The Energy Crisis

Unresolved Issues and Enduring Legacies

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7. Predictions, Prescriptions, and Policy

Lessons from the Record

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Large modeling or forecasting efforts and their associated analyses are inherently problematic. I argue that despite these problems, energy modeling and analysis efforts conducted since the energy shock of 1973 teach us much about energy policy. The most common and largely accurate criticism of much of formal modeling was summarized by Amory Lovins, a prominent energy analyst who followed a different path:

> Such models have trouble adapting to a world in which, for example, real electricity prices are rapidly rising rather than slowly falling as they used to. . . . Extrapolations have fixed structure and no limits, whereas real societies and their objectives evolve structurally over decades and react to limits. Extrapolations have constants, but reality only has slow variables. . . . Extrapolations assume essentially a surprise-free future even when written by and for people who spend their working lives coping with surprises such as those of late 1973. Formal energy models can functionally be stripped of surprises, but they can say nothing useful about a world in which discontinuities and singularities matter more than the fragments of secular trend in between. Worst, extrapolations are remote from real policy questions. (Lovins, 1979: 64)

Lovins's alternative to formal modeling is an analytical approach fraught with difficulties. It rejects exploitation of available data in favor of more speculative ruminations in which it is difficult to separate prescriptions from predictions that can be understood and reproduced by others. Therefore, despite its limitations, formal modeling is often better than the alternatives.

It is easy to show the follies of forecasting, and energy forecasting has a well-known record of mistakes and failures. As the famous physicist Niels Bohr is reported to have said, "It is difficult to make predictions, especially about the future." For example, energy forecasters are painfully familiar with previous published energy demand projections in which total energy demand declined at a compound rate of 7 percent per year between 1972 and 1983 (Greenberger and Hogan, 1987: 256). This phenomenon was repeated in countries other than the United States. In the electricity sector, the infamous National Electric Reliability Council (NERC) "fan" captures the failed extrapolations of electricity demand starting in 1973 by displaying each subsequent year's NERC projection shifted one year later to give the appearance of an unfolding fan, summarizing the stubborn belief that old electricity growth trends would repeat (Nelson, Peck, and Uhler, 1989).

A more interesting set of issues that addresses the connections between predictions, prescriptions, and policies are the complicated interactions between forecasting, analysis, and the political battles among interest groups. Previous analyses of the 1970s, and the rush of large-scale analytical efforts (Greenberger, 1983), show that there is no tidy, linear progression from formal model to final policy: "Professors of policy analysis would like to tell their students that an analysis done professionally attracts attention and gets used. We found, instead, that the highest quality analyses received the least attention and exerted the lowest immediate influence on policy. What is important is 'timing . . . ,' clarity, and whether the results accord or clash with the beliefs of those in power" (Greenberger and Hogan, 1987: 260).

A clash of values and beliefs can obscure the impact and importance of analysis. Few energy analyses that have assaulted existing values and beliefs have had wide influence. Amory Lovins's work may be the exception that proves the rule (Greenberger and Hogan, 1987: 260). But even he worked tirelessly to repeat and hone his message.

Wide acclaim and recognized success for forecasts are unlikely. If the answer is counterintuitive, it is wrong. And if the answer is counterintuitive, the most likely cause is a mistake in the analysis. If so, everything that can be done should be done to uncover the mistake. If the mistake is found and corrected, the conventional, intuitive answer will be shown to be right. If an explanation is found that supports the surprising answer, intuition will change and the decision rule still applies. This latter case is where analysis makes its greatest contribution. Whatever the outcome, the intuition, and not the analysis, is likely to get the credit. A good answer had better be consistent with common sense.

An interesting domain for studying the role of formal modeling is the interaction of insight from the analysis and the clarity of communication in the hard cases where "results . . . clash with the beliefs of those in power." In general, the message of the last two decades is simple: analysis must provide

insights more than predictions, and the insights must be communicated (Geoffrion, 1976; Huntington, Sweeney, and Weyant, 1982: 449–62). Marketing is just as important as production.

Applying this simple rule, however, is far from trivial. Its application has important implications that go far beyond a preference for simple models over complex ones. Analytical attention that focuses on insights and their communication can determine both the form and the content of the analysis. The following case studies are illustrative of past successes and failures in, and future opportunities for, acquiring and communicating the insights of formal analysis and energy models.

Insights Acquired and Communicated

The first domain to illustrate success is the set of examples from modeling and analysis. Here *success* is defined as cases where the conventional wisdom changed from one view to another, and in the same direction as indicated by available predictions and prescriptions. This definition forgoes a claim of success when the analysis merely confirms the conventional view. But this definition of *success* is generous in that it begs the question of what else could explain the change in the prevailing conception. The case studies summarized here do not prove, but they do support, the assertion that the analysis contributed to redirecting policy. These successes share a common theme of repeating the argument until the new idea permeates policy. There are few if any examples of analysis and modeling producing a sharp turn in policy. From this perspective, the educational function of policy analysis and modeling looms large.

