS (EIA)	0.047	0.090	0.135	0.195	0.223
Gately	0.045	0.178	0.287	0.441	0.560
IPE	0.000	0.024	0.078		
Penn-BU	0.000	0.108	0.153	0.195	0.193
CERI	0.050	0.159	0.198	0.204	0.161
HOMS	0.012	0.136	0.254	0.413	0.512
FRB Dallas	0.013	0.127	0.227	0.375	0.480
DFI-CEC		-0.004	0.401	0.680	0.833
WOMS	0.050	0.145	0.126	0.241	0.259
BP America	0.023	0.101	0.246	0.456	0.540
HOMS-I	0.076	0.266	0.384	0.545	0.641
Average	0.032	0.134	0.209	0.341	0.397

(Table A.3 Continued)

Non-OPEC ex US	1st Year	1995	2000	2005	2010
OMS (EIA)	0.000	0.061	0.088	0.143	0.170
Gately	0.052	0.174	0.283	0.435	0.553
IPE	0.000	0.026	0.101		
Penn-BU	0.000	0.106	0.151	0.197	0.200
CERI: WOMM	0.000	0.098	0.132	0.152	0.144
HOMS	0.000	0.130	0.247	0.408	0.510
FRB Dallas	0.013	0.123	0.224	0.374	0.480
DFI-CEC		-0.011	0.460	0.780	0.980
HOMS-I	0.076	0.260	0.377	0.537	0.633
Average	0.018	0.122	0.200	0.321	0.384

Notes:

Averages exclude DFI-CEC, an intertemporal optimization model in which the rate of increase in oil prices is critical to the observed supply response. First-year response is not reported for this model because results are reported for five-year periods.

Estimate for 1st year is for the year in which the initial supply response is observed--1990 for OMS, Gately, and BP America, and 1989 for all others. ETA Macro's supply response begins after 1990, i.e., in 1991, but is reported for every ten years only.

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Chapter 6

ALTERNATIVE METHODOLOGIES FOR REPRESENTING OPEC

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HISTORY OF OPEC[1]

Background and Evolution

The Organization of Petroleum Exporting Countries (OPEC) was created in an effort to prevent unilateral price cuts by the major oil companies without consultation of the countries whose oil was being exploited. Major oil companies had made such price cuts in order to preserve market share at a time of increased competition from smaller, independent oil companies.

To gain greater control over this situation, representatives of Saudi Arabia, Iran, Iraq, Kuwait, and Venezuela met in Baghdad in September 1960 to form OPEC. The principal objective of this Organization, as stated in the charter, was "the unification of the petroleum policies of the member countries and the determination of the best means of safeguarding their interests." Recognizing their dependence on oil revenues to finance development programs, the founders concentrated on the administration of oil prices, demanding that the oil companies maintain stable prices and consult with them before adjusting prices. In addition, the OPEC members agreed in principle to devise a system of production controls for stabilizing oil prices.

After that initial meeting in Baghdad, Qatar joined OPEC in January 1961, followed by Indonesia and Libya in 1962, Abu Dhabi (which later became part of the United Arab Emirates) in 1967, Algeria in 1969, Nigeria in 1971, Ecuador in 1973 and Gabon in 1975. When the Organization was first formed, the industrialized countries and the major oil companies ignored it; then as its membership grew, OPEC tried to pressure the oil companies for greater control over pricing and production, demanding that the price of oil should reflect the value of an exhaustible resource -- not just the costs of production and transportation. OPEC maintained that the ability to keep world oil prices and revenues high could best be achieved by a strong international cartel as opposed to a competitive market.

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*Energy Information Administration, U.S. Department of Energy.

[1]Source: Robert Copaken, Office of International Affairs, U.S. Dept. of Energy, August 2, 1989.

The Arab Oil Embargo

As the oil market began to tighten in the late 1960s and early 1970s, several OPEC members followed Libya in negotiating higher oil prices with the companies operating in their countries. The Arab-Israeli War in October 1973 set the stage for OPEC to emerge from a loose conglomeration of countries into a strong, cohesive Organization. Arab oil producers chose to use their oil exports as a political weapon against certain countries supporting Israel. Thus, Arab producers cut back production and embargoed exports to the United States and other targeted Western countries. These cuts briefly removed from the market as much as 4 MMBD, or about 7 percent of the non-Communist world's consumption. Crude oil prices more than tripled to $12 per barrel. The U.S. economy was jolted by shortages of crude oil and petroleum products, long lines at gasoline stations, inflationary pressure, and widespread concerns about energy security.

The Mid-1970s

The oil embargo ended in the spring of 1974. The Saudis, concerned that the price of oil was too high, broke with the rest of OPEC in December 1976 and together with the UAE held the line against the price hawks in OPEC, causing the first major split in OPEC since the Organization was created. While the price hawks agreed to a 10 percent increase to be followed by an additional 5 percent increase in July 1977, Saudi Arabia and the UAE agreed to only a 5 percent rise, with Arab Light rising to $12.09 per barrel.

The Iranian Revolution

The second oil shock hit the United States in 1978 with the Iranian revolution. Pre-revolutionary Iranian production of 5.6 MMBD was virtually shut down by riots and strikes that spread throughout the country. Increased production by other countries offset some of the loss in Iranian supplies in late 1978 and early 1979, but most OPEC members favored raising prices again by June 1979 and the decision was made to raise prices to $18 per barrel and allow members to add surcharges. Near the end of the year, even the Saudis, whose prices were still pegged to $18 per barrel benchmark, agreed to raise the benchmark to $24.

In December 1980, at Bali, the members of OPEC raised the benchmark price to $32 per barrel. In 1981, they reunified prices around a $34 per barrel benchmark and agreed to allow differentials of up to $4 above the benchmark. In 1982, they reaffirmed the $34/bbl benchmark, and agreed to restrict overall crude production to 18 million b/d. Despite efforts by OPEC to agree on price levels, however, demand for OPEC oil continued to weaken due to worsening economic conditions in the industrialized countries, gains in conservation, substitution of other energy sources for oil, the loss of market share to non-OPEC producers -- notably the United Kingdom, Mexico and the Soviet Union -- and the drawdown of inventories in consuming countries. In a general sense, what was occurring during the 1980's was a weakening of the historic relationship between economic growth and increased energy use. As a result, OPEC's share of Western oil demand declined from a 60 percent level in 1979 to 42.5 percent in 1982. By 1985, as OPEC's production fell, worldwide surplus oil production capacity had grown to between 9 and 10 MMBD. The result was that oil prices declined steadily, from an average of $37 per barrel during the peak year of 1981 to $27 in 1985. Despite repeated attempts, OPEC was unable to halt this price decline. Within OPEC, some countries failed to restrain production in their allotted quotas. Frustrated by declining production and revenues, Saudi Arabia abandoned its "swing producer" role late in 1985, triggering a collapse in oil prices, and general disarray within OPEC. In sum, by the late 1980's, the loss of market share to non-OPEC countries and the failure of certain OPEC members to respect production quotas had begun to pose serious problems for the cartel's future.

How OPEC works

The Organization is made up of four parts: a Conference of Ministers; a Board of Governors; a Secretariat; and an Economic Commission Board. The Conference of Ministers, which consists of delegations representing each of the 13 member countries, is charged with formulating policy and determining implementation. The Board of Governors directs the management of OPEC, including preparation of the budget. The Economic Commission Board is made up of experts from the member countries who meet to review oil market conditions.

The Conference of Ministers holds two ordinary meetings a year. Decisions, whether at ordinary or extraordinary meetings, are determined by votes of the members with all decisions requiring unanimity. Often, if a member dissents from a decision, it may attach reservations to its acceptance of resolutions of the Conference or exempt itself altogether from the application of the rule. Consensus is the general rule for OPEC negotiations, but there are generally at least two or three different factions within the overall membership, depending upon the issue and other circumstances.

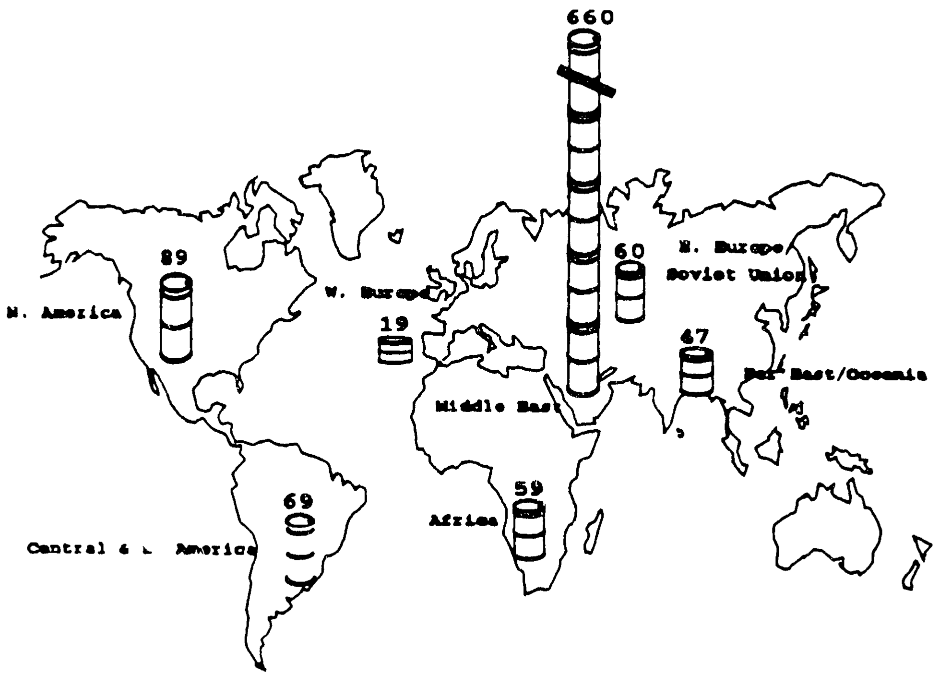
The Secretariat

The Secretariat of OPEC carries out the executive functions of the Organization under the direction of the Board of Governors. The chief officer of the Secretariat is the Secretary General, who is appointed by the conference for three years by a unanimous decision. He is the legally authorized representative, but can delegate some of his authority to the Deputy Secretary General. His Secretariat staff is composed of about 50 officers drawn from Member Countries, along with 150 support staff organized into five departments -- Personnel and Administrative, Energy Studies, Public Information, Economics and Finance, and Data Services. These departments undertake research and special studies into particular aspects of the petroleum industry, including refining, finance, and economics. In addition, the departments provide information about the Organization for the outside world, and compile statistics which are published periodically.

Market Monitoring Committee

An eight-member Market Monitoring Committee (MMC) within OPEC was created in November 1988 following the reintegration of Iraq within OPEC's production quotas in that

Figure 1. World Crude Oil Reserves, January 1, 1990 (Billion Barrels)



month. The membership of the MMC is composed of the members of both the Pricing and Long-Term Strategy Committees and includes the following states: Indonesia, Iran, Iraq, Kuwait, Nigeria, Saudi Arabia, the United Arab Emirates, and Venezuela.

Having concluded our brief review of OPEC's history and structure, we now turn to the modeling of OPEC's production decisions, and to the overall results of the world oil market analysis undertaken in this study.

ALTERNATE METHODOLOGIES

One of the keys to understanding the differences in the projections of world oil prices discussed in this study is understanding the different ways in which OPEC production decisions are modelled. Given current reserves estimates (Figure 1), it is clear that OPEC will become more dominant over time as the reserves of non-OPEC members are depleted. The world's two largest oil producers, namely the U.S.S.R. and the United States, have already started to experience significant production declines and are expected to continue to show declines for the foreseeable future. Therefore, most analysts expect that OPEC's market share and influence in the world oil market will grow over time.

Some of the difference in the world oil price projections examined in this study can be attributed to the alternative ways in which OPEC production and/or capacity is modelled. In general, the lower price projections are associated with higher OPEC production, while the higher price projections are associated with lower production. Attempts at modeling OPEC oil production and pricing behavior can be placed into three broad categories: intertemporal optimization models; recursive simulation models; and "bean counting" models. Intertemporal optimization models include the ETA MACRO and DFI models. Recursive simulation models include the remaining models examined in this study such as the Oil Market Simulation (OMS) model and WOMS models. The "bean counting" approach refers specifically to the report put out be the East-West Center in December, 1988, entitled "OPEC and Low Oil Prices: Impact on Production Capacity, Export Refining, Domestic Demand and Trade Balances." Each of these approaches is examined in order to identify the relative advantages and disadvantages.

Intertemporal Optimization Models

Intertemporal optimization models all stem from Hotelling's classic 1931 work entitled "The Economics of Exhaustible Resources," in which he establishes a wealth maximization theory of exhaustible resources, such as oil. Hotelling's model assumes that the owner of an exhaustible resource will choose a pricing and/or production path so as to maximize the net present value of the flow of revenue from its resource. Following this assumption, all intertemporal optimization models assume that OPEC behavior can be adequately explained by a revenue maximizing objective. The ability to maximize revenue is further based upon a key assumption that OPEC members possess perfect degree of foresight and that the members can act like a monopolist or oligopolist. Only two of the examined models in this study can be characterized as intertemporal optimization models. These are the ETA-MACRO and DFI models.

Numerous other intertemporal approaches have been tried in the past, and even though they have not been included in the current study, their different variations on this approach are interesting. A subset of the intertemporal optimization models is the game theoretic models, which use a Nash-Cournot or Stackleberg approach to determine OPEC production or capacity addition decisions. These models generally assume that OPEC behaves rationally and has perfect knowledge of future price/production/demand profiles. The pricing results of these models are generally determined by the assumption of the value of the discount rate.

Another approach for categorizing OPEC members has been made by Hnyllicza and Pindyck, who divide OPEC countries based on two main variables - immediate cash needs and proven reserves. Those countries with low immediate cash needs and high reserve to production ratios (i.e. Saudi Arabia, the UAE and Kuwait) are labelled as "saver" countries, whereas those with relatively high immediate cash needs and low r/p ratio's (Iran, Venezuela, Indonesia, etc.) are called "spenders." The main challenge in this approach is to model the interaction between these two subgroups to determine a resultant price and production path for OPEC as a whole. Hnyilicza and Pindyck apply cooperative game theory to this task. Their main conclusion is that resultant policy outcomes will depend primarily on the relative bargaining power of the two groups. Eckbo uses a similar approach but divides OPEC into three categories including "hard core" OPEC countries (Saudi Arabia, Kuwait, the UAE Qatar and Libya), "price pushers" (Iran, Venezuela, Algeria and Gabon) and "expansionist fringe."

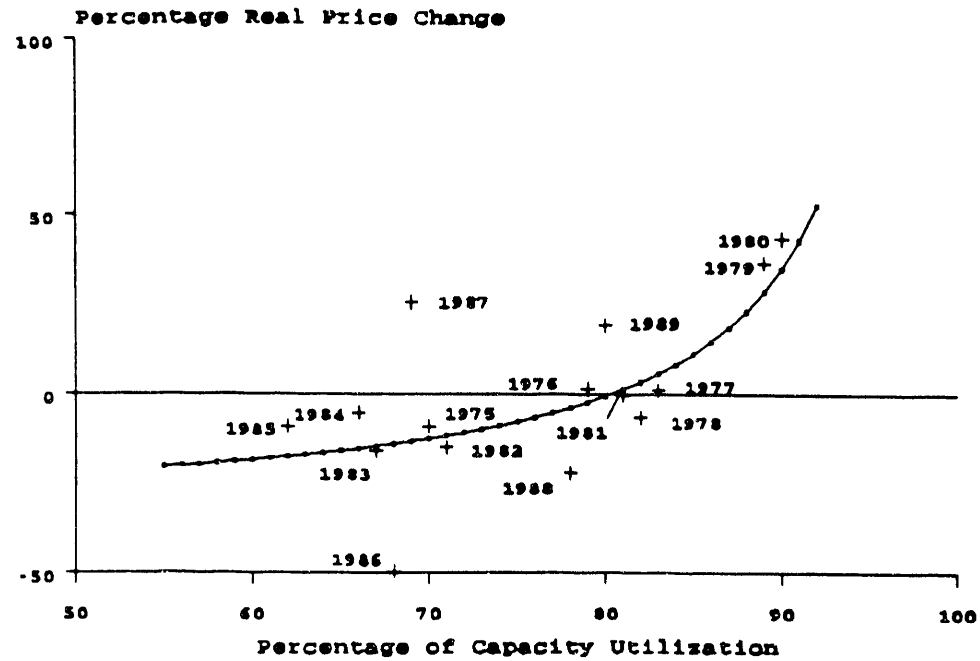
Daly, Griffin and Steele have put forth yet another way of subdividing OPEC, which has many similarities to Eckbo's approach. As in Eckbo's formulation, Daly, Griffin and Steele divide OPEC into three subgroups, including a "cartel core." The "core" group once again consists of Saudi Arabia, Kuwait, Qatar, Libya and the United Arab Emirates, all of which are distinguished by their vast oil reserves, small populations, and relatively flexible economic plans. The two other groups in this formulation correspond roughly to Eckbo's two "pusher" groups. The "output maximizers" group for instance, corresponds exactly to Eckbo's "expansionist fringe", except for the addition of Gabon, while the "price maximizers" group matches up with the "price pushers" without Gabon. "Output maximizers" in this approach are characterized by higher populations, lower reserves and greater pressures (and potential) for economic development relative to the "cartel core." "Price maximizers" also have relatively high populations and pressures for economic development, but do not possess the capabilities of the other two groups to expand output significantly at present or in the future. In this model, future oil production and pricing decisions are determined largely by the interaction of these OPEC subgroups, as well as by the non-OPEC suppliers. The key variables used to analyze this interaction are the market shares of each group as a measure of OPEC stability, and reserve/production ratios, particularly among the "price maximizers" and "cartel core" countries, as a guide to excess capacity. Daly, Griffin and Steele conclude their analysis with the determination that, given current behavior patterns, a $15 real price path produces a high likelihood of maintaining OPEC stability, while a $32 real price path results in serious instability.

Boum-Jong Choe of the World Bank developed a "Model of World Energy Markets and OPEC Pricing" which also divides OPEC into subgroups. Choe assumes OPEC to be a dominant firm type of cartel, whose goal is the maximization of the discounted present value of export revenues. Choe identifies two broad subgroups of OPEC countries, based on the size of their reserves and level of production relative to revenue needs. The "capital deficit" group (Algeria, Ecuador, Gabon, Indonesia, Nigeria, Venezuela) consists of countries that have relatively low reserve production ratios and limited potential for additional discoveries, while the "capital surplus" group (Iran, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, United Arab Emirates) are considered to have relatively high reserve to production ratios. These two OPEC subgroups are assumed by Choe to have conflicting economic interests, and thus different ideal pricing and production paths. As in previous approaches, understanding the interaction between the two subgroups becomes the key to determining a pricing and production path for OPEC as a whole.

Recursive Simulation Models

Recursive simulation and intertemporal optimization models differ greatly in their basic assumptions. Whereas the latter assume that some level of foresight exists among market participants, the former hold that perfect foresight is impossible in an inherently uncertain world. Instead, in recursive simulation models, market participants make decisions based on information only about the past and present, usually based on some form of a "price reaction" function. Price reaction functions generally assume that OPEC attempts to maintain capacity utilization at a

Figure 2. OPEC Pricing Behavior, 1975-1989



particular desired level, such as 80% in OMS (see Figure 2). OPEC is assumed to increase or decrease prices depending on whether capacity utilization is above or below the desired level. Other key assumptions made by these models include: production capacity is exogenous in all models but IPE; direct influence of price on demand occurs via changes in the capital stock; non-OPEC production is variously determined by elasticities or investments in capital, or exogenously; and an energy-GNP feedback relationship is included in most of the models, using one-parameter feedback loops with varying lags.

The major forecasting problem in recursive simulation models has been in determining OPEC production capacity. Gately points out that in these models, OPEC is assumed to be an imperfectly disciplined cartel that is uncertain about the underlying demand and supply parameters of the world oil market. It is groping toward an unknowable "optimal" price-path by implicitly following a target-capacity-utilization rule-of-thumb, i.e., increasing price when the market is tight or tightening, and letting it ease off when the market is sluggish. OPEC capacity limits on maximum production are specified exogenously, taking account of existing capacity, planned changes and known oil reserves. This approach is related to the "bounded rationality" models first proposed by Herbert Simon. Such an approach, although intended as a positive model of OPEC behavior, could also be viewed as a normatively sensible adaptation, given the unavoidable uncertainty about the market's true specification and parameter values. This view is similar in spirit to that of William Baumol and Richard Quandt, who argued that "rules of thumb are among the more efficient pieces of optimal decision making." With these models one of the prime determinants of forecast accuracy will be the determination of OPEC capacity, which is treated exogenously in most of the models examined in this study.

Bean Counting Approach

Having concluded our examination of the intertemporal optimization and recursive simulation models, we will now look at a "bean-counting" model - the East-West Center report. The assumptions of this model differ significantly from either of the other two types of models. For instance, the East-West Center model does not assume (as do the other models) that OPEC acts as a "residual", or "swing" supplier or crude oil. Instead, the East-West Center model looks at OPEC countries on an individual basis. In this approach, the demand side is modelled, but the supply side is projected based on "expert judgments of the political, technical, and economic situations of the oil-exporting nations."

Three main variables interact in this model to determine oil prices. The first is called "preferred level of output", and is defined as "the level with which OPEC would be satisfied given each country's economic, political, and international posture." The second is maximum sustainable capacity, defined here as "the maximum capacity that each OPEC country [can] produce at without damaging [its] reservoirs, while permitting itself long enough production life commensurate with its economic strategy". The third main variable is demand, which is not specifically addressed in the East-West Center report, but which is assumed to be projected by modelling techniques.

Oil prices are determined in this approach by the relationship between world demand for OPEC oil and the "preferred level of output" by OPEC of that oil. This is similar to the "price reaction" approach of the recursive simulation models, whereby as demand rises (or falls) above a particular percentage of capacity, prices rise (or fall) accordingly. In the East-West Center approach, "preferred level of output" is substituted for capacity, with 90 percent assumed to be the level above which prices tend to increase.

How, then, can "preferred level of output" be forecast in a systematic fashion? To begin with, one must forecast maximum sustainable capacity, since this variable sets the upper bounds of preferred level of output. For many OPEC countries, in fact, the preferred level of output will normally equal their maximum sustainable capacity. Thus, determination of a country's future maximum sustainable capacity is indispensable in forecasting its preferred level of output. As discussed in the East-West Center report, projections of maximum sustainable capacity must take into account technical/geological as well as economic factors. Baldwin and Prosser's logistic technique for making better forecasts of non OPEC supply may be relevant in this context.

Once maximum sustainable capacity is determined, the next step in the process is to forecast "preferred level of output" for each OPEC country, for OPEC subgroups, and/or for OPEC as a whole. In order to make this into an achievable goal, some degree of simplification is necessary. For instance, one can focus on a limited number of "key" variables in determining a country's "preferred level of output". Among the variables that might be considered "key" in determining preferred level of output are: a country's current and future revenue "needs" in relation to investment plans and absorptive capacity; internal political considerations; intra-OPEC or intra-regional pressures.

On the issue of revenue "needs", Theodore Moran, for one, has discussed in great detail a method of looking at these "needs" by determination of marginal utility curves for revenue for each country. In this approach, each OPEC country is assumed to gain a diminishing level of marginal utility from a given increment in oil revenues. Above a certain level, in fact, marginal utilities approach zero, as the country becomes indifferent towards additional revenues. As revenues fall, on the other hand, there comes a point where this decline begins to "hurt", whether in terms of forcing a country to give up some specific program or item (i.e. food subsidies which help maintain domestic stability in Algeria; a squadron of F-15's in Saudi Arabia), or in terms of a general "squeeze" on the budget. At this point on the curve the marginal utility of revenue for a country is very high, making it extremely reluctant to forego any revenue. The implications of this analysis for the oil analyst are profound, in that it implies that a country's oil policy will depend largely on its marginal utility of revenue curve. If Saudi Arabia, for instance, is close to the low end of its marginal utility of revenue curve, it may be much less willing to cut production and thereby lose additional revenues than if it is near the high end of the curve.

In forecasting a country's "preferred level of output", it is also necessary to consider other factors in addition to a country's revenue needs. For instance, the degree to which a particular OPEC country uses its oil exports as a means of foreign policy may be a very important variable in some cases. For countries like Saudi Arabia or Kuwait, for instance, oil and the revenues it brings is the only means of power that they possess in attempting to further (or protect) their interests. Another variable which may influence a country's "preferred level of output" is external pressure, particularly from more militarily powerful neighbors. As we see clearly in the current crisis, for example, Iraq had its own "preferred level of output" for Kuwait. The failure of Kuwait to comply with Iraq's wishes, despite Iraqi pressure throughout the summer of 1990, contributed directly to Iraq's decision to invade.

In sum, there are a number of variables which may help determine a country's "preferred level of output". It is necessary to examine not only the individual variables, but also the ways in which these variables interact in a particular context for each country. Only then can forecasts of "preferred level of output" be made with a reasonable degree of confidence.

ASSESSING THE PROSPECTS FOR AGGRESSIVE PRICE POLICIES

The past decade revealed the difficulty of forecasting long-term oil price behavior. Nonetheless, the importance of oil prices to energy futures as well as to policy evaluation compel continued forecasting efforts. The majority of projections currently available depict rising real price trends in the 1990s and into the following decade until levels of the early 1980s are reestablished. Global resource depletion does not underlie these forecasts. They are driven instead by an expectation that over the coming years OPEC market power will grow and be exercised to extract increasingly onerous rents from the world's oil-consuming community. Models of OPEC behavior assume that cooperation potential within the cartel is a simple function of market share within OPEC, and that agreements to raise prices will be implemented as unused production capacity diminishes.

Some argue that future oil prices will be unstable, rising to high levels as OPEC capacity is strained and falling to low levels as oil demand shrinks and non-OPEC supply grows in response to high oil prices. This style of forecast is also driven by assumptions regarding OPEC behavior. The cartel's collective desire for high revenue is assumed. Moreover, instability generated by aggressive OPEC pricing decisions in one period is assumed to have no effect on OPEC price and production strategies in subsequent periods.

When forecasters undertake to describe alternate possible future oil price trends, they tend to analyze factors external to OPEC which might affect the degree of market power held by the cartel. These include most particularly the level and elasticity of oil demand and non-OPEC oil supply. Little consideration is given to developing alternative behavioral assumptions within the context of the cartel itself. In some measure this reflects an understandable desire to simplify analysis. However, economists who study economic performance in industries where collusion potential is high find wide variations in actual behavior. There is no simple priori relationship between collusion potential, level of concentration, and actual exploitation of market power. Even when participants affirm willingness to jointly exploit market power, actual behavior may belie the expressed intent. In this context, analysis and modeling efforts which take OPEC behavior for granted tend to be too simplistic. Intent to collude and employ aggressive pricing strategies cannot be presumed. Rather, intent must be gleaned from evaluation of OPEC members' behavior over time.

Review of behavior involves more than monitoring the rhetoric of official OPEC communications. Investment decisions and other actions of individual cartel members must be considered. Decisions which make oil markets and each individual cartel participant's role in oil markets more transparent will tend to increase the potential for collusive behavior and with it the future prospect of aggressive cartel pricing policies. When any individual's behavior is more easily monitored by other members of the cartel, expectations of rewards from cooperative behavior are increased. When negotiations involve a limited range of well understood issues, the potential for agreement is increased. Decisions which make for less transparency will have the opposite effect.

National oil companies controlled by members of OPEC have changed markedly since the first oil crisis. The changes have made for less transparency regarding the way in which OPEC members participate in energy markets. In the mid-1970s, they were predominantly crude oil producers selling a relatively simple slate of products on a cash and carry basis. Downstream processing was undeveloped. The role of non-national oil companies was severely restricted. Indeed, the nationalization of oil assets in several OPEC countries repelled interest by private investors. In subsequent years, however, as the demand for OPEC oil shrank, individual members sought to readjust their operations to preserve or promote their position in product markets. New selling arrangements were developed. Barter trade of oil for goods became significant, as did sale on credit. Various forms of netback pricing were instituted. Those members adhering to posted price selling arrangements, including most notably Saudi Arabia, lost market share until the official OPEC pricing structure was abandoned in 1986.

The diversity of products sold by OPEC national oil companies also changed. As oil demand lagged, efforts to produce and market natural gas and natural gas liquids (NGLs) increased. Neither product is subject to OPEC production quota agreements. Refined product processing grew in importance in part through the building of new refineries and in part through the acquisition of refineries and downstream joint ventures in oil consuming countries. Petrochemical facilities were built to diversify local economies and to develop new outlets for oil and gas output.

Some diversification and vertical integration was accomplished through partnership with major multinational oil companies. Refining and petrochemical operations in Saudi Arabia include Shell, Exxon, and Mobil as major participants. Saudi Arabia is a partner with Texaco in a major joint venture refining operation in the United States. Petroleos de Venezuela (PDVSA) owns refining facilities in the United States, Germany, and Spain. Libya owns refining facilities in Italy. Kuwait operates major refineries throughout Western Europe. As a consequence of these developments, OPEC members undertaking direct sales of crude oil must confront combinations of crude, refined products, natural gas, and chemicals of other OPEC members. These developments make easy comparisons of pricing strategies among members difficult. They also make more difficult any assessment of adherence to production quotas. Thus, cooperative marketing arrangements within OPEC are more difficult to negotiate and to monitor. If significant restrictive arrangements are reached, opportunities for cheating are substantial and varied.

Further, the increasing diversity of asset deployment across oil market functions tends to dilute potential gains for cooperation within OPEC. Policies designed to raise crude oil prices hurt returns from the capital base for downstream processing. Thus, vertical integration would tend to strengthen interests in market stability, including stability in oil prices. The growing mix of private and public investment also tends to favor adoption of cartel policies which favor stability over aggressive price escalation. The range of joint ventures with non-OPEC partners differs across countries. Some involve product processing, some natural gas and petrochemicals, some upstream oil and gas production. Sharp variations in OPEC pricing strategy would undermine the ability to attract private investment now generally viewed as beneficial to sustained economic development.

The price collapse of 1986 was not caused by organizational changes within OPEC. More important were fundamental changes in oil demand and development of non-OPEC supply which eroded OPEC market share. However, observable changes in investment and business strategy within OPEC greatly complicated the ability to negotiate and administer restrictive production arrangements. The fact that such changes were undertaken revealed an intent by members within OPEC to reduce reliance on the prospective efficiency of cartel agreements and to behave as competitors. Those who bore the brunt of the effort to sustain high oil price levels prior to 1986 now have deployed investments, through vertical integration and diversification, which would potentially increase the costs of any renewed price support effort.

Though the changed circumstances of organization and investment within OPEC make collusion more difficult and potentially more costly now than in the early 1970s, we cannot assume that this will persist into the distant future. We can, however, continue to monitor the character of investment and organizational change to derive inferences as to the likely direction of future OPEC pricing strategy. In a world of growing oil demand and rising OPEC market share, investment strategies favoring increased production capability suggest pursuit of a moderate pricing strategy. Continuing expansion of multinational investment by OPEC and within OPEC suggests the same. These trends suggest further that leading members of OPEC may have learned from past experience that steady gains in revenue in the context of growing markets is preferred to the boom-bust experience of the past decade.

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Chapter 7

POLICY INSTRUMENTS THAT WOULD AFFECT OIL SUPPLY AND DEMAND

Policy Subgroup of EMF 11 Working Group
January 1991

A consensus exists with respect to the likelihood of increasing world dependence on OPEC and Middle Eastern sources of crude oil. The consensus is the result of the fact that about three-fourths of the world's proven reserves of crude oil are in OPEC, with most of the oil located in the Middle East. There is a difference of opinion, however, regarding the exact degree and timing of the dependence. Analysts disagree on the extent of the growth in future world oil demand, the development of non-OPEC oil resources, and OPEC policies regarding the production and pricing of their oil.

Many non-OPEC countries are attempting to delay the timing of their dependence by pursuing public policies designed to encourage increased indigenous or regional oil supply and/or to discourage domestic and regional oil demand. The challenge before public policy makers is to design policy instruments that thoughtfully and comprehensively consider the instruments' effects on fuel substitution, energy efficiency, the environment, energy security, continuing technological advancements, the macro-economy, and prevailing policy and regulatory issues.

In the past, non-OPEC countries have responded to OPEC actions in several ways and they may continue to do so in the future. These responses have taken many forms including altering tax structures to make indigenous production profitable, increasing taxes on petroleum products to reduce demand, and building strategic petroleum stocks. The National Energy Strategy for the U.S. published in February 1991 aims to address a range of institutional and regulatory barriers preventing the best use of the nation's energy resources. The strategy includes a program of greater energy efficiency, use of alternative fuels, and increased domestic production. In this context, this section will discuss some of the options non-OPEC countries have available with which to respond to actions of OPEC.

Policy Instruments Designed to Develop Non-OPEC Crude Oil Supply

For countries with known or potential crude oil resources and the capital and expertise to exploit them, a favorable environment for investment could greatly increase interest in petroleum exploration. Since the oil price decline of 1986, several countries have attempted to keep the economics of exploration and development favorable by improving their tax, royalty, acreage-access, and other policies applying to oil company activities. In general, profit-based rather than production-based excise taxation, the reconsideration of current front-end loaded bonus systems, and the extension of leasing terms might induce greater exploration activity in a number of countries.

There are developing countries, however, where the potential for petroleum production is unknown due to the lack of both capital and expertise to explore promising geological structures. Onerous contract terms or potential abrogation of contracts continues to discourage foreign company participation. These countries, if they improved their political and economic environment by embracing the concept of contract sanctity and by improving the flexibility of contracts, could benefit economically from the foreign capital investment and the expertise of private companies.

The encouragement of regional alliances of major producers and major consumers could, for a time, reduce the world's dependence upon Middle Eastern sources of crude oil. An increased market for Venezuelan and Mexican crude in the United States and Canada, for example, would likely encourage greater Latin American oil production than would otherwise occur. Alliances of this nature, however, may prove uneconomic if high cost oil is produced at the expense of low cost oil.

Consuming countries' governments could also encourage greater research and development (R&D) in advanced petroleum exploration and production technologies, such as enhanced oil recovery (EOR), horizontal drilling, and offshore production. Advanced technologies, in essence, would expand the recoverable resource base.

R&D could also reduce reliance on liquid petroleum fuels by proving alternative fuels technologies. Coal, and to a lesser extent natural gas, are more geographically dispersed than oil relative to current worldwide consumption. However, advanced technologies are needed to allow clean combustion of coal and, while natural gas is relatively environmentally benign, advanced technologies are needed to reduce the costs of gas transportation. Advancements in these areas would allow greater fuel choice.

Nuclear power, although it is an energy source that during normal operations emits no pollutant emissions, suffers from economic, political and institutional uncertainty. Advanced reactor designs that are inherently safe and modular in construction could go a long way towards resolving both energy security and environmental concerns. Similarly, as an energy supply option, conservation provides significant benefits as defined by economic, energy security, and environmental considerations. Investments needed to bring new energy conservation technologies and advanced nuclear reactor designs to market could be stimulated through governmental supported R&D and technology transfer programs.

<u>Policy Instruments Intended to Reduce Oil Demand</u>

There are three generic instruments that public policy makers can wield to reduce oil demand: taxes, prohibitions, and mandates. Increased consumption taxes, however, could pose hardships on certain segments of the economy. For example, many have suggested a higher gasoline tax to restrain transportation demand for oil. While relative to its trading partners the

U.S. has much lower gasoline taxes, the imposition of a higher tax might prove regressive, hitting hardest those who can afford higher prices the least. As a result, the effectiveness of a gasoline tax might be heavily diluted after all the special interests have been considered. Also, there is considerable debate regarding the impact that higher gasoline taxes would have on the U.S. economy.

The electric utility and the transportation sectors are likely to be the focus of oil consumption prohibitions and alternative fuels and conservation mandates. The electric utility sector, due to its centralized nature, is the easiest energy-consuming sector to regulate. The transportation sector, due to its near total reliance on liquid petroleum fuels, provides the greatest opportunity to reduce oil consumption growth with the introduction of alternative fuels and stricter conservation measures.

The prohibition of oil consumption in low form value uses such as electric utility boilers could reduce worldwide demand for oil by nearly 5 million B/D from current levels. It is likely that the electric utility sector will be the fastest growing energy-consuming sector as both industrialized and developing countries take advantage of electricity's versatility. As a result, the encouragement of the use of alternative fuels and multi-fuel capability could dramatically stem expected increases in future oil demand, especially in the developing countries.

By encouraging the use of alternative fuel vehicles and/or improving appliance and vehicle fuel economy standards, the demand for oil could be considerably reduced. Major car manufacturers have already developed prototypes that achieve substantially greater fuel economy. Public policy makers could encourage the mass production of these highly efficient cars. The marketing of alternative fuel vehicles might require subsidization. Encouragement through subsidization may, however, incur some unintended effects and economic losses if the external environment changes dramatically, as Brazil can currently attest.

<u>Oil Import Fee Example</u>

An example of a policy option that a government could exercise to influence both the supply and demand for crude oil is an oil import fee. Such a fee--a tariff on imports of crude oil and petroleum products--has frequently been discussed as a means of reducing U.S. dependence on imported oil. An oil import fee would stimulate domestic oil and natural gas production while simultaneously reducing demand.

An import fee could be either fixed or variable. A fixed fee would be set at a specific amount per barrel. A variable fee would equal the difference between a target crude oil price and the price of imported oil, thus raising the import price to the target level.

The price of domestic crude oil would rise to equate with the price of imported crude of similar quality. Natural gas prices would also rise because of gas and oil price competition in facilities where the fuels can be readily switched.

A tariff would also be necessary on imported petroleum products to reflect the impact of the crude oil tariff on domestic product prices.

Arguments For and Against Import Fees

One of the key arguments for enactment of an oil import fee is that U.S. energy security and economic stability would be enhanced by lowering import dependence and vulnerability to future supply disruptions, through both increased domestic production and greater conservation created by the higher price. This argument makes the point that the price paid by U.S. consumers and industrial users for imported oil does not fully reflect the true national cost. The greater the difference between the actual and the true cost, the more justification there is for government intervention. A crude oil tariff in the range of $8-12 per barrel has been proposed by Broadman and Hogan as being reasonable.[1]

An argument for a variable fee, or a fixed fee that is changed from time to time to reflect changing prices in the world marketplace, is that such a fee would provide price stability for U.S. producers. Price stability at an adequate level would encourage domestic producers to continue exploration and development in high cost, high-reserve-potential areas, including frontier areas such as Alaska and the deep water U.S. Outer Continental Shelf. Price stability would help justify the continued operation of possibly 100,000 marginal stripper wells, producing in total as much as 250,000 barrels of oil per day. If such wells are plugged, their reserves could be permanently lost.[2]

Another argument for an oil import fee is that it would raise significant revenue for the federal government. This revenue would result from the fee on foreign imports, increased income taxes from domestic producers, and increased federal royalties. In addition, increased state income and severance taxes could be generated. A fee could be imposed using the existing duty payment process administered by the U.S. Customs Service. Thus, establishment of a new agency to handle the collection of fees could be unnecessary.[3]

A key argument against the enactment of an oil import tariff is the large loss in economic efficiency incurred by oil consumers. As stated by Nesbitt and Choi, gains to domestic oil producers plus tariff revenue to the government will not be sufficient to offset the negative impact of the higher costs to oil consumers and the cost of tariff administration. A major factor in the projected economic losses is the depletion of U.S. oil resources and the switch to higher cost alternative fuels justified by the tariff on oil imports.[4] Some of the Middle East OPEC

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[1]Harry G. Broadman and William W. Hogan, "Is an Oil Tariff Justified? An American Debate II. The Numbers Say Yes", The Energy Journal, Volume 9, Number 3, July 1988.

[2]"Factors Affecting U.S. Oil & Gas Outlook", National Petroleum Council, February 1987, pp. 171-173.

[3]"Factors Affecting U.S. Oil & Gas Outlook," National Petroleum Council, February 1987, pp. 171-173.

[4]Dale M. Nesbitt and Thomas Y. Choi, "Is An Oil Tariff Justified? An American Debate, III. The Numbers say No," The Energy Journal, Volume 9, Number 3, July 1988.

producers have such a powerful advantage in crude oil production costs that costs for substitutes may be an order of magnitude higher.[5]

A disadvantage of an oil import fee as stated by the National Petroleum Council is that an import fee would have an immediate impact on the economy by raising the inflation rate and reducing GNP. This reduction in economic activity would cause a decline in corporate and individual income taxes collected from the oil industry.[6]

Another key argument against an oil import tariff is that it would cause difficulties between the United States and its trading partners. It would violate the U.S. commitment under the General Agreement on Tariffs and Trade, as well as bilateral agreements with Canada and Venezuela. Exemptions to the tariff for "favored nations" or to selected product imports could reduce the effectiveness of the fee as a revenue contributor and as a mechanism for raising domestic oil prices.[6,7]

Another argument against import fees is that areas of the U.S. with no oil production, but a heavy dependence on the use of oil, would be adversely impacted by an oil import fee, which would be perceived by people living in those areas as inequitable.[8] Many key U.S. industries dependent on oil and natural gas, such as agriculture, steel, automobiles and petrochemicals, would be competitively disadvantaged in domestic and foreign markets if the domestic costs of U.S. oil and natural gas were substantially above world prices. A substantial tariff would result in a loss of U.S. jobs.

An administrative problem associated with import fees is that fees might have to be established for a multitude of crude oils of different qualities and for products as well. If fees were not set properly, inequities or perceived inequities among individual producers and refiners could result. Enactment of a large import fee may require an expanded administrative staff. The present unit of the U.S. government which administers the current small import tariff may be too small to administer a large tariff.

Much has been written about the advantages and disadvantages of an oil import fee, and there are strong advocates as well as vocal dissenters. This discussion has been presented to illustrate how a policy instrument can influence oil supply and demand, rather than to take a position for or against import fees.

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[5]Arlon R. Tussing and Samuel A. Van Vactor, "I. Reality Says No," ibid.

[6]"Factors Affecting U.S. Oil & Gas Outlook," National Petroleum Council, February 1987, pp. 171-173.

[7]James L. Sweeney, "Oil Import Fees with Exemptions: An Empirical Examination," Resources and Energy, March 1990, 11(3):215-239.

[8]"Factors Affecting U.S. Oil & Gas Outlook," National Petroleum Council, February 1987, pp. 171-173

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Chapter 8

WHAT WAS LEARNED? COMMENTS BY PARTICIPATING MODELERS

Nicholas Baldwin* and Anthony Reinsch**
January 1991

Modelers were offered the opportunity to briefly discuss any of their results or to highlight what they learned during the study. Two modelers--Nicholas Baldwin (WOMS) and Anthony Reinsch (WOMM)--responded with the comments below.

WORLD OIL MARKET SYSTEM (WOMS)

The Summary Report asks if $18/BBL is sustainable, and identifies the main conditions for a flat oil price path in the 1990s. These conditions include :

- Nil decline in non-OPEC output.
- Economic growth below 3% per annum.

However, results from WOMS question the likelihood of non-OPEC production remaining high while prices stagnate. More importantly, this scenario also requires oil demand growth to be substantially slower than the increase in GDP, yet Table 3 of the Summary Report suggests growth in oil consumption of above 2% per annum in the market economies under a flat oil price path.

It is difficult to model the flat oil price path scenarios in WOMS because they soon result in high levels of demand and a lack of spare production capacity. Sustainable low oil prices would require an increase in OPEC capacity of around 6% per annum for the rest of this decade. Such a level of investment is unprecedented in recent times, and the ability of OPEC to raise the necessary finance must be seriously questioned. We were reminded here of a limitation with many oil market models, including WOMS, in that capacity choices are exogenous variables yet they are central to OPEC decision making and prices. We learned this is an area requiring further investigation.

The effect on oil prices of recent events in the Gulf indicate that oil markets are likely to be tighter in the future with prices subject to upward pressure. It can be argued that the determinants of the flat price scenarios are not much in evidence at this time.

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We learned that in running the 1989 IEO Price Path scenario that WOMS was consistent with other models in determining the main driving forces. These include a slow decline in non-OPEC supply with likely increases in oil consumption and an increased call on OPEC crude. This will result in a rising price path, especially if economic growth is high, that is more relevant to present oil market conditions because it suggests that the world is vulnerable to short term supply and price disruptions.

This may help explain why prices have risen so high during the Gulf crisis despite there being no apparent supply shortages.

The recent price spike might also provide evidence for the relatively inelastic nature of oil demand in the short term. Results from WOMS differ from some of the other models in that WOMS short run price elasticity is -0.04 for the world outside communist areas (WOCA) and -0.05 for the OECD, while other models calculate elasticities between -0.1 to -0.2.

