Chapter VII

Economic Impacts

Contents

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INTRODUCTION

A **permanent curtailment of imported oil would have widespread economic impacts throughout the entire U.S. economy. These can be projected by using a macroeconomic** model to aggregate and integrate information about technology and investment behavior into a system that simulates the national economy.

Macroeconomic models exist with many different levels of detail. Some use the simplest extrapolations of history and, of course, this is what most people do implicitly when they plan for the future. Other models have thousands of equations and hundreds of key parameters, The choice among the many existing models depends on the blocks of input information available and the analytical objectives. Since this is primarily an assessment of technology, and since technology is industry- and process-specific, OTA has **chosen** to employ a relatively large computer model of the macroeconomy that can trace fuel inputs to many economic activities, industry by industry and end-use by end-use.

The analysis is based on two types of future projections. Both cover the same period, 1985-90, but one assumes an oil import reduction of 3 million barrels per day (MMB/D), and the other a normal flow of oil imports. The normal scenario serves first to test the model and second to establish a baseline or reference case for comparison to shortfall scenarios. Shortfall scenarios are more difficult to simulate because macroeconomic models are based on historical trends and such trends may be substantially altered by the postulated oil supply shortfall. However, some confidence may be placed in their continuation, despite a shortfall, based on the analysis in chapter III, which showed that the shortfalls in 1973-74 and 1978-79 mainly affected energy consumption patterns by accelerating trends that were already evident.

Before describing the model, OTA acknowledges that all macroeconomic projections are uncertain because every projection (either implicitly or explicitly) involves complex trends in demography, labor markets, technology, consumer preferences, international trade, and so on. The widely publicized failure of prominent macroeconomic models to forecast events in the early 1980s confirmed once again that such prediction is very difficult. Nevertheless, despite the difficulties, the exercise of a formal computer model can be instructive if it illustrates plausible economic relationships that are closely related to the user's primary concerns.

One key concern is the 5-year timeframe, because it has significant implications for model choice. The most familiar macroeconomic models—Data Resources Inc., Chase Econometrics, Wharton Econometrics–provide more or less detailed, quarter-by-quarter accounts of national and regional economic activities because most of their users make private investments or policy decisions within a 2-year timeframe. In these models, money supply and demand, interest rates, product inventories, and retail sales receive considerable attention because each of these variables has major impacts on the rest of the economy in the short run.

For the longer term problem, most cyclic phenomena wash out, and what matters most are trends in variables such as investment, the rate of growth in labor productivity, the long-term accumulation of government debt, consumption patterns, savings rate, technological progress embodied in new capital, average rates of return on capital, and all of these variables compared to related trends abroad. The concern with oil dependence also leads to an emphasis on energy-using technologies, the relative prices and supplies of domestic oil and alternative fuels, and market opportunities for substituting capital and labor for energy which will become profitable as the price of oil rises.

The details of OTA's midterm perspective (5 to 10 years) are presented below, The main point here is that OTA's analysis does not consider in detail important economic impacts and adjustments immediately following an oil supply shortfall. By omitting them, primary attention can be focused on the expected changes in the technology embodied in the economy's base of capital stock, how rapidly these changes can occur, and how much they may cost. Such information (about the long term) can however, play an instrumental role in organizing emergency behavior **during the economic crisis immediately** following such a disrupting event. For example, if the longer term market clearing prices from oil can be roughly estimated, it suggests that short-term prices significantly above that level should be moderated by a drawdown of the Strategic Petroleum Reserve. Furthermore, however the economy makes it through the short-run turmoil, the longer term trends are presumably what should matter most when making strategic judgments about foreign policy (including military deployment), both of which in 1984 **are predicated** to a great extent on the goal of protecting political and economic stability in the oil-producing Middle East.

THE INFORUM MACROECONOMIC MODEL OF THE U.S. ECONOMY

Among the current, mid- to long-term models available, the IN FORUM model, resident at the University of Maryland in College Park, was chosen primarily because of its low-cost flexibility in simulating technological change. Like all such models, its structure and initial parameter specification are based on historical experience and economic theory. At the minimum, the introduction of a formal computer model, with its conventions for the consistent definition of variables and aggregates, provides a large accounting framework or map that can be manipulated at relatively low cost in order to trace economic impacts from an oil supply curtailment. This section outlines how this accounting is accomplished.

The Macroeconomics Without Energy Detail

The IN FORUM model like all macroeconomic models, makes a fundamental distinction between producers and consumers (see fig. 42, Frame A). Consumers consume goods and services that industries produce, and supply in return the labor and capital resources necessary for production. This circuit of physical flows is complemented by a parallel system of money flows. As shown in figure **42A, money flows in the opposite direction from goods and services** since the latter are exchanged for business revenues, and labor and capital are exchanged for wages, salaries, profits, interests, capital gains, and other forms of return on financial assets.

Notice that at this most elementary level the domestic economy is viewed as an integral or closed system. The interaction of producers and consumers (via both physical and monetary flows) constitutes the basic structure and the basic dynamics of the economy. The first part of this section describes the basic structure and dynamics in greater detail and then adds to it foreign exchange and governmental activities. The second part describes how energy flows enter into this larger economic framework.

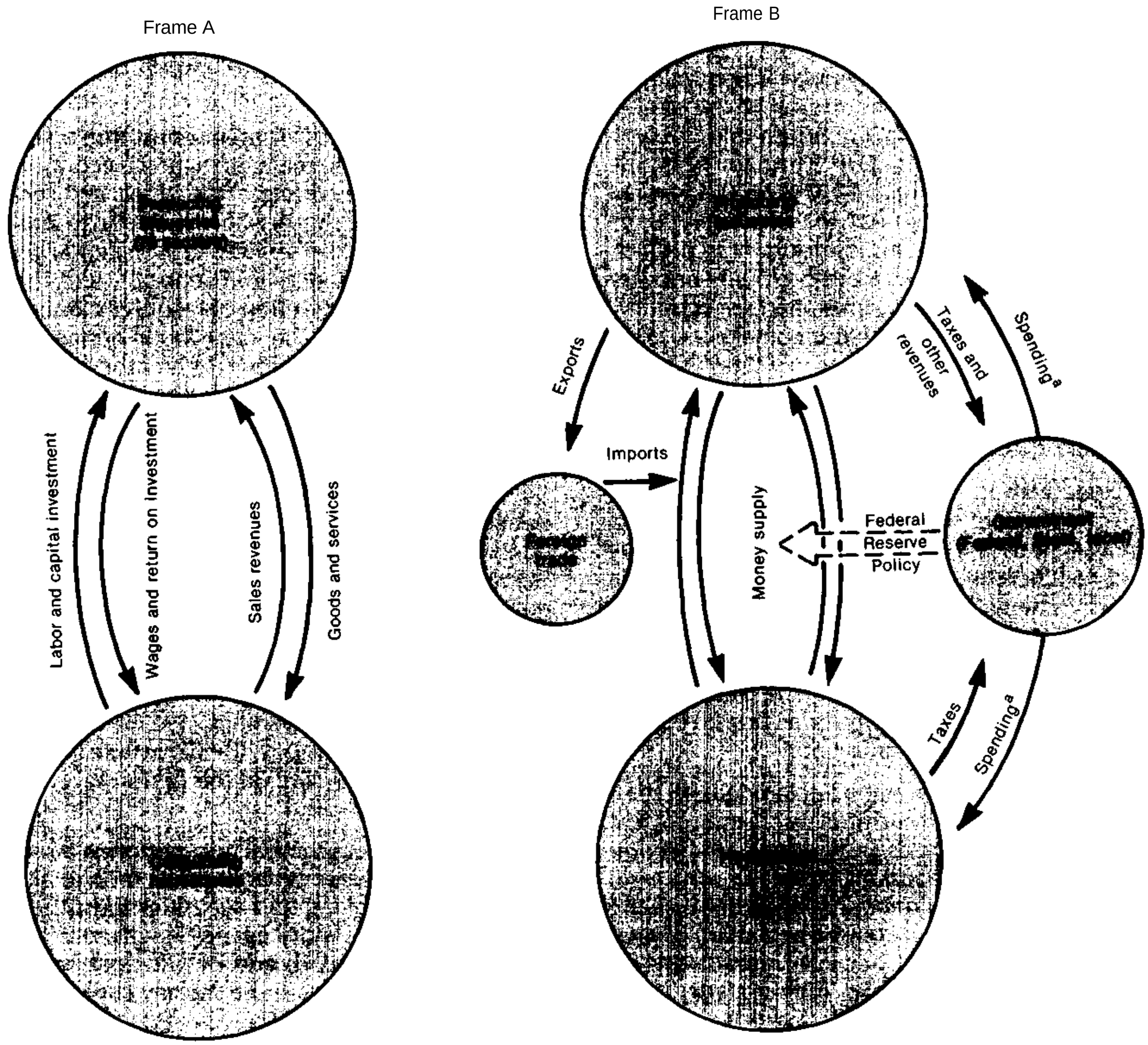
Industrial Input/Output

The core of the IN FORUM model is an input/output matrix that represents the activities of 78 distinct industries plus final demands. Final demands are purchases by consumers for personal consumption, by investors for the installation of plant and equipment, by the Government for implementation of governmental programs such as national defense, and by exporters for sales abroad. Numbers in each cell of the matrix (the input/output coefficients) allow the computer to track flows of all resources, goods, and services. OTA adjusted these material flows to incorporate technological replacement of oil into future economic projections.

Total Consumption and Consumer Demand Patterns

The model contains econometric demand functions for each of the 78 product categories. These

Figure 42.—Model of the U.S. Economy



[a]Includes both consumption and Investment,

SOURCE: Office of Technology Assessment.

determine the quantity consumed in terms of the product price, personal disposable income, total number of consuming households, and in some cases the prices of products that are either good substitutes or complements. If two goods substitute for each other, then a price increase for one will increase demand for the other, and vice versa for complements. These consumption demands and the associated consumer goods markets are illustrated as the exchange relationship on the right hand side of figure 42A. Along with investment functions (see below), these demand func-

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tions collectively drive the model by determining the volume and composition of goods and services over time.

Product prices and personal disposable incomes are determined as a result of the modeling exercise. The number of households is given to the model by assumption. Through 1995, the U.S. population is projected to grow 0.8 percent per year, with faster growth in the next few years and slower later on. This is important in projecting and evaluating economic growth because population growth tends to expand the economy and because total personal income must grow by at least this rate in order to maintain the level of income per capita.

Rest of the World

Trade with the rest of the world increases the effective size of the resource base and thus increases potential gross national product (GNP) and real income. The larger the volume of trade activity, the greater the base of world resources made available to U.S. producers and consumers. In terms of figure 426, other things being equal, an increase in the size of the circle labeled "Foreign Trade" "Increases industrial production or household consumption or both.