Energy Independence

The shock of the oil interruption and price increases accompanying the 1973 Yom Kippur War precipitated a major effort to review and redirect the nation's energy policy. President Richard Nixon, looking for dramatic impact—and a diversion from Watergate—set the goal of energy independence. Project Independence was born on November 25, 1973, in a televised speech on energy by President Nixon. The president carefully avoided setting a goal of zero energy imports: "What I have called Project Independence—1980 is a series of plans and goals set to ensure that by the end of this decade Americans will not have to rely on any source of energy beyond our own. . . . The capacity for energy self sufficiency is a great goal" (Havemann and Phillips, 1973: 1637).

Despite its cautious language, the goal of energy independence was widely interpreted as calling for zero oil imports. At least one early analysis in the Department of the Treasury led to a plan that started from the assumption of zero imports in 1980 and worked backwards to a massive program of government subsidies to expand domestic production. However, the Project Independence analytical effort soon challenged the conventional view and proved less ambitious. Eric Zausner, who supervised and polished Project Independence's analysis, recalled that his task amounted to two simple redefinitions of President Nixon's original goals: "redefining 'independence' and redefining '1980'" (Havemann and Phillips, 1973: 1637).

The message that emerged from the supporting studies and computer models was that the goal of literal energy independence was ill conceived and would be prohibitively costly. At best, an aggressive program put in place in 1975 might eliminate oil imports for a short span around 1985, but the respite would be brief as natural petroleum supply depletion and energy demand growth drove the United States inexorably toward more oil imports. A more plausible and useful goal, embodied in the final Project Independence report, would be to reduce oil imports through a combination of programs to increase energy efficiency, enhance domestic production, and better prepare for what were expected to be new oil supply interruptions.

The analytical work done in support of the report continued to be applied and expanded, but the basic policy theme was permanently changed. Huge programs like the $100 billion Energy Independence Authority, to subsidize massive capital investment in the domestic energy industry—originally developed by Vice President Nelson Rockefeller and later proposed by President Gerald Ford (*Public Papers of the Presidents*, 1975: 1494)—fell away before analysis showing that such subsidies could not achieve independence and would be less cost-effective than other modest alternatives to increase efficient use of resources.

The policy analysis work spawned by Project Independence was never fully embraced, and there were many skeptics: "*DOWNGRADED:* FEA will continue to issue its annual updates to the Project Independence report, but FEA Administrator John O'Leary says he doesn't place much importance in them. Econometric studies applied to mineral fuels 'are not worth the paper they are written on,' O'Leary claims" (*Energy Information*, 1977: 4).

Despite flaws in the models and the analyses (Hollaway, 1980), their main ideas could be communicated, tested, and understood. Moreover, it was not the "econometric studies" or associated models that were the principal product, but the insights acquired from them. Domestic oil supplies were becoming more and more expensive; oil imports were relatively cheap; coal was available but hard to use in a cost-effective and environmentally acceptable way; and the market would adjust to eliminate any gap between supply and demand. These ideas changed the definition of *energy independence* and led to the quiet demise of the original target date of 1980.

When compared with the conventional wisdom embodied in Nixon's speech, the fact that these ideas now seem obvious is testament to the power of the policy analysis completed, repeated, and communicated under Project Independence's analysis.

Supply and Demand Elasticities and Economic Growth

Introduction of prices and price elasticity into the policy debate was a premier analytical contribution. It captured the importance of markets and the ability of the economy to adjust to the changing availabilities of energy. Before Project Independence and related studies, prices barely entered the analyses. The dominant form of modeling was the extreme version of extrapolation condemned by Amory Lovins. The desired growth of the economy would lead to an inexorable growth in energy demand. Left alone, sources of domestic supply would decline, especially scarce oil and gas resources. The neo-Malthusian difference between supply and demand was a gap that called for government intervention to subsidize and expand secure energy supplies.

To the economist, the flaw in the logic was self-evident. The gap between supply and demand would never appear. Gaps could exist only briefly. When supplies fell short of demand, prices would rise in the natural rationing mechanism of the market. Higher prices would curtail demand and increase supply, soon eliminating the gap. Hence, from the economist's perspective, the question was not how to mobilize the government to provide energy independence. The proper focus was to look for and eliminate market failures that might prevent this natural process or increase the cost of adjustment.

The debate between those who saw impending gaps and those who saw opportunities for markets to adjust has been well documented (Greenberger, 1983). It spawned several investigations emphasizing the demand side with a variety of energy models to narrow the range of disagreement about the size of the aggregate elasticity of energy demand (Energy Modeling Forum, 1977; 1981). There was an equally vigorous debate on the comparative advantages of econometric studies of historical data versus engineering analyses of individual energy conservation technologies.

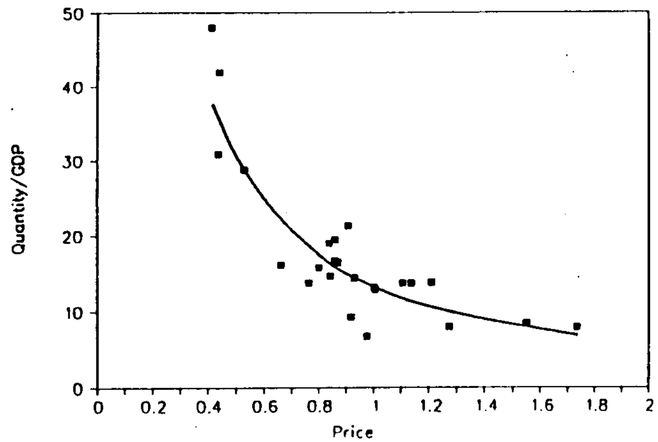

Figure 7.1 OECD Gasoline Demand, 1973
Source: Economic Report of the President, 1975.

