Macroeconomic Aspects of Oil Price Increases

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The unprecedented flow of dollars to the oil-producing countries since the 1973 oil price rises has caused major strains in the economies of the consuming countries. Numerous economists have attempted to analyze the effects, both good and bad, of energy price changes, and to propose solutions. In the following paper, Professor Dohner examines the macroeconomic consequences, concentrating on the situation in the United States, but with an analysis applicable to other industrialized countries as well.

Because of the considerable momentum of modern economies, and Milton Friedman's "long and variable lags," macroeconomic analysis is seldom identified with a single event. October 1979 marked the fiftieth anniversary of one exception, the collapse of the Stock Market, and the sixth of another, the Yom Kippur War and the associated oil embargo. The prospect posed by the embargo, that of a significant shortfall in world oil supplies, shocked the oil-consuming countries. The quadrupling of oil prices which followed in early 1974 had more lasting and profound effects. Rates of inflation accelerated at the same time as unemployment rose, and the OECD countries entered their worst postwar recession in 1974 and 1975.

The recovery from the recession was strong in the United States, but weak to non-existent in other OECD countries. A second rise in OPEC prices in 1979, though not as large as the previous one, came at a time when the industrialized countries were perhaps more vulnerable than in 1974, with higher rates of underlying inflation and lagging productivity growth.

The simultaneous rise in inflation rates and unemployment, termed "stagflation," created a popular conception that economics was irrelevant to understanding the behavior of industrialized economies in the seventies. This

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paper takes the opposite stance, although admittedly drawing exclusively upon work published after the oil price shock. In the sections which follow, a brief review is given of the events leading up to the oil price rises of 1974 and 1979. Then the effects of the oil price rise on prices and output are analyzed in a textbook model of aggregate supply and demand. Later sections consider the effects upon productivity and economic growth, and the last section deals with the effect on inflation and, in particular, the differing experiences of the American and the European and Japanese economies.

As a result of American support for Israel in the October 1973 war and its decision to supply arms, the Arab oil producers, with Saudi Arabian leadership, declared an embargo on oil exports to the United States, and a 10 percent reduction in oil production with further monthly reductions to follow. A few days later the Netherlands was also placed under embargo. A second conference in Kuwait modified the boycott; November production was to be reduced to 75 percent of the September level. In December production was raised to 85 percent of the September level, and in March the oil ministers agreed to end the embargo of shipments to the United States and restore production to pre-October levels.

The reduction in Arab oil production was offset only slightly by increases in other producing areas, and world crude oil availability has been estimated to have been reduced by about 14 percent in December 1973 from October 1973.[1] Even though the embargo was directed against the United States, the U.S. fared reasonably well during the October to March period. At first there was little effect on the volume of imports as tankers at sea continued to land at U.S. ports. Later, the oil companies were able to redirect supplies from non-Arab producing countries to the United States. A reduction in crude oil imports began to be felt in December, and the volume of crude oil imports reached a low in February of 60 percent of its October level. U.S. imports of refined products (mainly heavy fuel oil) were of roughly the same magnitude as crude oil imports and were scarcely affected by the embargo.[2]

The 1978-1979 Oil Crisis[3]

Events in Iran in late 1978 confronted the consuming countries with the prospect of a second shortfall of oil production. Apprehensions of the Shah's vulnerability increased in the latter half of the year among oil companies,

1. Robert Stobaugh, "The Oil Companies in the Crisis," *Daedalus,* Vol. 104 (Fall 1975), pp. 180-81.
2. George L. Perry, "The United States," in Edward Fried and Charles Schultze, ed., *Higher Oil Prices and the World Economy* (Washington: Brookings Institution, 1975), Table 2-1, p. 75.
3. The material in this section is drawn largely from Richard Mancke, "The American Response to the 1978-1979 Oil Crisis," *Orbis* (Spring 1980).

which began adding to their stocks of oil in anticipation of a possible reduction in supply. During the turmoil which eventually forced the Shah's departure, Iranian oil production dropped, and oil exports were suspended entirely in January and February of 1979. The fear of a prolonged shortage sparked considerable pressure on spot markets, where prices soared. Iranian oil production was eventually resumed in the second quarter, but at a level roughly 30 percent below that of the first nine months of 1978.

