THE ENERGY PROBLEM: A REAL WORLD LABORATORY FOR THE EMPIRICAL ECONOMIST

Hillard G. Huntington

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* I have benefitted from discussions with Dermot Gately, James Sweeney, Lester Taylor, and David Wood, although the usual disclaimers apply. This essay appears as "Energy Economics" in The New Palgrave, edited by J. Eatwell, M. Milgate, and P. Newman (Macmillan), forthcoming 1987. The paper is intended to provide a summary of energy economics for the professional economist who is not a specialist in the field. By request of the editors, there are no footnotes and references have been kept to a minimum.

Energy Modeling Forum
Stanford University
Stanford, CA 94305

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Political instability in the Middle East caused dramatic oil price increases in late 1973 and during a seventeen month period over 1979-80. These events created a natural laboratory for economists to study the response of markets and economies to shifts in the relative price of an important input.

Prior to the decade of energy shocks, economists specializing in this area usually focused on market structure of the critical oil market (Adelman, 1973) or the structure and regulation of specific fuel markets. While these issues continued to receive attention, new empirical issues were intensely studied, of which three key areas are highlighted here: energy demand and its response to price, the connection between energy and other factors of production, and the response of the aggregate economy to input price shocks. Analysis of cartel behavior in the world oil market also attracted much interest and is briefly reviewed.

The economic research on energy supply remained largely theoretical, focusing on the formal aspects of modeling depletion. In general, these contributions provided fewer empirical insights than those in the above areas. Additionally, contributions in the market structure and industrial organization of other fuel markets were not as noteworthy, although the shift away from oil and the recent deregulation trends in natural gas and electricity markets have regenerated new interests in these topics.

Energy Demand

Economists were more optimistic than others on the response of aggregate energy demand to a change in its relative price. And in hindsight, this optimism appears justified.

Most studies found that while energy demand was responsive to price, it tended to be price inelastic, even in the long run. During the late 1970s, many estimates placed the price elasticity of aggregate energy in the -0.3 to -0.7 range when measured at the wholesale (or secondary) level (Energy Modeling Forum, 1982). The oil price collapse in 1986, as well as a more modest price decline in 1983, are providing another real-world experiment for testing the symmetry of energy demand responses to rising and falling prices.

Price elasticities at the end-use level could be some 50 percent higher due to differences between end-use and wholesale price levels. Elasticities for individual fuels and electricity would also be higher, reflecting the potential for interfuel substitution within aggregate energy.

Interfuel substitution. The shift away from petroleum products accelerated after the 1979-80 oil price shocks, particularly for fuel oil where ready substitutes are available. These economic incentives, combined with environmental concerns about coal and nuclear power, have intensified the interest in the relationships between energy sources.

In contrast to the finding about aggregate energy, the econometric evidence appears to suggest considerably less substitution potential between fuels than is deduced from engineering studies of specific technologies. The econometric estimates may change, however, as competitive fuel markets become less regulated and as equipment that can burn multiple fuels penetrates the market more widely.

Energy-using capital. Energy is a derived demand that depends upon the mix of final goods and services desired by households and firms. Even for residential energy use, households are viewed as combining energy-using capital stock and energy inputs to produce service flows that provide utility to the decisionmaker. This approach provides a clear distinction between short and long-run energy demand responses. Working with a fixed capital stock, agents can alter their rate of utilization to changes in price, income and weather in the short run. In the long run, the demand for energy is tantamount to the demand for energy-using capital stock.

The development of reliable capital stock estimates for empirical applications is a decidedly more complex issue. Usually researchers have serious reservations about the quality of such estimates and seek ways to avoid them. Their recourse is to represent implicitly the capital stock adjustment by eliminating the capital stock variable in the theoretical model. The flow-adjustment model (Houthakker and Taylor, 1970) is also a tractable way for separating the short and long-run energy demand responses in the absence of explicit capital stock estimates.

The approach of using explicit capital stock estimates has been applied most successfully to the study of the demand for gasoline in the transportation sector (Sweeney 1979), where information on the planned fuel efficiencies of different makes and vintages of passenger cars is available. This approach has been applied with somewhat less success to the residential sector. Some U.S. studies have used state-level estimates of energy-using appliances over time (Taylor et al, 1982), while others have employed household surveys (Cowing and McFadden, 1984) to provide a cross-sectional view of appliance ownership. Estimates for the other sectors are unavailable. Commercial floor space does not commit the agent to any particular fuel; hence, the short vs. long-run distinction is lost. And industrial capital stock is too heterogenous to be meaningful for empirical studies of manufacturing.

Industrial energy demand appears to be particularly influenced by the significant shift in economic structure from more to less energy-intensive sectors. At least one-third of the reduction in fossil fuel use per dollar of output may be due to the compositional shift in output in this sector. The sources of shift are uncertain and require additional research; energy prices, the cost of capital, capital obsolescence, the business cycle, technological change, and the appreciating dollar have all been mentioned as potential contributing factors.

