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A COMPARATIVE ASSESSMENT OF ENERGY-ECONOMY INTERACTIONS

RICHARD J. GOETTLE IV, EDWARD A. HUDSON, AND JOAN LUKACHINSKI

December 1978

NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS
DEPARTMENT OF ENERGY AND ENVIRONMENT

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With contributions from
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ECONOMIC ANALYSIS DIVISION

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DEPARTMENT OF ENERGY AND ENVIRONMENT
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EXECUTIVE SUMMARY

The nature and magnitude of the relationship between energy and the rest of the economy are of great importance in the formulation and evaluation of energy policy. Understanding the nature of the relationship is critical to the identification of the types of effects resulting from energy policies. Knowledge of the magnitude of the relationship is essential to assessing the extent of the impacts and to evaluating the desirability of proposed policy measures. This report is directed toward both these issues. A particular focus of analysis is the relationships among the prices of substitutable energy forms, the quantities of energy used, and the performance of the U.S. economy as measured by real gross national product.

The role of energy in the U.S. economy is explored using the combined Brookhaven National Laboratory/Dale W. Jorgenson Associates (BNL/DJA) energy-economy model system. The BNL component of the system is a technological model of energy extraction, conversion, and end use and represents the economic and technical characteristics of the future substitution possibilities among new and conventional energy technologies and energy sources. The DJA model depicts production and spending throughout the economy on a sectoral basis within a flexible interindustry framework which permits substitution among capital, energy, labor, and materials in producing the goods and services that comprise the gross national product. The combined models give a comprehensive long-run representation of energy use and energy-economy interactions. Three alternative energy futures are analyzed within this system. These futures characterize the uncertainty which exists in the planning environment as a result of uncertainty about future energy prices. The three alternatives correspond to three different future growth paths for energy prices combined with an invariant set of energy policies. Thus, the only causal difference between the three projections are the different energy prices. The projections are labeled the Low, Medium and High price cases.

The economic impacts of higher energy prices are significant. Higher energy prices, irrespective of the sources of this escalation, have an appreciable effect on the structure of economic activity, the levels of production and income, and the structure and level of prices. Increased energy prices slow the growth of productivity and of the economy, and accelerate price inflation. Future real GNP is reduced, implying a real economic cost in terms of income and production foregone. By 2000, the difference in real GNP between the High and Low energy price cases is $168 billion, in constant dollars of 1972. The cumulative real income and production loss is still more substantial. Over the 1977 to 2000 period, the total real GNP foregone in moving from low to high price conditions is $1560 billion, in constant dollars of 1972; this total real GNP foregone exceeds the entire U.S. real GNP for 1977. Thus, while higher energy prices resulting from policy measures or other causes can be absorbed by the economy without precluding continued positive economic growth, there are real and significant economic costs associated with such price increases. Energy policies with these effects, therefore, should be introduced only if a careful comparison of these costs and the expected policy benefits indicates an expected net societal gain.

A second objective of the analysis is to compare the results with those obtained from the Data Resources, Incorporated (DRI) quarterly macroeconomic model. This model had previously been used to simulate the effects of the three price futures under the same policy conditions. In the DRI model, the economic impacts of the energy changes are, like those from the BNL/DJA system, significant. However, there are systematic and important differences between the results of the two models. Regardless of the measure chosen, the BNL/DJA system consistently generates more severe economic repercussions from the energy price increases. Specifically, the impacts estimated by the BNL/DJA system are typically twice as large as those indicated by the DRI model. In addition, there are substantial differences in the nature of the effects predicted by the two systems. For the BNL/DJA system, the GNP reductions in the early periods are dominated by decreases in consumption. In later periods, when the dynamic effects exert more influence, an increasing fraction of this reduction is borne by investment. In the DRI model, the pattern of allocation of the GNP loss between consumption and investment is reversed.

These numerical differences are analyzed in terms of the structural nature of each of the two models and are related to the scope of the equilibration processes contained in each. The BNL/DJA modeling system depicts technological and interfuel substitution in the energy sector, input substitution in the production of sectoral outputs, and product substitution and compositional changes in final demand. Also, it relates these changes, as they affect productivity growth and capital accumulation, to the growth of the economy. In contrast, the DRI model is specified to reflect the short-run, behavioral details of variations in final demand spending. It characterizes energy-economy interactions by a single, unidirectional link involving an aggregate energy price index. The nature of the energy-economy interaction is substantially less comprehensive and detailed than in the BNL/DJA system. Also, unlike the BNL/DJA system, the DRI model does not analyze economic supply and the process of economic growth. Since the purpose and, hence, the specification of the two methodologies are different, it is not surprising that they provide different measures of the economic impacts of higher energy prices.

The methodological issues reflected in the comparison of the two modeling systems serve only to accentuate the importance of quality information to the design and evaluation of energy policy. The numerical differences between the two methodologies characterize one aspect of the uncertainty surrounding the analytical basis of energy policy. Since it is not known for certain which, if either, of the models is correct, use of one of these systems for policy analysis entails the risk that policy will be based on incorrect information. It is possible, however, to analyze this risk within an explicit framework and to formulate rules for the optimal selection of an analytical base so as to minimize the expected damage resulting from informational errors. In selecting between alternative models, both the probability of a particular model being correct and the consequences of using that model when it is, in fact, wrong, should be considered. Since the BNL/DJA and DRI models are designed for different purposes the probability of BNL/DJA being correct is greater for some applications while there are other applications for which DRI has the higher probability of being correct. For assessing longer term economy-wide effects of energy changes, the BNL/DJA system is more appropriate. Also, given the systematic differences between the numerical results of the two models, it is shown that the consequences of incorrect use of a model are greater if the DRI system is used. Together, these considerations imply that the preferred analytical framework for assessing longer term, energy-economy interactions is the general equilibrium system represented by the BNL/DJA methodology.

I. INTRODUCTION

There is general agreement upon a set of broad and abstract concepts which characterize the principal dimensions of aggregate social welfare: material and social growth and progress, national security and stability, allocative efficiency, environmental quality, and distributional equity. The promotion of these objectives implies that several conditions are necessary:

- A healthy and sustainable economy.
- Stable international political and economic relations.
- Economic allocation systems yielding a pattern of use of goods and services consistent with patterns of social costs and benefits.
- Protection of and improvements in environmental quality and public health.
- Fairness and conformity to social values in the distribution of social benefits and costs.

The energy dilemma is a situation in which an imbalance exists among demands, capital stocks, and emerging availabilities, given current prices and other energy allocation mechanisms. A new policy is needed because the current energy situation is judged by many to adversely affect several of the social criteria enumerated above. However, the crux of the problem arises from the fact that a policy measure promoting one of the objectives is likely to have unfavorable impacts on other objectives. Conflicts between objectives inevitably occur, necessitating compromises in the choice of energy policies. This report cannot and does not attempt to make these compromises. Instead, it focuses on one dimension of social welfare--aggregate economic performance.

This analysis is concerned with the impact of energy policy measures on the level, growth, and structure of the U.S. economy. In particular, the nature and magnitude of the causal relationship between variations in the prices of various energy forms and economic performance, as measured by real gross national product (GNP), is studied. The combined Brookhaven National Laboratory/Dale W. Jorgenson Associates (BNL/DHA) energy-economy model system is used to determine the economic effects of three energy price futures combined with an invariant set of energy policies. The price alternaitves are intended to characterize the uncertainty which exists in the policy planning environment. In addition, the results are compared to those obtained from another DOE-sponsored analysis which used the Data Resources, Incorporated (DRI) quarterly macroeconomic model to assess the effects of these same three cases.

Significant numerical differences in the results from these modeling systems are observed and are attributed to structural differences between the two methodologies. The methodological issues emerging from this comparison have important policy implications which are independent of the specific numerical conclusions. Since it is uncertain which, if either, of the models is correct, the use of one for policy analysis entails the risk that policy will be predicated on inaccurate information. This risk is analyzed within an explicit framework and clear decision rules for information selection and the choice between the modeling systems are formulated.

The remainder of this paper is divided into seven sections. In Section II, a brief description of the component models and the combined BNL/DJA model integration scheme is presented. Section III provides the case specifications, common to the BNL/DJA and DRI analyses, for the three trajectories of future energy prices. Sections IV and V present and interpret the results obtained by the application of the BNL/DJA and DRI models, respectively. In Section VI, these two sets of results are compared, and numerical differences are analyzed by reference to fundamental structural differences in the methodologies. In Section VII, the policy implications of this model comparison are formalized in a framework for analyzing optimal information selection and model choice under conditions of uncertainty. From this analysis, precise decision rules and the circumstances for their application are determined. Finally, in Section VIII, the analytical conclusions of this comparative exercise are summarized.

II. MODEL DESCRIPTIONS

The analytical framework used in this report is provided by the coupling of an economic model, Dale W. Jorgenson Associates' Long-term Interindustry Transactions Model with an energy model, the Brookhaven Energy System Optimization Model (BESOM).

The DJA model is a simulation model of the structure and growth of the U.S. economy. This model presents economic activity on a sectoral basis; six energy sectors along with sectors covering non-energy production. Price formation, input patterns, and final demands are explicitly analyzed on this sectoral basis. The model features a flexible coefficient interindustry representation of sectoral production through which the sectors are brought into consistency. Productivity, investment, and labor supply are also explicitly treated so that the temporal expansion of the productive capacity of the economy is modeled. The energy system and its role in the economy, in relation both to production and to consumption, are emphasized. Therefore, the model provides a framework that can analyze the reciprocating interaction between energy and the economy (e.g., the effects of economic changes on the energy system and the effects of energy changes on the structure and growth of the U.S. economy).

BESOM is a linear programming model of the U.S. energy system in which the total annualized system cost of satisfying a given set of national energy service demands is minimized. Given a set of energy requirements defined by end use (e.g., motive power, space heat, electric power) and a set of available energy resources and conversion technology capacities, the model determines the minimum cost allocation of energy supplies to meet energy demands. The model has a comprehensive technological structure which includes all alternative energy resources, both electric and non-electric demands, and the full feasible range of interfuel and technological substitutability.

BESOM is formulated as a classical transportation problem. It determines the optimal routing of a set of intermediate energy products from a set of n resource supply nodes to m energy service demand nodes. A unit of energy passing over each of the possible n x m paths has associated with it a cost and set of environmental impacts. This representation is modified by the inclusion of conversion efficiency coefficients in the supply and demand constraints, and is augmented by additional equations reflecting the specific environmental features and technical relationships of the energy system. Incorporation of plant capacity constraints, resource supply curves, demand specifications, and constraints on technology penetration rates complete the detailed characterization of the national energy system and allow for a quantitative evaluation of energy technologies and policies within a systems framework.

The BESOM model allocates energy supply so as to satisfy a set of demands for energy services. The level and structure of the energy demands are set so as to incorporate the economic conditions reflected in the energy policy measures and generated by the DJA model. The model coupling operates through several stages. Initially, average energy supply prices are calculated in BESOM and then related to price-quantity elasticities of demand to yield estimates of primary energy consumption and corresponding energy service demand levels (the elasticities summarize the results from previous runs of the BNL/DJA system). BESOM is then solved, subject to providing these quantities of energy services. The solution values of energy prices, capital requirements, quantities, imports, and levels of new energy technologies are entered into the DJA model which is then solved, yielding specific estimates of the level and composition of production and spending throughout the economy. Economic sector outputs, and the energy input per unit of output, are mapped into a set of demands for energy services, specified in British thermal units. Next, these energy service demands are adjusted to incorporate the effects of any efficiency improvements in energy end-use devices. At this point, the energy demand vector reflects changes in energy prices, the level and composition of spending in the economy, energy and non-energy input substitutions in production, and end-use device efficiencies. These energy demands are inserted into BESOM and, along with the policy specific price assumptions, yield a second-round simulation of the configuration of the energy system. The iteration procedure then continues until consistency between the energy and economic systems in the two models is attained.

III. CASE SPECIFICATIONS IN THE BNL/DJA ANALYSIS

The combined BNL/DJA model system was employed to examine three alternative energy price/policy futures. These cases are denoted as Low, Medium, and High. They differ in that most energy prices are varied between cases, reflecting the uncertainty in domestic energy price conditions and world oil price levels. The detailed specification of the underlying policy and price conditions was developed by DOE; this effort takes, as its starting point, a set of energy supply prices. Thus, DOE policy assumptions concerning oil price deregulation, the price levels for domestic and imported oil and gas, and coal prices are incorporated directly into this analysis. These policies are assumed to be invariant across the three cases. The energy supply price assumptions are shown in Table III.1. Those analytical parameters which were unspecified by DOE, but which are required for the BNL/DJA system, were taken from an integrated, energy-economy, reference forecast denoted as the BNL/DJA Base Case.

