OECD OIL DEMAND: ESTIMATED RESPONSE SURFACES FOR NINE WORLD OIL POLICY MODELS

Hillard G. Huntington

EMF OP 36

May 1992

Energy Modeling Forum
Terman Engineering Center
Stanford University
Stanford, CA 94305

OECD OIL DEMAND: ESTIMATED RESPONSE SURFACES FOR NINE WORLD OIL POLICY MODELS

Hillard G. Huntington

Abstract

Econometric response surfaces for nine different world oil policy models are estimated for aggregate oil demand within the developed countries of the Organization of Economic Cooperation and Development (OECD). The estimates are based upon scenario results reported in a recent model-comparison study. The response surface approach provides a parsimonious summary of model responses. It enables one to estimate long-run price elasticities directly rather than to infer such responses from 20-year cross-scenario results. It also shows more directly the significant effect of initial demand conditions (in 1988) on future oil demand growth. Due to the dynamic nature of the oil demand response, past prices exert a strongly positive effect on future oil demand in some models, but little or even negative effect in other models. On the basis of this finding, we urge demand modelers to be much more explicit about what their systems reveal about the extent of disequilibrium embedded in their model's starting oil demand conditions.

OECD OIL DEMAND: ESTIMATED RESPONSE SURFACES FOR NINE WORLD OIL POLICY MODELS

Hillard G. Huntington

May 1992

1. INTRODUCTION

With the crude oil price collapse in 1986, it was widely anticipated that oil consumption would eventually rebound strongly, thereby creating pressure for higher oil prices in later years. By 1992, there has been only modest growth in oil consumption, particularly in the developed countries, and there has been no trend towards higher real oil prices.

Whether crude oil prices will eventually rise over the next decade will depend upon the rate of future oil demand growth, long-run supply conditions, and the pricing decisions of the oil-producing cartel. A recent comparison of world oil models (Energy Modeling Forum, 1991) revealed a very wide dispersion among models in oil consumption projections that had been standardized for oil price and economic growth paths. Much of this discrepancy was attributed to rather large differences in the response of oil demand to both past and current prices, economic growth, and autonomous technological advances.

This paper casts further light on the differences among models in their relative demand responses to important factors. Econometric response surfaces are estimated for each model's aggregate oil demand within the developed countries of the Organization for Economic Cooperation and Development (OECD). While demand growth is likely to be more rapid in some developing countries, e.g., the Pacific Rim countries, the relative size of the developed countries' current use ensures that their experience will have an important influence on oil prices over the next decade. The focus on the OECD countries also reflects the emphasis placed upon oil use in developed economies, with only a rudimentary representation of demand outside the OECD, by most world oil models and oil demand studies.

The models and scenarios are briefly discussed in the next section. After developing the methodology in Section 3, we report the results in Section 4 and interpret the elasticities and other coefficients in Section 5. Section 6 provides a summary discussion of the implications of the analysis for understanding oil demand projections.

2. THE EMF STUDY

The eleventh Energy Modeling Forum (EMF) study focused on the supply and demand trends over the next two decades for various scenarios and their implication for the world's dependence upon Persian Gulf oil. Proprietors of 11 economic models of the world oil market simulated 12 different scenarios with standardized input assumptions. These results were analyzed by an EMF working group comprised of leading analysts and decisionmakers from business, government, and academia.

Models

The analysis in this paper estimates response surfaces for 9 of the 11 models included in the study. These 8 models are listed in Table 1 with the name of the working group representative and affiliated organization. Two models were excluded from this analysis because they reported in five-year intervals. The Penn-BU model is included, although it reported oil demand for the market economies (including the developing countries). Two different response surfaces were estimated for the HOMS model for which results for two alternative demand specifications were reported.

Kress et al (1992) describe each model's structure and key variables. Key input variables include: the crude oil price and GDP (all models), substitute fuel prices (only BP America), and

Table 1. Models in EMF Study

Model	Working Group Contact*
EIA:OMS	Mark Rodekohr, Energy Information Administration
IPE	Nazli Choucri, Massachusetts Institute of Technology
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
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.

a time trend for autonomous improvements in oil efficiency, unrelated to price (OMS, WOMS, BP America). The demand functions for WOMS, HOMS, FRB-Dallas, BP America, and Gately are econometrically determined; those for OMS, IPE, and CERI are based upon judgmental parameters, often based partly upon available energy demand studies.