Resolution of the argument over prices and market adjustments is now fully embodied in the conventional wisdom (Hogan and Manne, 1977; Hogan, 1979). In the short run, price elasticities are small because there is little room to adjust energy use, and sharp shocks to supply and demand can cause large movements in price; hence the problem of oil supply interruptions. But with the slow turnover of capital stock, there are large opportunities to exploit new technology and change the utilization of capital, labor, energy, and materials. Over a reasonable period of time, adjustments can be large enough to make energy scarcity a lesser problem for all but those employed in the most energy-intensive industries.

The necessary evidence was readily available at the time of the great price-elasticity debate. One of the most striking examples of the long-run ability to adjust to different prices is also one of the simplest. Data shown in figure 7.1 compare the intensity of gasoline use per unit of GDP across OECD countries in 1973, plotted as a function of the final price of gasoline. A variant of this figure first appeared in the *Economic Report of the President* in 1975. The argument was that the complex, confounding analytical effects of price shocks can be avoided by looking at cross-national comparison after a period of relative stability of oil and gasoline prices. From this perspective, the figure depicts the long-run equilibrium of gasoline demand, after all the adjustments have been made to accommodate different gasoline prices. The implied elasticity of gasoline demand is near unity, consistent with many later studies that were completed with more data.

Figure 7.1 is as close to the textbook example of a highly elastic demand curve as we are ever likely to find.

Contrary to the initial fears and assumptions of the early calls for massive energy subsidies to maintain economic growth, the consensus of the analyses was that long-run demand elasticities were really quite large. Hence, economic growth could proceed almost indefinitely without corresponding growth in energy use. If energy became scarce, technology driven by higher prices would increase real economic output without using more energy. Thus, massive subsidies to the energy industry were viewed as detracting from economic growth, rather than necessary to its maintenance. Steady repetition of the many energy models and analyses was an important part of this story.

Price Controls and Shortages

A similar consensus emerged from analyses of supply-side responses to higher energy prices. There may not have been much confidence in the details of individual econometric models of oil and gas supply, but the evidence of positive price response was compelling. However, in each case, evidence had to overcome conventional wisdom through repeated studies and hard experience.

Consider the case of natural gas. By the mid-1970s extensive price controls had produced increasing shortages of natural gas in the interstate market. The excess of demand over supply caused growing curtailments that closed schools and factories in order to allocate the scarce supplies of available natural gas to higher-priority residential customers. By 1978 the Powerplant and Industrial Fuel Use Act forbade the use of natural gas in new power plants in an attempt to conserve limited supplies of natural gas for higher-valued uses. At the same time, the Natural Gas Policy Act imposed a complicated set of price regulations and ceilings designed to extract the few remaining gas reserves from deep deposits without allowing prices to increase much for the supposedly fixed supply of traditional sources of natural gas.

The result was a predictable fiasco. Price regulations distorted the industry completely out of connection with the underlying economics and created the anomalies of high-priced surpluses and subsidized consumption. This in turn drove up total demand. An accounting of the flaws in the argument and the high cost of policy recovery is now available (Pierce, 1988: 1–57; 1993). The failure was to approach natural gas as something intrinsically different from other commodities, with large segments of the market

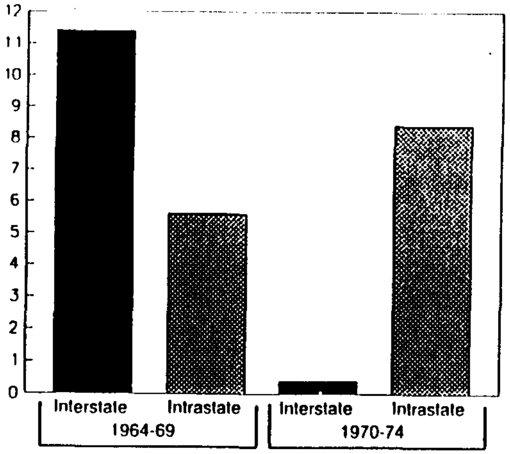

Figure 7.2 Average Annual Reserve Additions of Natural Gas, 1964–1969 and 1970–1974 (trillions of cubic feet)
Source: U.S. FEA, 1976: 122.

assumed to be impervious to the incentives price. As later studies showed, the opposite was closer to the truth. Natural gas supply and demand *was* responsive to price incentives. With unregulated prices the market would balance itself, often at much lower prices than those imposed by rigid regulations.

