REVIEW SECTION

Analytical Specifications of the World Oil Market

A REVIEW AND COMPARISON OF TWELVE MODELS

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One discernible reaction to the oil price increases of October 1973 is a variety of arguments and position papers about different features of the "crisis," yielding both diagnoses of the "problem" and prescriptions for its "solution." Much of this literature is dominated by a view that the problem is created by the oil exporting countries, and the solution is some form of induced price reduction. At the same time, however, there is a new line of research that seeks to apply techniques of mathematical modeling and simulation to analyses of the "problem." The importance of this new work on the world oil market lies in its intended contribution to our understanding of that market, by seeking to yield insights into precise relationships and provide specific predictions or forecasts.

The purpose of this review is to compare the structure of twelve models of the world oil market, identify the analytical formulations employed, and render explicit the world view adopted by each and its implications for modeling international trade in petroleum. This comparison is designed to highlight both the dominant assumptions and the characteristic features of price determination in models of the world petroleum market. We shall conclude that models reviewed all share the same general paradigm, that the implicit world view employed poses inherent difficulties, that important features of "reality" in international oil trade are omitted, and that some of these difficulties can be overcome by an explicit recognition of the broader international exchanges within which this particular market is imbedded.

AUTHOR'S NOTE: This review includes only studies with explicit *mathematical* formulations and excludes all works with implicit or unspecified representations of functional relationships.

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OBJECTIVES OF MATHEMATICAL MODELS

For the readers' convenience, Table 1 identifies the twelve models surveyed here, identifying the authors and noting the purpose of the model, the time horizon employed, and the explicit assumptions about major actors. Some models seek to compute optimal prices or to calculate future prices; other models begin with price and inquire into the alternative implications for consumer or producer countries; and still others make specific forecasts of supply and demand. However, these models all share a perspective on the oil industry and attendant relationships in terms of a market, with ther major characteristics of these relationships viewed exclusively in economic terms which view the interdependence of supply and demand as determining price and setting the boundaries of economic exchange. Most oil models seek to compare OPEC-generated prices with those likely to prevail under competitive conditions. The referent, implicitly, if not explicitly, is a market in which the OPEC phenomenon is regarded as an aberration of "normal" conditions, and the solution to market imperfections is a return to competitive conditions. Although competition is, strictly, only a useful idealization which is seldom even an approximate representation of reality, many studies succumb to the temptation to treat oil exchanges as if they should be competitive ones. That the conditions in the world oil exchanges prevailing before October 1973 were not characteristic of a competitive market is rarely observed in the rationale and background discussions for models, nor are the noncompetitive features of the market given preeminence in the input specifications of most models. Indeed, the changes from a market dominated by a company-cartel to one dominated by a country-cartel are seldom even acknowledged. In short, the theories of price formulation imbedded in these twelve models indicate the implicit world view and the methodological dispositions of their authors and determine the results obtained.

CHARACTERISTIC FEATURES OF OIL MODELS

A recent review of the state of the art in modeling the oil market categorized such models as either simulation or optimization models (Fisher, Gately, and Kyle, 1975). This distinction says little about the actual specifications employed to represent the world oil market, but it is a good introduction to a discussion of supply, demand, and price formulations, and of the attendant assumptions underlying each model.

TABLE 1
Twelve Oil Models

Model Author	*Purpose*	*Time Horizon*	*Assumptions Regarding Major Actors*	*Price**
Kennedy (1974)	Test Projections of OPEC power	1980	OPEC = Only Persian Gulf and North Africa Optimal royalty in terms of revenue	$3.50-$7.00 (1972 dollars) (royalty)
Levy (1974)	Test Projections of OPEC power	1980	OPEC = Saudi Arabia, Kuwait, Abu Dhabi Inspection of current price's effect in future	$10.72 (1974 price and dollars)
FEA (1974)	Determine prices for Project Independence Viability	1985	Case #1–OPEC = unified bloc Case #2–OPEC = Saudi Arabia, Kuwait, Abu Dhabi, Libya, Iraq, and Qatar Optimal price for maintenance of market share	about $6.00 $6.00-$9.00 (1973 dollars)
Blitzer Meeraus Stoutjesdijk (1975)	Harmonize OPEC objectives of maintaining markets and increased revenues	1995	Case #1–OPEC = unified bloc Case #2–OPEC = Saudi Arabia, Kuwait, Abu Dhabi Optimal revenues with maintenance of market share	Drop to $7.00 floor, rising slowly depending on other variables (1974 dollars)
Kalymon (1975)	Determine optimal OPEC prices	50-100 years	7 cases: simpler optimization; detailed optimization Optimized revenue and resource exhaustion	$8.50-$15.00 (1974 dollars)
Nordhaus (1973)	Project global energy demand	200 years	Competitive market–no cartel Competitive price	1980 – $1.70 1990 – $2.13 2010 – $7.12 (1970 dollars)
Bohi-Russell (1975)	Forecast actual OPEC prices	1990	Competitive optimization	$7.50-$10.00

Table 1 (Continued)

Model Author	*Purpose*	*Time Horizon*	*Assumptions Regarding Major Actors*	*Price**
Pindyck (1978)	Forecast optimal pricing strategies	2010	Case #1–OPEC = unified	1975 – $13.24 1979 – $ 9.82 2010 – $20.29
			Case #2–OPEC split into "saver" and "spender" countries Optimal price in terms of revenue	1975 – $14.39 1979 – $10.30 2010 – $20.61 (1975 dollars)
Murakami (1976)	Forecast appropriate consuming policies	1965-1985	Submodels of producers and consumers Revenue optimization	not specified
Ezzati (1976)	Reassess OPEC pricing strategies	1980	Submodels of producers and consumers	$17.40 (1973 dollars)
Eckbo* (1976)	Examine pricing strategies for varying coalitions	1973-1993	OPEC	1975 – $ 6.50 1990 – $11.50
			OPEC (without Iraq, Nigeria, Gabon, and Indonesia)	1975 – $ 4.00 1990 – $ 9.00
			OPEC (Saudi Arabia, U.A.E., Kuwait, and Libya) Price set for revenue optimization	1975 – $ 3.00 1990 – $ 8.00 (1972 dollars)
Ben-Shahar (1976)	Forecast optimal pricing strategies	1976-1990	OPEC = unified bloc	Price strategies–constant $11, $7 with 8%/yr. increase, or one-shot price hike in 1982 from $4 to $17.65.
			OPEC–4 blocs: Saudi Arabia, Iran, Other Middle East, Other OPEC Price set for revenue optimization	Saudi prices are all lower than in case 1, and all others are higher but equal to each other (1974 dollars)

*These are selected prices. The analysis itself is more extensive.