Price variables. Some ambiguity has arisen about the price variable in energy demand studies as well. The frequent use of ex post average prices introduces simultaneity biases because this price variable is determined in part by total demand. Moreover, electricity and natural gas are sold on a declining block basis, in which the marginal price falls as consumption increases. The substitution of marginal for average prices may be insufficient to capture adequately the full effects of rate schedules on fuel demand. Marginal prices will reflect changes in the slope of the budget line for households, but the budget line itself can be shifted inward by an increase in the fixed charge. This consideration would argue, at least conceptually, for the inclusion of both marginal and fixed charges in demand studies for such fuels (Taylor, 1975).

Fuel availability can be an important issue in some demand studies. Not all households in the U.S. have had access to natural gas pipelines, even when price controls were not binding. This access problem affects the demand for substitutes (e.g., fuel oil and electricity) as well as for the fuel itself (Blattenberger et al, 1983).

Moreover, price regulations have had similar distorting effects. Binding price regulations have prevented the estimation of the demand for natural gas during the 1970s in the U.S. Natural gas shortages have also induced greater demand for substitute fuels than would be the case if all markets were clearing. For the most part, these issues have been insufficiently analyzed in traditional demand studies.

Energy and Other Inputs

Energy-economy linkages. The price elasticity of aggregate energy demand measures the proportional change in the use of all energy for a one percent change in the aggregate price of energy. It is closely akin to the concept of the elasticity of substitution between energy and nonenergy inputs. If the supplies of nonenergy inputs are held fixed, the aggregate elasticity will shape the long-run, energy-economy linkage. Energy's relatively low historical value share of GNP may not be an appropriate indicator of energy's importance to the economy, if limited flexibility in substituting capital and labor for energy greatly influence the future value share of energy (Hogan and Manne, 1977).

A higher elasticity implies less economic loss resulting from a reduction in energy availability or from a change in the cost of imported energy. However, if energy costs are raised by a domestic tax on energy that keeps the higher energy expenditures within the country, the economic loss becomes greater as the aggregate elasticity increases.

Energy and capital. More indepth study of the energy substitution issue was made possible by significant conceptual advancements during the 1960s that provided general flexible forms for estimating production and cost functions. In particular, the translogarithmic and generalized Leontief functions were advanced during this period. These functions are appropriate for analyzing substitution and complementarity between three or more inputs.

This theoretical development was propitious for economists who were interested in probing the relationship between energy inputs and other factors. At the same time, the energy price shocks provided a real world problem for testing these functions.

The application of these general flexible forms became widespread during the 1970s. While there was consensus on the methodology for estimating functions, there was sharp disagreement on the principal findings. The empirical dispute centered around whether capital and energy were substitute or complementary inputs in manufacturing.

Some researchers found that energy and capital were net complements (Hudson and Jorgenson, 1974; Berndt and Wood, 1976). Thus, higher capital costs would reduce energy demand. More importantly, higher energy prices would reduce capital investment and hence the long-run GNP through a lower capital stock. The initial studies supporting this view used cost functions that were estimated on national time-series data and that included the prices of four inputs: capital, labor, energy, and materials.

Other researchers concluded that energy and capital were substitutes for each other. Energy demand would be discouraged by lower capital costs, while higher energy prices would encourage the substitution towards more capital, contributing positively to long-run potential GNP. These studies often used cost functions that were estimated by pooling time-series data across several countries and that excluded the price of materials (Griffin & Gregory, 1976; Pindyck, 1979).

Intuitive explanations for each finding were advanced. Within individual technologies, energy conservation could be realized by substituting more capital as the real price of capital declined. However, with more than two inputs, this effect could be offset or even reversed by the substitution towards more automated processes using more of both capital and energy and less of labor and materials.

While some think that this empirical issue revolves around differences in methodologies, e.g., pooled versus time series, there is some evidence that the results are sensitive to data construction, such as the calculation of a capital price series that accounts for tax variables in countries other than the U.S., or reliable estimates of the capital stock that incorporate the effect of energy shocks on capital obsolescence.

Economic Impacts of Higher Energy Prices

Energy economists shifted their attention from the long run to the short run after the 1979-80 disruption. Oil and macroeconomics became inextricably tied, as issues of long-run dependence received less attention in favor of short-run vulnerability concerns.

Perhaps no other issue has revealed so clearly the schism within the profession between microeconomists and macroeconomists. Microeconomists estimated the effects of disruptions and energy security programs by assuming full employment of resources, while macroeconomists often assumed exogenous oil prices. Some economists emphasized the adjustment in real prices while others focused on nominal price stickiness. With some exceptions, there was little bridging of this gap.

Types of losses. A permanent increase in the real resource cost of energy has a direct and lasting effect on a nation's real income. This can happen either with greater depletion of domestic energy resources or with an increase in the foreign price of energy. When foreign prices are the cause, this reduction in real income is also called the terms of trade effect. It is approximately equal to the change in real oil prices times the level of oil imports. The terms of trade losses are excluded from GNP as conventionally measured with national income accounts.