Regional disaggregation varies across models. Penn-BU, WOMS, and BP America project an aggregate demand for OECD countries, while FRB-Dallas specifies individual demand equations for the major seven OECD countries (United States, Canada, Japan, West Germany, France, United Kingdom, and Italy). The remaining models aggregate the European countries into one region. In the EMF study, modelers reported results for an aggregate OECD region. Thus, the response surfaces in this paper are estimated from the results reported for an aggregate OECD region, regardless of the level of disaggregation in the model.

Scenarios

The scenarios were chosen primarily for focusing the group's discussion of important factors in the world oil market. They were not constructed specifically to conduct an indepth evaluation of each system. They included nine scenarios specifying an exogenous crude oil price path and three scenarios in which oil prices were determined endogenously.

The ranges for the key independent variables--the crude oil price and OECD GDP--are summarized in Table 2, except for the endogenous price paths, which vary by model. The working group considered three different oil price paths: flat, rising, and the mid-price case from the Energy Information Administration's 1989 International Energy Outlook (hereafter referred to as the 1989 IEO path). Both the flat price and rising price paths were considered in conjunction with the low, base, and high economic growth paths. The 1989 IEO price path was run with the base economic growth assumptions only. Over the 1988-2010 period, economic growth in the market economies (including the developing countries) was assumed to grow by 1.9, 2.9, and 3.9% per year in the low, base, and high cases, respectively.[1]

Table 2: Scenario Values for Key Inputs in Selected Years

	1988	1995	2000	2005	2010
Oil Price (1988$/B):					
Flat Price	14.7	18	18	18	18
Rising Price	14.7	28	36	36	36
1989 IEO Price	14.7	21	28	32	36
OECD GDP (1980 $B):					
Base Growth	9694	11659	13255	15070	17218
High Growth	9694	12385	14686	17414	20783
Low Growth	9694	10969	11953	13026	14241
No Growth	9694	9694	9694	9694	9694

[1]The base economic conditions were those used by the U.S. Energy Information Administration (1990).

The flat price case was also considered in two additional scenarios. In the first, it was ombined with an assumption of no economic growth after 1988. In the second, it was run with both no economic growth and no autonomous trend improvements in oil efficiency unrelated to the oil price. Differences in demand between the two scenarios revealed the rate of autonomous improvement in oil efficiency unrelated to oil prices.

The last three scenarios allowed each model to derive the oil price path endogenously based upon its projected demand, non-OPEC supply conditions, and OPEC pricing behavior. Two cases had OPEC operating as a cartel under the high and base economic growth rate assumptions. The third assumed competitive behavior by all suppliers with base economic conditions.

It should be emphasized that the EMF working group designed scenarios to help sharpen insights about how oil markets operate rather than to generate pseudo data for estimating response surface model coefficients. For this reason, this paper does not address the appropriate research design for generating the data set to be used. The latin hypercube design, originally proposed by McKay et al (1979), allows each input variable to vary simultaneously over its full range. This technique uses a probabilistic approach to identify sample points. The orthogonal design used by Griffin (1977) changes one input variable at a time, holding constant the other independent variables of interest. The EMF scenarios include some cases where only price or GDP are changed and other cases where both variables change at the same time.

3. METHODOLOGY

The response surfaces were estimated using a log-linear adjusted-lag demand specification consistent with the structure of most but not all models. This formulation assumes that oil demand responds immediately to changes in income but only gradually to changes in price, as new capital replaces old equipment. Technical progress, if present, reduces demand at a constant rate in each period and hence operates like the income variable (with a constant rather than time-varying parameter.) These relationships allow oil demand to be expressed as:

$$Q_t = q_t\,(P_t)\,e^{gt}\,Y_t^{a} \qquad\qquad g < 0,\ a > 0 \tag{1}$$

where Q is actual demand, P is the oil price, Y is GDP, g is the rate of autonomous improvements in oil efficiency, and a is the income elasticity of demand. In this specification, the rate of autonomous improvements is constant each year and demand adjusts completely to income changes within the same year. In contrast, the oil price effect cumulates gradually over time through the variable $q_t(P_t)$.