The U.S. balance of trade (including both services and merchandise) and the technological composition of exports and imports are becoming increasingly important factors in long-term prospects for U.S. economic growth because the volume of trade has increased as a share of total economy activity and because imports are increasingly competitive in high-growth, high-technology industries. While there is considerable uncertainty about how these trade patterns will evolve, OTA derives trade patterns using behavioral functions included in the IN FORUM model. As discussed below, these functions call for a more or less even balance between imports and exports and for roughly the same composition of exports and imports into the foreseeable future, with and without an oil supply shortfall. To evaluate the potential importance of this assumption, it is noteworthy that exports and imports each amounted to about 11 percent of GNP in 1982 and that oil imports amounted to just under 18 percent of the total imports. '

Inflation and Government Fiscal and Monetary Policies

The activities of government constitute a second major adjunct to the basic national economy (fig. 42). Governments (e.g., local, State, and Federal) tax firms and households in order to provide public goods and services (e.g., national defense, public assistance, and schools), and this affects both the distribution of resources among productive activities, the size of total economic activity, and the distribution of income among households. The net impact on the economy of taxes and Government expenditures is commonly summarized under the heading of **fiscal policy.**

For this study Federal fiscal policy is assumed to be unchanged from 1982 for all future projections. While this may be unrealistic, as discussed below in the context of shortfall scenarios, the purpose in leaving it unchanged is to avoid introducing perturbations other than the oil supply curtailment and the technological and oil price responses to it. Please note that although fiscal policies (tax structure, spending, and transfer programs) remain unchanged, the Government deficit will vary, depending on the performance of the economy.

The Federal Government also performs a second, unique function when it prints money and regulates the banking and securities industries. The principal regulatory agency involved is the Federal Reserve Board, and its principal policy instrument is to regulate the **money supply.** As illustrated in figure 426 (the shaded area in between producers and consumers), the money supply is the central medium of business exchange. As money supply expands relative to the volume of goods and services exchanged, it tends to increase prices; and such price increases can

[1] *Survey of Current Business,* National Income and Product Accounts, October 1983, tables 1.1, 4.1, and 4.3. While 11 percent of the GNP may seem like a small share **in a firm's or household's operating budget, it** looms large in the context of national income accounts, From the latter viewpoint, a 1 -percent decline **in** GNP **is a major political event, one that would result from only a** 10-**percent decline in exports.**

lower real interest rates and stimulate economic activity if investors are optimistic and if there are unemployed resources. A relative expansion in the money supply can also cause general price inflation and raise interest rates if investors are pessimistic or if other resources are not available to increase production.

While the net effects of monetary policy can be large, the current academic and political debate leaves much uncertainty about both monetary policy and price inflation in the future. Because key issues are unresolved, the model makes the elementary assumption, except for transient instability, that inflation equals the difference between the growth in money supply and the growth in real GNP or the value of output measured in constant prices. In all scenarios, the supply of money (M2) is assumed to grow at a constant rate of 8 percent per year. Other rates might have been used, depending on Federal Reserve policy, but that would only affect this model's projected inflation, not the size or structure of economic activity. Because it serves (in effect) as the bottom-line measure for economic performance, growth in real GNP will be discussed by itself later in this section.

Gross Investment and Interindustry Investment Patterns

Firms, households, and governments decide more or less independently how much purchasing power is set aside and used to increase future production capacity (i.e., capital stocks), and then how to divide these capital funds between alternative long-lived material assets and human resources. These decisions or investments determine the future productivity of the economy. The investment choice, as reflected in aggregate national income accounts, is among residential structures, nonresidential structures, and producer-durable equipment.[2] The model also breaks down investment behavior by the 78 producing sectors, a level of detail that allows accounting for the capital cost of oil replacement.

Employment and Unemployment

In both the short and long run, the number of employed people tends to move in step with the real GNP. The relationship of real GNP to unemployment, however, is more complex. In the short term, during business cycles, unemployment moves in the opposite direction to the rate of growth in GNP. In the long term, however, the GNP/unemployment picture depends on the relative growth trends of the labor force and the GNP. As demonstrated during the past 15 years, even though the GNP grows along a positive long-term trend, growth in the labor force (including greater participation by women) can be greater, and thus the unemployment rate can increase.[3]

In the long term it is also important to distinguish growth rates among different types of economic activity. Depending on long-term trends in international competition, in technology change, and in the product mix for domestic consumption, jobs may be created at a faster or slower rate per dollar invested, and jobs may be of relatively high or relatively low productivity. In general, however, the greater amount of total investment in productive assets, the more rapidly the Nation's base of plant and equipment expands and thus the more jobs are created.

Real GNP

Real GNP is the commonly accepted principal measure of national economic well-being. From the point of view of demand for goods and services, it is the main single factor driving oil consumption. From the point of view of the supply of goods and services, GNP rises or falls depending on the availability and price of oil. However bewildering this might seem, the GNP (or the level and composition of economic activity) is both the cause and the effect of oil consumption. In National Income and product Accounts kept by the U.S. Department of Commerce, estimated

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[2]Investment in people, via general education and vocational training, is at least as important for future economic productivity as investment in material assets, but national accounts (in general and in the model) fail to treat such investment systematically because education has many noneconomic as well as economic objectives, and otherwise because it is much more difficult and controversial to measure human beings in terms of dollars.

[3]See *survey of Current Business,* October 1983, p. 8, table 10, for GNP/unemployment trends and cycles over the past 30 years.

GNP amounts to the simultaneous summation and equilibration of all forces that create demand and supply for goods and services.

However, as a measure of economic welfare during an oil disruption, GNP omits important economic services or activities as well as important elements in the perception of well-being. For example, it does not measure services of long-lived consumer durables such as private automobiles, which would be significantly curtailed during an oil shortfall by the high cost or actual shortage of gasoline. To this extent, estimated GNP decline following onset of a shortfall would underestimate the true loss in economic welfare.

On the other hand, GNP also does not include the value of domestic services by family members, production from gardens, direct barter, and various special sharing arrangements, all of which tend to expand in times of social stress. These activities help to explain how most people get along quite nicely during emergencies despite apparent hardships, by learning how to get more utility from the limited material and human resources that do remain available. To the extent that GNP does not measure the enhanced human adaptability that such activities represent, its apparent decline following an emergency such as an oil import curtailment can overestimate the actually perceived loss.

The INFORUM Energy Skirt

For this study, OTA disaggregated total energy consumption (or, depending on one's perspective, aggregated energy consumption by end-use technology) into the five major end-use sectors: residential, commercial, industrial, transportation, and electric utilities (chs. Ill through V). These distinctions are maintained in the formal model, within a larger economic framework.

Sometimes this economic framework calls for merely changing names, such as when residential consumption of heating oil is called "personal consumption expenditure" for heating oil. Other times, it involves a more important reorganization from technological to market relationships, such as the redistribution of technologically similar transportation activity into SIC (Standard industrial Classification) sectors and other end-user categories. For example, the chart in figure 43 gives this additional information about how oil is used.

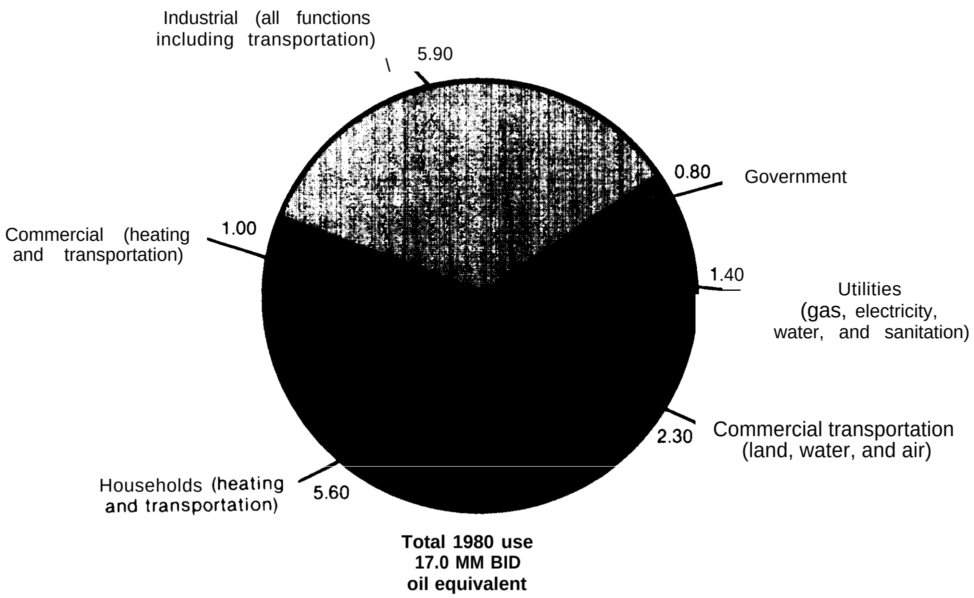
This type of reorganization of energy flows is an essential first step in understanding how sharply rising oil prices can increase the cost of products with oil inputs and decrease real personal income. In general, translations of engineering into market concepts is necessary to pursue the economic logic behind what the economy does with oil-replacing technology and with technology in general in the event of a disruption.

For example, consider again the two products made from petrochemicals, plastic contact lenses and milk bottles, which were initially described in chapter ill. Both types of manufacturing start with a commodity chemical (resin pellets) whose chemistry is adjusted after melting so that it can be resolidified and molded into the desired chemical structure and physical shape. The plant that makes milk bottles, however, will be handling a much larger volume of plastic material, which means in general that it will be using more petroleum feedstock and process heat (gas or oil) per dollar of product sales. The plant making contact lenses pays a much higher percentage of its costs for the precisely engineered machinery and skilled labor necessary to meet more complex and precise standards for product quality. Consequently, the bottle plant manager is likely to be more aware of energy costs and more likely to switch fuels or to add energy-conserving retrofits as energy costs rise.

It is an important part of this modeling exercise that industry be sufficiently disaggregated to allow detailed simulation of fuel switching and conservation, as projected in the previous chapters. The model also simulates another important path for oil replacement, product mix shift. The comparison between contact lenses and milk bottles again illustrates the point.

if products made from chemicals are more like contact lenses, then oil savings in the chemicals industry will be difficult to achieve by raising oil prices because the net affect on the price paid by the final consumer is relatively small and, in any case, final consumers have no practical alter-

Figure 43.—1980 Petroleum Consumption by Sector



SOURCE: Energy Information Administration, 1982 *Annual Review of Energy,* Washington, DC, April 1963, table 3, p. 69

native. Just the opposite is true if products made from chemicals are more like plastic milk bottles. In that case, oil price increases significantly drive up the cost of final consumer goods, and furthermore, consumers have good alternatives. While these two goods are not commonly used as standards for comparison in the chemicals industry, they nonetheless illustrate the importance of product mix. The model incorporates a complete spectrum of product substitutions and calculates a full set of market-based opportunities for oil savings via product mix shift.

Because of this study's primary focus on energy-related economic transactions, OTA has appended an "energy skirt" to the IN FORUM model. This additional block of data is called a skirt because it figuratively hangs below the basic input/output table, providing greater energy detail for each of the 78 industries and for personal consumption, investment, and government expenditures. Normally, this model identifies only two petroleum products, fuel oils and all other refined products, and provides no information about how these or other fuel products are used. The skirt identifies six petroleum product categories and a variety of energy end uses that are common to many industries (see table 23). Both kinds

Table 23.—Petroleum Products and End Uses Common to Many Industries

Energy end use functions	Petroleum products
1. Transport	1. Light hydrocarbons
2. Space conditioning and lighting	2. Gasoline
	3. Distillate fuel oil (#2)
3. Boilers	4. Kerosene
4. Process heat	5. Residual fuel oil (#6)
5. Other engines	6. Other products
6. Materials inputs	
7. Other	

SOURCE: Office of Technology Assessment

of additional information clarify opportunities and constraints for improvement in fuel efficiency and fuel switching (see table 24 for an illustrative skirt tableau).