WOMS price elasticities suggest that an immediate spurt in oil demand is not likely, even if prices stagnate - witness 1986 when a collapse in crude prices only gradually stimulated extra oil demand. When it comes to rising prices, oil markets exhibit a ratchet effect whereby a price spike only gradually reduces demand, and so in response, prices fall only slowly, suggesting an inelastic price-demand relationship that is particularly relevant to current oil conditions.

WOMS has a higher elasticity for the OECD compared to WOCA. This is consistent with the OECD oil demand reduction 1979-85, when OECD consumption fell by 7 MMB/d, while WOCA demand fell 6 MMB/d, indicating that demand growth in the LDC's offset some of the fall in the OECD. It may also reflect the greater success in developed economies in improving their energy efficiency.

Some of the other models do not show any relationship between oil demand and energy efficiency improvements, yet this effect has been observed in the OECD even during periods of falling oil prices. The results from the BP America and ETA- Macro models support WOMS in suggesting a trend decline in oil demand due to technological improvements which is an important feature of oil markets.

CANADIAN ENERGY RESEARCH INSTITUTE WORLD OIL MARKET MODEL

Introduction

From the standpoint of a world oil market analyst and model builder, the Energy Modelling Forum provided a unique opportunity to compare and contrast the performance of one's methodology and representation of the world oil market to those of other oil market modelers worldwide. This all too infrequent opportunity proved to be a tremendous benefit to all involved, and the Stanford University EMF group should be applauded for their foresight in doing so.

What follows are a few observations on the results of the Canadian Energy Research Institute's World Oil Market Model (WOMM) as presented in the EMF-11 summary report.

Non-OPEC Production

The CERI WOMM is based on a detailed representation of drilling activity, reserves additions, productive capacity and production for 14 non-OPEC producing countries/regions. In the scenarios analyzed for EMF-11, our projections suggest that non-OPEC production will peak in the 1994-96 period at levels only slightly above current production volumes.

This result is based on the relative maturity of the major non-OPEC producing regions--the United States, North Sea, and Canada. While the level of aggregation of results provided in the EMF-11 Summary report do not allow for the presentation of individual non-OPEC country results, the message relayed in the CERI WOMM projections is that the gains in production in the relatively new non-OPEC producing regions, such as Yemen, Colombia, offshore Brazil, and so on, will be insufficient to offset the projected declines in these mature producing regions.

The CERI WOMM also provides marginal (i.e. operating) and replacement cost estimates for the 14 non-OPEC producing regions. Our analysis suggests that of the 32 MMb/d of production captured in the supply cost submodel, 92 percent is produced at operating costs at or below $6 (US) per barrel. This suggests that the major impact of a price decline will come in the form of curtailed exploration and development activity, rather than in shut-in production. This reinforces the behavior observed during the 1986 oil price crash.

Finally, it should be noted that the CERI WOMM does not contain an evaluation of the incremental production possible through application of enhanced oil recovery (EOR) technologies, nor does the model contain a "learning curve" for new upstream technology applications, such as improved seismic techniques or primary and secondary recovery practices. To the extent that these factors are brought to play in a rising real oil price environment, the projected decline in non-OPEC production volumes could be postponed. However, in the absence of significant new resource discoveries, it appears clear that the 1990s will see a continued shift in world oil production in favor of the OPEC countries.

Endogenous Market Scenario

The CERI WOMM does not contain an endogenous decision rule for OPEC production or capacity expansion. Therefore, the WOMM is not represented in the Endogenous Cartel Case in the EMF-11 Summary report. The position of the Institute on this issue is that the decisions of OPEC regarding production and capacity expansion cannot be adequately captured by a capacity utilization or other decision rule. Rather, the mix of economic, political and social variables underlying this decision process represents the critical component of oil market analysis dependent on the skills, information and viewpoint of the analyst.

Price and Income Response

The response of refined petroleum product demand to changes in economic performance and product prices, as represented by the income and price elasticities built into the CERI WOMM, are among the lowest of the models represented in the EMF-11 exercise. This results in the CERI WOMM estimates being relatively robust across the price and income sensitivities performed for this exercise. On a regional basis, this reflects the ability of consumers in the industrialized economies to adjust to (i.e., escape from) increases in the relative price of refined petroleum products and the continuing impact of energy efficient production processes which, through the slow process of capital stock rollover, will continue to lower the oil-GDP ratio in all countries.

In the developing countries, while we agree that these economies are likely to become larger consumers of refined petroleum products through the 1990s (particularly in the case of stable or gradually rising real crude oil prices), it is likely that new production processes will reflect technology transfer from the industrialized countries, thereby benefitting from the gains in energy efficiency achieved over the last decade.

General Comments

Perhaps the most striking result emanating from the EMF-11 Summary report is the absence of consensus regarding the general direction of crude oil prices and production over the 20 year time horizon considered in this exercise. The results provided for the CERI WOMM definitely place the Canadian Energy Research Institute in the camp of those who perceive a return to dominance of the OPEC producing countries, and in particular the Middle East producing countries, in the determination of future oil prices.

The critical variable likely to be addressed in the 1990s is the ability of the OPEC member nations to expand productive capacity to meet the increase in refined petroleum product demand forecast over the decade. As the CERI WOMM results suggest, delays by OPEC in expanding productive capacity will result in a tight and unstable market by the middle of the decade. A third price spike under these conditions can be expected to spur a further round of upstream activity by the non-OPEC producers, this time focussed on incremental recovery technologies applied to established producing formations rather than the dramatic reserves and capacity additions witnessed in the early 1980s.

In such an event, it is likely that the principal response will come this time in the form of accelerated energy efficiency, conservation and substitution activity on the demand side of the equation, resulting in a permanent loss of energy market share for crude oil. Faced with this possibility, it is reasonable to expect that the OPEC member countries, led by Saudi Arabia, will endeavour to expand productive capacity to meet the expected demand growth and forestall a disruptive price escalation.

The current instability in the Middle East can be expected to delay this response, while the economic slowdown taking hold in North America (and perhaps elsewhere) may delay the critical period of market tightening.

Over the longer term, developments on the environmental front and in the Eastern Europe/Soviet Union regions can be expected to play a larger role in oil price determination. Oil market analysts and modelers will be challenged to incorporate these effects more completely into their analytical frameworks, in order to accurately capture developments in the world oil market over the next twenty years.

Chapter 9

PROJECTIONS OF CRUDE OIL PRODUCTION BASED UPON U.S. GEOLOGICAL SURVEY DATA ON POTENTIAL RESOURCES

David H. Root[*]

February 1991

Projections of crude oil production have been developed from U.S. Geological Survey data on the potential resource base. Estimates are based on current reserves and on an assessment of likely additions to reserves. Additions come from two possible sources: new discoveries and old field growth. Yearly production is modeled as a fraction of reserves for any given year. Three projections of oil production are prepared by varying the field growth factor and the fraction of proven reserves that are produced.

As projections evolve, reserves are reduced by the quantity of oil produced and increased by new discoveries and the growth in old fields. Annual projected new discoveries are calculated with an exponential decline function based on historical discoveries after 1960 and under the assumption that at least half of the estimated undiscovered oil would be found by 2010.

Field growth is the addition to reserves from oil fields already discovered. It was estimated using growth factors calculated in the US and Canada based on historical data (Root, 1981). Growth outside the US and Canada was assumed to be a fraction of the growth in the US. Three different ratios of non-US and Canadian field growth to US growth were used in the three different projections (shown in Table 1).

Table 1. Key Assumptions for Projections of Non-OPEC Supply

Scenario	Low	Mid	High
Foreign Field growth fraction of US Field Growth	1/3	1/2	2/3
Oil Production as a fraction of proven reserves	1/20	1/16	1/12

[*]U.S. Geological Survey. The author wishes to acknowledge Kenneth Ellis for his assistance in reporting these results.

Table 2. Percent Change (p.a.) in Non-OPEC, Non-Communist Production

Scenario	1990-2000	2000-2010
Low	-0.76	-1.43
Mid	-0.21	-1.39
High	0.53	-1.46

Oil production was modeled as a fraction of proven reserves which varies in the three projections (shown in Table 1). Countries currently producing above the upper limit of the production reserve ratio stayed constant at the current ratio throughout the projection. Otherwise, the production reserve ratios increased at least linearly to the upper limit constraint.

Table 2 summarizes the projections by reporting the percent change per annum of Non-OPEC non communist production for the three cases. Tables 3, 4, and 5 report the production levels from the three different projections, excluding estimates of natural gas liquids production (about 3.88 MMBD in 1989). The results show a general decline in Non-OPEC production.

Table 3. Projections of Crude Oil Production (in MMBBL/Day) Disaggregated by Country and Year From U.S. Geological Survey Lowest Forecast Case

Country	1990	1995	2000	2005	2010
Brazil	0.85	0.93	0.84	0.73	0.60
Canada	1.40	1.62	1.76	1.80	1.84
China	2.74	2.97	3.18	3.27	3.21
Mexico	2.58	2.80	2.98	3.08	3.08
Norway	1.30	1.60	1.78	1.86	1.85
United Kingdom	2.34	1.89	1.43	1.06	0.77
United States	7.30	6.38	5.60	4.91	4.40
USSR	10.54	9.48	8.66	7.97	7.25
Other Non-OPEC	7.43	7.45	7.11	6.62	6.08
Totals:					
Non-OPEC, Non-Communist	23.20	22.67	21.50	20.06	18.62
Non-OPEC, Incl. Communist	36.48	35.12	33.34	31.30	29.08

Table 4. Projections of Crude Oil Production (in MMBBL/Day)
Disaggregated by Country and Year
From U.S. Geological Survey Middle Forecast Case

Country	1990	1995	2000	2005	2010
Brazil	0.93	1.04	0.95	0.82	0.68
Canada	1.40	1.62	1.76	1.80	1.84
China	2.74	3.19	3.55	3.77	3.73
Mexico	2.61	3.05	3.35	3.53	3.55
Norway	1.35	1.79	2.07	2.20	2.18
United Kingdom	2.42	2.04	1.58	1.21	0.90
United States	7.30	6.38	5.60	4.91	4.40
USSR	10.61	9.56	8.75	8.15	7.49
Other Non-OPEC	7.65	8.03	7.85	7.23	6.58
Totals:					
Non-OPEC, Non-Communist	23.66	23.95	23.16	21.70	20.13
Non-OPEC, Incl. Communist	37.01	36.70	35.46	33.62	31.35

Table 5. Projections of Crude Oil Production (in MMBBL/Day)
Disaggregated by Country and Year
From U.S. Geological Survey Highest Forecast Case

Country	1990	1995	2000	2005	2010
Brazil	0.99	1.15	1.05	0.91	0.76
Canada	1.40	1.62	1.76	1.80	1.84
China	2.82	3.55	4.12	4.45	4.34
Mexico	2.70	3.45	3.93	4.15	4.08
Norway	1.41	2.08	2.49	2.65	2.54
United Kingdom	2.48	2.17	1.71	1.34	1.02
United States	7.30	6.38	5.60	4.91	4.40
USSR	11.68	10.58	9.37	8.49	7.86
Other Non-OPEC	7.89	8.73	8.94	8.43	7.35
Totals:					
Non-OPEC, Non-Communist	24.17	25.58	25.48	24.19	21.99
Non-OPEC, Incl. Communist	38.67	39.71	38.97	37.13	34.19

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Chapter 10

NON-OPEC SUPPLY AND WORLD PETROLEUM MARKETS: PAST FORECASTS, RECENT EXPERIENCE AND FUTURE PROSPECTS

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August 1990

EXECUTIVE SUMMARY

This paper examines the patterns of recent growth of non-OPEC supply, the degree to which such growth was anticipated by major forecasters in 1980, the prospects for continued growth in light of the 1986 price collapse, and the implications of such developments for the world petroleum market. First, it is shown that the growth of non-OPEC supply played a major role in the erosion of OPEC's market between 1973 and 1985. Second, it is shown that the pattern of supply growth since 1980 has been toward geographic dispersion of such supply from the developed to the developing world. Third, review of a number of prominent oil market forecasts prepared in 1980 indicates that the principal dimensions of the supply growth in the first half of the decade were almost wholly unanticipated. Finally, a preliminary examination of data covering the period since the price collapse in 1986 indicates that while overall levels of non-OPEC exploration and development activity have declined, the severity of the decline in the United States has been unique, and in some parts of the developing world activity has continued to grow. These findings have three principal implications for the petroleum market. First, the loss of market share alone has tended to increase quite drastically the effective elasticity of demand for OPEC's output, thus lowering its optimal price from that which prevailed in the 1970's. Second, the resiliency of non-OPEC supply indicates that recovery of OPEC's market share will rely heavily on consumption growth worldwide. Finally, the unique severity of the decline in U.S. supply implies that U.S. net imports will continue to grow as a share of the worldwide call on OPEC output, resulting in increased demand concentration (in the U.S.) at low prices quite analogous to the widely noted increased supply concentration (in the Persian Gulf).

INTRODUCTION

It has become fashionable in recent discussions of the world petroleum market to draw analogies between current conditions and those which led up to the two oil price shocks of 1973 and 1979. Indeed, there are some powerful analogies. World petroleum demand is rising once

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again, at an average rate in excess of a million barrels a day annually. Conservation efforts are far less intense than in the first half of the 1980's, with the result that oil growth has generally "recoupled" with that of GNP. Oil demand in the world outside of Communist areas (WOCA) is likely to exceed its 1979 peak of about 52 mmbd by more than 1 mmbd in 1990. Moreover, as in the 1970's, the U.S. is playing a very significant role in the revival of demand growth.

The inference drawn from these analogies is usually that growing demand will inevitably lead to a replay of the events of the 70's, as OPEC once again regains "control" of the market. OPEC's discovery of the market potential of exploiting the low price elasticities for its principal export commodity has been likened to the release of a genie, which once unbound can never be recaptured.

Nonetheless, it should be noted that all of the above analogies between the 70's and today are drawn from the demand side of the market, none from the supply side. That is not to say that there are no such analogies to be found on the supply side. There most certainly are. Most significantly, OPEC's share of WOCA supply, and particularly the share attributable to the Persian Gulf countries, is rising. Furthermore, in terms of the United States role in that market, the current decline in domestic supply is playing a major role in the growth of both U.S. import demand and the worldwide call on OPEC oil. Neither analogy is of small concern, either to the petroleum industry or to U.S. energy, security, or foreign policy. However, in looking at the supply side of the oil market in 1990, it is the differences from, rather than the similarities to the 1970's, that are by far the most striking. In 1973, OPEC supplied about 31 mmbd to the world oil market. By 1989, despite a total WOCA demand for oil 4 mmbd higher than in 1973, OPEC still faced a market about 25% smaller than the one it faced in 1973. New supplies, amounting to nearly 11 mmbd, had been added outside of OPEC, despite a decline of 1.7 mmbd in the U.S.

A fable perhaps more appropriate to OPEC's experience in the 70's would be that its supply policies unbottled *two* genies. The first granted the exporters large financial surpluses in the 70's and early 80's. The second, largely unanticipated by both OPEC and leading market forecasters, presented OPEC with new competition from a very wide range of sources. It is this second genie that has captured market share from OPEC throughout the 80's, and is showing resilience even in the face of lower prices.

This paper has three objectives. First, it examines the patterns of recent growth in non-OPEC supply, particularly that growth which occurred since 1980, and compares this experience with the patterns which had been anticipated by leading oil market forecasters at the beginning of the decade. A second objective of the paper is to assess, from the limited data now available, what effect the reduced oil prices since 1986 may have already had on exploration and development activity outside of OPEC. Finally, the paper examines the implications of such developments for current attempts to anticipate petroleum market characteristics of the next decade.

While this paper was researched and written before the August 1990 invasion of Kuwait by Iraq and the resultant embargo on oil from those two countries, one would expect that any interruption of supplies such as that experienced in August 1990 would, at least in the short run, enhance non-OPEC supply prospects relative to any scenarios considered here.

NON-OPEC SUPPLY: THAT OTHER GENIE

As seen in Figure 1, in 1973 OPEC accounted for nearly two thirds of WOCA oil supply. By far the largest source of potential competition was North America, with the U.S., Canada and Mexico making up over three fourths of non-OPEC supply. By about 1976, however, this situation began to change, rapidly. Figures 2, 3, and 4 disaggregate non-OPEC supply by region.

Between 1973 and 1980, the growth of non-OPEC supply was largely attributable to three areas: the Alaskan North Slope, Mexico, and the North Sea, which collectively contributed over 5 mmbd of new supply. The developing countries (excluding Mexico) were also growing, but contributed less than 1 mmbd of new supply. Moreover, over 40% of these supply increases were offset in the 1973-80 period by a loss of about 2.4 mmbd in supply from the U.S. Lower 48 states and Canada.

Between 1980 and 1985, the North Sea continued to contribute significantly to non-OPEC supply growth, adding another 1.5 mmbd in those 5 years. Apart from the North Sea, however, the pattern of non-OPEC supply growth changed markedly. First, the decline in North American supply halted, despite the fact that Alaskan supply had nearly peaked. In fact, by 1985 U.S. supply was some 0.4 mmbd higher than in 1980, with nearly half of this increase attributable to the previously declining Lower 48 states. Second, the non-OPEC developing countries contributed nearly 3 mmbd of new non-OPEC supply, with nearly two thirds of this increase from sources other than Mexico.

Since the reduction in world prices in 1986, the pattern of growth in non-OPEC supply has changed once again. Supply from the North Sea has at least temporarily leveled. The U.S. Lower 48 has resumed the decline observed from 1973 to 1980, and Alaska by 1988 had reached its expected peak production level.[1] Mexico was producing slightly less in 1989 than in 1985. However, in the developing countries (excluding Mexico), growth has continued, with those countries adding more than 1 mmbd to non-OPEC supply from 1985 to 1989.

Another significant source of growth in non-OPEC supply since 1973 has been that of growing net exports from the centrally planned economies (CPEs). Between 1973 and 1988, such exports contributed an increase of 1.8 mmbd, or 17% of the total growth in non-OPEC supply during the period. In 1989, however, net exports declined by nearly 14% due to the decline in Soviet production and a number of other factors.[2]

In summary, there have been major changes in the pattern of WOCA supply since 1973. In 1973 OPEC produced 31 mmbd of a 46 mmbd oil market, while the competition, principally the U.S. Lower 48 states and Canada, provided the balance from older high cost resources.

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[1]See *Oil and Gas Journal*, September 25, 1989, p. 25.

[2]For example, transportation bottlenecks in the Black Sea and declines in Chinese production.

Figure 1.

WOCA Petroleum Supply

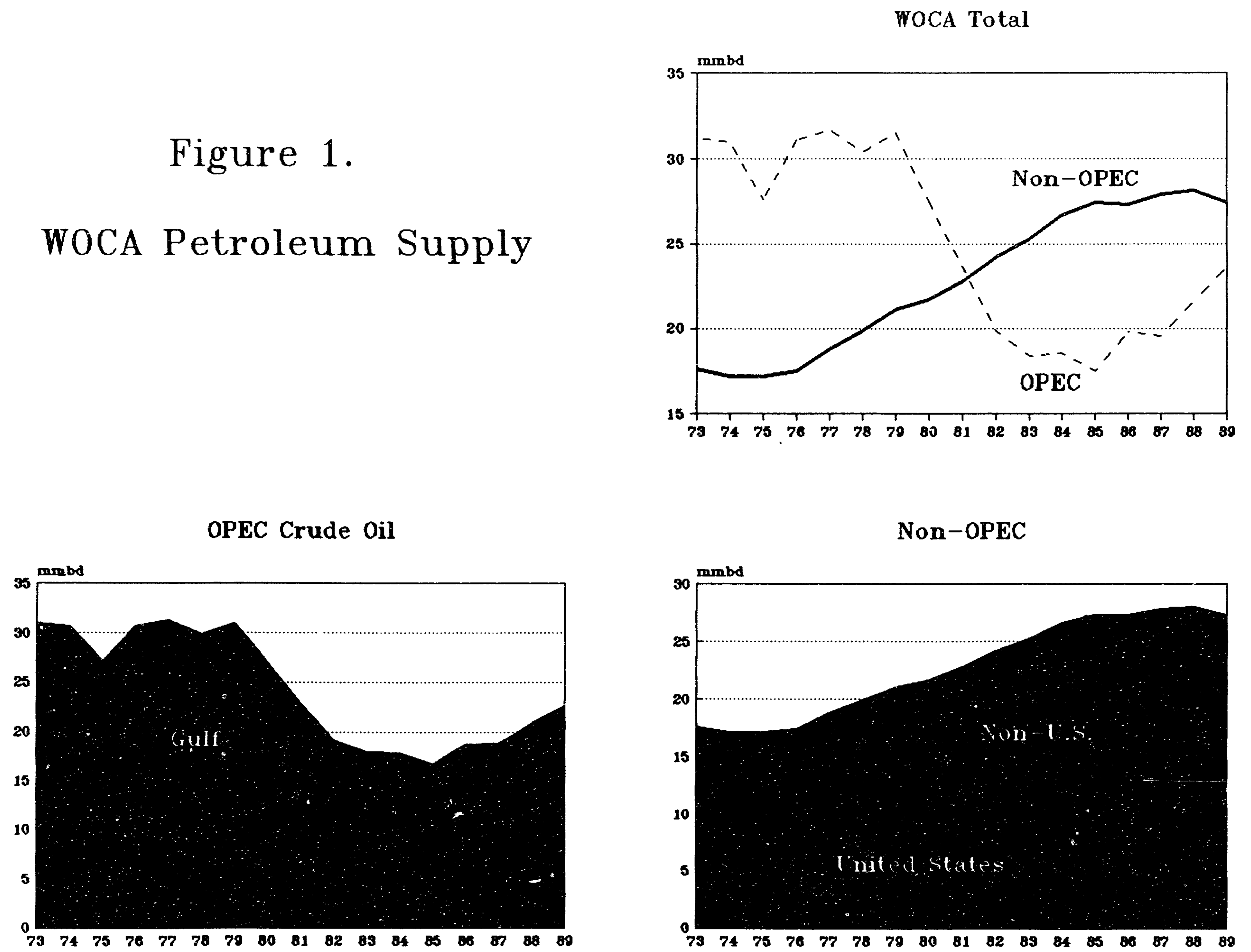
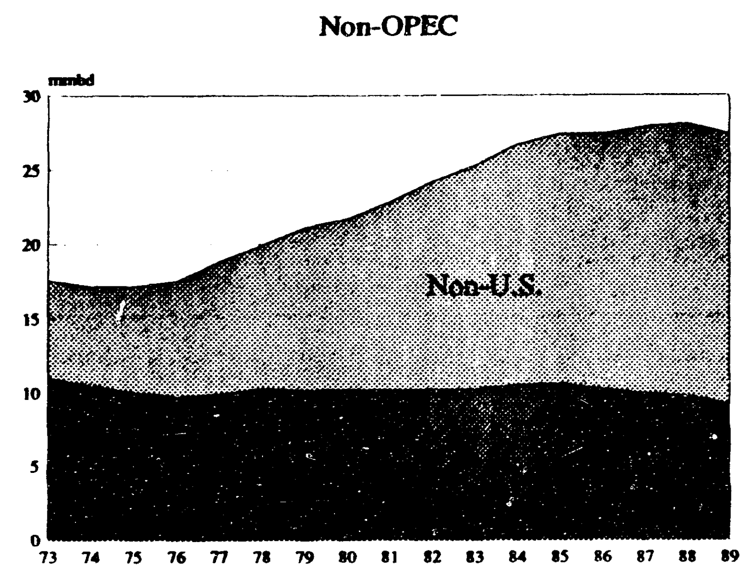
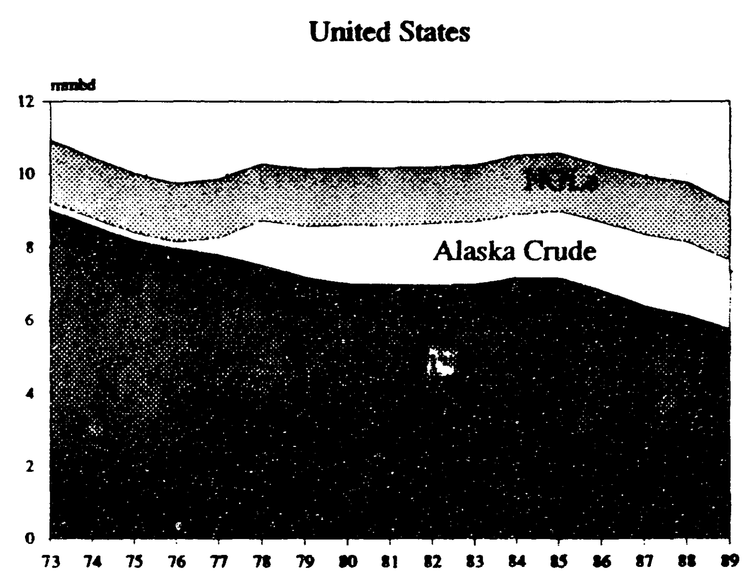


Figure 2.

Non-OPEC Petroleum Supply





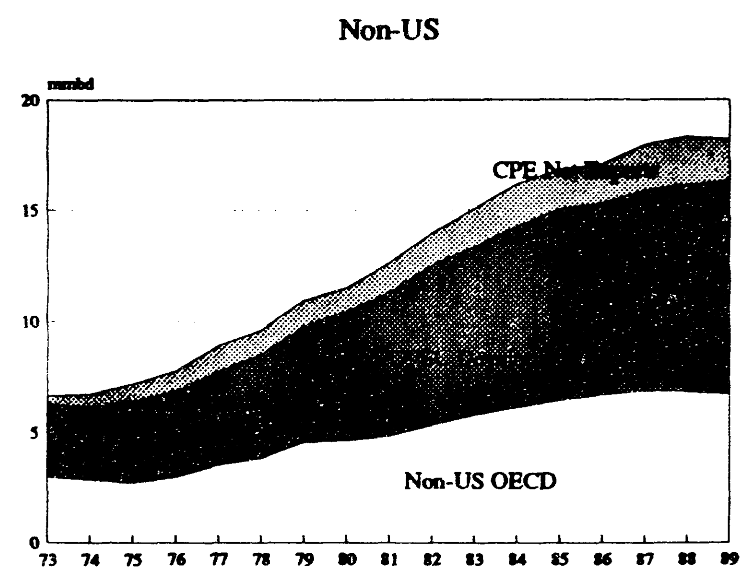
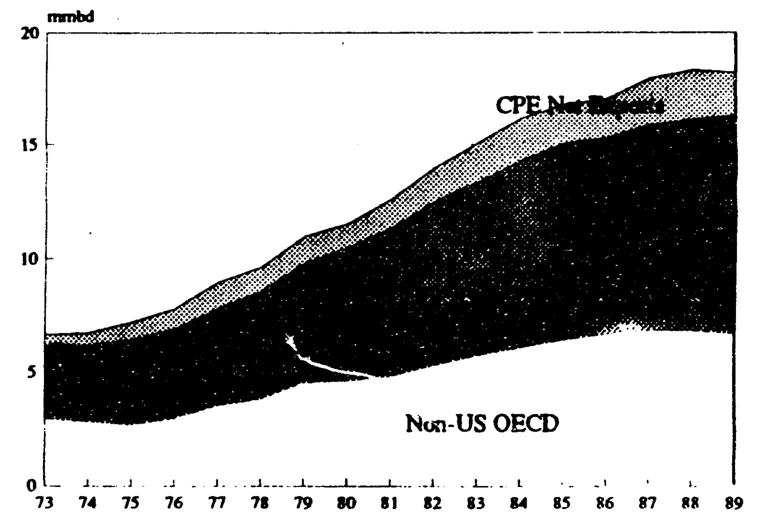


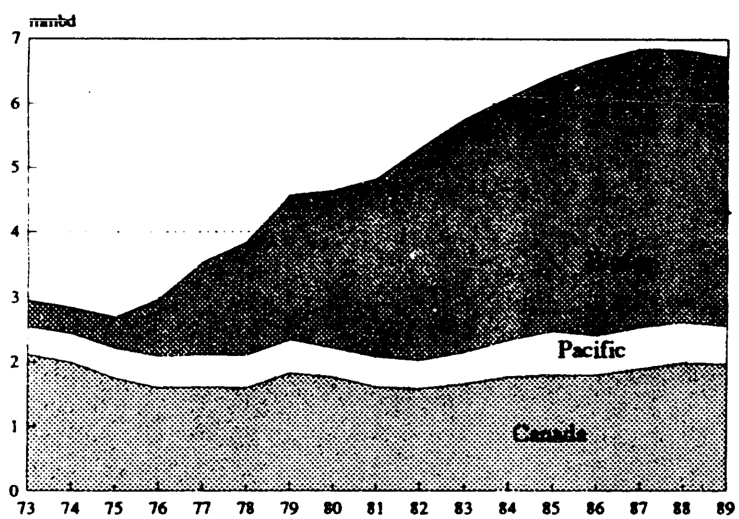
Figure 3.

Non-OPEC Petroleum Supply Outside of the U.S.

Non-US



Non-US OECD



Non-OPEC Developing Countries

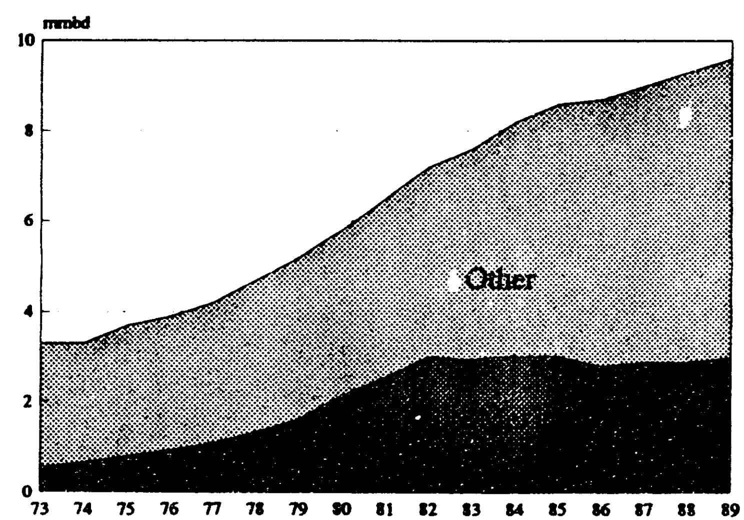
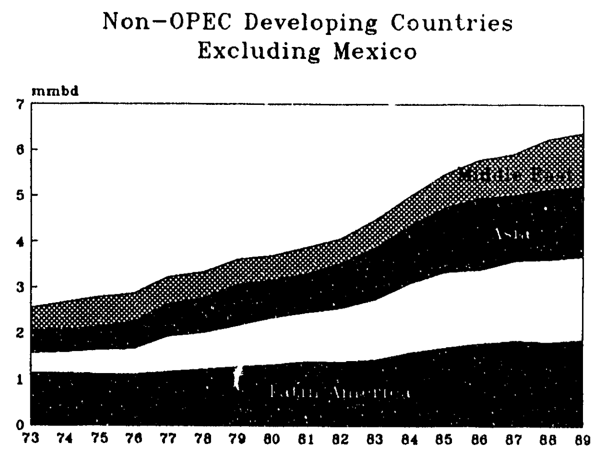
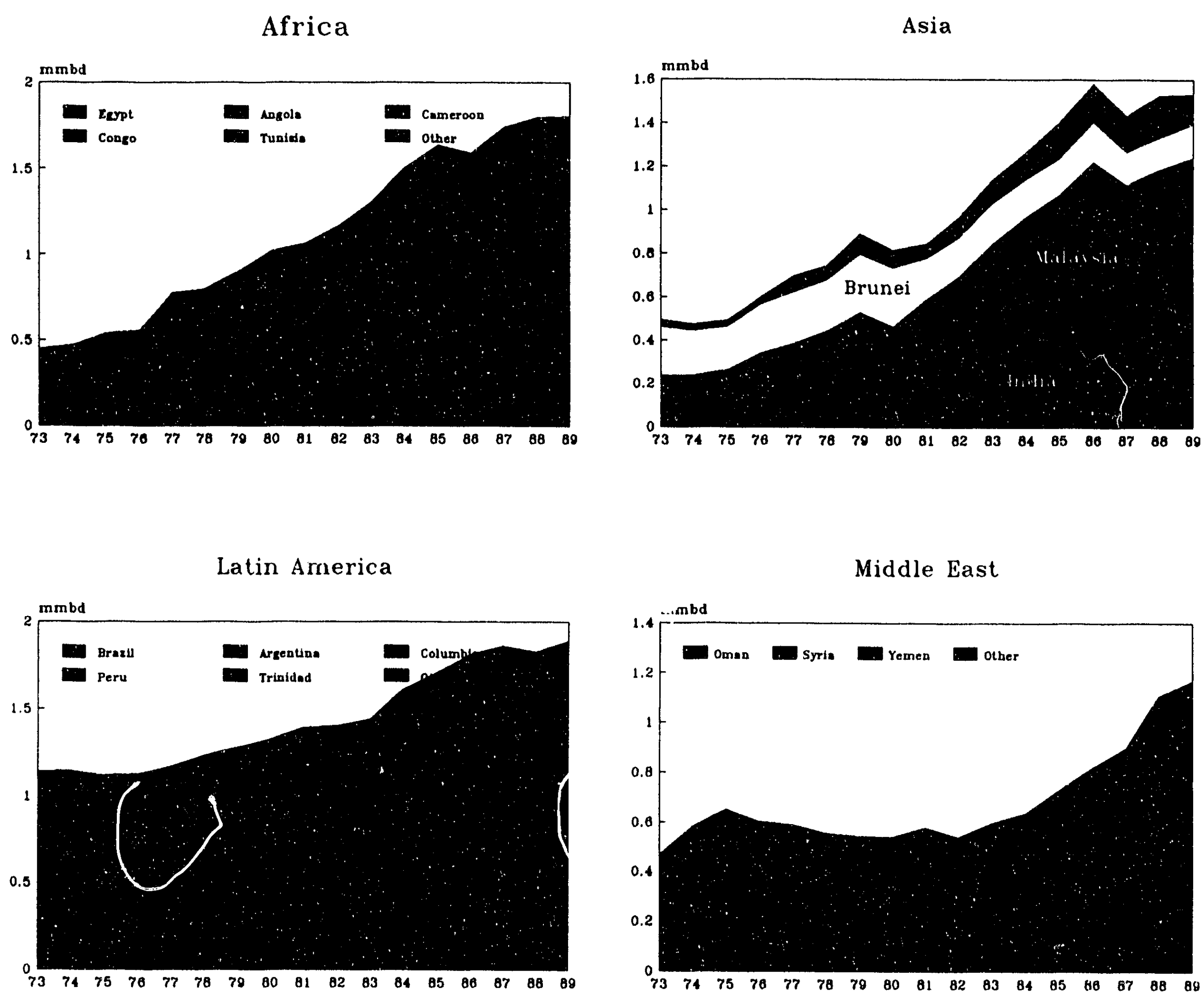


Figure 4.

Non-OPEC
Developing Country
Petroleum Supply

(excluding Mexico)





Between 1976 and 1985, an assortment of new competitors emerged to capture 10 mmbd of what was a generally shrinking market. In 1989, despite four years of prices which in real terms are comparable to those of late 1973, and demand levels well in excess of 1973 levels, OPEC faced a market for its exports which was about 25% smaller than the one it faced in 1973.

FORECASTS OF NON-OPEC SUPPLY: THE 1981 PERSPECTIVE

In 1980 and 1981, Stanford's Energy Modeling Forum (EMF) assembled a group of the most widely used forecasting models of the world oil market, and utilized these models in an assessment of future oil market conditions under a standardized set of assumptions, or "scenarios". The majority of the modelers explicity reported forecasts of non-OPEC supply in varying degrees of detail for the period from 1980 to (in most cases) the year 2020.[3] These forecasts of non-OPEC supply for the 1980-88 period were examined for the "reference case" scenario, in which it was assumed that OPEC capacity would remain constant at 34 mmbd and that the annual rate of GNP growth was 3% in the OECD and 5% in the oil importing developing countries. Oil prices consistent with these assumptions were generated by the individual modelers, and varied over a wide range, as shown in Figure 5.

Despite an upward trend in the expected prices generated by this reference case scenario over the long run[4], not all of the models predicted increases in the early years of the forecast. In fact, several modelers forecast an initial period of price weakness in the reference case. Nonetheless, even the closest price forecast to the actual was 30% above the actual price by 1985, and more than 200% above the actual from 1986 to 1989. The historical accuracy of the oil price forecasts is not our concern here, except to point out that the non-OPEC supply forecasts with which we are concerned were premised on *much* higher prices than actually materialized. Figures 6 and 7 present the reference case estimates of non-OPEC supply growth forecast by the various models used in the EMF exercise.

Generally, despite the large overestimates of price, the forecasts failed to anticipate most of the growth in non-OPEC supply which occurred since 1980, with one notable exception. The IPE forecast of non-OPEC supply was generally an outlier relative to the other forecasts, but represented a relatively accurate picture of supply in the first eight years of the forecast. The

[3]Only 5 of the 10 EMF models are reported on here, as follows: IEES/OMS: U.S. Department of Energy, Energy Information Administration; IPE: Nazli Choucri, Massachusetts Institute of Technology; WOIL: U.S. Department of Energy/ Energy and Environmental Analysis; Kennedy: Michael Kennedy/Richard Nehring, University of Texas/Rand Corporation; OILTANK: Leif Ervik, Chr. Michelson Institute.

The other 5 models are not reported due to the incomplete reporting detail associated with their output. However, based on the partial information which *was* reported for those models, it would appear that none of the unreported models included aggregate non-OPEC supply estimates significantly more accurate than those reported, while several were substantially less accurate than those reported here.

[4]See EMF, *World Oil*, p. 28.

Figure 5. World Oil Price

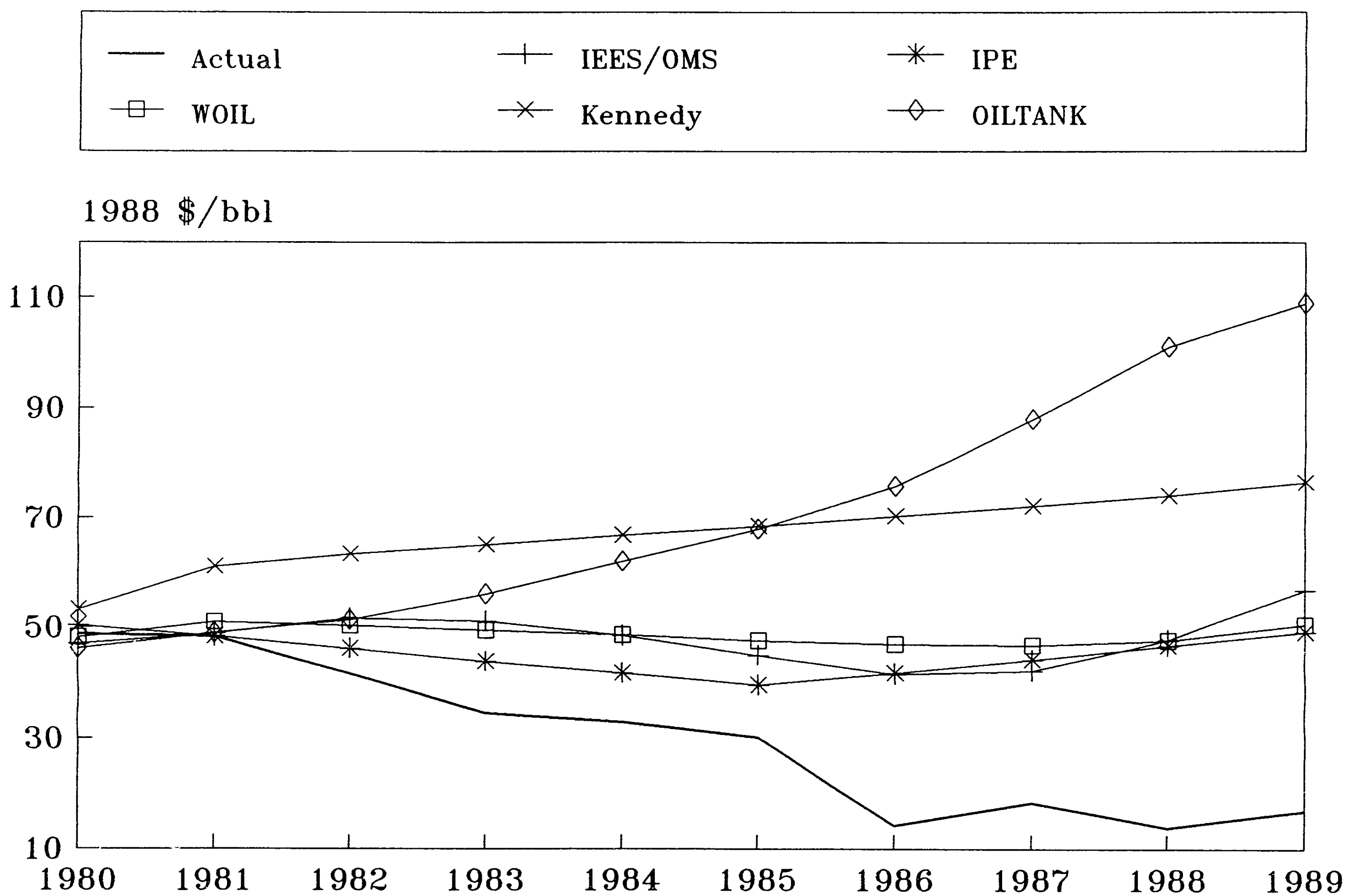
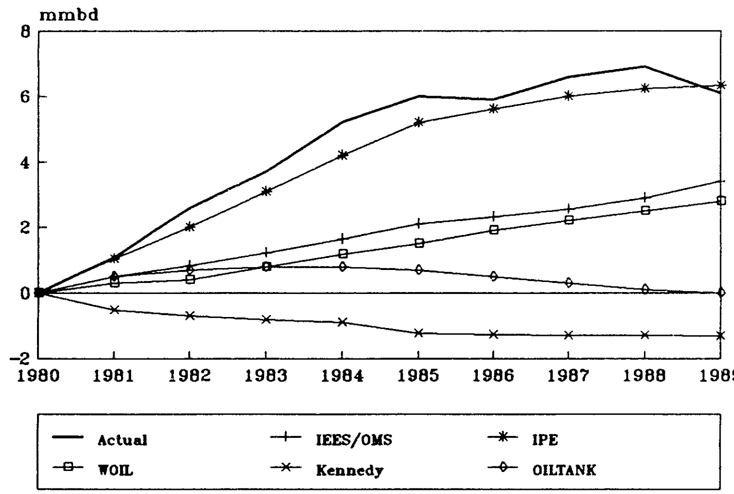


Figure 6.
Non-OPEC
Petroleum Supply Growth

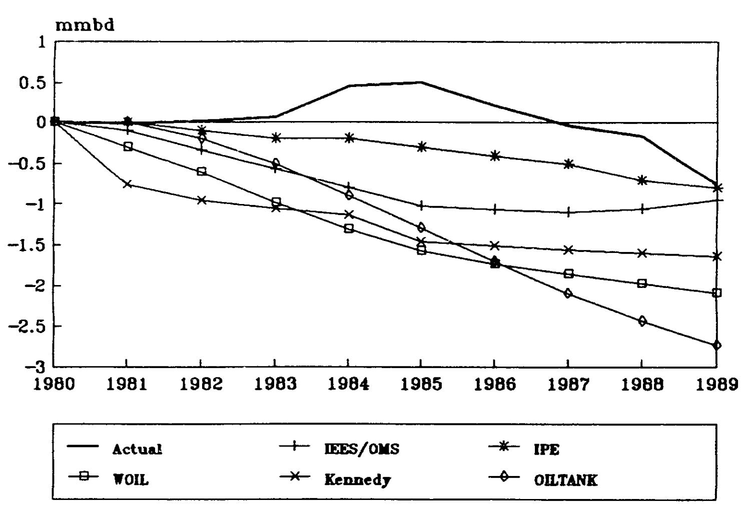
EMF6 Reference Scenario

(changes in supply from 1980)

Non-OPEC Total



United States



Non-US

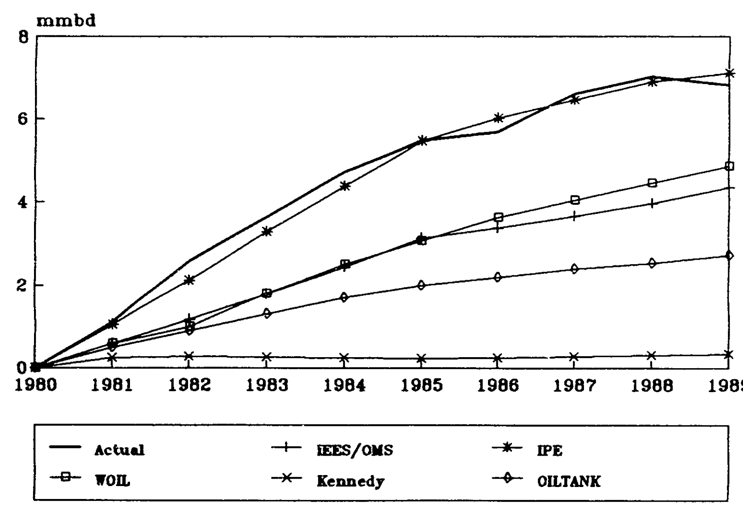


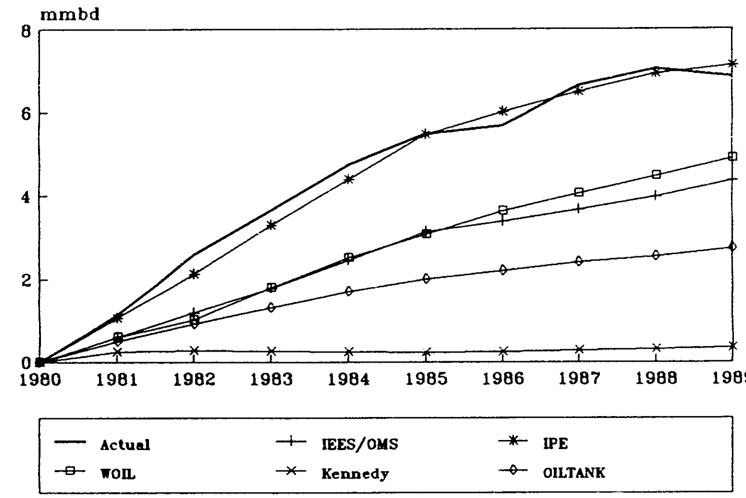
Figure 7.