OPTIMIZING MODELS

Of the twelve models listed in Table 1, four can be broadly characterized as employing mathematical optimization techniques to derive optimal price paths according to certain assumptions and the specification of a criterion function. The first such effort is by Nordhaus (1973), who focused on the world energy market as a whole and viewed petroleum as a component thereof. Nordhaus' work, presenting an initial rebuttal to the *Limits of Growth* literature and its frontal attack on economic growth, adopts an explicitly competitive view of the world energy market (including petroleum) with cost minimizing production and competitive supply conditions. The basic problem posed by Nordhaus is to identify the allocation of energy resources over time that minimizes the discounted costs of meeting a final set of demands, over different countries, and across five types of energy products. The implications for petroleum prices are worth noting. It is argued that the optimal solution yields a 1973 East Coast U.S. price of $1.70 per barrel. The discrepancy between that price and the prevailing May 1973 price of $4.00 a barrel is attributed partly to "excessive royalties to producing countries" (p. 567), import restrictions in the United States, and inefficiencies in regulations of the industry.

Two other, more narrowly conceived models, by Kalymon (1975) and Bohi and Russell (1975), both focus on optimal prices for OPEC. Kalymon (1975) employed an explicit optimization structure to compute OPEC prices with the total discounted benefits of oil production and exports as the criterion to be maximized. OPEC is treated first as a monolith, and then as composed of subgroups for which maximization is undertaken separately. In each case, the purpose is to isolate the "best" prices for the producer countries. Similarly, Bohi and Russell (1975) employ optimizing techniques to forecast future prices and evaluate the long-term stability of OPEC without assuming explicit collusion among its members. The two studies are broadly similar in the underlying analytical structure and in the modeling decisions made to set up the "problem."

A year later, Pindyck and Hnyilicza (1976) undertook an analysis of OPEC pricing policies, setting up explicit optimization problems for a monopolistic cartel and a two-part cartel composed of "spender" and "saver" countries. Pindyck sought to identify the set of feasible bargaining points in a game theoretic framework using the sum of discounted profits as the performance criterion. The weighting factor, which indicates the relative economic bargaining power of the two parts of the cartel, is used to obtain optimal price paths for the two-part cartel acting as a unified entity. The procedure is to change the weights repeatedly, recompute the optimal sums of discounted profits for each part, calculate the efficient frontier in the space of realized objectives for both "spenders" and "savers," and identify the set of weights that corresponds to an optimal cooperative solution in terms of price and market share. When production is allowed to vary, the optimal price obtained (under different assumptions about production levels) begins at a relatively high level of $14.85 in 1975, declines to $4.65 in 1985, and rises to $20.34 in the year 2000. When allocation of production is fixed, the optimal bargaining solution yields a price of $14.95 in 1975, never declining below $10.30, then rising to $18.40 by 2000.[1] No one has yet taken the Pindyck (or any other) optimal price calculations and employed them as an imput into further analysis of the world oil market.

STATIC SIMULATION MODELS

The simulation models follow a somewhat different set of specific concerns. Generally, they ask if OPEC maintains prices through a certain year, what will the effects be upon output and oil revenue for that year. The practice has been to use a constant price path to that given year rather than to allow price to vary (exogenously or through endogenously generated effects). With one or two exceptions, "naive" price expectations are employed, namely, that prevailing prices will persist.

Three static simulation analyses were undertaken in 1974 as an immediate response to the oil price increases to determine the effects of the new prices. Two of these models, by Levy (1974) and the Federal Energy Administration (1974), deal specifically with petroleum. The Levy analysis treats Saudi Arabia, Kuwait, and Abu Dhabi as the main oil suppliers and investigates the effects of sharp production cutbacks by these three countries at the terminal period. Only prices that can be sustained by these core producers are considered, and it is stipulated that prevailing prices are expected to persist, thereby precluding any responsiveness of price to changes in supply or demand.

The FEA (1974) simulation examines two cases: one in which OPEC behaves as a unified group; the other in which only a subgroup of OPEC engages in restricting output. Demand is set exogenously as a function of price; price is exogenous and the relationship is fixed. Supply is formulated in the same way. Again, neither supply nor demand is endogenously responsive to price changes.

The third static simulation, by Kennedy (1974), differentiates among crude oil production, transportation, refining, and consumption of products for seven regions. Regional supply and demand equations, technology of refining, and government intervention policies are set exogenously. Consumption, production, and trade for each region are determined endogenously. The major purpose is to observe the effects of OPEC behavior through price setting. Price is endogenously determined (but once set, it is not changed). The model is a par-

1. The parameters for Pindyck's model (1978) are obtained from econometric estimates of the coefficients of a simple model. These estimates are predicated on an exogenous price. Once this is done, determining optimal price under various assumptions becomes the major purpose of the analysis.

tial equilibrium one and oil prices do not affect quantities supplied and demanded. Since the Kennedy analysis is a static simulation, the dynamic behavior of the system in response to changing prices cannot be observed.

A similar set of concerns has been the central focus of a static simulation analysis completed two years later by Ezzati (1976), employing the same type of structure as Kennedy (1974), to identify the 1980 equilibrium supply, demand, price of petroleum and petroleum products in different regions, their worldwide effects, and the degree of U.S. dependence on external sources. The major difference is in the elasticities employed and in the results. Ezzati specifies price exogenously by setting the tax rate alternatively within a range from $4.00 to $18.00. He then argues that present OPEC prices are not optimal in terms of maximizing revenue, and that $14.00 to $16.00 could be a close approximation of optimal prices for such a purpose. Calculations of price, supply, and demand for different regions and products for time period t + 1 are computed only when the user provides price, supply, and demand information for time period t. This procedure is not sufficiently integrated with the context and produces a model that is too open-ended to be useful for predictive purposes.

DYNAMIC SIMULATION MODELS

Dynamic simulation models of the world petroleum market represent a more recent development of the modeling approaches to the oil "crisis." The first dynamic model was by Blitzer, Meeraus, and Stoutjesdijk (1975) to determine the price patterns that best satisfy the two goals of oil producing countries: maintaining their market share and obtaining high current revenue. In one scenario, it is stipulated that OPEC as a whole agrees to allocate market shares among all its members; in the other, that only a sub-group of OPEC will reach such an agreement and the remaining members will continue to maintain their current levels of projected output. The authors examine the implications of six alternative price paths, but no systematic procedures are employed to select among the outcomes.