The evidence was readily available before passage of the Natural Gas Policy Act in 1978. Figure 7.2 is from the *National Energy Outlook* of 1976, prepared by the U.S. Federal Energy Administration. Before 1970, natural gas was readily available. By 1970, curtailments began to appear, but only in the interstate market. The explanation was simple. By the early 1970s, prices for interstate sales were capped by controls at "52¢ per thousand cubic feet. . . . In contrast, unregulated prices for gas sold on the intrastate market usually range between $1.00 and $1.50 per Mcf" (U.S. FEA, 1976: 117–19).

As shown in figure 7.2, the market responded with ample supplies for the intrastate market and a complete collapse of new supplies in the regulated interstate market. It would be hard to find more dramatic evidence of the supply-side effect of prices. However, it took more than a decade and great cost to convert the analytical argument into natural gas policy. By the early 1990s the old analytical heresy that natural gas is a commodity for which supply and demand respond to price became the new conventional wisdom. Price controls create shortages, and market competition restores a supply and demand balance.

A similar and slightly faster revolution took place in oil markets analysis. However, the notion of a supply response to higher prices was still difficult to translate from analysis to policy. Coupled with the infamous "entitlements" program, domestic price controls in 1973 subsidized oil imports and increased oil dependence (Kalt, 1982). The only shortages that arose did so because of federal rules that allocated supplies to local markets but did not keep up with shifts in local demand. It soon became clear that the gasoline lines were caused by government intervention, and price controls only exacerbated the problem. Eventually, President Jimmy Carter took the political heat and used his authority under the Emergency Petroleum Allocation Act of 1973 to gradually eliminate domestic price controls on oil. In his first official act, President Ronald Reagan used the same authority to complete the process of price decontrol a few months early. Thereafter the Reagan administration felt able to take full credit for the coincidence that world oil prices declined almost immediately.

There has not been a full tabulation of the costs of oil and gas price controls. However, it is clear that the many supporting policy studies, coupled with the experience of shortages and unwanted costs, convinced most analysts and policymakers that the country would be better served by exploiting the market and allowing the evidently large long-run supply and demand elasticities to do their work. The precision of the estimates was never as important as the coherence of the argument and the reinforcement of the models in explaining the evolving turmoil. No single study turned the policy direction. The effect was cumulative. The analytical framework of price-responsive supply and demand came to replace the neo-Malthusian view of the irrelevance of price incentives. Energy pricing and market policy moved from protecting favored groups, or preventing wealth transfers, to promoting competition and free markets.

Natural Monopolies and Competition

Perhaps the most striking example of the power of analysis and the ability of an economic argument to affect the design of policy is the treatment of natural monopolies' prominent role in the energy market. Once convinced of the power of the forces of supply and demand, the competitive market is usually recommended as best able to find the efficient balance. A fair amount of evidence supports the notion that supply and demand respond to price changes and that the market can achieve an acceptable equilibrium.

In the energy market, however, some segments come close to the definition of natural monopolies. In the case of natural gas, for instance, the interstate pipeline bottleneck separated the many customers from the many producers. For competition to operate, so the argument went, customers and producers had to reach each other through the pipeline. Pipelines are a natural monopoly and an essential facility. Government intervention would be required to guarantee "comparable access" for all participants (Kalt and Schuller, 1987).

The opposite view was that the pipelines had effective competition or would be compelled under regulation to make cost-effective purchases of natural gas. Thus, no further government intervention was required. By its very nature, there is likely to be scant evidence of how the market would operate if there was no regulated monopoly. In most cases of access to an essential facility, the argument is based on analogy or first principles rather than empirical evidence.

Analysis from first principles and argument by analogy were applied to natural gas. Appeals to the experience with airlines, trucks, and telephones were made to bolster support for the benefits of competition and the need for access to essential facilities (Maryland People's Counsel, 1984). The monopoly pipeline that transported gas to others and sold gas on its own could hardly be expected to avoid the temptation to control one for the profit of the other. Examples of real or imagined discrimination accumulated as the debate progressed, but the touchstone was always the analytical idealized level playing field.

The notion of nondiscrimination in pipeline transport conveniently dovetailed with the simple model of a pipeline viewed as a bundle of straws connecting producing fields to the final consumer. Although flawed in detail, the basic notion that every customer could have its own little bit of pipeline capacity, reaching all the way back to the producer, survived intact in the final rules. Transition cost was high (Pierce, 1988; 1993), but federal rules embodied in Order 636 of the Federal Energy Regulatory Commission (FERC) completely reoriented the natural gas industry away from regional segmentation and interstate dominance by a few pipelines to a true commodity market where the only regulated service is transportation. As a result, the functions of buying and selling gas have become a fully competitive, highly integrated market (Doane and Spulber, 1991).

The same process that unfolded for natural gas extended to the electricity market in the early 1990s. Successful access to natural gas pipelines was used as the analogy supporting the need for access to the integrated transmission network connecting potential sources of electricity to customers wanting to take advantage of competition (Pierce, 1988; 1993). The Energy Policy Act of 1992 (sec. 211) gave FERC authority to ensure nondiscriminatory access to the electric transmission network in support of development of a fully competitive wholesale market.

The difficulties FERC faces in electricity are greater than those in natural gas because of the inherent complexity of the electric system. The simple model of a bundle of straws does not apply here. Something else must take its place. Competing generators must have access to the essential facilities that stand between them and potential wholesale market customers. Transmission is the essential facility, and open access to it is necessary for development and operation of a competitive market.