Energy skirt data have been obtained from many different sources, but the initial specification for base year 1980 was taken from the Energy Disaggregated Input/Output Data Base provided by the Departments of Commerce and Energy.[4] Because the latter was compiled and documented

4"Detailed Input-Output Energy Make and Use Data: 1977 and 1980; for the Bureau of Labor Statistics I-O Model and the Department of Energy EDIO Model," contract No. BLS 82-506, January 1983, prepared by Jack Faucett Associates.

Table 24.—illustrative Energy Skirt Table for 1982: Flows in 1977 Dollars, Quantities and Btu

14 Printing

	Coal (th tons)	2 Crude P (th bbl)	3 Nat gas (b cu ft)	4 L. hydr (th bbl)	5 Gasoline (th bbl)	6 Distil (th bbl)	7 Kerosene (th bbl)	8 Resid (th bbl)	9 Oth Petr (th bbl)	10 Elect (roil kwt)	11 Gas util (b cu ft)	12 Total
Transport												
	0.0		0.0	0.0	68.4	12.9	0.0	0.0	0.9	0.0	0.0	82.2
Q	0.0	0.0	0.0	1.9	4,359.4	910.5	0.0	0.0	51.2	0.0	0.0	5,323.0
Btu	0.0	0.0	0.0	0.0	22.9	5.3	0.0	0.0	0.3	0.0	0.0	28.5
Boilers												
$	0.7	0.0	0.0	0.0	0.0	10.0	0.0	7.2	0.0	0.0	16.1	34.0
Q	26.8	0.0	0.0	0.0	0.0	680.6	0.0	543.9	0.0	0.0	8.5	1,224.5
Btu	0.7	0.0	0.0	0.0	0.0	4.0	0.0	3.4	0.0	0.0	8.7	16.8
Process heat												
$	0.0	0.0		0.0	0.0		0.0	0.0	0.0	0.0	48.2	48.2
Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.6	
Btu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.2	26.2
Other												
$	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	265.9	0.0	268.4
Q	0.0	0.0	0.0	228.0	0.0	0.0	0.0	0,0	0.0	9,111.3	0.0	228.0
Btu	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	31.1	0.0	32.0
Total												
$	0.7	0.0	0.0	2.5	68.4	22.9	0.0	7.2	0.9	265.9	64.3	432.7
Q	26.8	0.0	0.0	230.0	4,359.4	1,591.1	0.0	543.9	51.2	9,111.3	34.1	6,775.6
Btu	0.7	0.0	0.0	0.9	22.9	9.3	0.0	3.4	0.3	31.1	34.9	103.4

15 Agriculture fertilizers

	Coal (th tons)	2 Crude P (th bbl)	3 Nat gas (b cu ft)	4 L. hydr (th bbl)	5 Gasoline (th bbl)	Distil (th bbl)	7 Kerosene (th bbl)	8 Resid (th bbl)	9 Oth Petr (th bbl)	10 Elect (roil kwt)	Gas util (b cu ft)	12 Total
Transport												
	0.0	0.0	0.0	0.0		2.6	0.6	0.0	0.1	0.0	0.0	9.1
Q	0.0	0.0	0.0	0.4	372.4	185.1	40.7	0.0		0.0	0.0	603.7
Btu	0.0	0.0	0.0	0.0	2.0	1.1	0.2	0.0	0.0	0.0	0.0	3.3
Boilers												
$	4.9	0.0	0.0	0.0	0.0	6.7	0.0	19.9	0.0	0.0	236.3	267.7
Q	260.0	0.0	0.0	0.0	0.0	493.1	0.0	1,760.7	0.0	0.0	185.9	2,253.9
Btu	6.5	0.0	0.0	0.0	0.0	2.9	0.0	11.1	0.0	0.0	190.2	210.6
Process heat												
$	0.0		0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	101.3	102.4
Q	0.0	0.0		0.0	0.0	87.0	0.0	0.0	0.0	0.0	79.7	87.0
Btu	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	81.5	82.0
Materials												
	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	384.0	398.8
Q	0.0	0.0	0.0	530.9	0.0	0.0	0.0	0.0	0.0	0.0	292.0	530.9
Btu	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	298.8	300.9
Other												
$		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	203.0	0.0	203.0
Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9,483.3	0.0	
Btu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.4	0.0	32.4
Total												
		0.0	0.0			10.5	0.6	19.9	0.1	203.0	721.5	972.1
Q	260.5	0.0	0.0	531.3	372.4	765.3	40.7	1,760.7	5.0	9,483.3	557.6	3,475.5
Btu	6.5	0.0	0.0	2.1	2.0	4.5	0.2	11.1	0.0	32.4	570.4	629.1

SOURCE: Office of Technology Assessment (dollars are in millions, Btu in trillions).

for use in input/output analyses, it is uniquely suited **for OTA's purposes** as the most comprehensive and detailed accounting available of all energy flows within the U.S. economy.

The energy skirt helps calibrate and analyze macroeconomic simulations because its greater detail sharpens associations between economic activities and energy-using technology. For example, one of the most important distinctions between petroleum products is between distillate used for engines and distillate used for heat and steam. This functional distinction, which **cannot** be **made with the IN FORUM model without the skirt, is crucial** in projecting opportunities for natural gas substitution. Natural gas is relatively easy to substitute for a large fraction of oil presently used for stationary heat/steam applications, but the opportunities for replacing distillate presently used in mobile engines are considerably more limited.

The skirt is especially well suited for tracking "intermediate" oil consumption (i.e., oil used in the production of other goods and services). In physical units, it traces oil flows through various stages of industrial activity so that it is possible to calculate the oil intensity of each of the 78 final product categories. In dollars, it tracks backward from the value of final products to derive the value of petroleum products used in their production. The two calculations, one in physical units and the other in dollars, are done in parallel as the model continues to shift the mix and the prices of final products (and thus intermediate oil consumption) until production costs for each of the 78 product sectors are balanced by the value of the product to consumers.

Before discussing the modeling exercise, however, it is important to mention that this model does not disaggregate energy and other commodity flows by region, nor does it address many important issues related to the development of local energy resources that are too small to be visible in national accounts (see box).

A MODELING STRATEGY BASED ON THE OTA TECHNOLOGY DATA BASE

The size and complexity of the INFORUM model suggests that OTA follow certain guidelines in order to integrate OTA's analysis of technology deployment while not losing an accurate, general perspective on the rest of the economy.

Three sets of guidelines were followed. First, energy technology deployment rates were explicitly inserted into the energy skirt and the input/output matrix in terms of specific coefficients. These coefficients serve as basic controls on how much the economy can produce, given limited oil supplies. Second, the rest of the input/output matrix as well as final demand functions and policy parameters of the INFORUM model were based on: 1) existing econometric work done by the IN FORUM staff, 2) certain consistency checks on investment behavior and on overall model performance, and 3) comparisons to results from other macroeconomic models. Third, the energy and nonenergy parts of the model were integrated by a process of iteration where fuel prices and technology deployment rates were readjusted to be consistent and to achieve the required savings of 3 MMB/D in oil consumption. All three guidelines are elaborated in this section.

The Energy Sector Guidelines

Of all activities and technologies related to oil consumption, OTA focused primarily on two fuel product/end-use combinations or technology blocks: gasoline for automobile transportation and fuel oil (both #2 and #6) for heat and steam. These two technology blocks receive the most attention, as they have in the technology analysis above, because they offer the greatest economic opportunities to replace oil demand.

As discussed above, auto gasoline accounted for about 37 percent of total petroleum consumption in 1982, and so even a small percentage improvement in auto fuel efficiency or decline in vehicle miles traveled can cause a relatively large reduction in total oil consumption. The analysis in chapter V showed that recent dramatic improvements in new car fuel economy will steadily increase the fuel economy of the entire auto fleet (without further investment by automakers) as old cars are replaced over time by new cars. The technological improvements that increase fuel efficiency and fleet turnover were combined and programmed into the model, like all other technology and technology change, as fixed coefficients (for any given year) that change gradually over time.

In addition to changing technology, current economic studies indicate a strong relationship between personal consumption of gasoline and personal disposable income, and a weaker but still significant relationship between the same consumption variables and gasoline prices. [5] As

[5] There is extensive economics literature dealing with the personal consumption of gasoline. For two recent surveys see Carol A. Dahl, *Survey of the Demand for* Gasoline, unpublished draft, Department of Economics, University of Wisconsin-Milwaukee, April 1983; and David L. Green, *The Aggregate Demand for Gasoline* and *Highway Passenger Vehicles in the United States: A Review of the Literature 1938-1978,* Oak Ridge National Laboratory, ORNL-5728, July 1981.

income rises (falls) vehicle miles traveled rise (fall). As petroleum prices rise (fall), vehicle miles traveled fall (rise). Both behavioral relationships are incorporated into the model as functions. For future projections, the income elasticity of personal vehicle miles traveled is set equal to + 0.5, and the price elasticity is set equal to – 0.2.[6] In other words, if personal disposable income goes up (down) by 10 percent, personal vehicular travel will rise (fall) by 5 percent. Similarly, if the price of oil rises (falls) by 10 percent, travel will fall (rise) by 2 percent.

This second mode for oil savings in auto transportation is more appropriately called oil conservation, not oil replacement, because it involves cutting back an energy service instead of maintaining service by alternative means. As a rational economic response to higher oil prices, it is an alternative to technological replacement; and to the extent that oil is not replaced with greater fuel efficiency in autos or efficiency gains and fuel switching anywhere else in the economy, it must be saved by cutbacks in driving and reductions in economic activity of all kinds.

Another behavioral relationship is also important, especially right after an oil shock. Experience with much smaller shortfalls during the past 10 years indicates that driving habits contain a discretionary component that can beat least temporarily eliminated during an emergency.[7] Although it can provide considerable savings in the short run, this opportunity for oil displacement is **not** included in the model since the model's focus is more long term.

Consumption for stationary heat and steam services accounted for only about half as much oil (about 18 percent), but it deserves attention because it maybe cost effective to replace almost all of it with a combination of natural gas, electricity, and coal.[8] Natural gas is an especially important **fuel substitute because,** if an existing distribution pipeline is nearby, gas can provide heat and steam service with relatively small capital investment. Furthermore, the energy service to the full spectrum of heat and steam **end** users is at least as valuable as that provided by oil. Electricity is cost effective primarily when heat pumps can be used efficiently by small residential and commercial customers; and coal is an attractive oil substitute mainly in relatively large boilers.

Again, in terms of the model, fuel switching for heat and steam is accomplished in a manner exactly parallel to that of auto fuel efficiency. For the 78-sector, input/output matrix, fuel oil coefficients for heat and steam services are reduced over time to reflect a priori rates of deployment for fuel switching technologies. Corresponding increases in coefficients for gas, electricity, and coal inputs must also be made so that total fuel inputs are sufficient to supply demands for heat and steam services.

