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Analysis Report

A Sensitivity Analysis of World Oil Prices

September 1979

**U.S. Department of Energy
Energy Information Administration
Assistant Administrator for Applied Analysis**

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A Sensitivity Analysis of World Oil Prices

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PREFACE

The analysis contained in this paper was requested by Charles Fisk of the Central Intelligence Agency (CIA), Office of Economic Research, for their continuing examination of the world oil market. All of the analyses presented in this paper are based on assumptions provided by the CIA's Office of Economic Research.

The analysis was performed under the direction of W. Calvin Kilgore. The authors wish to thank David Guthrie and Lulie Crump for their contributions to the study.

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EXECUTIVE SUMMARY

This paper presents an analysis of the impact of the political disruption in Iran on the world oil market. During the first quarter of 1979, this disruption caused a loss of approximately 5 million barrels per day (MMBD) of oil production available for export from Iran to the rest of the world. This loss of production and the political climate in Iran have caused much speculation concerning future Iranian oil production and total Organization of Petroleum Exporting Countries (OPEC) oil production in the nearterm and midterm. The analysis describes these issues in terms of two critical factors: the world oil price and the level of OPEC oil production in the nearterm and midterm.

The critical assumptions, namely the maximum rate of OPEC oil production or the price of crude oil, were provided by the Central Intelligence Agency (CIA), Office of Economic Research and differ from the corresponding assumptions used in other recent analyses performed by the Energy Information Administration (EIA).¹ This paper examines six cases

¹ See EIA Analysis Report AR/IA/79-41, "Petroleum Supply Vulnerability, 1985 and 1990," September 18, 1979.

that differ with respect to assumed economic growth, non-OPEC oil production, maximum OPEC oil production, and world oil prices. The first set of cases assumes different levels of economic growth and non-OPEC oil production with a common level of OPEC oil production to produce a set of three possible world oil price cases. The second set assumes the same three levels of economic growth and non-OPEC oil production; however, instead of assuming a maximum rate of OPEC production, it assumes that OPEC maintains the real world oil price (1978 constant dollars) at \$17.50 per barrel in 1979 and \$20.00 per barrel in the 1980 through 1995 time period. This second set produces estimates of the level of OPEC production required to satisfy world demand at the assumed price level. Simply stated, the first set assumes the maximum rate of OPEC production and then determines the world oil price that will clear the market of any excess demand, whereas the second set determines the required rates of OPEC oil production needed to sustain the world oil price assumption.

This paper also presents a detailed comparison of the CIA and EIA forecasting models of world oil prices. This comparison consists of examining reasons for differences in the price forecasts of the CIA model by using CIA assumptions within the EIA model. The paper also compares the CIA and EIA model structures and major parameters.

It is important to note that this analysis is not all encompassing. In particular, the analysis does not:

- Provide data on crude oil prices in the spot market, but does provide information on the average crude oil price; and
- Permit rationing of oil, since the market is forced to clear only through changes in oil prices.

Throughout this paper, world oil prices are defined in terms of real 1978 dollars per barrel of crude oil delivered to the East Coast of the United States net of any import fees.

Figures 1A and 1B summarize the results of this analysis. Figure 1A shows the real, world oil prices (1978 dollars) that would be expected to result from the assumed OPEC production constraint, while Figure 1B shows the required levels of OPEC production that would be needed to sustain a world oil price of \$20.00 per barrel. For the three cases where world oil prices were derived from the given OPEC production constraint, these data show:

- In 1979, oil prices rise to between \$18.30 and \$20.80 per barrel;
- In 1985, world oil prices are still at their 1979 levels of between \$18.30 and \$20.80 per barrel;
- In 1995, world oil prices range between \$18.30 and \$41.70 per barrel; and

Figure 1A. Alternative World Oil Price

Figure 1B. Required OPEC Oil Production (MMBD)

- After the initial price increase in 1979, world oil prices remain constant in real terms (as assumed) for a number of years until demand again forces the supply constraint to be binding.

For those cases that assume a \$20 per barrel real, oil price by 1980, these data show:

- In 1979, required, OPEC, oil production ranges from 29.5 to 30.8 MMBD;
- In 1985, required, OPEC, oil production ranges from 18.9 to 32.0 MMBD; and
- In 1995, required, OPEC, oil production ranges from 26.5 MMBD to 55.6 MMBD.

The comparison of the EIA and CIA forecasting models of world oil prices was completed by examining the underlying assumptions and structures of both models, and a series of simulations using CIA assumptions serve to quantify the differences in the two models.

The results of the simulations using CIA assumptions within the EIA model show:

- For 1979, the CIA and EIA world oil price forecasts are very similar with a difference of less than one dollar per barrel;
- For 1982, the CIA and EIA world oil price forecasts are very dissimilar with a difference of approximately five dollars per barrel;

- In terms of the model parameters, the most important difference is due to the CIA estimate (-0.25) of the price elasticity of demand for OPEC oil being approximately two thirds the EIA estimate (-0.39), within the price range and time period examined; and
- The lower CIA estimate of the price elasticity of demand for OPEC oil is largely due to the CIA's energy price equation that requires approximately a one hundred percent increase in the price of oil (in nominal terms) to cause a 20 percent increase in the real price of energy. Even though the CIA model treats oil as the marginal demand, the low response of energy prices to oil price changes causes a low oil demand response.