Table III.1

DOE Input Price Assumptions (1978$/physical unit) and Corresponding BESOM Price Inputs (1975$/$10^6$ Btu)

		1985			1980			2000	
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Coal									
78$/short ton Av price to industry	53.439	53.439	53.552	55.751	55.766	55.879	58.219	58.524	58.963
75$/$10^6$ Btu at minemouth	1.27	1.27	1.27	1.34	1.34	1.34	1.41	1.43	1.44
Domestic and imported oil									
78$/bbl at wellhead	14.588	15.312	19.778	15.834	19.622	29.116	20.270	32.157	41.983
75$/$10^6$ Btu at wellhead	2.12	2.23	2.88	2.30	2.86	4.24	2.95	4.68	6.11
Domestic gas									
78$/mcf at wellhead	2.270	2.322	2.374	2.497	2.807	3.488	3.200	5.020	7.536
75$/$10^6$ Btu	1.86	1.90	1.94	2.04	2.30	2.85	2.62	4.11	6.17
Imported LNG									
78$/bbl	13.239	13.239	16.970	13.962	17.208	25.452	18.242	28.884	44.181
75$/$10^6$ Btu	2.79	2.79	3.57	2.94	3.62	5.36	3.84	6.08	9.30

In addition, delivered energy prices were adjusted, where feasible, to reflect the DOE policy assumptions. The price of electricity is determined endogenously in the BESOM model, and is dependent upon the mix of fuel inputs to electricity generation determined by the cost-minimizing optimization process within BESOM. Thus, while the BESOM electricity price is reflective of the policy and price assumptions regarding the fuel inputs to this sector, the actual DOE electricity price could not be employed exogenously in the model runs. Retail prices for three refined oil products--gasoline, distillate oil, and residual oil--were aligned to DOE specifications for each year and case, by adjusting the BESOM markups to yield the required retail price for these refined oil products. Markups for delivered gas and coal remained at BNL/DJA Base Case levels. The components of the BESOM delivered prices for each fuel are shown in Table III.2.

As the world and domestic oil prices are increased over the three cases, the incentives for expanded domestic supply of crude petroleum become greater. To determine the change in the amount of new oil produced relative to a BNL/DJA Base Case level, a supply elasticity of 0.20 was applied to the Base Case level of domestic oil for oil prices through twenty dollars per barrel (in constant dollars of 1975). This value was estimated by BNL through comparisons of several 1985 and 1990 PIES runs for oil prices of $8 , $13, and $16 per barrel. For a price increase yielding a new oil price greater than $20/bbl, a lower elasticity of 0.05 was applied as it was assumed that further additions to domestic supply would come from more marginal sources. The quantity of domestic

Table III.2
BESOM Price Components: Low Case
(1975/10^6 Btu)

	Supply price	Supply price ÷ refining efficiency	+ Markup =	Delivered price
1985				
Gasoline	2.12	2.30	2.83	5.13
Kerosine	2.12	2.30	1.44	3.74
Distillate	2.12	2.30	0.47	2.77
Residual	2.12	2.30	-0.01	2.29
Coal to industry	1.27	1.28	0.46	1.74
Gas to industry*	1.95	2.12	0.49	2.61
Gas to residential/ commercial*	1.95	2.12	0.89	3.01
1990				
Gasoline	2.30	2.50	2.89	5.39
Kerosine	2.30	2.50	1.44	3.94
Distillate	2.30	2.50	0.52	3.02
Residual	2.30	2.50	-0.03	2.47
Coal to industry	1.34	1.35	0.46	1.81
Gas to industry*	2.13	2.32	0.49	2.81
Gas to residential/ commercial	2.13	2.32	0.89	3.21
2000				
Gasoline	2.95	3.21	2.88	6.09
Kerosine	2.95	3.21	1.44	4.65
Distillate	2.95	3.21	0.44	3.65
Residual	2.95	3.21	-0.15	3.06
Coal to industry	1.41	1.42	0.46	1.88
Gas to industry*	2.89	2.98	0.49	3.47
Gas to residential/ commercial*	2.89	2.98	0.89	3.87

*The supply price of gas is the quantity-weighted average of domestic and imported natural gas prices.

Table III.2 (continued)
BESOM Price Components: Medium Case
(1975$/$10^6$ Btu)

	Supply price	Supply price ÷ refining efficiency	+ Markup =	Delivered price
1985				
Gasoline	2.23	2.42	2.77	5.19
Kerosine	2.23	2.42	1.44	3.86
Distillate	2.23	2.42	0.39	2.81
Residual	2.23	2.42	-0.09	2.33
Coal to industry	1.27	1.28	0.46	1.74
Gas to industry*	1.99	2.16	0.49	2.65
Gas to residential/ commercial*	1.99	2.16	0.89	3.05
1990				
Gasoline	2.86	3.11	2.83	5.94
Kerosine	2.86	3.11	1.44	4.55
Distillate	2.86	3.11	0.48	3.59
Residual	2.86	3.11	-0.36	2.75
Coal to industry	1.34	1.35	0.46	1.81
Gas to industry*	2.43	2.64	0.49	3.13
Gas to residential/ commercial*	2.43	2.64	0.89	3.53
2000				
Gasoline	4.68	5.09	2.74	7.83
Kerosine	4.68	5.09	1.44	6.53
Distillate	4.68	5.09	0.25	5.34
Residual	4.68	5.09	-0.68	4.41
Coal to industry	1.43	1.44	0.46	1.90
Gas to industry *	4.11	4.24	0.49	4.73
Gas to residential/ commercial *	4.11	4.24	0.89	5.13

*The supply price of gas is the quantity-weighted average of domestic and imported natural gas prices.

Table III.2 (continued)
BESOM Price Components: High Case
(1975$/$10^6$ Btu)

	Supply price	Supply price ÷ refining efficiency	+ Markup	= Delivered price
1985				
Gasoline	2.88	3.13	2.77	5.90
Kerosine	2.88	3.13	1.44	4.57
Distillate	2.88	3.13	0.39	3.52
Residual	2.88	3.13	-0.13	3.00
Coal to industry	1.27	1.28	0.46	1.74
Gas to industry *	1.94	2.11	0.49	2.60
Gas to residential/ commercial *	1.94	2.11	0.89	3.00
1990				
Gasoline	4.24	4.61	2.77	7.38
Kerosine	4.24	4.61	1.44	6.05
Distillate	4.24	4.61	0.46	5.07
Residual	4.24	4.61	-0.26	4.35
Coal to industry	1.34	1.35	0.46	1.81
Gas to industry *	2.85	3.10	0.49	3.59
Gas to residential/ commercial *	2.85	3.10	0.89	3.99
2000				
Gasoline	6.11	6.64	4.93	11.57
Kerosine	6.11	6.64	1.44	8.08
Distillate	6.11	6.64	0.27	6.91
Residual	6.11	6.64	-0.64	6.00
Coal to industry	1.44	1.45	0.46	1.91
Gas to industry *	6.17	6.36	0.49	6.85
Gas to residential/ commercial *	6.17	6.36	0.89	7.25

* The supply price of gas is the quantity-weighted average of domestic and imported natural gas prices.

Table III.3
BESOM End-Use Device Efficiencies

	1985		1990		2000	
	Low	Medium & High	Low	Medium & High	Low	Medium & High
Oil						
Space heat	0.48	0.52	0.49	0.57	0.54	0.65
Water heat	0.63	0.63	0.63	0.63	0.63	0.63
Process heat	0.68	0.72	0.73	0.74	0.75	0.78
Automobile	0.30	0.31	0.37	0.42	0.42	0.45
Air transport	0.24	0.24	0.26	0.26	0.30	0.30
Truck, bus & ship	0.22	0.22	0.23	0.23	0.24	0.24
Petrochemicals	1.00	1.00	1.00	1.00	1.00	1.00
Gas						
Space heat	0.53	0.58	0.54	0.63	0.59	0.71
Water heat	0.55	0.61	0.55	0.62	0.55	0.63
Process heat	0.64	0.67	0.67	0.68	0.70	0.73
Petrochemicals	1.00	1.00	1.00	1.00	1.00	1.00
Coal						
Iron	0.24	0.24	0.24	0.25	0.24	0.27
Process heat	0.70	0.72	0.72	0.74	0.77	0.80
Petrochemicals	1.00	1.00	1.00	1.00	1.00	1.00
Electric						
Space, water, process heat, misc. elec., elec. rail	1.00	1.00	1.00	1.00	1.00	1.00
Electric heat pump to space heat	2.00	2.00	2.00	2.00	2.00	2.00
Automobile	0.40	0.40	0.40	0.40	0.40	0.40
Air conditioning	3.00	3.30	3.00	3.40	3.00	3.60
Solar & geothermal						
Space, water, process heat, air conditioning	1.00	1.00	1.00	1.00	1.00	1.00

natural gas supply for each case was determined by utilizing a relation between changes in domestic natural gas supply and changes in domestic oil produced. For every million barrels of additional oil supplied, an increase of 0.6 billion cubic feet of natural gas relative to the Base Case was made available.

Quantities of oil imports were not constrained in these simulations. Import quantities are BESOM solution values with imported petroleum meeting the difference between domestic use and supply. Therefore, import levels vary between cases, reflecting, as prices increase, reductions in energy consumption, interfuel substitution away from petroleum, and increases in domestic production. The resultant energy import levels lie above the DOE values for all years and cases except for the year 2000 High Case. This is due to pessimistic assumptions regarding the expansion of domestic oil production and the complete absence of shale oil and coal synthetics production in all cases.

The level of basic energy demand for each energy product demand category is a measure of the energy requirement for that end-use category, and is independent of the fuel or energy form employed. Each energy product demand category has an associated set of end-use device efficiencies reflecting the relative effectiveness of the various technologies that can satisfy that basic energy demand. It is more accurate to consider these efficiencies as indicators of relative performance since, in addition to reflecting the technical efficiency of an end-use device, other characteristics pertaining to the utilization of specific fuels are considered. For example, in the 1985 Low Case, the efficiency for electric space heating has a value of 1.00 as compared to 0.53 for gas, and 0.48 for oil. These reflect the improved level of insulation generally used in electrically heated homes as well as the relative technical efficiencies of the representative devices.

The efficiency of electricity for air conditioning in BESOM is a coefficient of performance for air conditioning equipment. The 1972 coefficient of performance values of 2.00 to 2.50, given in the ASHRAE Guide and Data Book of 1969, were increased for the forecast period and reflect the use of more efficient devices and the increased utilization of central air conditioning systems. The solar air conditioning efficiency of 1.0 is a first law efficiency characteristic of the vapor absorption technology.

Efficiencies for end-use devices were set at the BNL/DJA Base Case levels for the Low Case, and at the ERDA NEP (June 10, 1977 version) levels for the Medium and High Cases. Use of these two sets of efficiencies, given in Table III.3, implies that there will be efficiency improvements as energy prices are increased and the capital stock is replaced and augmented.

IV. ENERGY-ECONOMY INTERACTIONS AS MEASURED IN THE BNL/DJA SYSTEM

Introduction

In this section, the numerical and interpretive results of the BNL/DJA analysis are presented. As there is no identifiable reference point among the three scenarios, the following convention is adopted for comparative purposes: energy-economy interactions are described as energy prices are varied in an upward direction. Hence, in the subsequent discussions, generic energy and economic system changes are attributable to and identified by energy price increases -- Low to Medium, Medium to High, and Low to High.

Primary Energy Input

The impacts of successively higher world oil prices on aggregate primary energy consumption are shown in Table IV.1. Under all three cases examined there is continued positive growth in energy consumption over time. The Low Case yields an average annual growth rate in total energy consumption over the 1977 to 2000 period of 2.6% as energy use rises from 76.0 quadrillion Btu (quads) in 1977 to 98.1 quads in 1985 and 136.5 quads by the year 2000. This

Table IV.1
Primary Energy Consumption
(Quadrillion Btu)

	Low	Medium	High
1985			
Domestic crude oil	21.72	21.92	23.08
Imported crude oil	23.49	20.21	17.23
Domestic natural gas	18.66	18.68	18.80
Imported natural gas	2.06	1.96	0.00
Coal	20.31	22.42	21.36
Nuclear	7.75	8.00	8.00
Other non-fossil electric	3.94	4.07	4.23
Non-fossil direct	0.17	0.25	0.34
Total primary energy	98.10	97.51	93.04
1990			
Domestic crude oil	19.60	20.45	21.60
Imported crude oil	30.04	23.18	15.65
Domestic natural gas	17.84	18.18	18.30
Imported natural gas	2.06	1.96	0.00
Coal	24.17	22.47	21.47
Nuclear	14.70	14.30	14.15
Other non-fossil electric	4.60	4.73	5.00
Non-fossil direct	0.78	0.95	1.19
Total primary energy	113.79	106.22	97.35
2000			
Domestic crude oil	18.50	19.42	19.82
Imported crude oil	34.65	20.26	11.79
Domestic natural gas	17.64	17.74	17.78
Imported natural gas	2.06	0.00	0.00
Coal	26.56	26.39	23.48
Nuclear	27.75	25.03	19.04
Other non-fossil electric	7.45	7.45	10.00
Non-fossil direct	1.85	2.47	2.90
Total primary energy	136.46	118.86	104.81

Table IV.2
Primary Energy Shares

	Low	Medium	High
1985			
Domestic oil	22.1	22.5	24.8
Imported oil	23.9	20.7	18.5
Domestic gas	19.0	19.2	20.2
Imported gas	2.1	2.0	0.0
Coal	20.7	22.9	23.0
Non-fossil electric	11.9	12.4	13.1
Non-fossil direct	0.2	0.3	0.4
	100.0	100.0	100.0
1990			
Domestic oil	17.4	19.3	22.2
Imported oil	25.6	21.8	16.1
Domestic gas	15.9	17.1	18.8
Imported gas	1.8	1.8	0.0
Coal	21.2	21.2	22.0
Non-fossil electric	13.1	17.9	19.7
Non-fossil direct	0.7	0.9	1.2
	100.0	100.0	100.0
2000			
Domestic oil	13.7	16.4	18.9
Imported oil	25.4	17.0	11.2
Domestic gas	12.9	14.9	17.0
Imported gas	1.5	0.0	0.0
Coal	19.5	22.2	22.4
Non-fossil electric	25.8	27.4	27.7
Non-fossil direct	1.4	2.1	2.8
	100.0	100.0	100.0

of crude oil in total primary energy consumption declines substantially. In the Low Case, there is already a trend toward the substitution of coal and non- fossil inputs for oil. The share of oil in total energy input is 50% in 1977 but this declines to 46.0% in 1985 and to 39.1% by the year 2000. This movement away from oil is accelerated by the more rapid increases in oil prices in the other two cases. By 2000, oil accounts for 33.4% of total energy in the Medium Case and only 30.1% in the High Case.