A different approach is by Murakami (1976), who focuses exclusively on the policies of the consumer countries to determine whether there exists a set of policies that could effectively contain OPEC's "creeping cutback" without generating "an eye for an eye" type of reaction. The model is structured, as is typically the case, in terms of two entities: the oil producers and oil consumers. Each entity is characterized by certain economic and resource endowments and disaggregated into individual (or group) submodels. The base simulation is predicated on the assumption that economic policies designed to counter OPEC behavior will not be strongly pursued: that the patterns of energy consumption prevailing in the importing countries will not change dramatically and that the economic growth of the consumer and importer nations will not decline. The author refers to seven consumer policies that were examined, though little additional information is available.

A notable addition to the quantitative literature is by Eckbo (1976), who developed a formal modeling scheme to be employed with a scenario-writing process to provide a flexible analysis of oligopolistic oil markets. The model is structured as a dynamic simulation to examine the sensitivity of price to changes in different parameters of the model. Importers and exporters are disaggregated into different entities. In one version of the model, exporters are treated as one entity, all following a similar pricing strategy. In a more complex version, the exporters are disaggregated into four entities which can change their pricing behavior in any period. The same problem is to examine the effects of alternative pricing policies.

Seven scenarios representing the behavior of the exporting groups are examined by Eckbo: static perfect competition, static monopoly, income stabilization objectives, production stabilization, target pricing, exhaustible resource competition (whereby exporters determine future prices for non-renewable resources and set current prices to the value of the ultimate price), and exhaustible resource monopoly (whereby the present value of ultimate price substituted for cost in the static monopoly case is employed as the objective). Further, Eckbo presents the analytical derivation of the market clearing price for different types of analytically specified world petroleum markets.[2]

The final dynamic simulation reviewed here is by Ben-Shahar (1976), who examines several types of price policies and determines both optimal price and overall energy policy. The objective is to maximize the current (net) value of future petroleum sales and the size of the reserves at the terminal period. A unified cartel case is compared with four subgroups of OPEC behaving as individual maximizers.

The different characteristics and assumptions of the twelve oil models have been embodied in their different specifications of demand, supply, and price. The differences are partly related to the authors' initial purposes; they are partly a result of some necessary simplifications; they partly emerge from the basic world view adopted by the analysts. More important, they highlight the attendant limitations in shaping conclusions and understanding (and predicting) the outcomes generated by international trade in petroleum. A close look at the demand, supply, and price specifications will reveal more clearly what is actually done in models of the world oil market.

2. While the explicit purpose of the analysis is to determine the effects of alternative producers' strategies upon price, once price outcomes are identified, the marketwide implications can then be delineated. Eckbo does not seek to trace the systematic effects of alternative prices, but his model-generated outcomes can be employed as inputs into those (simulation or optimization) models that explicitly seek to delineate the worldwide effects of petroleum prices.

DEMAND SPECIFICATIONS

For the most part, all models of the world petroleum market seek to formulate demand as a function of economic growth, but vary in the extent to which this specification is explicit and to which price is taken into account in determining oil demand. In general, there are three types of demand formulation in the models reviewed. First are the cases in which demand is specified exogenously using available data. Second are the models in which demand is specified explicitly as a function of price by setting demand as responding to current prices, to past prices, or to the combination of both. Third are the specifications in which demand is formulated explicitly as a function of consumer income and of price, where income may be included directly as an explanatory variable or in terms of an elasticity of demand. There are also differences among oil models in their distinction among world energy demand, total demand for world oil, and demand for OPEC oil.

EXOGENOUS FORMULATION OF DEMAND

The simplest way of incorporating demand in a model of the world oil market is through an exogenous specification of future demand. This is done in two ways. First, a publicly available demand series may be employed. For example, Bohi and Russell (1975) employ the one prepared by the National Petroleum Council for the United States that is predicated on the assumption that a price of $7.88 a barrel will prevail to 1985.

A second way of incorporating demand exogenously is by setting demand as a function of a base level and an exogenous growth rate:

$$D_t = D_0(1 + g)^t.$$

This growth rate presumably reflects income growth. It is, in effect, represented as demand growth. Levy (1974) employs this specification in formulating actual demand for world oil, and sets desired demand as adjusting instantaneously to actual demand. The demand for OPEC oil is then formulated as the difference between world demand and the supply from non-OPEC sources.[4]

This relatively simple specification of demand is employed by one analyst to compute optimum price setting and by another to examine the effects of a given price of demand. Thus, the purpose of the model in itself does not dictate the need for this particular demand specification.

3. The distinctions are usually made largely for computational use rather than for some underlying theoretical or practical objective. A difference is sometimes also made between actual demand for oil and desired (or target) demand. Again, however, this distinction is made largely for computational use.

4. The growth rate parameters for the world demand formulation are set alternatively at .027 or .046, although little documentation is given for these numbers.

DEMAND AS A FUNCTION OF PRICE

When demand is determined endogenously, it is most commonly specified as a function of price. The Federal Energy Administration models (1974), developed for the purpose of determining the effects of price on output and on OPEC profits, follow this procedure. Demand for world oil is differentiated from the demand for OPEC oil, and desired demand distinguished from actual demand. As with the Levy (1974) model, an instantaneous adjustment of desired to actual demand is stipulated. The method of linking demand to price adopted by the FEA (1974) is apparently to set a level of demand that corresponds to a particular price; that correspondance is stipulated arbitrarily and is not estimated on the basis of an underlying model or empirical data. For example, at $3 a barrel, the demand for world oil in 1985 is set to 86.5 mmb/d; at $6 a barrel, that demand is set to 60.1 mmb/d. Demand for OPEC oil at $9 a barrel is stipulated to be 28.5 mmb/d by 1985. No persuasive reasons are given for this particular correspondence between demand and price.

A second way of specifying demand as a function of price is by including an exogenous growth rate as an additional explanatory variable. Both Kalymon (1975) and Nordhaus (1973) specify demand this way. Kalymon formulated actual demand for OPEC oil, X , as follows:

$$X_t = (a - bP_t) \cdot (1 + g)^t,$$

where P is price, g is the exogenous growth grate, and a and b are parameter values. The basic conceptualization of demand is still only explicitly in terms of a price response with the relation to growth generating influences implicit at best.