While access is necessary, however, there is more to transmission than simple connection to wires. The free-flowing electric grid requires coordination of short-term operations to maintain system stability and achieve least-cost dispatch. This coordination function operates most efficiently through a power pool that provides many services implicit in the economic dispatch. Dispatch provides an automatic source of backup supplies, short-term excess sales, reactive power support, spinning reserve, and many other services bundled into electric power transmission. Without equal access to these functions, new market participants will be at a competitive disadvantage relative to those having access to the full array of power-pool benefits. However, there is no consensus on how to provide this comparable access.

Learning from the gas experience, in 1993 FERC launched a series of inquiries aimed at analysis and investigation of alternative models for industry organization and access. These hearings steeped FERC in the details of economic incentives and engineering practice. While the debate was not resolved by late 1994, analysis and economic models stood at the center of the argument. The modelers showed that they had partly learned the lesson of the last two decades. The models offered in these FERC proceedings emphasized concepts and insights in preference to numbers and forecasts (Hogan, 1992: 211–42; 1993a: 171–200; 1993b: 18–29; 1993c). If the analysis is to affect electricity policy, which is still open to question, success will depend on finding a simpler way to capture the insights and relate them to the real world.

Insights Acquired but Not Accepted

We turn from successes, generously defined, to failures by any definition. Here the analyses failed to overcome conventional wisdom, even though the conventional wisdom may have been wrong. Something was awry. At a minimum, the insights seen by the analysts were not successfully communicated or accepted.

Emergency Management and the Strategic Petroleum Reserve

In 1973 the sudden disruption of the oil market and the associated price rise caused the United States and other oil-importing countries to reduce import dependence and stabilize supplies. Proposals for new policies ranged from promotion of energy conservation to reduce consumption to creation of a large synthetic fuels industry to convert abundant coal into newly scarce oil. In virtually every case, the debate over policy merits and the need for government intervention was contentious and confused.

The principal exception to this divisiveness was virtually unanimous support for an emergency petroleum storage capacity. The early analysis in the Project Independence report estimated the cost of a sudden oil supply interruption as a short-term reduction in GNP of $33 billion for each million-barrel-per-day supply curtailment (U.S. FEA, 1974: 377–92). The benefit of avoiding this loss was weighed against the ten-year cost of buying and storing crude oil, chiefly in salt domes, to be available for quick use in an emergency. Use of the ten-year horizon implied that such an interruption would occur once a decade, a forecast consistent with market disruptions and oil price increases since 1979. Borrowing from the wisdom of Joseph, who advised the pharaoh to store grain in times of plenty to prepare for times of famine, the analysis supported a large emergency reserve in excess of 1 billion barrels.[1]

Later work, notably that of Teisberg (1981: 526–46), applied principles of dynamic programming and game theory to reinforce this basic analysis (Hogan, 1983). These and many other studies concluded that the United States and other oil-importing countries should create, maintain, and, when necessary, use large supplemental oil supplies (Weimer, 1982; Leiby and Russell, 1989). The resulting Strategic Petroleum Reserve (SPR) became the centerpiece of U.S. energy security policy. Although the SPR was authorized by Congress and included in the budget, the powerful Office of Management and Budget (OMB) dissented. OMB noted that the cost of the SPR came out of the current budget, and the benefits would only come later. Because of this, progress was slow and Congress pressed to have the reserve filled (U.S. GAO, 1983; Stanfield, 1985: 1024–26). Eventually, OMB objections were overcome and the SPR grew slowly, reaching 587 million barrels in July 1990, just before the outbreak of the Persian Gulf War (U.S. DOE/EIA, 1992: 45).

Saddam Hussein's invasion of Kuwait removed Iraqi and Kuwaiti oil from the international market and in a stroke eliminated the excess capacity that had plagued OPEC with an oil glut. The predictable result was a sharp jump in oil prices, from $16/barrel in July 1990 to $30/barrel in September 1990 (U.S. DOE/EIA, 1992: 105). The U.S. economy was threatened, and thus was presented with the first major opportunity to apply the SPR and gain some of the benefits that came with the expense of filling the reserve during a high-cost era. There were immediate calls for using the SPR to supplement imported oil.

The SPR sat safely in its domes of salt, unused until January 1991, at the initiation of Desert Storm. Oil prices fell almost immediately, more as a result of the successful missile attacks shown live on the Cable News Network from downtown Baghdad. Early military success guaranteed the security of Saudi Arabian oil and changed perceptions and power relations in the world oil market. The SPR arrived too little and too late.

What went wrong? One concern in the early analysis of the SPR was that the very act of using the reserve could detrimentally signal to the world oil market that a developing problem was a true crisis. Thus, the president would be reluctant to acknowledge the severity of an oil market interruption in hopes of avoiding panic and to allow time for diplomacy to work. This early concern produced a variety of proposals to insulate the president from the immediate decision, including financial options and regular sales from the SPR. As serious as this weakness in the SPR process may have been, however, it hardly explains the reluctance to use the oil in the early fall of 1990. By then troops were on the ground, and President George Bush was working vigorously, both publicly and privately, to assemble the successful allied force that launched a major war to recover Kuwait and isolate Iraq. Arguably, a decision to use the SPR could not be more serious than a massive commitment of armed forces. This setting therefore reinforced both the need and the opportunity to use the SPR without the possibility that its very use would be counterproductive.