Non-OPEC
Petroleum Supply Growth
Outside of the U.S.

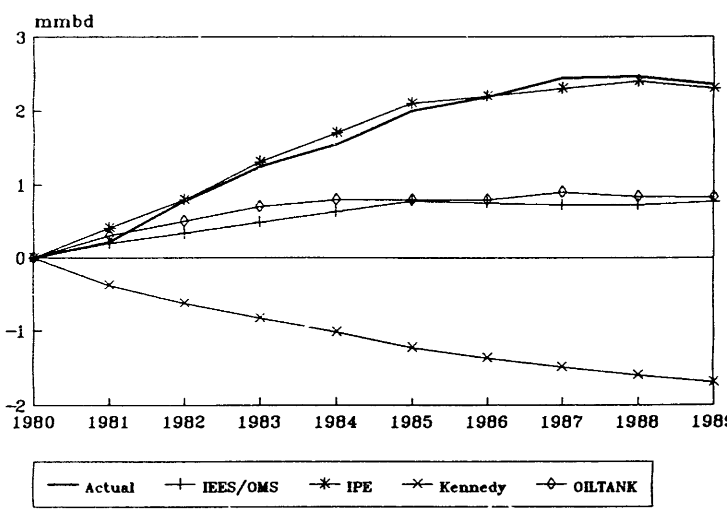
EMF6 Reference Scenario

(changes in supply from 1980)

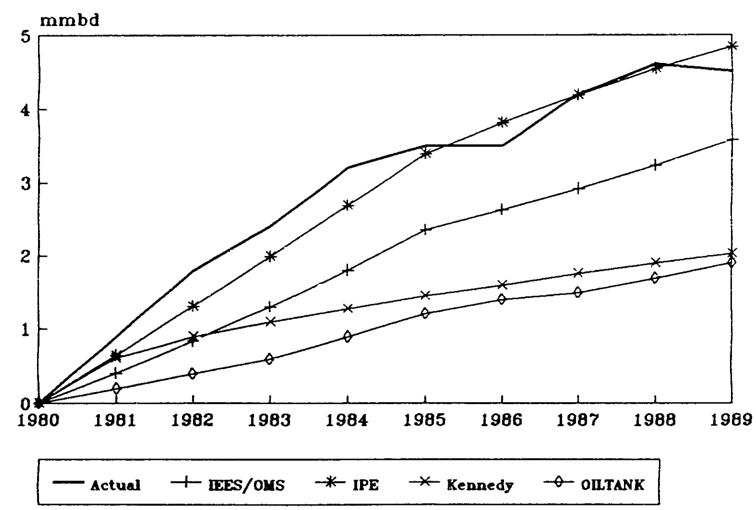
Non-US



Non-US OECD



Non-OECD



IPE forecast a 6.3 mmbd increase in non-OPEC supply between 1980 and 1989, within 3% of the actual 6.1 mmbd increase. The next closest forecast was produced by the DOE's IEES/OMS model, which anticipated growth of 3.4 mmbd over the 1980-89 period, representing a nearly 45% underestimate. The relative accuracy of the IPE model in forecasting non-OPEC supply also held up in examining the regional disaggregation of growth, as seen in Figure 7. Interestingly, however, none of the models examined anticipated the stabilization of U.S. supply after 1980. In fact, the most accurate forecast, the IPE model, consistently forecast non-OPEC supply outside of the U.S. more accurately than U.S. supply. In a similar vein, the U.S. DOE's IEES/OMS model actually provided a more accurate forecast of supply growth from the non-OPEC developing countries than it did for the U.S. itself. From 1985 to 1988, for example, OMS was underforecasting U.S. supply by 1.0 to 1.5 mmbd (10-14%), while underforecasting non-OPEC LDC supply by only 0.2 to 0.3 mmbd (2-3%).

Finally, while CPE net exports were not generally reported explicitly by the modelers, in several cases sufficient detail was reported to infer such a forecast[5]. In the IEES/OMS model, for example, such net exports were assumed to decline to zero in the first several years of the forecast period. In fact, until 1989, such exports had consistently risen, adding 1.1 mmbd to non-OPEC supplies during the 1980-88 period.

To summarize, it is fair to say that the leading forecasting models in 1981 appeared to exhibit a systematic tendency to underestimate non-OPEC supply growth. Generally, such forecasts did not anticipate the growth in non-OPEC supply which actually materialized, even at prices that were far higher than those which actually occurred. Furthermore, none of the forecasters anticipated the stabilization, and increase, in U.S. supply from 1980 to 1985, or the increase in net exports from the CPEs.

The reasons for this systematic understatement are difficult to generalize, insofar as the supply components of the various models differ in a number of ways. However, there are several observations worth reporting. First, the models which explicitly represented the supply process as the optimal intertemporal depletion of an exhaustible resource stock appeared to underestimate supply far more seriously than any other formulations. Second, with the exception of such "intertemporal optimization type" models, the supply side of each model was generally far simpler and less well developed than the demand side.[6] Often, non-OPEC supply was computed relative to a predetermined "reference case" as a function of an assumed elasticity and the

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[5]Or, more commonly, an assumption.

[6] The performance of the models was also generally better on the demand side than on supply. Gately [1986] points out that for the "low growth" scenario, whose standardized assumptions most closely resembled actual experience during the 80's, only one (again the IPE model) had declines in demand comparable to the 12 mmbd decline between 1980 and 1985 which actually occurred. However, several other of the EMF models did have significant demand declines in the 5-7 mmbd range, whereas significant increases in non-OPEC supply were anticipated *only* by the IPE model.

deviation between estimated prices and those in the "reference case". Finally, none of the supply models in the exercise was specified to determine non-OPEC supply as an explicit function of exploration and development investment.[7]

RECENT EXPERIENCE WITH LOWER PRICES: THE (LIMITED) EVIDENCE

It is clear from the supply data presented above that production from the non-OPEC areas has continued to grow, and in some areas to actually accelerate, since the collapse of prices in 1986. However, in itself this does not portend the prospect of future growth. That is, there are often significant lags between the initial development of an area and its initial production, raising the possibility that the post-1985 production growth may simply be the consequence of pre-1986 development activity and investment. Consequently, a continuation of development activity in the non-OPEC areas after 1986 would provide a more robust indication of continued growth prospects than production data alone, or similarly a clear decline in such activity might be taken as a "leading indicator" of a decline in such growth. Therefore, a number of sources were examined for indicators of changes in industry investment activity since the price decline.

In the United States, the evidence of declining investment in the upstream petroleum sector, as well as its effects, are already quite clear. As seen in Figure 8, drilling activity and exploration and development investment collapsed quickly after 1985, falling to about 50% of their 1985 levels. The effects of this decline also were visible early, as the decline in Lower 48 supply resumed almost immediately after the price collapse of 1986. Initially, these declines were partially offset by continued increases from Alaska, but by 1989 it appears that Alaska is past its peak, implying that the decline in U.S. production can be expected to accelerate[8].

Outside of the U.S.[9], the effects of reduced prices since 1986 are more difficult to discern. However, three sources of data were examined, namely exploratory well completions, active rig counts, and major U.S. company spending on non-U.S. exploration and development.

As seen in Figure 9, the pace of exploration in the OECD countries slowed in 1986, primarily due to a sharp decline in Canadian activity, but in 1988 Canadian exploration recovered quite rapidly. In the developing countries, there was a far less pronounced slowdown in exploratory activity, and a resumption of growth in 1988. Also of interest, as shown in Figure 10, is that the dispersion of activity so characteristic of the post 1980 supply growth appears to be

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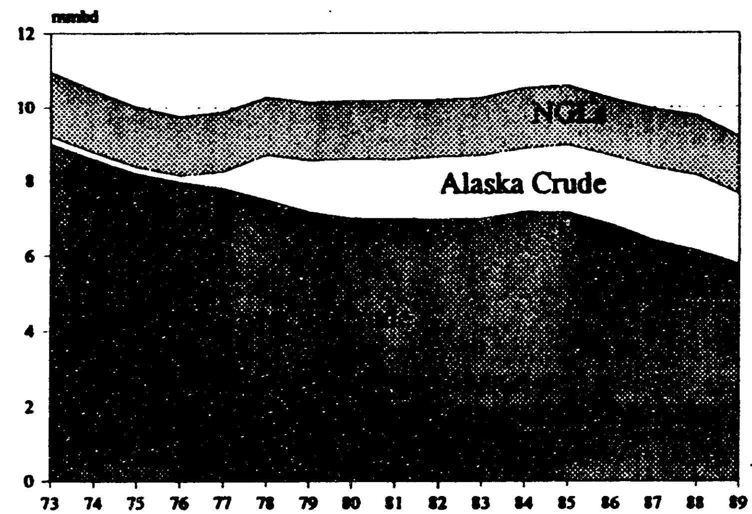
[7]With one exception. The WOIL model does this for the U.S., but not the rest of the world.

[8]U.S. production data from U.S. Department of Energy, *Monthly Energy Review*. Expenditure data from American Petroleum Institute, *Survey of Oil and Gas Expenditures* for 1983-88, from National Petroleum Council, Outlook for U.S. Oil and Gas for prior years. Well completion data from American Petroleum Institute, *Joint Association Survey on Drilling Costs* for years 1973-1988; 1989 from American Petroleum Institute, *Quarterly Completion Report*, Second Quarter 1990.

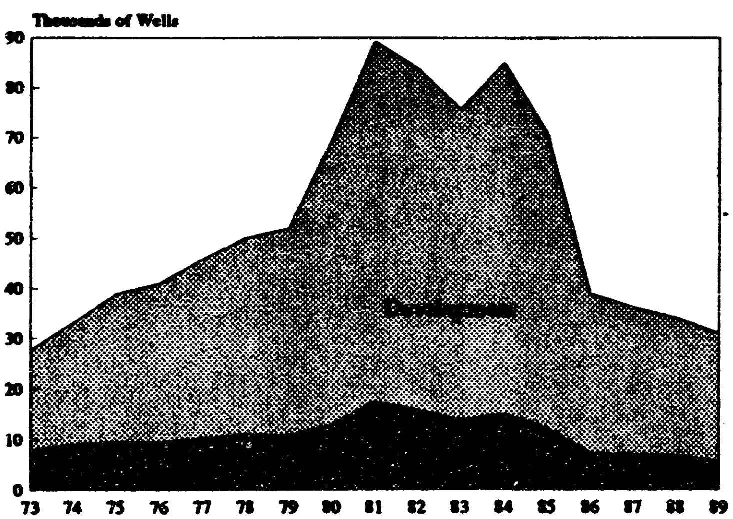
[9] Canadian completion data from Canadian Petroleum Association database, *CPASTATS*. All other countries completion data from Petroconsultants, Ltd., *World Petroleum Trends*.

Figure 8.
U.S. Petroleum Activity
1973-1989

US Petroleum Production



U.S. Well Completions



U.S. Petroleum Investment Spending

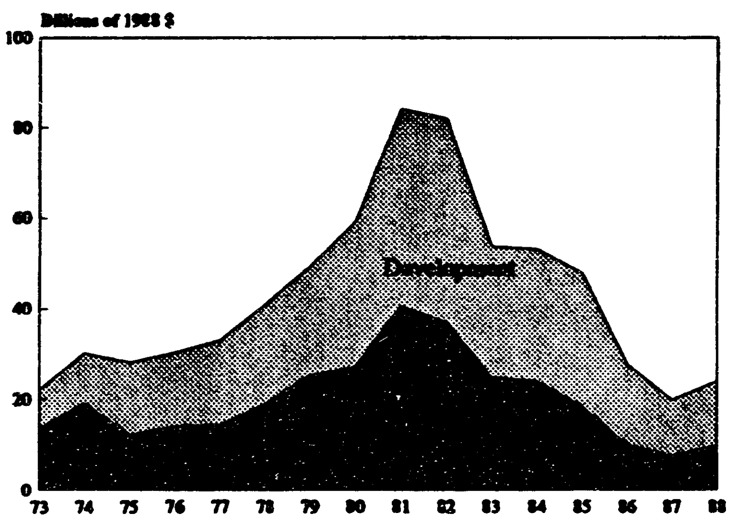
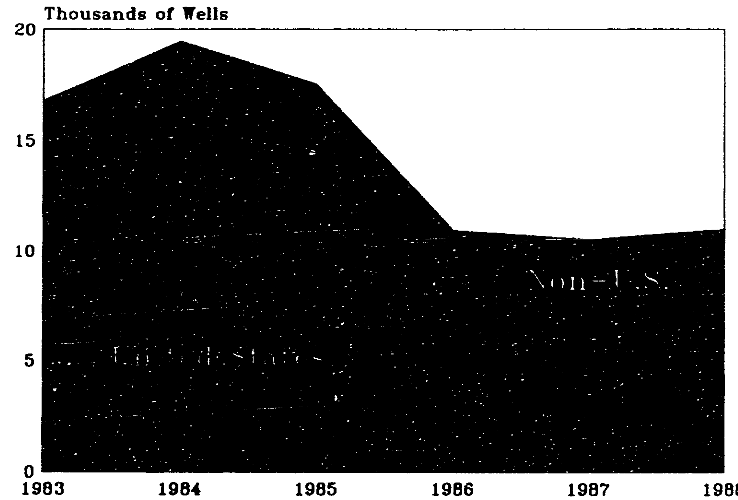


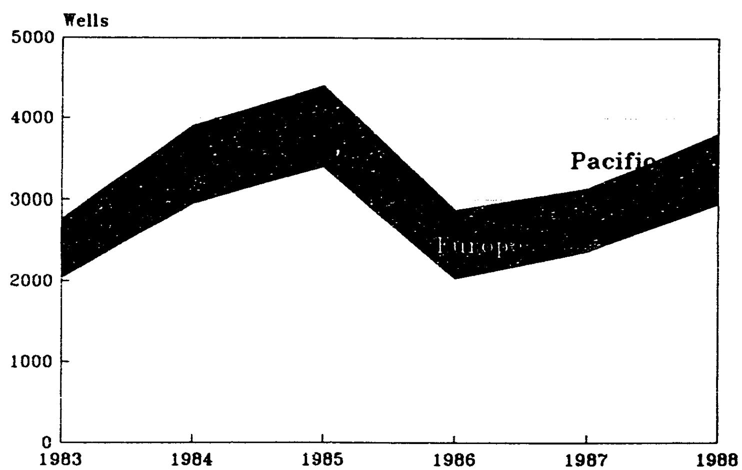
Figure 9.

Non-OPEC Exploratory Wells Drilled

Non-OPEC Exploratory Well Completions



Non-OPEC Exploratory Well Completions
Non-US OECD



Non-OPEC Exploratory Well Completions
Developing Countries

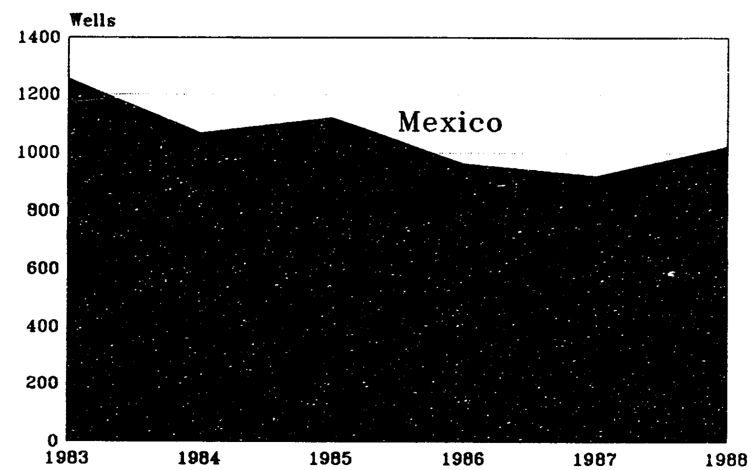
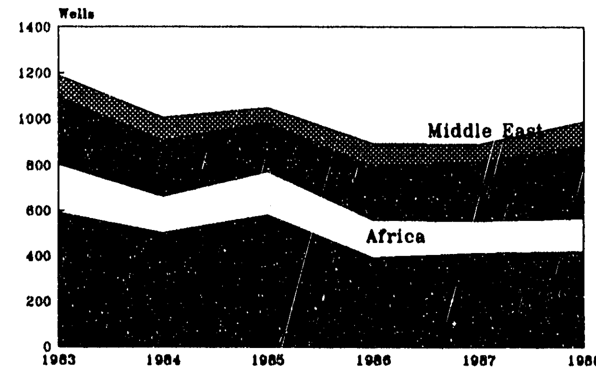


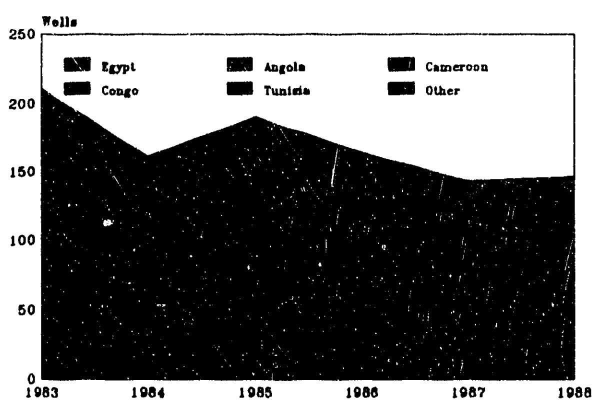
Figure 10. Non-OPEC Developing Country Exploratory Wells Drilled

(excluding Mexico)

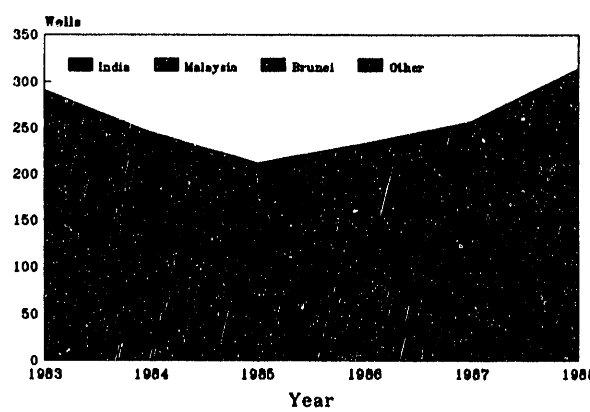
Non-OPEC Developing Countries Excluding Mexico



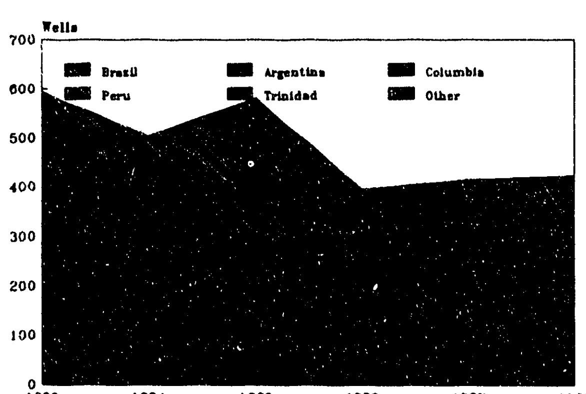
Africa



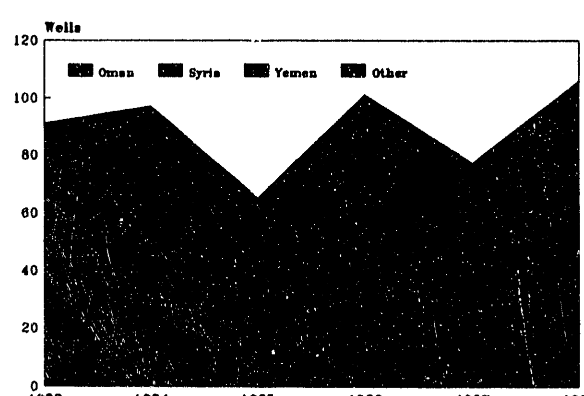
Asia



Latin America



Middle East



continuing. In 1988, nearly half of the non-OPEC exploratory wells drilled in Asia, nearly a third of those drilled in Africa, and nearly a quarter of those drilled in the Middle East, were drilled in countries which are currently not significant petroleum suppliers.

A broader (and more current) measure of drilling activity[10] is provided by the international rig count. As shown in Figure 11, no other non-OPEC region except Canada experienced declines in activity in 1986 as serious as those in the U.S. Even in Canada, however, there was a significant resurgence in activity in 1987 and thereafter. In the non-OPEC developing countries, the decline has been far less severe than in the U.S. As seen in Figure 12, there was a sharp drop in African drilling after the price decline in 1986, and in Latin America drilling has been declining steadily since 1981, with the decline primarily attributable to Brazil and Argentina. In non-OPEC Asia, drilling has increased sharply, primarily as a result of increases in India in late 1986. By 1989, India had replaced Canada as the country with the second highest number of active rigs. In the non-OPEC countries of the Middle East, there also was a recovery in drilling activity in 1988 and 1989. A third measure of upstream activity outside of the U.S. is the foreign exploration and development spending of the major U.S. firms.[11] As seen in Figure 13, while both exploration and development spending by those companies declined in the United States and abroad, the decline in investment outside of the United States was considerably more modest than that in the U.S., suggesting a much greater relative decline in the prospective profitability of U.S. prospects relative to those abroad. By 1989, exploration and development spending abroad by that group of U.S. companies was rapidly appoaching their domestic spending. One suggested explanation for the relative decline in the U.S. and the continued robustness of activity in some areas outside of the United States is that provided by Adelman and Shahi [1989], who argue that outside of the United States, the most significant constraints on development are institutional (tax regimes and concession terms, for example) rather than resource scarcity. Such institutional factors may actually become more attractive with the decline in price, in such a way as to preserve (or even increase) the profitability of prospects in those areas.

In fact, these institutional factors, outside of the United States, have generally been evolving toward a more favorable treatment of petroleum investment since the price collapse, as documented by Walde [1988] and Barrows [1988].

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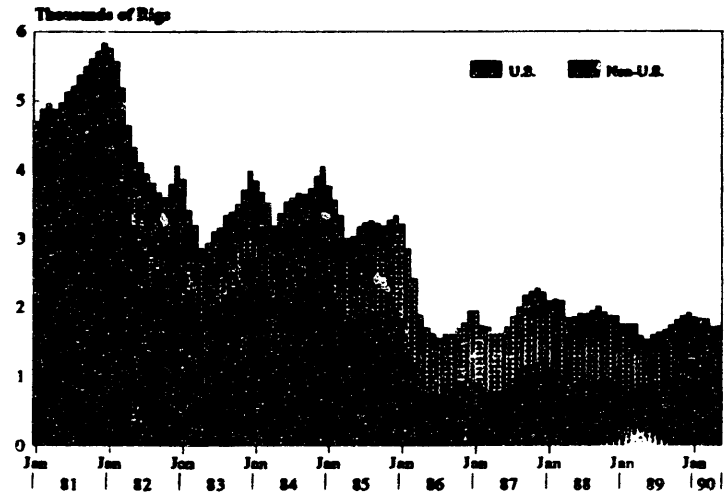
[10]The rig count provides a broader measure insofar as it captures both exploratory and development drilling activity. The international rig count is from Baker-Hughes, Inc. For consistency with the well completion data presented earlier, the regional totals in the Baker Hughes data are adjusted to include Egypt as part of the Africa region rather than the Middle East.

[11]The firms included in the sample were: American Petrofina, Amoco, Amerada Hess, Arco, Ashland, BP America, Chevron, Coastal, Conoco, Exxon, Kerr-McGee, Meridian, Mobil, Occidental, Oryx, Phillips, Shell (USA), Sun, Tenneco, Texaco, Union Pacific, Unocal, and USX. Data is taken from reserve recognition accounting information reported in annual reports. In the case of firms where major mergers occurred, the predecessor company spending was also included in the historical data.

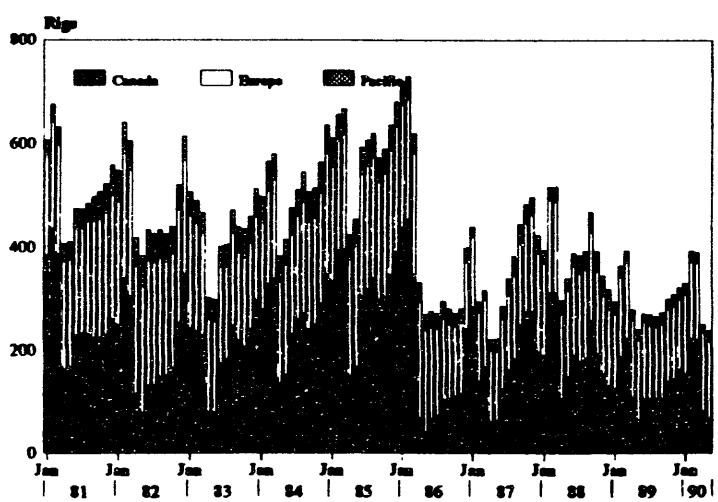
Figure 11.

Non-OPEC
Active Rigs

Non-OPEC Total



Non-US OECD



Non-OPEC Developing Countries

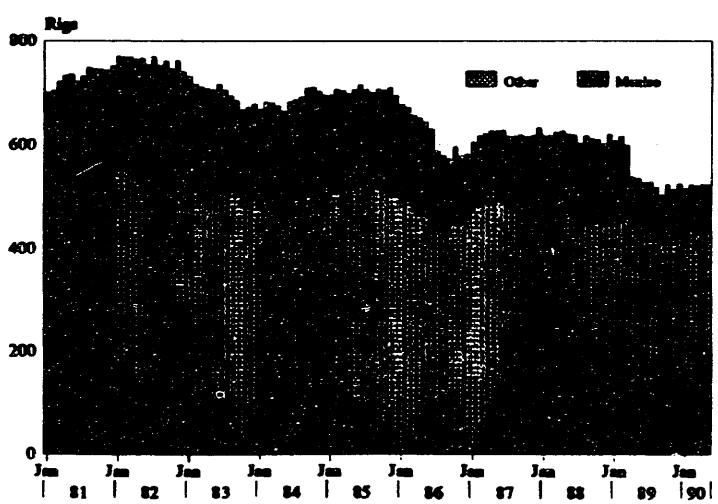
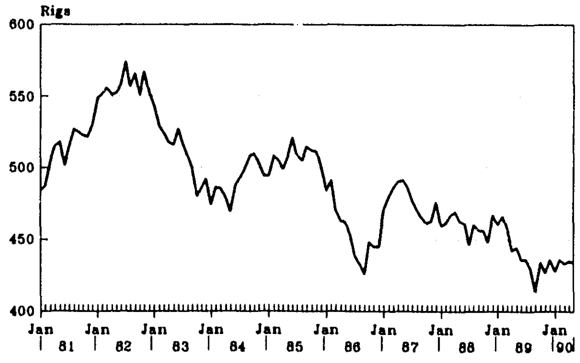


Figure 12.

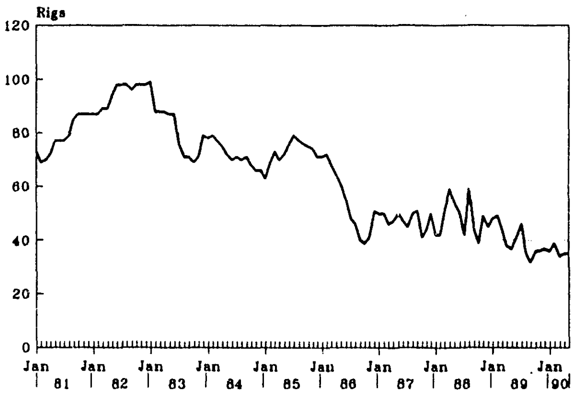
Non-OPEC Developing Country Rigs Active

(excluding Mexico)

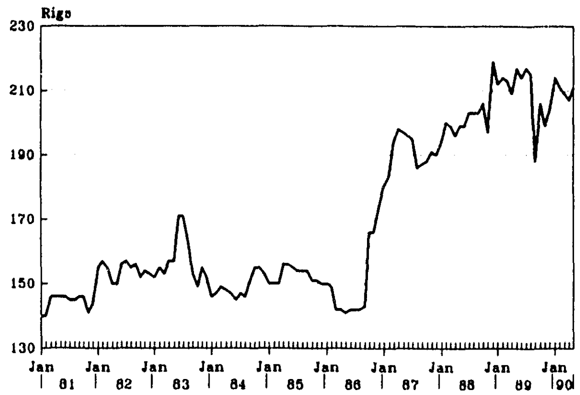
Non-OPEC Developing Countries Excluding Mexico



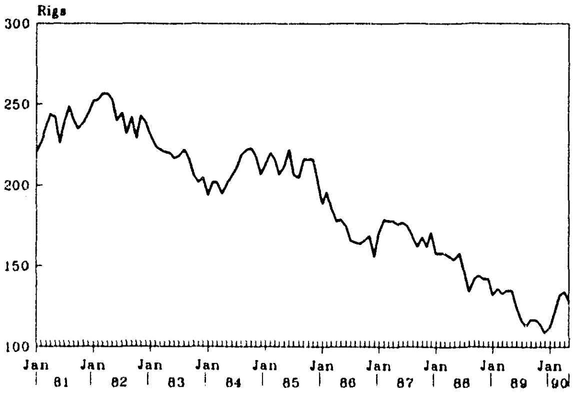
Africa



Asia



Latin America



Middle East

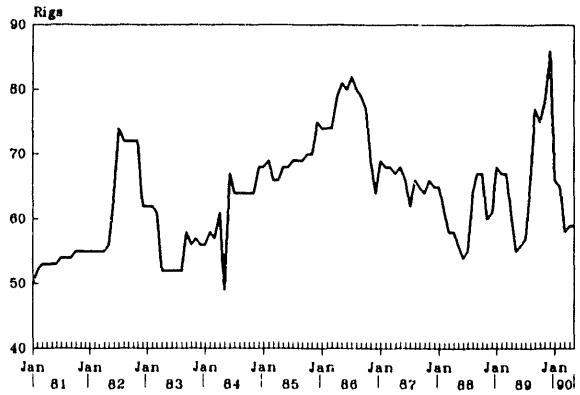


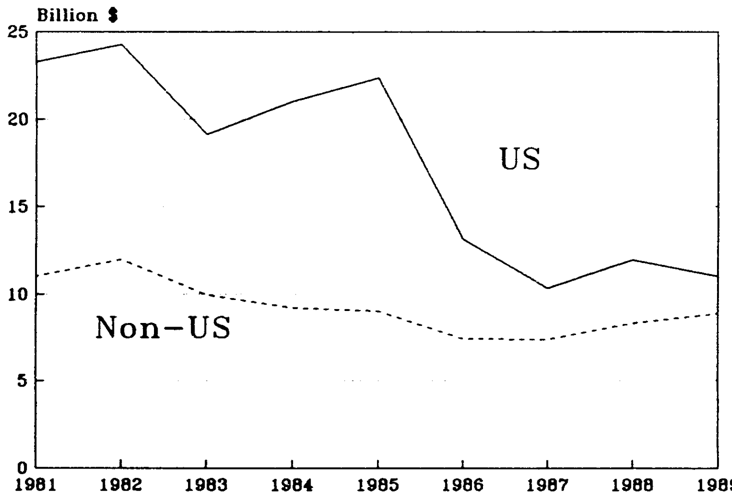
Figure 13.

Petroleum Investment

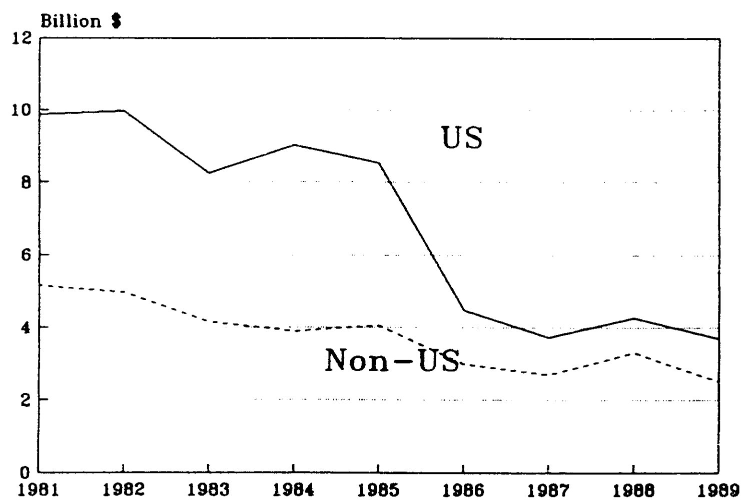
by 23 Large U.S. Companies

1981–88

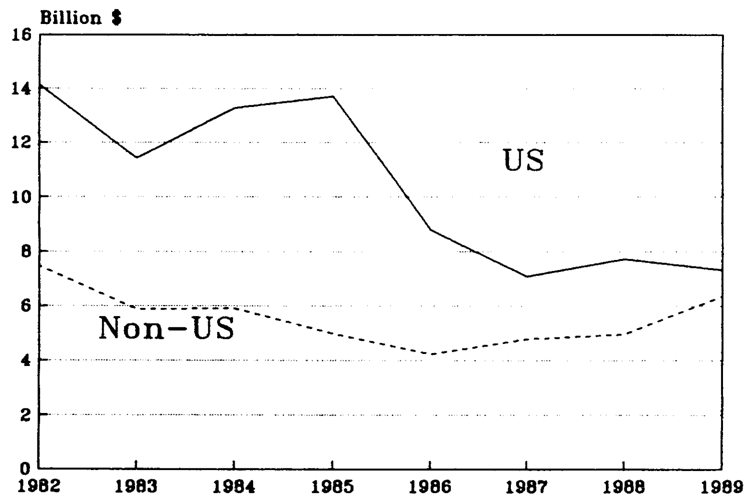
Exploration & Development Expenditure



Exploration Expenditures



Development Expenditures



FUTURE NON-OPEC SUPPLY PROSPECTS

Despite the overall decline in exploration and development activity outside of the U.S., there is no evidence that supply has yet peaked, or even that growth has slowed significantly since 1985 (as was seen in Figures 3 and 4, above). Moreover, as seen in Figures 14 through 17, non-OPEC crude oil reserves outside of the U.S. have continued to grow since 1985, primarily in the developing countries (other than Mexico). Even in those areas of the non-OPEC developing world where exploration and development activity have declined, such as in Africa and Latin America, both production and reserves have continued to grow steadily since 1985.

As seen in Figure 18, from the beginning of 1985 until the end of 1989, nearly 54 billion barrels of crude oil reserves were added in non-OPEC countries, with nearly 40 billion barrels of this being added outside of the U.S. Outside of the U.S., this rate of additions was down only 6% from the rate of additions in the first half of the 80's. Moreover, in the non-OPEC developing countries other than Mexico, the rate of reserve addition in the second half of the 80's more than *doubled* from that experienced during the first half, despite average oil prices which were more than 50% lower than in the first half of the decade.

While these rates of reserve addition were falling far short of replacement of production in the industrial countries, they more than completely replaced production in the developing countries. In fact, in both Mexico and the other non-OPEC developing countries, reserve additions in the last half of the 80's were being made at more than double the rate of production during the same period, as seen in Figure 19.

The above data do demonstrate clearly that the U.S. supply response to lower prices in the latter part of the 80's has been unique, at least in severity if not direction. Outside of the U.S., the geographical dispersion of activity is continuing, and growing activity in some areas suggests at least a potential for new supplies to at least partially offset the U.S. declines. In fact, a common theme of the outlook for non-OPEC supply among most current forecasts is that growth from non-OPEC sources outside of the U.S. will continue to offset part or all of the expected continuing decline in U.S. oil supply[12] for a significant part of the next decade.

Figure 20 presents the base case scenario from the U.S. Department of Energy's most recent International Energy Outlook (IEO). In the IEO base case, U.S. supply continues to fall, by more than 1 mmbd over the course of the decade. However, other non-OPEC supplies continue to grow at a sufficient pace to more than offset this decline for the early part of the decade.

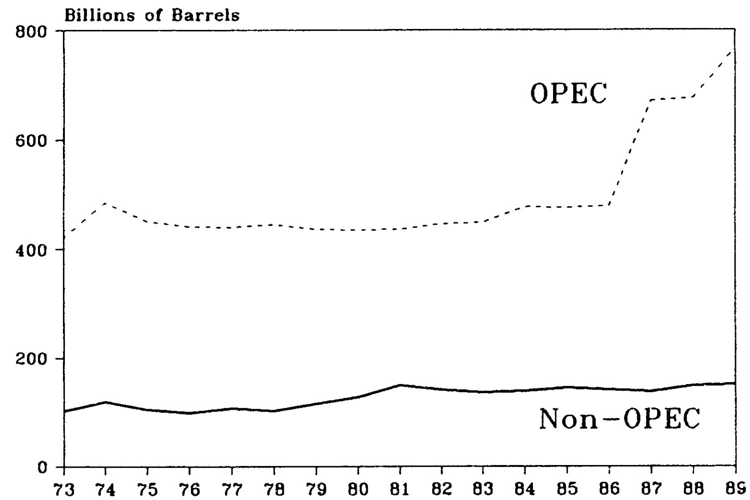
It should be noted that the decline in U.S. supply anticipated by the IEO forecast is considerably more modest than that experienced in the last half of the 80's. In part, this is due to the rise in real crude oil prices anticipated in the IEO base case scenario. If real oil prices are

[12]For example, see U.S. Department of Energy [1990], Conoco [1989] and Ashland [1990].

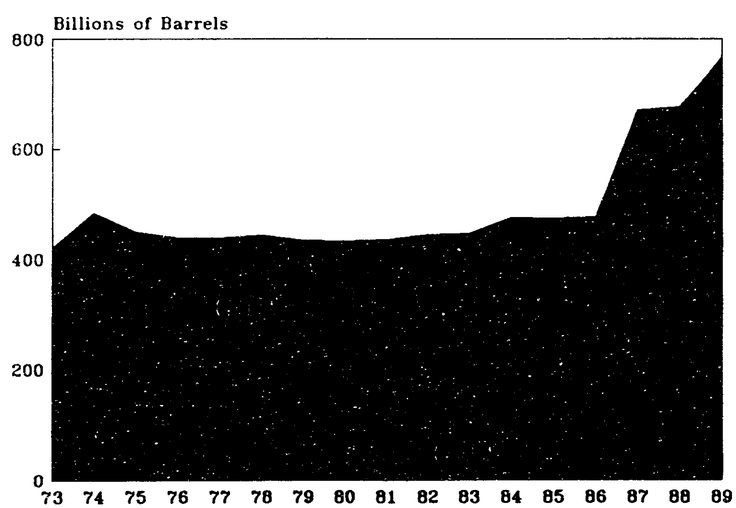
Figure 14.

WOCA Crude Oil Reserves

WOCA Total



OPEC



Non-OPEC

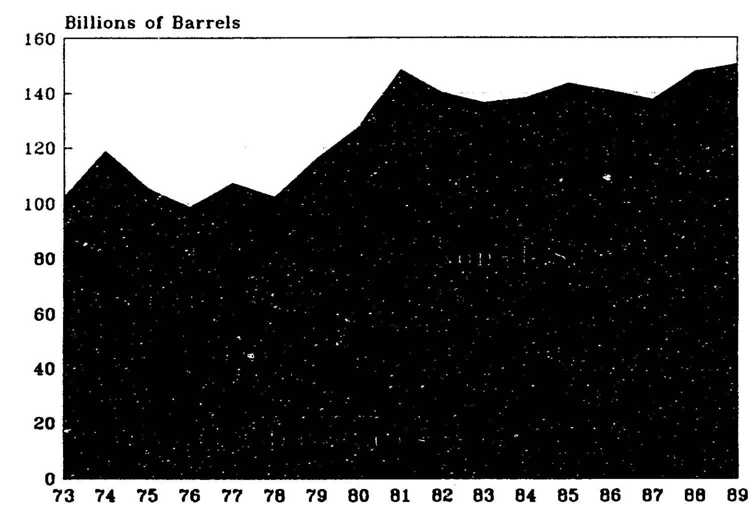
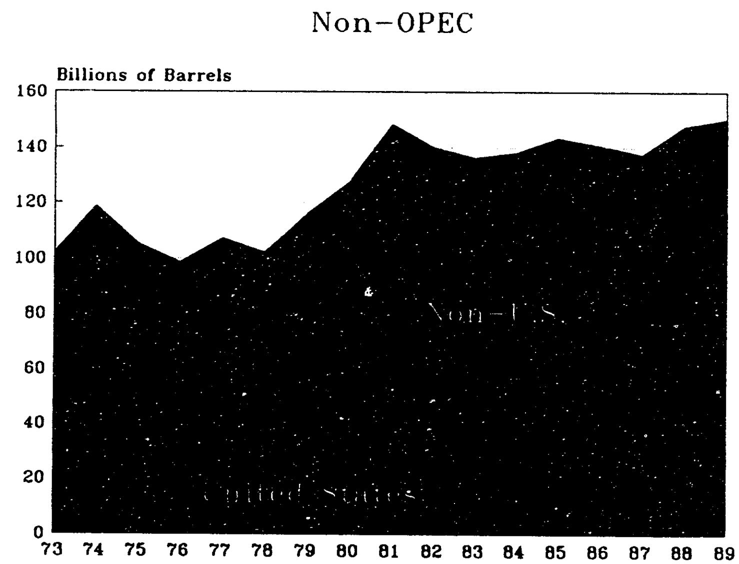
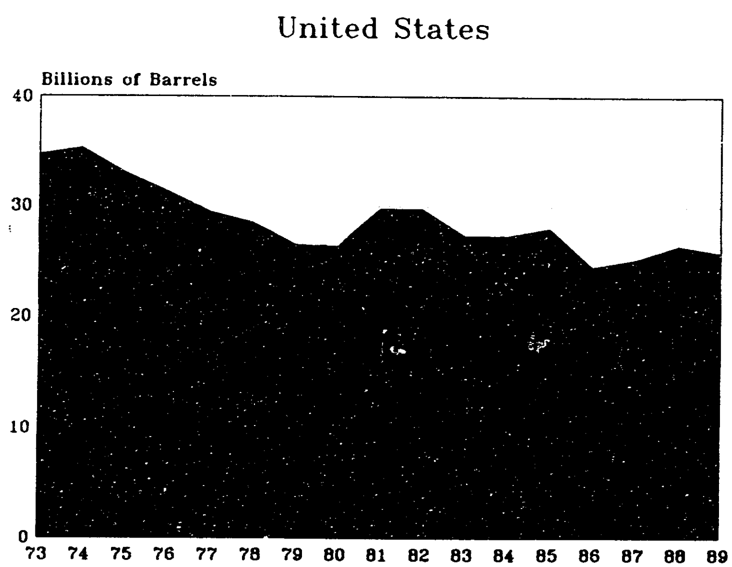


Figure 15.