Unlike auto fuel efficiency, where oil replacement investment pays off into the future as the fleet follows its normal rate of turnover, most oil replacement in stationary heat and steam does require capital investment for that specific purpose after onset of the shortfall, as estimated in table 25. The broad range of plausible costs per barrel introduces major uncertainty about cost effectiveness, and thus major uncertainty about projections of the rate of replacement. Although there is also uncertainty about the rate and cost of oil replacement in transportation (minor, relatively high-cost investment options for replacing oil use in transportation are shown in table 26), over 80 percent of the difference in the postulated high- and low-response scenarios (see ch. VI) is due to uncertainties for oil replacement in heat and steam.

In the model, investment projections are based on investment functions that **have been estimated from historical data.** To **some extent, these functions call for investment to rise with oil prices, in effect to support oil replacement as they have done in the past, but the primary determinant of investment is the level of production. If total projected investments for the seven key industries**

[6]These elasticities fall in the midrange of recent econometric estimates.

[7]For estimates of discretionary oil savings related to personal auto use see National Petroleum Council, *Emergency Preparedness for Interruption of Petroleum Impacts Into the United* **States, April 1981, ch. 2.**

[8]This end-use category includes virtually all oil consumption by residential and commercial users, all oil consumption by utilities, and about 18 percent of industrial demands.

[9]These industries are food and tobacco, paper, agricultural fertilizers, chemicals, petroleum refining, ferrous metals, and nonferrous metals.

Table 25.—Estimated Investment Costs for Major Oil Replacement Technologies

Option	Investment cost (thousand 1983 dollars per barrel per day of oil replaced)
• **Fuel switching** in industrial and utility boilers:	
Conversion to solid fuel (including coal-water mixtures).	10-20
Construction of new solid fuel boiler with coal-handling facility	**25-50**
Construction of coal-water mixture production plant	2-3
Completion of new powerplants currently under construction. . . . . , ...	5 0[a]
Conversion to natural gas	o-5
• Fuel switching in residential and commercial space heating and hot water:	
Natural gas	15-25
Electric heat pumps	35-60[b]
Electric resistance heating	1O-2O[c]
Solid fuel	5-35[d]
• Residential and commercial energy conservation:	
Building insulation	**40-60[e]**
• Industrial oil replacement:	
Amalgam of efficiency improvements and product mix shifts.	10-70[f]

[a]Assumes $50(1 per kilowatthour to complete and plant operation at 70 Percent of capacity.
[b]Based on an installation cost ranging from $2,000 to $3,500 for a system used only for space heating to $2,500 to $4,000 for a system for space heat and hot water and on the national average oil use of 676 gal and 1,055 gal per year for homes in which oil provides heat only, and both heat and hot water, respectively.
[c]Assumes $500 per household for electric resistance space heaters and 1,000 for a hot water heater,
[d]Assumes $250 t. $750 for wood stove (including installation) for space heating only or $2,500 for new wood-fired central boiler for heat and hot water.
[e]This estimate represents an average over a number of building types and ages Actual site-specific costs will vary frOm less than $1,000 per B/D up to over $200,000 per B/D.
[f]Industrial replacement involves a broad range for investment costs. At the low-cost end, investment is incidental (e.g., ‘or product mix shifts); and at the high-cost end, investments are large because firms are willing to pay an insurance premium in order to increase the security or price stability of its fuel supplies.

SOURCE: Office of Technology Assessment and Gibbs & Hill, Inc., “Oil Replacement Analysis Phase I—Selection of Technologies:’ contractor report to Office of Technology Assessment, April 1983,

Table 26.—Estimated Investment Costs for Selected Oil Replacement Technologies in Transportation

Option	Investment cost (thousand 1983 dollars per barrel per day of oil replaced)
CNG[a].	40-130
LPG[c].	15-55[d]
Gasifier.	**35-105[e]**
Ethanol production.	**70-95[f]**

[a]Compressed natural gas.
[b]Assumes $2,3oo to $3,600 per vehicle, including pumping facilities, and that vehicle gets 22 mpg of gasoline and is driven 10,000 to 20,000 miles per year.
[c]Liquefied petroleum gas.
[d]$1,000 to $1,500 per vehicle; vehicle gets 22 mpg of gasoline and is driven 10,000 to 20,000 miles per yr.
[e]$1,000 to $1,500 per vehicle; vehicle gets 22 mpg of gasoline and is driven 10,000 to 20,000 miles per y; gasifier replaces half of the vehicle’s fuel consumption.
[f]$75 to $100 million or a 50 million gal per yr distillery, for every 2 Btu of ethanol displacement, a net of 1 Btu of oil replaced.

SOURCE: Office of Technology Assessment and Gibbs & Hill, inc., “Oil Replacement Analysis Phase I—Selection of Technologies,” contractor report to Office of Technology Assessment, April 1983.

(which use 90 percent of the oil used for industrial heat and steam) plus electric utilities are insufficient to cover growth requirements plus fuel switching, the investment function can be disconnected and the total investment level specified directly. Assumptions and projections of investment patterns will be discussed further in the context of particular shortfall scenarios.

Besides gasoline for automobiles and fuel oil for heat and steam, there are many other refined products and end uses that total about 40 percent of total oil consumption (see table 27). However, they are not nearly so attractive as targets for oil replacement because they serve indispensable functions, primarily **in the industrial sector.** For example, as discussed in chapter **V,** diesel

Table 27.—Petroleum Uses Largely Excluded From Technological and Economic Analysis of Oil Replacement

	1982 consumption (million barrels per day)
Distillate for transportation	1.38
Distillate for other industrial engines	0.35
Residual for water transportation	0.55
Material feedstocks	
Distillate	0.13
Residual	0,22
Light hydrocarbons	1.00
Jet fuel	1.03
Other (e.g. asphalt, lubricants, still gas, petroleum coke)	1.80
Total	6.46

SOURCE: Energy Information Administration, *1982 Annnual Review of Energy*, Washington, DC, April 1963, table 31, p. 69; and Office of Technology Assessment, based on data developed by Jack Faucett Associates. See note above

engines for commercial transportation and for industrial drive are largely irreplaceable and are already fuel efficient, given load requirements. Efficiency has been achieved there and not for personal automobiles because in business applacations fuel cost has been a much larger fraction of total costs and has been otherwise of greater concern because value is mainly a matter of horsepower and cost, not all the other performance and appearance features that sell cars for personal property. For similar reasons, jet fuel and residual fuel for transportation were not treated.

The two other largest blocks of petroleum—industrial feedstocks (mainly liquefied petroleum gas and ethane) and asphalt–were excluded because they have no practical alternatives. However, consumption of all petroleum products, including the 40 percent that have been excluded from the replacement analysis, will be reduced during a shortfall, Some of this across-the-board savings has been simulated via product mix shift and GNP losses (see **below).** Beyond that, no doubt some oil savings have been excluded that would have occurred with sharp price increases, but these have been ignored in order to focus on technological options that provide the greatest opportunities for oil replacement at the least cost .

Guidelines for the Rest of the Economy

Unlike energy-related activities in the model, which are carefully programmed to conform to prior engineering results, the rest of the IN FORUM model was calibrated only after initial simulation results were obtained. At this intermediate stage in OTA's analysis, the limited goal for calibration is only rough consistency of model outputs with established norms for macroeconomic behavior and with related simulation outputs from comparable macroeconomic models. Only when certain results appeared to be anomalous was an effort made to reconsider nonenergy-related assumptions.

Comparisons to 14 other macroeconomic models could be made relatively easily owing to the recent completion of the Energy Modeling Forum study of macroeconomic impacts of major energy shortfalls (commonly called EMF-7).[10] Included in this assessment of energy/economic models was one scenario calling for a 50-percent in-

[10] See B. G. Hickman and H. G. Huntington, " EM F-7 Study Design," EMF Report 7.1, and "Macroeconomic Impacts of Energy Shocks and Overview, " EMF Report 7.2, Energy Modeling Forum, Terman Engineering Center, Stanford University, Stanford, CA. These two reports summarize information contained in 17 companion reports.

definite increase in the real price of oil. Although such a shortfall is less severe than the one postulated in this assessment, it nevertheless raised the same set of adjustment problems and, as discussed below, the general characteristics of that model's 14 projections were comparable to the present model projections.

The first major macroeconomic checkpoint involves investment behavior. Rapid oil replacement may put too great a burden on national capital markets. The extent of this potential problem can be evaluated by comparing total investment requirements for oil replacement to certain related financial aggregates. Assuming an average investment of $50,000 per barrel per day replaced,[11] total capital outlays for replacement of 3 MMB/D would amount to $150 billion. Spread overs years, it would equal $30 billion per year. While these are large numbers, they are not overwhelming when compared to current private domestic investment.

In 1982, private investment in producer durables was just over $200 billion. Assuming that 80 percent of oil replacing investment would fit into this category, oil replacement could lead to a 12-percent decrease in capital available for other purposes, or conversely, it would require an overall increase of 12 percent in total investment. (Note also that 1982 investment was relatively low owing to the most severe recession since the Great Depression,) Assuming that the remainder of oil replacement involves structures, the remaining $6 billion amounts to about 2.5 percent of total 1982 residential and nonresidential investment in structures.

While these appear to be manageable shares of total investment, given the apparent extremity of the shortfall, there is one additional comparison that reinforces the expectation of investment feasibility. Assuming that oil prices would double (from roughly $30 to $60 per barrel, see below for rationale) and that domestic oil production can be maintained at 8.5 MMB/D, then domestic oil revenues would increase by $93 billion annually, or three times the annual capital requirement for oil replacement. Some of this increase would undoubtedly be made available via normal market channels or by a policy of windfall profit taxation and investment subsidy.

The second general macroeconomic checkpoint concerns labor productivity over time. Growth in labor productivity in the longer term depends on investment in better tools and new processes, but the choice among such investment options and the volume of such investment may be significantly affected by sharply rising energy prices. The choice may change because labor will become relatively less expensive compared to energy, so the return on labor-saving/productivity-enhancing investments will fall **due to the oil shortfall.** Also, as **discussed above,** the volume of productivity-enhancing investments may decline generally owing to "crowding out" by investments in oil replacement.[12]

The net result on growth in labor productivity during a shortfall is difficult to anticipate. Unfortunately, the IN FORUM model did not project either investment effect on productivity, so these were specified by OTA as an input to the model (in terms of a range of plausibility). At the minimum, given low investment costs for oil replacement and low oil price inflation, labor productivity was set to decline by 4 percent below the level achieved in the reference case by the fifth year after the initial curtailment. At the maximum, given high investment costs and high oil price inflation, labor productivity was set to decline by 8 percent below the reference case. (See below for further description of assumptions for the two shortfall scenarios.)

Since OTA was primarily interested in the energy sector, other calibration efforts related to the rest of the economy were not repotted. However, integrated into the larger economic framework were two mechanisms for oil saving that help achieve a balance between oil supply and oil demand. First, the mix of goods and services shifts away from oil-intensive products and toward products that use relatively little oil. Second, total

[11] This is a rough upper boundary for capital costs of oil replacement for technologies which would actually be deployed. See ch. III.

