THE INTERNATIONAL PETROLEUM EXCHANGE MODEL

Reference results and validation

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The author describes the IPE model and compares its main results with the data for 1970–1978. The model's results are close to the actual consumer-import demand for those years. The model's forecasts of the future demand for oil imports, over the next 20 years, are considerably lower than the forecasts produced by some other studies.

THE INTERNATIONAL Petroleum Exchange (IPE) model was developed at MIT to provide a systemwide perspective on the exchanges between producers and consumers of petroleum and their interactions with the oil companies.[1] The model depicts not only the characteristics of the oil market, but many features of global exchanges that remain implicit in other models.[2] It is a general framework for analysing the flows of oil and of payments across national boundaries and identifying their worldwide repercussions. These flows generate a global interdependence which, in turn, is characterised by the consumer countries' claims upon the global production of oil; producing countries of the Gulf meet these claims with the objective of accelerating their own development; and oil companies continue to exert considerable influence and, to some extent, regulate the international oil industry.

The IPE model is structured around the determination of price and its effects internationally. Price is the rate of exchange in the buying and selling of petroleum. The parties to this exchange are specified as aggregate buyers (the oil-consuming and oil-importing countries of the OECD), aggregate sellers (the oil-exporting countries of the Gulf region in the Middle East), and agents performing managerial functions (the major international oil corporations).[3] Sellers besides those in the Gulf are not treated explicitly, but are assumed to play a role in market equilibration in the short run.[4] In 1970, the Gulf region accounted for 28% of all petroleum production and 51% of

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world exports. In 1978, the figures were 33% and 65%. Today, the OECD countries accounts for 82% of all imports worldwide and 79% of imports from the Gulf.

The model is structured as a dynamic simulation, starting with 1970 values and recalculated to 2000. Setting initial values (and key parameters) to 1970 is designed to delineate the structure of exchanges prior to the price increases of October 1973. The results are reported in 1979 dollars. The intent is to trace the effects of this disturbance, and compare changes since 1970 to the effects of alternative price changes. The concern is always with the international implications of the economic and political interdependence that is generated by trade in crude oil, and by the policies of buyers, sellers, and companies.

The major features of the IPE model are as follows.[5]

The model adopts a *political economy* perspective which includes, but extends beyond, the confines of one market, and takes into account oil-production processes, oil trade, and international financial and security consequences. It is structured in terms of interactions among three relevant entities—producer countries, consumer nations, and international oil companies.

A component of *price* is set by the exporting countries in their determination of the tax rate on extraction, but the importing nations and the international oil companies also influence price. Price is a function of the tax rate, oil production costs, and the markup of the international oil companies. Markup is a means by which the oil companies adjust to supply and demand influences in the world oil market.

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. Demand is formulated in terms of total consumer demand for oil and demand for imports from the Gulf area. *Imports* from the Gulf are calculated taking into account domestic sources of petroleum in the oil-importing countries. Imports and domestic production are influenced by the price of oil that also determines the extent to which *energy substitutes* become available.

Imports from the Gulf generate *oil payments* which contribute to the producer countries' revenues and appear as a major claim against consumer countries' balance of payments. The *balance of payments* is computed for all petroleum-related transactions—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.

Fundamentally, the model is one of international independence reflected in the economic, resources, and political interactions underlying oil trade.

The emphasis is on the price of crude petroleum; however, the price of final products for end use to the consumer countries can be specified as well.

Conceptual base

The IPE model is a dynamic model in which time is of great importance. Price is set as a function of the tax rate and the markup of the oil companies.

Prices changes affect both the quantity demanded and the amount supplied. In turn, supply and demand adjust to price. However, there are time lags involved on both sides. On the supply side, there are the lags associated with investment delays. In the short run, demand adjusts to price, and supply from the Gulf is relatively unresponsive. Non-Gulf supplies adjust to meet demand at the prevailing price. Over the longer run, both supply and demand adjust to price and, in turn, influence the final determination of price.