1. WORLD OIL PRICE IMPACTS OF THE IRANIAN SUPPLY DISRUPTION

This paper presents an analysis of the impact of the loss of oil production in Iran on the world oil market and future world oil prices. The analysis was requested by the Central Intelligence Agency (CIA), Office of Economic Research for their ongoing research in the area of world oil prices.

The reduction in Iranian oil production is important because in the most recent year of normal production (1977):

- Iran was the second largest oil producer in the Organization of Petroleum Exporting Countries (OPEC) and accounted for 18 percent of OPEC oil and natural gas liquids production; and
- Iran was the third largest oil producer in the free world, following the United States and Saudi Arabia, and accounted for 12 percent of the total free world crude oil and natural gas liquids production.

In early 1979, the political disturbances in Iran caused Iranian oil exports to cease and have led to a high degree of uncertainty in the world oil market. Sharply increasing oil prices in the spot market may be taken as evidence of this uncertainty.

¹ Central Intelligence Agency, International Energy Statistical Review, March, 1979.

The first part of this analysis focuses on two possible situations that could effect the world oil markets in the nearterm. The first situation assumes that the loss of oil production in Iran lowers world oil production, which will cause world oil prices to increase. The second situation assumes that the OPEC countries set a price of \$17.50 per barrel in 1979 and \$20.00 per barrel for the period 1980-95 and produce a quantity of oil just sufficient to clear the market at the assumed prices. For each of these situations, three, alternative, world economic growth rates and non-OPEC, oil production assumptions are made to quantify some of the uncertainty inherent in the world oil market.

The second part of this analysis focuses on the differences between the CIA and EIA world oil price forecasting models.

Assumptions

This analysis depends on assumptions about three variables: world economic growth, non-OPEC oil production, and either the maximum rate of OPEC oil production or the world oil price, depending on the scenario being considered. The economic growth rate assumption is a prime determinant of the rate of growth of free world oil demand, while the non-OPEC,

oil production assumption details the requirement for OPEC oil production. Table 1 provides the details of the assumptions used in the analysis. The high economic growth rate assumption is combined with low, non-OPEC, oil production to produce a "pessimistic case" in terms of world oil prices, and the low economic growth rate assumption is combined with high non-OPEC oil production to produce an "optimistic case", in terms of world oil prices. In addition a mid-range case that combines mid-range economic growth with mid-range non-OPEC oil production is presented. Each of the three, economic growth and non-OPEC, oil production assumptions is combined with either a maximum OPEC oil production assumption or a world oil price assumption to produce a total of six cases.²

One additional CIA assumption being made in all cases is that once oil prices increase, they are not allowed to fall in real terms even if there is excess supply.

² For a detailed discussion of these assumptions see EIA, Analysis Report AR/IA/79-27, "International Energy Assessment," May, 1979.

Table 1. Case Assumptions

<u>Case</u>	<u>Economic Growth</u>	<u>Non-OPEC Production</u>	<u>Maximum OPEC Production</u>	<u>World Oil Price</u>
1	High	Low	CIA ^a	N/A
2	Mid	Mid	CIA ^a	N/A
3	Low	High	CIA ^a	N/A
4	High	Low	N/A	\$20 ^b
5	Mid	Mid	N/A	\$20 ^b
6	Low	High	N/A	\$20 ^b

^a As specified by the CIA and shown in Table 3.

^b Price assumption is \$17.50 per barrel in 1979 and \$20.00 per barrel in 1980-1995, expressed in constant 1978 dollars per barrel.

Table 2 presents the EIA values assumed for world economic growth and non-OPEC, oil production. It shows world economic growth from 1976 to 1995 ranging from a low of 3.9 percent per year to a high of 4.7 percent per year and non-OPEC, oil production ranging from a low of 24.3 MMBD to a high of 41.1 MMBD in 1995.

Table 3 presents the assumed, maximum, OPEC, oil production figures for 1979-1995 which were provided by the CIA. It should be recognized that these OPEC capacities are higher than those used in other, recent, EIA analyses and were specified by the CIA only for the purposes of this paper.

The CIA figures assume:

- Iran's oil production capacity will rise from a level of 2 million barrels per day (MMBD) in 1979 to a high of 6 MMBD by 1982;
- Production from Saudi Arabia will not exceed a level of 8.5 MMBD through 1995; and
- Total available OPEC oil production will rise from 29.1 MMBD in 1979 to 37.6 MMBD by 1995.³

Results

The analysis shows that, under the OPEC production assumptions provided by the CIA, world oil prices are likely to rise in 1979 and then stay constant, in real terms, for a

³ Includes natural gas liquids.