[12] This term usually refers to diversion of private savings from the private to the public sector in order to finance the Federal debt. Perhaps another label should be attached here, but the analogy is appropriate in the sense that expected investment behavior is interrupted by extraordinary circumstances.

economic activity declines in the **shorter term** in response to lost real income and thus lower consumer demand, and in the longer term to reflect the fact that the energy resource base has now become significantly smaller.

Both of these more indirect means for oil replacement are initiated by rising oil prices, just as the latter provide incentives for motorists to buy more fuel-efficient cars or for firms to replace oil-fired boilers. The price mechanism will be discussed in the next section. At this point it is important to note that the two major model projections of interest for oil consumption are product mix **shifts and** GNP adjustments.

Guidelines for Scenario Integration by Iteration on Fuel Prices

The IN FORUM model is calibrated assuming two alternative oil supply futures. The first, or reference case, assumes that total oil consumption will be maintained at about 16 MMB/D for the period 1985-95. A second type of scenario assumes that total oil consumption must contract to about 13 MMB/D from 1985 on. The reference scenario is run first to provide a performance check on the general economic characteristics of the IN FORUM model, and it is then used as a standard for comparison with subsequent shortfall scenarios.

For both types of projections, the path taken by oil prices over time determines the rate of oil consumption because price incentives drive producer and consumer decisions toward efficient outcomes. Prices of all goods and services serve as economic drivers but other prices will not be discussed except to the extent that they are affected by oil prices. Furthermore, the oil price path is technically inputed into the model, not derived from the model, because the price of oil is substantially determined by conditions external to the national economy. (Based on the price of oil and other primary resources, the model sets the full range of intermediate and final product prices.) Careful side calculations, as well as iterations of the model assuming alternative oil price paths, are necessary to calibrate a final, realistic oil price path for each prescribed oil consumption scenario. This section describes how oil price paths were determined for the scenarios presented below.

For the reference case, the oil price path was set so that oil consumption remains at about 16 MMB/D from 1985 through 1990. This level rate of oil consumption was achieved with no change in real oil prices which are held at around $30 per barrel through 1990 (see table 28). While this single price/consumption projection does not reflect the considerable economic uncertainties which in fact exist, the latter were not considered to be significant, given that our primary purpose is only to establish a single, more or less realistic baseline for purposes of comparison to shortfall scenarios.

Table 28.—Petroleum Price Projections: Real Crude Price Per Barrel and Product Price Indices

	Reference case			Disruption case A			Disruption case B		
Year	Crude	Refined[a]	F. Oil[b]	Crude	Refined	F. Oil	Crude	Refined	F. Oil
1982[c]	**32**	158	158	—	—	—	—	—	—
1984	**30**	158	151	—	—	—	–	—	—
1985	**30**	150	150	55	258	227	77	342	301
1986	**30**	149	149	53	249	216	73	322	278
1987	**30**	148	148	53	249	213	73	319	273
1988	**30**	149	149	55	254	214	75	323	272
1989	**30**	150	150	55	256	213	75	327	272
1990	**30**	148	148	55	255	209	75	320	263

[a]Refined products include all petroleum products except #2 distillate, #6 residual, and diesel fuel.
[b]Fuel oils include the exceptions mentioned above. This breakdown was dictated by the IN FORUM model saris energy skirt. With the energy skirt, separate prices are calculated for six petroleum products.
[c]Referenced to actual prices.

SOURCE: Office of Technology Assessment.

For the simulation of oil shortfall, two oil price projections were used, both of which yielded approximately 3 MMB/D reductions in consumption in order to illustrate the range of uncertainty associated with engineering cost estimates and investor responses. The first shortfall projection (A) assumes that the capital costs for oil replacement presented in table 25 are indeed accurate and that investor response to oil replacement opportunities is strong. The **second shortfall projection** (B) **assumes that both of these economic situations are markedly less felicitous. So, in effect, it takes a** much higher price incentive to save oil in the second case (B) than in the first case **(A). As** discussed above, in both shortfall situations, the schedule for oil replacement is indicated in simulation runs by adjustments to input/output coefficients and by oil price responses built into investment behavior functions.

The ballpark for oil price inflation **in both shortfall** simulations can be roughly inferred from investment requirements for oil replacement (table 25). While these outlays are only one consideration in the decision to replace **oil,** for the bulk of replacement actions taken after the initial curtailment, they are the deciding factor because the economic tradeoff is essentially capital versus fuel cost. The following examples illustrate this situation.

First, consider fuel switching to coal in large boilers. In 1982, the use of oil in large industrial and utility boilers was about 1 MMB/D, and the total for oil and gas exceeded 3.5 MMB/D oil equivalent. Even though limitations on engineering resources and construction leadtimes limit coal substitution for there fuels within 5 years (see ch. VI), the **total for gas and oil is relevant because** gas is such a good oil substitute for stationary heating and because the full potential for switching away from premium fuels in large boilers is pertinent to long-term expectations for energy price stability. This fuel switch greatly reduces operating costs for boilers, because coal costs much less per Btu than the two premium fuels, and the price of coal is likely to remain steady due to large domestic reserves.[13] To **be** conservative, however, assume that operating costs for new or converted coal boilers are equal to what they are (or were) using oil and gas prior to the shortfall, then the $50,000 per barrel per day (upper boundary) investment cost for coal utilization can be profitably amortised if the price of oil rises by about $23 per barrel and holds at that level (or goes higher) .14

To infer the necessary price incentive for switching to gas or electricity in residential and commercial heat and hot water is more complicated because gas and electricity are also premium fuels whose price can inflate with the price of oil as people try to make the easiest (i.e., least capital cost) oil substations (e.g., resistance space heaters and replacing oil with gas in dual-fired boilers). However, within the 5-year time horizon, gas price inflation will be restrained by several economic adjustments discussed above: 1) increased fuel efficiency in buildings and industry (ch. V), 2) increased domestic gas production based on current excess capacity (ch. IV), 3) switching to coal in large boilers (see previous paragraph).

The price of electricity can be restrained and the supply increased by increasing generation capacity based on coal or other non premium fuels. Furthermore, replacement fuel (gas or electricity) costs for these two stationary heating services can be controlled by another means–investment in insulation which has an estimated cost per barrel of oil replaced which is comparable to the coal switching option described above. **However, even without taking into account increased insulation and other means for increasing fuel efficiency, the upper limit for the increase in gas demand** for oil replacement in the "high-response" case is 11 percent above current consumption (ch. VI), a very manageable increase.

Finally, behavioral changes can also reduce oil consumption and limit the need for expensive in-

[13] **During each of the earlier shortfalls, the real price of crude** oil **approximately doubled, and since 1973 the real price of natural gas at the well head also has increased by about a factor of 4. Coal, on the** other hand, doubled in price only during the 1973-75 period. It remained level or declined marginally since that time and it is unlikely in the future to experience inflation similar to the premium fuels due to very large domestic reserves,

[14] If, to be conservative, we assume a 10-year lifetime and a 10 percent rate of return (ROI) over that period (a normal lifetime would be closer to 20 years and a normal ROI would be closer to 5 percent) then capital costs of $50,000 per barrel per **day could be profitably amortized once oil prices have risen by $23 per barrel (or by about $4 per million** Btu).

vestments i n oil replacement. These include turning down the thermostat and driving less, and they also include the oil savings which occur indirectly when rapid oil price inflation reduces general economic activity. Unlike oil replacement, these behavioral changes are computed entirely within the model and their relative importance can be estimated only by running the model. Since the overall level of investment is also determined within the model, it means that shortfall simulation must be done iteratively with adjustments made in oil price until the net effect in terms of oil savings equals **3 MMB/D.**

In fact, the "high-response" simulation settled on oil prices in the range of $50 to $55 (1983 dollars, see table 28). **In other words, the inferred price increase based on the investment outlays of $50,000 per barrel of oil** per day replaced appears to be a reasonable estimate for the necessary price incentive to effectively replace the oil shortfall .

On the other hand, what if the capital costs estimates were too low and the estimated response of investors to oil replacement opportunities too high? What if investment requirements were off by 50 percent? That would raise the necessary price incentive proportionately. What if perceived risks in investment were twice as large? That could be illustrated as a doubling in the required rate of return and that would raise the necessary price incentive by another **50 percent. The point is not to guess errors in the economic projections but rather to suggest a plausible upper boundary** for oil price inflation as an input to the future simulation. For model iterations leading to the "low-response" scenario, the oil price in fact settled at a level of about **$75 per barrel, corresponding to a price increase approximately twice as large as that** in the "high-response" case.

A much larger study might explore additional scenarios that incorporate alternative assumptions about rate of technology deployment, investment cost, natural gas supplies, and the key macroeconomic variables described above. However, these two shortfall projections bracket the range of economic conditions most pertinent for this assessment, given OTA's primary data base related to oil replacement technology and given OTA's goals to establish rough orders of magnitude for shortfall impacts and how they might depend on the rate of technology deployment. The high-response scenario simulates how easy and the low-response scenario how hard it might be to live with 3 MMB/D lower oil imports.

ECONOMIC PROJECTIONS

A Normal Economic Projection: The Reference Case

In 1983, after many recent predictions by prominent macroeconomic models have proven wrong, there is obviously much uncertainty about how the economy will perform in the next decade. This uncertainty is manifest in serious academic and political debates surrounding trends in labor productivity and the even stronger debate over Federal monetary and fiscal policy.

In this assessment, a single future scenario is projected for the U.S. economy. Its purpose is not to predict the future, nor to define some "normal" future projection, but rather to establish a baseline or reference case that merely illustrates assumptions made in this assessment regarding future oil import dependence for the U.S. economy.

In general terms, the reference case describes an economy poised to maintain steady modest growth of GNP over the period 1986-90, after making a robust recovery from 1983-85. Unemployment falls sharply during the recovery and much more slowly during the period of modest growth. inflation also falls sharply during the recovery but then rises steadily as capacity limits force the economy into a much lower rate of growth. There are other key variables, such as the behavior of investors and consumers, but the overall impression conveyed by general trends in GNP, unemployment, and inflation is sufficient to suggest how the economy is poised at the onset of the postulated oil shortfall. Further discussion of these variables and others, in terms of comparisons between the shortfall and reference scenarios, is presented in the next section.

Within this reference scenario, energy patterns reflect recent historical trends. Oil and gas prices hold steady (in constant dollars), and consumption of both premium fuels remains steady because the growth in demand associated with expanding economic activity is offset by capital investment in new technology (e.g., more fuel-efficient cars and fuel switching in boilers as obsolete units are replaced). Electricity grows in step with the economy, and coal consumption grows more rapidly as the fuel of choice in new boilers.