The activities and interactions of the producer countries, the consumers, and the international oil companies generate the adjustments of supply and demand to price. These adjustments influence price by altering the markup of the oil companies. These adjustments to price are not instantaneous. Price at t_1 leads to a quantity demanded, which leads to an amount supplied. That amount is constrained by previous demand patterns and by the costs and investments that have generated productive capacity. Demand, in turn, is influenced by past prices and by price expectations. Depending on price and quantity, the process may be extremely stable. But with rapid changes in the tax rate, there is a dynamic interaction that may induce instabilities in the process because of the lagged response of both supply and demand. The driving mechanism is for supply to adjust to the amount demanded which, in turn, responds to price.

The IPE model does not specify the price-determining process in its full complexity by representing the decision process by which suppliers set their tax rate. However, it specifies and includes major factors that generate a final price of crude oil, and then examines the international economic and political consequences of these prices. The impacts of price upon key variables in the oil trade, such as consumer demand, expenditures on oil imports, balance of payments, corporate oil profits, and producer revenue are modelled explicitly, as are the alternative financial investment opportunities of the producer countries. This model of price determination is one in which there is an interdependence of supply and demand, but that interdependence is not the only influence on price. The model is based on key equations which represent dynamic behaviour and a set of accounting equations which monitor the effects of this behaviour. The essential features, of course, are the demand, supply, and price relationships.

The agents in the market—importers, exporters, and companies—can engage in activities that contribute to the adjustment process in both the short and the longer run. The IPE model combines the characteristics of two types of economic models—the dominant-firm model for a short-run analysis, and longer-run Marshallian adjustment process. The dominant-firm model applies to the Gulf producers who make price and quantity decisions in the short run by setting the tax rate on extraction and/or the amounts to be produced or of capacity to be utilised. In the longer run, their production responds to the size of the residual market (where excess demand is met in the short run by non-Gulf products) and to the price responsiveness of demand. Less directly relevant to the oil market, but important for the overall oil-related transactions, are the investment policies of the producer countries.

In the short run, consumers can influence the size of the residual supply, increase domestic production and, to some extent, cut their imports. In the

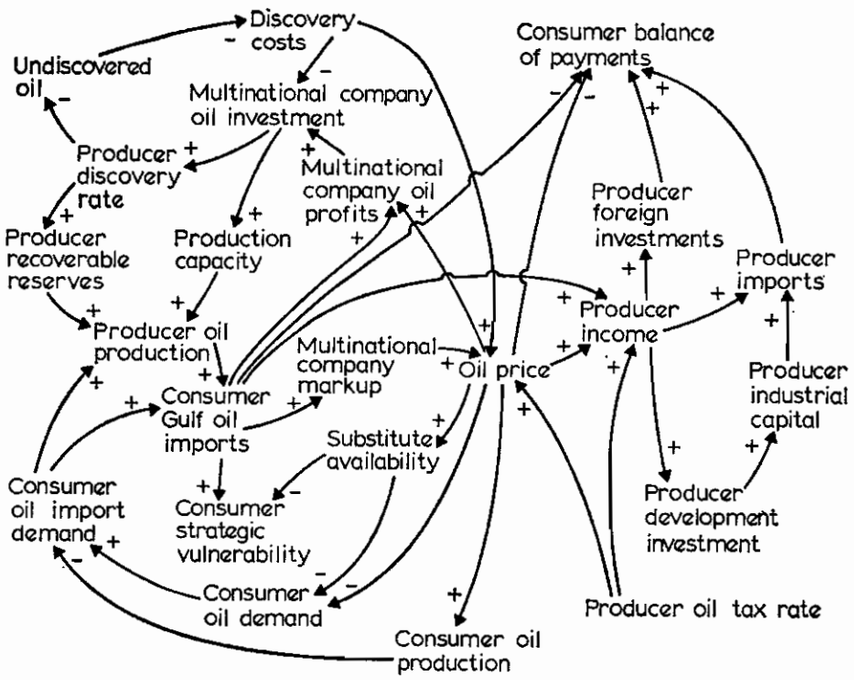

Figure 1. Simplified overview of major causal loops in the IPE model (plus sign denotes that an increase in one variable led to an increase in the other, minus sign that an increase in one variable led to a decrease in the other). *Source:* N. Choucri, *International Energy Policy* (in press)

longer run, they can reduce demand and expand the use of alternative sources of energy.

The companies' markup is the immediate adjustment to prevailing market conditions. In the longer run, they influence exploration and development through their investments in the oil industry. Their impact on Gulf supply is thus of a longer-run nature.