Non-OPEC Crude Oil Reserves





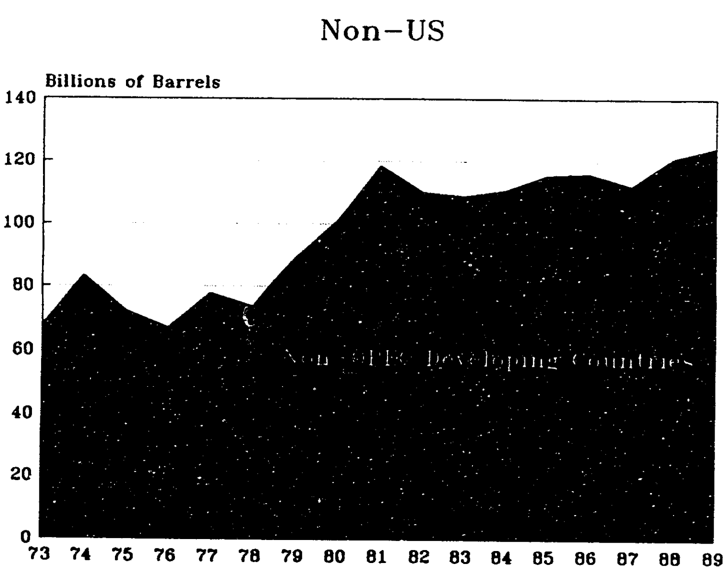
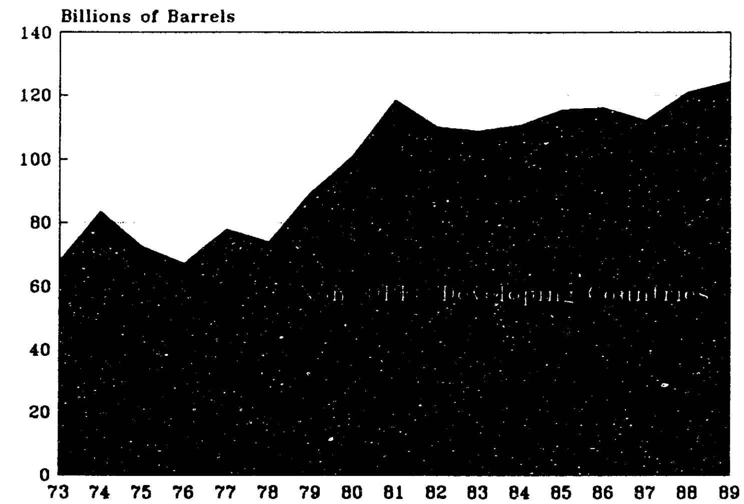


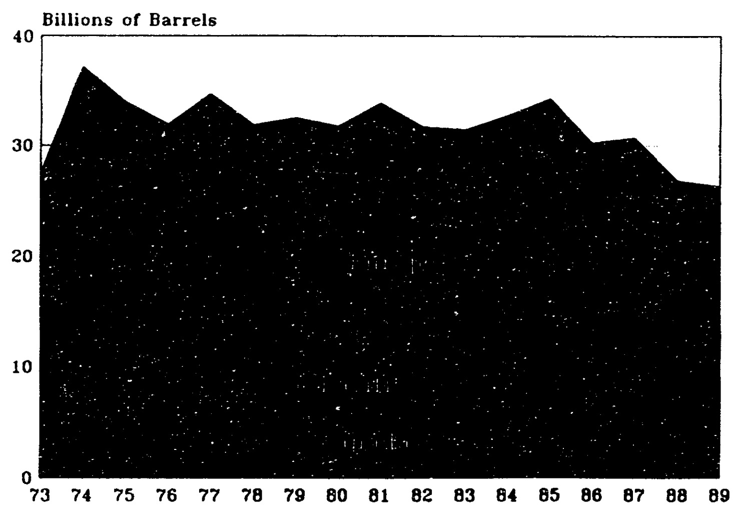
Figure 16.

Non-OPEC Crude Oil Reserves Outside of the U.S.

Non-US



Non-US OECD



Non-OPEC Developing Countries

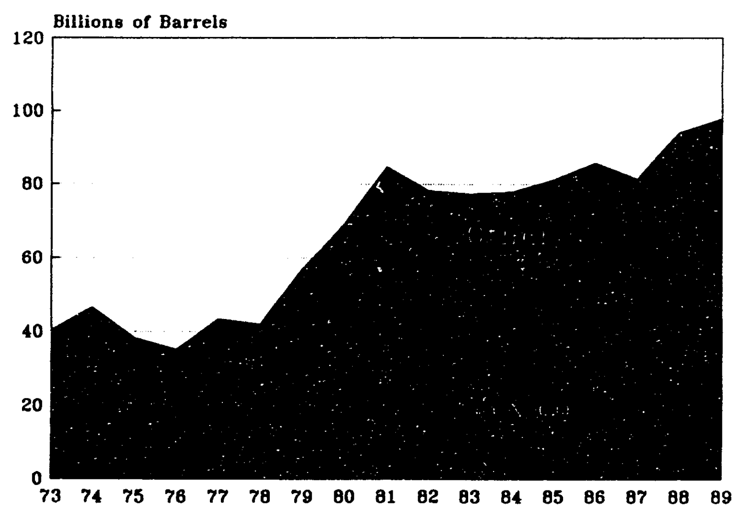
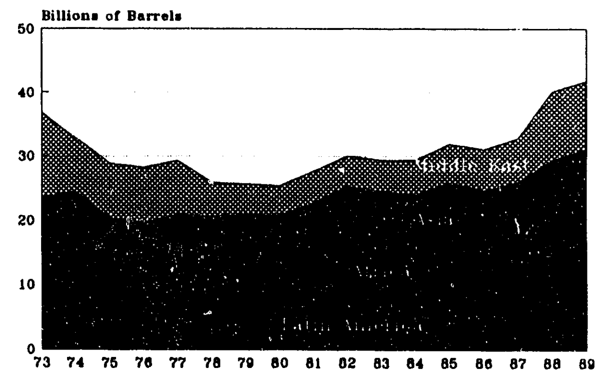


Figure 17.

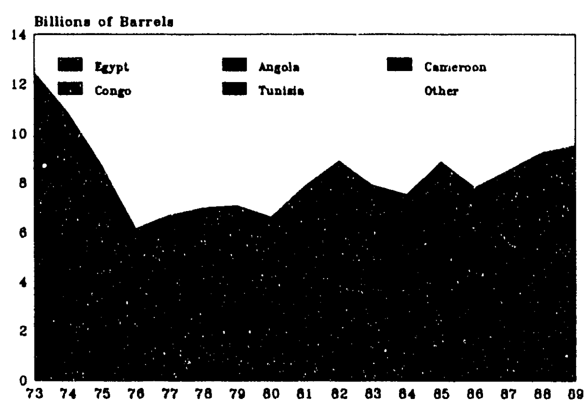
Non-OPEC Developing Country Crude Oil Reserves

(excluding Mexico)

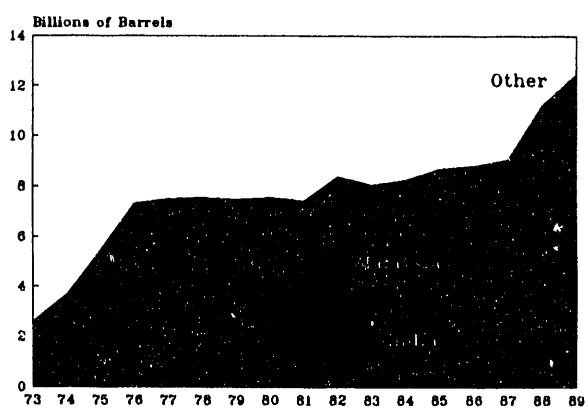
Non-OPEC Developing Countries
Excluding Mexico



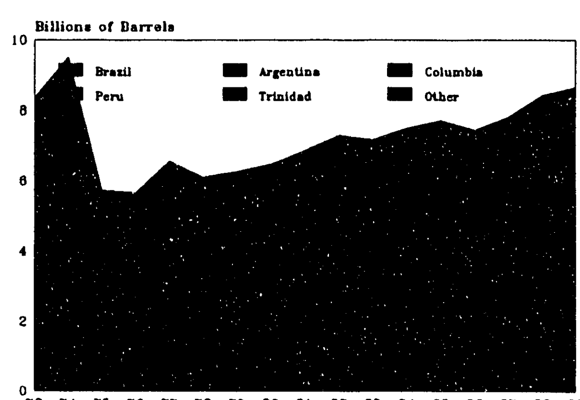
Africa



Asia



Latin America



Middle East

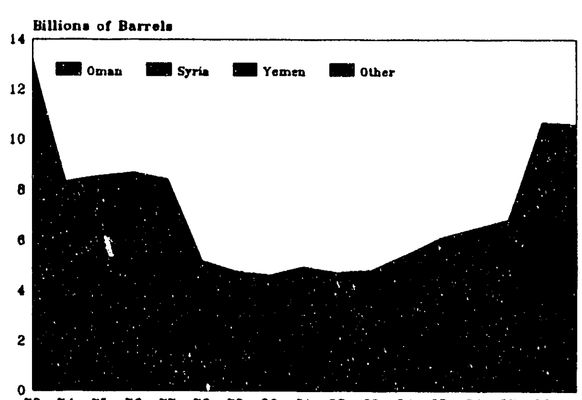


Figure 18.
Non-OPEC Gross Reserve Additions

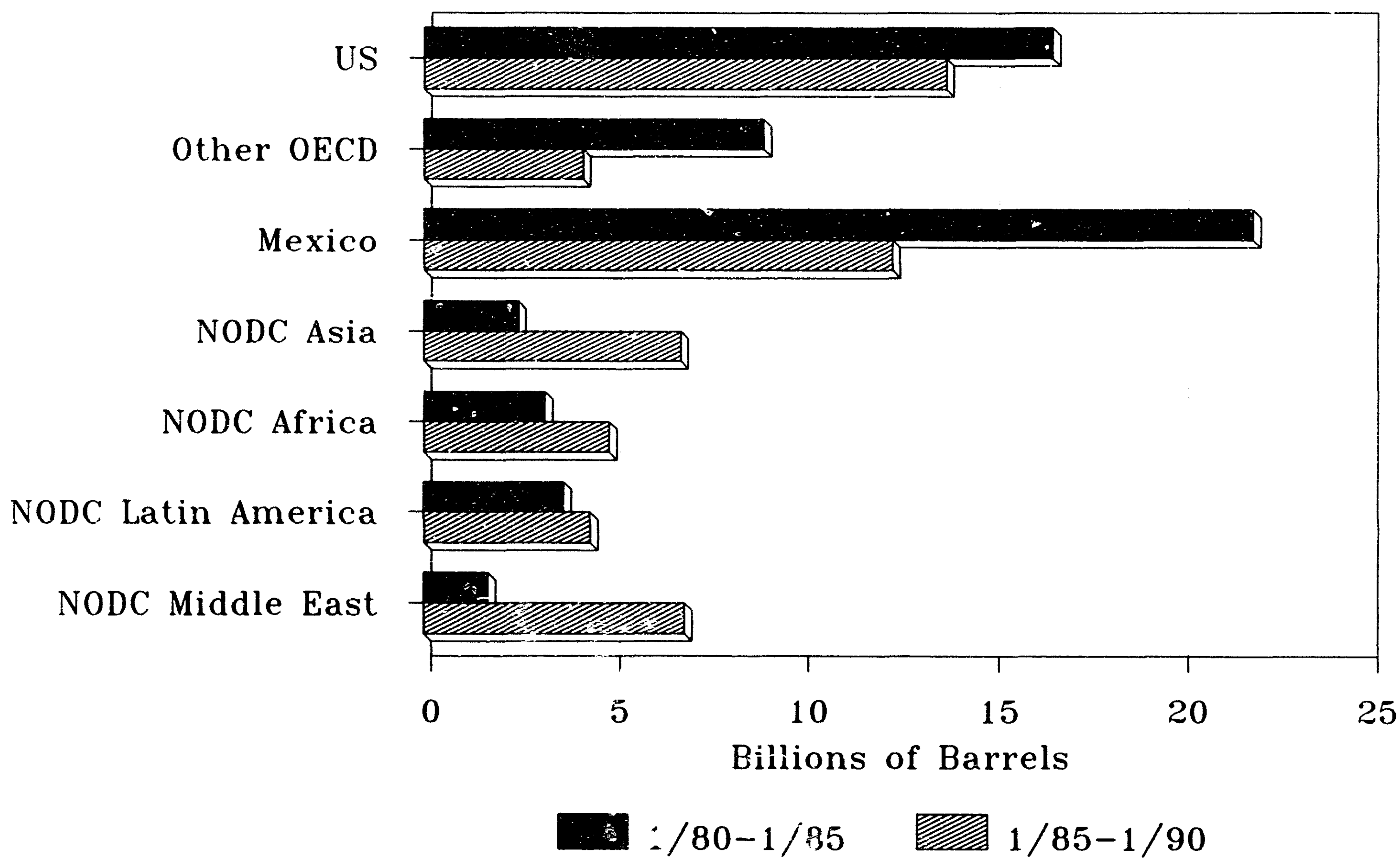


Figure 19. Reserve Replacement Rates (Non-OPEC Gross Reserve Additions as a Share of Crude Oil Production)

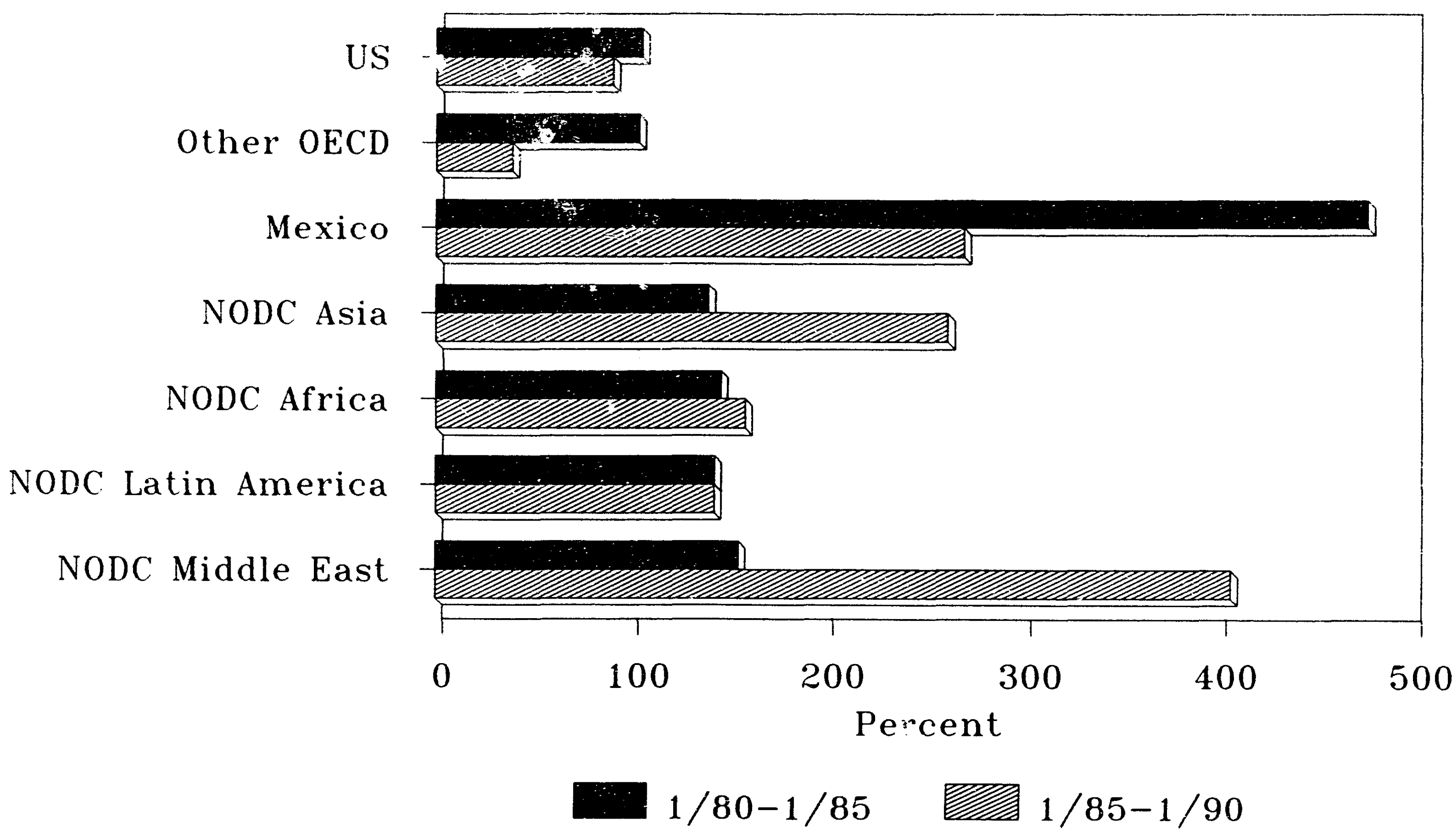
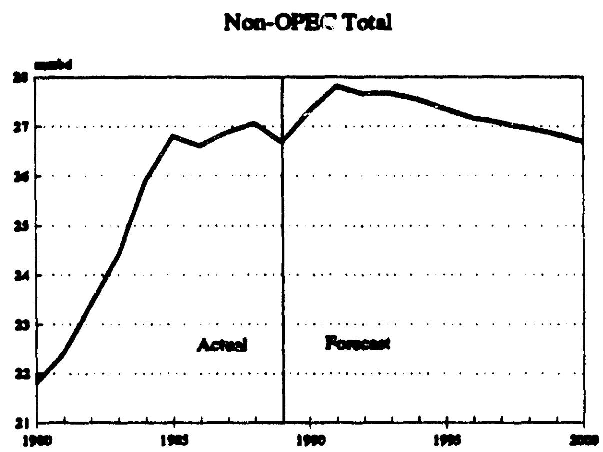
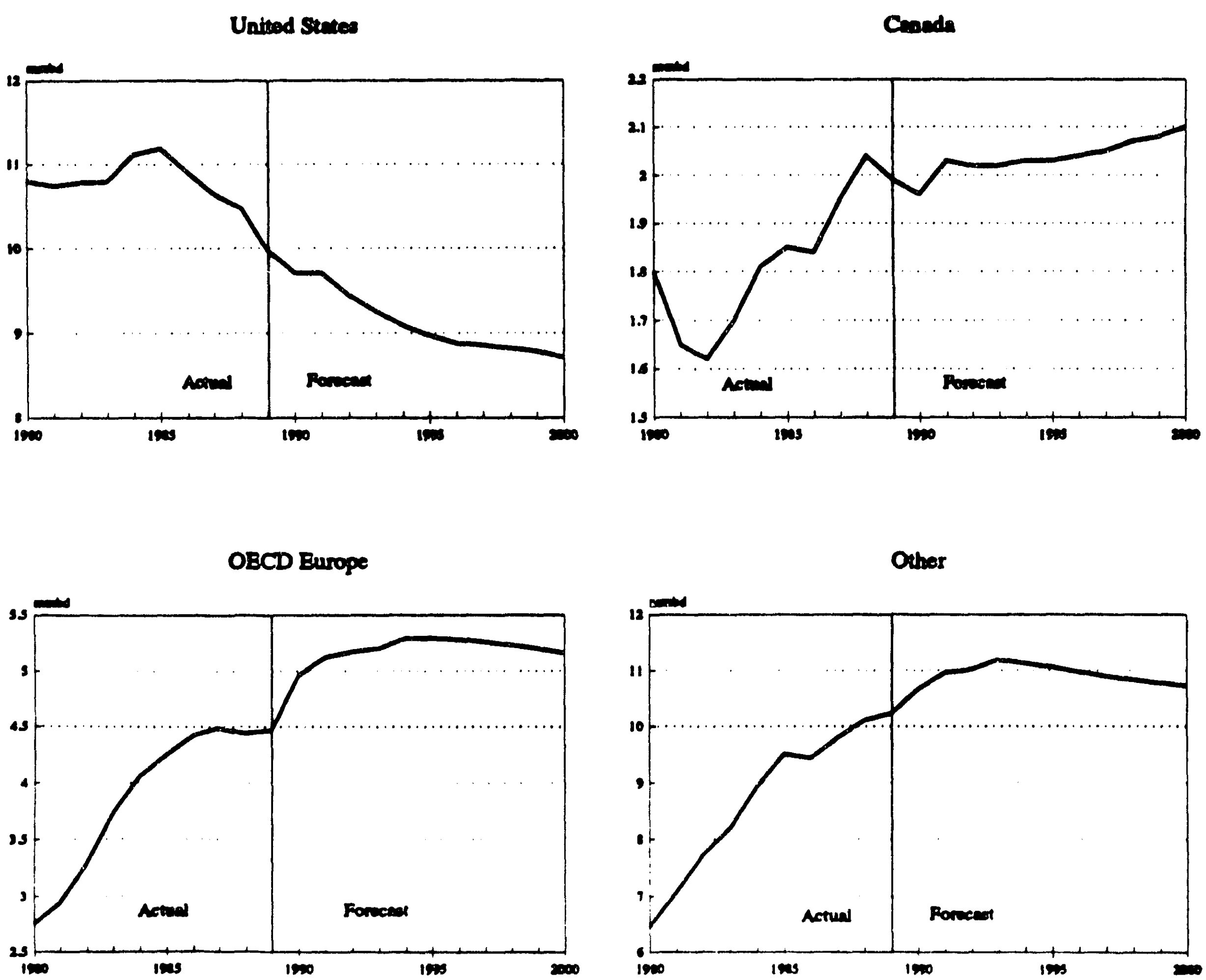


Figure 20.

Non-OPEC Supply: Recent Experience and IEO Base Case Forecast





held to their 1989 level, the forecast decline in U.S. supply would be closer to actual recent experience[13].

Supply from OECD Europe (principally the North Sea) in the IEO base case is expected to add nearly a million barrels a day to non-OPEC supply between 1989 and its expected peak in 1994, and to decline only about 3% below this peak by the end of the decade. This decline is consistent with recent experience, since (as noted above) reserve additions are not keeping pace with production in the OECD Europe region, causing reserve to production ratios to fall steadily.

Outside the industrial countries, the IEO forecast also expects non-OPEC supplies to peak in 1993, and to fall by about 0.5 mmbd by the end of the decade. This is the most highly speculative component of the IEO (and other) forecasts of non-OPEC supply, for several reasons. First, there is inherently more uncertainty regarding the reserve levels in this region, which is composed predominantly of developing countries. Second, apart from resource uncertainty, there are a wide range of institutional settings within which development proceeds in these countries, with government policy decisions playing a very significant role in development choices[14]. Nonetheless, the IEO forecast appears extremely conservative in light of existing reserve levels, production and replacement rates.

The reserve to production ratios for the non-OPEC countries are shown in Figure 21. In 1989, the reserve to production ratio, for the "other countries" category in the IEO[15] exceeded 30 years, nearly triple that of the U.S. and Canada, and more than double that of OECD Europe. Even if the rate of replacement of production with new reserves in those countries fell to *zero*

---

[13]An alternate case holding real crude oil prices constant was generated using the U.S. Department of Energy Oil Market Simulation (OMS) model, which DOE uses to develop the IEO forecast. In the alternate case simulation, oil price was held constant at its 1989 level, while all other assumptions and parameters were identical to those in the IEO base case. In that case, U.S. supply declines at an average rate of 1.6% per year during the 1989-2000 period, as opposed to 1.2% in the IEO base case. From 1985 to 1989, the decline averaged 2.8% annually.

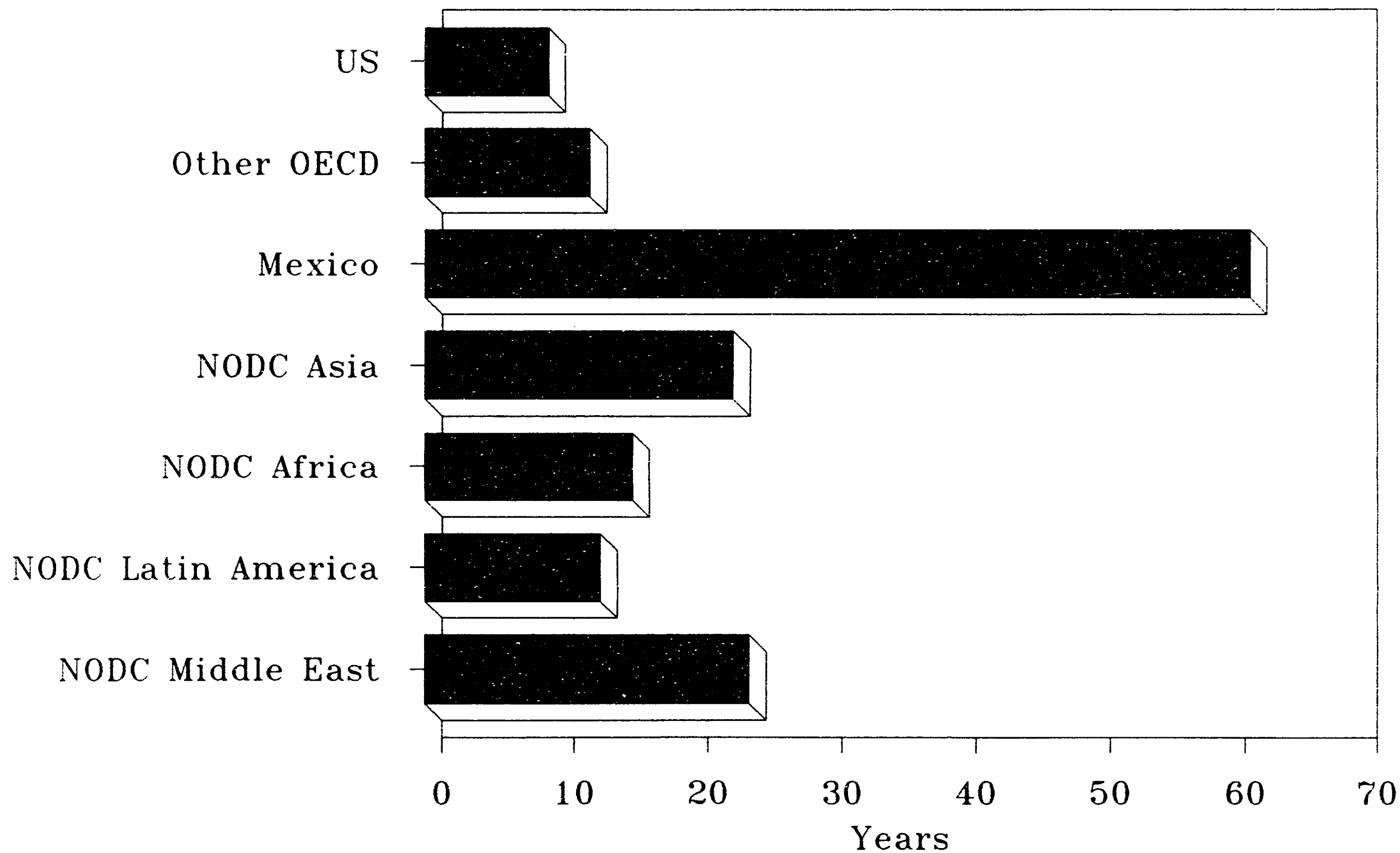
[14]Mexico, which in 1989 comprised over a quarter of the production and over half of the reserves in this region, provides an extreme example of both types of uncertainty.

[15]This region consists principally of the non-OPEC developing countries, although it also contains Australia and New Zealand. In 1989, the breakdown of crude oil production and reserves for the region was

	Production (mmb/d)	Reserves (bil bbls)
Pacific OECD	0.503	1.9
Mexico	2.507	56.4
Other Developing Countries	6.368	41.8
TOTAL	9.378	100.1

The IEO data reports 10.2 mmbd supply for the "other countries" category, with the difference being that the IEO supply includes NGLs and other non-crude oil supply.

Figure 21.
Non-OPEC Reserve to Froduction Ratios
1989



for the entire decade, the production rates contained in the IEO base case would only bring the reserve to production ratio in those countries from its current level of about 29 down to about 17 years in the year 2000, compared to levels of 10 years or less commonly experienced in the U.S. Moreover, a sustained growth of 2% through the year 2000, which approximates the rate of growth in supply from those countries actually experienced in the latter half of the 80's, would reduce the reserve to production ratio to only about 13 years by the year 2000, again assuming *zero* reserve replacement rates.[16] In fact, as was shown in Figure 19, the rate of replacement in those countries in the latter half of the 1980's was in excess of 200%[17]. These numbers suggest very strongly that if supply from this group of countries does indeed peak in the early to mid 90's, as anticipated in the IEO base case forecast, it will be for reasons other than resource scarcity.

To summarize, it would appear that the decade of the 90's offers mixed prospects for non-OPEC supply. On the one hand, there are no major new discoveries on the threshold of development as there were in 1980. In the industrial countries, there is again a consensus among forecasters that U.S. production will continue to fall, and that other OECD supply will also begin to fall within this decade. There is already evidence in recent experience to indicate such declines (declining production in the U.S., and reserve replacement rates falling short of production in Europe). In the developing countries, however, the prospects are more optimistic. While no major expansions comparable to Alaska or the North Sea are foreseen in the 1990's, the reserve levels and recent rates of reserve accumulation in those areas suggest a potential for modest growth in supplies from the developing countries to offset industrial country declines for most or even all of the next decade. Consequently, while no major increases in non-OPEC supply are expected, no major declines can be expected either. If OPEC is to regain market share, it is likely to hinge far more on the capture of consumption growth than on the elimination of its non-OPEC competitors.

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[16]In 1989 the crude oil reserves of the IEO "other countries" region were 100.1 billion barrels of crude oil, and production was 9.4 mmbd. If production were to continue growing at 2% per year until the year 2000, and the reserve replacement rate fell to zero, we would have the following:

	1989	2000
Reserves (bil barrels)	100.1	57.6
Production (mmbd)	9.4	11.7
R/P Ratio (years)	29.3	13.5

[17]The extreme nature of this conclusion is largely attributable to Mexico, but the general thrust of the result holds even if Mexico is excluded. Countries in this category other than Mexico had average reserve to production ratios of about 18 years in 1989, and added reserves at a rate more than double their production during the last half of the 80's.

WORLD PETROLEUM MARKET IMPLICATIONS

While there is no immediate prospect of rapid expansion in non-OPEC supply during the next decade, there are implications of the above assessment for the structure of the world petroleum market over the next decade. In particular, there are three such implications.

First, the loss of market share alone implies that prices optimal for the cartel today are lower than those which would have been so in the 70's. That is, as pointed out by Lynch [1989], the loss of market share not only changes the ability of OPEC to raise price, but perhaps more importantly affects its motivation for doing so. The loss of market share in the 80's presents the OPEC of 1989 with a far higher effective elasticity of demand for its product than was experienced in the 70's.[18] This is even more true when the focus is narrowed from OPEC to the Gulf, or from the Gulf to individual Gulf countries with the greatest resource potential. Lynch observes that "while OPEC as a whole is usually better off with higher [than current] prices...it is very difficult for the cartel to reach the point at which the residual supplier makes higher revenues from higher prices." In a similar vein, Askari and Deschmaltski [1987] argue that a strategy of volume growth represents a more secure path to increased revenues than price growth for the Gulf Cooperation Council countries. More recently, Ghalib [1990] makes a similar argument for Saudi Arabia.

However, it also follows that growing market share, such as that being experienced, will tend to raise the cartel's optimal price over time, by lowering the effective elasticity of demand for its exports. This may occur very slowly, since the increase in OPEC's market share will depend primarily on consumption growth worldwide, insofar as the market lost to non-OPEC producers may not be recoverable, at least for a very long time. In fact, in the IEO base case examined above, OPEC's market share rises steadily during the next decade, reaching over 45% of non-OPEC WOCA consumption by the year 2000, as shown in Figure 22. Nonetheless, two things should be noted about this widely noted growing concentration of supply. First, even at 45%, this share is well below historical peaks, which approached 70% in the 70's. More importantly, the rate and extent of this rebound in OPEC's market share is quite sensitive to small changes in supply growth by the non-OPEC developing countries. For example, if supply growth in the IEO "other countries" category does not peak in 1993 as anticipated in the IEO base case, but continues to grow at 2% per year through the decade, OPEC's market share (holding IEO base

---

[18]The "effective" elasticity faced by the cartel is given by

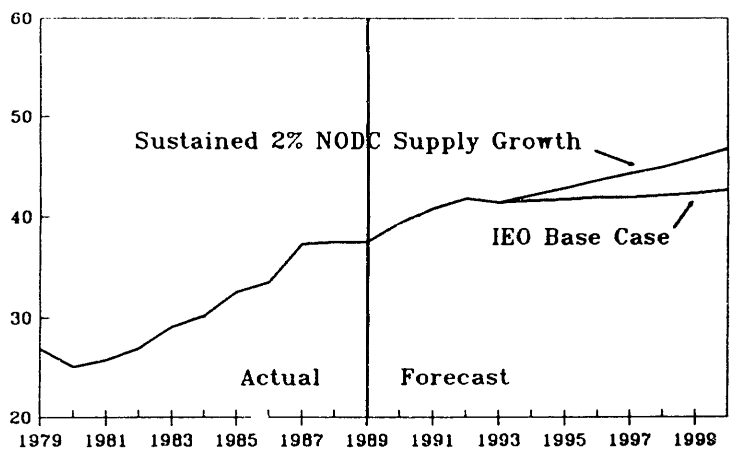
$$\epsilon' = (\alpha/\beta)\ \epsilon$$

where α is the share of incremental demand lost by the cartel as the result of a price hike, β is the cartel's share of the total market, and ϵ is the market demand elasticity. In the case that the cartel behaves as the residual supplier, $\alpha=1$. If ϵ is the same today as it was in the 70's, a 50% reduction in market share would have doubled its effective elasticity. Note that this increase is due to loss of market share alone, completely apart from any increase in the underlying market elasticity ϵ, which might have occurred as the result of increased flexibility associated with consumption (such as increased fuel substitutability) or inventory management (such as the availability of the strategic government stockpiles).

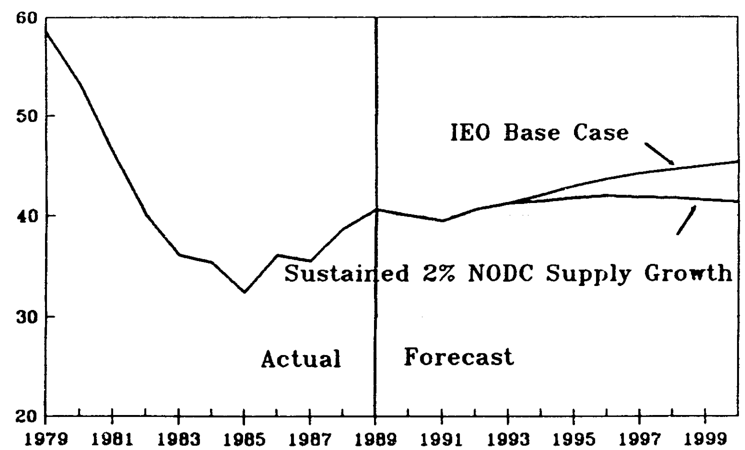
Figure 22.

Growth of Bilateral Market Concentration

Demand Concentration
US Net Imports as a Share of OPEC Net Exports



Supply Concentration
OPEC Net Exports as a Share of Non-OPEC Consumption



case prices and all other IEO base case assumptions unchanged) would peak at less than 42% in the late 90's.[19]

Finally, a far less noted feature of the evolving market structure is that demand for OPEC output has become, and is expected to continue to become, increasingly concentrated in the United States. In 1973, U.S. net imports accounted for less than 20% of OPEC net exports. By 1980, this share had risen to 25%, and is currently approaching 40%. In the IEO base case, U.S. net imports reach 42% of OPEC's net exports by the year 2000 as shown in Figure 22. At first glance this appears implausible because the U.S. has not had, nor is it expected to have, the fastest growing consumption in the future. Rather, this increasing concentration stems from the fact that outside of the U.S., growing supply offsets a large portion of consumption growth, serving to moderate net import demand, while in the U.S. import demand growth is doubly fueled by rising consumption and falling domestic production. Furthermore, the degree of such concentration in the future is also quite sensitive to changes in the assumed growth of developing country supply. As above, if supply growth in the IEO "other countries" category does not peak in 1993 as anticipated in the IEO base case, but continues to grow at 2% per year through the decade, the U.S. net import share of OPEC's export market (holding IEO base case prices and all other IEO base case assumptions unchanged) would continue growing throughout the 90's, reaching nearly 47% by the year 2000.

Consequently, as the widely noted "monopoly power" of the OPEC cartel appears to grow with increasing supply concentration in the Persian Gulf, the apparent "monopsony power" of the U.S. can be expected to grow with increasing demand concentration here.

Within such a market environment, there is a growing temptation for policymakers on both the demand and supply sides to attempt to exercise such power for unilateral gain.[20] However, it is well established that the apparent "market power" possessed by each party in such a market is illusory.[21] Rather than presenting each party with an opportunity for unilateral actions to exploit its trading partner, such a market structure tends to bind both the consumer and the supplier nations into a pattern of mutual dependence. Unilateral policy actions with significant

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[19]Of course, it could be argued that the base prices assumed in this scenario are not consistent with such a level of OPEC supply. This is true. In fact, OPEC possesses the low cost resources, and consequently can *choose* to make its market share higher by producing more (at a lower price). A more general point would be that any non-OPEC supply increase such as that considered here will make it more difficult for OPEC to regain market share (by requiring greater price reductions).

[20]For example, policies to constrain production or capacity growth by the Gulf countries, or policies designed to reduce imports by the United States.

[21]The extreme example of such concentration is the case of bilateral monopoly. As was shown by Bowley [1928] there is no unique equilibrium in such a market. Rather, as bilateral concentration increases, the prices and quantities resulting are heavily influenced by non-market factors.

impacts on the structure of demand or supply cannot be seriously evaluated in such a market without careful consideration of their effects on the strategic choices of the trading partner.

CONCLUSION

Six conclusions can be drawn from the information presented above.

First, the growth of non-OPEC supply played a very significant historical role in the erosion of OPEC's market since 1973. By 1981, such supply had overtaken that of OPEC itself. By 1989, despite three years of experience with prices at levels not unlike late 1973, OPEC still faced an export market 25% smaller than it had in 1973.

Second, the trend in the growth of such supply, particularly since 1980, has been increasingly toward geographic dispersion of supply sources. The concentration of non-OPEC supply in North America, characteristic of the early 70's, has now largely been eliminated by growing supplies from the North Sea, and more recently, the developing countries.

Third, the growth in non-OPEC supply since 1980 was largely unanticipated in forecasts prepared using a number of "state of the art" models of the world petroleum market prepared in 1980 and 1981. A common feature of most of those forecasts was the serious underestimation of non-OPEC supply growth outside of the U.S., and a tendency to underestimate the potential price responsiveness of U.S. supply.

Fourth, a preliminary examination of data covering the period since the price collapse in 1986 suggests that only in the United States has the collapse in prices brought a drastic reduction in exploration and development activities. Outside of the U.S., while overall levels of activity have declined, such declines have typically been far more modest, and in some areas of the developing world, exploration activity has continued to expand.

Fifth, while future long term prospects for non-OPEC supply from the U.S. are not optimistic, there is significant potential for other sources of non-OPEC supply outside of the U.S. to offset this decline for most if not all of the next decade. Consequently, the recovery of market share by OPEC will rely on the capture of consumption growth more than on the elimination of its non-OPEC competitors.

Finally, the effects of increased OPEC market share and the shift in non-OPEC supply away from the United States is likely to give rise to a market structure characterized by growing bilateral concentration, with a growing share of OPEC's export market being composed of U.S. net import demand and a growing share of non-OPEC consumption being supplied by OPEC. While such concentration is likely to tempt both the cartel and the U.S. to take unilateral actions aimed at improving their own terms of trade, any failure to recognize the mutual dependence inherent in such a market structure will make the consequences of any such actions prone to unpredictability.

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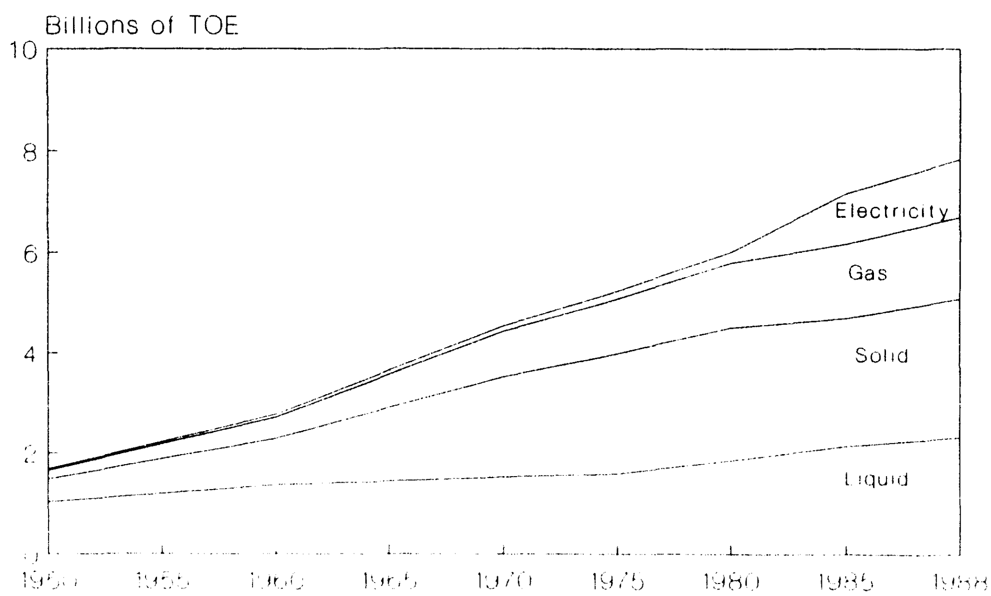
Chapter 11

SURVEY OF ENERGY DEMAND ELASTICITIES IN DEVELOPING COUNTRIES

Carol Dahl*
June 1991

Profound changes have taken place in global energy markets since World War II. Total energy consumption has more than quadrupled and per capita consumption has more than doubled. Oil with relatively low transport costs and a wide range of uses passed coal in 1968 and remains the fuel of choice even to this day with over 30 percent of global energy markets. However, Figure 1 shows that relatively fast growing natural gas and primary electricity have kept markets more diversified, and oil has never reached coal's earlier dominant position of well over half of global energy consumption.

Figure 1. World Primary Energy Consumption



Source: United Nations, World Energy Supplies, [illegible]; Yearbook of Energy Statistics, [illegible]; U.S. EIA, International Petroleum Annual, 1989

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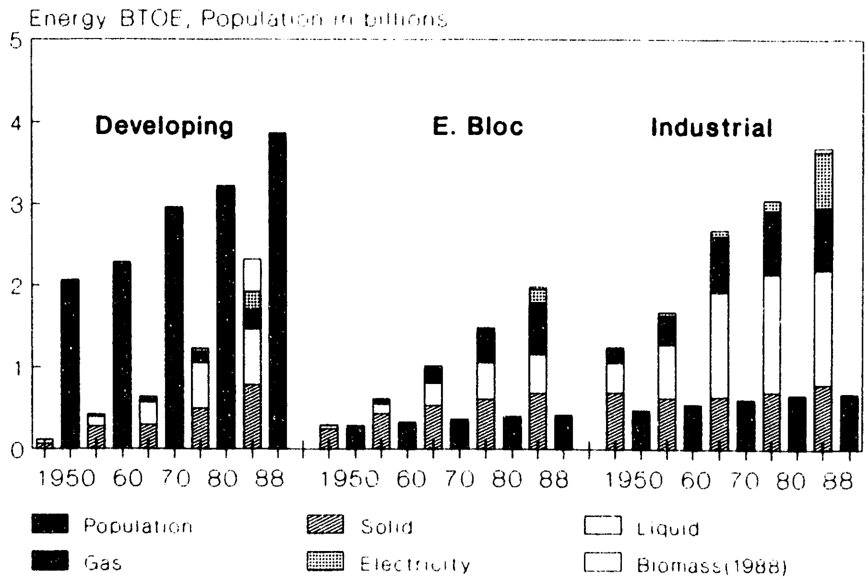
Figure 2. Energy Consumption and Population



Source United Nations, World Energy Supplies 1950 1973, Yearbook of Energy Statistics, 1986 US EIA, International Energy Annual, 1989

With the pace of global change quickening, the next four decades promise even more exciting changes in global energy markets as more of the "have nots" join the "haves". Figure 2 shows this potential for change. These "have nots"[1], which now comprise three fourths of the world's population, consume less than a quarter of the world's commercial energy and an even smaller proportion of the world's oil, gas, and primary electricity. At the same time they are consuming a disproportionate share of the world's traditional fuels. (Data on traditional fuel is only available in the graph for 1988.) Hence, not only do they consume less than a one tenth as much energy per capita as the "haves," they consume a larger share of lower quality fuels.

As these nations change the quantity and quality of their energy consumption, they could have critical effects on global energy markets, energy investment requirements, and atmospheric emissions. Hence, quantitative information on fuel market changes should be valuable to energy suppliers making investment decisions as well as government policy makers whose goal is to improve the economic well being of their people while mitigating the adverse environmental effects of such development.

