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A Ten-Year Retrospective: OPEC and the World Oil Market

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IF THE 1970s were not good years for macroeconomists, they were not alone. Microeconomists specializing in world oil markets fared little better. Their predictions were not particularly accurate, and the orthodox theoretical approach proved not very useful. Ten years after the 1973–1974 oil price quadrupling, there remains much disagreement about what happened and what we can expect in the future. Some argue that what happened was just an artificial scarcity, orchestrated by a cartel. Others say that the price increases reflected an emerging scarcity of an exhaustible resource, in a basically competitive market.

This paper reviews the main events in the world oil market since 1973 and some major explanations as to what happened and why (Section I). Then there is a discussion of some projections for the next two decades and of some implications of various theories about OPEC's decisionmaking process (Section II). Section III summarizes what we have learned about modeling OPEC and the world oil market. This includes: the dominant theoretical approach based on the wealth-maximization model of Harold Hotelling (1931); the simulation approach most common in the applied literature, which envisages target-capacity-utilization pricing by OPEC; and the difficult problem of modeling price behavior during disruptions. Finally, Section IV discusses some important unresolved issues, both theoretical and empirical.

A variety of contributions to the literature will be considered, but our discussion pays special attention to two important recent works. One is the book edited by James Griffin and David Teece, henceforth GT (1982), an important collection of papers on OPEC and world oil, prepared for a 1981 conference at the University of Houston. The other is the 1980–1981 world oil study by the Energy Modeling Forum of Stanford University, which involved ten prominent models of the world oil market (EMF 1982).

I. *Explaining OPEC Behavior*

A. *The 1973–1974 Oil Price Quadrupling*

The 1973–1974 oil price quadrupling was an astounding event. There was much disagreement at the time about its significance and sustainability. Even now, there are several explanations of its cause.

Initially, many people thought that OPEC had blundered, that it was pricing itself out of the market. The most prominent person to hold such an opinion was Milton Friedman (*Newsweek*, March 4, 1974). They believed that both OPEC and oil prices would collapse. For many, it followed almost axiomatically that OPEC would be unstable because it was a cartel.

Others argued that it was not OPEC but the U.S. State Department that had blundered. Instead of opposing a price increase, it had actively encouraged one. These charges were personalized as the "Kissinger-Shah" connection and were aired on CBS' "60 Minutes." These and other attempts at scapegoating are discussed by Martin Greenberger (1983, pp. 21–22), who concludes: "One may wish that certain representatives of government or certain institutions had acted differently at critical points in a crisis, but that does not mean they created the crisis or that they had the power to avert it."

Apart from these assertions of blundering behavior, there are basically two explanations of what happened in 1973–1974. The one most widely accepted by economists is that OPEC effectively cartelized the world oil market, exploiting its power to raise prices above competitive levels by restricting production. Earlier statements of this view are numerous, but the article by Robert Pindyck (1978a) is the clearest presentation. He utilized an applied wealth-maximization model, from the theory of exhaustible resources, to generate plausible numerical results.

The other explanation argues that OPEC was largely irrelevant as an organization and that its members acted competitively. In this view, the price increase merely reflected a shift in the underlying market conditions, in favor of OPEC, that had been occurring since the late 1960s. World oil demand had been increasing rapidly, non-OPEC production was stagnant and extraction costs were increasing, and the demand for OPEC oil surged. The 10 percent annual growth rate in OPEC production from 1960 through 1973 was unsustainable, even with OPEC's large oil reserves. By mid-1973, months before the Arab-Israeli War and subsequent price quadrupling, the market was already very tight: OPEC's official prices were well below those in the spot market, a freely competitive market in which a very small part (below 10 percent) of OPEC's exports were traded. As Paul MacAvoy has argued, ". . . there was no avoiding the substantial price increases necessary to clear the market of annual increases in crude oil demand" (1982, p. 56–57).

This latter explanation has at least two variants. Ali Johany (1980) argued that price increases were the natural result of the shift in property rights from the international oil companies to the producing countries that occurred in the late 1960s and early 1970s. Because the producing countries had lower discount rates than the oil companies, who feared expropriation, they sought to conserve their oil reserves by refusing to continue expanding production. Price increases were a natural consequence. But, such a view is challenged by Morris Adelman:

> When the Arab countries cut production during the so-called 'embargo' of 1973–74, this was a deliberate collusive act, not the gradual every-country-for-itself tightening of production schedules implicit in the low discount theories [1982, p. 39].

A second variant of the competitive explanation is proposed by Jacques Cremer and Djavad Salehi-Isfahani (1980) and by David Teece (1982). They argued that OPEC supply is best understood as a competitive supply curve which is backward-bending. Such a curve is the aggregated response of suppliers with limited absorptive capacity. This results from assumptions about diminishing marginal utility of consumption and domestic investment, together with an unwillingness to accumulate foreign assets. Thus, prior to 1973, the relatively low price was determined by the intersection of demand and the upward-sloping (lower) portion of the OPEC supply curve. With world economic growth, the demand curve shifted out far enough to intersect the backward-bending (upper) portion of the OPEC supply curve, at a price several times higher than before. (Alternatively, the demand curve could have intersected the backward-bending supply curve at three points: a low-priced stable equilibrium, a high-priced stable equilibrium, and an intermediate equilibrium that would be unstable. The shift from the low-priced to the high-priced equilibrium would have been caused by the supply shock of the Arab oil embargo.) However, none of these theories has been applied so as to generate plausible numerical results.