Changes in the structural characteristics of producers, consumers, and oil companies and changes in differential power and capacity can be inferred from observing the evolutionary behaviour of output variables under alternative scenarios and underlying assumptions. The key issue is who gains under different price and production policies. The issue sheds light on the oil market and the conditions of international petroleum exchange at any point in time. Figure 1 represents the major relationships in the IPE model. Producers and consumers interact through financial and economic transactions, mediated by the activities of the international oil companies, and constrained by the geological and technological features of the oil production process. Figure 1 depicts, in summary form, the theory of price formulation of this model.

Computational structure

From a computational point of view, the model is composed of seven sectors.[6] It is designed to represent the physical characteristics of oil production, the

economic context and constraints, and the international financial exchanges that ensue from the trade in oil.

The sectors of the models can be described briefly as follows:

- The *supply sector* represents the physical stages of oil production, tracing the process from exploration for oil-in-place and the development of recoverable reserves to the installation of productive capacity and actual production.
- The *financial sector* makes key calculations for each of the three entities in the oil market: oil-import expenditures for consumer countries, corporate profits and oil investments for the oil companies, and oil income for the producer countries.
- The *management sector* specifies the corporate investment decisions affecting the supply of oil. The major investments of the multinational corporations in development and exploration are based on information drawn primarily from the supply sector, in conjunction with considerations of oil demand from the consumer sector.
- The *price sector* calculates the price of oil based on inputs from other sectors of the model. The tax rate is the exogenous component; production costs and the corporate markup are also taken into account. Once calculated, the effects of price are then transmitted throughout the model to compute its financial and security implications for producers and consumers.
- The *producer sector* models the process of industrial development in the Gulf states, which generates demand for development investment and for imports of goods and services. The tax rate is set in this sector as an external policy variable. It is a key input of the price calculations.
- The *consumer sector* computes demand for oil imports and monitors the consequences of such imports for the consumers' strategic vulnerability and dependence upon external sources of supply. This sector models supply and demand for oil from domestic sources in consumer countries and the availability of substitutes.
- *The international economic sector* calculates the consumer balance of payments and traces the recycling activities of the producing states, thus linking and registering the consequences of actions taken by the consumer countries, the producers, and the oil companies.

Figure 2 depicts the *computational* structure of the IPE model in general terms. It indicates the connections among the sectors and the key variables providing the links. It is a guide to the design of the simulation model and its overall integration.

Simulation versus actual trend

When fully integrated, the seven sectors of the model, together, present a general international perspective on oil issues. The reference simulation of the IPE model employs the historical (actual) tax rates from 1970 to 1978 as the major exogenous input to price determination and, by extension, to generating overall model behaviour.[7] The *integrated* model generates results that are not, of course, identical to the results on a sector-by-sector basis.

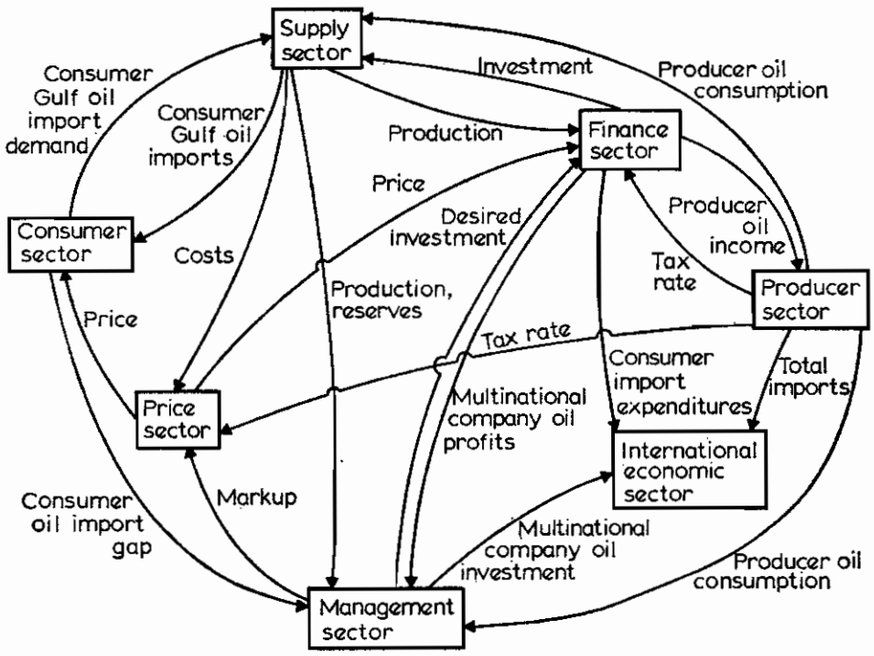

Figure 2. Selected linkages between sectors in the IPE model. *Source:* N. Choucri, *International Energy Policy* (in press)