Natural gas increases its share of total energy use in the Medium and High Cases relative to the Low Case. Most of this increase arises from the substitution of gas for oil in residential and commercial heating. By the year 2000, the share of gas in total primary energy consumption, which is 14.4% in the Low Case, is 14.9% in the Medium Case and 17.0% in the High Case.

The increased use of coal for electricity generation and its substitution for oil in meeting industrial energy service demands accounts for the significant increase in coal's share of total primary energy in the Medium and High Cases. Coal usage in the High Case accounts for 23.0% of total energy use in 1985, and 22.4% in 2000. This compares with 22.9 and 22.2% for the Medium Case, and relatively smaller shares of 20.7 and 19.5% in the Low Case for the same years.

Non-fossil electric inputs include nuclear fuel, hydro, geothermal, and solar. Non-fossil electricity generation becomes increasingly cost effective as the price of oil is increased. The Low Case share of non-fossil inputs into electricity generation in 1985 is 11.9%, which increases to 12.4% in the Medium Case and to 13.1% in the High Case. Similar increases in non-fossil inputs are projected through the year 2000, as the 25.8% Low Case share rises to 27.4 and 27.7% for the Medium and High Cases, respectively.

In addition to replacing oil with relatively cheaper fuels, government and industrial development of direct solar and geothermal applications is expected to increase as the cost of oil rises. Direct solar and geothermal inputs account for only 0.2% of total primary energy in 1985 and 1.4% by the year 2000 in the Low Case. These shares are increased in the Medium Case, and further raised in the High Case to essentially double the Low Case shares. However, because of the associated reduction in aggregate energy demand induced by higher energy prices, only a 56.8% increase in the actual quantity of direct solar and geothermal inputs occurs in the year 2000 in the High Case.

Levels of oil and gas imports decline significantly from the Low to the Medium Case, and even further from the Medium to the High Case. In 1985, imports provide only 18.5% of total energy for the High Case as compared with 22.7% in the Medium Case, and 26.0% for the Low Case. Larger relative reductions in oil and gas imports occur by the year 2000; the Low Case import share of 26.9% declines in the Medium and High Cases to 17.0 and 11.2%, respectively. Decreased demand for oil and gas as well as increased domestic supply, both due to higher prices, jointly result in the reduction in imports. The demand reduction, however, is the dominant force in the curtailment of imports. As between the Low and High Cases in 2000, for example, petroleum imports are reduced by 22.9 quads; 21.6 quads of this reduction is due to a decrease in domestic petroleum use and only 1.3 quads results from expanded U.S. petroleum supply.

Primary Energy Prices

The average energy supply price is computed as a quantity-weighted average of the prices of coal, oil, gas, and uranium. Table IV.3 lists the average supply prices and individual supply prices by energy resource type for each case. Increases in the average supply price from Low to Medium and Medium to High Cases, are moderated by the shift away from petroleum use as the price of oil rises between cases. The uranium price remains constant across the three cases for a given year and only very small increases (1 to 2%) in the coal supply price were specified for the year 2000 between cases.

Table IV.3
Primary Energy Supply Prices
(1975 dollars/million Btu)

	Low	Medium	High
1985			
Crude oil*	2.12	2.23	2.88
Crude natural gas*	1.93	1.99	1.94
Coal**	1.27	1.27	1.27
Uranium***	0.44	0.44	0.44
Average supply price	1.76	1.79	2.07
1990			
Crude oil	2.30	2.86	4.24
Crude natural gas	2.13	2.43	2.85
Coal	1.34	1.34	1.34
Uranium	0.46	0.46	0.46
Average supply price	1.80	2.09	2.69
2000			
Crude oil	2.95	4.68	6.11
Crude natural gas	2.89	4.11	6.17
Coal	1.41	1.43	1.44
Uranium	0.51	0.51	0.51
Average supply price	2.09	2.84	3.77

* Crude oil and crude natural gas prices are measured at the wellhead.

** Coal prices are measured at the minemouth.

*** Uranium prices are measured as the cost of thermal input to power plants computed from mills/kWh(e) assuming a 33% power plant efficiency.

The 1985 average supply price of (1975$)1.76 per million Btu in the Low Case, increases 1.7% to $1.79 in the Medium Case and an additional 15.6% in the High Case to $2.07 per million Btu. By the year 2000, large increases in gas and oil prices contribute substantially to the rise in the average supply price between cases. The year 2000 average supply price increases 35.9% from the Low to Medium Case, and 32.7% from the Medium to High Case. Increases in oil prices of 58.6 and 30.6% and in average gas supply prices of 42.2 and 50.1% are responsible for these changes.

Primary Energy Price-Quantity Relationships

Price elasticities of demand can be used to summarize the response of energy use to the increase in energy resource prices. These elasticities are shown in Table IV.4. They relate the proportionate change in energy use to the proportionate increase in the average price of primary energy. It should

Table IV.4
Elasticities of Primary Energy Demand* to
Primary Energy Prices**

Year	Low/Medium	Medium/High	Low/High
1985	-0.357	-0.323	-0.326
1990	-0.461	-0.346	-0.388
2000	-0.450	-0.444	-0.447

* The quantity of energy includes both fossil and non-fossil inputs.

** The elasticities are calculated as the logarithm of the ratio of total primary energy consumption levels divided by the logarithm of the ratio of average energy supply prices.

be noted that these are not ceteris paribus demand elasticities. As the full BESOM-DJA model linkage is employed in this study, these elasticities incorporate the feedback effects of changes in energy prices upon the rest of the economy which, in turn, alters the level and composition of energy resource demands. Therefore, these elasticities should be interpreted only as indicating the degree of response of energy demand to price changes.

In general, the absolute magnitude of these elasticities increases over time. There are short-term technological rigidities in the energy system and lags in demand response which do not allow for the more complete adjustment and restructuring of capital stocks that occur over the long term. Also, successive increases in energy prices are accompanied by successively smaller energy demand responses as it becomes increasingly more difficult and expensive to further substitute alternative fuels for oil and to accelerate the turnover of the existing energy-intensive capital stocks. Therefore, in 1985 the supply price elasticity from the Low to Medium Case is -0.357 and is somewhat smaller, -0.323, from the Medium to High Case. Similarly for the year 2000, the energy price elasticity is -0.450 between Low and Medium Cases, and -0.444 with the additional 32.7% increase in energy supply prices between the Medium and High Cases.

Electricity Generation

The impacts of higher energy prices on the input patterns for electricity generation are given in Table IV.5. The levels of oil and gas inputs to electricity are reduced significantly, as more economical coal, nuclear, and non-fossil inputs are substituted in the fuel mix. For the year 2000 coal inputs, which comprise 26.7% of total electric inputs in the Low Case, are increased to shares of 26.8 and 28.3% for the Medium and High Cases, respectively. Total non-fossil inputs rise from 65.4% in the Low Case to 66.9 and 67.2%. Displacement of higher priced oil and gas inputs results in a reduction in the share of electricity generated from these fuels from a Low Case value of 7.9%, to 6.3% in the Medium Case and 4.5% in the High Case.

Table IV.5
Composition of Electric Inputs
(Quadrillion Btu)

	Low	Medium	High
1985			
Coal	15.50	16.08	14.66
Oil	2.10	1.80	1.35
Gas	3.80	3.05	2.90
Nuclear	7.75	8.00	8.00
Other non-fossil	3.94	4.07	4.23
Total	33.09	33.00	31.14
1990			
Coal	17.12	14.33	12.40
Oil	2.45	2.07	1.67
Gas	3.10	2.45	1.75
Nuclear	14.70	14.30	14.15
Other non-fossil	4.60	4.73	5.00
Total	41.97	37.89	34.97
2000			
Coal	14.38	13.04	12.21
Oil	1.95	1.55	0.95
Gas	2.30	1.50	1.00
Nuclear	27.75	25.03	19.04
Other non-fossil	7.45	7.45	10.00
Total	53.83	48.57	43.20

The degree of electrification is defined as the share of total primary energy inputs used for electricity generation. Over time, its value increases for all cases. Electricity becomes relatively less expensive, compared to oil and gas. Thus, even though the quantity of electricity generated declines across cases (because of higher energy prices), the relative importance of electricity increases. The degree of electrification rises from 39.4% in the Low Case, to 40.9% for the Medium Case, and 41.2% under the High Case in 2000.

Delivered Energy Prices, Quantities, and Price-Quantity Relationships

Average delivered prices of refined fuels and electricity are given in Table IV.6. The price of delivered oil products is a quantity-weighted average of the prices for gasoline, kerosine, distillate, and residual fuels. Delivered gas prices are an average of the prices to residential, commercial, and industrial users. Delivered coal prices are the prices to industrial users, and the electricity price is an average cost of delivered electricity to all demand categories.

Table IV.6
Delivered Energy Prices
(1975$/million Btu)

	Low	Medium	High
1985			
Delivered oil products	3.37	3.49	4.19
Delivered gas products	2.84	2.87	2.86
Delivered coal	1.74	1.74	1.74
Delivered electricity	13.02	13.22	13.17
Average delivered price	4.55	4.61	4.94
1990			
Delivered oil products	3.58	4.19	5.78
Delivered gas products	3.02	3.34	3.82
Delivered coal	1.81	1.81	1.81
Delivered electricity	13.17	13.26	13.12
Average delivered price	4.86	5.13	5.89
2000			
Delivered oil products	4.24	6.20	8.64
Delivered gas products	3.65	4.89	6.98
Delivered coal	1.88	1.90	1.91
Delivered electricity	12.14	12.46	12.11
Average delivered price	5.18	6.27	7.53

The average annual growth rate over the 1985 to 2000 period in delivered energy prices rises from 0.9% in the Low Case to 2.1% in the Medium Case and 2.9% for the High Case. The year 2000 average High Case price of $7.53 per million Btu is 20.1% above the Medium Case price of $6.27 and 45.4% higher than the Low Case price of $5.18. Prices of refined oil products and gas products essentially double from the Low to High Case.

The successive escalations in the prices of delivered energy corresponding to supply price increases affect the quantity of delivered energy demand. These impacts are shown in Table IV.7 and are consistent with the reductions in primary energy consumption. The Low Case yields an average annual growth rate in total delivered energy consumption over the 1977 to 2000 period of 2.2% as usage rises from 55.7 quads in 1977 to 69.9 quads in 1985 and 92.5 quads in 2000. This growth is moderated, as energy prices increase, to averages of 1.6 and 1.0% in the Medium and High Cases, respectively. By 2000, total delivered energy use reaches levels of 79.9 quads in the Medium Case and 70.5 quads in the High Case. An analysis of the fuel shares (oil, gas, coal, electricity, and direct heat) of total delivered energy provides similar conclusions to those obtained from the share assessment of primary energy consumption.

Table IV.7
Delivered Energy Quantities
(Quadrillion Btu)

	Low	Medium	High
1985			
Delivered oil products	39.49	36.35	35.14
Delivered gas products	15.25	15.92	14.39
Delivered coal	4.71	6.23	6.59
Delivered electricity	10.24	10.23	9.66
Direct heat	0.17	0.25	0.34
Total delivered energy	69.86	68.98	66.12
1990			
Delivered oil products	42.21	37.08	31.71
Delivered gas products	15.14	16.00	15.02
Delivered coal	6.93	8.02	8.96
Delivered electricity	13.02	11.75	10.84
Direct heat	0.80	0.99	1.22
Total delivered energy	78.10	73.84	67.75
2000			
Delivered oil products	44.78	33.08	26.52
Delivered gas products	16.43	15.32	15.87
Delivered coal	12.05	13.22	11.16
Delivered electricity	17.18	15.60	13.89
Direct heat	2.05	2.66	3.10
Total delivered energy	92.49	79.88	70.54

Price elasticities, similar to those established for primary energy, can be determined for delivered energy. These are shown in Table IV.8 and relate the proportionate change in delivered energy use to the proportionate increase in the average price of delivered energy. Again, the cautionary note against the interpretation of these values as ceteris paribus elasticities applies. The equilibrium quantity changes reflect not only movements along demand curves but also demand shifts due to efficiency improvements, relative price changes, and energy-economy interactions. (A more detailed discussion of the efficiency improvements was presented in Section III.) Thus, these elasticities are indicative of only the degree of response of delivered energy demand to price changes.

The mix of fuels allocated for space heating and process heating demands in 1990 are displayed in Table IV.9 for all cases. Also given are the shares of total space heating and total process heating energy service demands satisfied by each fuel. For a given energy product demand category, these shares are computed for each fuel as the level of fuel input multiplied by its end-use efficiency divided by the total energy product demand. For space

Table IV.8
Elasticities of Delivered Energy Demand* to
Delivered Energy Prices

Year	Low/Medium **	Medium/High	Low/High
1985	-0.968	-0.612	-0.669
1990	-1.037	-0.623	-0.740
2000	-0.768	-0.679	-0.724

*Delivered energy quantities include coal, refined oil and gas, electricity, and direct heat.

**The demand elasticities from the Low to Medium Case are significantly higher than those between the Medium and High Cases. The elasticities from the Low to Medium Case incorporate energy demand reductions due to both price changes and efficiency improvements between cases, whereas efficiencies remain constant between the Medium and High Cases.