In 1978 Iran was the world's second largest exporter of crude oil, and responsible for about 15 percent of the world oil trade. The effect of the cessation of Iranian exports on the world oil market was of course considerable, but production increases in other countries (especially Saudi Arabia, Iraq, the United Kingdom and Nigeria) moderated the effect on world oil supplies. Data from the *Oil and Gas Journal* show that total production in non-communist countries fell by about 4½ percent from the fourth quarter of 1978 to the first quarter of 1979, and regained its previous level in the second quarter. A relatively minor effect on the available supply of oil was magnified by speculative buying and stockpiling to assure supplies and, in the United States, by regulations which precluded access to more expensive supplies.[4] The visible effects of the reduction in Iranian oil production were much smaller than the effects of the 1973-1974 oil embargo, but lengthy lines for gasoline developed in some sections of the country.

Oil Prices

The production cutbacks during the oil embargo exposed the vulnerability of the consuming countries to a protracted reduction of oil supplies, and the behavior of spot prices during 1973-1974 and 1978-1979 are an indication of the seriousness with which a potential supply shortfall is taken. However, the supply reductions had little effect upon the output or the employment of the industrial countries, just as the coal strike and the severe weather of 1977-1978 apparently had little effect on U.S. output. Economies show surprising resilience to supply interruptions in the short run, and perhaps even over longer periods, as the largely unsuccessful attempts at international boycotts seem to show. Although an extended embargo could have had serious consequences, the 1973 actions did not usher in an age of scarce oil supplies. The supply interruptions quickly subsided, spot market prices receded, and consumers were able to purchase all the oil they wished at the going prices. Indeed, the 1974-1975 recession in the industrial countries weakened demand for petroleum, and caused some concern among the producing countries of an oil supply glut.

This is not to say that the events of six years ago were unimportant. In fact,

4. This point is stressed by Mancke, *ibid.*

they had a profound effect upon the industrial economies, and changes in energy markets have had a great deal to do with their recent poor economic performance. But the effects have stemmed from the price of oil rather than from its lack of availability. It is the dramatic rise in the price of oil (and, for reasons which will be stressed below, the rise in the price of oil relative to the price of output of the consuming countries) which has forced difficult adjustments upon the rest of the world. This paper will review the effects of the oil price rise on the U.S. economy from a number of standpoints: the changes in aggregate demand, aggregate supply, potential (full employment) output, and the effects upon the inflationary process. Before examining these issues, it will be useful to present a chronology of price movements.

From the mid-1950s to 1970 the dollar price of crude petroleum drifted downward slightly; this reduction was even greater in real terms (relative to output prices in the consuming countries). Dividing the posted price of Saudi Arabian crude oil by the unit value of industrial country exports (as a rough measure of the relative price of crude oil imports) gives an average 1966-1970 value 31 percent below that of 1956-1960.[5] This may overstate the actual fall in the relative price of energy in the consuming countries since posted prices did not always reflect transactions prices, and since industrial countries gave tariff and quota protection to their domestic fuel industries. In the United States the wholesale price of fuels, power, and related products relative to the GNP deflator was 17 percent lower in 1966-1970 than in 1956-1960.

Although the most dramatic increase in world oil prices occurred in the first quarter of 1974, the price of oil had already risen substantially by the end of 1973. From December 1970 to October 1973, the posted price of Saudi Arabian light crude oil increased from $1.80 to $5.12 per barrel, and Saudi Arabian receipts are estimated to have jumped from $0.88 to $3.05 per barrel.[6]

In December 1973, during the embargo, the OPEC ministers met in Tehran and announced that the posted price for Saudi Arabian light crude for January 1974 would be raised to $11.65 per barrel, yielding a government take of $7 per barrel. Changes in sales prices and in participation further boosted the government take on crude oil production to $10.12 per barrel by December 1974.