I shall look at here the extent to which the forecasts generated by the IPE model are, in fact, within the range of plausibility and whether they highlight some features of a possible future that must be given more than the usual attention given to models of the oil market.[8] The comparisons of the model results are done in two ways: first by checking wherever possible the simulated values with actual data (1970–1978); second, by comparing for selected variables the simulation for the reference case with the results of other oil models or related works. To a large extent, the IPE model is based on empirical data. Nonetheless, the results must be evaluated as generated by the assumptions, analytical structure, initial conditions, and endogenous behaviour.

Table 1 presents the real and simulated values for eight years, for 10 critical variables in the integrated model which provide the basis for validation. These indicate the extent to which the reference simulation tracks known (historical) values on an annual basis, from 1970 to 1978. All results are in 1979 dollars. (Due to parameter changes, many variables have been revised, with slight fluctuations. The results still hold.)

Looking at consumer countries' demand for oil, it is clear that the model output is very close to actual demand prior to the price increase of 1973 and off by 2 thousand million barrels and more subsequently. This difference, though not extensive, represents a deviation of 15% of total demand. It is difficult to determine how much of this difference is due to an initial over-

TABLE 1. COMPARISONS OF MODEL RESULTS AND ACTUAL DATA

	1970	1971	1972	1973	1974	1975	1976	1977	1978
Consumer oil demand (thousand million barrels)									
actual	11·32	11·88	12·77	13·68	12·99	12·56	13·41	13·69	14·00
reference	11·14	12·01	12·88	13·69	14·47	15·19	15·75	16·09	16·23
Consumer oil-import demand (thousand million barrels)									
actual	7·53	8·09	8·49	9·91	9·63	8·61	9·64	10·04	9·73
reference	6·94	7·71	8·46	9·18	9·84	10·41	10·78	10·85	10·66
Consumer oil production (thousand million barrels)									
actual	4·29	4·23	4·27	4·16	3·99	3·88	3·90	4·12	4·41
reference	4·20	4·30	4·41	4·52	4·64	4·77	4·97	5·24	5·57
revised[a]	4·20	4·17	4·13	4·11	4·09	4·09	4·12	4·20	4·31
Producer oil production (thousand million barrels)[b]									
actual	4·37	4·44	4·80	5·70	5·74	5·18	5·86	5·95	5·47
reference	4·23	4·75	5·06	5·51	5·95	6·36	6·61	6·66	6·56
Producer oil demand (thousand million barrels)									
atual	0·111	0·121	0·136	0·160	0·181	0·217	0·266	0·294	0·362
reference	0·117	0·121	0·126	0·131	0·136	0·141	0·147	0·154	0·161
Producer oil income (1979 US$ thousand million)[b]									
actual[c]	16·83	19·79	19·73	27·92	79·98	70·58	85·58	80·95	80·44
reference	9·55	11·01	16·21	15·12	62·89	83·36	94·85	93·31	85·30
Producer investments (1979 US$ thousand million)									
actual	7·78	9·56	12·11	15·69	40·03	57·53	74·76	80·68	na
reference	0	0	0	0	7·0	57·3	118·3	186·6	253·7
revised[d]	0	0	0	0	3·92	38·60	75·03	112·79	145·45
Producer total imports (1979 US$ thousand million)									
actual	9·18	10·12	11·76	14·43	19·76	29·99	39·92	48·05[d]	nd
reference	5·44	5·74	6·12	6·53	7·14	8·55	9·85	11·04	12·00
revised[d]	9·26	9·64	10·75	11·92	14·86	25·32	34·03	41·04	45·44
Consumer oil-import expenditures (1979 US$ thousand million)[b]									
actual	25·71	29·61	31·66	40·92	95·75	82·73	97·07	100·95	88·24
reference	20·91	25·38	32·75	33·60	83·33	105·69	118·47	117·18	108·76
Consumer balance of trade (1979 US$ thousand million)[b]									
actual	−16·53	−19·49	−19·89	−25·17	−76·00	−52·74	−57·15	−52·90	na
reference	−15·47	−19·64	−26·62	−27·07	−76·19	−97·14	−108·61	−96·76	−92·17
revised[d]	−16·89	−21·54	−28·60	−28·81	−75·77	−88·24	−93·54	−86·47	−74·84