In retrospect, SPR policy analyses failed the test of "clarity," and "whether the results accord or clash with the beliefs of those in power." The wisdom of Joseph and the pharaoh was misconstrued in the very name of the SPR. The president and other senior decision makers believed that, like Joseph's grain, the reserve stock should be saved until it was really needed—the last source of supply rather than the front line of defense. But this missed the whole point of the underlying analysis in every SPR study: that the benefits came from avoiding the early economic shock effects of the sudden price rise, not from a prolonged capability to sustain a high level of imports. The role of the oil reserve was to cushion the transition, not to be saved till last. More than one wag suggested that it would have been better if Congress had created a *Tactical* Petroleum Reserve to convey the idea that oil should be drawn down quickly.

This analytical fine point was not so fine as to be missed in the choice of storage for the reserve. The choice of salt domes over other alternatives, such as shut-in production capacity, followed from the need to provide a very rapid flow rate once the reserve was opened. Conventional oil wells produce too slowly, and the SPR "wells" had to be the most prolific in the world when in use. This need for rapid production derived naturally from the analysis that showed that the benefits of SPR use came from early, rapid withdrawal, not later leisurely use.

The need for rapid withdrawal was lost in implementation, both in the United States and among its allies' diplomats, who were virtually unanimously in favor of saving supplies for a real emergency, all the while conducting one of the largest military buildups in history. It is hard to imagine a more ideal circumstance for using the oil reserve, and we did not. Given this experience, it is difficult to justify continuing the reserve without at least communicating its value, changing the policy for use, and changing its name.

Energy Security and Oil Import Fees

The costs of oil import interruptions that led to nearly unanimous support for the SPR did not produce agreement on the need for further intervention in the form of an oil import tariff. As a protagonist in the debate, I view the issue with some bias. However, it is not necessary to take a position on the merits of the arguments to make the case that any insights that spring from analysis have been lost in the conflict of ideology and interests.

The case for an oil import tariff is simple in the abstract (Hogan, 1981). If higher oil imports lead to higher prices and greater exposure to the damage of oil supply interruptions, then associated costs are not priced in the marketplace. These externalities create a wedge between the social and private costs of oil imports that could be replaced by an oil import tariff.

The case against an import tariff is equally simple. Free trade is generally good. If the larger objective of free trade, such as the General Agreement on Tariffs and Trade (GATT), is jeopardized by a tariff targeted at oil, then the balance can be tipped against market intervention. Besides, the government can ruin any good idea; witness the SPR blunder.

This summary of the case against an oil import tariff is different from the usual arguments:

—Everyone knows that tariffs reduce economic welfare; it is in the textbooks. (The textbooks soon used OPEC and oil as examples of exceptions to the rule.)

—An oil tariff is protectionist and creates gains for domestic producers. (True, but irrelevant in simple aggregate welfare analysis. Gains to holders of domestic oil reserves—e.g., Harvard, California pension funds—are not losses to the nation.)

—A tariff will reduce macroeconomic output and lower economic welfare (U.S. DOE, 1987). (Probably wrong, but if the analysis holds up, it argues symmetrically for subsidies for oil imports, but subsidies are also approved. There is no analytical support for this asymmetry.)

In short, opposition to an oil tariff has been built on ideological arguments isolated from the reality of the world oil market, which has been dominated by a cartel and for which the usual rules of thumb do not apply. Yet these arguments have been successful, and attempts to make the opposite case have failed. Failure can be partly attributed to inability to find the right model or metaphor to overcome the "clash with the beliefs of those in power." Free-market arguments applied to the competitive domestic market were transferred uncritically to the cartelized international oil market.[2]

Arguments against an oil tariff appealed to easy slogans and familiar truths. The arguments for an oil tariff built from unfamiliar perspectives and no appealing model. The notion of "internalizing the externalities" was no match for that of "defeating protectionism." The simultaneous call for removing domestic price controls and imposing an import tariff was viewed as inconsistent rather than as a coherent theory about the role of government based on a recognition of the degree of market failure. If there was any insight in the analysis, there was a failure of communication.

Insights Acquired but Not Yet Communicated

In addition to the successes and failures of communicating insights, energy market analyses have an inventory of important, evolving ideas that have not been rejected but have yet to be understood and communicated. They remain challenges to analysts and policymakers. Two examples illustrate the difficulties in finding good ways to analyze and communicate in the presence of hard problems.

Technological Change and Energy Demand

Over short time periods, technology is fixed and the economic focus is on choice and substitution. The analysis of energy demand can be reduced to the investigation of price incentives and opportunities to substitute capital, labor, and materials for energy at the margin. This framework dominates most models, explicitly or implicitly, in the form of fixed demand curves. And this approximation works rather well. This model might suffice over a decade or so in tracking movements of supply, demand, and oil imports.

