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RETROSPECTIVE ON OIL PRICES

SAMUEL A. VAN VACTOR and ARLON R. TUSSING*

Energy is the most abundant resource in the universe. While energy supplies are unbounded, useful energy is not. To convert naturally occurring energy resources into useful work, mankind must invest capital and labor—resources that normally are scarce. To produce or use primary energy, both producers and consumers must invest in specialized and often inflexible equipment. In calculating the perceived value of present and future oil supplies, the Organization of Petroleum Exporting Countries and almost everyone else mistook for economic rent the windfall profits associated with short-term rigidities in energy use. Attention focused on the cost of manufacturing a synthetic crude oil, rather than on the incremental cost of changing consumption patterns in end-use markets. Misjudgments on the future value of oil were compounded by ill-conceived government policies and inaccurate forecasts. Substitution of oil for other energy commodities can occur at nearly every point along the chain downstream from the production of primary resources, but it occurs most abundantly and importantly at the point of final consumption. Liquid petroleum remains the cheapest fuel to transport, chiefly because a vast infrastructure already exists to handle it. The steady advance of technology explains the long-term decline in the real prices of most products, including retail energy prices. Often, the increasing unit costs of harvesting or extracting a finite scarce natural resource has been more than offset by improvements in manufacturing or end-use technology. The mix of commodities bought and sold in the next generation may be unrecognizable to today's consumer. Thus, the cost of any one primary resource or intermediate product may be irrelevant.

I. INTRODUCTION

The last two decades have seen extraordinary misjudgments about the oil market. During the 1960s, it was commonly believed that oil prices would remain low and demand growth high throughout this century. During the 1970s, perceptions were altered dramatically as fashionable thought turned to fears of resource scarcity. As late as 1982, many analysts and most investors still thought that oil prices would march relentlessly upward, even beyond the 10-fold increase that began with the 1973 Arab oil embargo.

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The vision so often expressed by politicians and journalists, as well as by energy experts, was one that combined crippling shortages with unrestrained price gouging by the oil-rich kingdoms of the Middle East. Even now, after the Organization of Petroleum Exporting Countries' (OPEC's) collapse, many still cleave to these beliefs and think that constant-dollar oil prices inevitably will rise to surpass the peak reached in 1981. However, increasing evidence indicates that oil prices may never again reach that level and certainly will not do so on some ever-upward course.

How could so many observers err in their assessment of the future price and availability of the world's best known and most analyzed resource? Was their vision flawed only in timing, or did the experts' judgment falter on basic tenets of economics? Did the cadre of forecasters and analysts adopt faulty analytical techniques, or were their projections unduly influenced by short-lived perturbations and current political events?

II. LIMITS TO RESOURCES?

Energy is the most abundant resource in the universe. Man can harness direct solar radiation, falling water, tides, wind, photosynthesis, combustion of fossil fuels, and other chemical or physical reactions to produce useful heat, light, and motive power. The notion that supplies are not renewable is irrelevant to primary energy because there is no practical limit to these resources in the aggregate.

The supply of energy is unbounded but, at any one time, that of useful energy is not (see Lonnroth et al., 1977). To use naturally occurring energy resources, mankind must commit capital and labor—resources which normally are scarce. Moreover, converting primary energy to a serviceable form requires an investment by both consumers and producers. Producers must invest capital, labor, and other resources in extracting and converting the primary resource to salable energy commodities. Consumers must purchase facilities and equipment designed to use energy in its commodity forms.

In long-term equilibrium, the prices of primary energy resources are determined by their relative scarcity, the cost of converting them to useful forms, and the expense of moving them to a point of end use. Conversion and transport costs in turn hinge primarily on the scarcity of capital, and not on the scarcity of natural resources. The role of natural resources, capital, and labor in producing useful energy often has been misunderstood. For example, the report entitled *Limits to Growth*, sponsored by the Club of Rome, had as a major premise that natural resource scarcity, rather than shortages of capital and labor, would limit or even extinguish economic growth (see de Montbrial, 1979). Such a preoccupation with specific physical resources inevitably leads to dangerous and distorted inferences about the economics of energy markets.

During the 1970s, concern over the scarcity of natural resources led to crippling and shortsighted policies in energy-importing countries. OPEC's short-term success would not have been possible without price controls, inflexible regulations, and elaborate trade barriers established by consuming countries. These policies played into the hands of oil-exporting countries.

III. ECONOMIC RENT VERSUS WINDFALL PROFITS

In the short term, it is the utilization rate of equipment involved in producing, converting, and consuming energy that determines the price and availability of energy in its marketable forms. Shortages or bottlenecks in such equipment can result in inflated prices for energy commodities and increased payments of "quasi-rent" or windfall profits for using extraction and conversion facilities as well as natural resources. By contrast, if those who produce, convert, and transport energy commodities err and install more capacity than is required to meet end-user demand, energy prices likely will decline, generating financial losses at any stage of the production, conversion, transport, and marketing chain.

Producers can easily misjudge required capacity, and in fact inevitably do so, because the match between supply and demand depends on long-lived investment decisions by consumers as well as producers. For example, methanol from gas or coal theoretically could have fueled the world's motor vehicles during the last decade at an effective end-user cost below peak gasoline prices. However, major investments would have been required in production and distribution facilities as well as in the vehicles themselves.