Notes: [a] See text. [b] Variable labels refer to model variables as defined in N. Choucri, *International Energy Policy* chapters 3–9 (in press). Actual values include adjustments due to differences in definitions. [c] Producer petroleum exports. [d] See text.
Sources: BP Statistical Review of the World Oil Industry, 1972–1978; *International Financial Statistics*, International Monetary Fund, May 1979; *International Petroleum Encyclopedia*, 1977.

estimate of demand, and how much is subsequently due to the underestimate of the consumers' response to the price increases in 1973.

Consumer-import demand generated by the model is consistent with the actual values. The difference is < 1 thousand million barrels for six of the eight years. Differences can be explained by the year-to-year fluctuations due to inventory changes, price and demand expectations, and so forth. Imports are simply the difference between demand and domestic oil production. The model estimates production from domestic sources almost exactly from 1970–1972. The effects of the initial price increase result, by 1976, in the model overestimating consumer oil input demand by about 1 thousand million barrels.[9] Because both demand and domestic production are overestimated by 1977, partly offsetting each other, the result is an overestimate of about 1 thousand million barrels in the import demand of consumer countries.

Oil production in the Gulf is almost precisely estimated prior to the price increases. From 1975 to 1977, the model 'produces' about 500–1000 million barrels more than do the Gulf fields. Again, although this amount is not large, it is extensive given the total volume of oil production. Since demand is overestimated by the model, it probably is the source of the overestimate in Gulf production. In addition, price controls on consumer countries' domestic

production (notably the USA) increase demand, thus imports, and depress domestic supply.

The model also underestimates the oil consumption of the exporting countries. This can be explained by the fact that the coefficients in this equation are based on data to 1973, which may cause underestimates of the effect of higher petroleum revenues in the later years.

The total investment of the producer countries is generated entirely by the model, in the sense that it derives from oil revenue and is endogenously computed. This includes their foreign investments as well as the returns on their investments overseas. There is an obvious underestimate in comparison with actual data prior to 1974. One important explanation is that the model does not incorporate the constraints of absorptive capacity. The domestic limitation on the ability of the producer countries to carry out investment programmes are, accordingly, not reflected in the model's estimates of their investments. The figures generated indicate what is available for investment after other commitments are taken into account, but there is no specification that they are effectively invested. The revised line represents an adjustment of the equation specifying producer imports of goods and services. The results are improved.

The model markedly underestimates the imports demand of the producer countries—by about $5 thousand million in the early 1970s to $12 thousand million by 1974. This, of course, can be accounted for largely by the fact that the equations do not include a large-scale importation of weapon systems, complex technology, or other goods that have been imported by Iran and Saudi Arabia in recent years. These countries' import bill for noncommercial goods has been extensive and is not generated by our model—nor is it intended to be. Only an increase of the income coefficient in the import-demand equation by a factor of ten produced the close fit seen in the revised estimate. This confirms that the producers changed their behaviour substantially after the 1973 price increases.

A much closer correspondence between simulated and actual values is apparent in the consumer countries' payment for oil imports. There is a close correspondence in the consumers' balance of trade. There is an overestimate of $1 thousand million in 1970, becoming nearly $18 thousand million for 1972 and, from 1975, a continuous overestimate. Since the balance of trade is the difference between the producers' imports of goods and services from the consumer countries and the consumers' oil payments, it reflects the trends in both variables and, to some extent, offsets errors. The revised data are better, but still overestimate the later years.

In summary, the sources of external error include economic growth assumptions of the model which are based entirely on OECD assumptions, and regression underestimates of the effect of oil-income increases. (Note also that the model adjusts the tax rate only every six months, which causes some slight variations from historical data.)