B. *Aftermath of the Price Quadrupling: 1974–1978*

Despite some initial optimism that OPEC had blundered and would soon collapse, there was surprisingly little response by either demanders or non-OPEC suppliers. Demand for OPEC oil eased off in the 1974–1975 recession but, at its low point, was only 15 percent below 1973 levels. OPEC's ability to restrict output, which many had questioned, was barely tested. By 1976 world oil demand and OPEC production were back to 1973 levels. Non-OPEC production was virtually unchanged between 1973 and 1976.

During this period of declining demand for OPEC oil, virtually all OPEC members had cut back their output. Such "discipline" surprised many observers at the time, given OPEC's lack of a formal prorationing agreement. The OPEC countries were content to maintain the official OPEC price and to react passively to the international oil companies' decisions to reduce output. Such a response can be explained in terms of target-revenue behavior, or a backward-bending supply curve. Even Adelman, who dismisses such an explanation for *long-term* OPEC behavior, adopts it here:

> The higher the price, the better the financial condition of the sellers, and the less pressure on them to cheat and undersell each other in order to pay their bills [1982, p. 55].

Among modelers, the initial consensus in 1974–1975 was that OPEC had "overshot" by quadrupling the price. The new price level was said to be unsustainably high and not in OPEC's own best interest. (See the survey of seven models, from 1973–1975, by Dietrich Fischer et al. 1975.) Price was expected to drift lower by about 25 percent before stabilizing. In fact, it did decline, between 1974 and 1978, but only by about 10 percent in real terms.

Yet as OPEC demand recovered after 1975, there were voices of caution, such as the Workshop on Alternative Energy Strategies, or WAES (1977). They argued that post-1974 prices were unsustainably *low,* not high, and that further price increases would be necessary by the mid-1980s to ward off prospective shortages. Contributing to this view was the growing pessimism about the size and cost of non-OPEC oil reserves and higher-than-expected costs of alternative sources. Moreover, there was a growing realization that the price-responsiveness of demand was weaker and slower than anticipated.

Yet such views were not unanimous. By 1978 there remained substantial disagreement about the prospects for OPEC, especially over the longer term. (See the survey in Gately, 1979, of more than a dozen analyses from the period 1976–1978.) Some projected a sluggish market for OPEC for the rest of the century. But others, including Sheik Yamani (1978) and some scenarios in the WAES report (1977), projected a 50 percent growth in OPEC demand, to 45 million barrels per day (MBD), within 10 years.

C. *The 1979–1980 Oil Price Doubling*

The price doubling of 1979–1980, while not as astounding an event as that of 1973–1974, was certainly a surprise. Few expected such an abrupt and large price increase following the disruptions in Iranian production in late 1978. Even in retrospect, it remains somewhat puzzling: For example, in 1979, the year of the Iranian disruption, average OPEC production was actually bigger than it had been the previous year. Yet prices continued to rise well into 1980.

Just as with attempts to explain the 1973–1974 price increases, there are basically two alternative explanations of the 1979–1980 price increases. Some argue that OPEC consciously exploited the Iranian disruptions to extract still greater profits. But others argue that OPEC was irrelevant as an organization, that price rose because of the underlying demand and supply conditions.

The latter view of OPEC, as an irrelevant organization, has more proponents than it had for the price quadrupling of 1973–1974. The dynamics of the price increase, according to this view, were not substantially different from what would occur from a disruption in a competitive industry with low short-run elasticities. Certainly in 1979–1980 OPEC discipline had broken down. In the words of Robert Stobaugh and Daniel Yergin (1980), it was a process of "leapfrog and scramble." After the disruptions in Iranian production, as the spot market price kept rising, various OPEC members played "leapfrog" with their respective official prices. Aggravating the market tightness was an extended period of aggressive stockbuilding by the importing countries for much of 1979 and 1980. Such a stockbuilding "scramble" during a disruption was certainly perverse. It undoubtedly drove price higher than it would have gone otherwise.

The contrary view of the 1979–1980 price doubling argues that it was merely an extension of what happened in 1973–1974. OPEC further exploited its power to extract still greater profits. It seized the opportunity presented by the Iranian disruptions in a tightening market with low short-run price elasticities. As noted above, projections had been made by the WAES (1977) report and others that, by the mid-1980s, OPEC production would have to increase to 45 MBD, or that price would have to increase significantly. With such output levels now viewed as neither likely nor desirable, OPEC accelerated the shift to higher prices.