A more detailed specification of demand still as a function of price is adopted by Eckbo (1976), who differentiates between basic demand for energy in a particular region and the market share of oil. In each case, demand is responsive to present and past prices. The demand for imports (D) is specified in the same way, which is equivalent to the identity:

$$D = E \cdot M - S,$$

where E is the total demand for energy, S is the domestic supply of oil (for the entity in question), and M is market share. To solve analytically for the market clearing price and quantity, Eckbo respecifies and simplifies these relationships in a set of linear approximations that render the demand for energy as a function of a time dependent intercept, the price-slope coefficient, and adjustment process and price:

$$E = e1 - e2 \sum_{k=t-K}^{t} \lambda^k P^k,$$

where K is the length of the adjustment time and λ is the yearly weights on adjustment, and e1 and e2 are the time and price-slope coefficients with respect to demand. In short, Eckbo (1976) begins with the same simple analytical structure employed by the FEA (1974) and Kalymon (1975), but expands and delineates further the way in which demand responds to price.

Still another way of specifying demand as a function of price is by including a term for a base level demand as an added explanatory variable, as is done by Blitzer et al. (1975) and by Nordhaus (1973). Blitzer et al. distinguish between desired and actual demand for oil (but stipulate an instantaneous adjustment of one to the other) and specify actual demand for world oil, D_t, as follows:

$$D_t = D_0(1 + g)^{t} p_t^{a},$$

where g is an exogenous growth rate (set at .04) and a is the price elasticity of demand (specified either as 0 or −0.05). The actual demand for OPEC oil is simply the difference between world demand and the supply of non-OPEC oil.

Nordhaus (1973) adopts a similar procedure by formulating the demand for world oil in relation to a price threshold, P′, that would divert consumption to another fuel; at that threshold, demand for oil would disappear entirely:

$$D_t = D_o(1 + g)^t \qquad \text{for } P < P'$$
$$D_t = 0 \qquad \text{for } P > P'$$

where P′ is the threshold switching demand for a substitute fuel. Despite the provision for a substitute energy response, this general formulation is hardly realistic for any purpose, since demand for oil is not likely to be eliminated even at high price levels.

DEMAND AS A FUNCTION OF INCOME AND PRICE

An extension of the above demand formulation takes into account income as an added explanatory variable. Four oil models set that demand as a function of income and of price, namely, Kennedy (1974), Ezzati (1976), Pindyck (1978), and Ben-Shahar (1976). They do so either by setting income as an explicit determinant of demand or indirectly by incorporating an income elasticity term in the demand equation. [5]

Kennedy (1974) sets income as an explicit determinant of demand, in addition to price and to lagged demand. The formulation for actual demand for world oil, D_t, is specified as follows:

$$D_t = aY_t^{(1-d)b}P_t^{(1-d)c}D_{t-1}^{d},$$

5. Of course, the growth trend previously noted may be implicitly rationalized as representing income.

where Y refers to income, a to the income coefficient, P to price, and the other terms to adjustment mechanisms. The specification of actual demand for world oil is distinct from the formulation of desired demand, D_t^*, that responds directly to income and to price, as follows:

$$D_t^* = aY_t^b P_t^c.$$

Demand for OPEC oil is set as the difference between total demand for world oil and supply of non-OPEC oil, a procedure employed by most of the oil models that incorporate world as well as OPEC demand. In the Kennedy (1975) model, actual demand does not respond instantaneously to desired demand; each is formulated with a different specification, enabling the estimation of the desired demand for oil and the actual demand.

Recall that the purpose of the Ezzati model is to forecast supply, demand, and price to 1980 from the initial base of 1970. That objective is reflected in the specification of demand. Demand for oil in 1980 is formulated as follows:

$$D_{80} = D_{72} \cdot (1 + g)^{(IE) \cdot (80-72)} \cdot (P_{80}/P_{72})^{(PE)},$$

where the numerical subscripts refer to the years in question, g to the growth rate, IE to income elasticity, and PE to price elasticity. This formulation includes an initialization demand term, price changes, and responsiveness of demand to income and to price. The 1980 prices are simply "educated" guesses.

In the Pindyck (1978) model of OPEC as a unified entity, total demand for world oil is specified as follows:

$$D_t = 1.0 - .13P_t + .87D_{t-1} + 2.3(1.015)^t.$$

The last term in this formulation yields an autonomous growth in demand of 1.5% annually, a figure that reflects a long-run income elasticity of 0.5 and a real rate of growth in income of 3% a year. Demand is the difference between total world demand and demand from non-OPEC sources; the lagged demand term is to assist empirical estimation.

Ben-Shahar (1976) sets total demand for world energy, D_t, as a function of; price, the rate of growth in income, and various elasticity parameters as follows:

$$D_t = [1 + [(1 + g)^t - 1]n_y]\,[30.7 - 30.7n_p/n[(3/p_t)^n - 1]]$$

where P is price per barrel at t, g is the annual rate of real income increase, n_y is the income elasticity of energy demand, and n_p is the price elasticity of demand for prices at $3/bbl, and n represents the parameter of energy demand function. The value 30.7 is in billion barrels, and the value 3 is in dollars per barrel. These are quantitative estimates for 1973 data. Demand for OPEC oil is then taken as the difference between total energy demand and non-oil energy supply plus non-OPEC oil supply.

SUPPLY SPECIFICATIONS

There are basically three ways in which the supply of oil has been modeled: First, formulating supply as an exogenous input into an overall oil model; second, setting supply as a function of price; and third, making supply responsive not only to price but to a variety of factors reflecting the process of oil production.

EXOGENOUS SPECIFICATION OF SUPPLY

As with the formulation of demand, the simplest specification of supply in models of world oil is in terms of certain assumptions regarding an unchanging environment that allows for setting supply exogenously. This procedure is employed by Kennedy (1974) in formulating the crude supply sector of his overall analysis. The assumption is made that real prices remain unchanged and that supply represents output of oil for a given year under that assumption. Although Kennedy differentiates among different producers, simplifying assumptions prevent a full use of this distinction. For example, he assumes that non-Persian Gulf and North African oil producers maintain their current levels of production regardless of price. Also, new supplies from Alaska and the North Sea are postulated to become available at 2.5 and 4 million barrels a day regardless of price. Assumptions about price responsiveness are also limiting, as will be noted below.

A similar supply formulation is shared by Levy (1974), who also distinguishes between different types of suppliers. For the members of OPEC other than Saudi Arabia, Kuwait, and Abu Dhabi, supply is set at currently projected levels based on 1974 prices. These three core members of OPEC are then stipulated to provide the difference between demand and that supplied by other OPEC producers.