In this paper I survey this quantitative evidence on changes in energy consumption in the past 4 decades. I begin in Section I by briefly considering the structure of energy consumption

[1]The "have nots" considered in the context of this paper all countries except the industrial and former COMECON countries referred to as the Eastern Bloc.

in the developing world by major world region and comparing this structure to that in the industrial countries, Eastern Europe, and the USSR. From this discussion I develop some hypothesis about energy consumption and discuss some issues that will be useful in understanding the evolution of energy markets in the future. These issues include demand elasticities in the developing world, how they compare to the industrial world, and whether they imply that the developing world will follow in the path of the industrial world.

In Section II, I survey all the econometric energy demand studies for developing countries. Although the focus of the discussion is on oil and energy, other products will be included as well. These studies will be used to investigate the hypothesis and issues raised in Section I and to develop summary elasticities. Section II contains the conclusions of the analysis to date.

I. ENERGY MARKET STRUCTURE IN THE DEVELOPING WORLD

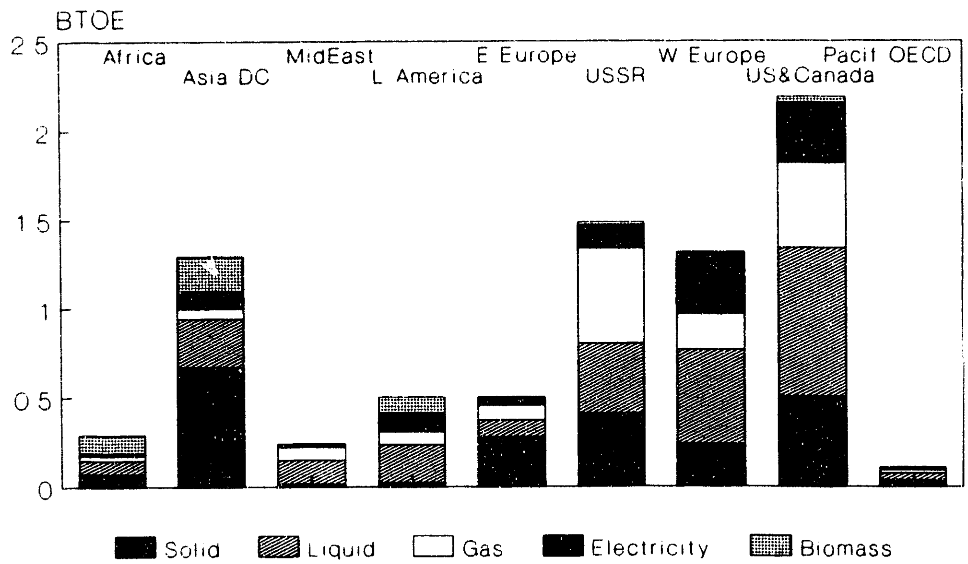
High relative income growth in the developing world (DCs) has led to relatively high energy and oil consumption growth rates. This energy growth seen earlier in Figure 2 has been more or less double that of the industrial countries (ICs) and suggests that energy and oil income elasticities might be greater than one and they might be more elastic for poorer than for richer countries.

Along with this energy growth has come a changing composition of energy consumption in the third world also seen in Figure 2. Except for a few large coal users such as the Peoples Republic of China (PRC) and India, the DCs tended to began the post war period with a higher proportion of liquid fuels than either the former Soviet Bloc countries (Bloc), comprised of Eastern European and the USSR, or the industrialized countries. Although there has tended to be growth in all fuels, their relative shares have changed. As in the rest of the world, the DCs tended to shift into oil through the early 1970s and shift away thereafter. Gas and primary electricity have continued to make inroads into the market. Coal has tended to lose share except in the 1980s.

The global dip in oil consumption in the 1980s came primarily from the industrialized world. In the developing world growth in oil consumption slowed but did not become negative. Despite the higher oil prices, the DCs as a whole managed to somehow pay for more oil. The move to diversify was larger in the more industrial world suggesting that the developing world may have lower price elasticities.

Global oil models such as those in EMF 11 are of necessity highly aggregated. Often the developing world is considered as a single entity represented by price and income elasticities along with income growth. Whether such a high degree of aggregation makes a difference will be the focus of some attention. For example, oil and energy can be aggregated across regions, products, and sectors. Although such aggregation makes analysis more manageable, we lose a great deal of information. Aggregation across diverse groupings with large and varying structural change may make long term forecasts rather unreliable. Therefore, the diversity across these various aggregations will be considered in this section and the differences aggregation makes in the econometric work will be considered in the next.

Figure 3. Energy Consumption by Major World Region 1988



Source US EIA, International Energy Annual, 1988

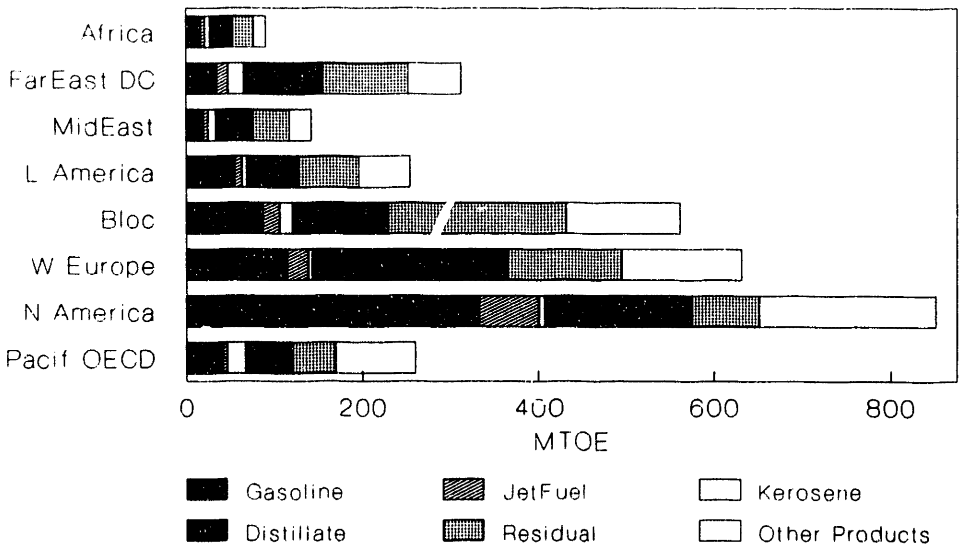
Figure 3 shows the structural differences in energy product consumption across major world regions with the industrial world and Eastern Bloc included for comparison purposes. Asian DCs have seen the fastest overall energy growth surpassing Africa's per capita consumption in the 1970s but still less than half of that for South and Central America. Oil at a quarter of energy consumption has the lowest share of any major developing region. Coal still supplies over half of fuel consumption in Asian developing countries because of the predominance of the People's Republic of China.

South and Central America with little coal have consistently consumed a higher percent of petroleum, although its share has consistently fallen as gas and primary electricity mostly in the form of hydropower have made significant inroads. Oil and gas, of course, predominate in the Middle East with coal falling from 40 percent of consumption to less than 10 percent. Although oil is less than half of energy consumption in Asia and Africa, this proportion shifts with the removal of China, India, and S. Africa.

Oil's share has converged to between 35 percent and 40 percent in the industrial world, but in the rest of the world the pattern is more mixed. It is a much lower percent in Eastern Europe, the USSR, and the PRC, but a higher percent in the Middle East and Latin America.

North America and Canada started the post war period with the most diversity in fuel use, Europe with the least. All industrial regions have become more diverse with W. Europe and the

Figure 4. Oil Consumption by Product by Major World Regions



Source: U.S. EIA, International Energy Annual, 1988

USSR approaching the diversity of North America. The developing world and Eastern Europe remain less diversified.

In the above fuel use patterns, we see a rather wide diversity across regions but some convergence within the industrial world. When examining the econometric work I will look for evidence of whether we might expect this same convergence to occur in the developing world.

Oil demand diverged more across the developing and Bloc countries than across the industrial world. However, if we look more closely, the demand for oil is really a derived demand from oil products. Therefore, the composition of the barrel might well influence consumption and the elasticity of demand for oil.

Figure 4 shows the product barrel for 1988 by major world region. Globally the product barrel has been lightening with a larger proportion of transportation fuels and distillate but less residual. Gasoline is over 30 percent of a barrel for the more industrialized countries, but is less than 20 percent of a barrel for the developing world and the Eastern Bloc. The high percent for the industrialized world is primarily from the US and Canada with over 40 percent of a barrel going to gasoline and over twice as much oil consumption per capita as the rest of the industrial world. The Bloc countries along with Japan and Oceania have the same percent of a barrel going to gasoline as the developing countries with Western Europe only slightly higher.

However, within the developing world there is a wide variation from the low gasoline share in Asia of 14 percent, because of the PRC, to the high in Latin America of 25 percent, which surpasses the Western European average. The convergence towards the North American gasoline proportions within the industrial world have been much lower than for overall fuel consumption.

Distillate shares do not vary as widely as for gasoline between the DCs and ICs. Residual shares, on the other hand, are highest in the Bloc and are substantially higher in the DCs than the ICs. The industrial world also has a larger share of a barrel in the other category, which includes LPG and lubricating oil.

There will be rather large differences in investment requirements, if the developing nations shift their percent of a barrel closer to the North American than the European average. There would be an even more dramatic affect if they were to achieve the North American rather than the Western European per capita consumption. Hence, in the demand elasticity survey, it will be important to consider not only the overall demand for oil but also the elasticities of the various products.

Since structural change tends to be high in the developing world, some attention will be paid to sectoral fuel use and demand elasticities. Figure 5 shows the share of energy use by sector in major world regions with more detailed sectoral use by fuel share contained in Table 2 in the Appendix.[2] As these countries industrialize, we might expect the share of energy going to industry should increase and the switch toward commercial fuels should hasten.

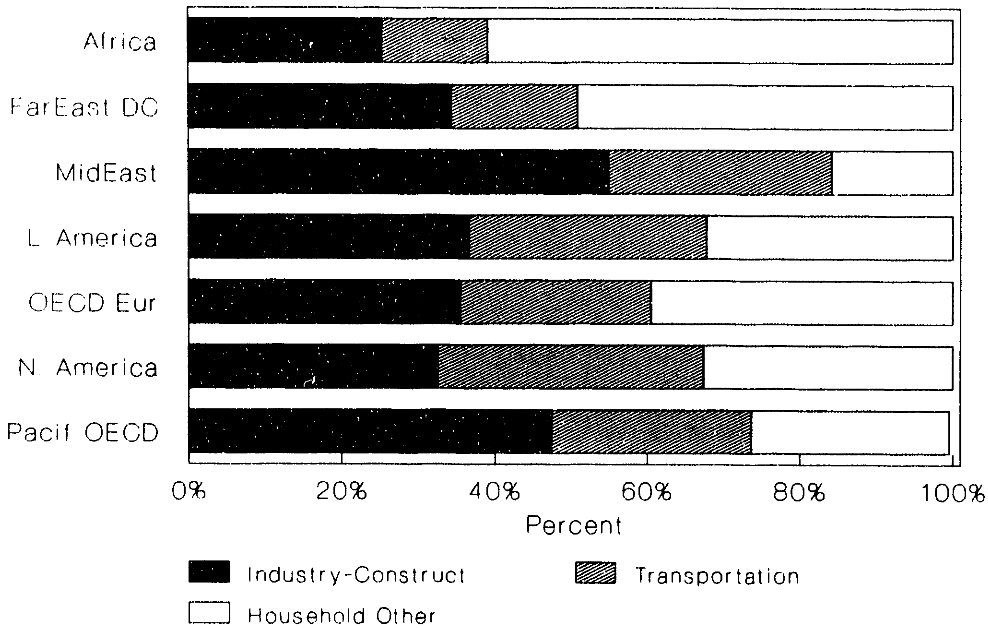
For Asia and Africa there is a higher share of total energy going to households. The Middle East is an outlier for both the developing and the industrial world with the largest share of energy going to industry and the smallest share to households. It is closest in consumption patterns to the Pacific OECD countries and is dominated by Saudi Arabia, Kuwait, and Qatar with their low populations and large refining and petrochemical complexes. Latin America has a pattern somewhat similar to N. America. Transportation's share is lower in Africa and the Far East DCs. In general there tends to be a greater diversity across the developing world than across the industrial world with considerable diversity across countries within each region.

Energy use also varies by fuel type and sector. Table 2 shows that between one fourth and three fourths of coal is used to generate electricity in all major regions. The share tends to be higher for the industrial world where close to a half or more of the coal is used to generate electricity. The Middle East is again an outlier with a very small amount of coal used in non oil producing countries mostly for electricity generation. Again there is more diversity across the developing than the industrial countries. Although some coal is still used for transportation in Africa and the Far East it has been largely phased out in the rest of the world.

Oil use is rather mixed. Over half of oil is used in transportation in North and Latin America but roughly 40 percent is used for transportation in most other major regions. Africa is an exception with less than a third being used for transport there. The Middle East uses the

[2]The developing world shares are for a sample of 48 countries with a large omission being China, Mexico, Taiwan, and S. Africa. These countries represent 30 percent or more of energy consumption in these regions.

Figure 5. Share of Total Energy Use by Sector 1986



Source: U.N., Energy Balances and Electricity Profiles, 1988.

highest percent of oil for electricity generation. There appears to be no systematic pattern between developing and industrialized countries.

Only a small but growing percent of gas is used for electricity generation in the US and Europe. In some of these countries regulations and protection of coal have discouraged the use of gas, and larger shares of gas have gone to the household/other sectors. In the Pacific OECD, as a result of heavy use of gas for electricity generation in Japan, the reverse is true with only 21 percent going to the household/other sector and well over half being used for electricity generation. The DCs tend to have small shares going to households with the bulk used in industry and electricity generation. The Middle East is the most extreme of the developing regions with a minimal amount going to the household/other sector and over half going to industry. For gas there is more diversity across the industrial than across the developing world.

From the electricity use shares we can see the heavy electrification of the Middle East with almost 3/4 of electricity going to the household sector. In electricity consumption the Middle East is closest to North American consumption patterns, while the rest of the developing world is closer to the Pacific OECD with over half of electricity going to industry. The European OECD is between these extremes.

The generation of electricity tends to have the most diverse patterns across major world regions. Latin America is the most extreme example with almost three fourths of its electricity generated by hydro power. At the other extreme is the Middle East with almost two thirds of its electricity generated by oil and almost 90 percent by oil and gas with almost no primary electricity production. Only in Latin America is there any significant use of biomass for the generation of electricity. Outside these two extremes between 30 and 40 percent of electricity is generated by primary electricity with hydro predominating in the DCs and a mix of hydro and nuclear in the ICs. The Far East and OECD Europe have somewhat similar patterns for electricity generation except for nuclear constituting over half of primary electricity generation in Europe.

Most biomass is used in the household-other sector in the developing world. The exception is Latin America where over one-fourth is used in industry and over 10 percent is used in transportation because of Brazil's alcohol program.

In the above brief survey we can see a wide diversity of fuel and oil product consumption and varying sectoral use. Although the level of aggregation may not matter for short term forecasting, in the long run structural shift may predominate. One hypothesis might be that as the developing countries mature, their consumption patterns will approach that of the industrial world. In some cases consumption patterns have been converging in the industrial world, towards more diversity, away from coal, towards the lighter end of a barrel, towards more gas and electricity. However, in other cases there is wide divergence across the industrial world. Energy-intensive North America consumes around twice as much oil and energy per capita as the rest of the industrial world, a very high share of gasoline, a low share of residual, and a high proportion of energy used by transportation. Which, if either, of these patterns the developing world might follow will be considered by studying energy and fuel demand elasticities by sector and across regions.

Although data limitations are quite severe in the developing world, data have been accumulating both at the national and international level. The most copious international source of consumption and production statistics by product and country are: United Nation, International Energy Yearbooks, preceded by World Energy Supplies; U.S. Department of Energy, International Energy Annual; and British Petroleum, Statistical Review of World Energy. Two sources of sectoral use for selected countries include the Organization for Economic Cooperation and Development, Energy Balances of Developing Countries 1971/1982; and the United Nation, Energy Balances and Electricity Profiles. Price data is harder to acquire at the international level. The U.S. Department of Energy, International Energy Annual contains data for selected products or import prices can be computed from the United Nation, International Trade Statistic. The International Studies Group at the Lawrence Berkeley Laboratory has developed a sectoral data base for 15 developing countries based on national sources. (See Sathaye et al. (1987)). Some authors generously include their data in their article. Since this practice helps maintain the integrity of the studies and allows the development of a more comprehensive data base for the developing world, I would encourage authors to include their data where feasible or make it available upon request.

Despite the data limitations, a number of courageous souls have tackled the problem of econometrically estimating energy demand in the developing world. In the next section I consider this econometric work to date. After discussing the estimates, I will consider the issues raised above: 1. Whether energy and oil price elasticities are greater than 1 in absolute value in the DCs; 2. Whether income elasticities are greater in the DCs than the ICs; 3. Whether price elasticities are lower in the DCs than the ICs; 4. Whether the degree of aggregation affects the oil elasticity estimates; 5. Whether the developing world will approach the aggregate level and pattern of consumption of the industrial world and when; and 6. The studies will also be examined for discernible trends and summary statistics will be developed for forecasting purposes.

II. SURVEY OF ECONOMETRIC DEMAND ELASTICITIES IN THE DEVELOPING WORLD

The survey data in Table 3 has been organized by level of fuel aggregation and further subdivided depending on whether estimates were made for total or per capita consumption. Beneath each category are means and standard deviations for the major reported elasticities. Where only one elasticity is estimated in static models, the elasticities are labeled as intermediate-run, although their interpretation may be somewhat different depending on the type of data and model used. The t statistics reported are those on the current prices and income. Hence, they are on the short-run elasticities in the models with a lagged endogenous or other lagged variable, but are on the intermediate elasticity for static models. I confine my survey to energy, oil and oil products.

Models without both price and income are considered mis-specified. They are nevertheless included for comparison purposes because they may provide information on systematic bias that might be caused by their omission. Price, being more difficult to acquire, is more often left out than income. Despite the problems of aggregation for both price and quantity, total energy has by far the largest number of elasticity estimates. There are 93 estimated equations of energy demand per capita including price (Category 1 (C1), Table 3) 80 excluding price (C2). There are 53 estimates of aggregate energy demand including price (C3) and 50 of aggregate energy demand excluding price (C4). Most are demand for commercial energy (E) but a few include biomass as well (Eb).

Energy per capita (E/) has the most estimates with the averages quite well behaved. Using consumption per capita is the preferred specification because aggregation can cause heteroskedasticity when population varies across the sample. For this specification, the average intermediate-run is between the short- and long-run for both price and income. Although there is a high degree of variation across studies, the averages suggest that energy demand is price inelastic (ϵ_p=-.44) but income elastic (ϵ_y=1.25). The average coefficient on the lagged endogenous variable is .61 suggesting a median adjustment lag of 1.4 years. Elasticities from static models, which I have labeled intermediate-run, measure somewhat smaller elasticities than the long-run from dynamic models.

Most models are lagged endogenous (LE) or static (Stat). In the LE model, variation in short-run elasticities is lower than variation in long-run elasticities, which include variation in short-run estimates multiplied by the variation in the lagged endogenous coefficient. There is particularly large variation across the long-run price elasticity. However, if the very elastic estimates of Wolfe et al. (1978)(WRN78) on 77 countries, that are close to -4, are omitted, the average long-run price elasticity is cut to -.28. which is smaller than the intermediate-run elasticity of -.35. These large long-run estimates come from the .99 on the lagged endogenous value. Since such values imply a median adjustment lag of over 68 years, they are clearly infeasible. Not even in the capital expensive developing world can they keep capital equipment running that long.

Such a high elasticity on the lagged endogenous model may result from two things. In the case of weak data, last years consumption explains much better than price and income. Alternatively, omitted variables cause large variation that is picked up by the lagged term. For example, there is a similarly high estimate on the lagged endogenous variable of .97 for Al Sahlawi (1988) (AlS88) on the Gulf Cooperation Council countries with no dummy variables to pick up the effect of omitted variables.

When country dummies (D*C) and a time trend (T) were added in Wolfe (1978) (WRN78), the long-run elasticities are reduced substantially. The long-run price elasticity falls to a third of the average in other studies, while the long-run income elasticity falls to almost nothing. Since there is not this same systematic variation when dummy variables are added in Hoffman 1978 (Hof78), the time trend must be picking up much of the effect of income. Further, both Al Sahlawi (1988) and Wolfe et al. (1981) use the price of oil (Po) as the energy price variable, which given the large cross country variation in energy product taxes is likely to be biasing the price elasticity. Hence, both of these studies are left out of the summary statistics developed for Table 3.

If country dummies and variables measuring the structure of the economy are added (SV), both average price and average income elasticities are made less elastic, which suggests that structural change may be an important driving force in energy consumption in the developing world. Hence, an advantage of cross country data is increased variation in price and income with a better chance of picking up long-run elasticities. A disadvantage is that the effects of omitted variables can be erroneously attributed to price and income.

The LE model constrains income and price elasticities to have the same geometrically declining lag structure. There are two studies that allow different lag structures. Wolfe et al. (1981) (WRN81) include lagged income and a lagged endogenous variable. Their income variable is significant and its inclusion makes the lag on income become slightly less than the lag on price. In Choe (1979) (Cho79) a PDL is allowed on price. The results are somewhat erratic, but he gets a somewhat more elastic price response with an inverted V shape for the lag on price.

The few reported cases of negative income elasticities are for very poor countries quoted in Choucri (1985) (Cho85q). The only reported estimate with a positive price elasticity is in Hoffman (1978) on southern European data.

The difficulties in acquiring price data have led to a number of studies omitting it, all of which are estimated using current income. Not unexpectedly we see a larger income elasticity variation and somewhat more of the adjustment is attributed to income. The average intermediate income elasticities for the 80 studies in C2 is 1.00 instead of .75 as in C1. Although world prices should be somewhat similar from country to country, there are large variations in taxes, implying large price variations.[3]

Differences in data types may provide information on different types of adjustments. For example, prices may vary more with cross-section than with time-series suggesting that longer run adjustments may be measured with cross-sectional data. Times series, particularly those as short as ones prevalent for studies in the developing world, may not be able to pick up total adjustment. Since almost all studies on E/ that include price were done on cross-section time-series, we can not investigate this hypothesis in C1. However, the studies that omit price in C2 are done on a variety of data sets and show this pattern nicely. The 7 on cross-sections have an average income elasticity of 1.4, those on cross-section time series have an average of 1.02, while those on time-series average only .87.

Demand elasticities for energy (C3) tend most often to be somewhat more elastic than for energy per capita (C1). Lagged per capita consumption had a larger effect on the current value than lagged total energy suggesting a longer lag for per capita consumption. Estimates in Wolfe et al. (1981) (WRN81) show the same pattern as in C1. Their omission lowers the long-run price elasticity to -.51 and raises long-run income elasticity to 1.22, which is close to the long-run elasticity in (C1). The only positive price elasticities reported are on Greece.

Leaving out price in the total energy demand equations in (C4) does not have a very large effect on average, but as in the per capita estimates the intermediate income elasticity is slightly larger on average with somewhat more variance across estimators when price was omitted.

Stratifying the total energy demand studies along data types reveals a reverse pattern to those on energy demand per capita with no price. Energy demand per capita tends to be more elastic with respect income on time-series than on cross-section time-series data in (C3) and (C4). However, times series capture a less elastic response to price in (C3).

One study (C5) using Greek data looks at Energy/GDP, which is equivalent to constraining the income elasticity to be equal to 1. On Greek data with no such constraint, the long and intermediate-run income elasticities are approximately 50 percent higher. This difference in elasticities suggests that constraining income elasticity to be unity may not be appropriate and could be biasing the estimates. Overall price elasticities are a third or more greater with the constraint. The biggest discrepancy in the constrained model is for the static models when two of the price elasticities are positive and insignificant.

Summing up: energy demand may be income elastic and price inelastic in the long-run. I hypothesized earlier that income elasticities might be larger for the developing world but a crude comparison of estimates in (C1) and (C3) to those surveyed in Kouris (1983) in Table 4 does not entirely support this contention. Although short and intermediate-run price elasticities seem to be more elastic in the industrial world, the long-run price elasticity appears to be similar. The

[3]Sterner(1988b), Frank and Kirwan (1988), Kumar (1987), and International Association of Energy Economists (1986) contain international energy price comparisons for developing countries.

long-run income elasticity appears to be less elastic for the industrial countries, while the intermediate-run elasticity appears to be more so.

The above discussion considers total energy demand. However, as some of the studies have indicated, structural effects may be important in determining demand and rapid structural change may make it risky to use estimates on aggregate demand to do long range forecasting. Aggregation bias may be clouding the issue as well.

Although there are not as many studies on sectoral energy use, there are quite a number in which to consider elasticities by sector and try to determine whether aggregation bias is a problem. Ten studies in (C6) consider energy demand in the industrial sector. Elasticities are rather similar to the overall demand with a long-run average price elasticity of -.5 and a long-run average income elasticity of 1.15. Omitting the two on Taiwan with no price variable raises the intermediate income elasticity. Comparing these to elasticities for industrial demand in the industrial countries in Table 4, the hypothesized pattern holds. Income elasticities are lower and price elasticities are higher in absolute value in the industrial world.

Much more numerous are the studies on demands for individual industries included in (C7). There are 84 studies looking at energy demand by individual industrial sectors of which 65 are estimated using the translog function. Their translog formulations implicitly assume homotheticity, so income elasticities are not estimated or reported. Since the short- and long-run elasticities in this category come from one study on the Greek transport sector, they are not representative of overall industrial demand. However, their high income elasticities will be seen again in the demands for individual transport demand below. The intermediate price elasticity for all studies in this category averages -.61 implying that on average these individual industries tend to adapt more to price changes than other sectors of the economy.

Examining duplicate estimates within this group, some patterns tend to emerge. Heavy industry--chemicals, iron and steel, machinery, and transport equipment--tend to have lower price elasticities. Food processing with an average elasticity of -.86 is quite high with the tobacco and the beverage industry somewhat similar. Fabricated metals and nonmetals, which includes cement and various glass industries, are on average similarly high having average price elasticities of -.73. Textiles have average elasticities almost as elastic as those for beverages, leather is similar but wearing apparel is much lower. Wood and wood furniture are well below average with paper and printing nearer to the overall average.

If we further stratify these studies by model type, we find that the average price elasticity for the translog model studies is -.70, but that for the static models averages only -.4. This large discrepancy for the price elasticity would warrant further investigation to determine if the difference is model specific. The average income elasticity for the non translog model on industrial energy use is near 1, suggesting the assumption of homotheticity may be quite reasonable.

There are two studies on residential energy demand in (C9). Fiebig et al (1988) (FST88) use a linear expenditure system on 22 countries. The documentation is not very clear on whether the sample is cross-section time-series or strictly cross-section. Both price and income elasticities are quite elastic averaging -.80 and 1.49, respectively. Only one other study is done for residential demand. Iqbal (1984) using an LE model for Pakistan finds quite different elasticities than are found for Pakistan using the linear expenditure system. The income elasticities estimated in this category appear to be higher than those for industrial and overall energy demand.

Comparing these estimates to those in the industrial world in Table 4, we find mixed results on price. Demand seems more price elastic in the developing world using the linear expenditure system, but has a more similar price elasticity to the industrial world using the LE model. Model comparison across consistent data sets would help clarify this issue.

Price elasticities on the Greek study for residential and commercial energy demand in (C11) are less elastic than those for the linear expenditure model for strictly residential demand but more elastic than those using the LE model in (C9). Income elasticity appears to be lower for residential and commercial demand than for strictly residential demand.

The above results seem to suggest that residential demand is more income elastic than average energy demand while industrial demand is less income elastic. Price elasticities are more mixed and seem more sensitive to the model used.

Next we consider the evidence to date on oil demand. There are 32 studies that look at oil demand per capita with rather mixed results. If we merely look at the averages, shorter term elasticities resemble those for total energy demand per capita while longer term demand tends to be more price elastic and income inelastic. However, upon closer scrutiny there are a number of questionable results. Again those for S. Europe are anomalous. Greece has a positive price elasticity in both Dahl and Boyd (1985) (D&B85) and Dahl and Fields (1985) (D&H85). In these same studies both Portugal and Turkey have exceptionally high long-run price elasticities and Portugal has an exceptionally high long-run income elasticity. Wolfe et al. (1981) (WRN81) shows the same pattern as for energy. Without country dummies the lagged endogenous variable elasticity is .99 implying unbelievably high long-run elasticities compared to most other studies. With dummies and a trend, the long-run price elasticities and income elasticities become almost negligible. Al Sahlawi and Boyd (1987), who use the price of oil instead of the price of products, find income elasticity is negative for three African countries. Chern (1987); Chern, Liang, and Soberon (1984); and Chern and Soberon (1985), all of which include dummies and structural variables, find the long-run price elasticity is quite low at -.16, but income elasticities are quite close to 1. Al Sahlawi and Boyd (1987) and Wolfe et al. (1981) use the price of oil as their price variable; the rest use the weighted average of the price of oil products.

If we omit the studies that use the price of oil instead of the price of products, the remaining averages suggest that oil per capita is somewhat more price elastic in the long-run and has a similar income elasticity to total energy demand per capita. However, eliminating the southern European estimates reverses these conclusions. The remaining studies all of which have country dummies and structural variables find oil demand per capita to be less price and income elastic on average.

Although ambiguous, these results seem to suggest that estimates for southern Europe are poor. Adding a time trend removes much of the income effect. Adding structural variables and country dummies lowers elasticities. Oil demand per capita is price inelastic, but it is unclear whether it is more or less price inelastic then total energy demand per capita.

In (C13), we find that omitting price raises the average income elasticity, as it did earlier for total energy.

There are 19 estimates in the total oil demand category (C14). Wolfe et al. (1981) (WRN81) showed a similar pattern to earlier estimates. If all studies are eliminated that use the price of oil instead of the price of products, the other studies yield a rather low average price elasticity at -.30 with an income demand response of 1.03. The results in this category agree in general with those for per capita oil consumption. When price was omitted in (C15), the income elasticity became very high at 1.8 and the variance almost doubled.

I conclude at this point that reasonable estimates for the oil price and oil income elasticities are -.3 and 1.03, respectively. However, since the inclusion of structural parameters seem to reduce the elasticity estimates, I would urge more work investigating whether they are endogenous or not and how to best incorporate them for estimating and forecasting.

Comparing the overall averages from (C12) and (C14) to those for industrial countries taken from Dahl and Boyd (1985) (D&B85), Dahl and Fields(1985) (D&H) and quoted from Al Sahlawi (1985) (Als85), demand in the developing countries appears to be both less price and income elastic than in the industrial countries.

(C16) contains miscellaneous oil demand specifications that will not be discussed. There are only 4 estimates on total industrial demand for oil in (C17). Since they are all done on the translog model, no income elasticities are reported. Price elasticity at -.35 is similar to the average for over all oil price. Almost all the estimates in (C18) for individual industries are on the translog model. Their price elasticities at -.46 are a bit more price elastic than for overall oil demand. There are a few industries with duplicate estimates. Demand elasticity in the agriculture sector is similar to the average of all the industries, but varies from the very inelastic estimates in India and Taiwan to the very elastic estimate in Greece. Estimates on the transport sector yield very low price elasticities on average as do those for the production of machinery, transport equipment, and the residential and commercial sector. Iron and steel, the chemical industry, and public utilities have higher than average elasticities for oil demand reflecting substitution across fuels, whereas for total energy they had below average elasticities.

There are only two estimates for total oil demand in the residential sector in (C19). That for India yields very low elasticities, that for Taiwan exceptionally high ones.

Next I consider the estimates for the various oil products. Results for fuels for air transport are mixed. There are only two estimates for aviation gasoline (C20). The one on Nigeria, which includes passenger kilometers rather than income, yields a rather elastic response to price. The one for Mexico, which is part of a two-system equation and does not have price available, yields income elasticities that are quite low. For the three estimates for elasticity for jet fuel demand in (C21), the results on Ecuador are quite weak with the coefficient on the lagged endogenous model greater than 1. Those for Mexico both suggest a low price elasticity and a high income elasticity.

The six studies on air transport fuel demand in (C22) by Dunkerley and Hoch (1987) are more consistent with those for jet fuel demand in (C21) but suggest lower price and income elasticities. They also find developing countries demand for air transport fuel less elastic than demand estimates for the industrial countries as shown in Table 4.

There are 94 estimates for some form of gasoline demand per capita in (C23). The overall long-run averages suggest very high price and income elasticities of -1.64 and 1.59. The low average intermediate run elasticities of -.21, however, does not seem consistent with such an elastic long run price response.

If we further stratify the intermediate price elasticities by data type, we find Drollas' estimates on a strict cross section are the most elastic at -.86. Dunkerley and Hoch's estimates on cross-section time-series average -.42, but their estimates on strict time-series average a mere -.09. Income elasticities, however, vary much less across data types.

Examining estimates within categories, adding a stock of autos to a LE model dramatically lowered price and income elasticities in Garbacz (1989) (Gar89). Adding a stock of auto variable to a static model in Drollas (1984) (Dro84) had little effect on the price elasticity but lowered income elasticity. Replacing the income with the stock of autos lowered the price elasticity in this same study. Removing all studies with a stock of auto variable has little effect on price elasticities but raises the average income elasticity from 1.59 to 1.89.

The elasticities for Miklius et al. (1986) (MLS86) are computed using their two equation model on Asian nations. These equations are included in (C37) and (C38). Their elasticities are quite high averaging over -2.16. Garbacz (1989) (Gar89) gets similarly high elasticities on a Taiwanese time series for a lagged endogenous model with no auto stock, but Dunkerley and Hoch (1987) get much lower estimates for some of these same countries using a static model. Iqbal (1985) gets lower price but higher income elasticities on Pakistani data using a lagged endogenous model. The average coefficient on the lagged variable is high relative to that for total oil and total energy demand at .83 suggesting a median lag of 3.72 years. These high coefficients on the lagged endogenous model and those for the second equation in Miklius et al. (1986) (MLS86) in (C37) are responsible for the elastic response shown here.

Dunkerley and Hoch (1987) (D&H87) find high income countries are less price but more income elastic. They did not find a great deal of systematic variation when their income variable was deflated by purchasing power parities rather than price deflators.

(C24) has information on gasoline consumption per auto rather than per capita. We find the estimates for Mexico, estimated using a two-equation model, are less elastic than gasoline demand per capita in (C23). However, they are not systematically different from the estimates on Mexico for total gasoline demand in (C25), which vary substantially across model and data types. The Dunkerley and Hoch (1987) results on a simpler static model do not support the income results on Mexican data. They find gasoline consumption per auto consistently decreasing as income increases for all of their estimated equations.

The results for total gasoline demand vary substantially from those for gasoline per capita and no studies get the long-run price elastic responses of (C23). None of the studies with long-run elasticities contain a stock of auto variable. A few of these studies get a rather elastic long-run income response but the average at 1.21 is far below the 1.89 average for studies without a stock of auto in (C23). The high intermediate price elasticity in (C24) comes from the strict cross-section of Koshal and Bradfield (1985) (K&B85) and the cross-section time-series on Latin American data of Sterner (1988) (Ste88). Sterner (1988) get's a much higher price response and a much lower income response on Latin American data through 1985 than Pindyck did on data through 1974. When studies in this category with the stock of autos and income are excluded the intermediate-run income elasticity increases to almost 1. Again studies including a stock of auto variable appear to not pick up the long run income effect.

(C26) contains estimates on total gasoline demand for Brazil on quarterly data. These estimates pick up smaller income elasticities in all cases and lower short- and intermediate-run price elasticities. However, the average long-run price elasticity is quite close to that for annual data in (C25).

Fewer conclusions can be drawn from the gasoline studies. The evidence seems to imply that both price and income are more elastic than for total oil or total energy demand. How much more elastic on average is difficult to determine. The use of quarterly data appears to pick up smaller income elasticities as does adding a stock of vehicles to the estimated equations. Price elasticities appear to be sensitive to data type with cross-sectional data picking up a more elastic response than time-series. Since estimates appear to be sensitive to model type, our understanding of gasoline demand in the developing world might benefit from a systematic study of the effect of model choice on elasticities.

Gasoline demand by individual industry in (C27) using the translog model on Taiwanese data and a tobit model on Indonesian data is quite high on average (-2.33), but quite variable across industry.

Comparing gasoline demand elasticity estimates in the developing world to averages of all gasoline demand elasticities in Dahl and Sterner (1991) shown in Table 4, we can come to no general conclusion. (C23) implies the developing world has a more elastic response to price and income, while (C25) implies that developing countries have a less elastic price response in the long-run but may have a similar income response to all gasoline studies.

Long-run average diesel demand elasticities in (C28) are quite high with that for price equal to -1.77, that for income equal to 1.46. Again Miklius et al. (1986) (MLS86) using a their two-equation model have a very elastic price response, largely as a result of the very high coefficient in their second equation for total fuel given in (C37). Garbacz (1989) (Gar89), however, gets a much lower price elasticity on diesel demand than he did earlier on gasoline. Berndt and Botero (1985) find elasticities on Mexican data to be sensitive to model choice with them smaller using a Balestra-Nerlove formulation compared to a lagged endogenous model. Dunkerley and Hoch (1987) find the intermediate price elasticity for diesel demand for transport to be insignificant whether they use the price of diesel or the price gasoline in order to increase their sample size.

In (C29) through (C31) Dunkerley and Hoch (1987) look at demands for diesel for various categories of transport. Income elasticities tend to be greater than 1 for both water and highway transport but quite low for rail transport. Price elasticity estimates tend to be weak for all transport categories especially when the price of diesel is used.

(C32) contains 5 estimates for total diesel demand. These studies suggest a more elastic short-run and a less elastic long-run response than those in (C28). Pindyck found no response in diesel demand to price in southern Europe. There is a wide variation in estimates for Mexican data. The income elasticity is much lower for the Balestra-Nerlove formulation, but there is even wide variation in price elasticity across the two estimates that use the LE model. Mendoza and Vargas (1987) (M&V87) get an estimate on the lagged endogenous variable of only .27 which yields a long-run price elasticity of -.35. Berndt and Botero (1985) (B&B85) with the coefficient on the lagged endogenous model of .78 find a long-run price elasticity of -1.11. Income elasticities from these studies are, however, quite similar.

These two studies illustrate a common problem with the LE model. It appears that collinearity between the lagged endogenous variable and income cause a lot of variation in their coefficients. Although this variation has little effect on the long-run income elasticity, it has a dramatic effect on the long-run price elasticity. More careful investigation of the adjustment process and the age and change in the capital stock might help to resolve these large discrepancies on price elasticity.

Estimates on quarterly data for Brazil (C33) find long- and short-run demand less price elastic than the other studies. Income, however, is found to be as elastic in the long-run as in (C28). As in Dunkerley and Hoch (1987), the static model gets weak results for price, but more reasonable results for income.

There are enough discrepancies to make it difficult to come up with summary elasticities for diesel demand. Static models do not appear to yield price elasticities. For the long-run the discrepancies are larger for price than for income and tend to center around the large variation in the coefficient on the lagged endogenous model. One might cautiously conclude that diesel demand is more price and income elastic than total oil demand.

The three studies on Brazil that leave out price in (C34) find a somewhat more elastic intermediate income response. However, the comparison is across annual cross-section and quarterly time-series. Demand elasticities for individual industries in (C35) using tobit and translog models on Asian data are again highly price elastic but with large variations across industries. These high price elasticities for industry compared to total oil demand could reflect more substitution across gasoline and diesel in industry or it could be model or region specific. More work on model comparison and data stratification across country might provide more information on this issue.

In (C36) the total demand for transport fuel is very price inelastic on average with low income countries having a positive and significant price elasticity. Comparing DC and IC elasticities for total transport fuel from Dunkerley and Hoch (1985) shown in Table 4, we find a more elastic response for the DCs especially for price.

(C37) contains studies on highway fuels including two equations in Miklius et al. (1986) that are used along with the two equations in (C38) to create their gasoline and diesel fuel elasticities above. The average long-run price elasticity of -2.02 is quite high compared to the inelastic average intermediate elasticity of -.24. As for gasoline and diesel, results on highway transport fuels conflict and no summary statistics are readily apparent. Highway fuels tend to be income elastic, but it is not clear whether they are price elastic or not. Comparing the results in Dunkerley and Hoch (1985) for DCs and ICs shown in Table 4 suggests that income elasticities are similar but the ICs have more price elastic demand.

Results for railroad demand for transport fuels in (C39) are poor. The price elasticity is always positive, income elasticities in many instances negative. The price elasticity of demand for fuels for water transport are also weak in (C40). Income elasticities, however, are more reasonable except where structural and demographic variables have been added to the equations.

In general, results for the developing countries for transportation fuels in this survey have been inconclusive. The most extensive study, that by Dunkerley and Hoch (1985), tends to find very low price elasticities for most categories of transport fuel demand in the developing world with industrial country demand more price elastic. Perhaps more studies that look at the effect of model types and further stratification across regions might resolve some of the discrepancies noted here.

Results on other product demands are also mixed. (C41) contains estimates for kerosene demand. Elasticities appear to be lower than for overall oil product demand. Pindyck finds the income elasticity to be negative and price elasticity to be insignificant for Southern European countries suggesting that at higher incomes kerosene may be an inferior good. Abdel-Khalek (1988) (Adb88) finds price from a static model to be between the short and long-run price elasticities from an LE model, but income elasticities from the static model are closer to long-run on Egyptian data. Koshal et al. (1988) (KRS88) find both the price and income elasticities from a static model to be closer to the long-run elasticities of a LE model on Indonesian data. The coefficient on the lagged endogenous variable is close to .8 for southern Europe but averages below .5 for the other four estimates suggesting very short lags.

Ramcharron (1988) (Ram88) gets very different income elasticities on residential kerosene demand for Jamaica using different models. A static model yields an income elasticity of 5.46, which is over five times that for the long-run in a lagged endogenous model. The Tobit model again yields high elasticities for two industries in Indonesia in (C43).

Total fuel oil demand in (C44) appears to be rather income inelastic compared to total oil demand and rather price inelastic compared to transport fuel demand. Abdel-Khalek (1988) (Abd88) finds a positive but insignificant price elasticity using an LE on Egyptian data. Without this positive coefficient, fuel oil demand becomes somewhat more elastic on average than total oil demand. In (C45) and (C46) Pindyck (1979) (Pin79) finds heavy fuel oil highly elastic in Southern Europe but light fuel totally price inelastic and highly income elastic. Abdel-Khalek (1988) (Abd88) finds a low price elasticity in a static model for light fuel oil on Egypt but an income elasticity over 1. With a lagged endogenous model these results are reversed. His light fuel oil demand becomes immensely elastic but the income elasticity disappears.

The estimates on industrial demand and demands for individual industries using the translog and the tobit model suggest that industrial demand is price elastic. However, the two estimates from a lagged endogenous model suggest that price is inelastic, but more elastic than for total oil demand. Income elasticity on the other hand is closer to the average for total oil demand.

We find the same sort of inconsistencies for LPG in (C49) and (C50) as for the fuel oil categories with dramatic changes in elasticities when switching from a static to an LE model. In (C49) LE models appear to give more reasonable results but in (C50) on residential LPG demand, there are problems with both model formulation. In the other petroleum product category, the translog model gives higher price elasticities than the one LE model.

The results for oil products tend to be rather disappointing. In no case was their enough consistency to come up with global averages. More work will need to be done to check for aggregation bias for oil demand.

CONCLUSIONS

As the developing world continues to grow and change, its call on energy markets will grow and change. To provide background information to help qualify and quantify these changes I have looked back at the global changes in energy and oil markets for the past four decades. From this broad comparison of energy markets across major developing and industrial regions, a number of hypothesis are developed related to the evolution of energy and oil markets in the developing world. All the available econometric evidence is then surveyed to try to develop summary statistics and investigate various hypothesis.

Although no formal testing has been done at this stage of the analysis, the following observations have been made. After surveying hundreds of equations in over 50 studies, there is overwhelming evidence that energy demands in the developing countries respond to both price and income with the responses most often in the inelastic region for price but in the elastic region for income. However, there does seem to be a lot of variation in elasticities across model types. Translog, tobit, and linear expenditure systems model appear to get larger price elasticities than other modeling types. Results may change dramatically on the same data set from a static to a lagged endogenous model with the changes tending to be larger for price than income. Leaving price out of the estimating model most often increases the estimated income elasticity.

A few patterns emerge from the summary statistics but many more problems remain. Within the developing world industrial energy demand may have elasticities similar to overall energy demand, residential demand may be more income elastic suggesting a shift towards household/use. Oil demand appears to be less price and income elastic than total energy demands, which would suggest a shift away from oil and towards other products.

The results on oil products are particularly confusing. No clear cut patterns emerge at this point to support a shift in the barrel towards lighter products.