In each year, oil demand adjusts partially to the current price to meet its optimal level (after incorporating income and technical progress).

$$q_t/q_{t-1} = (q_t^{*} / q_{t-1})^{\lambda} \qquad\qquad 0 < \lambda < 1 \tag{2}$$

where q is modified oil demand, λ is the fraction of the oil demand adjusted in each period and the asterisk indicates the optimal level. The optimal level of this variable, is itself a function of the oil price alone.

$$q_t^{*} = \alpha\, P^{\beta} \tag{3}$$

Substituting for q_t^{*} and q_t and combining terms in the demand equation (1) yield

$$\frac{Q_t}{Q_{t-1}} = A\, P^{\lambda\beta} \left(\frac{Y_t}{Y_{t-1}}\right)^{a} Y_{t-1}^{\lambda a}\; Q_{t-1}^{-\lambda}\; e^{-\lambda g(t-1)} \tag{4}$$

where $A = \alpha^{\lambda}\, e^{-g}$.

This equation is estimated in log-linear form by constraining the coefficients of the nonprice terms as indicated. The equation coefficients for the price, income growth, and lagged demand variables have these interpretations, respectively:

$\lambda\beta/\text{-}\,(-\lambda) = \beta$ = long-run price elasticity

$\lambda g/\text{-}\,(-\lambda) = g$ = autonomous improvement rate

$[A/e^{-g}]^{1/\lambda} = \alpha$

The parameter λ is useful for determining the effect of historical prices (i.e., prior to 1988) on future oil demand. This effect has been called initial momentum (Energy Modeling Forum, 1991), because it reveals the tendency of oil demand to change in the absence of any changes in the independent variables--price, income, or technical progress.

Initial momentum equals the difference between the steady-state demand level at 1988 prices and GDP without technical progress and the actual 1988 demand. The steady-state oil demand ($\hat{Q}$) shows no tendency to rise or fall, or

$$\hat{Q}_t = Q_t = Q_{t-1} \quad \text{when } Y_t = Y_{t-1} = Y_o$$

$$P_t = P_o$$

$$\text{and } e^{-\lambda g(t-1)} = e^o = 1$$

where the subscript o denotes the base-year value (e.g., for 1988). Upon substitution of these values in the estimating equation (4), the steady-state level equals

$$\hat{Q}_t = \alpha\, e^{-g/\lambda}\, P_o^{\beta}\ Y_o^{a}$$

This basic approach was used for all models. Income (Y_t) rather than income growth (Y_t/Y_{t-1}) was entered in the CERI equation because that model allows both the price and income effects to grow at the same rate over time. In addition, oil demand depends upon price rather than the logarithm of price in HOMS1. The reported price elasticity for this model equals the price coefficient times the average price ($27) in all scenarios and years for HOMS1.

The Koyck-lag model assumes that the oil price has its biggest impact in the initial year with decreasing impacts in subsequent years. Such a specification is technically incorrect for several models (e.g., FRB) that represent the adjustment as a polynomial distributed lag, in which the biggest effect need not occur in the first year. Accounting for this difference would be important for some applications--eg., forecasting--but does not appear to be critical for summarizing elasticities.

4. ESTIMATES

The estimates of each model's response surface for OECD oil demand are shown in Table 3. The Penn-BU estimates refer to market economies demand (including less developed countries), because OECD results were not reported in the EMF study. The top set of estimates explains the logarithmic change in OECD oil demand based upon Eq. 4 above; the bottom set explains the logarithmic level of oil intensity (demand divided by GDP) by constraining the GDP elasticity to equal unity. The latter are discussed in the next section. A time variable for the trend effect was included only for the three models that reported autonomous oil efficiency improvements in a special scenario designed to elicit that response. The equations explained more than 75% of the variation in each model's scenario results, except for IPE, WOMS, BP America, and Penn-BU.

The price coefficients range from -.03 to -.12, except for HOMS, in which demand is a linear rather than a log-linear function of price. The income coefficients ranged from .7 to 1.0, except for CERI and Penn-BU. The former employed a lagged adjustment on both price and income. By contrast, the coefficient on the lagged demand variable swung widely across models. While most coefficients were -.1 to -.2, indicating that 10 to 20% of total oil demand adjusted to