SUPPLY AS A FUNCTION OF PRICE

Making supply specifically responsive to price is a development toward greater complexity in representation of the world petroleum market. The FEA (1974) study distinguished between OPEC and non-OPEC sources. Then non-OPEC supplies are conceived in terms of U.S. fields and set as directly responsive to price, and this responsiveness is stipulated exogenously in the following terms:

for P = \$3 non-OPEC supply = 8.4 mmb/d
for P = \$6 non-OPEC supply = 11.5 mmb/d
for P = \$9 non-OPEC supply = 15.8 mmb/d.

This specification of non-OPEC supply is employed even when subgroups of OPEC are distinguished and Iran, Venezuela, Ecuador, Algeria, Indonesia, and Nigeria are stipulated to set supply at current revenue maximizing levels, and the other members of OPEC act as the residual suppliers meeting the demand for OPEC oil.

Treating a subgroup of OPEC as a residual supplier is one that is common in most oil models, the differences being largely in the specification of supply for the other members of OPEC. Kalymon (1975) follows this procedure by setting the output from non-OPEC sources as an explicit function of base-year output price, with a price responsiveness coefficient also included explicitly as follows:

$$S_t = S_0 p_t^m,$$

where m = 0.2 or 0.4. OPEC suppliers are assumed to act as a unified bloc and to meet the difference between non-OPEC supplies and the demand for oil. The major differences between this specification of supply and that employed by Kennedy (1974) or Levy (1974) lie in the degree of differentiation among suppliers and the formulation of price responsiveness.

Although Ben-Shahar (1976) does not explicitly determine OPEC supply, he employs supply functions to quantify non-oil energy supply and non-OPEC oil supply. Both are specified as functions of the price of oil in the previous period. In one set of analyses, he determines market share, allocating increasing increments in OPEC output on the basis of a country's reserves and cutbacks as a function of output during the previous year. In contrast to several other models, there is no provision for a residual supplier, such as Saudi Arabia, to absorb production cutbacks disproportionately.

A yet more complex formulation of supply is that by Pindyck (1976), who differentiates between non-OPEC supply and cumulative non-OPEC supply. The former is set as a function of price and lagged supply; the latter as the difference between cumulative supply and current supply. The formal specification is as follows:

$$S_t = (1.1 + .10P_t)\,(1.02)^{-CS/7} + .75S_{t-1},$$

where S refers to non-OPEC sources, P to price, and CS to cumulative supply of non-OPEC producers. Such cumulative supply, in turn, is formulated as follows:

$$CS_t = CS_{t-1} + S_t.$$

This formulation of supply is based on 6.5 billion barrels a year at \$6 a barrel, with short-run and long-run price elasticities of .09 and .35 at the \$6 price; and .16 and .52 for a situation in which price is set at \$12 a barrel. The coefficients in the supply formulation are obtained from empirical estimates based on time series econometric estimation employing OECD data. Additionally, Pindyck (1978) stipulated OPEC reserves at prevailing prices.

$$R_t = R_{t-1} - D_t,$$

where R is reserves and D is production. This identity enables the investigator to keep track of OPEC's reserves.

A somewhat different specification of supply and price responsiveness is by Blitzer et al. (1975) who distinguish between OPEC and non-OPEC producers, and set the former as a function of capacity and price, and the latter as "making up" the differential between non-OPEC supply and demand for OPEC oil. Non-OPEC supply is formulated as follows:

$$S_t = (\text{capacity})_t P_t^m,$$

where capacity is a function of expected price, and price expectation is formed by a distributed lag mechanism. The price responsiveness coefficient, m, is set at 0.2 for the base case.

In further differentiations among members of OPEC, Blitzer et al. (1975) set non-OPEC supply as noted above, and production output for OPEC producers other than Saudi Arabia, Kuwait, and Abu Dhabi exogenously at projected capacity, treating the three countries as residual suppliers. A useful feature of this formulation is the time-lag expression for price expectation in the supply specification.

SUPPLY AS A FUNCTION OF PRICE AND PRODUCTION PROCESSES

The third type of supply formulation entails an explicit responsiveness to price and some specification of the process that generates output. The simplest formulation in this *genre* is by Ezzati (1976), who projects 1980 supply as follows:

$$S_{80} = S_{72} \cdot (1 - DEC)^{(80-72)} \cdot (P_{80}/P_{72})^{SE},$$

where DEC refers to the decline rate in production in the absence of price changes, P represents price, and SE refers to the supply elasticity. The coefficients are provided exogenously by the user for each region in the model. In this respect, the Ezzati specification is extremely open-ended. However, some underlying assumptions provide bounds upon the model's behavior.[6] More complex formulations are provided by Nordhaus (1973) and Eckbo (1976).

6. For example, it is stipulated, first, that Persian Gulf sources have unlimited quantities of crude oil with a cost of production of 25 cents per barrel, and that non-Persian Gulf and African members of OPEC maintain production at 1972 levels regardless

Nordhaus (1973) formulates the supply of a given energy product in terms of three processes: extraction; transportation; and processing for meeting final demand. Since the purpose is to determine the allocation of energy resources that minimizes the discounted costs of meeting a set of end uses, he specifies production costs, C, activity levels, and the relevant interest rate, r, for each time period, t. Then, he formulates an aggregate costs equation based on costs of extraction, ex, transportation, tr, and processing, pr, simplified as follows:

$$C = (1 + r)_t(ex + tr + pro).$$

Extraction, transportation, and processing are further determined in terms of the investment requirements and the current inputs. This formulation applies to other fuels as well, thereby revealing differences in costs across fuels and across regions and over time. A distinguishing feature of the Nordhaus supply formulation is an explicit representation of the production process in terms of cost.

Eckbo seeks to determine the supplies provided by the oil producing countries when they pursue alternative market strategies or oil policies. In so doing, he differentiates between indigenous sources of supply available in the oil-importing countries and the supply of the exporting countries. The supply specification of the importing countries is formulated solely as a function of price and time, as follows:

$$S^t = S(P,t),$$

where P is a vector of past and current prices. The analytical solution for the market clearing quantity is specified as follows:

$$S^t = s0(1 - d^t)^t + s2 \sum_{k=t-K}^{t} \lambda^k P^k,$$

where s0 is the initial equilibrium intercept; d is the rate of change in supply, predicated upon the level of exploration-production processes; K the length of adjustment; λ is the weight on the adjustment process; and P refers to price.[7] The

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of price. Secondly, the supply elasticities for the United States and Canada are set at 0.4 each for 1980; for Latin America, Europe and Asia at 0.1; the decline rates for the United States and Canada are specified at 5 and 3 percent per year, respectively.