Table 2. Detailed Assumptions ^a

	<u>High</u>	<u>Mid</u>	<u>Low</u>
Economic Growth (Average Annual Growth, 1976-1995)			
United States	3.7	3.6	3.0
Canada	3.9	3.6	3.3
Japan	5.9	5.7	5.4
Western Europe	3.8	3.5	3.2
OPEC	7.6	7.2	6.8
Other Regions	<u>5.8</u>	<u>5.5</u>	<u>5.2</u>
Total Free World	4.5	4.2	3.9
Non-OPEC Oil Production (MMBD) ^{b c}			
1979	21.5	21.1	20.8
1985	31.1	25.7	21.4
1990	36.4	28.7	24.2
1995	41.4	35.0	29.6

^a These assumptions are from EIA's 1978 Annual Report to Congress: Series B (High); Economic Growth Series C (Mid); and Series D (Low).

^b Includes Centrally Planned Economies net oil exports.

^c Includes natural gas liquids production.

Table 3. Maximum OPEC Oil Production ^a
(MMBD)

Year	Crude Oil			Natural Gas Liquids	Total OPEC
	Iran	Saudi Arabia	Other OPEC		
1979	2.0	8.5	17.9	0.7	29.1
1980	3.0	8.5	18.2	0.9	30.6
1981	5.0	8.5	18.4	1.1	33.0
1982	6.0	8.5	18.7	1.3	34.5
1983	6.0	8.5	19.0	1.4	34.9
1984	6.0	8.5	19.2	1.6	35.3
1985	6.0	8.5	19.5	1.8	35.8
1986	6.0	8.5	19.6	1.9	36.0
1987	6.0	8.5	19.6	1.9	36.0
1988	6.0	8.5	19.7	2.0	36.2
1989	6.0	8.5	19.7	2.0	36.2
1990	6.0	8.5	19.8	2.1	36.4
1991	6.0	8.5	19.9	2.3	36.7
1992	6.0	8.5	19.9	2.5	36.9
1993	6.0	8.5	20.0	2.6	37.1
1994	6.0	8.5	20.0	2.8	37.3
1995	6.0	8.5	20.1	3.0	37.6

^a Source: CIA, Office of Economic Research.

number of years before increasing again. (Recall that it is assumed the real price will not decrease). In addition, if OPEC sets real, oil prices at \$17.50 per barrel in 1979 and \$20.00 per barrel for 1980 to 1995, OPEC production might need to exceed the maximum, OPEC production assumption, so reaching between 29.5 and 30.8 MMBD in 1979, between 18.9 and 32.0 MMBD in 1985, and between 26.5 and 55.6 MMBD by 1995.

Table 4 presents the results of the cases for which maximum OPEC production is assumed. These data show:

- In all cases, world oil prices would be expected to rise in 1979 and would likely range between \$18.30 per barrel and \$20.80 per barrel; and,
- After remaining constant, in real terms, for a number of years, world oil prices could range between \$18.30 and \$29.80 per barrel in 1990 and between \$18.30 and \$41.70 per barrel in 1995.

Table 5 presents the results of the cases in which the world oil prices were set at \$20.00 per barrel by 1980 and held at that price until 1995. These data show that:

- Required OPEC oil production is estimated to be between 29.5 and 30.8 MMBD in 1979; and
- Required OPEC production would range between 18.9 and 32.0 MMBD in 1985 and between 26.5 and 55.6 MMBD in 1995.

Table 4. World Oil Prices^a
(1978 Dollars Per Barrel)

	Economic Growth/Non-OPEC Production		
	<u>High/Low</u>	<u>Mid/Mid</u>	<u>Low/High</u>
Year of Initial Price Increase ^a	1979	1979	1979
World Oil Price			
1979	20.80	19.40	18.30
1985	20.80	19.40	18.30
1990	29.80	19.40	18.30
1995	41.70	25.70	18.30

^a Assumes OPEC production is constrained to 29.1 MMBD in 1979, 35.8 MMBD in 1985, and 37.6 MMBD in 1995.

Table 5. OPEC Oil Production ^a
(MMBD)

	Economic Growth/Non-OPEC Production		
	<u>High/Low</u>	<u>Mid/Mid</u>	<u>Low/High</u>
OPEC Oil Production			
1979	30.8	30.1	29.5
1985	32.0	26.1	18.9
1990	42.8	31.6	20.4
1995	55.6	40.8	26.5

^a Assumes that real oil prices average \$17.50/per barrel in 1979 and \$20.00 per barrel between 1980 and 1995.

2. COMPARISON OF THE CIA AND EIA WORLD OIL PRICE FORECASTING MODELS

The comparison of world oil price forecasting models is based upon assumptions that are different from those underlying the analysis in the first section of this paper. In particular, the EIA's world oil price forecasts presented in a post-Iranian supply disruption Analysis Report, (AR/IA/79-41) Petroleum Supply Vulnerability, 1985 and 1995, is compared to a CIA forecast contained in an unpublished CIA paper entitled, "CIA Energy Supply/Demand Study." Of the various forecasts contained in these studies, only the forecasts based upon mid-range assumptions are used for comparison, since the concern of this section is to ascertain whether or not differences in model structures as opposed to differences in assumptions (such as economic growth or OPEC production capacity) cause major differences in forecasts of world oil prices. The comparison is made for the time period of the CIA paper, 1979 to 1982.