Subsequent revisions raised posted prices to $13.34 in early 1979. After

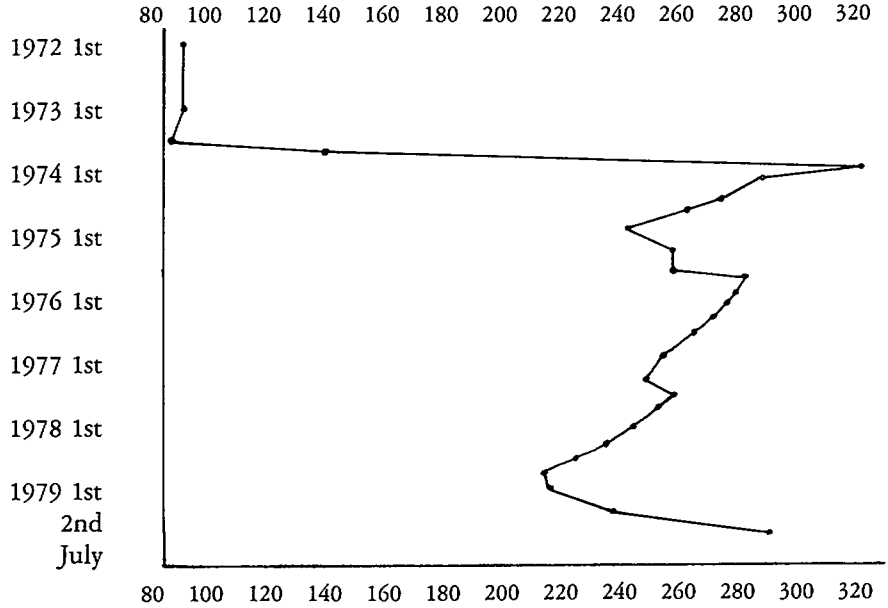
5. IMF *International Financial Statistic Yearbook,* 1979. The posted price of Saudi Arabian crude oil in US$/bbl. is divided by the Industrial Country export unit value index (pp. 70-71, line 110) which is also defined in terms of U.S. dollars. Posted prices are for tax reference purposes, and do not precisely measure the actual realizations of the producing states or the oil companies. However, the posted price trend gives an indication of relative price movements. A calculation by Adelman for Venezuelan crude oil realizations show that they dropped by 5 percent from 1956-1960 to 1966-1970, while Saudi Arabian posted prices fell by about 25 percent over this period. Thus the measure in the text probably overstates the fall in the real price of oil. Morris A. Adelman, *The World Oil Market* (Baltimore: Johns Hopkins University Press, 1972), Table V-A-4, p. 342.
6. Joel Darmstadter and Hans Landsberg, "The Economic Background," *Daedalus,* Vol. 104, (Fall 1975), p. 26.

Iranian oil production had resumed, OPEC ministers met in Geneva and announced that, effective July 1, oil prices would be raised to between $18.00 and $23.00 per barrel, depending upon various surcharges. The dispersion of crude oil prices has been substantial, with Saudi Arabian oil selling at $18.00, Kuwait's at about $19.50, Iran's at $22.20 and the African light crudes at about $23.50.[7]

Using the posted price of Saudi Arabian light crude as a rough indicator of world oil prices, and export unit values of industrial countries as an index of the prices of their products, Figure 1 shows the movement of the relative price of oil from 1972 to July 1979. The index rises at the end of 1973 and then reaches a peak in the first quarter of 1974. During the next five years the index of the relative price of oil falls, owing both to inflation in the industrial countries and the depreciation of the dollar, although the 1975 appreciation of the dollar relative to other industrial country currencies temporarily reversed the decline in the relative price of oil. In 1979, the deterioration of the relative price of oil was reversed by price increases early in the year and by those announced in Geneva at the end of June.