Table 3: Estimated Coefficients for OECD Demand

	Constant	Price	Income	Lagged Demand	Trend	Adjusted R-Squared
BP Amer	-0.422	-0.048	1.057	-0.087	-0.003	0.383
IPE	-0.146	-0.027	1.015	-0.035		0.647
CERI	0.068	-0.099	0.117	-0.233		0.841
OMS	-0.217	-0.062	0.701	-0.138	-0.001	0.779
Gately	-1.352	-0.067	0.782	-0.429		0.882
WOMS	0.030#	-0.029	0.862	-0.011#	-0.0002#	0.670
Penn-BU	0.015#	-0.056	0.493	-0.225		0.153
FRB	-0.866	-0.115	1.024	-0.213		0.969
HOMS	-1.192	-0.003	0.932	-0.261		0.956
HOMS1	-0.407	-0.115	0.979	-0.149		0.990
Constrained GDP elasticity:						
BP Amer	-1.159	-0.099		0.745	-0.003	0.990
IPE	-0.141	-0.026		0.966		0.995
WOMS	-0.030	-0.033		0.979	-0.0004	0.998
FRB	-0.816	-0.112		0.788		0.999
HOMS	-1.362	-0.003		0.738		0.997
HOMS1	-0.442	-0.116		0.849		1.000

Notes:

Not significantly different from zero at the 0.05 level.

Penn-BU estimates are for market economies based upon all flat and rising price path cases (6).

Gately estimates exclude cartel case.

CERI estimated income elasticity is short run.

HOMS demand response is a linear function of price.

the new price conditions each year, IPE and WOMS revealed a very slow turnover--less than 4% per year--and Gately revealed a rapid turnover--more than 40% per year. This adjustment coefficient has an important effect on the response coefficients summarized below.

5. ELASTICITIES

Table 4 reports key elasticities summarizing the model responses that have been derived from the econometric estimates in Table 3. The last column reveals that the models in this and the previous table have been placed in ascending order according to the OECD oil demand growth reported for the 1989 IEO price case. This scenario assumed an OECD economic growth of 2.6% per year and projected real oil prices rising to $28 per barrel by the year 2000 and to $36 by the year 2010 (all prices in 1988$).

The median results show OECD oil demand as being in the inelastic region for changes in the crude oil price.[2] Price elasticities are below -0.1 in the first year, but rise to about -0.4 in the long run. Income elasticities are approximately unity.

The reported WOMS elasticities are particularly sensitive to the very low estimated coefficient on the lagged demand variable noted above. With a very slow adjustment process, the long-run price elasticity at -2.5 substantially exceeds the values for the other models. Similarly, the revealed trend effect in Table 4 also appears very high. From inspection of the equations for these elasticities in the preceding section, both the long-run price elasticity and the trend effect are inversely related to the value of the adjustment coefficient. Thus, small errors in the low value for this coefficient can lead to substantial errors in the estimates for these effects. Indeed, our estimates for the WOMS responses appear higher than what they have reported previously

[2]The reported average and median results are based upon the top set of estimates except for BP America and WOMS, where the estimates based upon the constrained income elasticity have been used. See the later discussion.

Table 4: Estimated Elasticities for OECD Demand

	Short-Run Price	Long-Run Price	Income	Trend	Initial Momentum	Growth: 1988-2000
BP Amer	-0.048	-0.548	1.057	-0.036	-7.3	-3.3
IPE	-0.027	-0.772	1.015	0.000	-15.8	-0.4
CERI	-0.099	-0.425	0.501	0.000	5.7	2.1
OMS	-0.062	-0.448	0.701	-0.009	1.4	3.4
Gately	-0.067	-0.157	0.782	0.000	0.1	6.0
WOMS	-0.029	-2.544	0.862	-0.020	3.2	9.0
Penn-BU	-0.056	-0.247	0.493	0.000	5.0	13.6
FRB	-0.115	-0.538	1.024	0.000	12.2	14.3
HOMS	-0.083	-0.319	0.932	0.000	11.4	16.5
HOMS1	-0.115	-0.768	0.979	0.000	29.8	26.5
Constrained GDP elasticity:						
*BP Amer	-0.099	-0.387	1.000	-0.010	-0.3	-3.3
IPE	-0.026	-0.767	1.000	0.000	-15.6	-0.4
*WOMS	-0.033	-1.559	1.000	-0.019	-1.2	9.0
FRB	-0.112	-0.531	1.000	0.000	12.4	14.3
HOMS4	-0.088	-0.336	1.000	0.000	7.3	16.5
HOMS1	-0.116	-0.769	1.000	0.000	29.3	26.5
Summary:						
Average	-0.075	-0.562	0.843	-0.004	4.832	8.762
Median	-0.075	-0.437	0.955	0.000	3.192	7.500

Notes:

* Preferred specification for this model. Estimates replace those in the top set in computing the average and median results reported under summary.

Penn-BU estimates are for market economies.

HOMS4 price elasticity computed at price=$27.