7. The supply specification for exporting countries differs according to the oil policy to strategy adopted. Thus, for the case of static perfect competition, exporter supply is formulated in the same terms as for the indigenous sources of the importing countries. In the case of static monopoly, price is stipulated so as to equalize marginal revenue for long-term residual demand with long-term marginal production costs. In the case of an income distribution policy adopted by oil exporting countries, supply is set as the ratio of targeted oil revenue to price. And in a situation where the stabilization of production is desired, supply is formulated as a function of a fixed production path.

supply formulation for a cartel is made in terms of production capacity and cartel policies of prorationing output among its members. Production capacity is formulated as a function of past and current expected prices, P; development and production costs, MD; time, t; and cartel policies of prorationing capacity, cc:

$$C = C(P, MC, t, cc).$$

Production allocated to an exporter entity is determined as follows:

$$Q = Q(RD, W),$$

where Q refers to the production allocated to a particular unit, RD is the total demand for cartel output in period t, and W is the cartel specified (exogenous) quota system for that period.

Juxtaposing the supply specification presented by Eckbo (1976) with that imbedded in the FEA (1974) or Levy (1974) models reveals the analytical progress in the formulation of supply relationships. From an essentially prespecified responsiveness of supply to price there has been a progression to more complex specifications that take account of costs, production capacity, and oil policies.

PRICE DETERMINATION

The differences in the formulation of the price equation(s) among various models of the world petroleum market are a reflection of their different purposes and of commonly held views of price determination. At least four types of price specifications can be delineated.

First is the case in which price is set exogenously and its effects on both supply and demand are observed; whatever price is specified, it is assumed to persist unchanged.

Second is a variation on this formulation where price is computed as an arithmetic sum of cost-related components which are exogenously specified.

Third is the case in which the price per barrel of oil is itself estimated, given some underlying assumptions about the structure of the market.

Finally, there is the type of model in which optimal price for producer countries is estimated.

Imbedded in each approach is an implicit theory of price determination, and an attendant view of the world petroleum market. Except when price is set exogenously, this is based on economic theory that stipulates price as a function of the interaction of supply and demand relationships and of the factors that cause them to change.

EXOGENOUS SPECIFICATION OF PRICE

The simplest type of price specification is that in which price is formulated exogenously. This is commonly done when investigators seek to identify the consequences of alternative price paths. The earliest, and least sophisticated, example of this type of price formulation was employed by Kennedy (1974), Levy (1974), and the FEA (1974), who stipulate alternative and nonvarying prices. Levy uses three price paths: an expected price of $9 a barrel; a decline to $6 by 1980; and a more rapid decline to $3 for that same target year. The FEA (1974) figures are $3, $6, and $9 by 1985. All three studies share a common formulation that prices, once set, persist indefinitely.

Ben-Shahar (1976) also employed exogenous price specifications, set alternatively as a constant price level, a steadily increasing price, and an individual, singular price increase. Different levels are applied to each type of price; he stipulates a rate of increase for the second exogenous price specification; and he determines the year of increase in the third formulation.

The Bohi-Russell (1975) study represents a variant on this type of exogenous formulation of price by employing prevailing price estimates as an input into the model specifications, using a $7.88 price/bbl for the United States, incorporating various assumptions on drilling and finding rates. Murakami (1976) appears to set prices as a reflection of the level of energy development in a particular region; and both prices and energy development are exogenously determined.

PRICE AS A SUM OF EXOGENOUS COMPONENTS

The second type of specification sets price as the sum of individual components, each of which is exogenously determined. For example, Ezzati (1976) projects OPEC price as simply a function of past prices and the difference between future and past tax rates as follows:

$$P_{1980} = P_{1972} + (\text{OPEC tax}_{1980} - \text{OPEC tax}_{1972}),$$

where the 1980 tax is assumed by the user and the 1972 tax is based on the historical record. The role of the oil-producing countries in setting prices is recognized, yet no explicit awareness of the constraints on price setting or of the relationship of the oil market to other markets that might influence petroleum prices is found.

A somewhat different version of this type of price specification is that by Blitzer et al. (1975), who specify price as a distributed lag function of past prices. This is done by employing a set of weights to past prices in order to yield the expected price variable at each point in time.

$$\tilde{P}_t = \sum_{j=1}^{n} \alpha_j P_{t+1-j},$$

where the weights α_j sum to unity over n years and price expectation is a function of known past prices or, within the same framework, of exogenously stipulated prices.

PRICE AS A FUNCTION OF PRODUCTION PROCESS AND COST

A more complex type of price formulation takes into account the costs of production and the production process itself. Several such specifications have been employed in models of the oil market. One of the earliest formulations is by Nordhaus (1973), who specifies analytically the critical features of an efficient price in a competitive market, and formulates price as a function of extraction costs plus royalties at the backstop technology price. Assuming perfect competition for the world as a whole, Nordhaus formulates price as follows:

$$P_t = (\text{extraction cost}) + (\text{royalties})_0 e^{rt},$$

where r equals the discount rate at the switchover to another source of energy at year t; P_t assumes the value of P, the expected price; and oil production goes to zero at time t.

The price formulation by Eckbo (1976) involves a determination of the market clearing price derived from the supply and demand equations for each of the market situations examined. For example, in the cartel case, the individual country prices are calculated on the basis of a series of monopoly prices. Each "monopoly" price is a function of the price of backstop technology, the residual demand facing the cartel, the expected production quota, the expected growth rate of production, the level of reserves, the costs of production, and the discount factor relevant to the units in question and to the time period under consideration.

DETERMINING PRICE ACCORDING TO SOME WELFARE FUNCTION

The fourth type of price specification calculates price according to some predetermined welfare function to obtain "optimal" price for the oil-producing countries. Kalymon (1975) focuses on the total discounted sum of production profits derived over the time horizon of oil reserve utilization, taking into account domestic and export prices, production, costs, and a relevant discount factor.

Pindyck (1978) also seeks to calculate optimal price trajectories for OPEC and measure OPEC's potential monopoly gains. The objective of the oil-producing countries is stipulated as that of maximizing the sum of discounted profits, W, as follows:

$$\text{Max } W = \sum_{t=1}^{N} [1/(1+\delta)^t]\,[P - m/R_t]\,D_t,$$

where m/R_t equals production costs at time t, m indicates initial costs, δ is the discount rate, D the production level, and N is set at 40 years to approximate an infinite time horizon.