Figure 1

Posted Price of Saudi Arabian Crude Oil Relative to Industrial Country Export Unit Value Index in U.S. dollars 1973 = 100



Source: IMF, *International Financial Statistics Yearbook,* 1979.

7. *Petroleum Economist,* October 1979, p. 443.

As I shall argue at some length, it is the increase in the price of oil *relative* to the output prices of the industrial countries that is the crucial feature of the macroeconomic adjustment problems of the 1970s, and the feature that distinguishes "supply shocks" from a general inflation of the prices of goods traded on world markets. It is also the appropriate focal point from the point of view of OPEC price-setting behavior, since the price of oil relative to the price of manufactured goods appears to be the central concern of OPEC pricing policy. This concern is not new, but goes back to price negotiations in January 1972, when an agreement was reached for an increase in posted prices of 8.59 percent to compensate for the 1971 devaluation of the dollar, with a second revision in June 1973 after the second devaluation of the dollar.[8] In the period since the 1974 price rise, the OPEC ministers have repeatedly warned the industrial countries that failure to control their rates of inflation would lead to further increases in the price of oil. As the oil minister from Kuwait told a western audience before the 1979 Geneva meetings, "It is not to your benefit or to ours to see the real price of oil fall."[9]

The 1974-1975 Recession

Revised data for the U.S. show that real gross national product fell slowly in the first three quarters of 1974, and then dramatically in the fourth quarter of 1974 and the first quarter of 1975. The extent of the decline surprised most forecasters. Although consumer demand had weakened, business demand remained strong in 1974, and forecasters in September predicted little change in the coming quarters.[10] Real GNP fell by 6.6 percent from the fourth quarter of 1973 to the first quarter of 1975 and the unemployment rate peaked at 9 percent in May 1975. It was the worst postwar recession the United States had experienced.

Although the fall in business activity was sharpest in the United States, it coincided with a recession in the OECD countries. Between July 1974 and April 1975, OECD industrial production fell by 10 percent and GNP by 3½ percent.[11] Unemployment increased from 8 million workers to a high of 15 million workers, with migrant laborers in Europe being particularly hard hit. Inflation, already high in the wake of the expansion of 1973, accelerated in the OECD countries. Both the recession and the working-through of the oil price increases brought some moderation, but rates of price increase have nevertheless remained high in several of the OECD countries.

8. Edith Penrose, "The Development of Crisis," *Daedalus,* Vol. 104 (Fall 1975), pp. 44, 46.
9. *Economist,* 30 June 1979, p. 71.
10. U.S. Council of Economic Advisers, *Economic Report of the President 1975,* p. 37.
11. OECD, *Towards Full Employment and Price Stability* (McCracken Report) (Paris: OECD, 1977), p. 72.

Energy Prices, Aggregate Demand and Aggregate Supply

When the oil price increases were announced at the beginning of 1974, the initial reaction of U.S. policymakers was to consider the price changes as an external, inflationary impulse, and to advocate restrictive policies. Thus monetary growth slowed considerably in the United States in 1974. As an introduction to the discussion, it is useful to ask: What made the rise in the price of imported oil in 1974 different from an external inflation (a rise in the general world price level for traded goods)? To answer this, we will develop a simple aggregate demand and supply model and compare the effects of changes in world prices with changes in oil prices.[12]

Figure 2
Aggregate Supply and Demand, and
The Effects of General Foreign Inflation