Perhaps the most interesting decision during this period was that of Saudi Arabia, in early 1979, at the height of the Iranian disruption, to *cut* its own production. Adelman cites this as the cause of price doubling, placing the blame on a duplicitous—not "moderate"—Saudi Arabia:

> The Iranian revolution is generally considered as the cause for the price jump of 1979–80, from about $12 to about $32 per barrel. But this cannot possibly be true . . . [spot] prices again rose in January [1979], to not quite $20. Then on January 20, 1979—a day to remember—Saudi Arabia cut production from 10.4 to 8.0 MBD . . . by mid-February the [spot] price had jumped to over $31 . . . Saudi Arabia 'led the regiment from behind,' keeping its own official price usually $2 or so below the price for equivalent crudes sold by others . . . Saudi actions speak louder than words. Their 1979 output cutbacks drove the price up to $32 from $12 [1982, pp. 47–48, 55].

Such a view is consistent with a dominant-producer theory of OPEC: Saudi Arabia sets the price, allows other OPEC members to produce what they wish, and acts as the "swing producer," varying its own output to absorb demand and supply fluctuations so as to defend the price.

Theodore Moran (1982) discusses these

events from a different perspective. Although apparently agreeing with Adelman's conclusion that the price increase was engineered by Saudi Arabia, Moran describes a more complex picture of Saudi Arabian decisionmaking. He depicts the various centers of power within Saudi Arabia, such as the "foreign policy establishment" and the "petroleum bureaucracy," and the conflicts among them with respect to oil pricing and production decisions. He suggests a political interpretation of the Saudi reluctance to assert leadership within OPEC at this time:

> [The Saudis] were under great pressure from other Arab states to distance themselves from the US [Camp David] peace efforts, a pressure backed by threats of Palestinian sabotage against Saudi oil facilities . . . With the shock of the Shah's departure . . . and uncertainty about US dependability, Saudi leaders showed extrème reluctance to offend either the new regime in Iran or the newly preeminent Iraq . . .
>
> While there is no certain explanation for Saudi behavior from January to July, it seems apparent that the Saudi leadership could not or would not build the consensus necessary for an oil policy that would deny higher spot market premiums to its neighbors . . . or deprive them of markets, except for the highest political stakes [1982, p. 110].

D. *Aftermath of the 1979–1980 Price Doubling*

The period 1980–1983 is similar in some ways to the 1974–1975 period. The world economy entered a major recession, attributable at least in part to the oil price increases. World oil demand fell by about 20 percent, much more than the 6 percent decline from 1973 to 1975. This resulted from the combined effects of the recession and conservation, both the short-term response to the 1979–1980 price increases and the continuing response to the 1973–1974 price quadrupling. And the demand for OPEC oil dropped by even more, declining more sharply than in 1974–1975. In 1973–1975 it fell by 15 percent, but in 1980–1983 the decline was more than triple that figure.

Part of the differences between 1973–1975 and 1980–1983 can be explained by the expansion of non-OPEC oil production. Although virtually unchanged between 1973 and 1976, at about 17 MBD, it has grown by about 6 percent per annum since 1976, to about 25 MBD by 1983. Most of the increase has come from the North Sea and Alaska, whose reserves were discovered in the late 1960s. Increased output has also come from Mexico, where major discoveries were made in the 1970s.

As evidence of the dramatic adjustments that have occurred, consider the effects of the Iran-Iraq War. Beginning in the Fall of 1980, this knocked out more OPEC production than did the Iranian Revolution. But the timing was important. It happened when oil stockpiles were at historic highs, when demand for OPEC oil was falling and there was much spare capacity. As a result, the impact on price was minimal.

The demand declines facing OPEC were not only much deeper but also longer lasting than in 1974–1975. In early 1983, OPEC production was only about 55 percent of what it had been in 1979. Spot market prices remained almost 20 percent below the official price of $34, and there was widespread price undercutting by OPEC members. OPEC finally faced the reality of the weak market. It cut its official price to $29, the first-ever reduction in its nominal price, and it adopted formal production quotas for all members.

II. *Projections for the World Oil Market through 1990 and 2000*

There is, of course, unavoidable uncertainty about future oil demand, supply, and especially price. Some of this uncertainty is caused by unknown future events, such as supply disruptions, major oil discoveries, and technological breakthroughs. But uncertainty is also caused by lack of knowledge about the present. That is, we are unsure about the exact value of the long-run price elasticity of demand, about how much adjustment to the two major price increases has already occurred, and about the effects on demand of changes in GNP growth rates.

Yet, despite this uncertainty, there is now more agreement among analysts, compared with five or ten years ago, concerning the outlook for the world oil market over the next two decades, at least for a "surprise-free" scenario. But there remains a considerable range of opinion, especially for the late 1990s.

The increased agreement among analysts stems from the enormous amount of work on energy economics in the past ten years. The 1973–1974 price quadrupling provided the impetus for an extraordinary research effort in response to higher-priced oil. There was a substantial amount of scientific and engineering work on the technological and economic possibilities for energy conservation and interfuel substitution. Similar efforts were made on the supply side, to map out more clearly the reserves of conventional oil and to understand the technical problems and likely costs of alternative energy sources such as solar power and unconventional oil (from shale, tar sands and liquified coal).