Comparing summary statistics to those for the industrial world, there is no clear cut evidence that the developing world energy demand is less price elastic or more income elastic than for the industrial world. Industrial energy demand may be more income elastic in the developing world. Oil appears to be both more price and income elastic in the industrial world. Suggested long-run average elasticities for energy are -.54 and 1.19 for price and income respectively. Those for oil are less elastic at -.3 and somewhat over 1. Dunkerley and Hoch (1985) tend to consistently find transport fuel demands very price inelastic in the developing world, somewhat less inelastic in the industrial world.

Table 1: Energy Consumption by Product and Major World Region. BTOE

		Population	Solid	Liquid	Gas	Elec	Biomass
Africa	1950	249.3	16.8	7.1	0.0	0.1	na
	1960	283.0	25.1	15.2	0.0	0.5	na
	1970	372.5	37.6	31.4	0.4	2.1	na
	1980	443.5	56.4	60.2	16.5	5.3	na
	1988	604.5	72.2	73.0	28.2	13.8	103.0
Asia DC	1950	1599.5	39.8	7.2	0.6	0.5	na
	1960	1719.3	239.0	29.2	3.8	2.5	na
	1970	2206.6	244.5	93.0	7.2	6.5	na
	1980	2288.3	416.7	211.8	28.4	15.0	na
	1988	2659.9	670.4	270.9	58.7	95.4	197.7
Mideast	1950	57.2	2.2	3.2	0.1	0.0	na
	1960	70.8	3.1	14.0	2.5	0.1	na
	1970	96.6	5.0	30.2	14.4	0.5	na
	1980	136.2	8.9	84.0	30.0	1.7	na
	1988	177.0	16.6	132.1	74.5	11.1	6.0
L America	1950	164.8	5.8	32.7	2.4	1.1	na
	1960	214.8	6.9	66.5	10.1	3.0	na
	1970	283.9	9.0	123.0	29.0	7.1	na
	1980	357.5	16.3	205.9	57.2	19.5	na
	1988	427.0	22.6	210.4	77.7	101.6	87.0
E. Europe	1950	105.5	96.5	5.2	3.6	0.3	na
	1960	116.7	168.3	14.3	12.5	1.1	na
	1970	126.0	221.2	57.4	35.4	2.8	na
	1980	134.8	261.4	103.2	75.1	8.0	na
	1988	139.6	277.2	93.3	86.6	38.7	4.7
USSR	1950	178.6	148.8	33.1	5.6	1.1	na
	1960	215.3	266.3	104.4	43.6	4.4	na
	1970	241.9	310.4	222.8	158.7	10.6	na
	1980	265.2	346.6	354.5	317.0	19.5	na
	1988	283.7	408.4	389.9	540.9	124.8	20.4
W.Europe	1950	283.1	314.7	44.6	1.2	9.5	na
	1960	306.1	344.8	159.0	11.1	19.6	na
	1970	332.4	282.7	508.5	70.2	32.0	na
	1980	350.7	253.6	556.0	192.3	53.7	na
	1988	354.8	236.0	525.7	207.0	335.1	11.1
US&Canada	1950	166.0	361.9	318.5	157.5	13.3	na
	1960	198.5	258.1	480.0	333.0	22.1	na
	1970	226.4	326.9	739.5	588.4	37.2	na
	1980	251.9	401.2	835.0	538.9	71.4	na
	1988	271.4	501.6	835.3	484.7	334.6	30.7

Table 1: (continued) Energy Consumption by Product and Major World Region. Billions of tons of oil equivalent.

Pac. OECD	1950	13.2	12.9	4.7	0.0	0.4	na
	1960	26.9	16.8	15.1	0.1	1.0	na
	1970	31.5	21.1	30.0	2.3	2.0	na
	1980	38.5	28.8	42.7	10.4	3.9	na
	1988	32.1	36.0	37.4	18.8	11.8	3.7

Source: United Nations, World Energy Supplies 1950-1974, International Energy Yearbook, 1986. U.S. EIA, International Energy Annual, 1989.

Table 2: Share of Fuel Used by Product and Major World Region

	Share of Coal Used by				Share of Oil used by			
	Elec	I&C	Transp	H&O	Elec	I&C	Transp	H&O
Africa	35.2%	52.7%	4.2%	7.8%	19.1%	29.0%	29.5%	22.5%
Far East	42.1%	42.5%	5.2%	10.2%	15.6%	24.4%	37.8%	22.1%
MidEast	98.1%	1.7%	0.0%	0.2%	26.9%	38.0%	29.5%	5.6%
L America	25.9%	72.6%	0.1%	1.5%	9.6%	17.6%	56.0%	16.8%
OECD Europe	58.9%	27.0%	0.1%	14.0%	8.5%	21.6%	43.6%	26.3%
N. America	72.1%	21.8%	0.0%	6.1%	3.8%	15.7%	68.2%	12.3%
Pacif OECD	49.4%	47.6%	0.1%	2.9%	15.7%	26.6%	38.4%	19.3%

	Share of Gas Used by				Share Electricity Used by		
	Elec	I&C	Transp	H&O	I&C	Transp	H&O
Africa	46.0%	41.6%	0.0%	12.4%	53.6%	1.2%	45.3%
Far East DC	45.5%	41.1%	0.0%	13.3%	52.3%	1.3%	46.4%
MidEast	41.3%	52.6%	0.0%	6.2%	27.3%	0.0%	72.7%
L America	32.9%	49.6%	0.0%	17.4%	54.2%	0.6%	45.3%
OECD Europe	13.2%	35.4%	0.1%	51.3%	45.0%	2.5%	52.6%
N. America	18.2%	36.2%	0.0%	45.5%	35.2%	0.2%	64.5%
Pacif OECD	59.2%	19.7%	0.3%	20.9%	56.8%	2.4%	40.8%

	Share of Biomass Used by			
	Elec	I&C	Transp	H&O
Africa	0.0%	3.3%	0.0%	96.7%
Far East	0.0%	8.8%	0.0%	91.2%
MidEast	0.0%	0.0%	0.0%	100.0%
L America	2.0%	32.6%	10.7%	54.6%

	Share of Electricity Production by				
	Coal	Oil	Gas	Biom	Primary
Africa	7.7%	35.6%	18.4%	0.0%	38.3%
Far East	43.1%	17.4%	7.9%	0.0%	31.5%
MidEast	11.0%	63.1%	25.9%	0.0%	0.0%
L America	3.4%	10.0%	9.6%	1.2%	75.9%
OECD Europe	45.2%	11.8%	6.9%	0.0%	36.1%
N. America	53.0%	3.8%	10.4%	0.0%	32.7%
Pacif OECD	26.0%	18.3%	17.5%	0.0%	38.3%

Source: United Nations, <u>Energy Balances and Electricity Profiles</u>, 1987.

Table 3: Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
1	Als88	E/	GCC 6	80	83	CT	-0.03	-1.20		-1.00	0.06	0.90		2.00	0.97	LE	OLS	Po
1	Che87	E/	C5 As	~60	~82	CT	-0.15	-2.41		-0.24	0.85	3.72		1.37	0.38	LE	IV-h	C,SV
1	Che87	E/	C7 LA	~60	~82	CT	-0.09	-3.41		-0.32	0.44	3.48		1.62	0.73	LE	IV-h	C,SV
1	Che87	E/	C15	~60	~82	CT	-0.07	-3.09		-0.19	0.42	4.85		1.09	0.61	LE	IV-h	C,SV
1	Cho78	E/	C11 My	60	75	CT	-0.09	-4.56		-0.28	0.40	9.04		1.30	0.70	LE	OLS	C,Pi
1	Cho78	E/	C8 Ly	60	75	CT	-0.15	-1.89		-0.28	0.62	6.76		1.15	0.46	LE	OLS	C,Pi
1	Cho78	E/	C11 LMy	60	75	CT	-0.13	-1.83		-0.38	0.68	4.61		1.94	0.65	LE	OLS	C,Pi
1	Cho78	E/	C5 Hy	60	75	CT	-0.12	-4.19		-0.33	0.51	8.34		1.36	0.63	LE	OLS	C,Pi
1	Cho79	E/	C36	60	76	CT	-0.14	-1.26		-0.99		45.08	1.39			PDL:P5	D4	Pi
1	Cho79	E/	C26 OM	60	76	CT	-0.04	-0.36		-1.70		36.75	1.35			PDL:P5	D4	Pi
1	Cho79	E/	C36	60	76	CT	-0.05	-1.44		-0.41		21.90	1.32			PDL:P5	D4	Pi
1	Cho79	E/	C26 OM	60	76	CT	-0.01	-0.23		-0.43		14.70	1.19			PDL:P5	D4	Pi
1	Cho79	E/	9 OX	60	76	CT	-0.19	-2.11		-0.21		13.04	1.52			PDL:P5	D4	Pi
1	Cho79	E/	C9 OX	60	76	CT	-0.46	-1.80		0.81		28.79	1.54			PDL:P5	D4	Pi
1	Cho85q	E/	Alge	70	80	CT			-0.20				0.82			Stat	OLS	SV
1	Cho85q	E/	SAra	70	80	CT			-0.11				0.47			Stat	OLS	SV
1	Cho85q	E/	Kuwa	70	80	CT			-0.11				0.60			Stat	OLS	SV
1	Cho85q	E/	Liby	70	80	CT			-0.20				0.76			Stat	OLS	SV
1	Cho85q	E/	Sudu	70	80	CT			-0.03				-0.18			Stat	OLS	SV
1	Cho85q	E/	Jord	70	80	CT			-0.49				0.54			Stat	OLS	SV
1	Cho85q	E/	Tuni	70	80	CT			-0.09				0.86			Stat	OLS	SV
1	Cho85q	E/	YemeS	70	80	CT			-0.03				0.09			Stat	OLS	SV
1	Cho85q	E/	Djib	70	80	CT			-0.03				0.01			Stat	OLS	SV
1	Cho85q	E/	Syri	70	80	CT			-0.09				0.94			Stat	OLS	SV
1	Cho85q	E/	UAE	70	80	CT			-0.11				0.55			Stat	OLS	SV
1	Cho85q	E/	Iraq	70	80	CT			-0.20				0.88			Stat	OLS	SV
1	Cho85q	E/	Oman	70	80	CT			-0.11				0.46			Stat	OLS	SV
1	Cho85q	E/	Moro	70	80	CT			-0.49				0.46			Stat	OLS	SV
1	Cho85q	E/	Bahr	70	80	CT			-0.09				1.04			Stat	OLS	SV
1	Cho85q	E/	Maur	70	80	CT			-0.03				-0.08			Stat	OLS	SV
1	Cho85q	E/	YemeN	70	80	CT			-0.03				-0.24			Stat	OLS	SV
1	Cho85q	E/	Soma	70	80	CT			-0.03				-0.26			Stat	OLS	SV
1	Cho85q	E/	Egyp	70	80	CT			-0.09				0.94			Stat	OLS	SV
1	Cho85q	E/	Leba	70	80	CT			-0.49				0.56			Stat	OLS	SV
1	Cho85q	E/	Qata	70	80	CT			-0.11				0.62			Stat	OLS	SV
1	CLS84	E/	C15	~70	~80	CT	-0.07	-3.09		-0.19	0.42	4.85		1.09	0.61	LE	IV-h	SV,D*T
1	CLS84	E/	C5 As	~70	~80	CT	-0.15	-2.41		-0.24	0.85	3.72		1.37	0.38	LE	IV-h	SV,D*T
1	CLS84	E/	C7 LA&Af	~70	~80	CT	-0.09	-3.41		-0.32	0.44	3.48		1.62	0.73	LE	IV-h	SV,D*T
1	C&C85	E/	Paki	60	82	T	-0.13	-1.71		-0.20	0.64	4.51		1.02	0.38	LE	3S	SV,D*T
1	C&L78q	E/	NAf&ME	60	75	CT	-0.12	-0.95		-0.30	0.75	3.77		1.93	0.61	LE	OLS?	C
1	C&L78q	E/	LA	60	75	CT	-0.10	-5.57		-0.32	0.42	10.06		1.35	0.69	LE	OLS?	C
1	C&L78q	E/	SAs	60	75	CT	-0.14	-1.70		-0.25	0.65	4.63		1.17	0.45	LE	OLS?	C
1	C&L78q	E/	Af SS	60	75	CT	-0.06	-1.79		-0.58	0.18	1.68		1.67	0.89	LE	OLS?	C
1	C&L78q	E/	OM	60	75	CT	-0.08	-5.30		-0.21	0.49	14.40		1.24	0.60	LE	OLS?	C
1	C&L78q	E/	OX	60	75	CT	-0.08	-2.40		-0.23	0.52	8.05		1.53	0.66	LE	OLS?	C
1	C&L78q	E/	SE	60	75	CT	-0.12	-1.24		-0.31	0.54	3.59		1.39	0.61	LE	OLS?	C
1	C&L78q	E/	EAs&Pc	60	75	CT	-0.11	-1.62		-0.40	0.36	2.55		1.28	0.72	LE	OLS?	C
1	C&S85	E/	C15 Hy	~70	~82	CT	-0.11	-4.90		-0.42	0.26	2.60		0.99	0.73	LE	IV-h	SV,D*T
1	C&S85	E/	C15 Ly	~70	~82	CT	0.01	0.17		0.01	0.43	3.50		0.94	0.55	LE	IV-h	SV,D*T
1	C&S85	E/	C15 As	~70	~82	CT	-0.07	-1.74		-0.21	0.41	3.80		1.31	0.68	LE	IV-h	SV,D*T
1	C&S85	E/	C15 LPe	~70	~82	CT	-0.00	-0.07		-0.00	0.68	6.10		1.17	0.42	LE	IV-h	SV,D*T
1	C&S85	E/	C15 EX	~70	~82	CT	-0.09	-2.60		-0.10	1.06	4.90		1.18	0.10 ns	LE	IV-h	SV,D*T
1	C&S85	E/	C15	~70	~82	CT	-0.07	-3.60		-0.27	0.24	3.10		0.95	0.74	LE	IV-h	SV,D*T
1	C&S85	E/	C15 EM	~70	~82	CT	-0.05	-2.30		-0.18	0.28	3.20		0.95	0.71	LE	IV-h	SV,D*T
1	C&S85	E/	C15 Hp	~70	~82	CT	-0.08	-2.30		-0.22	0.34	2.80		1.03	0.67	LE	IV-h	SV,D*T
1	C&S85	E/	C15 LA	~70	~82	CT	-0.09	-3.90		-0.30	0.26	2.00		0.91	0.72	LE	IV-h	SV,D*T
1	C&S86	E/	C10 OM	~70	~82	CT	-0.06	-2.58		-0.14	0.49	5.54		1.23	0.60	LE	IV-h	C,SV
1	C&S86	E/	C4 OX	~70	~82	CT	-0.06	-1.50		-0.07	0.93	4.38		1.13	0.18 ns	LE	IV-h	C,SV
1	C&S86	E/	C14	~70	~82	CT	-0.07	-3.93		-0.18	0.52	6.55		1.29	0.60	LE	IV-h	C,SV
1	C&S86	E/	C10 OM	~70	~82	CT	-0.06	-2.81		-0.16	0.45	5.03		1.13	0.60	LE	IV-h	C,SV
1	C&S86	E/	C4 OX	~70	~82	CT	-0.06	-1.30		-0.07	0.91	3.96		1.13	0.19 ns	LE	IV-h	C,SV
1	C&S86	E/	C14	~70	~82	CT	-0.08	-4.37		-0.20	0.49	6.11		1.25	0.61	LE	IV-h	C,SV
1	Hof78	E/	SE	67	75	CT		0.85	0.19			6.68	0.54			Stat	OLS?	SV
1	Hof78	E/	LyAf SS	60	67	CT		-4.47	-0.96			8.22	0.93			Stat	OLS?	C,SV
1	Hof78	E/	LyAf SS	60	75	CT		-3.24	-0.73			7.61	0.76			Stat	OLS?	SV
1	Hof78	E/	LyAf SS	68	75	CT		-0.86	-0.31			7.76	0.94			Stat	OLS?	SV

Table 3 (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
1	Hof78	E/	SE	60	75	CT		-4.41	-0.45			15.85	0.66			Stat	OLS?	C,SV
1	Hof78	E/	SE	60	67	CT		-1.40	-0.25			10.90	0.54			Stat	OLS?	C,SV
1	Hof78	E/	SE	60	75	CT		-3.04	-0.42			9.93	0.49			Stat	OLS?	SV
1	Hof78	E/	LyAf SS	60	75	CT		-4.68	-0.75			12.46	0.92			Stat	OLS?	C,SV
1	Hof78	E/	SE	60	67	CT		-4.03	-0.76			8.36	0.44			Stat	OLS?	SV
1	Hof78	E/	SE	67	75	CT		-2.85	-0.45			12.69	0.84			Stat	OLS?	C,SV
1	Hof78	E/	LyAf SS	60	75	CT		-4.78	-0.77			13.13	0.94			Stat	OLS?	C,SV
1	Hof78	E/	LyAf SS	68	75	CT		-1.09	-0.30			11.50	0.99			Stat	OLS?	C,SV
1	Hof78	E/	LyAf SS	68	75	CT		-1.07	-0.30			11.08	1.01			Stat	OLS?	C,SV
1	Hof78	E/	LyAf SS	60	67	CT		-3.75	-0.84			7.79	0.85			Stat	OLS?	C,SV
1	Hof78	E/	LyAf SS	60	67	CT		-1.33	-0.36			5.00	0.69			Stat	OLS?	SV
1	Hof80	E/	C8 SE&ME	~60	~75	CT		-3.98	-0.54			7.84	0.40			Stat	OLS?	SV
1	Hof80	E/	C8 LyAf	~60	~75	CT		-4.35	-0.89			10.14	0.89			Stat	OLS?	SV
1	Hof81	E/	Braz	60?	75	T?	-0.10	-1.92		-0.38	0.39	1.37		1.49	0.74	LE	OLS?	
1	IS182q	E/	UAE	77	79	CT			-0.51				1.20			Stat	OLS	
1	IS182q	E/	Egyp	77	79	CT			-0.51				0.66			Stat	OLS	
1	IS182q	E/	Tuni	77	79	CT			-0.51				0.84			Stat	OLS	
1	IS182q	E/	Liby	77	79	CT			-0.51				1.36			Stat	OLS	
1	IS182q	E/	Jord	77	79	CT			-0.51				1.50			Stat	OLS	
1	IS182q	E/	Syri	77	79	CT			-0.51				0.72			Stat	OLS	
1	IS182q	E/	SAra	77	79	CT			-0.51				0.77			Stat	OLS	
1	IS182q	E/	Oman	77	79	CT			-0.51				1.00			Stat	OLS	
1	IS182q	E/	Iraq	77	79	CT			-0.51				0.69			Stat	OLS	
1	WRN81	E/	C77 OM	67	76	CT	-0.06	-3.41		-0.11	0.03	1.67		0.05	0.47	LE	OLS	C,Po,T
1	WRN81	E/	C77 OM	67	76	CT	-0.05	-3.23		-0.10	0.07	2.92		0.13	0.47	LE&y-1	OLS	C,Po,T
1	WRN81	E/	C77 OM	67	76	CT	-0.05	-4.36		-3.75	0.02	2.97		1.75	0.99	LE	OLS	Po
1	WRN81	E/	C77 OM	67	76	CT	-0.05	-4.49		-3.83	0.09	3.28		1.67	0.99	LE&y-1	OLS	Po
#E	93					Avg	-0.09		-0.35	-0.44	0.46		0.75	1.25	0.61			
						Std	0.07		0.27	0.79	0.25		0.42	0.39	0.20			
						#	46		47	46	40		53	40	40			
2	Des86	E/	C47	70&	76	CT						15.00	1.35			Stat	OLS?	
2	Des86	E/	C47	70&	76	CT						4.71	0.89			Stat	OLS?	D*T
2	Des86	E/	C47	70&	76	CT						4.33	0.81			Stat	OLS?	SV
2	Des86	E/	C47	70&	76	CT						3.64	0.71			Stat	OLS?	R
2	Des86	E/	C47	70&	76	CT						4.44	0.80			Stat	OLS?	SV
2	Des86	E/	C47	70&	76	CT						4.76	0.90			Stat	OLS?	
2	Des86	E/	C47	70&	76	CT						2.68	0.50			Stat	OLS?	R,SV
2	Hof78	E/	SE	60	75	CT						14.58	0.66			Stat	OLS?	C,SV
2	Hof78	E/	SE	60	75	CT						9.97	0.50			Stat	OLS?	SV
2	Hof78	E/	SE	67	75	CT						7.01	0.58			Stat	OLS?	SV
2	Hof78	E/	LyAf SS	60	67	CT						9.34	0.81			Stat	OLS?	C,SV
2	Hof78	E/	LyAf SS	60	75	CT						9.64	0.93			Stat	OLS?	SV
2	Hof78	E/	SE	60	67	CT						10.76	0.53			Stat	OLS?	C,SV
2	Hof78	E/	SE	60	67	CT						6.91	0.40			Stat	OLS?	SV
2	Hof78	E/	LyAf SS	68	75	CT						14.30	1.12			Stat	OLS?	C,SV
2	Hof78	E/	LyAf SS	68	75	CT						14.40	1.99			Stat	OLS?	C,SV
2	Hof78	E/	LyAf SS	60	75	CT						15.74	0.96			Stat	OLS?	C,SV
2	Hof78	E/	LyAf SS	60	67	CT						9.67	0.82			Stat	OLS?	C,SV
2	Hof78	E/	LyAf SS	60	75	CT						15.25	0.95			Stat	OLS?	C,SV
2	Hof78	E/	LyAf SS	60	67	CT						4.72	0.67			Stat	OLS?	SV
2	Hof78	E/	LyAf SS	68	75	CT						10.39	1.22			Stat	OLS?	SV
2	Hof78	E/	SE	67	75	CT						11.81	0.84			Stat	OLS?	C,SV
2	Hof80	E/	Mala	~60	~75	T						0.00	0.00			Stat	2eq w	1&2
2	Hof80	E/	Yugo	~60	~75	T						7.30	0.75			Stat	2eq w	1&2
2	Hof80	E/	Turk	~60	~75	T						3.50	0.60			Stat	2eq w	1&2
2	Hof80	E/	Buru	~60	~75	T						4.10	0.00			Stat	2eq w	1&2
2	Hof80	E/	Ethi	~60	~75	T						5.90	2.35			Stat	2eq w	1&2
2	Hof80	E/	Rwan	~60	~75	T						0.00	0.00			Stat	2eq w	1&2
2	Hof80	E/	Tanz	~60	~75	T						3.50	1.00			Stat	2eq w	1&2
2	Hof80	E/	Gree	~60	~75	T						8.00	1.02			Stat	2eq w	1&2
2	Hof80	E/	Isra	~60	~75	T						0.80	0.12			Stat	2eq w	1&2
2	Hof80	E/	Port	~60	~75	T						0.00	0.00			Stat	2eq w	1&2
2	Hof80	E/	Malt	~60	~75	T						8.20	0.57			Stat	2eq w	1&2
2	Hof80	E/	Keny	~60	~75	T						0.00	0.00			Stat	2eq w	1&2
2	Hof80	E/	Cypr	~60	~75	T						6.30	0.81			Stat	2eq w	1&2

Table 3 (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
2	Hof80	E/	Ugan	~60	~75	T						5.00	2.11			Stat	2eq w 1&2	
2	Hof80	E/	Zair	~60	~75	T						0.00	0.00			Stat	2eq w 1&2	
2	Hof80	E/	Spai	~60	~75	T						7.80	0.70			Stat	2eq w 1&2	
2	Hof81	E/	C22 LA	60&71&75		CT						14.15	0.91			Stat	OLS?	SV
2	LJ086	E/	Indi	71&76&79		T						ns	3.53			Stat	gEn/gY	
2	LJ086	E/b	Chil	71&76&80		T						ns	0.50			Stat	gEn/gY	
2	LJ086	E/	Paki	71&76&81		T						s	1.61			Stat	gEn/gY	
2	LJ086	E/b	Port	71&76&81		T						s	0.90			Stat	gEn/gY	
2	LJ086	E/	Braz	71&76&81		T						s	1.11			Stat	gEn/gY	
2	LJ086	E/b	Phil	71&76&81		T						s	1.05			Stat	gEn/gY	
2	LJ086	E/	C4 Ly	~71	~81	T a							1.48			Stat	gEn/gY	
2	LJ086	E/b	Paki	72&76&81		T						s	0.90			Stat	gEn/gY	
2	LJ086	E/	SLan	70&76&81		T						s	0.47			Stat	gEn/gY	
2	LJ086	E/b	Braz	70&76&81		T						s	0.77			Stat	gEn/gY	
2	LJ086	E/	Phil	75&79&81		T						s	0.50			Stat	gEn/gY	
2	LJ086	E/b	SLan	70&76&81		T						s	0.89			Stat	gEn/gY	
2	LJ086	E/	Keny	71&79&81		T						s	0.29			Stat	gEn/gY	
2	LJ086	E/b	C4 Ly	~71	~81	T a							1.16			Stat	gEn/gY	
2	LJ086	E/	Port	71&76&81		T						s	1.01			Stat	gEn/gY	
2	LJ086	E/b	Keny	71&79&81		T						s	0.54			Stat	gEn/gY	
2	LJ086	E/b	C4 My	~71	~81	T a							0.81			Stat	gEn/gY	
2	LJ086	E/	C4 My	~71	~81	T a							0.79			Stat	gEn/gY	
2	LJ086	E/	Chil	71&76&80		T						ns	0.52			Stat	gEn/gY	
2	LJ086	E/b	Indi	71&76&79		T						ns	2.29			Stat	gEn/gY	
2	Z&A81	E/	C7 OX	70	70	C						3.70	1.49			Stat	OLS?	
2	Z&A81	E/	C47	70	70	C						15.20	1.37			Stat	OLS?	
2	Z&A81	E/	C4 Eu	70&74&76		CT						2.46	1.35			Stat	OLS?	SV
2	Z&A81	E/	C47	70&74&76		CT						18.00	1.23			Stat	OLS?	SV
2	Z&A81	E/	C8 As	70&74&76		CT						25.90	1.36			Stat	OLS?	
2	Z&A81	E/	C4 Eu	70	70	C						1.73	1.38			Stat	OLS?	
2	Z&A81	E/	C47	70	70	C						16.20	1.43			Stat	OLS?	R,SV
2	Z&A81	E/	C11 Af	70&74&76		CT						5.46	1.29			Stat	OLS?	
2	Z&A81	E/	C47	70&74&76		CT						27.60	1.34			Stat	OLS?	
2	Z&A81	E/	C11 Af	70	70	C						3.85	1.35			Stat	OLS?	
2	Z&A81	E/	C7 OX	70&74&76		CT						4.87	1.43			Stat	OLS?	SV
2	Z&A81	E/	C47	70&74&76		CT						26.90	1.35			Stat	OLS?	
2	Z&A81	E/	C17 Am	70	70	C						2.92	1.38			Stat	OLS?	
2	Z&A81	E/	C8 As	70	70	C						15.70	1.43			Stat	OLS?	
2	Z&A81	E/	C8 As	70&74&76		CT						18.70	1.39			Stat	OLS?	SV
2	Z&A81	E/	C17 Am	70&74&76		CT						4.08	1.34			Stat	OLS?	SV
2	Z&A81	E/	C47	70&74&76		CT						19.30	1.39			Stat	OLS?	SV
2	Z&A81	E/	C17 Am	70&74&76		CT						4.10	1.32			Stat	OLS?	
2	Z&A81	E/	C4 Eu	70&74&76		CT						2.39	1.32			Stat	OLS?	
2	Z&A81	E/	C11 Af	70&74&76		CT						5.47	1.32			Stat	OLS?	SV
2	Z&A81	E/	C7 OX	70&74&76		CT						4.95	1.41			Stat	OLS?	
#E	80					Avg							1.00					
						Std							0.58					
						#							80					
3	Abd88	E	Egyp	60	81	T		-2.37	-0.42			10.60	0.76			Stat	OLS	D*T
3	Abd88	E	Egyp	60	81	T	-0.15	-1.59		-0.52	0.26	3.11		0.88	0.71	LE	OLS	
3	Abd88	E	Egyp	60	81	T		-2.11	-0.34			13.38	0.71			Stat	OLS	
3	Hof78	E	LyAf SS	68	75	CT		-0.67	-0.18			12.21	1.06			Stat	OLS?	C,SV
3	Hof78	E	LyAf SS	68	75	CT		-0.67	-0.18			12.80	1.06			Stat	OLS?	C,SV
3	Hof78	E	SE	60	75	CT		-3.08	-0.43			7.17	0.45			Stat	OLS?	SV
3	Hof78	E	SE	60	75	CT		-4.03	-0.40			14.62	0.75			Stat	OLS?	C,SV
3	Hof78	E	LyAf SS	60	75	CT		-4.98	-0.74			14.03	0.96			Stat	OLS?	C,SV
3	Hof78	E	LyAf SS	60	75	CT		-5.11	-0.77			14.74	1.00			Stat	OLS?	C,SV
3	Hof78	E	LyAf SS	68	75	CT		-0.82	-0.30			7.88	0.96			Stat	OLS?	SV
3	Hof78	E	LyAf SS	60	67	CT		-3.44	-0.68			9.61	0.96			Stat	OLS?	C,SV
3	Hof78	E	SE	67	75	CT		-2.88	-0.45			12.26	0.90			Stat	OLS?	C,SV
3	Hof78	E	LyAf SS	60	67	CT		-0.74	-0.19			5.75	0.76			Stat	OLS?	SV
3	Hof78	E	LyAf SS	60	67	CT		-4.55	-0.88			9.75	1.01			Stat	OLS?	C,SV
3	Hof78	E	SE	67	75	CT		0.59	0.13			5.30	0.53			Stat	OLS?	SV
3	Hof78	E	LyAf SS	60	75	CT		-3.27	-0.73			7.85	0.79			Stat	OLS?	SV
3	Hof78	E	SE	60	67	CT		-1.38	-0.24			8.01	0.65			Stat	OLS?	C,SV

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
3	Hof78	E	SE	60	67	CT		-3.52	-0.73			4.23	0.41			Stat	OLS?	SV
3	Hof81	E	Braz	60?	75	T?	-0.09	-1.84		-0.27	0.41	2.54		1.25	0.67	LE	OLS?	
3	ISI82q	E	17 Ar	77	79	CT			-0.51				0.45			Stat	OLS	
3	I&H90	E	Moro	70	84?	T	-0.04	-2.78		-0.10	0.41	2.71		1.03	0.60	LE	OLS	Po
3	I&H90	E	Kore	70	84?	T		-2.39	-0.11			11.51	0.81			Stat	OLS	Po
3	I&H90	E	Kore	70	84?	T	-0.11	-1.41		-0.24	0.55	3.49		1.22	0.55	LE	OLS	
3	I&H90	E	Paki	70	84?	T		-1.46	-0.25			8.46	1.33			Stat	OLS	
3	I&H90	E	Phil	70	84?	T		-4.52	-0.17			15.48	1.14			Stat	OLS	
3	I&H90	E	SAra	70	84?	T		-2.11	-0.24			8.62	1.23			Stat	OLS	Pp,SV
3	I&H90	E	Egyp	70	84?	T		-2.48	-0.27			5.66	0.85			Stat	OLS	Pp,SV
3	I&H90	E	Taiw	70	84?	T	-0.24	-2.35		-0.53	0.56	2.21		1.24	0.55	LE	OLS	
3	I&H90	E	Thai	70	84?	T	-0.11	-1.47		-0.15	0.78	3.92		1.08	0.28 ns	LE	OLS	Po
3	I&H90	E	Mexi	70	84?	T		-2.14	-0.12			32.38	1.27			Stat	OLS	Pp,SV
3	I&H90	E	Alge	70	84?	T		-4.26	-0.89			7.98	0.89			Stat	OLS	Pp,SV
3	I&H90	E	Braz	70	84?	T	-0.14	-4.71		-0.25	0.64	3.69		1.12	0.43	LE	OLS	
3	KKL90	E	Kore	60	83	T	-0.08	-1.36		-0.19	0.31	1.36		0.80	0.61	LE	OLS?	D*T
3	KKL90	E	Phil	57	83	T	-0.37	-2.66		-1.35	0.52	2.12		1.92	0.73	LE	OLS?	D*T
3	KKN88	E	Indi	57	80	T		-2.47	-0.39			3.46	0.69			Stat	2S	D*T
3	KKN88	E	Indi	57	80	T		-1.79	-0.35			4.05	0.89			Stat	2S	
3	S&M84	E	Gree	58	80	T		-6.47	-0.46			78.21	1.60			Stat	GLS	
3	S&M84	E	Gree	72	80	T	-0.37	-6.04		-0.62	0.92	4.62		1.55	0.41	LE	GLS	
3	S&M84	E	Gree	64	80	T		-5.61	-0.28			65.06	1.48			Stat	GLS	
3	S&M84	E	Gree	72	80	T	-0.25	-6.13		-0.31	1.17	9.78		1.45	0.20	LE	GLS	
3	S&M84	E	Gree	72	80	T		-5.23	-0.16			31.33	1.31			Stat	GLS	
3	S&M84	E	Gree	58	77	T		-7.94	-0.88							LE	OLS?	
3	S&M84	E	Gree	58	77	T	-0.62	-4.73		-1.06					0.41	Stat	HL	
3	S&M84	E	Gree	58	80	T	-0.20	-1.94		-2.16					0.91	LE	HL	
3	S&M84	E	Gree	64	77	T		-9.98	-0.57							Stat	OLS?	
3	S&M84	E	Gree	64	77	T	-0.52	-8.37		-0.61					0.15 ns	LE	HL	
3	S&M84	E	Gree	64	80	T	0.11	0.89		0.42					0.74	LE	HL	
3	Tze89	E	Taiw	62	84	T	-0.12	-2.43		-0.19	0.67	3.55		1.04	0.36	LE	OLS	Pi
3	WRN81	E	C77 OM	67	76	CT	-0.05	-4.52		-3.92	0.02	3.10		1.42	0.99	LE	OLS	Po
3	WRN81	E	C77 OM	67	76	CT	-0.05	-4.64		-3.92	0.07	2.60		1.42	0.99	LE&y-1	OLS	Po
3	WRN81	E	C77 OM	67	76	CT	-0.05	-3.11		-0.10	0.05	2.22		0.10	0.49	LE&y-1	OLS	C,Po,T
3	WRN81	E	C77 OM	67	76	CT	-0.05	-3.31		-0.11	0.01	0.78		0.02	0.49	LE	OLS	C,Po,T
3	W&C87	E	Indi	61	80	T		-1.57	-0.26			9.56	1.24			Stat	NL3S	D*T
#E	53					Avg	-0.17		-0.41	-0.81	0.46		0.93	1.10	0.56			
						Std	0.17		0.25	1.16	0.32		0.29	0.47	0.23			
						#	20		33	20	16		31	16	20			
4	Cho85q	E	Niga	72	76	T							1.31			Stat	gEn/gY	
4	Cho85q	E	Liby	72	76	T							1.15			Stat	gEn/gY	
4	Cho85q	E	Indo	72	76	T							1.65			Stat	gEn/gY	
4	Cho85q	E	Iraq	72	76	T							1.96			Stat	gEn/gY	
4	Cho85q	E	Vene	72	76	T							0.48			Stat	gEn/gY	
4	Cho85q	E	Iran	72	76	T							1.61			Stat	gEn/gY	
4	Cho85q	E	Ecua	72	76	T							0.69			Stat	gEn/gY	
4	Cho85q	E	SAra	72	76	T							1.97			Stat	gEn/gY	
4	Cho85q	E	Alge	72	76	T							1.64			Stat	gEn/gY	
4	Hof78	E	LyAf SS	68	75	CT						15.36	1.13			Stat	OLS?	C,SV
4	Hof78	E	LyAf SS	60	67	CT						10.36	0.85			Stat	OLS?	C,SV
4	Hof78	E	LyAf SS	60	67	CT						10.52	0.86			Stat	OLS?	C,SV
4	Hof78	E	LyAf SS	60	67	CT						4.75	0.68			Stat	OLS?	SV
4	Hof78	E	LyAf SS	60	75	CT						9.75	0.94			Stat	OLS?	SV
4	Hof78	E	LyAf SS	68	75	CT						14.94	1.14			Stat	OLS?	C,SV
4	Hof78	E	SE	60	67	CT						2.74	0.26			Stat	OLS?	SV
4	Hof78	E	SE	60	75	CT						14.19	0.77			Stat	OLS?	C,SV

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
4	Hof78	E	SE	67	75	CT						11.54	0.92			Stat	OLS?	C,SV
4	Hof78	E	SE	67	75	CT						5.47	0.51			Stat	OLS?	SV
4	Hof78	E	LyAf SS	60	75	CT						16.63	0.99			Stat	OLS?	C,SV
4	Hof78	E	LyAf SS	68	75	CT						10.54	1.22			Stat	OLS?	SV
4	Hof78	E	SE	60	75	CT						7.38	0.48			Stat	OLS?	SV
4	Hof78	E	LyAf SS	60	75	CT						16.21	0.97			Stat	OLS?	C,SV
4	Hof78	E	SE	60	67	CT						7.84	0.64			Stat	OLS?	C,SV
4	Hof81	E	C22 LA	60&71&75		CT						19.90	0.94			Stat	OLS?	SV
4	Hof81	E	C22 LA	60&71&75		CT						16.13	1.71			Stat	OLS?	
4	Hof81	E	C22 LA	60&71&75		CT						9.55	1.11			Stat	OLS?	SV,D*T
4	I&H90	E	Indo	70	84?	T						23.37	1.19			Stat	OLS	Pp
4	I&H90	E	Indi	70	84?	T						23.26	1.56			Stat	OLS	
4	LJO86	E	Paki	72&76&81		T						s	1.31			Stat	gEn/gY	
4	LJO86	E	Chil	71&76&80		T						s	0.48			Stat	gEn/gY	
4	LJO86	E	Phil	75&79&81		T						s	0.71			Stat	gEn/gY	
4	LJO86	E	SLan	70&76&81		T						s	0.58			Stat	gEn/gY	
4	LJO86	Eb	Phil	75&79&81		T						s	1.01			Stat	gEn/gY	
4	LJO86	E	Keny	71&79&81		T						s	0.70			Stat	gEn/gY	
4	LJO86	Eb	Chil	71&76&80		T						s	0.46			Stat	gEn/gY	
4	LJO86	E	C4Ly	~71	~81	T a							1.08			Stat	gEn/gY	
4	LJO86	Eb	SLan	70&76&81		T						s	0.95			Stat	gEn/gY	
4	LJO86	E	Port	71&76&81		T						s	1.01			Stat	gEn/gY	
4	LJO86	Eb	Braz	70&76&81		T						s	0.84			Stat	gEn/gY	
4	LJO86	Eb	C4Ly	~71	~81	T a							1.02			Stat	gEn/gY	
4	LJO86	Eb	Paki	72&76&81		T						s	0.94			Stat	gEn/gY	
4	LJO86	E	C4My	~71	~81	T a							0.82			Stat	gEn/gY	
4	LJO86	Eb	C4My	~71	~81	T a							0.81			Stat	gEn/gY	
4	LJO86	Eb	Keny	71&79&81		T						s	0.80			Stat	gEn/gY	
4	LJO86	E	Indi	71&76&79		T						s	1.74			Stat	gEn/gY	
4	LJO86	E	Braz	70&76&81		T						s	1.07			Stat	gEn/gY	
4	LJO86	Eb	Port	71&76&81		T						s	0.93			Stat	gEn/gY	
4	VBC85	E	Braz	53	82	T					0.49			0.72	0.32 ns	LE	OLS	T
#E	50					Avg					0.49		1.02	0.72	0.32			
						Std					0.00		0.40					
						#					1		49	1	1			
5	S&M84	E/Y	Gree	58	80	T		-6.46	-0.46							Stat	OLS?	
5	S&M84	E/Y	Gree	58	80	T	-0.27	-3.85		-0.64					0.59	LE	HL	
5	S&M84	E/Y	Gree	58	80	T		0.10	0.01							Stat	OLS?	SV
5	S&M84	E/Y	Gree	58	80	T	-0.13	-2.33		-0.84					0.84	LE	HL	SV
5	S&M84	E/Y	Gree	58	77	T	-0.35	-3.01		-0.84					0.58	LE	GLS	
5	S&M84	E/Y	Gree	64	80	T		-4.26	-0.20							Stat	GLS	
5	S&M84	E/Y	Gree	64	80	T	-0.20	-4.98		-0.32					0.37	LE	GLS	
5	S&M84	E/Y	Gree	64	80	T		0.78	0.08							Stat	GLS	SV
5	S&M84	E/Y	Gree	64	80	T	0.01	0.34		0.03					0.55	LE	GLS	SV
5	S&M84	E/Y	Gree	64	77	T	-0.28	-4.37		-0.41					0.32	LE	GLS	
#E	10					Avg	-0.20		-0.14	-0.50					0.54			
						Std	0.12		0.21	0.31					0.17			
						#	6		4	6					6			
6	Hof81	E-i	Bra-R26	70	70	C		-4.87	-0.41			27.78	0.98			Stat	OLS?	
6	Iqb86	E-i	Paki	59/60	69/70	CT		-9.30	-0.82							TL--KLE	ISur	I
6	S&M84	E-i	Gree	58	80	T		-2.25	-0.32			28.16	1.35			Stat	GLS	
6	S&M84	E-i	Gree	58	80	T	-0.28	-2.99		-0.76	0.46	3.02		1.24	0.63	LE	GLS	
6	S&M84	E-i	Gree	64	80	T		-0.10	-0.01			27.76	1.20			Stat	GLS	
6	S&M84	E-i	Gree	64	80	T	-0.11	-1.79		-0.23	0.50	4.19		1.07	0.53	LE	GLS	
6	S&M84	E-i	Gree	72	80	T		1.45	0.16			5.40	0.89			Stat	GLS	
6	Tze89	E-i	Taiw	62	84	T						75.25	0.63			OLS	OLS	
6	Vas84	E-i	Indi	60	71	CT?		-1.25	-0.65							TL-KLE	Sur	
6	Wan85	E-i	Taiw	61	79	T							1.09			Stat	OLS?	
#E	10					Avg	-0.19		-0.34	-0.50	0.48		1.03	1.15	0.58			
						Std	0.09		0.34	0.26	0.02		0.23	0.09	0.05			
						#	2		6	2	2		6	2	2			