Table IV.9
Mix of Fuels Used to Provide Space Heating and
Process Heating Service Demands: Year 1990

	Space heating		Process heating	
	Quads*	% of Total service demand**	Quads*	% of Total service demand**
Low Case				
Oil	5.80	34.4	8.32	45.6
Gas	6.80	44.4	3.95	19.9
Coal	0.0	0.0	3.85	20.8
Electricity	1.30	18.2	1.35	10.2
Heat	0.25	3.0	.47	3.5
Total		100.0		100.0
Medium Case				
Oil	3.70	24.2	5.90	34.9
Gas	7.40	53.5	4.34	23.6
Coal	0.0	0.0	4.95	29.2
Electricity	1.35	19.0	0.95	7.6
Heat	0.30	3.4	0.59	4.7
Total		100.0		100.0

Table IV.9 (continued)

	Space heating		Process heating	
	Quads*	% of Total service demand**	Quads*	% of Total service demand**
High Case				
Oil	2.25	15.6	4.16	26.4
Gas	7.82	59.7	3.67	21.4
Coal	0.0	0.0	6.00	38.1
Electricity	1.25	20.6	0.90	7.6
Heat	0.34	4.1	0.76	6.5
Total		100.0		100.0

* Quads represent fuel inputs to the end-use demand category measured prior to their conversion in an end-use device.

** The shares represent the contributions to the total energy service demand after their conversion in an end-use devices.

heating, the shift away from oil products is evidenced by a decline in oil's share from 34.4% in the Low Case to 24.2 and 15.6% in the Medium and High Cases. Oil for space heating is displaced primarily by natural gas, whose share rises from 44.4 to 59.7%. The growth of electric resistance and direct solar\heating devices is also accelerated as the household and commercial sectors respond to rising oil prices.

Fuel shares for industrial process heating also shift significantly between the Low and High Cases. Coal becomes the dominant fuel used for process heating in the High Case; its share increases from 20.8 to 38.1%. This offsets the reduction in oil's share from 45.6% in the Low Case to only 26.4% with higher oil prices. Small reductions in electricity inputs to process heating occur over the cases, and direct solar and geothermal heating substitute for relatively more expensive residual oil in the High Case.

Energy System Efficiency

Energy service levels and their growth rates for the three alternative oil price cases, given in terms of the BESOM end-use demand categories, are listed in Tables IV.10 and IV.11, respectively. Higher energy prices, in general, slow the growth of energy service demands. In 2000, these demands are reduced 12.1% from the Low to Medium Cases, and 10.8% between the Medium and High Cases. Also, the changing structure of relative energy prices, particularly the rise in oil and gas prices, leads to a change in the mix of fuels used. The restructuring of energy demands is characterized by a shift away from oil-intensive energy product demands, such as transportation and petrochemicals, and toward electricity-intensive demands and those with greater potential for the

Table IV.10
Energy Service Demands
(Quadrillion Btu)

	Low	Medium	High
1985			
Space heat	7.02	7.87	7.48
Air conditioning	2.80	3.00	2.81
Intermediate electric	1.12	1.08	1.02
Base load electric	5.34	5.14	4.89
Water heat	1.96	2.07	1.90
Process heat	11.18	11.56	11.29
Air transport	1.35	1.33	1.26
Truck, bus, and ship	1.67	1.63	1.56
Private ground transport	3.01	3.10	3.09
Iron production	0.53	0.50	0.49
Petrochemicals	5.22	5.37	5.19
Electric rail	0.13	0.13	0.12
Total energy service demand	41.33	42.78	41.10
1990			
Space heat	8.26	8.72	8.25
Air conditioning	3.52	3.54	3.21
Intermediate electric	1.36	1.24	1.14
Base load electric	6.48	5.92	5.42
Water heat	2.07	1.92	1.76
Process heat	13.31	12.51	11.66
Air transport	1.62	1.62	1.44
Truck, bus, and ship	2.00	1.99	1.77
Private ground transport	3.91	4.39	4.18
Iron production	0.62	0.63	0.59
Petrochemicals	7.03	6.77	6.16
Electric rail	0.17	0.14	0.13
Total energy service demand	50.35	49.39	45.71
2000			
Space heat	9.10	8.99	8.19
Air conditioning	4.34	4.10	3.59
Intermediate electric	1.93	1.58	1.40
Base load electric	9.19	7.50	6.69
Water heat	2.40	2.12	1.99
Process heat	18.31	15.41	13.80
Air transport	2.12	1.83	1.57
Truck, bus, and ship	2.61	2.25	1.93
Private ground transport	4.93	5.15	4.46
Iron production	0.96	0.91	0.84
Petrochemicals	10.90	8.88	7.89
Electric rail	0.22	0.18	0.17
Total energy service demand	67.01	58.90	52.52

Table IV.11
Average Annual Growth Rates of Energy Service Demands from 1985 to 2000
(Percent/Year)

	Low	Medium	High
Space heat	1.75	0.89	0.61
Air conditioning	2.96	2.10	1.65
Intermediate electric	3.69	2.57	2.13
Base load electric	3.69	2.55	2.11
Water heat	1.36	0.16	0.31
Process heat	3.34	1.93	1.35
Air transport	3.05	2.15	1.48
Truck, bus, and ship	3.02	2.17	1.43
Private ground transport	3.34	3.44	2.48
Iron production	4.04	4.07	3.66
Petrochemicals	5.03	3.41	2.83
Electric rail	3.57	2.19	2.35
Total energy service demand	3.27	2.15	1.65

substitution of relatively more efficient and less costly inputs. These latter demand categories include space heating, air conditioning, water heating, and iron production.

Higher oil prices lead to both a more efficient use of fuels, as evidenced by the improvements in end-use device efficiencies across cases, and the substitution of more efficient fuels in certain demand categories where the displacement of oil's share can occur. As shown in Table III.3, gas is more efficient than oil for space heating, and therefore is substituted for oil as its price increases. In process heating, coal is more efficient than oil, and its increased use reduces oil's share for this demand category as well.

The ratios of total energy service demands to aggregate primary energy consumption yield measures of average system efficiency. Table IV.12 displays these average efficiencies for each case and year. The combined impacts of the increased substitution toward more efficient fuels and the general increase in all demand efficiencies for the Medium and High Cases, result in significant improvements in the average efficiency of the energy system. For 1985 the average efficiency rises from 0.421 in the Low Case, to 0.442 in the High Case, and for 2000, the corresponding efficiency levels are 0.491 and 0.501. For all three cases, average system efficiencies are projected to increase over time, with the most rapid rate of efficiency improvement, from the present, occurring in the High Case.

Table IV.12
Average System Efficiencies

	Total primary energy Quads	Total energy services Quads	Average system efficiency
Low			
1985	98.10	41.33	0.421
1990	113.79	50.35	0.442
2000	136.46	67.00	0.491
Medium			
1985	97.51	42.78	0.439
1990	106.22	41.39	0.465
2000	118.86	58.89	0.495
High			
1985	93.04	41.11	0.442
1990	97.35	45.71	0.470
2000	104.81	52.52	0.501

Overview of the Economic Effects

The reductions in the level of energy use, and the redirection of the structure of that use, induced by higher energy prices as described above, are closely related to changes in the level and patterns of economic activity. Indeed, it is the changes in spending and production patterns which allow the reductions in energy input to be achieved without a comparable reduction in the level of economic activity. However, the adjustment to a pattern of activity characterized by a lower aggregate intensity of energy use does involve a significant real cost to society in terms of lost income and economic output. Higher energy prices have an appreciable effect on the structure of economic activity, the levels of production and income, and the structure and level of prices.

The level and compositional effects of higher energy prices on real GNP are presented in Table IV.13. Real GNP declines as a result of the higher energy prices and the corresponding economic adjustments. In proportionate terms, the reductions are moderate; for the year 2000, the High Case GNP is 6.0% below that of the Low Case. However, the dollar magnitudes of these changes are indeed significant: $(1972) 168.1 billion for the same year and case comparison. The economy, under ever-increasing energy prices, moves along a growth path, that is, at every point in time, relatively lower. The average annual growth rates of real GNP between 1977 and 2000 are 3.24, 3.10, and 2.96% in the Low, Medium, and High Cases, respectively.

The general price level increases as a result of the higher energy prices. However, for several reasons, the magnitude of the price effect is not large. First, energy forms only a small part of total input expenditures, so a rise in

Table IV.13
GNP and Components
(Billions of 1972 dollars)

	Low	Medium	High
1985			
GNP	1779.4	1776.5	1757.4
Consumption	1149.8	1146.1	1129.9
Investment	264.7	264.6	262.7
Government	344.6	344.6	344.6
Net exports	20.2	21.1	20.1
GNP price (1972=1.00)	2.0177	2.0158	2.0198
1990			
GNP	2075.6	2039.3	2003.3
Consumption	1351.2	1322.8	1292.9
Investment	304.6	299.2	293.5
Government	408.0	408.0	408.0
Net exports	11.8	9.2	8.9
GNP price (1972=1.00)	2.4291	2.4300	2.4341
2000			
GNP	2785.8	2696.3	2617.7
Consumption	1806.8	1737.5	1680.6
Investment	408.0	388.3	367.4
Government	567.0	567.0	567.0
Net exports	4.1	3.5	2.8
GNP price (1972=1.00)	3.5554	3.5603	3.5962

average energy prices results in only a marginal increase in direct cost. Second, substitutions away from relatively more expensive household and production inputs tend to dampen the initial impact of the cost increase. Finally, the economic adjustments to higher energy prices lead to partially offsetting changes in other relative factor prices; in particular, labor prices increase less rapidly over time. (It should be noted that the model does not include a wage-price spiral mechanism. If such a mechanism were incorporated, the inflationary impacts would be larger than those estimated here.)

The adverse macroeconomic impacts of the energy price increases arise from a restructuring of economic activity at the microeconomic level. Conceptually, this restructuring, at any point in time, may be divided into:

- Changes in final demand spending patterns.
- Changes in production input patterns for a given structure of final demand.

In addition to these "substitution" effects, there are dynamic effects operating through investment and the capital stock.

Final Demand Adjustments

First, variations in the patterns of final demand spending are considered. Higher energy prices result in relatively more expensive energy, energy-intensive, and energy-associated products and outputs. The response of purchasers to these price increases is to reduce the rate of growth of spending on these items and to divert expenditures toward non energy-intensive goods and services. Thus, energy and certain of the non-energy outputs (e.g., manufacturing and transportation) are reduced in their relative importance within final demand spending, while the role of services is increased. These changes are shown in more detail in Tables IV.14 and IV.15 and reflect the adaptation of final demand, and, particularly, personal consumption, to higher energy prices. That the level of economic activity is reduced by so much less than the energy input is explained, in part, by the reduced energy intensity of final spending.

A further effect attributable to these demand substitutions concerns labor and capital productivities. The production of services is characterized by relatively higher labor and capital contents. Therefore, the shift of spending toward these industries results in an increase (*ceteris paribus*) in the quantities of capital and labor required, on average, per unit of output. But this is equivalent to a reduction in the quantity of output obtained, on average, per unit of capital and labor input. Thus, the average productivities of capital and labor fall as a result of the higher energy prices. (In fact, as these adjustments occur over time, the rates of growth of capital and labor productivities are slowed.) Reduced productivity in conjunction with the limited availability of capital and labor inputs means that the level of total final output is reduced (or, that it grows at a slower rate). This output decline is matched by a decline in real incomes. Reduced real rates of return to capital and labor, corresponding to the productivity changes, lead to a decline in both capital and labor incomes, with labor income showing the relatively larger decline. In turn, the income decline is matched by a reduction in real expenditures; both consumption and investment, at every point in time, are lowered.

Adjustments in Inputs to Production

In addition to product substitutions in final demand, there are adjustments in the pattern of factor inputs into production. Higher energy prices lead producers, motivated by the objective of cost minimization, to undertake a systematic redirection of productive input patterns away from energy, energy-intensive, and energy-associated products and processes. As with final demand purchases, non-energy interindustry transactions are redistributed toward the increased utilization of purchased services (Tables IV.16 and IV.17). However, in terms of aggregate factors of production (capital, labor, energy, and materials), it is primarily labor which substitutes for the energy input. (Indeed, there is evidence, summarized in Tables IV.18 and IV.19, that, for the economy as a whole and for many of its sectoral groupings, complementary relationships exist between capital and energy and between materials and energy. This implies that the utilization of capital and materials inputs is reduced as part of the effort to save on energy which is of extreme importance for investment and, hence, economic growth.) When this factor substitution occurs,

Table IV.14
Aggregate Non-Energy Final Demand Purchases
(Billions of 1972 dollars)

	Low	Medium	High
1985			
Agriculture, non-fuel mining and construction	173.0	172.2	169.9
Manufacturing	523.4	521.5	513.7
Transportation	55.4	54.7	54.0
Services	994.8	991.7	982.0
1990			
Agriculture, non-fuel mining and construction	189.0	186.4	181.6
Manufacturing	613.0	604.5	589.5
Transportation	68.9	67.6	65.4
Services	1168.5	1158.7	1140.4
2000			
Agriculture, non-fuel mining and construction	241.0	229.4	220.9
Manufacturing	870.9	833.7	808.9
Transportation	106.2	101.1	96.2
Services	1548.2	1516.1	1497.4

Table IV.15
Percentage Changes in Aggregate Non-Energy Final Demand Purchases between the Low and High Cases

Sector	1985	1990	2000
Agriculture, non-fuel mining, and construction	-1.79	-3.92	-8.34
Manufacturing	-1.85	-3.83	-7.12
Transportation	-2.53	-5.08	-9.42
Services	-1.29	-2.40	-3.28

Table IV.16
Aggregate Non-Energy Interindustry Purchases
(Billions of 1972 dollars)

Type of purchase	Low	Medium	High
1985			
Agriculture, non-fuel mining, and construction	104.6	104.2	102.9
Manufacturing	489.1	487.7	480.2
Transportation	73.6	73.4	72.7
Serivces	332.1	331.4	328.3
1990			
Agriculture, non-fuel mining, and construction	109.1	107.4	104.9
Manufacturing	564.4	556.6	542.6
Transportation	86.9	86.1	84.6
Services	376.6	373.2	367.4
2000			
Agriculture, non-fuel mining, and construction	126.9	122.2	118.8
Manufacturing	769.3	738.4	717.1
Transportation	122.4	118.5	115.9
Services	495.9	483.8	475.3

Table IV.17
Percentage Changes in Aggregate Non-Energy Interindustry Purchases between the Low and High Cases

Type of purchase	1985	1990	2000
Agriculture, non-fuel mining, and construction	-1.63	-3.85	-6.38
Manufacturing	-1.82	-3.86	-6.79
Transportation	-1.22	-2.65	-5.31
Services	-1.14	-2.44	-4.15

Table IV.18
Input-Output Coefficients for Aggregate Output*

Year	Factor	Low Case	High Case	Percent change
1985	Capital, K	0.1711	0.1707	-0.23
	Labor, L	0.2138	0.2161	1.08
	Energy, E	0.0331	0.0315	-4.83
	Materials, M	0.5820	0.5817	-0.05
2000	Capital, K	0.1887	0.1855	-1.70
	Labor, L	0.1795	0.1882	4.85
	Energy, E	0.0303	0.0260	-14.19
	Materials, M	0.6015	0.6003	-0.20
Percent change (1985-2000)	Capital, K	10.29	8.67	
	Labor, L	-16.04	-12.91	
	Energy, E	-8.46	-17.46	
	Materials, M	3.35	3.20	

* Coefficients are calculated as the normalized ratio of constant dollar expenditures on a particular productive input to constant dollar output. For a given year or case, directional and percentage changes in these measures are indicative of factor substitution.