(Baldwin and Prosser, 1988; Kress et al, 1992), suggesting that our approach has tended to understate the speed of adjustment incorporated in the model.

Among the remaining models, a relatively slow adjustment places the IPE model's long-run price elasticity at the higher end of the range shown in Table 3, while a relatively rapid adjustment places the Gately model's elasticity at the very low end.[3]

Oil Intensity Functions

The above estimates for WOMS based upon Eq. 4 are suspect as indicated above. An insignificant and very small coefficient for the lagged oil demand level (Table 3) causes both the long-run price elasticity and time trend effect to be suspiciously high (Table 4). Moreover, the income elasticity (0.86) is well below unity, although the original model was estimated by constraining the income elasticity to equal unity. And finally, two other coefficients--for the constant and the time trend--in the WOMS equations are also not statistically different from zero.

To overcome some of these problems, we tried an alternative specification which constrains the income elasticity to unity. The dependent variable becomes the oil intensity, or oil consumption divided by GDP. The coefficient on the lagged dependent variable now equals $(1-\lambda)$ rather than $-\lambda$. This equation was estimated for all models with an income elasticity exceeding 0.85 in the top set of estimates; it appears that these models impose the income-elasticity constraint in projecting oil demand.

The estimated coefficients for this specification are shown in the bottom part of Table 3. The much higher explanatory power of these equations reflects the different dependent variable--the logarithmic level rather than logarithmic difference. For the most part, this

[3]As discussed in the Energy Modeling Forum (1991), the Gately price elasticity would increase once the oil price has increased beyond the historical maximum level. This maximum was not reached in the EMF scenario simulations. This behavior reflects the irreversibility in oil demand resulting from the "sunk cost" nature of energy-using capital. See Gately (1992) for a fuller discussion of this important point.

specification does not appreciably change the derived price elasticities shown in Table 4 for a particular model.

The clear exceptions, however, are very interesting. The long-run price elasticities for both BP America and WOMS are substantially smaller. The WOMS elasticity falls from -2.5 to -1.6, a value virtually identical to the proprietors' own estimate. Moreover, the trend effect for BP America is diminished substantially to about -1 percent per year. Estimations that do not constrain the income coefficient (Eq. 4) appear to perform poorly for models (BP America and WOMS) that incorporate an oil-saving trend effect into a dynamic demand specification.

For these reasons, it appears preferable to use the oil intensity specification (constraining the GDP elasticity) rather than the one based upon Eq. 4 for the BP America and WOMS models. In computing the average and median results to summarize the results in Table 4, the estimates based upon the oil intensity specification were used for these two models. For the remaining models, it appears to make little difference which set of estimated elasticities is used. The averages and medians include those from the top set (based upon Eq. 4).

Initial Conditions

The initial momentum effects shown in Table 4 indicate how much oil demand would change, in millions of barrels per day (MMBD), from its 1988 level, if there were no change in price and GDP from their 1988 levels and no further autonomous improvements in oil efficiency unrelated to past as well as current oil prices. It reflects the fact that oil demand, changes in which are tied to the gradual turnover in capital stock, may not have adjusted completely to current price conditions. When 1988 prices are below recent historical levels, oil demand may tend to grow due to the disequilibrium in initial conditions; the momentum effect would therefore be positive. The value shown for the momentum effect represents the total change after all capital-stock adjustments to the previous price changes are complete.

The strongly negative momentum effect for IPE (-15.8 MMBD) is striking and unexpected. In this model, momentum exerts a strong dampening effect on future oil demand levels, resulting in a slightly negative demand growth (see last column) in the scenario based upon the Energy Information Administration's 1989 mid-price case referenced above. This result contrasts with strongly positive momentum effects ranging from 11 to 30 MMBD for HOMS1, HOMS, and FRB, which exhibit the strongest demand growth. Clearly, initial momentum explains much of the difference between the highest and lowest growth projections in the EMF study.

If the negative momentum effect estimated for IPE is due to a lagged response to past oil prices, this implies that the 1988 price level is above the long-run equilibrium price associated with the 1988 consumption level. Similar negative momentum effects were found for BP America and IPE in a previous decomposition of the reported demand growth projected by each model in the EMF study (1991). Those previous estimates were based upon a case assuming flat oil prices, zero economic growth, and the elimination of any time trend. Initial momentum was then measured as the change in oil demand in this scenario between 1988 and some target year, e.g., 2000. If autonomous improvements in oil efficiency were imbedded in other variables besides a time variable (e.g., a reference demand series), the modeler may not have removed them from this scenario. In this case, the measured initial momentum effect in this previous decomposition would include some autonomous improvements in oil efficiency.