The increased agreement is evident in the energy projections submitted to a June 1983 conference of the International Energy Workshop (IEW), held at the International Institute for Applied Systems Analysis (IIASA). The results of this polling effort are summarized in Alan Manne and Leo Schrattenholzer (1983). Participating were 78 respondents from around the world—oil companies, government agencies, international organizations, universities, and research institutes. Most projections were for a surprise-free scenario: no major disruptions nor any technological breakthroughs. The IEW poll results are, briefly, as follows.

Median projections of world energy consumption reveal an annual growth rate of about 2 percent between 1980 and 2000. This is much slower than that for world GNP, which is expected to grow at about 3.0 percent. Growth in energy consumption varies among regions: below average in the OECD countries and higher elsewhere. But this increase in energy consumption entails only a slight increase in oil demand over the next two decades—about three-fourths of one percent annually. Within the OECD, oil consumption is expected to decline by about 10 percent in the 1980s and flatten out in the 1990s. This decline will help to offset increases elsewhere. With oil production relatively flat, the increase in energy consumption is provided by increased production of natural gas, coal and nuclear power.

The international price of crude oil, in real terms, in the median projections, is expected to be about 10 percent higher in 1990 than its 1980 level, and another one-third above that by 2000. Of course, there is dispersion among the various responses. But virtually all project a 1990 price level that is no more than 50 percent above 1980 nor more than 25 percent below. For 2000, the vast majority project a price level between the 1980 value and 100 percent above it. Although this represents a fairly wide range, it is not nearly as wide as in the past.

In addition to summarizing the IEW poll results, Manne and Schrattenholzer discuss various reasons for the differences among the projections. Not surprisingly, an important part is played by different assumptions: GNP growth rates, demand elasticities (price and income), the geological resource base for conventional oil, the cost of alternative energy sources and the speed of their market penetration. More surprising, however, is the fact that the source of some of the differences are definitional, as evidenced by the unexpectedly wide variation in the base-year 1980 statistics. These definitional discrepancies may have occurred because of differences in the preparation date of the individual analyses. Finally, they regard the importance of model structure in explaining the variation in poll responses as an "open issue," but observe that their "personal conjecture is that far less is explained by structure than by differences in the numerical assumptions related to supply and demand scenarios" (1983, p. 19).

This IEW polling effort involved a huge number of models and analyses, making it virtually impossible to standardize the assumptions or to determine precisely the sources of the differences in the projections. In contrast, a controlled comparison was done for ten participating models in EMF (1982). Standardized assumptions were made about many parameters, such as demand elasticities, GNP growth rates, the geological resource base for conventional oil, and the cost of alternative energy sources. For twelve "scenarios," each defined by a given set of assumptions about the world oil market, each model generated its projections.

Among the assumptions for the Reference Case scenario were the following. Long-run demand elasticities were: an income elasticity of demand for oil of 1.0, price-elasticity of $-.4$ for aggregate primary energy, and $-.6$ for crude oil. Short-run demand adjustment was specified so as to be consistent with a Koyck-lag structure with a coefficient for lagged demand of .9. The amount of world conventional oil reserves remaining, to be produced if price were $10 per barrel (in 1979 $), was estimated at 1075 billion barrels. This represents about forty-five years' worth of reserves at 1980 levels of world oil consumption. If price were to be $20, it would become economic to produce an additional 15 percent, and at $40 another 6 percent above that. Of these reserves, nearly two-thirds are in OPEC; their productive capacity was assumed to be 34 MBD. With respect to unconventional oil, it was assumed to be available at a cost of $60 per barrel, but only after 1995, with capacity increasing to (at most) 5 MBD by 2000 and 35 MBD by 2020.

For the Reference Case scenario in EMF (1982) the results to the year 2000 are similar to those of the median projections of the IEW poll described above. Energy consumption, for the World Outside Communist Areas (WOCA), grows at 2.4 percent per annum; although higher than the 2.0 percent energy growth for WOCA in the IEW poll median, this is partly attributable to higher GNP growth assumptions for WOCA in EMF (3.0 percent) than in the IEW poll (3.0 percent). Oil consumption grows very slowly, again at a slightly higher rate than in the IEW poll. The world oil price is about double its 1980 level, in real terms, by the year 2000; this is about one-third higher than the IEW poll median.

In the other EMF scenarios, the changes are all in the expected direction. World oil prices are higher if the assumed demand elasticity is reduced, if there is a disruption of OPEC supply, or if the development of alternative energy sources is restricted. Conversely, oil prices will be lower if there is greater conservation, lower economic growth, or if there is a major cost reduction for alternative energy sources.