Both the CIA and EIA models produce forecasts of world oil prices by determining market clearing, world oil prices using forecasts of the notional demand for OPEC oil that are balanced against forecasts of the supply of OPEC oil through world oil price adjustments.

However, the two models differ significantly with respect to details, assumptions, and model structures in arriving at the demand for OPEC oil. These differences will be examined in the following sections through:

- A comparison of the reference case assumptions underlying constant world oil price demand for OPEC oil forecasts;
- A comparison of the market clearing oil price forecasts that are needed to balance world supply and demand;
- A description of model structures and major parameter estimates;
- A comparison of implicit estimates of the elasticity of the demand for OPEC oil and an examination of reasons for differences in the estimates; and, finally,
- A separation of the impact on world oil price forecasts due to differences in model structures and parameter estimates from the impact due to differences in reference case assumptions, by using CIA reference case assumptions in the EIA model.

At the outset, it is instructive to provide an overview of how the two models operate. The CIA model:

- Forecasts the regional demand for energy in the Organization for Economic Cooperation and Development (OECD) as a function of Gross National Product (GNP) and the price of energy (expressed in real terms);
- Subtracts the supply of non-oil products (exogenously specified) from the total energy demand to forecast the demand for oil in the OECD;

- Adds oil demand for the developing countries to the OECD oil demand and then subtracts non-OPEC oil supply to produce an estimate of the notional demand for OPEC oil; and
- Given estimates of the available supply of OPEC oil, determines the world oil price that will clear the oil market of any excess demand.

This contrasts to the EIA model, which:

- Simultaneously forecasts the regional supply and demand for oil as well as other energy forms assuming a reference world oil price path using the EIA International Energy Evaluation System (IEES) and EIA Midterm Energy Forecasting System (MEFS) models;
- Using special runs of the IEES and MEFS models, estimates a regional set of system price elasticities for the demand for oil that are based upon equilibrium conditions in the energy sector for all energy forms; and
- Assuming a maximum rate of OPEC oil production, the EIA model determines a price that clears the oil market of any excess demand. (A description of the EIA oil market clearing model is provided in Appendix A.)

Key differences between the CIA and the EIA model structures are:

- The EIA model allows interfuel competition between oil and other energy forms since the supply of non-oil products are not exogenous as in the CIA model; and
- The price of energy in the EIA model is determined through quantity weighted averages of equilibrium prices of all fuel types, whereas in the CIA model the price of energy is determined through an econometric estimate of a relationship between the price of energy and nominal, OPEC oil prices.

Constant World Oil Price Forecasts

The demand for OPEC oil based upon constant world oil price forecasts (at \$15 per barrel) and mid-range case assumptions are presented in Table 6. The average OECD economic growth rates from 1978 through 1982 assumed by the CIA and EIA differ by 0.3 percentage points (3.7 for the CIA and 3.4 for the EIA), and the demand for OPEC oil forecasted by the CIA is 2.5 MMBD higher in 1982 than the EIA forecast (38.8 MMBD for the CIA and 36.3 for the EIA). This difference between the CIA and EIA estimates for the demand for OPEC oil in 1982 is broken down by major component in MMBD as:

	<u>Component</u>	<u>CIA minus EIA</u>
	OECD Energy Demand	3.2
minus	OECD Non-Oil Supply	1.9
	OECD Oil Demand	<u>1.3</u>
plus	Non-OECD Oil Demand	2.3
	Free World Oil Demand	<u>3.6</u>
minus	Non-OPEC Oil Production	1.1
minus	CPE net Oil Export	0.0
	Demand for OPEC oil	<u>2.5</u>

As observed, there is no difference between the CIA and EIA estimates for communist country (CPE) net exports, and only a 1.1 MMBD difference in estimates for non-OPEC oil production. The major differences, however, are attributed to larger estimates by the CIA for OECD energy demand, OECD

Table 6. Comparison of CIA and EIA Mid-Range Projections,^a
 Constant World Oil Prices
 (Million Barrels Oil Equivalent Per Day)

	Actual 1978	Forecast			Growth 1978-1982
		1979	1980	1982	
<u>OECD Economic Growth</u>					
CIA		3.2	4.0	3.5	3.7
EIA	4.2	3.2	3.7	3.2	3.4
<u>OECD Energy Demand</u>					
CIA	^b	78.3	81.4	86.9	3.4
EIA	76.0	78.2	80.0	83.7	2.4
<u>OECD Non-Oil Supply</u>					
CIA		37.3	38.3	41.4	3.9
EIA	35.5	36.6	37.2	39.5	2.7
<u>OECD Oil Demand</u>					
CIA		41.0	43.1	45.5	3.0
EIA	40.5	41.0	42.8	44.2	2.2
<u>Non-OECD Oil Demand</u>					
CIA		11.0	12.2	14.7	11.0
EIA	9.7	10.4	11.0	12.4	6.3
<u>Free World Oil Demand</u>					
CIA		52.0	55.9	60.2	4.6
EIA	50.2	52.0	53.8	56.6	3.0
<u>Non-OPEC Oil Supply</u>					
CIA		20.0	20.6	22.0	4.0
EIA	18.8	19.8	20.5	20.9	2.7
<u>CPE^c Net Oil Exports</u>					
CIA		0.8	0.3	-0.6	-
EIA	1.0	0.9	0.6	-0.6	-
<u>Demand for OPEC Oil</u>					
CIA		31.2	35.0	38.8	6.4
EIA	30.3	31.3	32.6	36.3	4.6

^a Mid-range cases underlying the constant world oil price (at \$15 per barrel) assumptions in "CIA Energy Supply/Demand Study," and the EIA Petroleum Supply Vulnerability, 1985 and 1990. Scenario (SPRMJD).