Prices in energy industries are determined no differently than those in any other industries. Excess demand begets higher prices, and excess supply begets lower prices. The process in oil, gas, coal, and other energy markets is particularly complex, however, because a variety of intermediate goods and discrete stages of production and marketing exists. For a competitive market to be in long-term equilibrium, each firm at every stage of production must make a normal rate of return on its capital investment. But in a dynamic economy, market prices coincide with their long-term norms only episodically. Thus, in the short run, one sector of an industry may garner substantial windfall profits at the expense of other sectors or consumers.

The windfall profits which accrue to shrewdly (or luckily) invested capital are quite distinct from the Ricardian scarcity (or economic) rent which accrues to a resource of fixed supply. (For a simple discussion of the distinction between economic rent, quasi-rent, and monopoly rent, see Samuelson, any edition.) In practice, distinguishing between such short-term profits and economic rent can be difficult. For example, assume that crude-oil refiners invest in too much heavy fuel-oil reduction equipment so as to increase gasoline output. The result could be a drop in gasoline prices from which motorists would benefit. Alternatively, if gasoline prices did not drop, refiners might compete more vigorously for available supplies of heavy crude oil. This demand shift likely would increase heavy crude-oil prices. In effect, the expected return on investment arising from installing fuel reduction facilities would be transferred from refiners to heavy-oil producers, who need not do anything to capture the added income. In time, however, the windfall would dissipate, as refiners cut back on investments and new crude-oil supplies were developed.

Profits shift constantly among the energy industry sectors devoted to production, conversion, transportation, and use because no one can accurately predict the vagaries of demand and supply. During the last decade, much of the windfall profit associated with the dynamic oil market was mistaken for Ricardian rent.

The leap-frogging of OPEC crude-oil prices during the early 1970s often has been linked to the shortage of crude-oil transportation facilities. Supposedly, a bulldozer broke the Trans Arabian Pipeline (TAP) from Saudi Arabia to the Mediterranean Sea in 1971 and, as a result, crude oil had to shipped around the Cape of Good Hope. The resulting increase in freight rates gave North African oil producers a competitive advantage, spurring Libya's Colonel Gadhafi into the first round of crude-oil price increases (see Blair, 1978).

In retrospect, the break in the TAP and the militancy of Gadhafi were simply the most visible elements in a much larger picture. From the end of the recession in 1971 through 1973, the worldwide petroleum refining and transport infrastructure was stretched thin. Global consumption increased 8 million barrels per day in just two years (see British Petroleum Company, 1985). Petroleum product prices in many markets were higher, after adjusting for inflation, than they are today.

Until 1971, consumers had enjoyed a decade of record low oil prices, and their investments in energy-using facilities reflected oil's abundance. Product inventories dropped as demand surged, refineries ran at full capacity, and delivery systems developed spot shortages. Petroleum product prices began their ascent well before OPEC recognized its power over the crude-oil market.

Similar problems in product markets occurred in 1979, but for different reasons. Higher crude-oil price levels after 1973 resulted in higher petroleum product prices. This led to a decrease in the demand for heavy fuel oil relative to the demand for gasoline and diesel. Refineries did not adapt quickly enough to the shifting mix of product demand. Even before the drop in Iranian crude-oil production, U.S. refiners were predicting gasoline shortfalls during the summer of 1979. During the Iranian crisis, heavy-fuel oil inventories reached record high levels while gasoline inventories plummeted. Once again, however, increases in product price led to increases in the crude-oil market.

As crude-oil prices were bid up, windfall profits shifted from brokers and refiners to producers. Globally, crude-oil production is the most concentrated sector of the petroleum industry. OPEC's key members discovered that they could preserve high price levels by cutting back production; windfall profits became monopoly profits. By contrast, refiners and transporters could not preserve their profit margins; competition quickly dissipated their windfall.

Because crude oil is a nonrenewable resource, it was assumed to be in limited supply. As a result, the willingness to sell oil at then-current prices depended on perceptions about its future value. The scarcity theories sweeping the major consuming nations helped OPEC members to persuade themselves that their monopoly profits really were Ricardian rents.

IV. CONFLICT OF IDEOLOGIES AND IDEAS

The debate over energy policy during the last decade was a conflict of ideologies as well as of ideas. This conflict was a battle, in part, between free-market advocates and those who prefer control and regulation.

Analysts and politicians who perceived a future of energy shortages tended to argue for price controls and government investment in renewable energy sources. Those who believed that decentralized markets could best determine the mix and timing of energy investments tended to advocate deregulated energy prices and less government intervention. Many from the energy industries concocted mixtures of arguments from both ideological camps to suit their particular interests. The debate resulted in a structure of distorted energy pricing and piecemeal government investment—a policy mix that satisfied no one.

World events sharpened this conflict of ideas. Studies such as the Club of Rome's *Limits to Growth* were followed by the Arab oil embargo and a fourfold increase in crude-oil prices. Those already preoccupied with the seemingly accelerated depletion of conventional oil and gas resources pointed to the Arab oil embargo as the first in a series of certain shortages. By contrast, many economists emphasized the inevitable impact of crude-oil price increases on demand and supply, along with long-term contradictions that ultimately would cripple OPEC. These economists predicted an eventual price collapse.

Some economists also pointed out that as one resource grows scarce, inevitably others are substituted. Perceived crude-oil scarcity would yield high oil prices only until supplies of some substitute were developed. A striking historical example often was cited. During the first half of the 19th century, whale oil was the major domestic lighting fuel. As the world's sperm whale population approached extinction in mid-century, lamp-oil prices soared. Kerosene distilled from natural petroleum was, however, a satisfactory (and indeed superior) substitute. In less than a decade, petroleum products were available everywhere in Europe and America more cheaply than whale oil had ever been.