The results of the various models were systematically compared: across models for a given scenario, and across scenarios for a given model. Although standardizing some assumptions reduced the dispersion of results across models, there remained some significant differences. These are discussed in some detail in an excellent paper by Perry Beider, whose conclusions included the following:

> 1. The choice of recursive simulation or intertemporal optimization model influences types of behavior and major trends in the outputs. The latter models assume here that one or more sectors have perfect foresight, allowing these sectors the advantage of smoothing out over time their responses to changing market conditions.
>
> 2. The inclusion of a feedback effect, in which higher oil prices reduce the economic growth of the oil importing nations, is significant in moderating the magnitude of price changes.
>
> 3. Alternative assumptions about the price responsiveness of non-OPEC oil production have a major impact on the projected prices, although part of this relative significance may be due to greater standardization of other sectors in this study (1981, p. 3).

This EMF study, because it involved a variety of models and because it examined a range of assumptions, provides a valuable benchmark against which to compare other models. For example, within GT (1982) is included a simulation model by George Daly, Griffin, and Henry B. Steele (DGS). This yields results that are relatively optimistic, from the viewpoint of the importing countries. Briefly, they conclude that the 1981 price, in real terms, is likely to provide an upper limit to the long-run price through the year 2000. In contrast, in the EMF study, none of the ten models, under any of the twelve scenarios, projected price in 2000 to be at or below its value in 1980; in most cases it was projected to be from 50–150 percent higher. The source of the differences can be found by comparing three DGS assumptions with the less optimistic assumptions of EMF. DGS use a higher price elasticity of demand for oil (−.73 versus −.6 for EMF) and a lower income elasticity of demand (.75 versus 1.0 for EMF). And they assume extremely high additions to oil reserves in the 1980s and 1990s—rates double to triple those of the 1970s, or about equal to those of 1945–1965 when the "super-giant" fields of the Middle East were discovered. The importance of this oil supply optimism is apparent when the EMF Reference Case results are contrasted with those from a comparable case for DGS (4.5 percent GNP growth, with .75 income elasticity). With DGS, non-OPEC supply doubles by the year 2000, with real price at its 1981 level, and world oil consumption increases by 40 percent. But in EMF, by the year 2000, non-OPEC supply has increased by only one-third, even though real price has doubled from its 1980 level, and oil consumption is only 12 percent higher.

Of course, this does not mean that the DGS assumptions are incorrect—it merely helps us to understand why the models yield different results. But if DGS *do* turn out to be correct, then OPEC will be faced with a prolonged weak market for the rest of the century. Given such a scenario, it is important to understand what would be implied by different theories of OPEC behavior. On this topic, GT (1982) has an excellent discussion, bringing together various theories: political, target revenue, and dominant producer.

With some of the models, the consequences would be optimistic. OPEC behavior in a sluggish market would be the opposite of that in a tight market—an extended period of low prices and excess supply. Using a target revenue model, the symmetric response to climbing up a backward-bending OPEC supply curve in a tight market would be sliding down in a weak market. Lower prices induce greater output to achieve revenue targets.

With a political model such as Moran's, the results are ambiguous. But Griffin and Teece take an optimistic view. They note that, unlike a tight market when OPEC's main producers can both achieve high revenue and advance their political goals (such as influencing the structure of an Arab-Israeli settlement), a sluggish market makes both more difficult. They even suggest that ". . . 'linkage' might be made to work in reverse—the United States and other consumers might continue to purchase OPEC output in exchange for political favors in the Mideast" (GT 1982, p. 212).

But Moran's own political analysis suggests very different conclusions:

> Declining demand for OPEC oil will intensify the pressure on Saudi Arabia from its colleagues and neighbors to reduce production, pick up a disproportionate share of the common export cutback, slow or reverse capacity expansion, adopt budgetary restraint . . . and pay for the basic fiscal needs that remain through low exports at high prices rather than high exports at low prices. . . . A forecast for the mid-1980's based on this scenario could envision Saudi exports continuously modulated to accommodate the demands of the hawks for a tight market, with maximum sustainable capacity actually shrinking to 8.5 MBD, and periodic oil shocks permitted to keep the West from concluding that it can ignore Saudi views on the Middle East [1982, pp. 122–23].

Interestingly, these conclusions are close to those of Adelman (1982), who uses a dominant producer model of OPEC behavior.

III. *What We've Learned about Modeling OPEC Behavior*

A. *The Wealth-Maximization Approach to OPEC Pricing Behavior*

Within economics, the dominant theoretical approach to OPEC behavior has been the wealth-maximizing theory of Hotelling (1931). Recent summaries of this literature appear in Partha Dasgupta and Geoffrey Heal (1979) and in Shantayanan Devarajan and Anthony Fisher (1981). Briefly, the owner of the exhaustible resource chooses prices or quantities, over time, so as to maximize the net present value of the stream of profits from its resource. Under competitive conditions, quantities offered at each date are chosen so that the price (minus marginal extraction costs) will increase over time at the rate of interest. Under monopoly ownership, it is marginal revenue (minus marginal extraction costs) that will increase at the rate of interest. Marginal extraction costs are relatively low within OPEC; in Saudi Arabia they are estimated to be less than $1 per barrel.