Two Macroeconomic Projections of Oil Import Shortfall Impacts

With the reference case as background, the model is used to project how the economy might adjust to a curtailment of 3 MMB/D in oil imports. Needless to say, the shock to the economy would be massive, and many important impacts would undoubtedly be impossible to predict given current knowledge about the economy. In the latter category, especially, would be the emergency predicaments facing families, firms, industries, and regions of the Nation during the first year, when the economy would be highly unstable. However, OTA's plan is to consider short-term conditions only to the extent that they contribute to the economic situation 5 years out, when the shock will have dissipated and some measure of economic order should have reestablished itself, much as it has following the shocks in the 1970s. Although the shortfall postulated here is unprecedented, OTA believes that much has been learned from the earlier experiences concerning the value and priority of alternative oil uses and concerning the U.S. ability to do without normal supplies if necessary.

Two shortfall projections are described below. The first (the high-response case A) simulates an extremely optimistic scenario where investments in oil replacement have been large and well targeted to fuel switching for heat and steam applications (where they displace the most oil for the **least** cost) and where actual investment costs per barrel replaced are relatively low. About 2.2 MMB/D of the 3 MMB/D loss in imports are effectively replaced in stationary heat and steam after 5 years, leaving only about 0.8 MMB/D for replacement elsewhere.

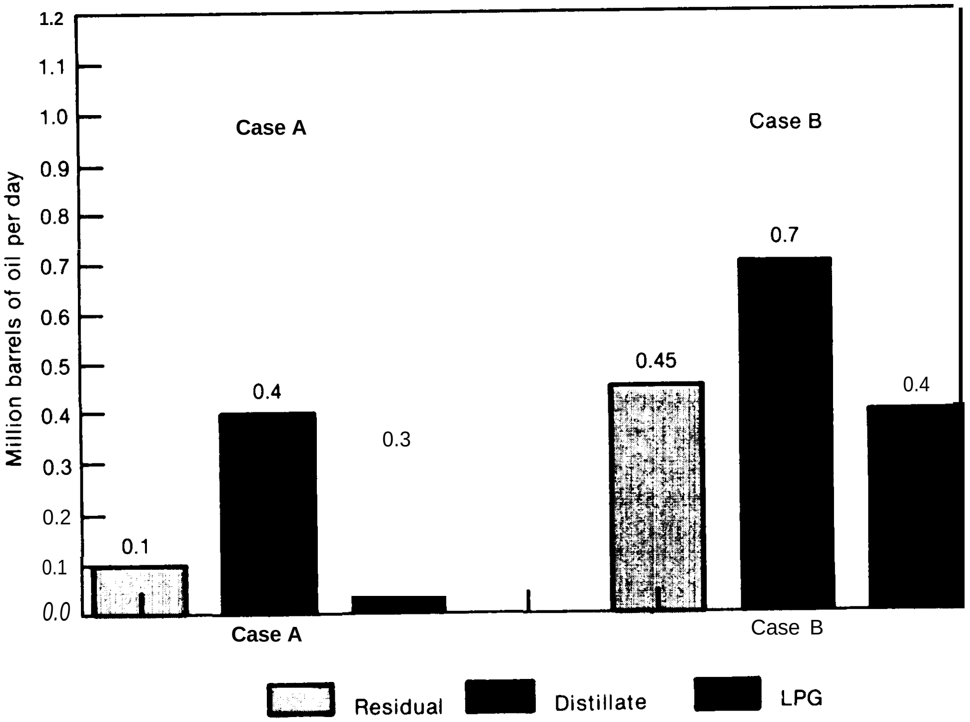
The second shortfall case (the low-response case B) is less optimistic about the size and targeting of investment as well as about actual investment cost per barrel replaced. In terms of oil consumption, figure 44 shows that 0.75 MM B/D more oil is replaced from stationary heat and steam applications in case A than in case B, which means that much less is available for use in engines in case B (see fig. **45).** (Note in reading the figures that the vertical scales change.) It also means that crude oil prices must be driven up by more than twice as much as in case A to create an investment incentive and to displace or choke down transportation and general economic activity as an alternative means to achieve the necessary total of 3 MMB/D savings (see table 28 for oil prices).

Note that rates of oil consumption reported in these shortfall scenarios (figs. 44 and 45) represent the combined effects of technological replacement and behavioral adjustments. Both are motivated by higher oil prices, but behavioral adjustments also occur as a result of reduced economic activity. This combination of technological and behavioral responses to oil shortfall is a major extension of the engineering analysis presented in earlier chapters, and it is an essential aspect of an integrated assessment of potential macroeconomic impacts from oil shortfall.

As the following discussion of key macroeconomic variables indicates, the two oil replacement scenarios lead to different states of the economy. Although the effective oil savings is the same in both scenarios, the differences in investment costs and oil prices lead to major differences in the apparent costs to the economy of the oil curtailment. These differences are illustrated in figures 46 through 50.

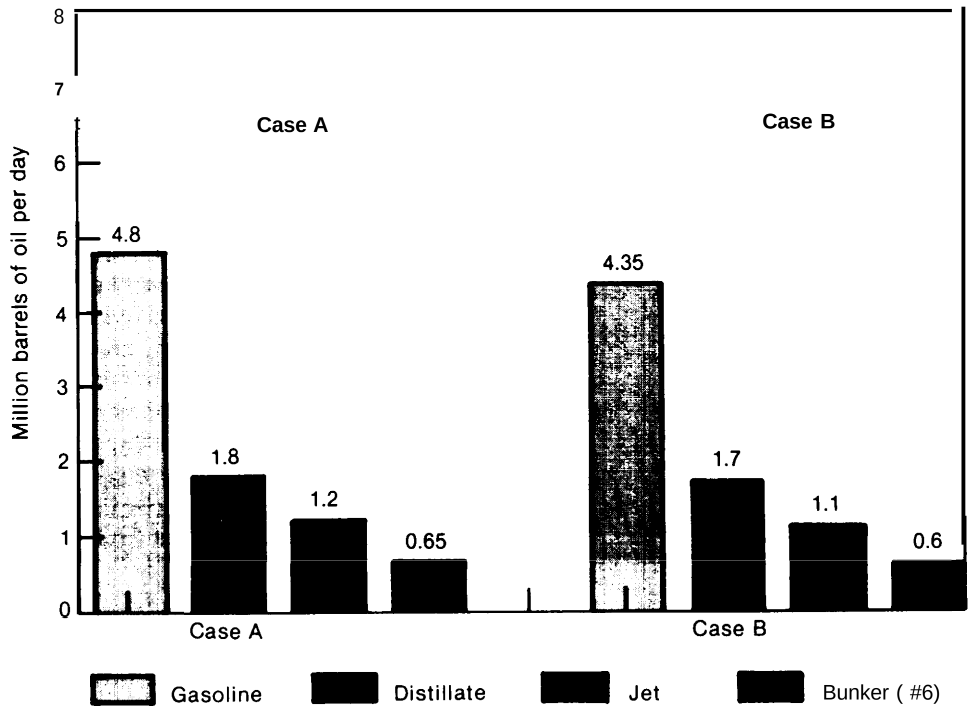
The following discussion considers five key macroeconomic variables plus product mix shift. For each, the implications of a shortfall are presented in the order of their reliability, given that

Figure 44.—Comparison of Shortfall Projections (petroleum use for heat and steam)



SOURCE: Office of Technology Assessment

Figure 45.—Comparison of Shortfall Projections (petroleum use by engines)



SOURCE Office of Technology Assessment

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the **primary** OTA **data base pertains to long-term technology deployment and given the strengths and weaknesses of the IN FORUM** model of the U.S. **economy. Although consideration of each variable will include its time path during the entire 5-year period following the onset of a shortfall, the year-to-year fluctuations are considered much less significant in all cases than 5-year averages and trends established after 5 years of economic adjustment.**

Gross National Product

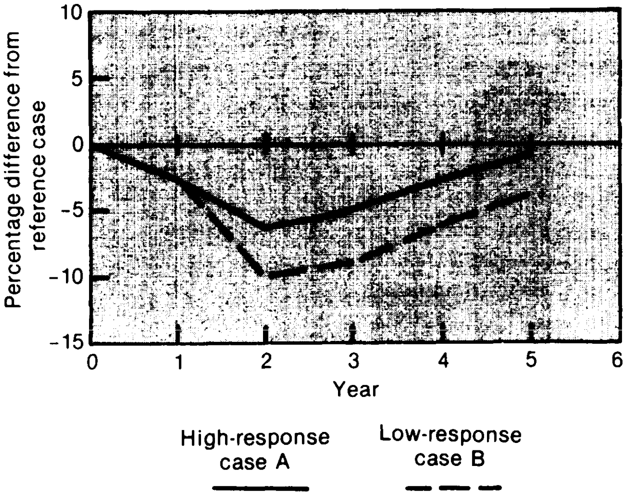
While there are many other statistics that describe important dimensions or patterns of national economic behavior, including the five discussed below, a general perspective on potential economic impacts, from a permanent shortfall of oil imports, can be obtained most easily by comparing the alternative time patterns for GNP presented in figure 46. This comparison can be made from several different viewpoints, and these are discussed in order of their relevance and reliability, given the design of this technology-based study.

Up to the 5-year horizon after the initial import curtailment, projected GNP lies well below that in the reference case, but the difference caused by the shortfall narrows over time, since the shortfall apparently does not reduce the po**tential for growth in the economy. Furthermore, after 5 years, the annual loss in** GNP due to the shortfall may be considered manageable in the sense that it can be made up in 1 to 2 years by continued economic growth, which in all these projections moves around a trend rate of 2 percent annually. This conclusion should not be surprising, given the wide range and large size of technological opportunities for oil replacement described in the preceding chapters, but it does reinforce from a macroeconomic perspective the conclusion that there is considerable flexibility in the economy to respond to a large oil shortfall.

A second general observation concerns the average loss in the level of GNP over the first 5 years after a shortfall compared to that in the reference case.[15] In the high-response replacement scenario, the permanent loss of oil imports lowers GNP on the **average by about 3.5 percent compared to the reference case. In the low-response scenario, the average loss is about 6.2 percent. Note that the differences between the reference and two shortfall projections are much larger during the first 2 years and much smaller during the last 2 years. In part, this unevenness over time is due to a macroeconomic cycle caused by the onset of the shortfall (see** below), but a major reason why GNP comes back 5 years later is because investments in oil replacement have reduced the burden of high energy costs on the economy.

A third and less important comparison (from OTA's longer term perspective) involves year-to-year change in the GNP during the first 2 years following the onset of the shortfall (note that this information is not contained explicitly in fig. 46). While growth trends and average output over 5 years are most interesting, given the model used, this shorter term perspective is probably most important for public perceptions of economic hardship. In both shortfall cases, the only actual decline of GNP occurs in the second year after the curtailment begins. The decline in the optimistic case A is only 1.3 percent from the previous year

Figure 46.—GNP: Two Shortfall Projections Percentage Reductions From Reference Case



SOURCE: Office of Technology Assessment.

[15] Please note that the model's behavior at the start of the postulated shortfall in 1985 is strongly influenced by current expectations that the economy will have considerable growth momentum. If, on the other hand, the United States were mired in recessionary doldrums, the projections could be quite different.