Table IV.19
Directional Changes in Factor Shares*
between the Low and High Cases for the Year 2000

Sector definition	Capital, K	Labor, L	Energy, E	Materials, M
Agriculture, non-fuel mining, and construction	-	+	-	-
Manufacturing	-	+	-	-
Transportation	-	+	-	+
Services	+	+	-	-
Aggregate energy	+	+	-	+
Aggregate non-energy	-	+	-	-
Aggregate output	-	+	-	-

"+" Increasing intensity.
"-" Decreasing intensity.

* Factor share is defined as the normalized ratio of constant dollar expenditures on a particular productive input (K, L, E, and M) to total constant dollar factor purchases. Directional changes in these measures are indicative of factor substitution.

there is a reduction in total attainable output. In part, this arises because inputs are only imperfect substitutes. Further, in a general equilibrium system, factor substitution requires that inputs be taken from other productive uses which causes reductions in both sectoral and aggregate outputs. Specifically, there is a reduction in the average productivity of labor. This follows from the use of relatively more labor, on average, per unit of output which is equivalent to less output per unit of labor input. As indicated, the result is a reduction in the total real output attainable from the economy. Correspondingly, there is a reduction in real labor income: the effect due to the slight increase in employment is more than offset by the effect of the equilibrated reduction in productivity and, hence, the real wage rate.

Dynamic Effects

These substitutions, with their adverse effects on productivity growth, slow the growth of real incomes and production. This is compounded by the "dynamic" effects of the energy price increases which operate through investment. In part, investment as a component of aggregate demand is reduced because of the reduction in real income and the associated decline in saving. But also there is a reduction in the prospective rate of return to capital which reduces the incentive for saving and investment. The total decline in investment, under higher energy prices, slows the growth of capital stock and, hence, slows the rate of growth of the productive potential of the economy.

These effects are reflected in the real GNP information in Table IV.20. Initially, the substitution effects dominate and underlie virtually all the GNP reduction resulting from higher energy prices. In these early years, the expenditure reductions are concentrated on consumption rather than investment, as the energy price increases primarily affect consumption and as there is a partially offsetting boost to investment demand associated with the sectoral shifts of expenditures. By the 1990s, however, the situation is altered. The proportionate fall in investment becomes more substantial because of the saving and rate of return effects. The consequent slowing of capital growth accentuates the reductions in real GNP.

Aggregate Economic Efficiency of Energy Use

The aggregate economic efficiency of energy use can be indicated by the energy-GNP ratio (Table IV.21). This ratio is projected to decline over time, even in the Low Case, as spending and production patterns move away from energy and as efficiencies in energy conversion and use increase. Under the higher energy prices, the decline in the energy-GNP ratio is accelerated as the energy input is reduced to a greater extent than real GNP.

Alternatively, these same causal variations in the aggregate energy-GNP relationship may be characterized by a descriptor elasticity (Table IV.22) which measures the proportionate change in real GNP relative to the proportional change in the quantity of primary energy input. Here, it is seen that, on average, the relative GNP response is slightly less than one quarter of that measured for energy. Thus, a price-induced, 10% reduction in primary energy utilization is associated with a 2.4% reduction in the level of total real income and output in the economy.

Table IV.20
Real GNP and Components: Changes Between Cases
(Billions of 1972 dollars)

	Medium-Low	High-Medium	High-Low
1985			
GNP	-2.9	-19.1	-22.0
Consumption	-3.7	-16.2	-19.9
Investment	-0.1	- 1.9	- 2.0
Government	0	0	0
Net exports	0.9	1.0	- 0.1
1990			
GNP	-36.3	-36.0	-72.3
Consumption	-28.4	-29.9	-58.3
Investment	- 5.4	- 5.7	-11.1
Government	0	0	0
Net exports	- 2.6	- 0.3	- 2.9
2000			
GNP	-89.5	-78.6	-168.1
Consumption	-69.3	-56.9	-126.2
Investment	-19.7	-20.9	- 40.6
Government	0	0	0
Net exports	- 0.6	- 0.7	- 1.3

Table IV.21
Summary of Economic Effects of Higher Energy Prices

	1985	1990	2000
Primary energy input, 10^{15} Btu			
Low Case	98.10	113.79	136.46
Medium Case	97.51	106.22	118.86
High Case	93.04	97.35	104.81
Real GNP (Billions of 1972 dollars)			
Low Case	1779.4	2075.6	2785.8
Medium Case	1776.5	2039.3	2696.3
High Case	1757.4	2003.3	2617.7
Energy-GNP ratio*, 10^3 Btu/1972$			
Low Case	55.1	54.8	49.0
Medium Case	54.9	52.1	44.1
High Case	52.9	48.6	40.0

*The actual 1976 energy-GNP ratio is 58.4 x 10^3 Btu/1972$.

Table IV.22
Summary of Energy-Economy Interactions
(Percent)

	1985	1990	2000
Percentage change in primary energy input			
Low to Medium	-0.60	-6.65	-12.90
Medium to High	-4.58	-8.35	-11.82
Low to High	-5.16	-14.45	-23.19
Percentage change in real GNP			
Low to Medium	-0.16	-1.75	- 3.21
Medium to High	-1.08	-1.77	- 2.92
Low to High	-1.24	-3.48	- 6.03
Descriptor elasticity of GNP response to primary energy input response			
Low to Medium	0.270	0.256	0.236
Medium to High	0.230	0.204	0.235
Low to High	0.235	0.227	0.236

V. ENERGY-ECONOMY INTERACTIONS AS MEASURED IN THE DRI SYSTEM

As the exact details of the analysis using the DRI model are currently unknown to the authors, a thorough discussion of the results cannot be presented. However, it is our impression that the DRI macroeconomic model was used to summarize the relative responsiveness of GNP and its components to proportional changes in:

- The wholesale price index of fuels and lubricants (WPI05).
- The constant dollar value of fuel and lubricant imports by end-use categories (MEND1067).
- The unit value index of fuel imports (JMEND10).
- Industrial production indices for Canada (JQIND@C156). Japan (JQIND@C158), and OECD Europe (JQIND@C930).
- Real personal consumption expenditures (PCE) on gasoline and oil (CNGAS72).
- The implicit PCE (PCNGAS) price deflator of fuels and lubricants.

The exogenous changes in these variables were derived from independent analyses using certain policy assumptions, inter-model definitional and statistical price relationships, demand-supply balance scenarios from various DOE energy and energy sector models, the Petroleum Price Forecasting Model (developed by Scientific Time Sharing Corporation - STSC), and the DRI foreign sector models. Additional assumptions regarding price-induced variations in other exogenous DRI macrovariables (e.g., the index of consumer sentiment, fiscal and monetary policy responses, etc.) have not been identified.

The level and compositional effects of higher energy prices on real GNP are presented in Tables V.1 and V.2. In the DRI system, real GNP declines as the economy adjusts to relatively more expensive energy. In proportionate terms, the reductions are not large; for the year 1995, the High Case GNP is only 2.5% below that of the Low Case. Although the dollar magnitudes are significantly smaller than those from the BNL/DJA system, they are still substantial, e.g., (1972$) 60.4 billion between the Low and High Cases in 1995. Higher energy prices move the economy onto a permanently lower growth path. The average annual growth rates of real GNP between 1977 and 1995 are 3.42, 3.34, and 3.27% in the Low, Medium, and High Cases, respectively.

For higher energy prices, the DRI energy-economy interactions may be characterized by a descriptor elasticity (Table V.3) which measures the relative responsiveness of real GNP to proportional changes in the wholesale price index for fuels and lubricants (WPI05). Using the post-1985 information, a doubling of wholesale energy prices results in an average 5.3% reduction in the level of annual, real GNP. These results clearly imply that upward movements in energy prices impose an economic cost on society, in terms of foregone income and consumption.

In addition, the higher energy prices lead to some increase in inflation. As between the Low and High Cases, the increase in the general price level in 1995 is estimated to be 2.2%. This impact, spread over 17 years, is not a large inflationary effect, but it does exacerbate other inflationary pressures which might exist in the economy.

Table V.1
DRI GNP and Components
(Billions of 1972 dollars)

	Low	Medium	High
1985			
GNP	1800.4	1799.9	1783.5
Consumption	1163.0	1163.1	1155.6
Investment	265.7	265.2	257.6
Government	348.1	348.1	347.5
Net exports	23.6	23.5	22.7
GNP price (1972=1.00)	2.253	2.255	2.283
1990			
GNP	2108.0	2089.3	2065.6
Consumption	1370.0	1359.3	1343.9
Investment	313.1	305.6	294.8
Government	400.1	399.1	397.7
Net exports	24.8	25.2	29.3
GNP price (1972=1.00)	2.871	2.893	2.947
1995			
GNP	2447.7	2416.5	2387.3
Consumption	1605.8	1583.9	1558.6
Investment	360.6	350.7	341.0
Government	453.9	452.2	450.5
Net exports	27.5	29.8	37.1
GNP price (1972=1.00)	3.684	3.708	3.765

Table V.2
DRI GNP and Components: Changes Between Cases
(Billions of 1972 dollars)

	Medium-Low	High-Medium	High-Low
1985			
GNP	-0.5	-16.4	-16.9
Consumption	+0.1	- 7.5	- 7.4
Investment	-0.5	- 7.6	- 8.1
Government	0.0	- 0.6	- 0.6
Net exports	-0.1	- 0.8	- 0.9
1990			
GNP	-18.7	-23.7	-42.4
Consumption	-10.7	-15.4	-26.1
Investment	- 7.5	-10.8	-18.3
Government	- 1.0	- 1.4	- 2.4
Net exports	+ 0.4	+ 4.1	+ 4.5
1995			
GNP	-31.2	-29.2	-60.4
Consumption	-21.9	-25.3	-47.2
Investment	- 9.9	- 9.7	-19.6
Government	- 1.7	- 1.7	- 3.4
Net exports	+ 2.3	+ 7.3	+ 9.6

Table V.3
Summary of Energy-Economy Interactions for the DRI Results
(All numbers reported as ranges)

	1982-84	1985-89	1990-95
Percentage change in DRI GNP:			
Low to Medium	--	-0.03/-0.73	-0.89/-1.28
Medium to High	-0.08/-0.53	-0.92/-1.17	-1.14/-1.22
Low to High	-0.08/-0.53	-0.94/-1.88	-2.03/-2.50
Percentage change in WPI05:			
Low to Medium	--	1.88/11.23	12.40/21.57
Medium to High	4.00/12.80	15.94/24.22	24.10/26.42
Low to High	4.00/12.80	17.82/35.45	38.82/45.67
Descriptor elasticity of GNP response to WPI05 response:			
Low to Medium	--	-0.015/-0.065	-0.060/-0.072
Medium to High	-0.019/-0.041	-0.048/-0.066	-0.043/-0.052
Low to High	-0.019/-0.041	-0.053/-0.057	-0.052/-0.055

The ranges give the low and high numbers, respectively, for the variable over the years considered in each period.

VI. A SUMMARY AND COMPARATIVE ASSESSMENT OF THE BNL/DJA AND DRI RESULTS

Restrictive energy conditions and higher energy prices have a significant impact on the economy. The levels of real income and output are reduced and the rate of economic growth is slowed by these energy changes. For the energy changes considered in this report, positive economic growth continues so that the economic losses take the form of slower real income growth rather than an absolute decline over time. However, at every future date real incomes and output, as measured by real GNP, are less, under higher energy prices, than they would otherwise have been. This represents a real cost, in terms of foregone income and production, spread over the entire economy.

For the BNL/DJA model system, the magnitudes of the effects of higher energy prices on real GNP are summarized in Table VI.1. Growth continues even with the higher energy prices, but the rate of growth is significantly slowed. In the Medium and High Cases, the energy changes have their maximum effects in the 1980s. Economic growth rates in the 1990s recover slightly but remain substantially below the rates characterizing the Low Case.