Pindyck (1978) postulates that production costs become infinite as the resource base is exhausted, thereby making the analytical problem one of unconstrained discrete optimal control for which numerical solutions are readily obtainable. That solution generates an optimal price path and an optimal sum of discounted profits for the monopolist.

In exploring the case of competitive producing entities, the price specification is formulated as follows:

$$P_t = (1 + \delta)P_{t-1} - \delta m/R_{t-1}.$$

Since producers in this situation do not collectively set prices, each one individually determines his output given a certain price. That price specification is then the formulation that results from competitive relationships. Pindyck's contributions lie in attempting to determine "optimal" prices in accordance with an explicit set of criteria and in recognizing that calculations of optimal price made under assumptions of completely coordinated behavior are misleading at best.

The Eckbo (1976) and Pindyck (1978) studies are the most analytically sophisticated in specifying the price determination process. They are both undertaken within the context of economic theory, subject to the assumption, constraints, and value orientation of that paradigm. Since their purpose is to determine price, rather than to isolate the implications of prices upon the structure of petroleum exchanges, the consequences of alternative prices are left for the reader to discern.

Table 2 summarizes the types of results obtained in each of the twelve models reviewed here, indicating conclusions with respect to price and attendant effects of assumptions regarding different actors in the world oil market. This summary reveals commonalities among results and expectations regarding both short-term and long-term prices. Equally important is the fact that the parameters employed for elasticities of supply and demand are also fairly similar, thereby assuring similar results. These similarities indicate some generally agreed upon features of the world oil market that emerge, in part, from assumptions made regarding major actors, partly from the conception of the world oil market

TABLE 2
Comparison of Some Basic Parameters

Model Author	Elasticity Supply	Demand	Type of Conclusion (Major actors in model)
Kennedy	0.33 (non-OPEC) long-term	1.0	OPEC = (only Persian Gulf and North Africa). $3.50 royalty is the most likely in the long-run. (Even with favorable assumptions, it should not exceed $5.00). Revenue optimization, 1980-1985.
Levy			(OPEC–Saudi Arabia, Kuwait, Abu Dhabi). Current price levels unlikely to be sustained if demand growth rate drops (to 2.7%). Inspection of effect of current price in future. 1980-1985.
FEA			(OPEC = unified bloc). $6 is the most likely sustainable price. (OPEC = Saudi Arabia, Kuwait, Abu Dhabi, Libya, Iraq, and Qatar). Sustainable price between $6 and $9, depending on amount of suppressed capacity. Optimal price for maintenance of market share, 1985.
Blitzer, Meeraus-Stoutjeskijk	0.2 (non-OPEC) short-term	not specified	(OPEC = unified bloc). Price should be lowered to preserve demand and market share. (OPEC = Saudi Arabia, Kuwait, Abu Dhabi). Reduced price and increased output is best strategy; actual price dependent on demand elasticity. Optimal revenues with maintenance of market share. 1995.
Kalymon	0.2-0.4 long-term	−0.2 – −0.4 long-term	(Monolithic OPEC). Price reduction to $8.68 with annual 1% increases, reaching $15.00 in 2027. (Sub-OPEC cartels). Reduce price lower, raise them slower to achieve maximum revenue. Optimized revenue and resource exhaustion. 2027.
Nordhaus	"no responsiveness of final demand to price" (p. 541)	not specified	(Competitive Market–no cartel). Future long-range prices do not exceed $3.20. Totally competitive price. 200 years.

Table 2 (Continued)

Model	*Elasticity*		
Author	*Supply*	*Demand*	*Type of Conclusion (Major actors in model)*
Bohi-Russell			(Competitive optimization). Long-range price between $7.50 and $10 (probably closer to $7.50). OPEC generally stable.
Pindyck	$6/bbl short-run, .09; long-run, .35; $12/bbl short-run, .16; long-run, .52	$6/bbl short-run, .04; long-run, .33; $12/bbl short-run, .09; long-run, .90	(OPEC = unified bloc). Price hike to $14, drop to about $9 by 1980, gradual increase to $20 by 2010. (OPEC–saver countries and spender countries). With variable output shares, spender countries satisfy all demand until exhaustion in 10 to 12 years; then saver countries produce to meet demand. Price drops until just prior to saver countries' reentry into the market, shoots up, then stabilizes, rising after 2000. With fixed output shares, results are similar to (OPEC = unified bloc) case. Optimal price in terms of revenue. 2010.
Murakami	not specified	not specified	(Submodels of producers and consumers). Various alternate policies examined and their utility shown. No price specified. 1965-1985.
Ezzati	0.4 (U.S. and Canada); 0.1 (Latin America, Europe, Asia)	0.4 long-run	(Submodels of producers and consumers). OPEC revenue maximized at $16. 1972-1980. Elasticities are 1980 price elasticities.
Eckbo			(OPEC = unified bloc). Optimal price is $6.50 in 1975, climbing to $11.50 in 1990. (OPEC without Iraq, Gabon, Nigeria, and Indonesia). Optimal price is $4 in 1975, growing to $9 in 1990. (OPEC = Saudi Arabia, U.A.E., Kuwait, and Libya). Optimal price is $3 in 1975, growing to $8 in 1990. Revenue optimization. 1975-1990.
Ben-Shahar		.3 long-term	(OPEC = unified bloc). Either one-short price hike in 1982 from $4 to $17.65, a $7 price increasing 8% per year, or a constant $11 price, in that order, are optimal pricing polices for OPEC. (OPEC = Saudi Arabia or everybody else). Optimal prices for Saudi Arabia are lower than total OPEC's. Everybody else's optimal strategies are slightly higher than total OPEC's. Revenue optimization. 1975-1990.

employed, and in part from initial conditions that determine long-term prices. With few exceptions, future prices tend to be lower than those prevailing at the present time. Indeed, the functional specification of major relationships modeled go a long way in accounting for the apparent convergence of results.

Finally, it should be noted that the models reviewed employ specifications of supply, demand, and price that are common in the commodity-modeling literature.[8] There is little innovation or theoretical development. More important, there is a marked lack of cumulativeness in theory, substance, or policy analysis. Indeed, with few exceptions, the predominant tendency is to employ conventional specifications regardless of their relevance to the particular market at hand or to their usefulness as an approximation of the world oil market and its idiosyncratic features.