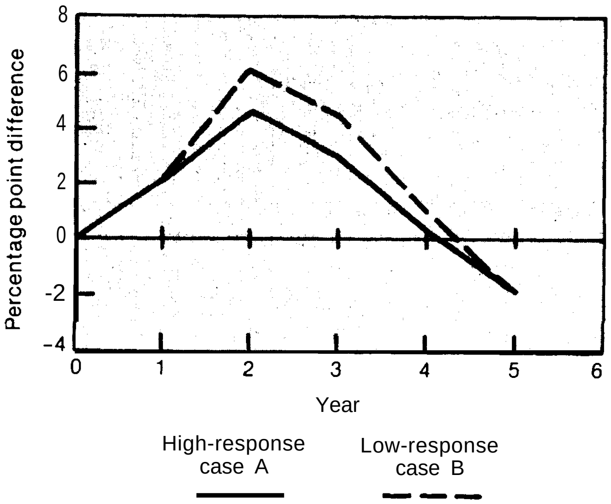
and 5.2 percent in case B. This difference can be appreciated by noting that during the worst recession since the Great Depression, real GNP declined in 1982 by 1.7 percent from 1981. The recession just prior to that, from 1979 to 1980, involved only a 0.2-percent decline in GNP.[16] In other words, case A is within recent historical experience; case B is well outside of it.

A series of test runs with the model indicate that oil price inflation would be the main factor driving the economy down into a trough 2 years after the shortfall begins. While most of these projected losses are made up shortly, the economic recovery may not in fact be so energetic if the model has been too optimistic about the dynamics of unemployment and inflation. As discussed further below, macroeconomic instabilities (resulting from a rapid and large oil price inflation) can become chronic, making it difficult for investors, managers, and workers to see and to adjust to new long-term trends. Consequently, it would be much safer if initial oil price inflation could be moderated. Based on the technical analysis presented in this study, moderation can be achieved by rapid and extensive deployment of oil replacement technologies. When such replacement is reliably expected in the future, this expectation feeds back to the short-term market behavior of oil users and price speculators, who would thus be encouraged **not** to hoard and speculate against the prospect of more severe oil price inflation. Since, in the short run, price expectations appear to be self-fulfilling, the favorable longer term prospects for oil replacement can cap and otherwise stabilize short-term oil prices.

Unemployment

On the average, over the 5-year shortfall period, unemployment would be pushed up by the shortfall by over 1.7 percentage points in case A (high-response) and by over 2.3 percentage points in case B (see fig. 47). However, after the initial, sharp runup associated with the deep recession (in the second year after the start of the shortfall), the rate of unemployment would drop sharply until it actually fell below the reference

Figure 47.—Unemployment: Two Shortfall Projections Percentage Point Changes From Reference Case



SOURCE: Office of Technology Assessment

case. This surprising result raises important questions about labor and capital markets, but before considering them, it should be emphasized that the projected differences between 5-year average unemployment rates (among the three future projections) are the most important and reliable result from this model.

In this model, the sharp decline in unemployment after the second year is due to a combination of conditions that lead to the substitution of labor for energy. This happens: 1) because of "crowding out" of investments (which in normal times would increase labor productivity and reduce labor demand per dollar of output, see note 12 above and the discussion of investment below) by investments that replace oil; 2) because real wages decline sharply; and 3) because the rapid economic expansion following the recessionary trough (2 years after the curtailment) is driven by aggressive investment behavior, which increases labor demand in general. Investment by industry is based on behavioral equations in the INFORUM model. The "crowding out" affect was programmed into the shortfall cases, and real wages were assumed to change as necessary to move the economy toward full employment.

Compared to other macroeconomic modeling of oil shortfalls, this result about unemployment and the previous results for GNP are relatively

[16] Data Obtained from *Survey of Current Business*, April 1981 and April 1982.

optimistic.[17] **This is because instabilities associated with unemployment, inflation, and Government deficit (see below) are treated by IN FORUM as temporary problems, not chronic disorders. They are temporary, at least to the extent that they are exacerbated** by the oil supply shortfall, because real wages adjust quickly (downward) to the level necessary to achieve full employment and because investment behavior is robust (see below). If wages were not so flexible or investors not so responsive, unemployment **5 years after the shortfall begins could indeed be abnormally high; and furthermore, it could take much longer** for the economy to recover from the recession brought on by the onset of shortage.

Comparisons among models, which lead to rather different projections for shortfall impacts, suggest that all such projections should be interpreted cautiously. Caution is necessary because economic uncertainties, which go far beyond those directly related to oil replacement technologies, are very large. A major permanent loss of imported oil, such as the one postulated in this study, could make the chronic macroeconomic problem of unemployment (and inflation, see below) much more troublesome than anything experienced during the last decade; or it could serve as a catalyst for market reorganization, which means that workers, firms, and investors, must compete more vigorously, with the resulting discipline and efficiency that competition engenders. While the present modeling analysis does not reduce this uncertainty, its relative optimism is consistent with the preceding analysis of technology, which suggests that market conditions, in general, should be positively affected by relatively large technological opportunities for oil replacement.

As a final note about unemployment, the year-to-year changes in unemployment during the first 2 years suggest the potential severity of the short-term problems for the economy and for workers in particular. Compared to the reference case, both shortfall cases reverse a declining trend in the rate of unemployment. Furthermore, the post-disruption peak for case **A** closely approximates the 1982 peak annual rate of 9.7 percent, and in case B the peak exceeds the 1982 peak (which was a postdepression high) by about 1.3 percentage points.

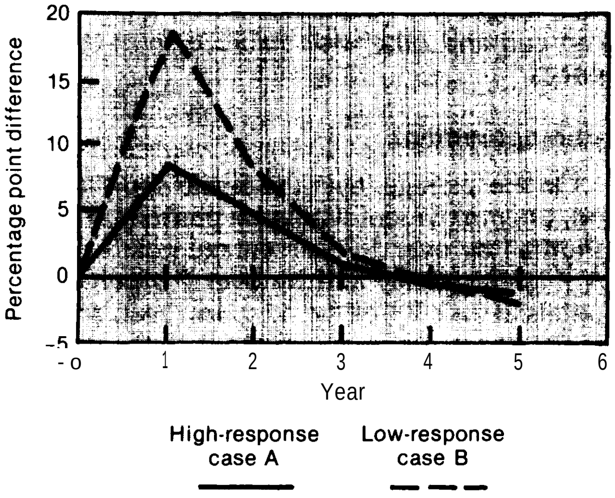
[17] Results reported by the Energy Modeling Forum (EM7) indicate a range of **GNP losses** from 2 to 4 percent, 4 years after a disruption, assuming a permanent increase in oil prices of 50 percent. **Since OTA's price projections are either somewhat higher (70-percent increase for case A) or much higher (120-percent increase for case B), OTA's conclusion that GNP losses fall in the same 2- to 4-percent range is by comparison optimistic.**

Inflation and Federal Macroeconomic Policy

The third major index of macroeconomic health is inflation, in particular the rate of growth in the GNP deflator. In a pattern very similar to its impact on unemployment, the path that prices take over time is shaped like a spike, with a peak unprecedented since **1946 (see fig.** *48).* In other words, when oil prices shoot upward in response to reduced supply, they sharply drive up the average price level, but soon after (as oil prices level off) the rate of inflation falls quickly back down to the reference case. Over the 5-year shortfall period, the shortfall increased the average annual rate of inflation by about 2.7 percentage points in case A and 5.4 percentage points in case B.

This result must be heavily qualified, however, because so little is known about inflationary dynamics and because so much depends on Federal monetary and fiscal policy. Federal policy depends on changing perceptions about macro-

Figure 48.—inflation: Two Shortfall Projections Percentage Point Changes From Reference Case



SOURCE: Office of Technology Assessment.

economic behavior, international relations, and the relative strength of concerns about inflation and investment incentives on the one hand versus unemployment and inequity on the other. Needless to say, in the event of an actual oil shortfall, there would be many controversial policy issues to resolve. This model (and perhaps any current macroeconomic model) does not attempt to simulate complex, political choices. However, as a first order approximation, OTA assumes that the money supply will be held to a constant annual rate of growth (6 percent) (i. e., no allowance is made to accommodate inflation caused by the discontinuous jump in oil prices). This stability in the money supply is perhaps the main reason why inflation is forced to moderate quickly. Also, by adjusting taxation, the Federal deficit was allowed to increase as a percent share of GNP in response to the oil curtailment. In both shortfall cases, the share of the Federal deficit in GNP increased by 1 percentage point over the reference case, from about 3.2 percent to about 4.2 percent.

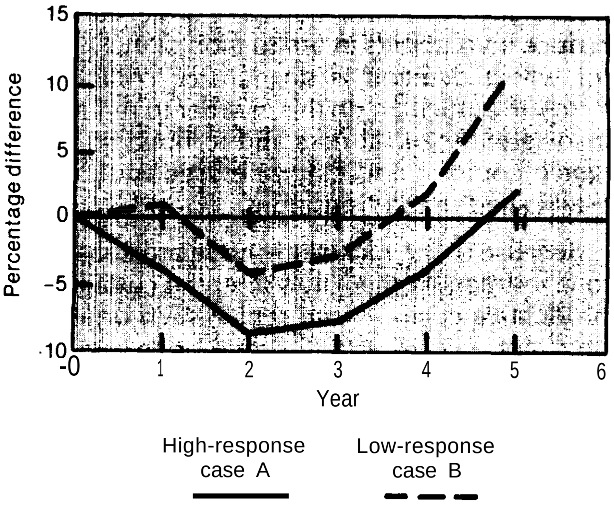
The optimistic result in the present projections, that inflation will quickly moderate, figures heavily in limiting GNP losses in both shortfall cases. It does so by focusing investor attention on plant and equipment (instead of, for example, gold and real estate), and thus it makes investment a force sufficient to drive the economy smartly out of its **initial recessionary trough.**

Private Investment

The key to both oil replacement and economic growth during the shortfall is investment (see fig. 49). As discussed above, the projected strong recovery 3 to 5 years after the oil cutoff is to a large extent driven by robust private investment. In the economy and in this economic model, investment behavior (or the decision to invest) depends on general economic expectations, including among many other things relative oil prices, as well as on the set of new technologies that makes new capital investment more productive than existing capital stock. While the robust behavior projected by the model was determined by its investment behavior functions, this result is consistent with and to an extent corroborates the technological conclusions of the earlier chapters.[18] That is, by and large, oil and capital assets are substitutes for each other, and thus there are many profitable investment opportunities to replace oil by the time crude oil prices increase by *70* to 140 percent above their current level of around $30 per barrel.

Weighing against this optimistic, longer term perspective, are short-term obstacles to investment that are caused by a deep recession that can be expected immediately following the cut-

Figure 49.— Investment in Producer Durables Percentage Change From Reference Case



SOURCE: Office of Technology Assessment.