^b Estimate.

^c Centrally Planned Economies.

non-oil supply, and non-OECD oil demand. Since the CIA estimate for OECD non-oil supply is 1.9 MMBD higher than the EIA estimate, the estimated difference in oil demand is misleadingly reduced to only 1.3 MMBD.

The reason for the difference in oil demand forecasts for the non-OECD countries could not be determined because of a lack of sufficient data in the CIA paper. The major reason for the difference in energy demand for the OECD region is due to different estimates of income elasticities and conservation impacts, which is evidenced by differences in energy/GNP growth ratios (defined as the ratio of energy growth to economic growth). The OECD energy/GNP growth ratio for the CIA is .92 compared to the .71 ratio for the EIA. The lower estimate for the EIA reflects both higher estimates of conservation and lower income elasticities. Although the income elasticities underlying the two models will be presented later in the review, it should be noted at this point that the income elasticity for the OECD region underlying the CIA model is a constant long run estimate of approximately unity; whereas, the income elasticities underlying the EIA model are low initially (at approximately 0.2), but, increase geometrically over time to approach

near-unity in the long run. Hence, in the short time period addressed by this review, the CIA demand response to growth in income is larger than the EIA demand response.

Market Cleared, World Oil Price Forecasts

The demand for OPEC oil forecasted under an assumption of constant, world oil prices is called notional if the supply at the assumed price is not available. Both the CIA and EIA models balance demand against supply through adjustments in the world price of oil. This balancing causes at least two demand reductionary effects: a direct price response and a feedback impact on economic growth. On the supply side, a positive, non-OPEC production response occurs in the EIA model as well. However, this response does not exist in the CIA model, since the CIA estimates of non-OPEC oil production and OECD non-oil supply are exogenously fixed assumptions.

The forecasts of market clearing, world oil prices assuming the respective CIA and EIA, maximum OPEC production estimates and mid-range case assumptions are presented in Table 7. The CIA forecasted, real oil price more than doubles to approximately \$32 by 1982 from its \$15 price in 1978 in

Table 7. Comparison of CIA and EIA Mid-Range
Case - Market Clearing Price Forecasts

	Maximum OPEC Production (Million Barrels per Day)		World Oil Price (1978 Dollars per Barrel)	
	CIA ^a	EIA ^b	CIA ^a	EIA ^b
1979	30.3	30.7	17.50	18.00
1980	31.7	30.3	26.00	20.00
1981	31.7	30.8	25.00	20.80
1982	31.8	31.4	31.50	21.80

^a CIA mid-range forecast as described in "CIA Energy Supply/
Demand Study."

^b The EIA maximum OPEC production assumption underlying
this forecast is the mid-range estimate specified in the
EIA Analysis Report, (AR/IA/79-41) Petroleum Supply
Vulnerability, 1985 and 1990. AR/IA/79-41.

response to the OPEC capacity assumption imposed upon the mid-range assumptions presented in Table 6. This contrasts to the EIA mid-range forecast of approximately \$22 by 1982. In a later section, the CIA assumptions are used in the EIA model to ascertain the effect of differences in model structures and the effects of differences in assumptions.

CIA Model Structure

This section reviews a reduced-form model used by the CIA to analyze the impact of changes in world oil prices on economic activity and energy demand in the OECD region. As outlined above, the CIA determines oil demand for the OECD region by subtracting an estimate of OECD non-oil production, which is exogenously specified, from total energy demand.

The CIA model consists of three main equations used to forecast the demand for energy in the OECD region. The first equation estimates the demand for energy, $Q_{t,i}$, as a function of the real price of energy, $P_{t,i}^E$, real GNP, $Y_{t,i}$, GNP lagged one period, $Y_{t-1,i}$, and the demand for energy in the previous period, $Q_{t-1,i}$, or:

$$(1) \ln Q_{t,i} = \alpha_i + \beta_{1,i} \ln P_{t,i}^E + \beta_{2,i} \ln Y_{t,i} - \beta_{2,i} \beta_{3,i} \ln Y_{t-1,i} + \beta_{3,i} \ln Q_{t-1,i}$$

in the year t for region i , where $\ln$ is the natural logarithm. The lagged GNP variable is included to eliminate the effect of cumulative adjustments to changes in GNP.¹

Thus, coefficient $\beta_{1,i}$ is the short-run elasticity of oil demand with respect to the real price of energy; coefficient $\beta_{2,i}$ is the constant elasticity of oil demand with respect to real GNP; and coefficient $\beta_{3,i}$ determines the speed of adjustment.