V. THEORY OF DEPLETING RESOURCES

Concern over depleting oil reserves was not entirely misplaced; it had some backing in economic theory. Petroleum has special properties that set it apart from other commodities. Most goods can be reproduced without limit, provided that appropriate amounts of capital and labor are applied. However, conventional oil deposits exist in defined places and volumes. As a result, the costs of consuming oil today are not restricted to the value of labor and capital services used in their production. "Scarcity rent," the present value of all future sacrifices related to the current use of oil, also is a consideration. Thus, the marginal cost of producing oil is the sum of the marginal extraction cost plus scarcity rent that can be attributed to the sacrifice of future consumption.

In 1931, Harold Hotelling concluded that the economically efficient rate of change in the scarcity rent for a fixed depletable resource should equal the interest rate. Later works elaborated on Hotelling's paradigm, making allowances for changing demand in environmental amenities, macroeconomic feedbacks, etc. This view of resource depletion in all its variants led to the inference that in a competitive market, oil prices would start low and then rise as the resource was exhausted.

Nearly every energy price forecasting model since the 1973 Arab oil embargo focused on the oil sector and used some adaptation of the Hotelling paradigm. Oil almost always was treated as a depleting resource, and oil prices were expected to reflect the cost of the fuel's replacement sometime in the future, discounted to the present. The demand for liquid fuels—petroleum products—was considered inelastic in the long run as well as in the short run. In this conceptual approach, oil's replacement had to be a synthetic hydrocarbon liquid that was chemically and physically equivalent to natural petroleum. The prospects for developing oil shale, tar sands, and oil from coal thus came to dominate long-term oil price projections.

VI. SUBSTITUTION

It is useful to return to the whale-oil analogy to understand the subtle error that crept into forecasting models—indeed, the fallacy that skewed most energy analysis—during the OPEC era. When whale oil became expensive, kerosene replaced whale oil as lighting fuel; crude oil did not substitute for whale carcasses. Substitution was triggered at the point of end use and not at the point of manufacture. The high cost of lighting lanterns with whale oil provided both the incentive and the opportunity to market a wholly different commodity at retail. The effect was more than just encouraging the use of an alternative resource. (In urban areas, gas manufactured from coal was a powerful competitor to both whale oil and kerosene for lighting.)

At the beginning of the OPEC era, the U.S. found itself short on new sources of conventional crude oil, but it had vast deposits of coal and oil shale while Canada had tar sand deposits of comparable magnitude. Initially, production cost estimates for synthetic petroleum from oil shale and tar sands were about $7 per barrel; the price of coal-based synthetics was a couple of dollars per barrel more. Each year, however, the estimated cost increased. The second oil price shock of 1979 enhanced incentives to expand pilot projects in the U.S. for oil-shale production and coal liquefaction. The federal government provided subsidies and price guarantees through the Synthetic Fuels Corporation. Curiously, in retrospect, the expected cost of synthetic oil rose at least as quickly as did crude-oil prices themselves.

As noted, a major part of the marginal cost of producing oil is, arguably, the economic rent associated with its scarcity. Not surprisingly, escalating estimates of the cost of synthetic oil fueled ever-higher expectations about future values for conventional crude oil. This outlook, in turn, provided an incentive for the world's low-cost oil producers to hold back on production, keeping current oil prices higher than they otherwise would have been.

One quixotic aspect of this fascination with the cost of synthetic fuels is identified in the neoclassical theory of the firm. When the price of a good rises, producers generally attempt to increase output. In so doing, they are likely to bid up the prices of production inputs—natural resources and the services of labor and capital. In the short term, if limits exist on the amount of petroleum-related capital goods and labor, prices and wages surely will increase, raising both the marginal and the average cost of the resource commodity. The constant-dollar cost per unit of oil-related investment (100 feet of well drilling, for example) in 1981, at the crude-oil price peak, was about double that of a few years earlier; by 1986, it had fallen by about half.

The focus on supplying a physical alternative to crude oil was wholly misplaced. Opportunities for substitution are not concentrated in the manufacturing process, much less at a single point such as the source of refinery feedstocks. Substitution can occur at nearly every point along the chain downstream from the choice of primary resource, but it occurs most abundantly and importantly at the point of final consumption.

Numerous viable substitutions exist for the use of petroleum products. In Western Canada and parts of Asia, compressed natural gas and Liquid Propane Gas (LPG) have made great strides as substitutes for motor fuel. New Zealand is manufacturing a gasoline substitute from natural gas. Ethanol has taken a large chunk of the motor fuels market in Brazil. Coal could once again drive the world's ships, just as it has again become competitive for generating electricity. Liquified natural gas could fuel jet aircraft.

Liquid petroleum remains the cheapest fuel to transport and use, chiefly because a vast infrastructure already exists to handle it. Given enough time and adequate economic incentive, the infrastructure could be changed. If prices had stabilized at their 1982 levels and kept pace with inflation, gasoline would have all but disappeared as a motor fuel by early in the next century.

If crude oil is to command a sustained high price, economic rent arising from its scarcity—not windfall or monopoly profits—must be high. However, the large number of substitution possibilities among fuels at various stages of their production, transformation, and use will, in the long run, tend to keep economic rents low. The most egregious error remaining in most energy price forecasting models is a disregard for the millions of potential end-use substitutions; these are small individually, but are of great consequence in the aggregate. It is these small substitutions that drive the energy market. To determine the true scarcity rent, a complex set of alternatives and trade-offs in each stage of production and distribution and, above all, end-use markets would have to be quantified. This task all but defies execution.