[18] The strikingly rapid **recovery 3 to 5 years out is caused** also **by a number of other factors typical of a Keynesian, "demand-driven" macroeconomic model. All of them are self-corrections embodied in the initial very severe inflation and recession. First, one of the forces underlying robust investment** *is* the **large pool of industrial profits for oil-related industry. In the model, this pool of liquidity motivates investment. Second, although high interest rates make borrowing more expensive, they also increase the income of creditors, and like oil profits, this enlarged pool of funds becomes liquidity available for investment. Finally, high unemployment rates drive down personal savings, since, on the average, people have lower budgetary surpluses above basic consumption needs. Thus, as the recession becomes worse, it increases the marginal propensity to consume and** thus **increases the associated income multipliers which make a dollar of investment worth more in terms of the economic activity it can generate (i.e., it has a greater impact on GNP).** While all of these demand-side adjustments are no doubt significant, it would **have been better to model also the supply-side constraints associated with depletion of corporate funds by high oil prices, with inflation as investors attempt to shelter their funds against a depreciating dollar, and with chronic local and** regional **stagnation caused by widespread losses in real personal income. Unfortunately, neither the IN FORUM model nor perhaps any of the major macroeconomic models has been able to simulate the highly complex interaction of both demand- and supply-side factors.**

off. When the economy is headed down or settled into a recessionary trough, investors, entrepreneurs, and corporate managers understandably reduce investments in production of most goods for which demand is stagnant or contracting. Firms, in particular, do this in order to reduce the associated financial risks and to build liquidity, which could, if necessary, be used to shore up established market positions.

Because of the recession and related obstacles to investment immediately after the curtailment, productive capital is **not** replenished or at least does not expand at a "normal" rate, and thus the productivity of the economy **cannot** grow normally. (Productivity in this case is measured as output per unit of labor input.) Furthermore, following the postulated curtailment, investment patterns will **shift toward** oil replacement, at least temporarily, and away from technologies that increase labor productivity (since labor becomes relatively less expensive compared to energy). The latter diversion of funds from normal pursuits was called above a "crowding out" effect, an effect that reinforces the recessionary drag on labor productivity.[19]

Indeed, the recovery is so strong by the end of the fourth year in both shortfall scenarios that investment in producer durables, the key component of private investment related to labor productivity and oil replacement, exceeds that in the reference case. This particular aspect of these shortfall projections, like certain aspects of inflation and unemployment discussed above, appears to be extremely optimistic. While it may be plausible, it probably would not occur if the model had incorporated the likely negative "supply-side" conditions.[20]

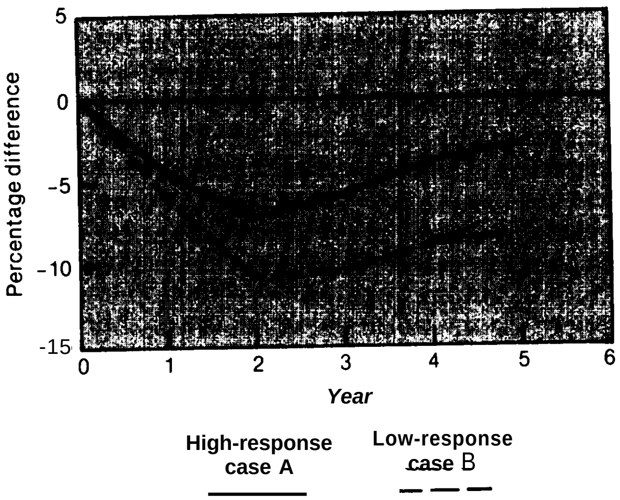
Personal Consumption Expenditures

The fifth summary viewpoint on macroeconomic impacts involves private or personal consumption expenditures (PCE). Along with private investment and government expenditures, personal consumption drives the economy (i.e., it determines the size and composition of GNP) through the decisions of consumers to use income for consumption purposes (see fig. 50) and through their decisions to allocate their consumption expenditures among alternative products. As with GNP, the oil supply shortfall interrupts the pre-1 985 upward trends in total consumption expenditures for 2 years as the economy **goes into a recession, and then** growth trends reappear and make up some of the recessionary losses.

However, the average loss (compared to the reference case) in consumption over the 5-year period is greater than that for the GNP. In case A, PCE averaged 4.7 percent lower than in the reference case, compared to a loss of 3.5 percent **for the** GNP. In case B, PCE loss averaged 8.8 percent, compared to 6.2 percent **for the** GNP. Consumption losses exceeded GNP losses because investment led the way to the economic recovery and thus expanded its share in total economic activity.

Nevertheless, despite this shift from consumption to investment, the overall effect of the oil shortfall on consumption is more or less similar to its effect on the GNP. While the short-term hardships are severe, the longer term effect amounts to a temporary delay in the achievement of consumption objectives, not a permanent loss. The delay may be for a bit longer than for the recovery of the GNP, because the average loss over the

Figure 50.—Personal Consumption Expenditures Percentage Change From Reference Case



SOURCE: Office of Technology Assessment.

[19] OTA has specified exogenously certain reductions in the rate of growth in labor productivity that have a large impact on projected GNP and unemployment. See p. 140 for further discussion.
[20] See note 18 above.

5-year period is somewhat larger, but the robust investment response eventually pays off in greater productive capacity and real income, and thus greater purchasing power for consumers.

Within total consumption, major product categories can be identified that describe consumption and how it changes. Table 29 presents product share data for the three future projections, 5 years after the oil import cutoff. At the first level of disaggregation, when total consumption is divided into just three gross categories, the impact of oil shortfall appears to be insignificant. Overall, durable goods, nondurable goods, and services share about equally in the lost personal consumption since they maintain their shares i n total consumption. However, within each of these categories, certain changes are noteworthy.

Within consumer durables, the disruption shifts consumption away from motor vehicles, boats, recreational vehicles, aircraft, wheel goods, durable sports equipment, and jewelry but toward furniture and household equipment (especially household appliances, communications, and entertainment equipment, for which use actually increases significantly). In other words, as a result of higher energy prices, people may stay at home more often and wear less expensive baubles.

With insignificant exceptions, consumption of all nondurable declines, but two categories decline more and one declines less than others. The largest change occurs in food consumed at home, which increases its share of total nondurable by more than 1 percent. That comes about primarily at the expense of gasoline and oil and clothing. The 15 other product categories decline more or less in step with one another.

Among consumption service categories, the major shift was away from housing and toward operating activities within households. The two

Table 29.—Product Mix for Personal Consumption Expenditures (PCE) After 5 Years (in percent, using 1972 product prices)

Gross product mix	Reference case	Case A	Case B
Durable manufactures.	16.0	16.0	**15.4**
Nondurable manufactures.	35.6	35.8	**36.4**
Services.	48.4	48.2	**48.2**
Total	100.0	100.0	**100.0**
PCE durable manufactures:			
Motor vehicles and park.	37.3	**34.3**	**32.1**
Furniture and household equipment	44.1	47.9	50.9
Other	18.5	17.9	17.0
***PCE** nondurable manufactures:*			
Food and alcohol.	49.4	49.9	50.5
Clothing ... , ...	25.2	25.3	24.7
Gasoline and oil.	4.5	4.0	3.9
Fuel oil and coal.	.7	.6	.5
Tobacco	3.6	3.7	3.8
Drug preparations and sundries.	3.3	3.2	3.2
Other	13.2	13.3	13.3
PCE services:			
Housing	38.3	37.3	36.5
Owner occupied.	27.9	27.1	26.4
Tenant	9.4	9.2	9.1
Household utilities.	14.4	15.5	16.3
Electricity.	4.3	4.7	5.0
Telecommunications.	5.7	6.3	6.7
Water.	1.2	1.3	1.4
Transportation	6.7	6.5	6.3
Medical services.	17.0	17.1	17.3
Education	2.6	2.7	2.7
Other	21.0	21.0	20.8

SOURCE: Office of Technology Assessment

changes just about offset each other. Declines in housing stem primarily from high interest rates, which are driven up by shortfall-induced inflation. However, the effect of inflation and high interest rates on housing in the model may be somewhat exaggerated because the model reflects problems of "disintermediation," which occurred during the last two oil shortfalls, but which should be less significant in the future due to structural reforms in financial markets.[21] The increase in household activities mirrors the changes in consumer durables. The leading growth activity is telecommunications, with smaller increases in electricity, water and sanitation, and postage.

Product Mix Shift Over the Entire Economy

Compared to the previous discussion of consumption mix, product categories for the entire economy are much less detailed in terms of end uses, but they include intermediate goods and services which are entirely omitted from the classification of consumer products (see table 30). For example, the gross output mix includes lumber as well as furniture, ferrous metals as well as autos and electric appliances, and agriculture as well as food. While this is a broader classification system than was used for consumption, which leads to different relative product shares, the interesting point for analysis is the same—how product shares change as a result of the oil supply shortfall.

From this overall viewpoint on the economy, most of the product categories that increase their share in total output (at the end of 5 years) are related to private investment. This especially includes machinery for mining, metal working, engines and turbines, computers, and communications equipment. Presumably, the latter two types of machinery are related to the expected shift from energy-intensive transportation to electronics as means for conducting business and social relations. All of these producer durables increased their level of physical output as a result of the oil supply shortfall, not just their share in total output, The same is true for domestic gas and coal production because these products are direct substitutes for oil.

[21] Disintermediation refers to the problem experienced in the past by the savings and loan industry, which has typically concentrated lending in long-term home mortgages and borrowing in short-term savings. During unstable periods in the past, when interest rates were abnormally high, large numbers of depositors sought higher returns from other financial institutions, leaving savings and loan institutions unable to make new mortgages and thus drying up the primary source of funds for residential construction. In the future, mortgage lending should be more resilient as financial institutions use variable rate mortgage instruments and otherwise diversify to minimize their own risks from inflation and to offer depositors greater investment flexibility,

Table 30.-Product Mix for All Economic Activity (GNP) 5 Years After Curtailment (in percent, using 1972 product prices)

Product category	Reference case	Case A	Case B
Agriculture, forestry, fishery	6.3	6.3	6.4
Mining	3.7	3.8	3.9
Construction	5.0		
Nondurable manufactures	31.0	30.5	30.7
Durable manufactures	37.4	37.3	38.2
Nonelectric machinery	7.6	7.7	8.4
Electric machinery	5.9	6.1	6.5
Transportation equipment	7.9	7.7	7.7
Transportation services	6.4	6.4	6.4
All utilities	11.2	11.5	11.6
Wholesale trade	9.2	9.1	9.3
Retail trade	9.4	9.3	9.2
Eating and drinking establishments	4.6	4.5	4.4
Finance and insurance	6.4	6.3	6.3
Real estate	7.3	7.3	7.2
Owner occupancy housing	8.3	7.8	7.5
Business services	9.8	11,5	10.8
Medicine, education, NPO	7.8	8.6	8.7
Other services	7.3	5.3	5.8
Government industry	7.8	8.8	9.1

SOURCE: Office of Technology Assessment.

Other product categories increased their share in total output by lessor amounts by suffering relatively small declines in physical output. Some of these, such as stone/clay/glass, ferrous metals, and paper are obviously related to the investment in producer durables, either as intermediate goods in their production or (as in the case of paper) as a complementary (communications) product. others increased share because their use is not highly sensitive to price inflation, such as medicine and government enterprise.

On the other hand, products losing share in total output include most other major categories, and the losses are by and large marginal. However, the most significant losses occur for housing (as discussed above) and for the construction industry, which suffers because many fewer homes are built as a result of high interest rates during most of the postcutoff period. Of course, the petroleum refining industry suffers a major loss in output due to diminished crude oil supplies. The production of motor vehicles also loses significantly in its share due to high fuel prices.