The second equation effectively reduces economic growth (or GNP) as OPEC oil prices increase. This equation expresses the change in GNP relative to a reference case (denoted by a "-") as a three period lag function of the nominal OPEC oil price P_t^O relative to the reference OPEC oil price P_t^O or:

¹ The inclusion of the lagged income term in Equation (1) has the effect of keeping the income elasticity constant in all time periods, presumably at its long run equilibrium value.

$$\begin{aligned}
 (2) \quad \ln \left(\frac{Y_{t,i}}{Y_{t,1}} \right) &= \gamma_{1,i} \ln (P_t^O / \bar{P}_t^O) \\
 &+ \gamma_{2,i} \ln (P_{t-1}^O / \bar{P}_{t-1}^O) \\
 &+ \gamma_{3,i} \ln (P_{t-2}^O / \bar{P}_{t-2}^O) \\
 &+ \gamma_{4,i} \ln (P_{t-3}^O / \bar{P}_{t-3}^O)
 \end{aligned}$$

The final equation expresses the real price of energy as a function of the nominal OPEC oil price. In this equation, the price of energy, relative to a reference case, is expressed as a three period lag function of the nominal price of OPEC oil relative to a reference case price, or:

$$\begin{aligned}
 (3) \quad \ln (P_{t,i}^E / \bar{P}_{t,i}^E) &= \delta_{1,i} \ln (P_t^O / \bar{P}_t^O) \\
 &+ \delta_{2,i} \ln (P_{t-1}^O / \bar{P}_{t-1}^O) \\
 &+ \delta_{3,i} \ln (P_{t-2}^O / \bar{P}_{t-2}^O) \\
 &+ \delta_{4,i} \ln (P_{t-3}^O / \bar{P}_{t-3}^O)
 \end{aligned}$$

Table 8 presents the model parameters for Canada, Japan, the United States, and Western Europe. The price elasticities of demand, presented in the top section of the table, have the correct negative sign; however, the value for Canada is significantly higher than the value for any other region. The long-run, income elasticities of demand are all in the unity range.² The second section of this table shows the effect of a change in the price of OPEC oil on income (GNP), and, with the exception of the first parameter for Canada, all have negative signs and become smaller in absolute values as the lag terms go back in time. The last set of parameters values shows the effect of a change in the nominal, OPEC, oil price on the total, real, energy price. The estimates are all positive in the current period with a value of approximately 0.2, except for a 0.1 estimate for Canada. The lagged parameter estimates are generally positive, except for Canada, and are small, except for Japan, which shows a 0.2 positive, second period impact.

² The inclusion of the lagged income term in equation (1) has the effect of keeping the income elasticity constant in all time periods, presumably at its long run equilibrium value.

Table 8. CIA Model Parameters ^a

	Oil Demand (Equation 1)		
	β_1	β_2	β_3
Region			
Canada	-0.44	0.95	0.39
Japan	-0.15	1.00	0.43
United States	-0.06	1.10	0.64
Western Europe	-0.28	0.99	a

	Change in GNP (Equation 2)			
	γ_1	γ_2	γ_3	γ_4
Region				
Canada	0.004	-0.027	-0.021	-0.016
Japan	-0.038	-0.037	-0.039	-0.013
United States	-0.014	-0.014	-0.014	-0.007
Western Europe	-0.029	-0.025	-0.020	-0.010

	Energy Price (Equation 3)			
	δ_1	δ_2	δ_3	δ_4
Region				
Canada	0.109	-0.012	-0.007	-0.003
Japan	0.207	0.194	0.023	-0.003
United States	0.192	-0.018	0.001	0.001
Western Europe	0.217	0.025	0.010	0.001

^a No lag included in this equation.

EIA Model Structure

This section describes the EIA, Oil Market Simulation (OMS) model. The OMS model is a reduced-form model whose parameters have been calibrated to reproduce the results of the larger, EIA, energy sector equilibrium models, the International Energy Evaluation System (IEES) for the non-U.S. regions, and the Midterm Energy Forecasting System (MEFS) and Short-Term Integrated Forecasting System (STIFS) for the United States. The parameters of the OMS model are derived, at least in the midterm, in an equilibrium environment, and, therefore, represent total, energy system responses as opposed to own (partial) price responses even though only oil demands are being considered in the OMS model.

The EIA, reduced form model consists of three main equations for each region. The EIA model expresses all variables relative to a reference case denoted by a "-". The demand for oil, $Q_{t,i}$, is expressed as a function of the real price of oil, P_t , real GNP, $Y_{t,i}$, and the lagged quantity demanded, $Q_{t-1,i}$, or:

$$\begin{aligned}
 (4) \quad \ln (Q_{t,i} / \bar{Q}_{t,i}) &= \beta_{1,t,i} \ln (P_t / \bar{P}_t) \\
 &+ \beta_{2,i} \ln (Y_{t,i} / \bar{Y}_{t,i}) \\
 &+ \beta_{3,i} \ln (Q_{t-1,i} / \bar{Q}_{t-1,i})
 \end{aligned}$$