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
7	Lia85	E-ag	Taiw	61	81	T?		-0.20	-0.98							TL-KLEM	NL3S	T
7	Hof81	E-ag	Bra-R26	70	70	C		-1.86	-0.42			12.55	1.02			Stat	OLS?	
7	Pit85	E-bv	Indo	76	78	CT		-20.65	-0.72							TL-EL	ISur	
7	Pit85	E-ch	Indo	76	78	CT		-17.36	-0.57							TL-EL	ISur	
7	Iqb86	E-ch	Paki	59/60	69/70	CT		-2.74	-0.56							TL--KLE	ISur	I
7	Hof81	E-ch	Bra-R26	70	70	C		-0.66	-0.14			10.36	1.13			Stat	OLS?	
7	Pit85	E-ch	Indo	76	78	CT		-8.11	-0.50							TL-EL	ISur	
7	Lia85	E-co	Taiw	61	81	T?		-2.80	-1.10							TL-KLEM	NL3S	T
7	Tze89	E-ep	Taiw	62	84	T						35.61	0.92			Stat	OLS	
7	Iqb86	E-fp	Paki	59/60	69/70	CT		-0.23	-1.60							TL--KLE	ISur	I
7	Pit85	E-fp	Indo	76	78	CT		-28.91	-0.71							TL-EL	ISur	
7	SKR87	E-fp	Thai	74	77	CT			-2.26							TL-KLE	ISur	
7	SKR87	E-fp	Phil	70	73	CT			-0.66							TL-KLE	ISur	
7	SKR87	E-fp	Phil	70	78	CT			-0.52							TL-KLE	ISur	
7	SKR87	E-fp	Phil	74	78	CT			-0.42							TL-KLE	ISur	
7	Pit85	E-fp	Indo	76	78	CT		-34.58	-0.68							TL-EL	ISur	
7	S&P83q	E-fp	Indi	63&66&71		CT			-0.04							TL-KLEM	?	
7	S&P83q	E-i5	Indi	63&66&71		CT			-0.20							TL-KLEM	?	
7	Iqb86	E-le	Paki	59/60	69/70	CT		-34.92	-0.91							TL--KLE	ISur	I
7	Pit85	E-le	Indo	76	78	CT		-20.21	-0.62							TL-EL	ISur	
7	Pit85	E-ma	Indo	76	78	CT		-10.71	-0.52							TL-EL	ISur	
7	Iqb86	E-ma	Paki	59/60	69/70	CT		-1.57	-0.25							TL--KLE	ISur	I
7	Hof81	E-ma	Bra-R26	70	70	C		-1.65	-0.30			10.95	0.81			Stat	OLS?	
7	SKR87	E-mc	Thai	74	77	CT			-1.67							TL-KLE	ISur	
7	Hof81	E-me	Bra-R26	70	70	C		1.78	0.53			11.21	1.17			Stat	OLS?	
7	Iqb86	E-me	Paki	59/60	69/70	CT		0.40	0.29							TL--KLE	ISur	I
7	Pit85	E-me	Indo	76	78	CT		-13.75	-0.56							TL-EL	ISur	
7	Lia85	E-mf	Taiw	61	81	T?		-0.01	-0.96							TL-KLEM	NL3S	T
7	Lia85	E-mi	Taiw	61	81	T?		-0.33	-0.83							TL-KLEM	NL3S	T
7	Hof81	E-mi	Bra-R26	70	70	C		-1.83	-0.51			7.19	0.92			Stat	OLS?	
7	Hof81	E-mi	Bra-R26	70	70	C		-6.39	-0.95			10.24	0.90			Stat	OLS?	
7	SKR87	E-mm	Thai	74	77	CT			-1.50							TL-KLE	ISur	
7	Pit85	E-mo	Indo	76	78	CT		-8.10	-0.41							TL-EL	ISur	
7	Pit85	E-mp	Indo	76	78	CT		-16.60	-0.58							TL-EL	ISur	
7	Iqb86	E-mp	Paki	59/60	69/70	CT		-0.18	-0.88							TL--KLE	ISur	I
7	Hof81	E-mt	Bra-R26	70	70	C		-5.92	-1.14			12.31	0.88			Stat	OLS?	
7	Iqb86	E-mt	Paki	59/60	69/70	CT		-0.05	-0.01							TL--KLE	ISur	I
7	Cha82qS	E-mt	Indi	68	74	CT			-0.00							TL-KLEM	?	
7	S&P83q	E-mt	Indi	63&66&	71	CT			-0.03							TL-KLEM	?	
7	SKR87	E-mx	Thai	74	77	CT			-2.60							TL-KLE	ISur	
7	Pit85	E-nm	Indo	76	78	CT		-9.04	-0.83							TL-EL	ISur	
7	Pit85	E-nm	Indo	76	78	CT		-23.04	-0.53							TL-EL	ISur	
7	Pit85	E-nm	Indo	76	78	CT		-20.78	-0.64							TL-EL	ISur	
7	Iqb86	E-nm	Paki	59/60	69/70	CT		-9.67	-0.86							TL--KLE	ISur	I
7	Pit85	E-nm	Indo	76	78	CT		-15.62	-0.75							TL-EL	ISur	
7	Pit85	E-nm	Indo	76	78	CT		-13.36	-0.79							TL-EL	ISur	
7	Iqb86	E-ot	Paki	59/60	69/70	CT		-39.43	-0.91							TL--KLE	ISur	I
7	Hof81	E-ot	Bra-R26	59/60	69/70	C		can't r	-0.28			can't	0.01			Stat	OLS?	
7	Hof81	E-pa	Bra-R26	70	70	C		-3.31	-0.56			13.82	0.95			Stat	OLS?	
7	Iqb86	E-pa	Paki	59/60	69/70	CT		-28.23	-0.37							TL--KLE	ISur	I
7	Pit85	E-pp	Indo	76	78	CT		-11.83	-0.49							TL-EL	ISur	
7	Iqb86	E-pr	Paki	59/60	69/70	CT		-13.09	-0.86							TL--KLE	ISur	I
7	Pit85	E-pr	Indo	76	78	CT		-5.68	-0.37							TL-EL	ISur	
7	Lia85	E-pu	Taiw	61	81	T?		-0.35	-0.54							TL-KLEM	NL3S	T
7	Pit85	E-pw	Indo	76	78	CT		-16.10	-0.57							TL-EL	ISur	
7	Iqb86	E-rb	Paki	59/60	69/70	CT		-0.58	-0.24							TL--KLE	ISur	I
7	Pit85	E-rb	Indo	76	78	CT		-19.72	-0.57							TL-EL	ISur	
7	Iqb86	E-sh	Paki	59/60	69/70	CT		-28.31	-0.91							TL--KLE	ISur	I
7	Pit85	E-sh	Indo	76	78	CT		-7.67	-0.47							TL-EL	ISur	
7	Lia85	E-sv	Taiw	61	81	T?		-0.44	-1.00							TL-KLEM	NL3S	T
7	Iqb86	E-tb	Paki	59/60	69/70	CT		-28.69	-0.92							TL--KLE	ISur	I
7	Pit85	E-tb	Indo	76	78	CT		-12.73	-0.69							TL-EL	ISur	
7	Hof81	E-te	Bra-R26	70	70	C		-0.68	-0.11			15.17	0.94			Stat	OLS?	
7	Iqb86	E-te	Paki	59/60	69/70	CT		-25.53	-0.92							TL--KLE	ISur	I
7	Pit85	E-te	Indo	76	78	CT		-0.50	-0.50							TL-EL	ISur	
7	S&M84	E-tr	Gree	58	80	T		-0.64	-0.08			15.54	1.34			Stat	GLS	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
7	S&M84	E-tr	Gree	72	80	T		-6.58	-0.42			18.00	1.93			Stat	GLS	
7	S&M84	E-tr	Gree	64	80	T		-4.52	-0.33			25.17	1.68			Stat	GLS	
7	S&M84	E-tr	Gree	72	80	T	-0.34	-3.49		-0.40	1.32	7.12		1.55	0.15 ns	LE	GLS	
7	S&M84	E-tr	Gree	72	80	T	-0.38	-4.85		-0.43	1.51	8.37		1.74	0.13 ns	LE	GLS	
7	Lia85	E-tr	Taiw	61	81	T?		-0.05	-0.86							TL-KLEM	NL3S	T
7	SKR87	E-tx	Bang	70	80	CT			-0.31							TL-KLE	ISur	
7	SKR87	E-tx	Phil	70	77	CT			-1.25							TL-KLE	ISur	
7	S&P83q	E-tx	Indi	63&66&71		CT			-0.46							TL-KLEM	?	
7	Cha82qS	E-tx	Indi	68	74	CT			-0.66							TL-KLEM	?	
7	Pit85	E-tx	Indo	76	78	CT		-2.60	-0.62							TL-EL	ISur	
7	Hof81	E-tx	Bra-R26	70	70	C		-4.05	-0.87			10.75	0.78			Stat	OLS?	
7	Iqb86	E-tx	Paki	59/60	69/70	CT		0.27	2.26							TL--KLE	ISur	I
7	Pit85	E-tx	Indo	76	78	CT		-16.89	-0.60							TL-EL	ISur	
7	SKR87	E-tx	Thai	74	77	CT			-1.71							TL-KLE	ISur	
7	Pit85	E-wa	Indo	76	78	CT		-7.29	-0.46							TL-EL	ISur	
7	Pit85	E-wd	Indo	76	78	CT		-9.47	-0.42							TL-EL	ISur	
7	Pit85	E-wf	Indo	76	78	CT		-0.85	-0.07							TL-EL	ISur	
#E	83					Avg	-0.36		-0.61	-0.42	1.42		1.02	1.64	0.14			
						Std	0.02		0.58	0.01	0.10		0.42	0.09	0.01			
						#	2		80	2	2		15	2	2			
8	Tze89	E-ag	Taiw	62	84	T						16.08	0.65			Stat	OLS	
9	FST87	E-r	Mala	75	75	C			-0.75				1.39			LExp	ML	
9	FST87	E-r	Kore	75	75	C			-0.75				1.38			LExp	ML	
9	FST87	E-r	Roma	75	75	C			-0.73				1.33			LExp	ML	
9	FST87	E-r	Yugo	75	75	C			-0.72				1.31			LExp	ML	
9	FST87	E-r	C1 Ly	75	75	C			-0.96				1.80			LExp	ML	
9	FST87	E-r	Irel	75	75	C			-0.71				1.29			LExp	ML	
9	FST87	E-r	Urug	75	75	C			-0.71				1.29			LExp	ML	
9	FST87	E-r	Thai	75	75	C			-0.78				1.44			LExp	ML	
9	FST87	E-r	Pola	75	75	C			-0.71				1.29			LExp	ML	
9	FST87	E-r	C1 Ly	75	75	C			-1.25				2.36			LExp	ML	
9	FST87	E-r	Indi	75	75	C			-0.88				1.64			LExp	ML	
9	FST87	E-r	Syri	75	75	C			-0.73				1.34			LExp	ML	
9	FST87	E-r	Mexi	75	75	C			-0.72				1.31			LExp	ML	
9	FST87	E-r	Paki	75	75	C			-0.83				1.55			LExp	ML	
9	FST87	E-r	Braz	75	75	C			-0.74				1.35			LExp	ML	
9	FST87	E-r	Iran	75	75	C			-0.73				1.34			LExp	ML	
9	FST87	E-r	Colo	75	75	C			-0.73				1.35			LExp	ML	
9	FST87	E-r	SLan	75	75	C			-0.81				1.51			LExp	ML	
9	FST87	E-r	Hung	75	75	C			-0.71				1.29			LExp	ML	
9	FST87	E-r	Phil	75	75	C			-0.78				1.44			LExp	ML	
9	FST87	E-r	C1 Ly	75	75	C			-1.05				1.98			LExp	ML	
9	FST87	E-r	C1 Ly	75	75	C			-0.91				1.70			LExp	ML	
9	Iqb84	E-r	Paki	61	81	T	-0.08			-0.15	1.23	2.53		2.32	0.47	LE	OLS	
9	Iqb84	E-r	Paki	61	81	T	-0.21	-2.43		-0.38	1.42	3.06		2.63	0.46	LE	OLS	
#E	24					Avg	-0.14		-0.80	-0.27	1.33		1.49	2.48	0.47			
						Std	0.06		0.13	0.11	0.09		0.26	0.15	0.00			
						#	2		22	2	2		22	2	2			
10	Wan85	E-r/H	Taiw	61	79	T						25.11	14.60			Stat	OLS?	
#E																		
11	S&M84	E-r&c	Gree	58	80	T		-5.25	-0.80			29.86	1.40			Stat	GLS	
11	S&M84	E-r&c	Gree	72	80	T	-0.46	-3.18		-0.44	1.32	5.32		1.28	-0.03 ns	LE	GLS	
11	S&M84	E-r&c	Gree	72	80	T	-0.67	-4.56		-0.87	1.02	3.70		1.32	0.23 ns	LE	GLS	
11	S&M84	E-r&c	Gree	72	80	T		-2.27	-0.29			7.53	1.16			Stat	GLS	
11	S&M84	E-r&c	Gree	64	80	T		-3.64	-0.50			26.78	1.27			Stat	GLS	
#E	5					Avg	-0.57		-0.53	-0.66	1.17		1.28	1.30	0.10			
						Std	0.11		0.21	0.21	0.15		0.10	0.02	0.13			
						#	2		3	2	2		3	2	2			

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
12	A&B87	O/	C3 Af	70	82	CT	-0.08	-1.37		-0.25	-0.43	-2.98		-1.42	0.70	LE	OLS	Po,Ps
12	A&B87	O/	C3 As	70	82	CT		-4.86	-0.72			7.86	0.88			Stat	IV-sc	Po,Ps
12	A&B87	O/	C3 As	70	82	CT		-3.17	-0.63			9.29	0.97			Stat	OLS	Po,Ps
12	A&B87	O/	C5 LA	70	82	CT	-0.19	-2.99		-1.07	0.18	3.18		1.02	0.82	LE	OLS	Po,Ps
12	Che87	O/	C7 LA	˜60	˜82	CT	-0.07	-2.13		-0.25	0.33	2.75		1.21	0.73	LE	IV-h	C,Pp,SV
12	Che87	O/	C5 As	˜60	˜82	CT	-0.08	-2.51		-0.26	0.20	2.18		0.63	0.68	LE	IV-h	C,Pp,SV
12	CLS84	O/	C6 LA&Eg	˜70	˜80	CT	-0.07	-2.13		-0.25	0.33	2.75		1.21	0.73	LE	IV-h	C,Pp,SV,D*T
12	CLS84	O/	C7 As	˜70	˜80	CT	-0.08	-2.51		-0.26	0.20	2.18		0.63	0.68	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C15 -	˜70	˜82	CT	-0.07	-2.09		-0.19	0.31	4.00		0.91	0.66	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C7 LA&Af	˜70	˜82	CT	-0.07	-2.80		-0.13	0.41	3.70		0.79	0.48	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C3 As	˜70	˜82	CT	-0.09	-1.91		-0.22	0.44	4.20		1.14	0.62	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C6 L[illegible]	˜70	˜82	CT	-0.00	-0.06		-0.00	0.42	3.20		0.66	0.37	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C9 Hy	70	˜82	CT	-0.10	-4.30		-0.30	0.40	4.60		1.25	0.68	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C10 EM	˜70	˜82	CT	-0.05	-1.70		-0.13	0.34	4.00		0.90	0.62	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C4 EX	˜70	˜82	CT	-0.08	-2.60		-0.09	1.03	5.60		1.13	0.09 ns	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C7 Lpo	˜70	˜82	CT	-0.05	-1.50		-0.09	0.49	3.40		0.86	0.43	LE	IV-h	C,Pp,SV,D*T
12	C&S85	O/	C8 Hp	˜70	˜82	CT	-0.09	-2.40		-0.23	0.38	3.70		1.04	0.63	LE	IV-h	C,Pp,SV,D*T
12	C&S86	O/	C10 OM	˜70	˜82	CT	-0.06	-1.82		-0.14	0.43	3.76		1.14	0.62	LE	IV-h	C,Pp,SV
12	C&S86	O/	C4 OX	˜70	˜82	CT	-0.03	-0.69		-0.05	0.78	3.20		1.06	0.27 ns	LE	IV-h	C,Pp,SV
12	C&S86	O/	C4 OX	˜70	˜82	CT	-0.04	-0.92		-0.06	0.86	3.70		1.13	0.24 ns	LE	IV-h	C,Pp,SV
12	C&S86	O/	C14	˜70	˜82	CT	-0.07	-3.02		-0.19	0.48	4.72		1.24	0.61	LE	IV-h	C,Pp,SV
12	C&S86	O/	C10 OM	˜70	˜82	CT	-0.05	-1.74		-0.14	0.49	4.39		1.25	0.61	LE	IV-h	C,Pp,SV
12	C&S86	O/	C14	˜70	˜82	CT	-0.07	-2.62		-0.18	0.51	5.26		1.36	0.62	LE	IV-h	C,Pp,SV
12	D&B85	O/	Gree	55	80	T		2.31	0.22			41.89	1.40			Stat	OLS	Pp,Ps
12	D&B85	O/	Port	55	80	T		-2.54	-0.52			4.80	1.08			Stat	OLS	Pp,Ps
12	D&F85	O/	Gree	55	80	T	0.07	0.79		0.09	1.02	7.18		1.32	0.23	LE	SUR	Pp,Ps
12	D&F85	O/	Turk	55	80	T	-0.37	-5.29		-3.36	0.17	0.86		1.55	0.89	LE	SUR	Pp,Ps
12	D&F85	O/	Port	55	80	T	-0.36	-9.37		-5.14	0.28	3.74		4.00	0.93	LE	SUR	Pp,Ps
12	WRN81	O/	C77 OM	67	76	CT	-0.07	-3.98		-0.16	0.02	1.33		0.05	0.56	LE	OLS	C,Po,T
12	WRN81	O/	C77 OM	67	76	CT	-0.04	-4.11		-2.93	0.09	3.19		1.36	0.99	LE&y-1	OLS	Po
12	WRN81	O/	C77 OM	67	76	CT	-0.04	-4.04		-3.08	0.02	2.76		1.54	0.99	LE	OLS	Po
12	WRN81	O/	C77 OM	67	76	CT	-0.06	-3.81		-0.14	0.07	2.88		0.01	0.55	LE&y-1	OLS	C,Po,T
#E	32					Avg	-0.08		-0.41	-0.69	0.37		1.08	1.03	0.61			
						Std	0.09		0.37	1.26	0.30		0.20	0.81	0.22			
						#	28		4	28	28		4	28	28			
13	Z&A81	O/	C8 As	70&74&76		CT						26.70	1.39			Stat	OLS?	
13	Z&A81	O/	C7 OX	70&74&76		CT						3.29	1.42			Stat	OLS?	
13	Z&A81	O/	C4 Eu	70&74&76		CT						2.46	1.35			Stat	OLS?	
13	Z&A81	O/	C47	70&74&76		CT						27.10	1.38			Stat	OLS?	SV
13	Z&A81	O/	C11 Af	70&74&76		CT						4.41	1.33			Stat	OLS?	
13	Z&A81	O/	C47	70&74&76		CT						30.50	1.37			Stat	OLS?	
13	Z&A81	O/	C17 Am	70&74&76		CT						3.23	1.36			Stat	OLS?	
#E	7												1.37					
													0.03					
													7.00					
14	I&H90	O	Taiw	70	84?	T		-2.55	-0.43			12.20	1.41			Stat	OLS	Pp
14	I&H90	O	Moro	70	84?	T		-2.10	-0.15			8.44	2.11			Stat	OLS	Po
14	I&H90	O	Alge	70	84?	T		-1.71	-0.26			10.1[illegible]	0.84			Stat	OLS	Pp,SV
14	I&H90	O	SAra	70	84?	T		-1.61	-0.19			8.67	1.26			Stat	OLS	Pp,SV
14	I&H90	O	Thai	70	84?	T		-5.08	-0.72			4.36	0.73			Stat	OLS	Pp
14	I&H90	O	Kore	70	84?	T		-4.86	-0.26			21.85	1.09			Stat	OLS	Pp
14	I&H90	O	Phil	70	84?	T		-2.17	-0.14			5.15	0.85			Stat	OLS	Pp,SV
14	I&H90	O	Moro	70	84?	T		-0.30	-0.04			8.10	1.68			Stat	OLS	Pp
14	I&H90	O	Braz	70	84?	T		-2.71	-0.32			6.15	0.98			Stat	OLS	Pp
14	I&H90	O	Paki	70	84?	T		-2.01	-0.34			2.67	0.62			Stat	OLS	Pp,SV
14	I&H90	O	Taiw	70	84?	T		0.97	0.11			5.84	1.03			Stat	OLS	Po
14	I&H90	O	Egyp	70	84?	T		-1.38	-0.24			2.74	0.67			Stat	OLS	Pp,SV
14	I&H90	O	Kore	70	84?	T		-3.32	-0.21			7.41	0.85			Stat	OLS	Pp,Ps
14	I&H90	O	Taiw	70	84?	T		-9.57	-0.64			22.33	1.33			Stat	OLS	Pp,Ps
14	Uri79	O	Indi	60	71	T		-1.80	-0.10							TL-COE	ISur	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
14 WRN81	O	C77 OM	67	76	CT	-0.04	-4.22		-2.73	0.07	2.43		1.07	0.99	LE&y-1	OLS	Po
14 WRN81	O	C77 OM	67	76	CT	-0.04	-4.13		-2.86	0.02	2.79		1.14	0.99	LE	OLS	Po
14 WRN81	O	C77 OM	67	76	CT	-0.06	-3.69		-0.14	0.05	2.11		-0.01	0.5[illegible]	LE&y-1	OLS	C,Po,T
14 WRN81	O	C77 OM	67	76	CT	-0.06	-3.85		-0.15	0.01	0.59		0.02	0.[illegible]	LE	OLS	C,Po,T
#E	19				Avg	-0.05		-0.26	-1.47	0.04		1.10	0.56	0.78			
					Std	0.01		0.21	1.33	0.02		0.40	0.55	0.21			
					#	4		15	4	4		14	4	4			
15 Cho85q	O	Indo	72	76	T							2.35			Stat	gOi/gY	
15 Cho85q	O	Vene	72	76	T							0.98			Stat	gOi/gY	
15 Cho85q	O	Niga	72	76	T							3.31			Stat	gOi/gY	
15 Cho85q	O	Ecua	72	76	T							1.42			Stat	gOi/gY	
15 Cho85q	O	Iran	72	76	T							2.26			Stat	gOi/gY	
15 Cho85q	O	Liby	72	76	T							0.70			Stat	gOi/gY	
15 Cho85q	O	Iraq	72	76	T							2.04			Stat	gOi/gY	
15 Cho85q	O	SAra	72	76	T							2.63			Stat	gOi/gY	
15 Cho85q	O	Alge	72	76	T							2.21			Stat	gOi/gY	
15 I&H90	O	Indo	70	84?	T						12.54	1.03			Stat	OLS	
15 I&H90	O	Mexi	70	84?	T						24.69	1.46			Stat	OLS	SV
15 I&H90	O	Indi	70	84?	T						14.61	1.39			Stat	OLS	
15 I&H90	O	Moro	70	84?	T						15.37	1.63			Stat	OLS	
#E	13				Avg							1.80					
					Std							0.71					
					#							13					
16 I&H90	OIm	Moro	70	84?	T		-0.63	-0.07			8.32	1.68			Stat	OLS	Pp
16 I&H90	OIm	Taiw	70	84?	T		0.44	0.06			2.91	0.74			Stat	OLS	Po
16 I&H90	OIm	Taiw	70	84?	T		-2.14	-0.54			6.55	1.12			Stat	OLS	Pp
16 I&H90	OIm	Moro	70	84?	T		-2.21	-0.16			8.51	2.16			Stat	OLS	Po
16 W&C87	O/C	Indi	61	80				-1.02				rn			TL-COE	NL3S	SV,Ps,D*T
16 Rah82	O&NG	Indi	61	78	T		-2.1[illegible]	-0.25			4.08	1.45			Stat	2S-sc	D*T
16 Rah82	O&NG	Indi	61	78	T		-1.70	-0.22			2.97	0.67			Stat	2S	D*T
16 I&H90	O/E	Braz	70	84?	T		-2.77	-0.25							Stat	OLS	Pp
16 Tze89	O/E	Taiw	62	84	T	-0.28	-3.41		-1.68					0.84	LE	OLS	Pi
#E	9																
17 V&S86	O-i	Gree	60	80	T		-0.66	-0.05							TL-COE	ISUR	
17 V&S86	O-i	Gree	60	80	T		-0.68	-0.08							TL-COE	ISUR	
17 C&C83q	O-i	Gree	63	77	CT			-0.83									
17 Vas84	O-i	Indi	60	71	CT?		-1.92	-0.43							TL-COE	Sur	
#E	4				Avg			-0.35									
					Std			0.32									
					#			4									
18 Lia85	O-ag	Taiw	61	81	T?		-1.20	-0.13							TL-COEN	NL3S	T
18 Uri79	O-ag	Indi	60	71	T		-1.80	-0.03							TL-COE	ML	
18 V&S86	O-ag	Gree	60	80	T		-4.56	-1.31							TL-COE	ISUR	
18 Roy86	O-bv	Indi	59	74	CT		-0.17	-0.81							TL-COE	ISUR	
18 Roy86	O-ch	Indi	59	74	CT		-6.80	-0.89							TL-COE	ISUR	
18 L&W81	O-ch	Indi	68	68	C		-5.30	-0.63							TL-COE	ISUR	
18 Lia85	O-co	Taiw	61	81	T?			-0.09							TL-COEN	NL3S	T
18 L&W81	O-fb	Indi	68	68	C		-62.21	-0.42							TL-COE	ISUR	
18 Uri79	O-gc	Indi	60	71	T		-1.80	-0.03							TL-COE	ML	
18 V&S86	O-in	Gree	60	80	T		-1.50	-0.02							TL-COE	ISUR	
18 Roy86	O-is	Indi	59	74	C[illegible]		-9.50	-1.57							TL-COE	ISUR	
18 V&S86	O-ma	Gree	60	80	T		-1.07	-0.31							TL-COE	ISUR	
18 L&W81	O-me	Indi	68	68	C		-0.58	-0.09							TL-COE	ISUR	
18 Lia85	O-mf	Taiw	61	81	T?		-1.87	-0.79							TL-COEN	NL3S	T
18 Lia85	O-mi	Taiw	61	81	T?		-1.49	-1.35							TL-COEN	NL3S	T
18 Uri79	O-mm	Indi	60	71	T		-1.80	-0.09							TL-COE	ML	
18 L&W81	O-mn	Indi	68	68	C		-5.13	-0.28							TL-COE	ISUR	
18 L&W81	O-mp	Indi	68	68	C		-13.24	-0.44							TL-COE	ISUR	
18 Roy86	O-nm	Indi	59	74	CT		-0.32	-0.30							TL-COE	ISUR	
18 Roy86	O-nm	Indi	59	74	CT		-0.16	-0.67							TL-COE	ISUR	
18 Roy86	O-nm	Indi	59	74	CT		-0.36	-0.48							TL-COE	ISUR	
18 L&W81	O-nm	Indi	68	68	C		-1.05	-0.22							TL-COE	ISUR	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
18	Roy86	O-pp	Indi	59	74	CT		-0.06	-0.94							TL-COE	ISUR	
18	Lia85	O-pu	Taiw	61	81	T?		-6.80	-0.84							TL-COEN	NL3S	T
18	B&B85	O-rr	Mexi	60	79	T			-0.16				0.58			Stat-2E	ML-sc	
18	Lia85	O-se	Taiw	61	81	T?			-0.64							TL-COEN	NL3S	T
18	L&W81	O-te	Indi	68	68	C		-3.25	-0.25							TL-COE	ISUR	
18	V&S86	O-tr	Gree	60	80	T		1.86	0.01							TL-COE	ISUR	
18	Uri79	O-tr	Indi	60	71	T		-1.80	-0.10							TL-COE	ML	
18	Lia85	O-tr	Taiw	61	81	T?		-0.07	-0.03							TL-COEN	NL3S	T
18	L&W81	O-tx	Indi	68	68	C		-5.94	-0.55							TL-COE	ISUR	
#E	31					Avg			-0.46				0.58					
						Std			0.42									
						#			31				1					
19	Uri79	O-r	Indi	60	71	T		-1.80	-0.14							TL-COE	ML	
19	Wan85	O-r/H	Taiw	61	79	T		-1.96	-2.43			8.19	10.90			Stat	OLS?	
#E	2					Avg			-1.29				10.90					
						Std			1.15									
						#			2				1					
20	A&D89	F-Av	Niga	?	?	CT		-1.89	-0.63							Stat	OLS	
20	B&B85	F-Av	Mexi	69	79	T							0.40			Stat-2E	ML-sc	T
#E	2																	
21	B&B85	F-Jt	Mexi	69	79	T							1.30			Stat-2E	ML-sc	
21	M&V87	F-Jt	Ecua			T?	-0.00				0.03				1.20	LE	?	
21	M&V87	F-Jt	Mexi			T?	-0.10			-0.31	0.63			1.99	0.68	LE	?	
#E	3					Avg	-0.05			-0.17	0.33		1.30	0.92	0.94			
						Std	0.C5			0.15	0.30			1.07	0.26			
						#	2			2	2		1	2	2			
22	D&H85	F-Ai/	C17	˜71	˜80	CT		-2.39	-0.32			4.08	1.06			Stat	OLS	Pg
22	D&H85	F-Ai/	C16	˜78	˜81	CT		0.08	0.02			5.22	1.06			Stat	OLS	Pd
22	D&H85	F-Ai/	C17	˜71	˜80	CT		-3.05	-0.49			3.61	0.97			Stat	OLS	Pg
22	D&H85	F-Ai/	C17	˜71	˜81	CT		0.57	0.06			10.88	0.84			Stat	OLS	Pg
22	D&H85	F-Ai/	C17	˜71	˜81	CT		0.47	0.05			9.58	1.01			Stat	OLS	Pg
22	D&H85	F-Ai/	C16	˜78	˜81	CT		-0.06	-0.01			6.14	0.88			Stat	OLS	Pd
#E	6					Avg			-0.12				0.97					
						Std			0.21				0.09					
						#			6				6					
23	Gar89	G-ac/	Taiw	54	86	T	-0.34	-2.29		-0.62	-0.10	-0.27		-0.17	0.46	LE-S	OLS	
23	Gar89	G-ac/	Taiw	54	86	T		-0.07			0.31	3.66		0.43	0.29	LE-S	OLS	
23	Gar89	G-ac/	Taiw	54	86	T	-0.45	-1.93		-1.78	0.55	3.78		2.18	0.75	LE	OLS	
23	Gar89	G-ac/	Taiw	54	86	T	-0.33	-2.24		-2.68	0.33	1.12		2.73	0.88	LE	OLS	
23	Dah82	G/	C40	70	78	CT	-0.20	-6.52		-0.98	0.10	3.51		0.50	0.80	LE-S	OLS	
23	Dro84	G/	C37	77	77	C		-2.60	-0.79							SforY	FIML	
23	Dro84	G/	C37	77	77	C		-3.20	-0.91			12.40	1.13			Stat	FIML	
23	Dro84	G/	C37	77	77	C		-3.20	-0.90			2.50	0.83			Stat-S	FIML	
23	Iqb85	G/	Paki	60	81	T	-0.11	-1.14		-0.73	0.33	2.00		2.20	0.85	LE	GLS-sc	
23	Iqb85	G/	Paki	60	81	T	-0.10	-1.42		-0.77	0.27	1.93		2.08	0.87	LE	OLS	
23	MLS86	G/	Indi	74	81	CT	-0.55			-1.89	0.10			1.63		2ELESh	3S	
23	MLS86	G/	Phil	74	81	CT	-0.57			-2.32	0.10			1.63		2ELESh	3S	
23	MLS86	G/	SLan	74	81	CT	-0.56			-2.03	0.10			1.63		2ELESh	3S	
23	MLS86	G/	Indo	74	81	CT	-0.59			-2.67	0.10			1.63		2ELESh	3S	
23	MLS86	G/	Bang	74	81	CT	-0.55			-1.83	0.10			1.63		2ELESh	3S	
23	MLS86	G/	Kore	74	81	CT	-0.56			-1.94	0.10			1.63		2ELESh	3S	
23	MLS86	G/	Thai	74	81	CT	-0.58			-2.46	0.10			1.63		2ELESh	3S	
23	D&H85	G/	C29C	˜65,˜70-	˜81	CT		-15.05	-0.51			42.41	1.57			Stat	OLS	
23	D&H85	G/	C29C	˜65,˜70-	˜81	CT		-18.15	-0.55			48.22	1.21			Stat	OLS	
23	D&H85	G/	C5 Ly	˜65,˜70-	˜81	CT		-3.31	-0.69			1.74	0.65			Stat	OLS	
23	D&H85	G/	C5 Ly	˜65,˜70-	˜81	CT		-5.26	-0.69			9.49	1.54			Stat	OLS	
23	D&H85	G/	C13 My	˜65,˜70-	˜81	CT		-15.56	-0.63			7.71	1.03			Stat	OLS	
23	D&H85	G/	C13 My	˜65,˜70-	˜81	CT		-14.81	-0.62			6.82	0.67			Stat	OLS	
23	D&H85	G/	C11 Hy	˜65,˜70-	˜81	CT		-10.77	-0.36			14.39	1.18			Stat	OLS	
23	D&H85	G/	C11 Hy	˜65,˜70-	˜81	CT		-11.76	-0.40			14.55	0.83			Stat	OLS	
23	D&H85	G/	C5 Af	˜65,˜70-	˜81	CT		-2.16	-0.39			9.82	1.12			Stat	OLS	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1 y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
23	D&H85	G/	C5 Af	~65,~70-~81	CT		-3.57	-0.50			14.08	1.14			Stat	OLS	
23	D&H85	G/	C9 As J	~65,~70-~81	CT		-9.53	-0.86			33.12	1.66			Stat	OLS	
23	D&H85	G/	C9 As J	~65,~70-~81	CT		-7.94	-0.72			32.66	1.12			Stat	OLS	
23	D&H85	G/	C10 As J	~65,~70-~81	CT		-4.08	-0.28			29.89	1.00			Stat	OLS	
23	D&H85	G/	C6 Na	~65,~70-~81	CT		0.60	0.04			50.61	1.73			Stat	OLS	
23	D&H85	G/	C6 Na	~65,~70-~81	CT		-3.28	-0.13			77.89	1.21			Stat	OLS	
23	D&H85	G/	C9 La	~65,~70-~81	CT		-16.60	-0.38			23.56	1.16			Stat	OLS	
23	D&H85	G/	C9 La	~65,~70-~81	CT		-15.68	-0.36			23.36	0.82			Stat	OLS	
23	D&H85	G/	Ghana	65,70-81	T		0.31	0.04			0.15	0.05			Stat	OLS	
23	D&H85	G/	Ghana	65,70-81	T		-0.07	-0.01			-0.56	-0.19			Stat	OLS	
23	D&H85	G/	Kenya	65,70-81	T		2.94	0.42			3.22	1.75			Stat	OLS	
23	D&H85	G/	Kenya	65,70-81	T		-0.46	-0.06			5.75	1.60			Stat	OLS	
23	D&H85	G/	Moro	65,70-81	T		-0.85	-0.14			-0.00	-0.00			Stat	OLS	
23	D&H85	G/	Moro	65,70-81	T		-1.38	-0.21			0.54	0.20			Stat	OLS	
23	D&H85	G/	SAfr	65,70-81	T		0.59	0.03			3.05	0.72			Stat	OLS	
23	D&H85	G/	SAfr	65,70-81	T		-0.23	-0.01			3.47	0.93			Stat	OLS	
23	D&H85	G/	Tuni	65,70-79	T		0.71	0.08			7.13	0.69			Stat	OLS	
23	D&H85	G/	Tuni	65,70-79	T		0.95	0.08			9.36	0.78			Stat	OLS	
23	D&H85	G/	Burm	65,70-79	T		0.52	0.04			1.61	1.16			Stat	OLS	
23	D&H85	G/	Burm	65,70-79	T		0.62	0.04			2.26	0.95			Stat	OLS	
23	D&H85	G/	Indi	65,70-81	T		-5.17	-0.36			0.05	0.02			Stat	OLS	
23	D&H85	G/	Indi	65,70-81	T		-5.26	-0.36			0.17	0.05			Stat	OLS	
23	D&H85	G/	Indo	70 81	T		1.36	0.20			10.23	0.82			Stat	OLS	
23	D&H85	G/	Indo	70 81	T		1.25	0.19			10.03	1.41			Stat	OLS	
23	D&H85	G/	Isra	65,70-81	T		-0.51	-0.03			5.69	1.21			Stat	OLS	
23	D&H85	G/	Isra	65,70-81	T		-0.29	-0.02			5.75	1.18			Stat	OLS	
23	D&H85	G/	Paki	65,70-81	T		0.93	0.35			0.60	0.73			Stat	OLS	
23	D&H85	G/	Paki	65, 70-81	T		1.01	0.39			0.30	0.23			Stat	OLS	
23	D&H85	G/	Phil	65, 70-81	T		-5.47	-0.31			1.57	0.57			Stat	OLS	
23	D&H85	G/	Phil	65, 70-81	T		-5.55	-0.30			1.54	0.46			Stat	OLS	
23	D&H85	G/	Thai	65, 70-81	T		-0.89	-0.15			5.01	1.45			Stat	OLS	
23	D&H85	G/	Thai	65, 70-81	T		-0.91	-0.16			5.03	1.40			Stat	OLS	
23	D&H85	G/	Turk	65, 70-81	T		-2.19	-0.37			7.46	2.32			Stat	OLS	
23	D&H85	G/	Turk	65, 70-81	T		-0.86	-0.11			9.39	2.51			Stat	OLS	
23	D&H85	G/	Gree	65, 70-81	T		-1.83	-0.13			20.73	2.07			Stat	OLS	
23	D&H85	G/	Gree	65, 70-81	T		-1.45	-0.07			27.16	1.97			Stat	OLS	
23	D&H85	G/	C4 La	~65,~70-~81	CT		0.64	0.05			9.59	1.68			Stat	OLS	
23	D&H85	G/	C4 La	~65,~70-~81	CT		-2.24	-0.10			17.60	1.42			Stat	OLS	
23	D&H85	G/	DRep	70 81	T		-3.04	-0.27			3.52	1.13			Stat	OLS	
23	D&H85	G/	DRep	70 81	T		-2.99	-0.31			3.26	1.08			Stat	OLS	
23	D&H85	G/	Jama	65,70-81	T		-0.26	-0.04			2.05	1.09			Stat	OLS	
23	D&H85	G/	Jama	65,70-81	T		-1.13	-0.16			0.94	0.46			Stat	OLS	
23	D&H85	G/	Mexi	65,70-79	T		-1.90	-0.09			10.65	1.25			Stat	OLS	
23	D&H85	G/	Mexi	65,70-79	T		-0.91	-0.04			12.06	1.47			Stat	OLS	
23	D&H85	G/	Pana	65,70-79	T		0.43	0.05			3.62	1.20			Stat	OLS	
23	D&H85	G/	Pana	65,70-79	T		-0.18	-0.02			4.90	1.39			Stat	OLS	
23	D&H85	G/	Arge	65,70-81	T		-0.63	-0.05			1.41	0.66			Stat	OLS	
23	D&H85	G/	Arge	65,70-81	T		-0.32	-0.03			0.86	0.44			Stat	OLS	
23	D&H85	G/	Boli	65,70-81	T		0.66	0.05			9.47	2.45			Stat	OLS	
23	D&H85	G/	Boli	65,70-81	T		0.71	0.61			9.06	2.84			Stat	OLS	
23	D&H85	G/	Braz	65,70-81	T		-2.58	-0.25			3.56	0.84			Stat	OLS	
23	D&H85	G/	Braz	65,70-81	T		-2.53	-0.24			3.54	0.84			Stat	OLS	
23	D&H85	G/	Chil	65,70-81	T		-5.49	-0.25			5.24	1.17			Stat	OLS	
23	D&H85	G/	Chil	65,70-81	T		-4.92	-0.30			3.72	1.08			Stat	OLS	
23	D&H85	G/	Colo	65,70-81	T		-0.05	-0.00			13.48	0.89			Stat	OLS	
23	D&H85	G/	Colo	65,70-81	T		-0.09	-0.00			12.18	0.92			Stat	OLS	
23	D&H85	G/	Ecua	70-74,77-80	T		-0.85	-0.26			2.31	1.23			Stat	OLS	
23	D&H85	G/	Ecua	70-74,77-80	T		-1.19	-0.48			1.14	0.94			Stat	OLS	
23	D&H85	G/	Peru	65,70-81	T		-2.55	-0.24			2.48	1.46			Stat	OLS	
23	D&H85	G/	Peru	65,70-81	T		-2.51	-0.11			7.28	2.19			Stat	OLS	
23	D&H85	G/	Urug	65,70-78,	T		-3.30	-0.44			1.71	1.06			Stat	OLS	
23	D&H85	G/	Urug	65,70-78,	T		-3.89	-0.43			2.05	0.84			Stat	OLS	
23	D&H85	G/	Vene	65,70-81	T		-5.54	-0.41			12.70	1.27			Stat	OLS	
23	D&H85	G/	Vene	65,70-81	T		-4.54	-0.26			17.57	1.80			Stat	OLS	
23	D&H85	G/	C23	~65,~70-~81	CT		-8.54	-0.36			38.78	1.43			Stat	OLS	SV
23	D&H85	G/	C23	~65,~70-~81	CT		-5.97	-0.41			13.78	1.52			Stat	OLS	SV