Comparison with other models

In comparing the IPE model results with those generated by other models, several facts must be kept in mind:

- the IPE model is a general model, in contrast to other oil models which are explicitly partial-equilibrium structures;
- the model assumes a tax rate per barrel, but price is generated endogenously;
- none of the existing models includes all the variables of the IPE model, so the comparisons are shaped by the limitated scope of other models; and
- the IPE model does not disaggregate individual consumer or producer countries, thereby precluding specific comparisons with models that address themselves specifically to individual countries.

Due to space limitations, the comparisons which follow will focus on consumer demand and on price.

TABLE 2. COMPARISONS OF CONSUMER OIL DEMAND (total for Western Europe, Japan, and the USA unless otherwise specified)

	Consumer oil demand (thousand million barrels)				
	1970	**1975**	**1980**	**1985**	**2000**
Reference analysis	11·06	15·13	16·32	16·90	21·45
Historical data[a]	11·32	12·56			
American Petroleum Institute	10·95	14·84	19·27		
Gay (1976)	12·67		14·42[b], 16·06[c]		
Middle Eastern Oil (1971)[d]			14·48		
Kennedy (1974)					
Base case: $5·25 duty (PG)			12·74–12·92[e]		
$7·00 duty (PG)			11·83–11·97		
$8·75 duty (PG)			11·02–11·28		
OECD (1974)					
Base case: $3/bbl			20·0	24·7	
$6/bbl			16·8	19·3	
$9/bbl			14·9	16·9	
OECD (1977)					
Reference case			15·0	17·2	
Accelerated policy				14·6	
High growth				18·5	
Low growth				16·2	
CIA (1977)			14·3–15·3	16·8–19·2	
ITC (1977)			14·3	16·4	
WAES (1977)[f]					
Case C, C-1[g]				15·81	21·0
Case D, D-1[h]				15·51	17·41
FEA (1974)					
$3/bbl				25·3	
$6/bbl				20·1	
$9/bbl				16·8	

Notes: [a] *British Petroleum Statistical Review of the World Oil Industry* (1975); [b] 2·8% growth in demand for oil, 1975–1980; [c] 5·2% growth in demand for oil, 1975–1980; [d] North Sea production not considered; [e] using base and high supply elasticities (0·33 and 0·67); [f] using North America instead of the USA; [g] $11·50 oil from 1977–1985, $17·25 oil from 1985–2000; [h] $11·50 oil.
Sources: American Petroleum Institute (1969); Central Intelligence Agency (1977); Federal Energy Agency (1974); Gay, as sited in Bhattacharya (1977); Kennedy (1974); Gersic and Deyman (1977); Organization for Economic Cooperation and Development (1974 and 1977); Schurr and Homan (1971); Workshop for Alternative Energy Strategies (1977).

Table 2 compares the oil-demand estimates of ten other sources with the model's forecasts and with actual data provided by British Petroleum. Note that for 1975 the model demand is higher by 2 thousand million barrels than the historical data, but is within the existing range of other estimates. If we consider that the recession of 1975–76 in the West caused a lower demand for oil, an

event that the model incorporates only through its use of the OECD demand assumptions, then the forecasts generated are consistent with empirical realities. By 1980, the model's estimate of 16·32 thousand million barrels is well within the middle of the range provided by other estimates.

In calculating the import requirements of consumer countries, we have taken account of production from domestic sources. In 1975, the model estimate for consumer oil production is about 1 thousand million barrels more than the actual figure. By 1980, it is well within the range of other estimates. By 2000, the IPE model generates a forecast for consumer oil production that is lower by about 2 thousand million barrels than the WAES estimate. Thus, in this respect, our assessment of domestic production for the long range is somewhat less optimistic than the WAES study, whereas it is well with the range of the estimates for 1980 and 1985.

Undoubtedly, the *raison d'être* for these estimates is, in part, to determine the magnitude of consumer oil-imports expenditures. In the IPE model, these expenditures are simply the number of barrels times the price per barrel. On the whole, from the consumer countries' perspective our estimate of their expenditures on oil imports is relatively optimistic. These comparisons are presented in Table 3.