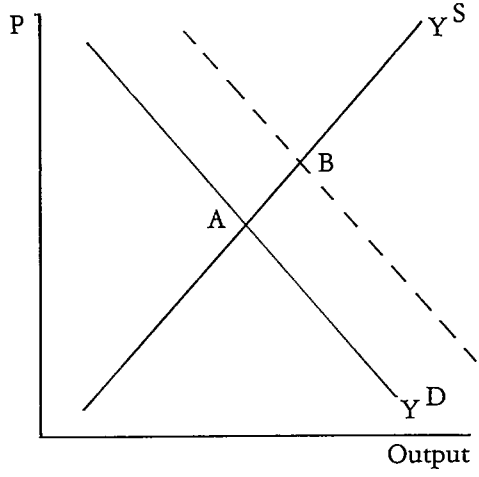


Figure 2 graphs aggregate demand and supply (volume of domestic output) against the price of domestic output, P. The aggregate demand curve is drawn with the assumption of a fixed quantity of money, government fiscal policy, and level of foreign prices. It slopes down and to the right for the following reasons: An increase in the price of domestic output lowers the real value of the

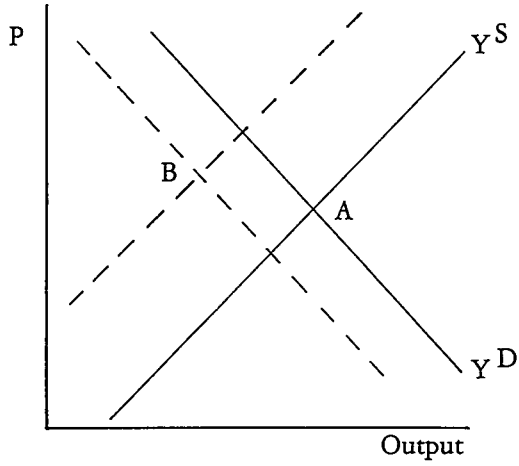
12. For a further discussion of the aggregate supply and demand model, *see* Roger Dornbusch and Stanley Fischer, *Macroeconomics* (New York: McGraw-Hill, 1978), Chapters 11, 12, and pp. 600-03. The effects of the oil price rise in this context are discussed in Robert Dohner, "Terms of Trade Changes and the Domestic Inflationary Process" (Massachusetts Institute of Technology, 1978, unpub.) and Michael Bruno and Jeffrey Sachs, "Supply vs. Demand Approaches to the Problem of Stagflation," *Weltwirtschaftliches Archiv* (forthcoming).

money stock, and raises interest rates. This causes demand (particularly investment demand) to fall. The fall in the real value of money holdings may also discourage domestic demand through its adverse wealth effect. Finally, a rise in the price of domestic goods, given foreign prices, makes foreign goods cheaper, shifting demand away from domestic goods.

The aggregate supply curve in Figure 2 is drawn on the assumption that wages are fixed (at least in the short run).[13] Aggregate supply slopes up and to the right because an increase in price leads firms to operate at a higher marginal cost and therefore higher output.

A general rise in the price of traded goods (a general external inflation) is illustrated in Figure 2. The aggregate supply curve is unaffected by the rise in external prices, but the aggregate demand curve shifts to the right for the following reason: An increase in foreign prices relative to domestic prices raises foreign demand for domestic goods. The foreign price increase also shifts domestic demand away from foreign and toward domestic goods. The increase in output at B implies reduced unemployment and upward pressure on wages. Rising wages cause the aggregate supply schedule to shift up, reducing output and further increasing prices, unless a contractionary policy reduces domestic demand. Thus a general rise in foreign prices leads to an eventual rise in domestic prices, and perhaps only a temporary increase in output.

Figure 3
A Rise in the Relative Price of Imported Oil



13. The derivation of the aggregate supply curve is discussed in Dornbusch and Fischer, Chapter 11. The positive slope depends upon wages and other input prices not being completely flexible in the short run. When full adjustment of wages takes place the supply curve is much steeper, if not vertical. In drawing the aggregate supply curve, I also assume that the ratio of other input prices to the output price (the real price of the other inputs) is constant.

However, an increase in the price of oil relative to the prices of other traded goods has quite different effects in this framework; these are illustrated in Figure 3. Since oil (or more generally, energy) is an input to the productive process, at a given wage and level of output, costs of production increase and therefore the supply price must rise. The aggregate supply curve shifts up in Figure 3.