Table VI.1
Impacts of Higher Energy Prices on Real GNP:
BNL/DJA System
(Real GNP in billions of 1972 dollars)

	1985	1990	2000
Real GNP			
Low Case	1779.4	2075.6	2785.8
Medium Case	1776.5	2039.3	2696.3
High Case	1757.4	2003.4	2617.7
Rate of Growth of Real GNP*			
Low Case	3.63	3.13	2.99
Medium Case	3.61	2.80	2.83
High Case	3.47	2.65	2.71
Change in Real GNP (Billions of 1972 dollars)			
Medium-Low	-2.9	-36.3	-89.5
High-Medium	-19.1	-36.0	-78.6
High-Low	-22.0	-72.3	-168.1
Change in Real GNP,%			
Medium from Low	- 0.2	- 1.8	- 3.2
High from Medium	- 1.1	- 1.8	- 2.9
High from Low	- 1.2	- 3.5	- 6.0

*Average annual percentage growth rates for the periods 1977-1985, 1985-1990, and 1990-2000. Real GNP in 1977 is taken as (1972$) 1337.3 billion.

This reduced growth translates into a loss in real income and production. By 1990, real GNP in the High Case is (1972$) 72 billion or 3.5% less than the Low Case Level; by 2000 the reduction is (1972$) 168 billion or 6.0%. Over the 1977-2000 period, the total loss of real GNP between the High and Low Cases is approximately (1972$) 1560 billion. This is more than the entire final output of the U.S. economy in 1977. It corresponds to a lump sum cost of approximately $17,100 in constant 1972 dollars, or $24,100 in current dollars, for every family in the U.S. in 1977. Alternatively, this loss can be compared to the budget of the Department of Energy which, in 1977-78, was approximately (1972$) 7.1 billion. If this budget were to remain constant in real terms, the total GNP loss over the 1977-2000 period corresponds to over 200 years of DOE operation. By any measure, therefore, the economic costs of higher energy prices are very substantial. Further, the role of DOE, in designing and implementing policies which partially or wholly mitigate these effects is clearly justified.

Comparison of the results from the BNL/DJA and DRI models show that the estimated impacts on real output and incomes are substantially different. In view of the importance of the estimated magnitude of the real economic effects of these price variations for the appraisal and evaluation of energy policy, it is essential to analyze these differences in more detail.

In the BNL/DJA system, the responsiveness of real GNP to energy price increases is, in absolute value, always greater than that observed in the DRI model. Between the Low and High Cases in the BNL/DJA results, the 1977-1995 average annual growth rate of real economic activity declines from 3.31 to 3.03%, a reduction of 0.28 percentage points. The corresponding reduction in the DRI model is much smaller, from 3.42 to 3.27%, a 0.15 percentage point decline. By the end of the DRI forecast period (1995) the reduction in real GNP between the Low and High Cases is 4.8% for the BNL/DJA system and 2.6% for the DRI model.

These differences are further illustrated by the comparison of the implicit GNP-energy price elasticities presented in Table VI.2. In absolute terms, the summary measures from the BNL/DJA system range anywhere from 1.3 to 2.7 times greater than the DRI values for similar time periods. Given the constant supply-to-wholesale markups which characterize the price structure in the BNL energy model, these differences would be more pronounced were the BNL/DJA prices converted to their wholesale equivalents.

A final comparison between the BNL/DJA and DRI estimates of GNP effects is given in Table VI.3. This shows the changes in the total present value of real GNP foregone over the period 1977-1995 in the two models. As an order of magnitude, therefore, the real economic effects of energy changes calculated in the BNL/DJA system are twice as great as those estimated in the DRI model.

Another aspect of the economic effects of energy changes that is different between the two models is the distribution of the GNP loss between consumption and investment. In the BNL/DJA system, the GNP reductions in the early periods are dominated by decreases in consumption. It is not until the later periods (post-1990), when the long-run adjustments begin to clearly emerge, that the percentage decreases in investment exceed those in consumption. Table VI.4 summarizes these effects. In the DRI system, however, percentage changes in investment exceed those in consumption for every time period. These reductions are shown in Table VI.5. There is the further difference that the fraction of GNP loss represented by investment is decreasing over time.

These differences are of importance for policy analysis and policy evaluation purposes. The difference in the real GNP impact is of great significance in assessing the overall economic costs of energy price variations. A given price change would have less net social benefit if the BNL/DJA numbers were accurate than if the DRI figures were accurate since the economic cost of such a policy, wherever it originates, is about twice as severe in the BNL/DJA system. Also, the split of the spending reduction is of significance in determining who bears the cost of these price changes; if consumption is more affected, then the citizens of today bear more of the cost but if investment is more affected, then the cost falls more intensively on the citizens of the future.

The observed differences in the model predictions appear too large to be attributed solely to numerical differences in parameter values and error properties. Rather, a large part, and possibly most, of the difference in results is due to the difference in the methodology and specification of the two models.

Table VI.2
Summary of Energy-Economy Effects
in the BNL/DJA and DRI Models

BNL/DJA GNP/supply elasticities*	1985	1990	2000
Low/Medium	-0.097	-0.118	-0.106
Medium/High	-0.075	-0.071	-0.104
Low/High	-0.077	-0.088	-0.105
DRI GNP/WPI05 elasticities**	1982-84	1985-89	1990-95
Low/Medium	--	-0.040 (-0.015/-0.065)	-0.064 (-0.060/-0.072)
Medium/High	-0.029 (-0.019/-0.041)	-0.057 (-0.048/-0.066)	-0.048 (-0.043/-0.052)
Low/High	-0.029 (-0.019/-0.041)	-0.054 (-0.053/-0.057)	-0.054 (-0.052/-0.055)

*Computed as the product of the descriptor elasticities from Tables IV.4 and IV.22.

**Reported numbers are averages. Numbers in ( ) represent the ranges as presented in Table V.3.

Table VI.3
Changes in the Present Value of Future Real GNP
Levels from 1977 to 1995: A Comparison of
BNL/DJA and DRI Model Results
(Billions of 1972 dollars)

	Medium-Low	High-Medium	High-Low
BNL/DJA: Discount rate, %			
0	-372.44	-458.90	-831.34
6	-153.40	-211.53	-364.93
12	-68.56	-108.22	-176.78
DRI: Discount rate, %			
0	-181.10	-282.20	-463.30
6	-72.55	-126.48	-199.03
12	-31.19	-61.46	-92.65

Table VI.4
BNL/DJA GNP and Components - Percent Changes Between Cases

	Medium-Low	High-Medium	High-Low
1985			
GNP	-0.16	-1.08	-1.24
Consumption	-0.32	-1.41	-1.73
Investment	-0.04	-0.72	-0.76
1990			
GNP	-1.75	-1.77	-3.48
Consumption	-2.10	-2.26	-4.31
Investment	-1.77	-1.91	-3.64
2000			
GNP	-3.21	-2.92	-6.03
Consumption	-3.84	-3.27	-6.98
Investment	-4.83	-5.38	-9.95

Table VI.5
DRI GNP and Components - Percent Changes Between Cases

	Medium-Low	High-Medium	High-Low
1985			
GNP	-0.03	-0.91	-0.94
Consumption	-0.01	-0.64	-0.64
Investment	-0.19	-2.87	-3.05
1990			
GNP	-0.89	-1.13	-2.01
Consumption	-0.78	-1.13	-1.91
Investment	-2.40	-3.53	-5.84
1995			
GNP	-1.27	-1.21	-2.47
Consumption	-1.36	-1.60	-2.94
Investment	-2.75	-2.77	-5.44

Each model is designed for a particular set of tasks and, hence, its specification reflects this objective. The BNL/DJA model system is designed to consider energy and economic performance, taking supply constraints into account so that it is appropriate for those analyses where supply considerations are important. The DRI model is designed to consider detailed expenditure patterns and neither represents nor takes account of supply conditions. It is suited for analyses of short-run changes when demand adjustments are of principal importance. The different purposes and, therefore, the different structures of the two models are sufficient to imply that systematically different outcomes can be expected for the same energy price changes.

The BNL/DJA model is designed to simultaneously allow for demand and supply possibilities in simulating the performance and structure of the economy. Technological and interfuel substitutions in the energy sector, input substitutions in production activities, and product substitution and compositional changes in final demand are all incorporated in the model. The resulting economic picture reflects what people want (desired expenditure) constrained by what is achievable, given input availabilities and production requirements (supply possibilities). Within this system, the spending on and supply of energy are treated in detail; however, the demand for and supply of nonenergy inputs and outputs are also included. Further, the growth of the economy, from the points of view of both demand and supply, is explicitly modeled. The structure of the model can be viewed in terms of the framework given in Figure VI.1. Input prices in conjunction with the supply of inputs determine incomes (income is essentially composed of capital income and labor income). Incomes in conjunction with prices (as well as wealth, rates of return, and other variables) determine expenditure. Final demand and input patterns, reflecting prices, determine the industry total outputs and demands for inputs; if demand and supply quantities are not equal, then prices adjust and the process repeats until demands are equal to supplies. The solution level and structure of the economy have, inter alia, these features:

- Final demand expenditure on each type of good or service which reflects income, prices, and other influences.
- The real level of final demand which is feasible in terms of the supply position of each sector and of the economy.
- The supply position which reflects both patterns of inputs and productivities in each sector and the availability of these inputs and resources to the economy.

The DRI model is designed to be a short-run forecasting model of the economy. Since aggregate demand is the main variable in the short run, the model focuses on final demand expenditure and contains a highly detailed representation of spending patterns. Supply considerations are not included and there are no constraints on output and spending which reflect the ability of the economy to produce. The structure of the model can be viewed in terms of the framework presented in Figure VI.2. The essence of this structure is that there is great detail and sophistication in the demand representations. However, there is a unidirectional causal flow; demand determines economic performance without allowance for or interaction with supply possibilities.

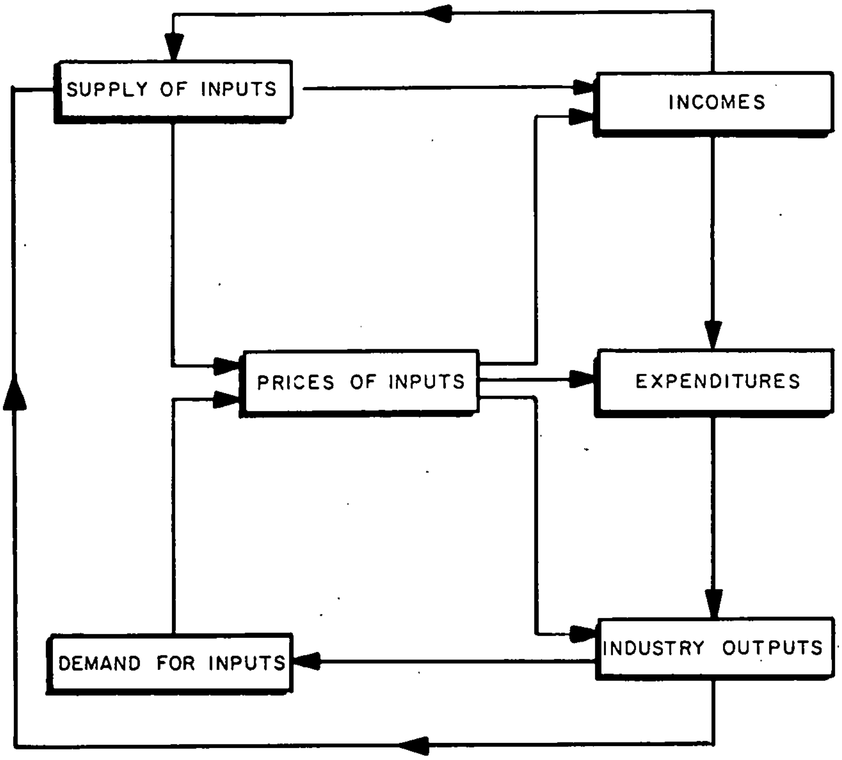


Figure VI.1. Aspects of the Structure of the BNL/DJA Model

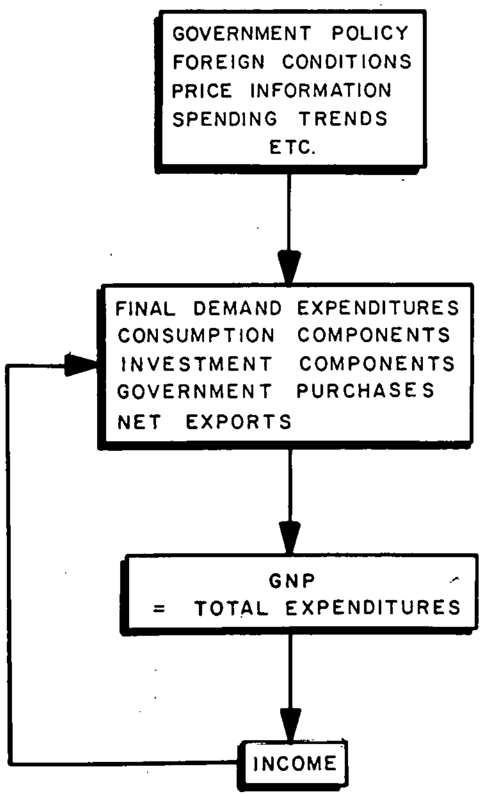


Figure VI.2. Aspects of the Structure of the DRI Model

Current economic conditions (including fiscal, monetary, and foreign sector variables, prices, and previous trends) lead to the estimation of final demand expenditures. These expenditures are estimated on a detailed basis, with each demand equation being tailored to reflect the characteristics of the particular good or service. The spending components are then aggregated to obtain GNP. From the "income equals expenditure" identity of national income accounting, total income is determined and separated into its components. The solution level and structure of the economy have, inter alia, these features:

- Final demand expenditure on each type of good or service which is analyzed in detail, incorporating income, prices, and other influences.
- No consideration of input patterns, resource availabilities, factor productivities, or supply conditions in each sector.