Over a longer horizon, however, technological changes will shift the range of potential substitution in fundamental ways. Think only of the configuration of energy consumption at the turn of the century to realize that understanding technological change is the key to explaining differences between then and now. Careful analysis of turn-of-the-century technology in steam engine design or trade-offs between horse and horseless carriages are of little use today. Hence, when addressing policy questions that span decades, such as how to deal with greenhouse gases, there is no alternative but to adopt a view on trends in technology and the impacts on energy demand.

The work of Manne and Richels has been most prominent in the debate in highlighting the importance of technological change in the "autonomous energy-efficiency improvements" factor. In their model, technology is an exogenous trend that reduces energy consumption over time, other things being equal (Manne and Richels, 1992). The trend assumption is among the most important inputs, and there is very little guidance to help get an empirical fix on it. Worse, the rate of technological change cannot be truly exogenous for a large economy over a long period of time. Common sense dictates that scarcity, as summarized in relative prices, should substantially affect the rate of technology development. Thus, technological change is endogenous. It is affected by the path of economic development and energy prices.

Although this commonsense argument is easy to accept, it has had relatively little impact on energy modeling and analysis and even less on the communication of the analytical results intended to guide policymakers. Here, Lovins's more holistic approach is closer to the mark, but his approach is divorced from any formal model that exploits empirical evidence. The only formal modeling framework that attempts to capture both the theory of endogenous technological change and the empirical implications in estimation is that of Jorgenson and Fraumeni (1981: 17–47). Although their work and, later, that of Jorgenson and Wilcoxen (1993) have been extensively applied by their developers, they have not been widely emulated or fully utilized. Yet the available evidence suggests that many of the most popular assumptions about the nature and rate of technological change may be biased. For example, they may have the wrong sign (i.e., they assume positive technological change where a negative change may be correct) (Hogan and Jorgenson, 1991).

The theoretical foundations for modeling technological change are shaky, and empirical implementation is especially difficult. Analysis must concentrate on separating all the effects of substitution and the messy dynamics of energy and related prices. Once these other factors have been explained and controlled, the model of technological change tries to explain the residual factors that make up total factor productivity. Any hope of cracking the problem requires a general equilibrium analysis. The data and estimation requirements are daunting and have prevented most from following this path. It is surprising that more of the analyses and associated policy pronouncements have not incorporated the fruits of this research. This is a challenge for analysis and communication that lies ahead.

Consumer Myopia, Discount Rates, and Market Failure

An exciting area of energy analysis combines the old decision-analysis approach with a new twist to integrate the theory of options with the investigation of energy investment and conservation decisions. This line of work holds a key insight that may resolve an old conundrum regarding the disparity between consumer and corporate discount rates.

Consumers appear to substantially underinvest in cost-effective energy conservation technologies. The usual characterization of the problem in terms of consumer discount rates laments the myopia of consumers in failing to adopt cost-effective energy conservation technologies. That such overlooked technologies are in fact cost-effective usually derives from an engineering analysis of costs and benefits and a present-value calculation based on an electric utility's assumed cost of capital (approximately 12 percent). There are many difficulties in the cost analysis based on engineering projections (Joskow and Marron, 1992), but the self-evident proposition that consumer discount rates are too high is widely accepted, often based on the econometric work of Hausman, who found discount rates as high as 89 percent, depending on income level (Hausman, 1979: 53).

This interpretation of consumer choice as a market failure has contributed to the rationale for programs to substitute regulated utility decision making, discount rates, and choice of energy-efficiency investments. The rationale is that the utility makes supply-side investments in new generating facilities based on cost-effectiveness using its low cost of capital. A level playing field would require demand-side investment to be evaluated on the same basis. Of course, such cost-effective investments would require subsidies to overcome the consumer's unwillingness to invest alone. Resulting large-scale demand-side management (DSM) programs soon began to amount to a noticeable portion of total electricity costs.

The thrust of the new energy research is that this old analysis may have the story partly backwards (Jaffe and Stavins, 1993). The new insight draws from options theory and its application to energy decision making (Dixit, 1992: 107–32; Dixit and Pindyck, 1993). Here the argument harkens back to decision analysis and the value of information with sequential resolution of uncertainty. The usual cost-effectiveness analysis assumes certainty in estimates of investment costs and energy savings or, at most, performs a simple sensitivity analysis. But the analytical approach usually submerges the option value of waiting in the presence of uncertainty. If there is significant uncertainty about energy prices and technology, then the usual choice of investing in energy conservation is not a once-and-for-all decision, but one to invest now or to wait and revisit the issue when more information becomes available.

Investing now forecloses the option to wait. If the option has value, as it does when there is a significant chance that new information will change the decision, then the impact is to require a higher threshold of return before making an investment.

This higher threshold is indistinguishable from a higher discount rate applied to the existing "cost-effective" technologies. This recent research could go a long way toward explaining the otherwise "irrational" behavior of consumers.