VII. CHANGING TECHNOLOGY

The substitution of one resource for another almost always is accompanied by a change in technology. For example, the technology of finding, extracting, refining, and transporting petroleum advanced dramatically during the period in which kerosene replaced whale oil as lighting fuel. Indeed, the new technology made that substitution economically feasible. The development of a kerosene market and the consequent need for refineries, in turn, led to abundant supplies of gasoline and residual oil. These substances, inconvenient byproducts at first, proved to be cheap and effective alternatives to alcohol for fueling internal combustion engines, and to coal as a boiler fuel.

The steady advance of technology explains the long-term decline in the real prices of most products, including those of retail energy. Often, the higher cost of harvesting or extracting an increasingly scarce natural resource has been more than offset by improvements in manufacturing technology. Moreover, technological change can occur anywhere in the chain from production to consumption. The mix of commodities bought and sold in the next generation may be unrecognizable to today's consumer. Thus, the cost of any one resource or product may be irrelevant.

Despite the overwhelming evidence of technological advance, many—if not most—energy forecasting models developed in recent years contain precisely the same fallacy and analyze only a limited number of proven technologies. This is because without some such assumption, it is difficult to construct a quantitative relationship between relevant variables. Technology changes in spurts and its advance is predictable only in the aggregate. In the real world, change is an all-encompassing process; consumers learn to use new products, resources are substituted, institutions wax and wane and, despite higher wages, manufacturing costs usually decline. History teaches us that it is safer to assume that the unknowable will indeed happen, and to expect that the net impact of all surprises will be to lower and not raise end-user costs.

VIII. CAPITAL INTENSITY IN ENERGY INDUSTRIES

A critical feature of all the depleting resource models has been the assumption that the quantity of the resource in question is fixed and known. This certainly is not the case with either oil or gas. Once oil is discovered and developed, it can be treated similarly to any other capital asset; this treatment is the essence of the Hotelling approach. The owners of developed oil and gas fields decide how much to produce based on lifting costs, current prices, expectations about future prices, and the opportunity cost of borrowing or lending money. Exploration and development decisions are much more complex, however, and hinge on a wide array of uncertainties.

Exploration and development activities are determined by, among other things, the menu of development prospects in known reservoirs, the character of hydrocarbon endowment of reservoirs yet to be discovered, and the future course of exploration, production, and conversion technology. The combined impact of these uncertainties is devastating to any resource development model whose first premise is the "fixity" of the primary resource base. Geologists do not know how big that resource base is, even with today's definition of crude oil, at today's prices and with today's technical options. Projecting the volume of all kinds of natural hydrocarbons that are economic to extract and utilize in the future is a stupendous speculation. The only certainty is that the definition of the resource base, the relative prices of production inputs and resulting products, and technology all will change dramatically.

The cost of capital is also a critical consideration in assessing the value of a hydrocarbon stock, and it ~~also~~ varies dramatically over time. This consideration is critical because the dollars invested in petroleum exploration compete with every investment opportunity in the world. When oil prices rise, they are accompanied by two countervailing phenomena whose interaction may cause exploration activity to rise or fall. Higher oil prices make it possible to explore and develop high-cost petroleum provinces, such as those in the Arctic. At the same time, however, higher oil prices drive up the prices of gas, coal, and other fuels. Thus, investment opportunities in competing fuels also improve. It is impossible to predict where the incremental investment dollars will be channeled or which set of new fuel supplies will put a lid on the rise in oil and other energy prices. The oil-price surge of the late 1970s, for example, brought a proportionately far greater increase in production capacity for coal and natural gas than it did for crude oil.

As interest rates fluctuate, the value of capital assets fluctuates. According to Hotelling-type theories of depleting resources, higher interest rates relative to inflation should cause oil prices to decline as the opportunity cost (in terms of the value of future consumption) of selling oil falls. Experience during the past decade, however, has been the inverse. Peak interest rates from 1979 to 1981 coincided with the oil price peak. And, as interest rates have fallen, oil prices (as well as the value of reserves) have declined. By contrast, stock and bond prices have risen.

One reason for the counterintuitive direction in the linkage between interest rates and oil prices is the change in expectations regarding future inflation. But equally compelling explanations exist that are based on competition among fuels and the nature of the energy industries. Interest is the price of capital, and the energy industries are relatively capital intensive. Thus, higher interest rates mean that the cost of new energy facilities will be higher than that of existing ones. This observation holds true for new coal mines, oil and gas exploration plays, new nuclear power stations, or any other capital-intensive project.

Oil prices play a pivotal role in energy markets in that they drive interfuel competition during each period and provide a connecting link between current and future energy costs. More competition exists between present and future supplies of oil than between those of any other fuel. If the incremental cost of new producing capacity for oil, gas, coal, and other fuels is very high, oil producers easily can hold back on current production until oil prices rise to meet the cost of future competition. On the the other hand, if the incremental cost of new energy supplies is falling, oil will be pumped faster and its price will decline.

IX. POLICY QUAGMIRE

In 1974, world oil prices zoomed to more than $11 per barrel, perplexing the Nixon administration. Two years before, policymakers had used every means available to contain domestic prices at less than $4 per barrel. The price increase spawned a major policy conflict. The President's objective of price stabilization clearly was at odds with the newly announced goal of "Project Independence." This conflict never was formally resolved. By the time President Carter took office, natural gas and oil prices were well into their longest and highest cyclical swing of this century.