Higher domestic or foreign energy prices will also reduce physical output as measured by gross national product. Much of the observed reduction in output during the 1970s appears to reflect macroeconomic adjustment costs (or indirect costs) as a result of the sudden oil price shocks. Quantitatively, these output effects tend to dominate the terms of trade effects. The adjustment costs appear to depend upon the change in energy prices, the stickiness in wages and prices, and the relative importance on energy use (rather than just imports) in the economy. Macroeconomic adjustment costs from an oil shock are experienced by both oil importers and oil exporters.

Policies. In contrast to a foreign price shock for final goods, an energy shock reduces real output in the short run while increasing the aggregate price level. Since the problem originates on the supply side, demand-oriented policies alone are usually considered insufficient. Policy prescriptions usually include supply-oriented policies that reduce prices while augmenting output. Some policies like oil stockpile releases are aimed at directly lowering the oil price, while others like reductions in payroll or excise taxes operate on lowering production costs generally.

Aggregate demand and supply. There are alternative and not mutually exclusive explanations for this adjustment to a lower level of activity. Greater unemployment can be attributed to either aggregate demand or supply conditions, and it is difficult to distinguish empirically between the effects.

Aggregate demand will be reduced by an oil price shock if prices of other goods exhibit nominal stickiness, resulting in a higher aggregate price level. Unless money demand is allowed to grow faster, real money supply will contract, interest rates will rise, and expenditures will decline.

Real domestic income will also be drained by the OPEC tax, which shifts income overseas where it is unlikely to be fully respent in the oil-importing country. While this effect is often emphasized, its importance can be limited by several conditions. First, export prices for some countries can also increase in real terms, as might be the case for energy-intensive exports. Moreover, the tax multiplier effect may be relatively modest, as has been exhibited by empirical models of the U.S. economy (Energy Modeling Forum, 1984).

Aggregate supply conditions can also create unemployment during an oil shock as well. If wages are rigid in real terms, reductions in the demand for labor after an oil shock will result in classical unemployment in which wages are too high for full employment. The unemployment emerges from an imbalance in the labor market rather than from insufficient demand in the product market. These conditions appear to be important for explaining the response of European countries to the oil price instability of the 1970s (Sachs, 1979).

World Oil Markets

Analyzing the market. Empirical studies of the world oil market generally decompose the market into at least three sectors: demanders, cartel producers (OPEC), and residual producers. OPEC's behavior is critical to determining the price and output in such a system.

The standard approach in economics is to represent OPEC as a cartel that maximizes its wealth subject to the constraint of an exhaustible resource. Following the Hotelling principle, the cartel adopts a pricing path that allows marginal rents (marginal revenue minus the marginal extraction cost) to increase over time at the rate of interest. Since the monopolist's price exceeds the competitive price, the cartel encourages more conservation than otherwise, for well behaved demand functions.

Additional complications can be introduced through various assumptions about the reactions of a group of producers to the pricing strategy of another group; both Nash-Cournot and Stackelberg models have been applied to this market. Generated price paths will be sensitive to these assumptions about the optimizing behavior of all sectors of the market, including the strategy of oil consumers.

These models appear to be most suitable for gaining insights about long-run price trends over a period of several decades. Applied models have been less satisfactory for shorter periods, e.g., during the 1970s. They could not explain the price doubling in 1979-80 and do not address many important short-run phenomena due to the absence of lags in the supply, demand, and pricing relationships.

As a result, applied wealth-maximization models have generally been replaced by simulation models using ad hoc pricing relationships based upon the experiences of the 1970s (Gately, 1984). In these models OPEC sets its price on the basis of a desired capacity-utilization target. The cartel increases price when the market becomes tighter and lowers it when excess capacity increases.

Policy. The presence of market power in international oil has some interesting policy implications as well. Although economists have a strong predilection towards keeping government out of domestic energy markets, they often retain a role for public intervention in the world crude oil market.

Economic inefficiencies result from cartel prices that are artificially high. Policies that make an oil-importing economy less dependent upon oil in undisrupted markets reduce the demand for OPEC oil as well as increase the price elasticity for OPEC oil. Both factors will place downward pressure on the cartel's price, providing economic benefits by lowering the price on the oil that the economy does import. This argument is based upon the optimal tariff literature in international trade economics. Oil-demand reduction policies in stable markets may also provide additional benefits during a disruption by reducing the losses in real income caused by the oil price shock.

These benefits must be compared with the resource costs of the policy action itself. Moreover, a number of qualifications apply, including the assumption of no retaliation by cartel producers.

A Concluding Comment

The oil decade has given the economist a very rich experience with which to test his analytical tools. Even so, research on energy demand must often bend to the dictates of available data rather than to theory.

General agreement exists on the role of markets with limited government intervention, the importance of the price elasticity of demand, and broad policy responses to sudden oil price shocks. Less consensus emerges, however, on the more technical issues, like energy-capital complementarity and the relative importance of aggregate demand and supply factors in the economy during oil disruptions.

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