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
23 Iqb85	GU/	Paki	60	81	T	-0.11	-1.55		-1.00	0.28	2.31		2.55	0.89	LE	OLS	
23 Iqb85	GU/	Paki	60	81	T	-0.21	-1.27		-0.91	0.34	2.43		1.48	0.77	LE	GLS-sc	
#E 94					Avg	-0.39		-0.21	-1.64	0.19		1.13	1.59	0.73			
					Std	0.19		0.30	0.71	0.15		0.58	0.74	0.20			
					#	15		78	15	16		77	16	9			
24 B&B85	G/A	Mex-R	73	78	CT	-0.23	-2.31		-0.96	0.23	3.76		0.94	0.76	Util-2E	ML	
24 B&B85	G/A	Mexi	60	79	T	-0.24	-3.22		-1.26	0.15	0.63		0.81	0.81	Util-3E	ML-sc	
24 D&H85	G/A	C29	~65,~70-~81		CT		-21.43	-0.68			-6.60	-0.23			Stat	OLS	
24 D&H85	G/A	C29	~65,~70-~81		CT		-20.72	-0.68			-5.90	-0.16			Stat	OLS	
24 D&H85	G/A	C5 Ly	~65,~70-~81		CT		-8.08	-0.69			-4.37	-0.67			Stat	OLS	
24 D&H85	G/A	C5 Ly	~65,~70-~81		CT		-7.91	-0.75			-1.70	-0.20			Stat	OLS	
24 D&H85	G/A	C13 My	~65,~70-~81		CT		-15.51	-0.96			-0.44	-0.09			Stat	OLS	
24 D&H85	G/A	C13 My	~65,~70-~81		CT		-15.55	-0.95			-1.64	-0.24			Stat	OLS	
24 D&H85	G/A	C11 Hy	~65,~70-~81		CT		-13.98	-0.50			-6.37	-0.54			Stat	OLS	
24 D&H85	G/A	C11 Hy	~65,~70-~81		CT		-12.50	-0.50			-5.36	-0.36			Stat	OLS	
24 D&H85	G/A	C27	~65,~70-~81		CT		-11.24	-0.58			-3.86	-0.30			Stat	OLS	SV
24 D&H85	G/A	C27	~65,~70-~81		CT		-10.72	-0.59			-3.58	-0.31			Stat	OLS	SV
#E 12					Avg	-0.24		-0.69	-1.11	0.19		-0.31	0.87	0.78			
					Std	0.00		0.15	0.15	0.04		0.17	0.07	0.03			
					#	2		10	2	2		10	2	2			
25 Abd88	G	Egyp	60	81	T		-0.63	-0.24			10.54	1.42			Stat	OLS	
25 Abd88	G	Egyp	60	81	T	-0.04	-0.26		-0.31	0.29	1.75		2.10	0.86	LE	OLS	
25 Abd88	G	Egyp	60	81	T		-0.47	-0.18			7.52	1.29			Stat	OLS	D*T
25 B&B85	G	Mexi	60	79	T	-0.16	-4.50		-0.49	0.16	8.22		0.48	0.72	BN	ML	
25 B&B85	G	Mex-R	73	78	CT	-0.07	-4.40		-0.65	0.05	7.25		0.41		BN	ML	
25 B&B85	G	Mex-R	73	78	CT	-0.17	-2.35		-1.04	0.15	3.16		0.90	0.84	LE	ML	
25 B&B85	G	Mexi	60	79	T	-0.17	-2.67		-0.33	0.73	2.56		1.41	0.48	LE	ML-sc	
25 Cas76	G	Mexi	73:1	76:3	Tq		-3.55	-0.49			4.44	0.55			Stat	?	D*T
25 KKR87	G	Indo	66	81	T	-0.03			-0.17	0.23			1.50		LE?	OLS?	
25 K&B77	G	C Ly	70	70	C		-8.72	-1.28							SforY	OLS	
25 K&B77	G	C Ly	70	70	C		-7.75	-1.13							SforY	OLS	
25 K&B77	G	C Ly	70	70	C		-8.86	-1.18			3.05	0.26			Stat-S	OLS	
25 K&B77	G	C Hy	70	70	C		-6.37	-1.69							SforY	OLS	
25 K&B77	G	C Hy	70	70	C		-5.74	-1.51							SforY	OLS	
25 K&B77	G	C Hy	70	70	C		-5.17	-1.44			0.81	0.11			Stat-S	OLS	
25 K&B77	G	C40	70	70	C		-5.90	-1.34							SforY	OLS	
25 K&B77	G	C40	70	70	C		-5.37	-1.19							SforY	OLS	
25 K&B77	G	C40	70	70	C		-4.35	-0.94			2.53	0.58			Stat-S	OLS	
25 K&B77	G	C Ly	70	70	C		-5.68	-0.99			3.03	0.49			Stat-S	OLS	
25 K&B77	G	C Hy	70	70	C		-4.15	-1.23			2.49	0.33			Stat-S	OLS	
25 K&B77	G	C40	70	70	C		-9.13	-1.12			4.56	0.31			Stat-S	OLS	
25 M&V87	G	Ecua			T?	-0.10			-0.46	0.25			1.10	0.77	LE	?	
25 M&V87	G	Mexi			T?	-0.17			-0.46	0.41			1.09	0.62	LE	?	
25 Pin79	G	C2 LA	54	~74	CT	-0.12	-1.72		-0.55	0.26	2.41		1.22	0.79	LE	OLS?	
25 Pin79	G	C3 SE	55	74	CT	-0.16	-1.54		-0.41	0.74	6.04		1.94	0.62	LE	OLS?	
25 Pin79	G	C3 SE	55	74	CT		-2.09	-0.33			20.90	1.72			Stat	OLS?	
25 Ste88	G	C4 LA	62	85	CT	0.01	-0		-1.07		23.00	0.60			OL	OLS?	
25 Ste88	G	C4 LA	62	85	CT		-8.70	-0.94			5.00	0.48			Stat-S	OLS?	
25 Ste88	G	C4 LA	62	85	CT		-8.60	-0.82			22.00	0.59			Stat	OLS?	
25 Ste88	G	C4 LA	62	85	CT	-0.01	-0		-1.09		23.00	0.60			OL	OLS?	
25 Ste88	G	C4 LA	62	85	CT	-0.03	-0.10		-1.08		5.00	0.51			OL-S	OLS?	
25 Ste88	G	C4 LA	62	85	CT	-0.05	-0.20		-1.12		5.00	0.51			OL-S	OLS?	
#E 32					Avg	-0.09		-1.00	-0.66	0.33		0.65	1.21	0.71			
					Std	0.06		0.43	0.33	0.22		0.43	0.52	0.12			
					#	14		18	14	10		16	10	8			
26 Tor85	G	Bra-R1	69	82	Tq	-0.11	-2.99		-0.52	0.21	2.64		0.97	0.78	LE	GLS-sc3	
26 Tor85	G	Braz	69	82	Tq	-0.15	-3.00		-0.62	0.25	2.77		1.02	0.75	LE	GLS-sc3	
26 Tor85	G	Bra-R1	69	82	Tq			-0.33				0.61			Stat	GLS-sc3	
26 Tor85	G	Bra-R1	69	82	Tq	-0.07	-1.04		-1.09	0.05	0.85		0.80	0.94	LE	GLS-sc3	
26 Tor85	G	Bra-R1	69	82	Tq	-0.17	-2.48		-0.55	0.17	2.31		0.57	0.70	LE	GLS-sc3	
26 Tor85	G	Bra-R1	69	82	Tq	-0.02	-0.30			-0.02	-0.55			1.01	LE	GLS-sc3	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
26	Tor85	G	Bra-R1	69	82	Tq			-0.28				0.46			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.19	-2.87		-0.70	0.26	2.92		0.93	0.72	LE	GLS-sc3	
26	Tor85	G	Braz	69	82	Tq			-0.31				0.62			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.20				0.37			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.26				1.06			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq			-0.29				0.60			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq	-0.12	-2.98		-0.48	0.34	3.10		1.34	0.75	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	0.63	1.36		0.85	-0.01	-0.04		-0.01	0.26 ns	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.17				0.47			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.12	-2.72			0.02	0.62			1.07	LE	GLS-sc3	
26	Tor85	G	Braz	69	82	Tq			-0.35				0.87			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq	-0.09	-1.77		-2.09	0.08	0.99		1.77	0.96	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.23				0.23			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.15	-2.65		-0.79	0.23	2.83		1.17	0.80	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.14	-2.13		-1.05	0.14	2.08		1.08	0.87	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.39				0.73			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq	-0.13	-2.06		-0.83	0.16	2.28		1.00	0.84	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	0.11	0.77		0.29	0.06	0.58		0.15	0.62	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.11	-1.56		-0.85	0.13	1.59		0.97	0.87	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.23				0.62			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq			-0.20				0.55			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq			-0.28				0.43			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq			-0.24				0.38			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.12	-2.47		-3.26	0.10	1.72		2.63	0.96	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.16	-1.74		-0.31	0.24	2.15		0.47	0.50	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.16	-1.99		-0.59	0.21	2.15		0.80	0.74	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.11	-1.42		-0.60	0.13	1.64		0.76	0.82	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.11	-2.22		-0.75	0.11	1.54		0.75	0.85	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.43				0.74			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq	-0.06	-1.00		-0.40	0.06	1.33		0.40	0.85	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.20				0.32			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.05	-0.57		-0.19	0.13	1.18		0.53	0.75	LE	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq			-0.26				0.81			Stat	OLS	
26	Tor85	G	Bra-R1	69	82	Tq			-0.18				0.75			Stat	GLS-sc3	
26	Tor85	G	Bra-R1	69	82	Tq	-0.03	-0.40		-0.07	0.12	1.60		0.23	0.50	LE	GLS-sc3	
#E	41					Avg	-0.07		-0.27	-0.70	0.14		0.59	0.87	0.78			
						Std	0.16		0.07	0.79	0.09		0.21	0.56	0.18			
						#	23		18	21	23		18	21	23			
27	Lia85	G-mf	Taiw	61	81	T?			-1.00							TL-GDFO	NL3S	T
27	Lia85	G-mi	Taiw	61	81	T?		-1.86	-3.97							TL-GDFO	NL3S	T
27	Lia85	G-co	Taiw	61	81	T?		-4.08	-3.16							TL-GDFO	NL3S	T
27	Lia85	G-pu	Taiw	61	81	T?		-1.73	-5.40							TL-GDFO	NL3S	T
27	Lia85	G-se	Taiw	61	81	T?			-1.00							TL-GDFO	NL3S	T
27	Lia85	G-tr	Taiw	61	81	T?		-2.70	-0.94							TL-GDFO	NL3S	T
27	Lia85	G-ag	Taiw	61	81	T?		-2.10	-1.86							TL-GDFO	NL3S	T
27	Pit85	G-fp	Indo	76	78	CT		-5.52	-2.30							TobGFDKEML		
27	Pit85	G-mp	Indo	76	78	CT		-3.68	-1.35							TobGFDKEML		
#E	9					Avg			-2.33									
						Std			1.47									
						#			9									
28	B&B85	D/	Mexi	60	79	T		-2.54		-0.88		2.07		0.53		BN	ML?	
28	B&B85	D/	Mexi	60	79	T	-0.26	-1.51		-1.21	0.25	1.27		1.17	0.78	LE	ML?	
28	Gar89	D/	Taiw	54	86	T	-0.03	-0.31		-0.44	0.11	0.43		1.73	0.94	LE	OLS	
28	MLS86	D/	Thai	74	81	CT	-0.12			-1.90	0.08			1.60		2ELE&Sh	3S	
28	MLS86	D/	Bang	74	81	CT	-0.15			-2.47	0.08			1.60		2ELE&Sh	3S	
28	MLS86	D/	Indo	74	81	CT	-0.11			-1.70	0.08			1.60		2ELE&Sh	3S	
28	MLS86	D/	SLan	74	81	CT	-0.14			-2.29	0.08			1.60		2ELE&Sh	3S	
28	MLS86	D/	Indi	74	81	CT	-0.15			-2.42	0.08			1.60		2ELE&Sh	3S	
28	MLS86	D/	Kore	74	81	CT	-0.15			-2.38	0.08			1.60		2ELE&Sh	3S	
28	MLS86	D/	Phil	74	81	CT	-0.13			-2.02	0.08			1.60		2ELE&Sh	3S	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
28	D&H85	D-TR/	C18	~77	~80	CT		1.60	0.09			20.44	1.23			Stat	OLS	Pg
28	D&H85	D-TR/	C18	~77	~80	CT		1.03	0.06			18.26	0.92			Stat	OLS	Pg
28	D&H85	D-TR/	C12	~77	~80	CT		0.35	0.02			15.07	1.25			Stat	OLS	Pd
28	D&H85	D-TR/	C12	~77	~80	CT		-0.24	-0.02			13.51	0.94			Stat	OLS	Pd
#E	14					Avg	-0.14		0.04	-1.77	0.10		1.08	1.46	0.86			
						Std	0.06		0.04	0.67	0.05		0.15	0.34	0.08			
						#	9		4	10	9		4	10	2			
29	D&H85	D-Hw/	C17	~71	~80	CT		-0.93	-0.09			17.47	1.38			Stat	OLS	Pg
29	D&H85	D-Hw/	C17	~71	~80	CT		-1.15	-0.12			16.62	1.08			Stat	OLS	Pg
29	D&H85	D-Hw/	C16	~78	~80	CT		-0.71	-0.18			8.11	1.49			Stat	OLS	Pd
29	D&H85	D-Hw/	C16	~78	~80	CT		-1.06	-0.29			7.20	1.11			Stat	OLS	Pd
#E	4					Avg			-0.17				1.26					
						Std			0.08				0.18					
						#			4				4					
30	D&H85	D-Rr/	C10	~77	~80	CT		0.52	0.26			2.20	0.33			Stat	OLS	Pd
30	D&H85	D-Rr/	C10	~77	~80	CT		0.75	0.20			1.74	0.35			Stat	OLS	Pd
30	D&H85	D-Rr/	C11	~77	~80	CT		-0.84	-0.27			2.29	0.27			Stat	OLS	Pg
30	D&H85	D-Rr/	C11	~77	~80	CT		-0.71	-0.24			1.60	0.25			Stat	OLS	Pg
#E	4					Avg			-0.01				0.30					
						Std			0.24				0.04					
						#			4				4					
31	D&H85	D-Wa/	C12	~77	~80	CT		-2.00	-0.94			5.73	1.11			Stat	OLS	Pg
31	D&H85	D-Wa/	C11	~77	~80	CT		0.29	0.14			4.09	1.34			Stat	OLS	Pd
31	D&H85	D-Wa/	C12	~77	~80	CT		-1.60	-0.80			4.90	1.32			Stat	OLS	Pg
31	D&H85	D-Wa/	C11	~77	~80	CT		-0.14	-0.07			4.64	1.12			Stat	OLS	Pd
#E	4					Avg			-0.42				1.22					
						Std			0.46				0.11					
						#			4				4					
32	B&B85	D	Mexi	60	79	T		-2.89		-1.07		3.05		0.57		BN	ML?	
32	B&B85	D	Mexi	60	79	T	-0.25	-1.41		-1.11	0.25	1.64		1.14	0.78	LE	ML?	
32	M&V87	D	Mexi	?	?	T?	-0.35			-0.38	0.91			1.25	0.27	LE	?	
32	M&V87	D	Ecua	?	?	T?	-0.08			-0.35	0.22			0.96	0.77	LE	?	
32	Pin79	D	C3 SE	55	74	CT					0.37	1.98		1.53	0.76	LE	OLS?	
#E	5					Avg	-0.23			-0.73	0.44			1.09	0.65			
						Std	0.11			0.36	0.28			0.32	0.22			
						#	3			4	4			5	4			
33	Tor85	D	Bra-R1	69	82	Tq			0.22				1.06			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq	0.00	0.00		0.00	0.08	1.59		0.78	0.90	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			-0.36				0.93			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq			0.18				0.85			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	0.09	0.79		0.67	0.07	1.02		0.51	0.87	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.18				0.64			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.06	-0.49		-0.87	0.12	1.97		1.65	0.93	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.38				0.74			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			-0.09				0.70			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.42	-2.32		-1.59	0.55	4.42		2.04	0.73	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	0.15	0.62		0.73	0.11	1.23		0.57	0.80	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	0.44	0.81		1.12	0.33	1.22		0.84	0.61	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.44				0.74			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq	-0.07	-0.34		-0.28	0.16	1.05		0.67	0.76	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	0.07	0.71		0.21	0.07	2.31		0.24	0.70	LE	GSL-sc3	
33	Tor85	D	Braz	69	82	Tq			0.23				0.75			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.72				1.00			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq			0.58				0.44			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.07	-0.85		-0.76	0.11	1.31		1.15	0.90	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.16				0.38			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.71				0.63			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.63				0.77			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq	-0.07	-0.56		4.86	-0.01	-0.13			1.01	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			-0.06				0.93			Stat	OLS	

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
33	Tor85	D	Bra-R1	69	82	Tq			0.36				0.59			Stat	GSL-sc3	
33	Tor85	D	Braz	69	82	Tq			0.29				0.94			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq	-0.21	-1.36		-3.66	0.19	2.38		3.31	0.94	LE	GSL-sc3	
33	Tor85	D	Braz	69	82	Tq	-0.06	-1.47		-1.03	0.10	1.70		1.71	0.94	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			-0.01				1.12			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq	-0.09	-1.11		-0.92	0.13	1.34		1.26	0.90	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	0.02	0.19		0.27	0.04	0.73		0.47	0.91	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.09	-1.22		-0.97	0.16	1.28		1.70	0.91	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.10				1.00			Stat	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.02	-0.16		-0.15	0.11	1.10		0.70	0.85	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.12	-1.22		-2.64	0.12	1.64		2.58	0.96	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	0.13	0.72		1.20	0.07	0.79		0.67	0.90	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.07	-1.72		-6.18	0.06	1.16		5.36	0.99	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.14	-2.83			0.01	0.30			1.06	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.08	-0.87		-1.33	0.07	0.64		1.03	0.94	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.20				0.93			Stat	OLS	
33	Tor85	D	Bra-R1	69	82	Tq	-0.10	-1.55		-0.76	0.20	2.44		1.43	0.86	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq	-0.13	-1.23			-0.03	-0.52			1.07	LE	GSL-sc3	
33	Tor85	D	Bra-R1	69	82	Tq			0.04				0.88			Stat	OLS	
#E	43					Avg	-0.04		0.25	-0.58	0.12		0.80	1.43	0.89			
						Std	0.15		0.27	2.05	0.12		0.19	1.17	0.11			
						#	23		20	21	23		20	20	23			
34	deC85	D	Bra-R437	80	80	C							0.77			Stat	GLS	
34	deC85	D	Bra-R437	80	80	C						12.50	1.04			Stat	GLS	
34	deC85	D	Bra-R437	80	80	C						11.20	1.07			Stat	OLS	
#E	3					Avg							0.96					
						Std							0.13					
						#							3					
35	Lia85	D-mf	Taiw	61	81	T?		-2.30	-2.21							TL-GDFO	NL3S	T
35	Lia85	D-mi	Taiw	61	81	T?		-3.60	-3.86							TL-GDFO	NL3S	T
35	Lia85	D-co	Taiw	61	81	T?		-1.93	-1.35							TL-GDFO	NL3S	T
35	Lia85	D-pu	Taiw	61	81	T?		-1.00	-1.52							TL-GDFO	NL3S	T
35	Lia85	D-se	Taiw	61	81	T?		-6.41	-3.63							TL-GDFO	NL3S	T
35	Lia85	D-tr	Taiw	61	81	T?		-1.71	-1.00							TL-GDFO	NL3S	T
35	Lia85	D-ag	Taiw	61	81	T?		-6.23	-1.27							TL-GDFO	NL3S	T
35	Pit85	D-fp	Indo	76	78	CT		-11.26	-4.06							TobGFDKEML		
35	Pit85	D-mp	Indo	76	78	CT		-2.68	-1.46							TobGFDKEML		
#E	9					Avg			-2.26									
						Std			1.17									
						#			9									
36	D&H85	F-Tr/	C4 Ly	~71	~81	CT		4.03	0.23			12.58	1.01			Stat	OLS	Pg
36	D&H85	F-Tr/	C27	~71	~82	CT		-4.85	-0.12			47.77	1.29			Stat	OLS	Pg
36	D&H85	F-Tr/	C10 Hy	~71	~82	CT		-3.01	-0.08			14.78	1.09			Stat	OLS	Pg
36	D&H85	F-Tr/	C24	~71	~80	CT		-2.56	-0.09			23.98	1.17			Stat	OLS	Pg,SV
36	D&H85	F-Tr/	C13 My	~71	~81	CT		-6.46	-0.27			9.78	1.12			Stat	OLS	Pg
36	D&H85	F-Tr/	C4 Ly	~71	~82	CT		2.31	0.25			3.18	0.70			Stat	OLS	Pg
36	D&H85	F-Tr/	C10 Hy	~71	~81	CT		-5.03	-0.13			16.51	0.80			Stat	OLS	Pg
36	D&H85	F-Tr/	C27	~71	~81	CT		-7.25	-0.16			52.57	1.01			Stat	OLS	Pg
36	D&H85	F-Tr/	C26	~78	~81	CT		-2.52	-0.13			22.92	1.30			Stat	OLS	Pd
36	D&H85	F-Tr/	C26	~78	~81	CT		-4.28	-0.17			29.06	1.01			Stat	OLS	Pd
36	D&H85	F-Tr/	C13 My	~71	~82	CT		-8.77	-0.28			14.43	1.81			Stat	OLS	Pg
36	D&H85	F-Tr/	C24	~71	~80	CT		-1.79	-0.05			24.85	1.19			Stat	OLS	Pg,SV
#E	12					Avg			-0.08				1.12					
						Std			0.16				0.27					
						#			12				12					
37	Gar89	F-TB/	Taiw	54	86	T	-0.24	-4.14		-0.98	0.44	3.43		1.81	0.76	LE	OLS	
37	Gar89	F-Hw/	Taiw	54	86	T	-0.34	-4.33		-1.63	0.49	2.83		2.37	0.79	LE	OLS	
37	MLS86	F-Hw/	C6 As	74	81	CT	-0.13	3.00		-2.63	0.08	1.76		1.59	0.95	LE 2E	INL3S	
37	MLS86	F-Hw/	C6 As	74	81	CT	-0.13	-2.92		-2.83	0.07	1.59		1.57	0.95	LE 2E	INL3S	
37	D&H85	F-Hw/	C6 Hy	~71	~82	CT		-2.78	-0.15			7.72	1.16			Stat	OLS	Pg
37	D&H85	F-Hw/	C16	~78	~81	CT		-7.03	-0.31			30.48	1.16			Stat	OLS	Pd
37	D&H85	F-Hw/	C7 My	~71	~82	CT		-1.11	-0.31			5.31	2.26			Stat	OLS	Pg

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
37	D&H85	F-Hw/	C6 Hy	ˉ71	ˉ81	CT		-6.27	-0.23			9.47	0.81			Stat	OLS	Pg
37	D&H85	F-Hw/	C17	ˉ71	ˉ81	CT		-5.69	-0.22			39.94	1.50			Stat	OLS	Pg
37	D&H85	F-Hw/	C7 My	ˉ71	ˉ81	CT		-1.87	-0.43			7.05	1.91			Stat	OLS	Pg
37	D&H85	F-Hw/	C16	ˉ71	ˉ80	CT		-3.14	-0.20			11.84	1.24			Stat	OLS	Pg,SV
37	D&H85	F-Hw/	C16	ˉ71	ˉ82	CT		-5.69	-0.22			39.94	1.50			Stat	OLS	Pg
37	D&H85	F-Hw/	C17	ˉ71	ˉ81	CT		-6.66	-0.22			46.22	1.16			Stat	OLS	Pg
37	D&H85	F-Hw/	C16	ˉ71	ˉ81	CT		-6.66	-0.22			46.22	1.16			Stat	OLS	Pg
37	D&H85	F-Hw/	C17	ˉ71	ˉ80	CT		-4.34	-0.18			36.12	1.32			Stat	OLS	Pg,SV
37	D&H85	F-Hw/	C3 Ly	ˉ71	ˉ82	CT		-3.07	-0.40			2.09	0.66			Stat	OLS	Pg
37	D&H85	F-Hw/	C30	ˉ71	ˉ80	CT		-4.68	-0.21			22.92	1.38			Stat	OLS	Pg,SV
37	D&H85	F-Hw/	C15	ˉ71	ˉ80	CT		-10.17	-0.56			11.98	1.31			Stat	OLS	Pg,SV
37	D&H85	F-Hw/	C16	ˉ78	ˉ81	CT		-4.28	-0.24			23.23	1.52			Stat	OLS	Pd
37	D&H85	F-Hw/	C3 Ly	ˉ71	ˉ81	CT		-2.32	-0.18			9.92	1.21			Stat	OLS	Pg
#E	20					Avg	-0.21		-0.27	-2.02	0.27		1.33	1.83	0.86			
						Std	0.09		0.11	0.75	0.19		0.37	0.32	0.09			
						#	4		16	4	4		16	4	4			
38	MLS86	G/F-H	C6 As	74	81	CT	-0.54	-4.94		-1.55	0.03	0.94		0.09	0.65	LE 2E	INL3S	
38	MLS86	D/F-H	C6 As	74	81	CT	-0.03	-1.28		-0.11	0.00	0.22		0.01	0.70	LE 2E	INL3S	
39	D&H85	F-Rr/	C5 Hy	ˉ71	ˉ81	CT		0.96	0.15			-2.15	-0.53			Stat	OLS	Pg
39	D&H85	F-Rr/	C3 Ly	ˉ71	ˉ81	CT		8.31	3.31			-0.21	-0.13			Stat	OLS	Pg
39	D&H85	F-Rr/	C11	ˉ78	ˉ81	CT		7.12	1.40			0.42	0.07			Stat	OLS	Pd
39	D&H85	F-Rr/	C5 Hy	ˉ71	ˉ82	CT		2.01	0.31			-2.64	-0.80			Stat	OLS	Pg
39	D&H85	F-Rr/	C11	ˉ71	ˉ80	CT		3.01	0.63			-0.47	-0.15			Stat	OLS	Pg,SV
39	D&H85	F-Rr/	C12	ˉ71	ˉ81	CT		3.43	0.71			3.15	0.43			Stat	OLS	Pg
39	D&H85	F-Rr/	C12	ˉ71	ˉ81	CT		3.40	0.70			3.25	0.34			Stat	OLS	Pg
39	D&H85	F-Rr/	C12	ˉ71	ˉ81	CT		3.40	0.70			3.25	0.34			Stat	OLS	Pg
39	D&H85	F-Rr/	C12	ˉ71	ˉ80	CT		3.03	0.63			-1.18	-0.15			Stat	OLS	Pg,SV
39	D&H85	F-Rr/	C3 Ly	ˉ71	ˉ82	CT		9.24	3.66			-3.51	-2.84			Stat	OLS	Pg
39	D&H85	F-Rr/	C12	ˉ71	ˉ82	CT		3.43	0.71			3.15	0.43			Stat	OLS	Pg
39	D&H85	F-Rr/	C11	ˉ78	ˉ81	CT		7.03	1.40			0.33	0.04			Stat	OLS	Pd
#E	12					Avg			1.19				-0.24					
						Std			1.08				0.86					
						#			12			12	12					
40	D&H85	F-Wa/	C10	ˉ71	ˉ81	CT		-0.64	-0.12			10.96	1.16			Stat	OLS	Pg
40	D&H85	F-Wa/	C10	ˉ71	ˉ81	CT		-0.52	-0.11			9.95	1.40			Stat	OLS	Pg
40	D&H85	F-Wa/	C9	ˉ78	ˉ81	CT		1.23	0.33			6.20	1.47			Stat	OLS	Pd
40	D&H85	F-Wa/	C10	ˉ71	ˉ80	CT		0.57	0.26			-2.00	-1.08			Stat	OLS	Pg,SV
40	D&H85	F-Wa/	C10	ˉ71	ˉ80	CT		0.73	0.22			-1.91	-0.94			Stat	OLS	Pg,SV
40	D&H85	F-Wa/	C9	ˉ78	ˉ81	CT		0.64	0.17			6.90	1.21			Stat	OLS	Pd
#E	6					Avg			0.12				0.54					
						Std			0.18				1.10					
						#			6				6					
41	Abd88	K	Egyp	60	81	T		-5.98	-0.35			12.92	0.48			Stat	OLS	
41	Abd88	K	Egyp	60	81	T	-0.23	-2.99		-0.41	0.26	2.73		0.47	0.45	LE	OLS	
41	Abd88	K	Egyp	60	81	T		-5.06	-0.32			8.38	0.45			Stat	OLS	D*T
41	KRS88	K	Indo	57	81	T	-0.11	-2.90		-0.24	0.48	3.69		1.07	0.55	LE	OLS?	D*T
41	KRS88	K	Indo	57	81	T		-4.53	-0.22			36.01	0.97			Stat	OLS?	D*T
41	M&V87	K	Mexi	?	?	T?			-0.01				0.06			Stat	?	
41	M&V87	K	Ecua	?	?	T?	-0.23			-0.45	0.54			1.09	0.50	LE	?	
41	Pin79	K	C3 SE	55	74	CT	0.16	1.24		0.30	-0.09	-1.18		-0.3[illegible]	0.76	LE	OLS?	
41	Pin79	K	C3 SE	55	74	CT					-0.18	-3.93		-0.83	0.79	LE	OLS?	
41	Pin79	K	C2 LA	ˉ54	ˉ74	CT	-0.13	-2.14		-0.20	0.10	1.44		0.15	0.35	LE	OLS?	
#E	10					Avg	-0.11		-0.22	-0.20	0.19		0.49	0.26	0.57			
						Std	0.14		0.13	0.27	0.27		0.32	0.71	0.16			
						#	5		4	5	6		4	6	6			
42	Ram88	K-r	Jama	70	83	T		-0.56	-0.34			2.49	5.46			Stat	OLS?	Ps,T
42	Ram88	K-r	Jama	70	83	T	-0.25	-5.90		-0.46	0.43	2.03		0.80	0.46	LE	OLS?	
#E	2					Avg	-0.25		-0.34	-0.46	0.43		5.46	0.80	0.46			
						Std												
						#	1		1	1	1		1	1	1			

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
43	Pit85	K-mp	Indo	76	78	CT		-9.04	-3.75							TbGFDKE	ML	
43	Pit85	K-fp	Indo	76	78	CT		-12.94	-3.55							TbGFDKE	ML	
#E	2					Avg			-3.65									
						Std												
						#			2									
44	Abd88	FO	Egyp	60	81	T		-4.15	-0.52			1.93	0.25			Stat	OLS	D*T
44	Abd88	FO	Egyp	60	81	T	0.02	0.15		0.06	0.31	2.29		0.88	0.64	LE	OLS	
44	Abd88	FO	Egyp	60	81	T		-2.96	-0.41			1.33	0.20			Stat	OLS	
44	Pin79	FO	C2 LA	54	¯74	CT	-0.08	-1.87		-0.38	0.13	1.53		0.57	0.78	LE	OLS?	
#E	4					Avg	-0.03		-0.47	-0.16	0.22		0.23	0.72	0.71			
						Std	0.05		0.06	0.22	0.09		0.03	0.16	0.07			
						#	2		2	2	2		2	2	2			
45	Pin79	FO-Hv	C3 SE	55	74	CT		-7.74	-2.25			5.97	1.52			Stat	OLS?	
45	Pin79	FO-Hv	C3 SE	55	74	CT	-1.01	-3.70		-2.89	0.37	1.79		1.05	0.65	LE	OLS?	
#E	2					Avg	-1.01		-2.25	-2.89	0.37		1.52	1.05	0.65			
						Std												
						#	1		1	1	1		1	1	1			
46	Abd88	FO-Lt	Egyp	60	81	T		-1.01	-0.17			8.73	1.18			Stat	OLS	D*T
46	Abd88	FO-Lt	Egyp	60	81	T		-0.41	-0.06			10.50	1.07			Stat	OLS	
46	Abd88	FO-Lt	Egyp	60	81	T	-0.26	-5.45		-3.61	0.01	0.12		0.14	0.93	LE	OLS	
46	Pin79	FO-Lt	C3 SE	55	74	CT					0.65	2.86		3.20	0.80	LE	OLS?	
46	Pin79	FO-Lt	C3 SE	55	74	CT	0.39	1.42		1.60	0.68	2.29		2.82	0.76	LE	OLS?	Ps
#E	5					Avg	0.06		-0.12	-1.01	0.45		1.13	2.05	0.83			
						Std	0.32		0.06	2.61	0.31		0.05	1.36	0.07			
						#	2		2	2	3		2	3	3			
47	Iqb86	FO-i	Paki	60	81	T		-1.25	-1.45							TL-COEN	ISur	
48	Lia85	FO-ag	Taiw	61	81	T?		-2.37	-1.40							TL-GDFO	NL3S	T
48	Lia85	FO-se	Taiw	61	81	T?		-5.63	-2.56							TL-GDFO	NL3S	T
48	Lia85	FO-mf	Taiw	61	81	T?		-0.78	-0.96							TL-GDFO	NL3S	T
48	Lia85	FO-pu	Taiw	61	81	T?		-1.76	-2.01							TL-GDFO	NL3S	T
48	Lia85	FO-tr	Taiw	61	81	T?		-1.90	-1.50							TL-GDFO	NL3S	T
48	Lia85	FO-mi	Taiw	61	81	T?		-2.29	-3.72							TL-GDFO	NL3S	T
48	Lia85	FO-co	Taiw	61	81	T?		-0.67	-1.10							TL-GDFO	NL3S	T
48	M&V87	FO-Bk	Ecua	?	?	T?	-0.37			-0.46	0.75			0.96	0.22	LE	?	
48	M&V87	FO-Bk	Mexi	?	?	T?	-0.24			-0.96	0.30			1.17	0.74	LE	?	
48	Pit85	FO-fp	Indo	76	78	CT		-7.38	-0.81							TbGFDKE	ML	
48	Pit85	FO-mp	Indo	76	78	CT		-5.27	-0.75							TbGFDKE	ML	
#E	11					Avg	-0.31		-1.64	-0.71	0.53			1.07	0.48			
						Std	0.06		0.92	0.25	0.22			0.10	0.26			
						#	2		9	2	2			2	2			
49	Abd88	LPG	Egyp	60	81	T		1.06	0.55			7.79	3.14			Stat	OLS	D*1
49	Abd88	LPG	Egyp	60	81	T	-0.32	-1.89		-0.70	0.42	3.26		0.94	0.55	LE	OLS	
49	Abd88	LPG	Egyp	60	81	T		1.90	0.96			8.17	3.14			Stat	OLS	
49	M&V87	LPG	Ecua			T?	-0.19			-0.55	0.92			2.66	0.65	LE	?	
49	M&V87	LPG	Mexi			T?			-0.03				1.66			Stat	?	
49	Pin79	LPG	C2 LA	54	¯74	CT		-3.45	-0.76			6.21	1.72			Stat	OLS?	
#E	6					Avg	-0.25		0.18	-0.63	0.67		2.41	1.80	0.60			
						Std	0.06		0.65	0.08	0.25		0.72	0.86	0.05			
						#	2		4	2	2		4	2	2			
50	Ram88	LPG-r	Jama	70	83	T		-0.21	-0.29			2.70	6.47			Stat	OLS?	Ps,T
50	Ram88	LPG-r	Jama	70	83	T	0.15	0.81		0.33	0.55	2.27		1.22	0.55	LE	OLS?	
#E	2					Avg	0.15		-0.29	0.33	0.55		6.47	1.22	0.55			
						Std												
						#	1		1	1	1		1	1	1			

Table 3: (continued) Summary of Energy, Oil and Petroleum Product Demand for Developing Countries.

C	Ref	Prod	Country	y1	y2	Type	Psr	t(p)	Pir	Plr	Ysr	t(Y)	Yir	Ylr	Q-1	Model	ET	Other
51	Pin79	OP	C3 SE	55	74	CT	-0.22	-0.94		-0.51	0.70	1.58		1.63	0.57	LE	OLS?	
51	Lia85	OP-ag	Taiw	61	81	T?		-0.98	-1.30							TL-GDFO	NL3S	T
51	Lia85	OP-co	Taiw	61	81	T?		-1.38	-1.01							TL-GDFO	NL3S	T
51	Lia85	OP-mf	Taiw	61	81	T?		-2.67	-1.00							TL-GDFO	NL3S	T
51	Lia85	OP-mi	Taiw	61	81	T?		-0.08	-1.11							TL-GDFO	NL3S	T
51	Lia85	OP-pu	Taiw	61	81	T?		-0.57	0.00							TL-GDFO	NL3S	T
51	Lia85	OP-se	Taiw	61	81	T?		-0.79	-1.06							TL-GDFO	NL3S	T
51	Lia85	OP-tr	Taiw	61	81	T?		-1.92	-1.73							TL-GDFO	NL3S	T
#E	8					Avg	-0.22		-1.03	-0.51	0.70			1.63	0.57			
						Std			0.48									
						#	1		7	1	1			1	1			

<u>Definitions for Table 3 and 4</u>: C Stands for category: 1 = demand for total energy per capita, 2 = demand for total energy per capita with no included price variable, 3 = demand for total energy, 4 = demand for total energy with no included price variable, 5 = demand for total energy divided by GDP, 6 = demand for energy for industry use, 7 = demand for energy for separate industries, 8 = demand for energy for separate industry no price variable, 9 = demand for energy for residential use, 10 = demand for energy for residential use no included price variable, 11 = demand for energy in the residential and commercial sectors, 12 = total demand for oil per capita, 13 = total demand for oil per capita no price variable, 14 = total demand for oil, 15 = total demand for oil no price variable included, 16 = miscellaneous specifications for oil demand, 17 = demand for oil in industry, 18 = demand for oil for separate industries, 19 = demand for oil in the residential sector, 20 = demand for aviation gasoline, 21 = demand for jet fuel, 22 = demand for air transport fuel, 23 = demand for gasoline per capita, 24 = demand for gasoline per auto, 25= demand for gasoline, 26 = demand for gasoline estimated on quarterly data, 27 = gasoline demand by specific industry, 28 = demand for diesel fuel per capita, 29 = demand for diesel fuel for highway transport, 30 = demand for diesel for rail transport, 31 = demand for diesel fuel for water transport, 32 = demand for diesel fuel, 33 = demand for diesel fuel estimated on quarterly data, 34 = demand for diesel fuel with price excluded, 35 = demand for diesel fuel by specific industry, 36 = demand for transport fuels per capita, 37 = demand for highway transport fuels, 38 = miscellaneous demands for highway fuels, 39 = demand for transport fuel by railroads, 40 = demand for transport fuel for water transport, 41 = demand for kerosene, 42 = demand for kerosene for residential use, 43 = demand for kerosene by specific industry, 44 = total demand for fuel oil, 45 = demand for heavy fuel oil, 46 = demand for light fuel oil, 47 = demand for fuel oil by industry, 48 = demand for fuel oil by specific industry, 49 = demand for LPG, 50 = demand for LPG in the residential sector, 51 = demand for other petroleum products and demand for other petroleum products by specific industry.

Ref stands for reference: References are abbreviated as the first three letters of the last name of one author, the first initial for the first author followed by & and the first initial of the second author for two authored pieces, and the first three initials of the first three authors for pieces with more than two coauthors. All initials are followed by the last two digits of the year of publication. A q signifies that the estimates were quoted from a secondary source. The source is designated after the reference in the bibliography.

Prod designates the product demanded: E = total energy consumption, / = per capita, b = biomass included, /Y = divided by gdp, /A divided by auto stocks, D = diesel fuel consumption, F = liquid transport fuel consumption, FO = fuel oil consumption, G = gasoline consumption, GU = gasoline consumption in urban areas, K = kerosene consumption, LPG = liquid petroleum gas consumption, O = total oil consumption, O/C = oil divided by coal consumption, O/E = oil divided by energy consumption, OIm = oil imports, O&NG = oil and natural gas consumption, OP = other oil products. generation. A dash indicates a subaggregate which includes: -ac= automobiles and motorcycles, -ag=agriculture, -Av = aviation gasoline, -Ai = fuels used for air transport, -bk=Bunkers, -bv=beverages, -ch=basic chemicals + fertilizer, -co=construction, -em=electrical machinery, -ep = electricity production, -fm=fabricated metals, -fp=food processing, -gc=government and commercial, -Hv=heavy, Hw = highway fuel consumption, -i=industry, -i5=5 industries, -in=intermediate industries, -is=iron and steel, -Jt = jet fuel consumption, -le=leather & substitutes, -Lt= light, -ma=machinery except electrical, -mc=import competing, -mt metals including basic metal, aluminum,and copper,-mf=manufacturing, -mi=mining, -mm=metals and machinery ?, -mm=mines and manufacturing, -mo=measuring and optical, -mp=mineral products, -mx=manufactured exports, -nf=non fossil fuel, -nm=nonmetallic products including cement, glass, ceramics,and other similar products, -ot=other, -pa=paper, -pp=paper and pulp, -pr=printing & publishing, -pu=public utilities, -pw=plastic ware, -r =residential, -rb=rubber products, -r&c=residential and commercial, -Rr = fuel consumption for rail transport, -se=services, -sh=shoes, -sp=steel pipe, -ss=secondary steel, -sw=spinning & weaving, -tb=tobacco, -TB=trucks and buses, -te=transport equipment, -tr=transport and communication, Tr = fuel consumption for transportation, -tx=cotton&textiles, -T&B=trucks and buses, -wa=wearing apparel, -Wa = fuel consumption for water transport, -wd=wood and wood products, -wf=wood furniture.

^SCountry^S designates the region of estimates. For one country the first for letters of the country are used. If the country names is two words, the first letter of the first and the first three letters of the second are used with both first letters capitalized. C# designated that # countries were used in the estimation. Ly = low income developing countries, My = medium income developing countries, LMy = low medium income developing countries, Hy = high income developing countries, Af = African countries, SS = Sub Sahara, NAf = North Africa, SE = southern Europe, LA = Latin America, which includes the Caribbean, , Ar = Arab, Eu = Europe, ME = the Middle East, As = Asia, SAs = Southeast Asia, EAs = east Asia, Pc = Pacific, OM = oil exporters, OM = oil importers, EX = energy exporters, EM = energy importers, Lpe = low energy price country, Lpo = low oil price country, GCC = the Gulf Cooperation Council. -R# signifies # subregions of the designated country have been used.

y1 is the first year of the estimation period. y2 is the last year of the estimation period. ~ indicates some countries in the sample have varying first and last years from the ones designated.

Type is the type of data: T = time series, C = cross section, CT = cross section time series, a = data has been averaged, q = quarterly data.

^SPsr^S is the short run price elasticity from dynamic models. ^St(p)^S is the t-statistic on the estimated price variable.

^SPir^S is labeled the intermediate run price elasticity and is from the price coefficient on static models.

^SPlr^S is the long run price elasticity from dynamic models.

^SYsr^S is the short run income elasticity from dynamic models. ^St(y)^S is the t-statistic on the estimated income variable.

^SYir^S is labeled the intermediate run income elasticity and is from the income coefficient on static models.

^SYlr^S is the long run income elasticity from dynamic models. ^SQ-1^S is the coefficient on the lagged endogenous model. This coefficient is usually significant at the 5% or better level. Exceptions have an ns beside them.

Model is the estimation model: BN=estimated with a Balestra-Nerlove function, LE = estimated with a lagged endogenous model, LE&y-1 = lagged endogenous model with lagged income term included, LExp = estimated as part of linear expenditure system, OL = other lagged values than a lagged endogenous variable, OL-S = estimated including a stock of automobiles and other lagged variables, PDL:P# = a polynomial distributed lag with a # period lag on price. Sh = the dependent variable is a fuel share equation, Stat= no lagged values included in the estimation, LE-S=estimated with a lagged endogenous and a stock of vehicle variables, SforY = stock of auto included instead of income, TbGFDKE = tobit estimation with shares for gasoline, fuel oil, diesel, kerosene, and electricity, TL-COE = estimated using a translog model including coal, oil, and electricity, TL-COEN = estimated using a translog model including coal, oil, electricity, and natural gas, TL-EL= estimated using a translog model including energy and labor, TL-GFDKE = estimated using a translog model with gasoline, fuel oil, diesel, kerosene, and electricity, TL-KLE = estimated using a translog model with capital, labor, and energy, TL-KLEM = estimated using a translog model using capital, labor, energy, and material, TL-KLMEF= estimated using capital, labor, materials, electricity, and fossil fuels, Util = vehicle utilization model with fuel divided by vehicle as the dependent variable.

ET is the estimation technique. D4 is PDL of degree 4, GLS = generalized least squares, gE/gY = elasticity is the ratio of the growth of energy consumption over the growth in income, gO/gY = elasticity is the ratio of the growth of oil consumption over the growth in income, -h = correction for heteroskedasticity, HL = estimated by Hildreth Lu, INL3L = iterative nonlinear three stage least squares, ISUR = iterative seemingly unrelated regressions, IV = instrumental variables, ML = maximum likelihood, NL = estimated by nonlinear techniques, OLS = ordinary least squares, OLS? = no specific estimation technique was stated but OLS implied. 2S = estimated by two stage least squares, 3S = estimated by three stage least squares, sc = estimated with a correction for serial correlation, sc3 = estimated with a correction for serial correlation for third order serial correlation, SUR is seemingly unrelated regressions, # E = estimated as a # system of equations.

Other indicates price definitions and other included variables: C = country dummy, R = regional dummy, I = industry dummy, Pd = the price of diesel fuel is the price variable, Pg = the price of gasoline is the price variable, Pi = price index as the price variable, Po = the price of oil is the price variable, Pp = the weighted average price of oil products is the price variable, Ps = a price of substitutes has been included, SV indicates that some sort of economy structural variables or dummies have been included such as the share of income in manufacturing, D*T = time dummy, T = time trend.

? under any category means exact information not given or was not clear.

#E = number of estimated equations in each category.

Avg = the average of the estimated elasticities in the category.

Std = the standard deviation of the estimated elasticties in the category.

Table 4: Comparison of Summary Elasticities Developing (DC) and Industrial Countries (IC).

Source	Reg	Prod	#E		Psr	Pir	Plr	Ysr	Yir	Ylr	Qt-1
C1 & C3#	DC	E	145	Avg	-0.12	-0.38	-0.54	0.47	0.82	1.19	0.58
				Std	0.12	0.27	0.94	0.27	0.39	0.41	0.21
				#	65	80	65	55	84	55	59
Kouris (1983)	IC	E	33	Avg	-0.22	-0.50	-0.45	na	1.13	0.93	
				Std	0.29	0.23	0.45		0.25	0.27	
				#	19	14	19		14	19	
C6	DC	E-i	8	Avg	-0.19	-0.34	-0.50	0.48	1.11	1.15	0.58
				Std	0.09	0.34	0.26	0.02	0.18	0.09	0.05
				#	2	6	2	2	4	2	2
Kouris (1983)	IC	E-i	31	Avg	-0.24	-0.57	-0.35	na	0.88	0.84	
				Std	0.26	0.30	0.45		0.26	0.26	
				#	13	20	13		12	20	
C9	DC	E-r	24	Avg	-0.14	-0.80	-0.27	1.33	1.49	2.48	0.47
				Std	0.06	0.13	0.11	0.09	0.26	0.15	0.00
				#	2	22	2	2	22	2	2
Kouris (1983)	IC	E-r	24	Avg	-0.23	-0.59	-0.74	na	1.45	0.99	
				Std	0.19	0.31	0.41		0.52	0.53	
				#	12	12	12		12	12	
C12 & C14#$	DC	O	34	Avg	-0.06	-0.26	-0.17	0.46	1.10	1.03	0.55
				Std	0.02	0.21	0.08	0.21	0.40	0.22	0.18
				#	19	15	19	19	14	19	19
Als85 D&B85 D&F85	IC	O	38	Avg	-0.35	-0.88	-1.01	0.74	1.59	1.35	
				Std	0.21	0.64	0.57	0.34	0.38	0.37	
				#	19	19	19	11	12	11	
C22@	DC	G	19	Avg	-0.41	-0.55	-1.77	0.22	1.33	1.89	0.83
				Std	0.20	0.22	0.68	0.14	0.14	0.39	0.05
				#	13	6	13	13	5	13	6
C24@	DC	G	24	Avg	-0.10	-0.95	-0.59	0.33	0.88	1.21	0.71
				Std	0.07	0.50	0.30	0.22	0.49	0.52	0.12
				#	12	12	12	10	8	10	8
C25	DC	G	41	Avg	-0.07	-0.27	-0.70	0.14	0.59	0.87	0.78
				Std	0.16	0.07	0.79	0.09	0.21	0.56	0.18
				#	23	18	21	23	18	21	23
D&S91	IC& DC	G/&G		Avg	-0.26		-0.86	0.48		1.21	0.65
				#	126		92	114		195	

Table 4 (continued): Comparison of Summary Elasticities Developing (DC) and Industrial Countries (IC).

Source	Reg	Prod	#E		Psr	Pir	Plr	Ysr	Yir	Ylr	Qt-1
C36	DC	F*Tr/	12	Avg		-0.08			1.12		
				Std		0.16			0.27		
				#		12			12		
D&H85	IC	F*Tr/	7	Avg		-0.68			1.31		
				Std		0.14			0.53		
				#		7			7		
C37	DC	F*Hw/	20	Avg	-0.21	-0.27	-2.02	0.27	1.33	1.83	
				Std	0.09	0.11	0.75	0.19	0.37	0.32	
				#	4	16	4	4	16	4	
D&H85	IC	F*Hw/	7	Avg		-0.67			1.36		
				Std		0.14			0.55		
				#		7			7		
C39	DC	F*Wa/	6	Avg		0.12			0.54		
				Std		0.18			1.10		
				#		6			6		
D&H85	IC	F*Wa/	5	Avg		-1.31			-0.19		
				Std		0.15			0.23		
				#		5			5		
C22	DC	F*Ai/	6	Avg		-0.12			0.97		
				Std		0.21			0.09		
				#		6			6		
D&H85	IC	F*Ai/	4	Avg		-0.61			1.46		
				Std		0.22			0.60		
				#		4			4		
C38	DC	F*RR/	12	Avg		1.19			-0.24		
				Std		1.08			0.86		
				#		12			12		
D&H85	IC	F*RR/	7	Avg		-0.81			1.51		
				Std		0.21			0.64		
				#		7			7		

#All studies using the price of oil have been omitted.
@All studies including income and the stock of autos have been omitted.
$Studies on Southern Europe have been omitted.

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