The second equation expresses the supply of non-OPEC oil, $S_{t,i}$, as a function of the real price of oil, P_t , and the lagged quantity supply, $S_{t-1,i}$, or:

$$\begin{aligned}
 (5) \quad \ln (S_{t,i} / \bar{S}_{t,i}) &= \gamma_{1,t,i} \ln (P_t / \bar{P}_t) \\
 &+ \gamma_{2,i} \ln (S_{t-1,i} / \bar{S}_{t-1,i})
 \end{aligned}$$

The last equation expresses the change in GNP as a function of the real price of oil, or:

$$(6) \quad \ln (Y_{t,i} / \bar{Y}_{t,i}) = \epsilon_{t,i} \ln (P_t / \bar{P}_t)$$

All equations in the EIA model are expressed as log-linear functions and, therefore, the current period parameters may be interpreted as elasticities. Contrary to the constant coefficient model of the CIA, the price coefficients of the EIA model vary over time in order to capture the larger, EIA models' system responses.

Table 9 summarizes the various parameter estimates used in the EIA model. These data show that the short-run price elasticities of demand vary slightly with a range of -0.09 to -0.10, excluding the LDC (Developing Countries) estimate of -0.30, which may be interpreted as a long-run elasticity due to the zero lag coefficient. Although the short-run income elasticities range from 0.1 to 0.2, the effective long-run income elasticities all lie in the 0.8 to 1.0 range. The supply elasticities are relatively small in the short run, but grow significantly over time, as a result of the relatively long lag as implied by the large coefficient on the lagged supply term.

Comparison of OPEC Oil Price Elasticities

Given these two model structures, the price elasticity of demand for OPEC oil is the most important parameter when examining world oil price forecasts, because it describes how both consumers and producers react to price changes. Table 10 summarizes the implicit elasticities for both models. The EIA estimate is one and one-half times larger than the estimate contained in the CIA model in all years. Both studies show that the elasticity increases over time and, by

Table 9. EIA Model Parameters^a

	Oil Demand (Equation 4)		
	β_1^a	β_2	β_3
Canada	-0.10	0.11	0.82
Japan	-0.10	0.15	0.79
United States	-0.09	0.10	0.88
Western Europe	-0.09	0.17	0.81
Developing Countries	-0.30	1.00	b

	Oil Supply (Equation 5)		Change in GNP (Equation 6)
	γ_1^a	γ_2	ϵ^a
Canada	0.04	0.95	-0.06
Japan	0.00	b	-0.08
United States	0.04	0.95	-0.01
Western Europe	0.04	0.95	-0.05
Developing Countries	0.03	0.95	-0.05

^a The EIA parameters are average values overtime for the mid-range forecast contained in (AR/IA79-41) Petroleum Supply Vulnerability, 1985 and 1995.

^b No lag included in this equation.

Table 10. CIA and EIA Estimates of the Price Elasticity of Demand for OPEC Oil ^a

	CIA	EIA
1979	-0.14	-0.22
1980	-0.16	-0.26
1981	-0.25	-0.34
1982	-0.25	-0.39

^a Calculated as the percentage reduction in the demand for OPEC oil due to the percentage increase in world oil prices, implied by the respective CIA and EIA market clearing price forecasts, relative to a reference price forecast.

1982, the CIA figure is -0.25 as compared to the EIA estimate of -0.39. As we will show in the next section, this is probably the most important reason for the differences between the CIA and EIA price forecasts.

Assessment of the CIA Price Forecast

The previous three sections have described many of the differences in the CIA and EIA world oil price forecasting models. The relative importance of these differences, however, has not yet been addressed. In this section, simulation techniques are used to assess the importance of these differences. This technique consists of simulating the EIA model, under assumptions identical to those used by the CIA, for both the exogenous and endogenous variables. When all of the CIA assumptions are accounted for, any differences in the world oil prices forecasted can then be attributed to the different parameter estimates and model structures. To complete this analysis, four cases are developed that sequentially incorporate the CIA assumptions into the EIA reference path data, until the only difference between the models relates to the structure and parameter estimates.

- Case 1 replaces the EIA estimates of OPEC production capacity with the CIA estimates.

- Case 2 replaces the EIA Estimates of OPEC production capacity and free world oil demand with the CIA estimates.
- Case 3 replaces the EIA estimates of OPEC productive capacity and free world oil demand and non-OPEC oil supply with the CIA estimates.
- Case 4 replaces the EIA estimates of OPEC capacity, free world oil demand, non-OPEC oil supply, and net CPE oil exports with the CIA estimates.

The only difference between the CIA and EIA models in Case 4, therefore, is due to different parameter estimates and model structures.

Table 11 provides the EIA, world oil price estimates for each of the four cases, with the corresponding CIA world oil price forecast. These data show that:

- The use of the CIA, OPEC capacity estimate produces only moderate price increases over the simulation period and shows prices rising by \$2.40 in 1979 and increasing by \$7.80 by 1982;
- The combined use of the CIA, OPEC oil capacity estimate and free world oil demand estimates makes the most noticeable difference in the price projections and shows prices increasing to approximately \$30 per barrel in 1982; and
- The addition of the CIA, larger estimates of non-OPEC oil production and CPE net oil imports changes the price forecast downward to a figure of about \$26 per barrel in 1982.