The effects upon aggregate demand are not completely clear, but there are strong reasons for thinking that the aggregate demand curve will shift to the left instead of the right. First, there is no longer a reason for assuming a substitution effect toward domestic goods, since the price of oil, and not the price of foreign goods with which domestic output competes, has gone up. Secondly, if expenditure on energy cannot be reduced very much when the price of energy goes up, total spending on energy must rise, requiring fewer expenditures on domestic goods. Finally, as was the case with the 1974 price increases, if the oil producers cannot spend their increased revenues and instead save a large fraction of them, then world demand for the kind of goods the home country produces will fall. The resulting reduction in aggregate demand (leftward shift of the curve) reduces total output and employment, although perhaps moderating the rise in prices.

It is the rise of the relative price of oil that is crucial in this context. If the oil price rise is accompanied by an equal rise in the world price of the goods the country produces, then the analysis of Figure 2 applies. It is the effect of the relative price change which will show up throughout the analysis, altering the conclusions of conventional macroeconomic models with a single commodity price.

Effects Upon Demand

We shall now consider in some detail the effect of oil price increases upon aggregate demand in Figure 3. The argument will discuss first the effects upon income, then the effects upon expenditure, with a brief discussion of the expenditure effects of any induced changes in wealth. Finally we shall consider the effects upon investment demand.

In the textbook development of macroeconomics, the circular income-expenditure process is introduced to show that each product sale results in an equal amount of income, divided among the factors of production. The income generated in an economy that imports some of its inputs is divided between domestic and foreign factors of production. If relative prices and input proportions do not change, then an increase in output leads to a proportionate increase in domestic income, and no harm is done by referring to domestic output as domestic income, as most models do.

However, when the price of the imported input rises relative to that of

domestic output, then domestic income changes occur. These income changes are most severe in the case of fixed input proportions, when the amount of imports needed to produce one unit of output cannot be reduced. To illustrate this point, suppose that imports make up 10 percent of total costs, and the price of imports rises by 50 percent relative to the price of domestic output. If there are fixed proportions, then the share of imports in total factor income rises from 10 to 15 percent, and the domestic income from one unit of production falls by 5/90, or 5.56 percent. The domestic income generated by any level of domestic production falls as a result of the relative price change.[14]

If there are possibilities for substitution in production, then the use of imports in production can be reduced, and the effect upon domestic income moderated. The extent to which domestic income is maintained depends upon the extent of substitution, as measured by the own-price-elasticity of substitution. If this elasticity is 1, as in a Cobb-Douglas production function, then imported inputs are reduced by the same proportion as their price increases, and domestic income per unit of product does not change.

George Perry has assembled a series on business inputs of energy. He finds that the ratio of energy to output declined by 10.2 percent between 1973 and 1976, a period in which the relative price of energy rose by 57 percent.[15] Perry attributes most of the 10.2 percent fall to causes other than the rise in energy prices (a point which will be discussed below), but if we take the entire figure as representing price substitution, payments to energy per unit of output rose by 41 percent. If we take the share of energy in inputs to be 5 percent (the finding of several recent estimates),[16] non-energy factor income per unit of output fell by 2.16 percent. Econometric estimates of the own-price-elasticity of energy demand have been somewhat larger. Ernst Berndt and David Wood find an elasticity of -0.47, which would imply a fall in domestic factor income of 0.79 percent per unit of output.[17]

If the country produces some of its energy and imports the rest, then part of the increased payments for energy inputs provides additional income to domestic factors in the energy industries. However, in the United States, prices for domestically produced fuels were largely controlled, so that most if not all