In 1975, Secretary of the Treasury William Simon, Secretary of State Henry Kissinger, and economists such as Milton Friedman predicted an oil-price collapse. Their public proclamations, however, were at odds with the rigid set of domestic oil-price controls and allocation regulations imposed by Congress and being enacted by civil servants. Not only did federal policy thwart the normal development of domestic oil and gas, it had a profound impact on perceptions—particularly in the OPEC countries.

Between 1971 and the end of 1978, at least 44 studies included independent projections of U.S. oil-import levels for 1985 (see Brodman and Hamilton, 1979). The forecasts of the U.S. oil-trade balance for 1985 ranged from imports of 16 million barrels per day (mmbd) to exports of 1.5 mmbd (see Brodman and Hamilton, 1979).

The CIA published the most famous of the reports in April 1977. The CIA did not disclose its assumptions, but its conclusion was trumpeted to all. According to the CIA, "by1985. . .the demand for OPEC oil will reach 47 to 51 million barrels per day." This forecast contrasts dramatically with OPEC's actual production in 1985 of around 17 mmbd. In fairness to the CIA, it projected a price break by 1983 that would bring demand and supply into balance. Other analysts were not so cautious. They described decades of energy shortages, endless gasoline lines, ever-wealthier Middle Eastern regimes, a cash-rich energy industry, and a banking sector ever more tied to both petrodollar deposits and energy investments.

In December 1978, at the onset of the Iranian Revolution, The Congressional Research Service (CRS) completed *Energy: An Uncertain Future*, which analyzed the major energy projections made in preceding years. To a large extent, the late 1970s were the watershed years in the energy forecasting business. While no one was projecting world crude-oil prices to triple again in the near future, the forecasts were gloomy; they depicted increasing competition among consuming nations over limited resources. Table 1 summarizes the key results of the forecasts made during this era. Table 1 is arranged in descending order, with the smallest error presented last. The projections made by industry and by its supporting consulting services had the lowest errors; the projections made by the U.S. government had the largest errors.

Two points about the projections are striking. First, all forecasts of non-OPEC oil supply were nearly on target. The CIA's estimate was the worst but, even so, it was within 14 percent of the actual value. Second, the forecasts of

TABLE 1
Comparison of 1985 Oil Production and Consumption[a]
from Forecasts Published in 1977 and 1978
(in millions of barrels per day, net of CPE)

		Supply		
Organization	Total Demand	Non-OPEC	OPEC	GAP
CIA	70.5	21.5	44.2	5.2
EIA/DOE	68.1	23.8	39.8	4.5
CRS	67.8	25.0	42.8	-
Exxon	64.0	24.0	40.0	-
PIRA	61.0	24.4	36.6	-
Petroleum Economists	61.0	25.5	35.5	-
Actual	41.4	25.0	16.4	-

[a]Congressional Research Service.

demand were off by 47 to 69 percent. Once again, the CIA figure was the furthest from 1985 reality.

Of course, the projections made in 1977 and 1978 presumed only moderate oil-price escalations. Most analysts recognized that prices would have to rise to bring demand and supply into balance, but a critical unanswered (and often unasked) question remained: If the static projections of demand and supply were correct, how much would prices have to rise to bring the market to equilibrium?

The models and other quantitative techniques used during the 1970s simply did not focus on price. In the U.S., prices of all major fuels were heavily regulated and thought to be relatively immobile. The world oil price was thought to be fixed by OPEC, which in turn was dominated by Saudi Arabia. At the time, the Saudis were perceived as price moderates and were presumed willing to increase production to stabilize oil prices. In short, price didn't matter much in the political and other institutional assumptions used in these models.

The models inevitably made assumptions about market parameters such as the price elasticity of demand and supply, but such assumptions seldom were published. When price elasticity assumptions were revealed, they were not treated as important enough for systematic review or for serving as operating variables of sensitivity analyses. The oil market simulation model (OMS), developed for the Project Independence study by the Federal Energy Administration and used later for routine projections, is typical of the forecasting effort. In the OMS model, the price elasticity of aggregate demand for oil averaged less than -0.2 over a variety of regions and scenarios. Non-OPEC supply-price elasticity averaged just less than +0.1 over the same simulation runs.

These coefficients can be translated into a combined impact on the demand for OPEC crude-oil exports. Broadly speaking, if the OMS model were correct, a 10 percent real oil-price increase should have diminished the demand for OPEC oil by about 3 percent, all other things being equal. This may seem like a small response now, but it corresponded roughly to actual demand reductions after the first flurry of OPEC oil-price increases in 1973 and 1974. Extrapolation from the 1974–1978 experience resulted in a simple inference: Oil demand is relatively insensitive to price.

Reflections on the principle of diminishing returns, however, underscore the absurdity of the preceding conclusion. If OPEC really faced a price elasticity of -0.3, it could have maximized revenue by producing less than one barrel of oil per day. Analysts were misled by U.S. price regulations and the fact that product prices did not sustain a rise of more than $5 to $6 per barrel. Even though crude-oil prices tripled, the capital investment required to burn an alternative fuel precluded an immediate switch.

X. FOCUS ON CRUDE-OIL PRICES

By 1980, fashion in forecasting models had changed profoundly. Analysts now recognized that any gap between demand and supply could be (and had been) closed by higher oil prices. Thus their emphasis shifted away from assuming future levels of oil prices to forecasting the growth rate in oil prices.