TABLE 3. COMPARISONS OF TOTAL CONSUMER OIL-IMPORT EXPENDITURES[a]

	Expenditure (1979 US$ thousand million)					
	1970	1975	1976	1980	1985	2000
Reference analysis	43·6	191·8	213·3	190·2	196·0	399·5
Historical data	43·71	140·48	162·53			
Kennedy (1974)[b]						
Persian Gulf duty						
$5·75				87·5–72·4		
$7·00				79·7–99·9		
$8·75				61·7–95·0		
OECD (1974)						
Base case ($3/bbl)				100·1	129·5	
$6/bbl				144·6	162·9	
$9/bbl				162·9	196·3	
OECD (1977)						
Reference case				167·1	194·6	
Accelerated policy					135·1	
High growth					217·2	
Low growth					178·5	
FEA (1974)						
$ 4/bbl					168·5	
$ 7/bbl					199·2	
$11/bbl					198·7	
WAES (1977)[c]						
Case C, C-1[d]					201·1	549·1
Case D, D-1[e]					212·4	299·4

Notes: [a] With the exception of the historical data, the reference analysis, and the figures of Kennedy (1974), all data have been derived by multiplying price times oil consumption. Thus, the first three are closer to consumer expenditures, and the last four are more representative of producer revenues (ie not including delivery costs, etc, a difference of about $1–2/bbl). This represents total imports, not just Gulf, and is not comparable to Table 1. [b] Using base and high supply elasticities (0·33 and 0·67). [c] Using North America instead of the USA. [d] $11·50 oil from 1977–1985; $17·25 oil from 1985–2000. [e] $11·50 oil.

Sources: Federal Energy Agency (1974); Kennedy (1974); Organization for Economic Cooperation and Development (1974 and 1977); Workshop for Alternative Energy Strategies (1977).

Conclusion

In general the IPE model gives an excellent 'fit' for consumer-import demand and for consumer imports. Producer development variables were underestimated, as was the size of the consumer's oil import bill. From the perspective of consumer countries, our results are far less pessimistic than those of other studies. The reference analysis projects a considerably lower future demand than by another model, and considerably more optimistic than the OECD studies. For producer countries, our results are much more detailed than are currently available elsewhere, thereby precluding any comparisons. Since the basic parameters of the producer equations are based on empirical estimates (pooling cross-sectional and empirical data), the key parameters are solidly gounded. The resulting interconnections with the remainder of the model generate behaviour that is extremely plausible.

The IPE model is being used to examine—and forecast—the effects of alternative price policies internationally and the implications of different consumer responses and policies.

Notes and references

1. For a full description, see Nazli Choucri, with D. S. Ross and the collaboration of Brian Pollins, *International Energy Policy: Petroleum Politics, Price, and Power* (Cambridge, MA, MIT Press, in press).
2. Nazli Choucri, "Analytical specification of the world oil market: a review and comparison of 12 models", *Journal of Conflict Resolution, 23*(2), June 1979, pages 346–372.
3. This aggregation is for conceptual clarity: it imposes no irrevocable constraints on results. Nothing in the model precludes a disaggregation of producers, consumers, or companies.
4. In a version of the model, the non-Gulf producers are modelled explicitly in terms of their reserves and responsiveness to oil prices.
5. Choucri, 1979, *op cit* reference 2.
6. An earlier version appeared in Nazli Choucri, David Scott Ross, and Dennis Meadows, "Toward a forecasting model of energy politics", *Journal of Peace Science, 1*(2), 1976, pages 97–111.
7. See N. Choucri, *International Energy Policy*, chapter 11 (in press).
8. In presenting these comparisons, I would stress that the IPE model results have not been 'tuned'. This is intentional. The parameters are not adjusted to approximate reality more closely, nor has exogenous 'tinkering' been done to produce better 'fits'. The difficulties of simulation and forecasting in international relations have been widely discussed, and a synthesis of the major issues is presented in Nazli Choucri, *International Politics of Energy Interdependence: the Case of Petroleum* (Lexington, MA, D. C. Heath, 1976), and a comparison of 12 world oil models in Choucri, 1979, *op cit* reference 2.
9. We did not 'tune' the model. However, a level base production series is tested here to show the validity of such an assumption. Chapter 10 in Choucri, *International Energy Policy* (in press) points to the results of some sensitivity analyses.