The structural differences between the BNL/DJA and the DRI models center on the treatment of supply possibilities; the BNL/DJA system includes a detailed representation of supply constraints, whereas the DRI model has no supply constraints. This difference is crucial in accounting for the differences in model results. In both models, higher energy prices lead to an adjustment in total spending with real final demand being reduced. In DRI there is no further adjustment; the total estimated effect is the demand adjustment. In BNL/DJA there is an additional effect: the impacts of the energy price changes on the supply side are considered. Reduced energy input has a direct cost in lower output. Further, reduced energy input requires additional input of other factors, in particular, labor. Labor productivity and, hence, labor income are reduced. This, in conjunction with the strictly limited availability of capital and labor, reduces the output that the economy can produce. In short, the change in input supplies and productivities limits the volume of output that can be produced. With these energy sector changes, the supply effects are significant and result in total GNP reductions greater than those purely due to the demand effects. The BNL/DJA model, by including both demand and supply adjustments, gives a more comprehensive picture than the DRI model and, consequently, yields greater economic impacts from the energy price changes.

These same features appear to be the cause of the different shares of the total GNP effect falling on consumption and investment. For the two models, these compositional differences are illustrated by the percentage changes between cases in the consumption and investment shares of real GNP which are shown in Table VI.6. The values for the BNL/DJA system further evidence the previous discussions of the interrelationships among the substitution and dynamic effects and the consumption and investment effects. By contrast, the values for the DRI model again reveal significant behavioral differences in its prediction of the economy's response to higher energy prices. A preliminary analysis of the equations of the DRI model provides an explanation for these differences in terms of the causal flows presented in Figure VI.2. In the DRI model, consumption and investment are estimated as the summations of their respective spending components which are determined individually. These, with government purchases and net exports, sum to yield GNP which, by a national income accounting identity, determines real disposable income. Simultaneity in the DRI model is achieved as

Table VI.6
The Percentage Changes in the Consumption and Investment Shares of Real GNP between the Low and High Cases

Year	BNL/DJA consumption share of GNP	DRI consumption share of GNP	BNL/DJA investment share of GNP	DRI investment share of GNP
1985	-0.50	+0.30	+0.49	-2.13
1990	-0.86	+0.10	-0.17	-3.91
1995	---	-0.48	---	-3.05
2000	-1.01	---	-4.17	---

real disposable income enters the expenditure relationships (primarily those for consumption spending components and residential investment). As there is no supply side representation in the DRI model, incomes are neither constrained nor adjusted by the changes which occur in factor markets, input patterns, and supply conditions. Thus, expenditures are not limited by either the economy's ability to produce or the incomes originating from production.

Income is stabilized in the DRI methodology as it is determined from expenditures (the product side) rather than from earnings (the factor side). Indeed, there appear to be only weak relationships between the price-induced, expenditure variations and their impacts on labor and property incomes. As real disposable income is stabilized, so too are real consumption and, from the simultaneity of the model, real GNP. The major variations result from the changes in spending components occurring in such key sectors (automotive, housing, consumer durables) so as to primarily affect investment expenditure. What is unclear, however, is the dynamics in the DRI system of so large a reduction in investment (in absolute and percentage terms) and the relatively moderate declines in real economic activity. It appears that the answer again lies in the inability of a partial equilibrium model to fully explain long-run income determination. The DRI model does not allow for the input-related, income effects of changing expenditure patterns and their associated implications for saving and investment. This is particularly true of those income effects resulting from variations in capital and labor requirements.

The inflationary impacts predicted by the two models are also slightly different. These differences are summarized in Table VI.7 and yield several conclusions. Principally, consistency and, to some degree, similarity seem the more appropriate characterizations for a comparison of the inflationary response to higher energy prices. Directionally, the influence of these price changes on the rate of inflation is identical for the two methodologies; that is, higher energy prices accentuate the inflationary pressures in the economy. Between the Low and Medium cases, the models predict little, if any, change in their respective annual average growth rates for the GNP price deflator. Of importance, then, are the different inflation rates between the models and the differential inflationary response between the Low and High cases. It has

Table VI.7
The Annual Average Rate of Increase
in the GNP Price Deflator:
1978-1995
(Percent per year, 1972 = 1.0)

	BNL/DJA	DRI
Low Price	4.01	5.40
Medium Price	4.01	5.44
High Price	4.05	5.53

been suggested that these differences are attributable solely to the presence (absence) of the monetary and financial sectors in the DRI (BNL/DJA) model. Such a conclusion, however, is unwarranted.

In the DRI model, there are many sectoral price-price and cost-price relationships. For the most part, the price indices which enter as independent variables do not reflect comprehensive market interactions; prices and quantities do not adjust in response to exogenous relative price changes. Consequently, these indices are higher than they otherwise would be in the long run. Further, the price weights (coefficients) in these relationships are fixed. These features introduce into the DRI model potentially significant price-price and cost-price mechanisms for price inflation.

The DRI model has, therefore, an inherent cost-push mechanism underlying the inflationary impacts of higher energy prices. In contrast, monetary policy is invariant across the cases so any monetary influence on inflation is the indirect result of changes in cost and spending patterns. This implies that it is not the monetary sector but rather cost and spending adjustments that underlie the DRI inflation estimates. In view of this, it cannot be said that the role of the monetary sector accounts for the small difference in the inflation estimates between the BNL/DJA and the DRI models. Instead, this difference arises from the differences in the cost-price linkages and market price formation mechanisms between the models.

There are further differences between the structures of the two models concerning the specific impact of energy on the economy. The DRI models has only very rudimentary mechanisms by which energy affects the economy; the entire impact occurs primarily through changes in only two variables, WPI05, the wholesale price of energy, and the constant dollar value of oil imports. This necessarily prevents much relevant energy information from being introduced into the analysis of economic impacts. These mechanisms preclude any allowance for or consideration of interfuel substitution possibilities or input adjustments between energy and nonenergy factors. Within the DRI model and between energy prices and economic spending, there is no explicit consideration of energy/nonenergy effects. Further, with the exception of oil imports and their valuation, energy quantity does not appear in the causal linkage. By comparison, the BNL/DJA system has a detailed set of interactions between energy and the economy. The prices and availabilities of each fuel impact the level of energy use, the structure of demand for each fuel, imports, and the level and composition of final spending. This set of interactions is considerably more complete and more detailed than that contained in the DRI model and, thus, permits a fuller analysis.

There are differences, summarized in Table VI.8, in the level of oil imports between the two model systems. At issue, then, is the significance of these differing import levels. First, the BNL/DJA system explicitly models oil import quantities to reflect the actual role of imports as making up the difference between domestic oil demand and domestic crude petroleum production. In contrast, as the DRI model does not represent fully energy-economy interactions and as it does not determine oil demand and supply, imports must be treated as exogenous. Because of this, the BNL/DJA import figures are more analytically based. Second, the differences in oil import payments cannot account for a significant part of the differing GNP impacts. For the differences to be significant implies that the economic effects of eliminating the payment differentials dominate those of the domestic spending, production, productivity, and supply adjustments caused by changes in the price and availability of energy. This proposition may be appropriate for import-constrained economies, which are dominated by international trade considerations that largely determine domestic economic performance, but hardly seems defensible for a mature economy such as that of the United States.

Table VI.8
Oil Import Quantities and Values

	Low Case		Medium Case		High Case	
	BNL/DJA	DRI	BNL/DJA	DRI	BNL/DJA	DRI
Quantity of oil imports, MM bbl/Day						
1978	8.50	8.50	8.50	8.50	8.50	8.50
1980	9.30	9.30	9.30	9.30	9.30	9.30
1985	11.10	8.50	9.55	8.50	8.14	7.80
1990	14.19	10.80	10.95	10.20	7.39	6.80
1995	---	12.80	---	11.20	---	6.80
2000	16.37	---	9.57	---	5.57	---
Value of oil imports, 10^9 1972$						
1978	44.986	44.986	44.986	44.986	44.986	44.986
1980	49.220	49.220	49.220	49.220	49.220	49.220
1985	39.219	30.032	35.415	31.521	38.981	37.353
1990	54.435	41.430	52.038	48.474	52.113	47.952
1995	--	55.550	--	68.147	--	57.582
2000	80.424	--	74.542	--	56.661	--

A final difference concerns the dynamics of the two models. In the BNL/DJA system, reductions in investment lead to reductions in the growth of capital stock and, so, to reductions in the future productive capacity of the economy. Through the supply constraints on current economic activity, these effects accentuate the GNP reductions caused by the energy price changes. In contrast, the DRI model only incorporates the effects of the investment declines into the determination of "potential" GNP which, as well as showing virtually no response to the higher energy prices, does not impact the level or structure of real production in the economy. Thus, the productivity and supply impacts which are central to the longer-run economic effects of energy changes are not incorporated into the DRI model.

Each of these features has the same implication: the BNL/DJA model provides comprehensive coverage of the energy-economy adjustment mechanisms and, thus calculates a greater economic impact than the DRI model, which includes only a partial set of effects. In particular, the effects of energy changes on input availability and productivity, on capital stock and productive capacity, and through supply constraints to real GNP changes are included in the BNL/DJA model but not the DRI model. Reflecting these structural differences, the BNL/DJA estimates of the economic effects are about twice as large as the DRI figures. Further, the need for including this full set of effects in order to get a reliable estimate of longer run energy-economy interactions suggests that the BNL/DJA model system provides an appreciably more comprehensive and applicable methodology.

VII. OPTIMAL STRATEGY FOR POLICY DESIGN

Energy policy must be predicated upon an analytical and informational base. However, no such base can be viewed as being absolutely correct; there is always the possibility that the analysis or information will contain inaccuracies. It is essential, therefore, to recognize and allow for the uncertainty surrounding any information base. In this study, the results from two analytical systems, the BNL/DJA model and the DRI model, were reviewed and were found to yield systematic differences in their informational product. These differences reflect one aspect of the uncertainty surrounding the information base.

Since it is not known which of the models is correct, use of one for policy analysis entails the risk that policy will be based on incorrect information. This risk is compounded by the possibility that neither of the models is correct. It is possible, however, to analyze these risks within an explicit framework and to formulate a selection strategy that minimizes the damage that could result from the use of incorrect information. Drawing upon the results of this study, the focus of this chapter is to formulate guidelines for the optimal selection of an analytical base for policy design. Clear rules for information selection and, hence, for choice between the models, emerge from the subsequent assessment.

Consider first the case in which either the BNL/DJA or the DRI model is to be used as the analytical framework and that one of these models, without it being known which one, yields accurate information. Four possibilities exist:

- BNL/DJA is used for analysis and BNL/DJA information is correct;
- BNL/DJA is used for analysis and DRI information is correct;
- DRI is used for analysis and DRI information is correct;
- DRI is used for analysis and BNL/DJA information is correct.

These four cases are all possible combinations of model use and model correctness. They are displayed in schematic form in Figure VII.1.

For each of these four cases there is an associated cost with the use of what is possibly wrong information. For whichever model gives accurate information, appropriately designed policy predicated upon that model is optimal. This is optimality in the sense of the best policy that can be designed for the current situation. If it happens that correct information is used in the policy design, then there is no difference between the best policy that can be designed, given correct information, and that which appears to be best, given the information base acutally used. In these cases, the informational loss in social welfare is zero. Thus, in Figure VII.1, the costs on the main diagonal are zero. If, however, the model used as the basis for policy design happens not to be accurate, then the resulting policy will be inferior to that which would be designed on the basis of the true information. The actual policy, therefore, involves a social cost which, conceptually, equals the net social benefit generated by the optimal policy less the net social benefit resulting from the policy designed on the basis of the incorrect information. In Figure VII.1, the costs stemming from the use of incorrect information are shown as the nonzero, off-diagonal elements.

Given the possibility of using incorrect information for policy design, the question arises of how best to choose between the two available models and information systems. This selection problem may be formulated in a more formal way. Specifically, which model system should be used so as to minimize the expected net social cost of introducing suboptimal policy? Selection based on this criterion involves the specification of the costs involved in each possible choice and outcome and the probabilities, p and q, that each of the models is correct. This information is given in Figure VII.1. In terms of these variables, the selection criterion may be evaluated as:

Expected Cost of Using BNL/DJA Information

$$= p*0 + q*C_{II};$$

Expected Cost of Using DRI Information

$$= p*C_{III} + q*0.$$

The preferred model system is that for which the expected cost is the least. Thus, the BNL/DJA model is selected if and only if its expected cost is less than that for the DRI model, i.e.,

$$\text{Use BNL/DJA} \leftrightarrow q*C_{II} < p*C_{III}, \text{ or}$$

$$\text{Use BNL/DJA} \leftrightarrow p*C_{III} - q*C_{III} > 0.$$

ACCURATE INFORMATION GIVEN BY:

MODEL USED FOR POLICY DESIGN:	BNL/DJA WITH PROBABILITY P	DRI WITH PROBABILITY Q
BNL/DJA	0	C_{II}
DRI	C_{III}	0

THE OFF-DIAGONAL ELEMENTS, C_{II} AND C_{III}, ARE DETERMINED AS THE NET SOCIAL BENEFIT FROM POLICY DESIGNED ON THE BASIS OF CORRECT INFORMATION LESS THE NET SOCIAL BENEFIT GENERATED BY POLICY DESIGNED ON THE BASIS OF INCORRECT INFORMATION.