OPEC, under Saudi sponsorship, advanced a long-term price strategy linking oil prices to an index that incorporated international currency exchange rates, inflation rates, and real economic growth. With this index, the official price of Saudi Arabian light crude oil was projected to rise to more than $45 per barrel by 1985, in nominal dollars.

OPEC's indexing idea was clothed in intellectual respectability because it reflected a Hotelling-type model for pricing of depletable resources. The price-indexing scheme was a pragmatic application of such a model, which had one main tenet: Crude-oil prices would increase in real terms only when economic growth in the consuming nations made it possible. This pricing strategy appealed to the consuming nations as well, because it was predictable and stable.

In the U.S., energy research paralleled the OPEC calculations. The models built to project future oil demand and supply were revised to project prices under the assumption of a fixed OPEC supply. But estimations of the key coefficients—price elasticities—were based on consumption data that did not yet reflect either 1979 or 1980 oil-price increases, or even those responses to the 1973–1974 upheaval that depended on energy-serving capital goods designed and installed after 1979.

The forecasting errors of the early 1980s can be blamed partly on the one- to two-year lag in compiling accurate data and the inventory adjustments under way in the oil market during this period. Long-term trends were difficult to identify, much less to quantify.

Nevertheless, it always is poor judgment to extrapolate long-term trends from short-term market movements. The results of a sound projection methodology should be relatively insensitive to current events. In this light, it is

TABLE 2
Comparison of Annual Forecasts of Crude-Oil Prices by the Department of Energy for 1990: 1977–1984 (in 1985 dollars)

Report Year for 1990 Projection	DOE Forecast	Actual Import Price
1977	24.11	24.11
1978	28.62	22.54
1979	52.58	30.80
1980	58.64	44.17
1981	63.86	44.03
1982	41.00	37.48
1983	39.43	31.53
1984	30.99	27.95

interesting to compare various Department of Energy (DOE) crude-oil price forecasts for 1990 with the average price for the year in which each report was prepared. Table 2 summarizes such data. In 1977, the DOE projected that oil prices in 1990 would average $24—the same price level that prevailed in the year the forecast was made. In 1981, after prices had nearly doubled, the DOE projected a nearly 50 percent increase during the following nine years. Subsequently, as current prices have declined, projected oil prices have declined even more rapidly.

Projections made by Data Resources Inc., Chase Econometrics, Wharton, Foster Associates, and other major forecasting services show a similar pattern. Also, during the early 1980s, the Electric Power Research Institute funded a comparative study by Stanford's Energy Modeling Forum (EMF). In the EMF report, eight different models produced a range of future oil prices not significantly different from the DOE's 1981 and 1982 forecasts (see Electrical Power Research Institute, 1982). The similarity of results illustrates an important point made by a recent Arthur Andersen report of energy forecasting errors: Forecasters tend to bunch together (see Arthur Andersen and Cambridge Energy Research Associates, 1984). Projecting oil prices, particularly specific figures for specific years, is speculative. A consensus figure provides some safety, no matter how outrageous or inconsistent such a figure might be.

The disturbing feature of these energy forecasts is their blatant inconsistency from year to year. In 1977, after only three years of relative price ~~stability~~, the DOE and the CIA projected an oil demand and ~~oil~~ supply gap, but the DOE's annual report assumed that oil prices would hold constant in real terms for the following 13 years. On the other hand, in 1980, when real oil prices were projected to increase another 30 percent after already nearly doubling over the previous two years, the DOE projected that energy consumption would increase 9 percent. Neither kind of inference was consistent with the most elementary insights of economic theory regarding consumer and producer behavior.

In their frenzy of quantitative modeling, those involved in the process lost sight of basic economic principles. By accounting for just a few discrete substitutions among fuels or consumption technologies, analysts assumed they were accounting for everything that might occur in a dynamic and complex energy economy. Price elasticities derived from time-series estimation during one set of market conditions were presumed to apply to future experiences. (Errors were compounded by widespread disregard for existing cross-sectional consumption studies, which implied much higher price elasticities for energy and specific fuels than did those derived from time-series data during an era of declining prices.) Conventional resources of oil and gas were assumed fixed, and the cost of synthetic oil was estimated at many times the current price of crude oil.

In retrospect, of course, it was conceivable that no novel energy supply technology (say, photovoltaics or fusion) could emerge and be brought to commercial feasibility during the next generation. Nonetheless, even during the panic over resource scarcity, there remained an abundant base of known resources of conventional hydrocarbon fuels—oil, gas, and coal. In any event, it should have been obvious that the production of liquid hydrocarbons from shale or coal need not be the critical backstop or replacement for oil. Therefore, exotic oil-producing techniques should not have dominated oil-price forecasts during this period.

The analysis and models developed just before and during the Iranian Revolution had a singular and unwarranted focus on petroleum liquids. The projections faltered within a few years, because the degree and speed at which coal and gas could substitute for oil in lower-grade uses was seriously underestimated. In addition, exploration and development already under way for other conventional energy resources, particularly natural gas, were ignored.

XI. NATURAL RESOURCE ABUNDANCE

Since the Prudhoe Bay find in 1968, no confirmed discovery of a "super giant" oilfield has occurred outside the Middle East. There has been nothing to compare with the crude-oil reserve discoveries that took place between the end of World War II and 1974. Crude oil has been discovered all over the world—and some of the finds have been significant—but none has been sufficiently large to shift the focus of the industry away from the Persian Gulf. In 1973, 53 percent of the world's proved oil reserves were in the Middle East; by 1985, despite a decade of high oil prices and almost no Middle East exploration, the proportion had increased to 56 percent (see British Petroleum Company, 1985).