Initially there was optimism that this approach would help us understand OPEC behavior; several such applied models were built. As noted above, Pindyck (1978a) used such a model to explain the 1973–1974 price quadrupling as the effective cartelization of the world oil market by OPEC. A one-time event, it involved the restriction of OPEC's output and the shift to a higher price-path. He also argued that this theory was the best predictor of OPEC behavior:

> OPEC's behavior is surprisingly predictable, since the cartel is most likely to take only those actions that are in its best economic interest . . . It makes most sense, then, to adjust the price so that it always maximizes the flow over time of all current and discounted future revenues [1978b, p. 37].

Indeed, this approach so dominated the theoretical literature in economics that its applicability to OPEC was taken as almost self-evident. Such belief in a theoretical model capturing objective reality was reminiscent of the opening sentence of an article by Paul Samuelson, in a different context:

> A rope will hang in the shape of a catenary,
>
> $$y(x) = a_1 e^{\lambda x} + a_2 e^{-\lambda x}$$
>
> because even a dumb rope knows that such a shape will minimize its center of gravity [1965, p. 486].

Thus, even a dumb OPEC would know that it would have to set its price so as to satisfy the appropriate Hotelling conditions.

However, the applied models using this approach were unable to surmount serious practical problems. There are now few such models in use. For example, in the Introduction to GT (1982), although they explain in detail the wealth-maximization model, their (numberless) price-path diagrams are not derived from an operational model nor is one cited. In fact, of the ten models participating in the EMF (1982) study, there was only one wealth-maximizing model of OPEC behavior, that of Stephen Salant (1982). Even among its practitioners, such as Pindyck, disillusionment has set in:

> . . . from a theoretical point of view models of OPEC oil pricing have reached practical limits as tools of analysis . . . economic rationality probably applies even less to OPEC than to many other economic agents [1982, p. 109].

The normative sensibility of such models has been questioned for several reasons, mostly having to do with the simplifications made to ensure mathematical tractability. The most important of these simplifications is the neglect of lags in the price-responsiveness of demand and non-OPEC supply. Such an omission prevents the proper evaluation of OPEC pricing strategies that are designed to take advantage of such lags. Another important simplification involves the assumption of perfect foresight in the expectations of some or all market participants. Related to this, and perhaps the most serious weakness of this approach as normative modeling, has been its neglect of the unavoidable uncertainty facing OPEC. Like the rest of us, they are uncertain about the true functional specification of world oil demand and non-OPEC supply. Nor are they sure of the underlying parameter values: elasticities, future GNP growth rates, and costs of alternative energy sources. This is important because the "optimal" price-path results are sensitive to different assumptions within the range of uncertainty.

In addition, this approach has also been criticized as not providing a plausible description of OPEC behavior, either for understanding the past or for predicting the future. For example, it is especially difficult for such models to explain the price doubling of 1979–1980. Conceivably, OPEC could have been adjusting its price-path to reflect new market conditions: higher-than-expected costs of alternative energy sources, the limited price-responsiveness of the market in 1975–1979, and the growing realization that the projected growth of OPEC production to 45 MBD was neither likely nor desirable. But such an explanation seems at odds with the apparent short-run orientation of OPEC's pricing decisions. Following increases in spot market prices, OPEC members would gropingly adjust their official prices upward, and continue the process until the spot and official prices were back in equilibrium.

Moreover, such models typically have had difficulty in explaining the actual initial price level. That is, given some set of parameter values, the assumption that OPEC behaves as a wealth-maximizing price-setter often yields an initial-year price quite different from the actual value. For example, in the EMF (1982) reference case scenario, the Salant model's price for 1980 was 28 percent above its actual value. In addition, such a model's initial price is quite sensitive to the underlying parameter values assumed. Using Salant in EMF (1982) again as the example, a change in the assumptions caused as big a change in the *1980* price as in that for the year 2000: an average change of 18 percent from the reference case. Of course, one would expect a model's *long-term* results to be affected if, say, the assumed GNP growth rate for the 1990s were to be increased. Price in the year 2000 would be higher than in the reference case. But, with this model, price in the *initial* year is affected as much as in the year 2000. Given the theory, this is what one would expect to happen. But it seems implausible that OPEC would be so farsighted and so certain about its forecast of future economic conditions that its current price would be so sensitive to changes in assumptions about the distant future.

Finally, some have argued that OPEC's profits, discounted to present-value terms, are relatively insensitive to the price-path chosen. That is, OPEC and its members would do quite well over a wide range of price-paths, giving it considerable discretion to pursue other goals as well. For example, Saudi Arabia could "link" its output decisions to progress on an arms-sale agreement or to a satisfactory Arab-Israeli settlement.

Some of these difficulties with the wealth-maximization approach could be related to the cartel nature of OPEC and the absence of a satisfactory theory of cartel behavior. A generally accepted cartel theory is lacking, even for the static case, let alone for the dynamic case with an exhaustible resource. But many of the weaknesses of this approach are more fundamental and would persist even if we had better cartel theories.