This remaining difference in the 1982 price forecasts of more than \$5 per barrel between Case 4 (at \$26) and the CIA forecasts (at over \$31) is due to differences in the model

Table 11. Simulation Results World Oil Prices
(1978 \$/bbl)

	CIA ^a <u>Forecast</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>
1979	17.50	17.40	17.40	16.90	17.10
1980	26.00	17.00	21.40	21.40	22.20
1981	25.00	19.90	26.20	23.40	23.20
1982	31.50	22.80	29.00	26.40	26.00

^a EIA model simulations using CIA mid-range assumptions and OPEC capacity as described in "CIA Energy Supply/Demand Study."

structures and parameter estimates. Since the EIA estimate of the price elasticity of demand for OPEC oil is approximately one and one-half times the CIA estimate, this large difference in forecasted prices is not surprising.

The difference in the elasticity of demand for OPEC oil is primarily due to the CIA pricing equation, which says that if the nominal OPEC price increases by 100 percent, the real price of energy will only increase by about 15 percent. This low response of energy prices to a change in oil prices causes the effective elasticity of demand with respect to oil prices to be low when compared to the EIA estimate.

In particular, if the OPEC price increase is 100 percent, then, based upon the CIA model parameters presented in Table 8, the short-run, price elasticity of oil demand (as opposed to energy demand) for Canada, Japan, the United States, and Western Europe are -0.03, -0.05, -0.02, and, -0.06, respectively. The EIA, short-run elasticities presented in Table 9 are approximately -.10 for these regions and are much larger than the CIA elasticities. Another factor contributing to the difference in the elasticity of the demand for OPEC oil is due to the CIA assumption that non-OPEC oil production is not responsive to changes in oil

prices, as compared to an EIA price elasticity of 0.05 for non-OPEC oil production by the second year. In the long run, the differences in these elasticity estimates become even larger.

To conclude, relative to EIA estimates, the CIA understates the total price response of the demand for OPEC oil due to differences in model structure and parameter estimates and, as a consequence, the CIA overestimates the impact of supply capacity constraints on world oil prices.

APPENDIX

Methodology of the EIA, Oil Market Simulation Model

This analysis was completed using the Oil Market Simulation (OMS) model,¹ which is a reduced form version of several larger energy and macroeconomic models used by EIA. These models are the International Energy Evaluation System (IEES), the Midterm Energy Forecasting System (MEFS), and the Data Resources, Inc., (DRI) macroeconomic model. Simply stated the CMS model:

- Initially assumes a reference price and regional world oil supply and demand paths;
- Given a specified maximum rate of OPEC production, the model compares the supply and demand for OPEC oil; and
- If demand exceeds supply, then prices are allowed to increase until the market is restored to equilibrium (i.e., when free world supply and demand are equal).

The critical parameters in the determination of the market clearing price are the short-run and long-run elasticities of supply and demand with respect to the price of crude oil. These parameters are estimated by comparing base case price

¹ This model is documented in Appendix B of EIA Analysis Memorandum AM/IA - 7805, "An Analysis of Future World Oil Prices."

runs with high, real world oil price runs of the IEES and MEFS models. The DRI macroeconomic model provides estimates of the effect of higher world oil prices on economic growth in the developed countries. As oil prices increase in real terms, economic growth decreases and, therefore, the demand for oil also decreases.

In order to understand the operation of the OMS model, it is instructive to follow the price-quantity adjustment that conceptually occurs if market equilibrium is disturbed. This market clearing mechanism is explained with the aid of Figure 2, which represents a snapshot of the adjustment process for a given year. Reference equilibrium price and quantity (P_r , Q_r) are designated by point A. Under reference case assumptions, OPEC produces only that quantity which maintains the reference real oil price (usually assumed constant). Now, if OPEC capacity is assumed to be below reference production levels, such as in the present analysis, world supply will decrease (shift to the left) by the amount of the OPEC reduction. This is indicated in Figure 2 by the shift in world supply function from S_r to S_f . At the reference price, there is now excess demand equal to the OPEC reduction (on the figure, this would be represented by the quantity A - B).

Figure 2. OMS Model Market Clearing Mechanism

Under this condition of excess demand, consumers bid up the price of oil. The movement to higher prices causes three adjustments to take place simultaneously. These are:

- The direct impact of higher oil prices on oil demand causes the quantity demanded to decrease and an increase in the demand for alternative energy forms (in the figure, price moves toward point C);
- A decrease in the rate of growth of real GNP due to economic feedback causes total energy and oil demands to decrease (the demand shifts down as indicated from D_r to D_f); and
- An increase in the quantity supplied of non-OPEC oil takes place in response to increasing prices (world supply increases from B toward C offsetting a portion of the OPEC reduction).

Final equilibrium is then reached when supply and demand are equalized (this will be point D on the new demand and supply schedules). Further lagged adjustments to the higher price by consumers and producers will take place over time as energy-saving capital adjustments are implemented, as the efficiency of the stock increases, and as new wells and other advanced production techniques are introduced. Therefore, the OMS model is specified as being dynamic with the appropriate demand and supply elasticities conditioned by the supply of alternative energy forms.