From 1965 to 1974, oil was discovered worldwide at an average rate of 129 million barrels per day, while consumption averaged 44 million barrels per day. The trend of consumption was upward, however, and that of discoveries was downward. During the decade since, oil reserve discoveries and revisions have averaged 63 million barrels per day and consumption 57 million barrels per day. The trend of oil demand growth has changed, however; 1984 consumption just about matched that of 10 years earlier (see Van Vactor and Johnson, 1985). Moreover, these figures on conventional oil reserves do not include deposits of very heavy crude oils, such as those in Venezuela, which exceed the whole world's proved reserves of crude oil defined conventionally. They omit even the newly found resources of moderately heavy crude oil such as the cretaceous sands of Arctic Alaska, where the known volume of "oil in place" is of the same order of magnitude as total proved reserves in the U.S.

Developments in natural-gas reserve additions offer a different picture, but one whose thrust is in the same direction. Since 1974, global gas consumption has increased more than 25 percent and the addition of new gas reserves has been staggering. During the last decade, the industry discovered an average of 158 trillion cubic feet of gas each year—in contrast to average consumption of 54 trillion cubic feet (see Van Vactor and Johnson, 1985). Since 1978 alone, an amount of gas reserves equal in heat value to 28 years of OPEC's 1985 oil production has been added to the world's inventory, and the bulk of the additions could readily be delivered to major industrial markets (albeit at a substantial initial outlay for transport facilities). From a global perspective, the displacement of oil by gas has been the most significant event in energy markets. Moreover, the capability of natural gas to displace oil over the coming decades is unquestioned.

The natural resource base of coal is so vast that it defies adequate description. It has been estimated, for example, that 1/11th of the surface of Alaska overlies coal deposits. Of course, extracting, transporting, and cleaning coal often is more expensive than using like amounts of oil and gas. But for all practical purposes, the resource is unbounded.

In short, no energy resource shortage exists. Conventional deposits of oil, gas, and coal would have gradually increasing costs of extraction if neither the knowledge of the resource base nor the means of exploiting it improved over time. If technology improves, however, long-run energy costs actually may decline. Indeed, this seems to have been the nearly unbroken trend over the past two centuries. Of course, if an unexpected jump in demand or dislocation of supply occurred, short-term marginal costs would be driven well above long-term marginal costs—for a time. Similarly, whenever a surplus of energy capital exists, short-term marginal costs can plunge well below long-term equilibrium.

XII. OIL-PRICE DETERMINATION

Price movements in the oil market, like those in all commodity markets, are cyclical. In 1969, some heavy crude oils in the Persian Gulf had a value to refiners of less than their lifting costs, and so production was closed down. At the same time, the spot price of Saudi Arabian light crude oil was less than $1 per barrel. A decade later, in 1979, some spot prices shot to more than $40 per barrel. Thus, oil prices ranged from about $0 to $56 per barrel in the space of 10 years (in 1986 dollars).

In the past, the most important factor bearing on the oil-price cycle has been the random and unpredictable flow of crude-oil reserve discoveries. Crude oil usually is discovered in large accumulations. The opening of a new geological province or the development of a new technology (such as the rotary drill or seismic exploration) often results in a massive set of discoveries. When this occurs, crude-oil prices are depressed greatly. After the East Texas field was discovered in 1930, crude oil became so cheap that it literally was allowed to run free in the streets. Similarly, the discovery of enormous reserves in Saudi Arabia and other Middle East countries following World War II ultimately depressed crude-oil prices in the Middle East for two decades. Part of the reason that the present oil-price slide is so perplexing is that it was not caused by the sudden discovery of large crude-oil reserves. Rather, it was caused by the slow accumulation of investments in energy conservation and supplies of alternate fuels, and by certain OPEC members' cheating on production quotas.

Before 1973, world oil prices were dominated by the U.S. market, which was less volatile. At the wellhead, U.S. prices averaged \$8.34 per barrel between 1879 and 1978 (see Department of Commerce, 1975). Through that entire century, crude-oil prices averaged less than \$5 or more than \$14 in only one year each (in 1986 dollars). However, during the 1970s, this predictability was broken by the natural decline in production from U.S. oil and gas reserves, and by domestic price controls. Since the early 1970s, U.S. energy prices have been tied to the world market—despite domestic price controls that complicated the connection—and the pattern of price predictability has been lost.

The rise and fall of oil prices from 1969 to 1986 is unlikely to be repeated in its extreme. The depths to which prices sank during the 1960s drove out most competing fuels. When prices ascended a few years later, most fuel-using equipment was designed to burn only a narrow range of petroleum products. In the short term, consumers had little choice other than to pay higher fuel prices. As time went on, however, consumers learned to conserve energy and adopted flexible burner-tip designs. Worldwide, coal and gas consumption expanded, while oil demand contracted.