Figure VII.1. Social Costs Associated With Information Selection in Policy Design

To interpret this condition, it is necessary to obtain the relationship between C_{II} and C_{III}, the costs of using BNL/DJA and DRI, respectively, when in fact the other model gives correct information. The comparison of these costs can be analyzed using Figure VII.2 which shows illustrative schedules for the marginal social benefits and marginal social costs of energy policy. Energy policy is characterized by a single dimension, policy strength measured along the horizontal axis. Policy effects, both costs and benefits, are measured in dollar terms, as a convenient unit of account, on the vertical axis. Benefits are represented as a function of policy strength alone and are assumed to be independent of the model results. This corresponds, for example, to deriving a policy-induced reduction in energy use and valuing each Btu of this reduction in terms of dollars. Policy costs are those estimated by the model systems and may be interpreted as reflecting the economic cost of increasing policy strength to achieve energy reductions. The entire difference between the models is incorporated in the different cost curves. From the above numerical results, it is known that the estimated economic cost in the BNL/DJA system is approximately twice that in the DRI system. This means that the marginal cost line generated by the BNL/DJA model has a slope twice as great as the marginal cost line for the DRI model. Finally, it can be noted that the optimal policy is that defined by the intersection of the marginal benefit and the true marginal cost curve. This is the policy strength, P, that maximizes the net social benefit resulting from energy policy. Thus, if the BNL/DJA information is correct, the optimal policy is P_1, whereas P_2 is optimal if DRI is correct.

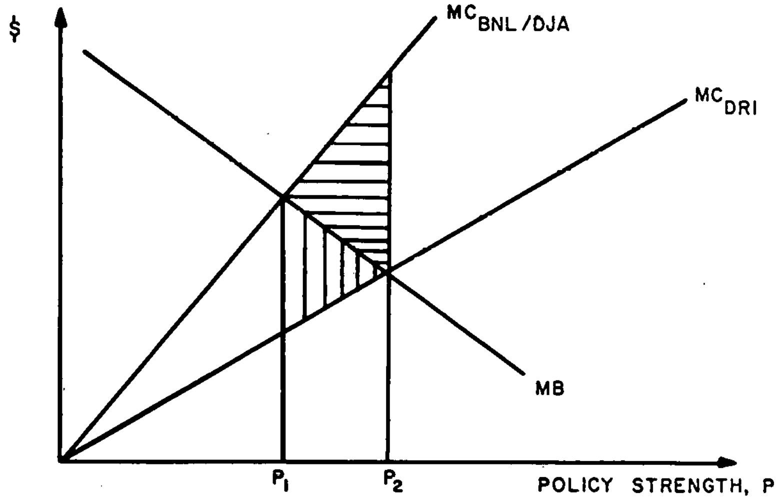
Consider next what happens if DRI is correct but BNL/DJA is used for policy design. In this case, the estimated cost curve is above the true cost curve. The chosen policy is P_1 which is weaker than the optimal policy, P_2. The loss in net social welfare resulting from the incorrect policy choice is given by the vertically shaded area in Figure VII.2, i.e., by the gain in social benefit over and above the additional social cost as between P_1 and P_2. If the opposite case obtains, i.e., BNL/DJA is correct but DRI is used for policy design, the estimated cost curve is below the true cost curve. The chosen policy is P_2 which is stronger than the true optimal policy, P_1. The loss in net social welfare resulting from this error is given by the horizontally shaded area.

These results give rise to the first set of conclusions:

- If the BNL/DJA model system is used for policy design when DRI is actually the correct model, the resulting energy policy will be weaker than optimal.
- If DRI is used for policy design when BNL/DJA is actually the correct model, the resulting energy policy will be stronger than optimal.

A more precise comparison between the cost of each alternative can be obtained by using the information that the cost line estimated by BNL/DJA is steeper than that estimated by DRI. From the geometry of Figure VII.2, it is necessarily true that the horizontally shaded area is larger than the vertically shaded area, i.e.,

$$C_{III} > C_{II}.$$



MB = MARGINAL SOCIAL BENEFIT
MC = MARGINAL SOCIAL COST

Figure VII.2. Policy Benefits and Costs under the BNL/DJA and the DRI Models

This gives the next conclusion:

- The social cost of using the BNL/DJA information when DRI is correct is less than the social cost of using the DRI model when BNL/DJA is correct.

This result also permits the expected cost of each strategy to be compared. It is known that:

$$C_{III} = C_{II} + D, \text{ where } D > 0,$$

and where D represents the excess informational cost of the DRI model over the BNL/DJA system when, in fact, a policy mistake has been made. From the previous results, therefore, the decision rule may be restated as:

$$\text{Use BNL/DJA} \leftrightarrow \left(\frac{p-q}{p}\right) * C_{II} + D > 0.$$

The result of this criterion depends upon the numerical values of the variables involved. The possible outcomes can be presented as further conclusions:

- If $p = q$, i.e., both models have the same probability of yielding correct information then, since BNL/DJA always involves the lower expected cost of wrong information, BNL/DJA is the preferred analytical system.
- If $p > q$, i.e., BNL/DJA has a higher probability of yielding correct information, then BNL/DJA is the preferred system.
- If $p < q$, i.e., DRI has a higher probability of yielding correct information then, as long as

  $$\left|\frac{p-q}{p}\right| < \frac{D}{C_{II}},$$

  BNL/DJA is the preferred system.
- If $p < q$ and if

  $$\left|\frac{p-q}{p}\right| > \frac{D}{C_{II}},$$

  then DRI is the preferred system.

In the absence of any further information, or as an agnostic position, equal probabilities would be assigned to either model being correct. In this case, the BNL/DJA model is the appropriate choice for use in policy analysis. If more information on the probabilities were known, it is also likely that the BNL/DJA system would be preferred. This results from its more favorable rating, not only for any probability p greater than q, but also for probabilities p less than q, provided the proportionate difference in probabilities does not exceed the proportionate excess in DRI costs.

There is, however, additional information available to permit a qualitative ranking of the models with respect to their probabilities of being correct. The evaluations in the previous chapters revealed that the DRI model is a short-run, demand-oriented model without a supply side, whereas the BNL/DJA system is a longer-run model with both demand and supply representations and technological detail. For the types of policy effects considered above and in particular the real income and output effects over the remainder of the century, the comprehensive features of the BNL/DJA model are of great importance. This implies that the BNL/DJA model has the higher probability of being correct in the calculation of the full economic costs of energy changes. Therefore, both the probabilities and the conditional costs favor the use of the BNL/DJA model as the information system for policy design. When these two facets are combined, the relative advantage of the BNL/DJA system is further enhanced. (It must be noted that for some applications, the DRI model would be preferred. For issues involving very short-run economic impacts, the demand-oriented detail of the DRI system provides an appropriate analytical basis. In this case, the probability of the DRI information being correct is relatively high so that it is likely that the expected net benefit of policy would be higher when DRI information is used.)

The preceding analysis considered optimal model selection for the case when either BNL/DJA or DRI is correct but it is not known which model is correct. The optimal strategy for information selection in this case is to use the BNL/DJA model system. The next step in the analysis is to allow for the possibility that neither model is correct. The decision problem in this instance is the same as above. That is, which model should be used as the information base for policy design in order to minimize the expected cost of implementing wrong policy? The analytical framework for this problem in strategy design is given in Figure VII.3. This is similar to the previous diagram except that now there is a true marginal cost curve, and its actual position is unknown. There is also a true optimal policy, P_o, defined by the intersection of the marginal benefit and the true marginal cost curve.

If the true cost line is above the BNL/DJA cost line, then it can readily be shown that BNL/DJA is the best available information base. Similarly, if the true cost line is below the DRI cost line, then the DRI model should be used to provide the information for policy design. The more difficult case is that in which the true cost falls between the BNL/DJA and the DRI cost lines. This is the situation depicted in Figure VII.3. If the position of the true cost line is as shown, then the expected social cost of designing policy on the basis of the BNL/DJA model is the vertically shaded area while the expected cost of designing policy using the DRI model is the horizontally shaded area. The BNL/DJA model is preferred if and only if the expected social cost of policy designed on this information, relative to the true optimal policy, is less than the expected cost, similarly determined, for DRI. From the geometry of the diagram, this can be expressed as

$$\text{Use BNL/DJA} \leftrightarrow a > c.$$

The result of the application of this criterion depends upon precisely where the true cost line falls relative to the other cost lines, i.e., on the relative magnitudes of the distances, b and c. Consider first the case in which the true cost lines is precisely midway between the two other cost lines, Here, b equals c

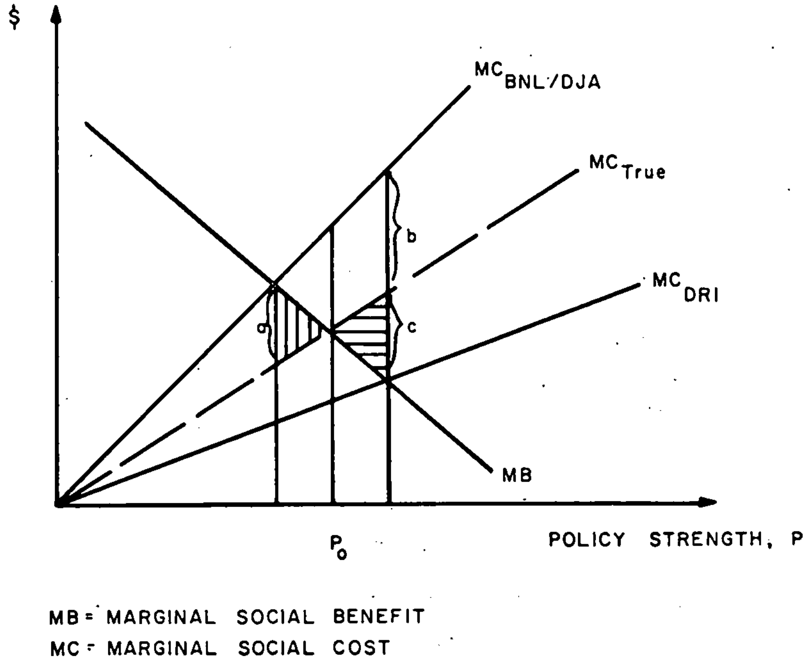


Figure VII.3. Policy Effects in the Case where Both Models are Subject to Error but, as a < b is necessarily true from the geometry of the diagram, then a < c. Thus, if either model has equal likelihood of being in error, the BNL/DJA system is to be preferred. Even if the true cost line is closer to the DRI cost line, it is still preferred so long as a is no greater than c. For the true cost very close to DRI, DRI is preferred.

If it were known where the true cost line is located, then there would be no need to use models of the energy and economic systems. However, this location is not known, so models must be employed to estimate the effects of energy changes. If all that is known about the true cost line is that it falls between the BNL/DJA and the DRI estimates, then the model system that should be selected is BNL/DJA. This is preferred, on the criterion of minimizing the social cost of policy errors, over a larger part of the total range in which the true cost line may lie. But, from the discussion above, it appears that the BNL/DJA model has a greater probability of approximating the true cost line than does the DRI model. In this case, the BNL/DJA system is definitely preferred on the criterion of minimizing the social cost of energy policy. These results may be summarized in a further set of conclusions:

- If nothing is known about the location of the true costs of energy policy, then use of the BNL/DJA model minimizes the expected social cost of using incorrect information in the design of energy policy.
- As the true long-run effects appear better represented by the BNL/DJA model, the case for use of the BNL/DJA system is further strengthened.

This analysis has reviewed the question of the optimal selection of an analytical system for the design and evaluation of energy policy. Optimality, in this context, is the minimization of the expected social cost caused by inappropriate energy policy which, in turn, is due to the use of incorrect information in policy design. If either the BNL/DJA or the DRI model is correct, but it is not known which, then the optimal strategy was shown to be the use of the BNL/DJA system. In the more general case, where neither model accurately estimates the long-run economic effects of energy changes, the optimal strategy for the selection of an analytical system still involves the use of the BNL/DJA model. In sum, then, it emerges that the choice of the appropriate information base for the design, analysis, and evaluation of energy policy over the remainder of the century is the BNL/DJA model system.

VIII. POLICY CONCLUSIONS

As a final component of this study, it is important to list briefly and succinctly a set of conclusions which are relevant to the Department of Energy for the design and evaluation of energy policy. Energy policy can impose significant costs on the economy in terms of lower levels of and lower growth in real incomes and production. To try to ensure that energy policies promote social welfare, it is important, therefore, to compare the costs and benefits of proposed policy measures and only to implement those policies which have a reasonable probability of yielding positive net social benefits. Further, the magnitudes of the economic costs resulting from energy policy can be reduced by appropriately designed countermeasures. To this end, policy measures should be directed toward:

- Minimizing the price increases (either in explicit market prices or implicit effective prices) and disruptions occuring in the energy system;
- Increasing the abilities of consumers and producers to substitute away from energy toward other goods and services and other inputs.

The quality of the informational base necessary to the design and evaluation of energy policy is of great importance. Correspondingly, it is important to focus on the analytical and informational services available to policy-makers. In reducing the risk associated with the adoption of inappropriate policy measures, it is of course important to continue to insure that model systems and data bases for addressing and measuring energy effects and energy-economy interactions are of the highest quality. In selecting between alternative available models which cover these areas, both the probability of a particular model being correct and the consequences of using a particular model when it is, in fact, wrong should be taken into account. For models which, by design and structure, represent the same phenomena, relatively more weight should be given to the model which has the larger probability of being correct and to the model which leads to the smaller expected cost of being wrong. On both these criteria and for the model systems as applied and compared in this report, the preferred analytical framework for assessing longer-term, energy-economy interactions is the general equilibrium system represented by the BNL/DJA methodology.

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