This argument also cuts against utility decisions to invest in capital-intensive generating equipment. Investment in generating plant can also be compared to the option of waiting for more information. In the presence of significant uncertainty, this behavior would be indistinguishable from applying a higher discount rate to the evaluation of generation investment. Hence, the resolution of the conundrum is not that consumers are myopic and use discount rates that are too high, but that utilities are overconfident and use discount rates that are too low. The level-playing-field argument still applies, but its application is on a field of higher discount rates, smaller modular investments, and greater attention to flexibility in the face of uncertainty.

While it is not likely that this new perspective will resolve all the debate surrounding the proper balance between conservation investments and new generation, it shows how analysis and careful modeling can go a long way toward a powerful insight that has escaped many analysts not using the proper framework. More work remains to be done to pin down the magnitudes and communicate the ideas. The challenge lies ahead.

Insights Not Yet Acquired

There is a long list of important unsolved problems in energy analysis that inherit all the dilemmas of economic modeling in general. Perhaps the most persistent is cartel behavior. Early work on models of OPEC and its effects struggled with the difficulties of modeling anything other than the extreme cases of perfect competition and perfect monopoly. The range between these extremes covers too much and we know too little to be confident about anything we say in this domain, despite the importance of the questions.

Early published analyses of cartel behavior assumed that OPEC producers, or a subset, acted as a unified market leader surrounded by a competitive fringe (Pindyck, 1978). Originally it was thought that prices could not rise much above the level in 1974, as the present value-maximizing price had been reached or exceeded. However, additional analytical work not exposed until much later, but performed in 1975, revealed that the conclusion was entirely dependent on the seemingly innocuous assumption of linear demand curves. With linear demand, elasticities rise rapidly with rising price, soon reaching the economic ceiling for the monopolist. Changing to alternative demand variants that were equivalent over the range of the data but did not extrapolate rapid increases in elasticities produced a dramatically different result (Fromholzer, 1981; Wirl, 1985). This insight, accepted at the time, led to the conclusion that the government should not discuss the strong upside potential in OPEC prices. However, the practical result can be seen as the focus of the Federal Energy Administration's *National Energy Outlook* of 1976, which shifted to the higher price range compared with the *Project Independence Report* of 1974. The higher prices and revenues of 1979 and the early 1980s confirmed that a coordinated oil cartel could maintain higher prices and might wish to do so on behalf of its own interest.

Despite this one success, the problem for oil market analysts is that the cartel is anything but coherent and monolithic, and all formal attempts to get us further than the view of Adelman, summarized so well as the

"Clumsy Cartel," have been less than convincing (Adelman, 1980). Most advanced game-theory models, or extensive, diligent efforts to build simulation models to provide a better understanding of OPEC behavior, including my own, performed badly and reverted to the poorly supported target capacity utilization model that called for OPEC price increases when its production exceeded 80 percent of available capacity (Salant, 1982; Gately, 1977; Powell, 1990). Moreover, this default model was completely inconsistent with the high rates of capacity utilization and low oil prices of 1991–93. This model is useless, and there is nothing else on the horizon.

The contributions of formal modeling are limited to the valuable but narrow "under-the-lamppost" investigations where the light is better. For those who wish to examine the range of options that are available to the cartel, Gately's many sensitivity studies examining the interaction of prices and demand under a wide range of cartel pricing rules can be of real help (Gately, 1977). Many near-optimal pricing paths are available, and each pricing path is different. This will be of little comfort to OPEC, but it may in part explain why analysts with models have such a hard time making useful predictions in this domain.

Another perspective is the analysis of the competitive bounds on OPEC prices. A collection of papers from the time of the big oil price drop in 1986 demonstrates that this problem is amenable to analyses that point to a competitive price floor far lower than even the low oil prices of 1986 (Adelman, 1986; Griffin and Jones, 1986). As for the cartel, there is not much that can be said and believed based on the analysis of the formal models. The cartel is not dead, nor is it irrelevant. Prices are higher than the competitive floor and lower than the maximum that could be sustained. In between, we are all groping along with the clumsy cartel. Extensive and repeated analysis has not produced, much less communicated, any real insights about the behavior of the oil cartel or its effects on the world oil market.

Conclusions

Energy modeling and policy analysis is a fertile field for studying the interaction between ideas and the practical world. The surprise and impact of the 1973 oil embargo motivated an array of studies that still echo two decades later. Along the way, the practice of energy policy analysis changed with shifts in policy and gradual maturation of understanding of how to do and use formal policy analysis built on models and data. These illustrations highlight a prominent lesson concerning the interaction of analysis and policy, and of analysts and policymakers. The contribution of successful energy models has not been specific predictions or prescriptions, but insights into the complexities of the energy-economic system. Achieving success and improving the track record depend on a conscious effort to balance investment in analysis with investment in communication. In the marketplace of ideas, as in most markets, marketing is as important as production. Both marketing and production of analysis must adapt to be mutually reinforcing.

NOTES

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1. "And all the peoples came to Egypt to buy grain from Joseph, for the famine was grievous everywhere" (Gen. 41:57).
2. For those who doubt the disconnect between argument and analysis, there is succinct evidence in the 1988 exchange in *Energy Journal*, a presentation of three different views in what was billed as a debate (Tussing et al., 1988). Virtually any reader would conclude that the authors were talking past each other, not debating the merits of an analytical argument.

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