THE CONSTRAINTS OF CENTRAL TENDENCIES

The structure of these twelve models is indicative of the dominant approach used to represent the world petroleum market, and, more significantly, the perspective adopted to depict central features of trade in crude petroleum. That representation is characterized as follows.

First, there is generally an explicit formulation of an adversarial situation in which only producers and consumers interact and in which the emphasis is generally on the concerns and priorities of the consumer countries or the constraints and optimal prices for producer countries. World oil models seldom adopt or appreciate a systemwide or broader perspective on the overall exchanges linking these countries.

Second, most models seek to determine the implications of various "policies" or interventions. But the evaluations are made largely in terms of comparing numerical values for the target variables, and not assessments of overall gains and losses attending each policy, or of comparing the target variables that reflect the interests of different parties in the oil market, thereby revealing the different implications for different groups. There is seldom an explicit referent against which the impact of different policies is evaluated.

Third, a narrowly conceived market perspective continues. In only a few cases is there reference to a broader view of oil exchanges. The market imposes a closure on the interactions modeled that precludes a more comprehensive international analysis or evaluation of the extent, type, and economic and political consequences of trade in petroleum under different supply, demand, and price assumption.

8. See, for example, Labys (1973) for a review of the analytical structure of commodity models.

Fourth, by defining the "problem" as created by the oil exporting countries for the oil importing countries, analysts ignore the role of the international oil companies. Reference is rarely made to these companies, and in no case is there an explicit inclusion of their influence or leverage in representation of the oil market. This omission may have serious distorting effects.

These four tendencies are particularly revealing of the world view (or paradigm) prevailing in world oil models, and they point to a profound irony: while everyone has recognized the pre-OPEC (and by some observers' assessments, post-OPEC) importance of the oil companies in shaping the world petroleum market, in setting prices, allocating market shares, and controlling production, both simulation and optimization models of the world oil market ignore the international oil companies' interests. No attempt is made to distinguish between the roles of the oil companies in the worldwide oil exchanges and those of the producers and consumers. The interactive impact of country-cartel and company-cartel upon the world petroleum market is, therefore, not delineated, nor can the implications of prevalence of complex cartel arrangements be revealed by the paradigm employed or specific functional relationships modeled.

Clearly, the dominant approach in the modeling literature for examining petroleum prices under competitive and cartel conditions is predicated on important policy concerns. Among these is the belief that persistent OPEC price departures from competitive norms reflect a degree of misallocation of resources in the long-run that may have some severe inefficiencies. So, too, by juxtaposing competitive and noncompetitive conditions there is a recognition of the "distorting" features of the market. This recognition is a prerequisite for policy deliberations regarding appropriate responses to OPEC.

Such policy concerns cannot be addressed within the context of economic analysis that pays insufficient attention to the prevalence of dual types of cartel influences—the country-based OPEC cartel and the persistent influence of the company-cartel. Sophisticated analysts of the petroleum market continue to acknowledge the influence of the international oil companies in allocating market shares and regulating production schedules, but economists modeling the world oil market (or components thereof) neglect this fundamental influence. The complicating features, of course, are created by the persistence of company-cartels in the context of a growing strength of a country-cartel.

TOWARD A RESPECIFICATION OF INTERNATIONAL PETROLEUM EXCHANGES

Against this background, we propose a view of the world oil market that takes explicit cognizance of the consumer countries, the producer countries, and the international oil companies in influencing the nature of the exchanges and the determination of price and presents a more realistic representation of oil-related exchanges. An explicit recognition of the differences in the roles and functions performed by each entity and their potential effects upon price setting, oil policies, and overall economic transactions is an important extension of the market perspective presented in the oil models reviewed.

We must begin with the recognition of the role of oil-exporting countries in influencing prices, and acknowledge that role by setting a tax component of price exogenously, but at the same time constrain their influence by modeling endogenously the supply and demand relationships that impinge upon price (Choucri, Ross, and Meadows, 1976). The simulation model we propose entails a fairly comprehensive specification of global energy exchanges in terms of supply-and-demand relationships and in terms of interactions and leverages available to producers, consumers, and international petroleum companies for influencing price. In this context, the main objective of this revised view is the delineation of the structure of petroleum exchanges to enable an explicit determination of influences on—and effects of—prices upon worldwide economic transactions.

For comparative purposes, it is useful to highlight the major features of the International Petroleum Exchange Model (IPE) presented elsewhere (Choucri, 1979) as it contrasts with the other twelve models of the world petroleum market reviewed in this paper.

(1) The IPE model represents *generic* processes in the global exchanges revolving around trade in petroleum. The perspective adopted includes, but extends beyond, the confines of one market, and it takes into account oil production processes, oil trade, and international financial consequences.
(2) The model is structured in terms of interactions among *three entities:* producer countries, consumer nations, and international oil corporations.
(3) The *price* of oil is set largely by the exporting countries in their determination of the tax rate; but the importing nations and the international oil companies also influence price.
(4) Price is specified as a function of the tax rate, oil production *costs*, and the markup of the international oil companies.
(5) *Markup* is a means by which the oil companies adjust to supply-and-demand influences in the world oil market.
(6) The quantity of oil supplied is determined largely in terms of oil *production* in the exporting countries; however, there is provision for the use of domestic sources of oil in the consuming countries.
(7) *Demand* is formulated in terms of total demand for oil and demand for imports from the Gulf area.
(8) *Imports* from the Gulf are calculated taking into account domestic sources of production in the oil-importing countries.
(9) Imports and domestic production are influenced by the price of oil that also determines the extent to which *energy substitutes* become available.

(10) Imports from the Gulf generate *oil payments* which contribute to the producer countries' balance of payments.
(11) The *balance of payments* are computed on the basis of oil payments to the exporting countries, the investments of the oil producers in the economies of the consumer nations and their purchases of goods and services from the consumers, as well as the repatriation of profits by the international oil companies.
(12) Fundamentally, the model is one of international *exhanges*, modeled endogenously, except for the tax rate which is exogenous.

The International Petroleum Exchange Model represents an integrated framework for thinking about our common resource predicaments. To be useful, it must be employed as a simulation model to examine the implications of alternative assumptions about energy demand and international relations and consequences of policies designed to bring about preferred outcomes. This framework stresses the broader economic and structural contexts within which the oil market operates. The resultant price emanates from the overall exchanges involved and not from narrow market relationships alone. Such a perspective will contribute to the avoidance of state-centric, market-oriented distortions inherent in prevailing discussions of energy "crisis" and the attendant bias of focusing on either the consumer or producer states alone.

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