Such shortcomings have persuaded Moran that the wealth-maximizing price-path represents, in the words of Griffin and Teece (1982, p. 34), ". . . an empirically elusive concept and, therefore, of dubious predictive value." As Moran argues:

> In short, the idea of economic rationality and the pursuit of economic self-interest have not been able to play the role of precise guide to, or constraint on, the determination of OPEC oil policy. Rather, there has been considerable leeway for the OPEC states . . . to suggest alternative courses of action without being met by a decisive demonstration that the damage to national interests would be overwhelming [1982, p. 103].

Parenthetically, Moran's article provides an excellent survey of the applied modeling work on OPEC. Since he is a political scientist, Moran has reviewed this literature as an "outsider"; and, in the tradition of de Toqueville, he has provided us with insight and perspective.

B. *Simulating OPEC Behavior via Target-Capacity-Utilization Pricing*

While theorists have been working within the Hotelling tradition, many of OPEC's applied models have used pricing strategies which, in effect if not by intent, aim toward some capacity-utilization target for OPEC. In these models, OPEC is assumed to be an imperfectly disciplined cartel that is uncertain about the underlying demand and supply parameters of the world oil market. It is groping toward an unknowable "optimal" price-path by implicitly following a target-capacity-utilization rule-of-thumb: increase price when the market is tight or tightening, and let it ease off when the market is sluggish. OPEC capacity limits on maximum production are specified exogenously, taking account of existing capacity, planned changes and known oil reserves. (There have been only a few attempts at endogenizing OPEC capacity decisions, e.g., the model of Nazli Choucri in EMF 1982.)

Seven of the ten models in the EMF (1982) study used such pricing rules for OPEC; an updated version of one of these can be found in Gately (1983). Five of these seven used very similar price-determination functions for OPEC (Beider 1981, p. 20). The percentage change in price for next year is an upward-sloping, convex function of this year's capacity utilization for OPEC. (OPEC productive capacity is assumed to be 34 MBD.) The "target" capacity utilization, at which price would be held constant, was 85 percent on average across these models. The more that capacity utilization is below this target level in a given year, the more OPEC's price would be reduced. And the more it is above, the more price would be increased. This "target" capacity utilization, incidentally, refers to the target of an instrument and is not itself a goal.

Additional explanatory variables are sometimes included in these price-determination functions. Among these are the capacity utilization level for the previous year (as well as the current year), or the rate of change of capacity utilization. This is often necessary to prevent short-term price oscillations, which can be a problem with such models.

This approach is related to the "bounded rationality" models first proposed by Herbert Simon. As James March observes in his excellent survey:

> . . . the original argument . . . started from the proposition that all intendedly rational behavior is behavior within constraints . . . [such as] limitations on computational capability, the organization and utilization of memory, and the like . . . human beings develop decision procedures that are sensible given the constraints, even though they might not be sensible if the constraints were removed [1978, p. 590].

Such an approach, although intended as a positive model of OPEC behavior, could also be viewed as a normatively sensible adaptation, given the computational complexity in modeling the world oil market and given the unavoidable uncertainty about the market's true specification and parameter values. This view is similar in spirit to that of William Baumol and Richard Quandt (1964, p. 23), who argued that "rules of thumb are among the more efficient pieces of optimal decision making."

Unlike wealth-maximization models, this approach has no difficulties in determining price in the initial year because it may be set equal to its observed value. Moreover, changes in assumptions about the underlying parameter values have little immediate impact on OPEC's price or output. The effect of such changes would be gradual, increasing over time as the emerging underlying conditions have a greater and greater effect.

The use of such pricing rules is sometimes described as "arbitrary." To evaluate this criticism, it is important to distinguish the three basic assumptions involved: (1) the level of OPEC productive capacity over time, (2) the target level of capacity utilization, at which price would be held constant, and (3) the shape of the function relating the change in price to the level of capacity utilization.

The assumed level of OPEC capacity over time would affect the longer-term results, as one would expect, but it has relatively little effect on the results over the first few years. Until the late 1980s, there is likely to be sufficient spare capacity, as a result of continuing adjustments by demanders and non-OPEC suppliers to the big price increases of the 1970s. But it should be recognized that results beyond 1990 are partly the consequence of assumptions made about OPEC capacity; this is important for evaluating the results in EMF (1982).

Changes in assumptions (2) and (3) can affect the timing of price changes by a few years. But these differences have relatively little effect on the ultimate price levels or the general shape of the price-path over time. In fact, as was evident from work related to EMF (1982), there is less price-path variation with different pricing functions but a single scenario than there is with a single pricing-rule but different scenarios.

But this is not to say that OPEC capacity utilization is a sufficient explanatory variable for predicting a particular year's price change. As Moran argues in GT (1982), understanding the pricing and output decisions of Saudi Arabia during 1974–1979 requires attention to political factors. Yet, although such political forces are important and perhaps decisive for any given year's decision, the underlying economic factors affecting capacity utilization cannot be resisted indefinitely. Thus, Saudi Arabia has a great deal of discretion in price and output policy in any given year, such that it could ignore underlying economic pressures for a year or even a few years. But these forces would then become increasingly difficult to ignore and, ultimately, will have their effect.