If the U.S. historical experience is any guide to future behavior in global energy markets, the active presence of competing fuels again will tend to hold down the oil-price cycle. The U.S. experience may not be replicated in other countries with regard to the equilibrium level of oil prices or the ultimate mix of primary fuels. Nevertheless, interfuel competition is likely to temper the long-term volatility of energy prices everywhere. The historical oil price level for the U.S. may have been somewhat lower than that which might be expected in the future because the cost of coal and gas transportation in North America has been much lower than it has been in most other industrialized nations. As a consequence, the range of prices at which the major B-fuel[1] suppliers have

1. We use the B-fuels market as short for those various uses that are tagged as bulk fuels, boiler fuels, or black fuels. The B-fuels market refers to fuel uses in which the object of demand is

competed in the U.S. is lower than that in the international market. Ultimately, however, the cost differential between U.S. and world energy markets will be set by the cost of transport and not by the value of natural resources.

Competition among fuels likely will prevent a complete collapse of oil prices. In world energy markets, oil penetrates very rapidly into the B-fuel market when its price is less than $10 per barrel. Under such circumstances, global oil consumption could increase by 2–3 million barrels per day within a few months, largely at the expense of coal, and could continue to grow by at as much as 5 percent per year as oil captured virtually the entire increment in world B-fuels demand. In both North America and Europe, contractual and regulatory impediments to quick downward price adjustments exist for natural gas. But these barriers are being eliminated rapidly. Thus, industrial gas prices would follow oil prices further down within several months. The result likely would be considerable switching back and forth among fuels before a new balance is reached. Large investments in the gas-transmission infrastructure are uneconomic, however, in the face of very cheap oil. Coal in international trade has a high variable cost, and its market share will decline rapidly if oil prices are too low. Thus, oil prices below $10 are stable only if very substantial oil reserve discoveries occur, such as those that took place during the 1950s and 1960s.

On the other hand, competition among fuels prevents oil prices from sustaining a level much above $20 per barrel. In the longer term, coal from South Africa, Australia, the U.S., and other producing areas can easily be delivered into major European and Asian markets for $20 to $25 per barrel equivalent. Natural gas is an even stronger competitor. The recent decision to develop the Norwegian Troll field is based on an expected delivered price as low as $18 per barrel oil equivalent. Of the alternatives under consideration, the Troll field gas is more expensive than gas from either Siberia or Algeria, but is considered more secure. Similar gas deposits in Canada and Mexico can be developed for the North American market at less expense than those in Europe.

However, one significant difference exists between U.S. energy markets over the past century and the current world market. Cheap oil reserves now are concentrated in the Middle East, and particularly in Saudi Arabia and Kuwait. Thus, the burden of oil market stability rests on the governments that control crude oil that can be developed inexpensively.

calories as such, and in which residual and other heavy fuel oils compete actively with coal, natural gas, and other energy sources. In the U.S., these markets most often are referred to as boiler fuel markets, although the uses extend much further than raising steam for generating electricity and for other industrial purposes. These uses include distilling a host of substances, melting and drying bulk materials, metallurgy, and other large-scale industrial-process heat. A decade ago in Europe, it was fashionable to call these uses the black fuels market. But supplies no longer are confined to coal and heavy fuel oil; they include natural gas, uranium, municipal waste, and vegetation. For those who prefer to use whole words, bulk fuels probably is the best term.

XIII. SIGNIFICANCE OF SAUDI ARABIA

Day-to-day oil-price changes are driven by Saudi production decisions more than by anything else. Since the drop in the demand and price peak of 1981, oil prices could stabilize above their earlier levels only because the Saudis and a few other OPEC members were willing to decrease production to balance the market. In the summer of 1985, however, Saudi production had fallen to 2.5 million barrels per day—about one-half of the Kingdom of Saudi Arabia's OPEC production quota, and nearly a 50 percent drop from production levels of the summer before. The only way that the Saudis could restore their production and stem the erosion of their export revenues was to retreat on price. They did so through a set of complicated "netback" agreements that guaranteed profit margins to refiners buying Saudi crude oil. As they executed these agreements, Saudi officials warned that they no longer were willing to act as swing producer. Simply stated, the Saudis lost control of the marginal barrel of crude oil and thus the ability to set price.

Sooner or later, however, oil suppliers outside the core of the Persian Gulf will be unable to support further demand growth at prevailing prices, and Saudi production rates will rise. When its market is restored, will Saudi Arabia meet the world's incremental oil demand by raising price or raising production?

As late as 1972, the major oil companies projected Saudi crude-oil production potential in excess of 20 million barrels per day. Such an output still is plausible, and the investment required to arrive at that production level is an order of magnitude lower than the cost of providing a similar increment in primary energy supply from any other set of resources. It is a good bet the Saudis now realize that higher capacity levels should have been installed during the mid-1970s to prevent the price runups of 1979 and 1980. (The Saudis themselves wittingly or unwittingly helped engineer those price runups by holding back on production.)

So long as Saudi Arabia's leaders are rational, they will price their energy just below the costs of its closest competitors. In the short run, that competition is from other sources of oil as well as from natural gas in North America and Europe, where the long-distance transmission infrastructure is more than adequate to meet current demand. In the longer run, the competition is from coal and new natural-gas supplies, including the substantial cost of adding new transport capacity. Thus, the most important determinant of oil prices, in both the short and the long run, is competition among fuels in the B-fuels market.

Put another way, the marginal supplier of energy to the world will base its price on the marginal uses of energy and the marginal development costs of fuels competing in that market. Because the Saudis' reserves are unlikely to ever be worth much more than the value of substitute B-fuels, they have little economic incentive to restrain developing their fields. In short, Saudi Arabia has both the incentive and the ability to meet the world's incremental energy demand through the rest of the century, and at prices comparable with those that prevailed in mid-1986.

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