The new estimates of the momentum effect, shown in Table 4, have been derived from the constant term in a regression equation estimated on results from all scenarios in the study.[4] It would appear, therefore, that the observed negative momentum effects for certain models reveal important information about their tendency to project low future oil demand levels.

Initial momentum effects are very important in explaining differences in oil demand projections in the scenario based upon the Energy Information Administration's mid-price case.

---

[4]The "zero growth, zero trend" case mentioned above was included only if the results from this scenario differ from the "zero growth" case.

The most rapid demand growth over the 1989-2000 period is 29 MMBD greater than the least rapid one. The largest momentum effect is 46 MMBD more than the smallest one![5]

6. SUMMARY

OECD oil demand response surfaces for nine world oil models have been estimated from the results of 11 scenarios that were simulated during a model-comparison study. While the main focus of the model-comparison study was on developing policy-relevant insights from a collection of models rather than on conducting indepth technical evaluations of each individual model, the response-surface methodology has proved effective in expanding our knowledge about these modeling systems.

Most importantly, the results provide a parsimonious summary of each model's response to various key factors. These responses are based upon the simultaneous consideration of all scenarios rather than upon the simple comparison of two scenarios at a time. In a previous paper, the author (Huntington 1991) derived inferred price and income elasticities from a comparison of results from two different price (or GDP growth) paths. For the most part, the estimated responses in the current paper are consistent with the previous inferred elasticities.

One key advantage of the response surface approach is the ability to estimate long-run price elasticities directly rather than to infer that 20-year cross-scenario results represented the long-run result. Some models, e.g., IPE and WOMS, apparently have considerably larger long-run price elasticities than what was reported in the earlier paper. Slow turnover rates in the capital stock prevented an accurate measure of this long-run response from the cross-scenario results after 20 years.

---

[5]By the year 2000, most models have almost completed their adjustment to prices prior to 1988. Exceptions are WOMS and IPE, which have very slow implied turnover rates for energy-using capital. For these models, the momentum effect realized by 2000 is about half of the full effect after complete adjustment that is shown in Table 4.

The response surfaces also allowed a more direct and interesting analysis of the initial momentum effect that was discussed in the EMF study. Given the dynamic nature of oil demand, past oil prices can affect future oil demand as the capital stock is gradually replaced[6]. We were able to show more sharply that models projecting low future oil demands had strongly negative momentum effects and those projecting high future oil demands had strongly positive momentum effects. On the basis of this finding, we urge demand modelers to be much more explicit about what their systems reveal about the extent of disequilibrium embedded in their model's starting oil demand conditions. This information should be as routinely published as are summary measures of the aggregate price and income elasticities of demand.

---

[6]This effect may be diminished if oil demand's response to price is imperfectly reversible, as explained by Gately (1992).

REFERENCES

Baldwin N. and R. Prosser, "World Oil Market Simulation." Energy Economics, July 1988, pp.185-198.

Energy Modeling Forum, International Oil Supplies and Demands: Summary Report, Stanford University, Stanford, CA, September 1991.

Gately, D., "Oil Demand in the US & Japan: Why The Demand Reductions Caused by the Price Increases of the 1970's Won't be Reversed by the Price Declines of the 1980's," draft Economics Department, New York University, 1992.

Griffin, J.M., "Long-run Production Modeling With Pseudo-Data: Electric Power Generation." The Bell Journal of Economics, 8(1):112-127, 1977.

Huntington, Hillard G., "Inferred Demand and Supply Elasticities of Oil Supplies and Demands from a Comparison of World Oil Models," Energy Modeling Forum, Stanford University, Stanford, CA, January 1991, also in International Energy Economics, edited by Thomas Sterner, London: Chapman & Hall, 1992.

Kress, Andrea, Douglas Robinson, and Kenneth Ellis, "Comparison of the Structure of International Oil Models," Energy Modeling Forum, Stanford University, Stanford, CA, December 1990, in International Oil Supplies and Demands, Energy Modeling Forum, Vol. 2, 1992.

McKay, M.D., W.J. Conover, and R.J. Beckman, "A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code," Technometrics, 21(2): 239-245, 1979.

U.S. Energy Information Administration, "International Energy Outlook: 1989," U.S. Department of Energy, Washington, D.C., DOE/EIA-0484(89), March 1989.