C. *Modeling OPEC Behavior During a Disruption*

Perhaps the least developed aspect of modeling the world oil market is its behavior during disruptions; even the definition and measurement of a disruption remains problematic. Within EMF (1982), for example, the results of the disruption scenarios were probably the least satisfactory of all the scenarios. The disruption was defined as a permanent 10 MBD cut in OPEC productive capacity at the start of 1985. In one model, the adjustment of demand and non-OPEC supply was instantaneous, occurring entirely within 1985. But in other models, the impact on price was so slow that the maximum price increase did not occur until several years after the disruption had happened. Only in a few of the models were the results believable. In hindsight, perhaps, this should not have been surprising, given that these EMF models had a longer-term focus. Most of them were annual models and ignored many of the most important short-term aspects of a disruption: inventory changes, the role of expectations, and the interaction between the spot price and official price for oil.

Recently, an important contribution has been made by Philip Verleger (1982). It is an ambitious and sophisticated attempt to model the behavior of the world oil market during a disruption. Using monthly data, he estimates equations for the behavior of inventories, the spot price of crude oil, the official price, the consumer price, expected production, and demand.

With this model he simulates a simple disruption: a 1 MBD production cut for six months. The result is striking: spot prices continue to increase, even well after supply is restored. As Verleger observes:

> . . . the model as initially configured is unstable in the short term . . . . The initial results highlight the characteristics of the world oil market that prolong and exacerbate disruptions, including the historically sluggish response of official crude oil prices to changes in spot values; the fact that consumer prices have historically followed [official] crude prices and not spot values; the speculative nature of inventory demand; and the very sluggish response in consumer demand [1982, pp. 130–31].

He then explores the effects upon the model's short-term instability of changing the specification of different equations or values of parameters such as adjustment speeds. This work represents a nice example of how applied modeling, when it accepts the challenge of generating plausible numerical results, can help to focus the discussion and improve our understanding.

Yet, just as the telescopic view of longer-term models does not analyze short-term disruptions very well, Verleger's microscopic view does not capture the importance of the longer-term goals and expectations of the main participants. For example, he does not explain what motivated the decision by the Saudis on January 20, 1979 to cut production at the height of the Iranian disruptions, or of subsequent decisions to raise OPEC's official prices. But, presumably, these events represented purposeful behavior, taken with some expectation of the post-disruption consequences for the world oil market. In this model, the Saudi cutback is a given, a part of the disruption whose consequences are to be determined by the model. And the official price increases are determined mechanically, as a weighted average of current spot and official prices. But, to analyze these events properly requires that attention be paid to the expectations of the participants. Perhaps this could be done by embedding this disruption model in a longer-term model of the world oil market.

The second half of Verleger's book discusses policies for coping with disruptions and mitigating their effects. Some of the policy prescriptions, however, are incongruously bold, in view of the underlying model in the first half of the book.

Other analyses of disruptions and policies to mitigate their effects can be found in two recent books, one edited by David Deese and Joseph Nye (1981), the other edited by James Plummer (1982). The latter contains an especially well-integrated treatment of the issues. Among the behavioral questions considered are the macroeconomic impacts of energy price changes. This, incidentally, is the focus of a study by the Energy Modeling Forum subsequent to its study of world oil models.

IV. *Outstanding Issues*

There are numerous important issues, both empirical and theoretical, that remain unresolved.

With regard to empirical questions, there are important uncertainties about both demand and supply. On the demand side, there remains disagreement about the long-run price elasticity, the form of the lag structure, and the income elasticity, including the feedback from oil prices to economic growth rates. There is similar disagreement on the supply side, about the geological resource base for conventional oil and the cost and likely capacity of alternative energy sources.

With regard to theoretical issues, it remains an open question how best to design a model of the behavior of OPEC. This is true especially for behavior during disruptions but also for decisions in more normal times, concerning production levels, pricing and capacity changes. There are a large number of alternative theories, but a much smaller number of sensible applied models.

Finally, there is the continuing dispute about the significance of OPEC for what has happened in the past decade. In our view, OPEC as an organization undoubtedly controlled the timing and the magnitude of the price increases, and it prevented more rapid price declines after 1980. But, it seems equally clear, in the light of plausible estimates for the demand elasticities and the costs of oil and of alternative energy sources, that pre-1973 oil prices were too low to be sustained much beyond the mid-1970s. Similarly, pre-1979 prices were too low to be sustained beyond the mid-to-late 1980s.

OPEC will continue to have power over price, especially in the short term, and its power will increase when its capacity utilization increases. But, over the longer term, taking ten-year or twenty-year averages, OPEC's market power will be constrained by the underlying price-responsiveness of demand and of non-OPEC supply, for oil and alternative energy sources.

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