14. A note on measurement: GNP is measured net of imports, so GNP and income would be reduced at any level of goods and services production. Figures 2 and 3 show the volume of goods production, and not GNP.
15. George Perry, "Potential Output: Recent Issues and Past Trends," Center for the Study of American Business (St. Louis), *U.S. Productive Capacity: Estimating the Utilization Gap*, Working Paper #23. Reprinted as Brookings Institution General Reprint Series #336.
16. *See* Roger Brinner, *Technology, Labor, and Economic Potential* (Lexington, Mass.: Data Resources, 1978), p. 74 for an estimate of 5 percent, and William W. Hogan and Alan Manne, "Energy-Economy Interactions: The Fable of the Elephant and the Rabbit?" in *Modeling Energy-Economy Interactions*, ed. Charles Hitch (Resources for the Future, 1977).
17. Ernest Berndt and David O. Wood, "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics*, Vol. 62 (August 1975), pp. 259-68.

of the additional payment for energy in production went to foreign producers. This was an unfortunate aspect of the price controls policy — it minimized substitution away from energy and maximized the payment of foreign factors.

The effect of the rise in the price of imported oil in 1974 was therefore to lower domestic income for any level of output. Here domestic income is measured by the ability to buy domestic goods, since it is the production and sale of domestic goods which generate domestic income. But a given level of income in units of domestic goods now represents a lower real income when measured in terms of a basket which includes domestic goods and imported oil. This is the appropriate measure, since a significant proportion of consumer expenditures — 9.16 percent in the last consumer price index (CPI) revision[18] — goes to direct energy purchases for transport, heating and lighting.

A rise in the relative price of oil at a given level of domestic income (measured in units of domestic goods) produces an income effect which reduces expenditure on all goods, and a substitution effect away from oil and other energy. If the substitution effect is small (i.e., if the short-run price elasticity of energy demand is less than 1) then the income effect dominates, and expenditure on domestic output at a given level of income falls.

However, expenditure on domestic goods and expenditure on foreign goods are not the only alternatives for disposal of income. Part of income is saved, and savings may absorb some of the effects of the relative price change. If the *proportion* of income saved increases with *real* income, as most simple Keynesian models assume, then a rise in the price of imported oil would lower real income and the proportion of income saved. This effect, associated with Svend Laursen and Lloyd Metzler, might increase expenditure on both foreign oil and domestic goods from reduced savings, moderating the decline in aggregate demand mentioned above.

These are the main effects that occur through the income-expenditure channel. Several macroeconomic models emphasize the effects of changes in real wealth upon consumption. If other prices (in particular the price of labor) are not sufficiently flexible to fall, then through its own rise and through its effect upon prices of domestic output, the rise in the price of oil forces the general price level up. This causes asset holdings to fall in real value, decreasing the wealth and therefore the expenditure of domestic consumers. The rise in prices may also severely affect the liquidity of consumers, causing a further retrenchment of expenditure. The "consumer balance sheet" as a determinant of expenditure is examined by Frederic Mishkin, who finds that it explains a signifi-

18. U.S. Bureau of Labor Statistics, *Facts About the Revised Consumer Price Index* (Washington, D.C.: GPO, 1978), p. 8. The 9.159 figure is for urban wage earners and clerical workers. The share of energy in the expenditure of all urban consumers is given a weight of 8.585.

cant proportion of the decline in expenditure, particularly for consumer durables, during the 1974-1975 recession.[19]

Two additional policy-determined factors which played a role in the 1974-1975 recession deserve mention. The first is the behavior of the money stock, and the second is the effect of the price rises on fiscal policy through the progressive tax system. To combat what was seen as an inflationary shock to the economy, the authorities slowed the growth in the money supply in 1974. As a result the real value (in terms of the consumer price index) of the broadly defined money stock (M2) fell by 4 percent from the fourth quarter of 1973 to the fourth quarter of 1974. Interest rates rose to record levels in mid-1974, and the demand for investment goods, particularly housing, was severely affected. Inflation rates reached 11 percent in 1974, raising nominal, but not real, incomes. This forced many taxpayers into higher tax brackets and, owing to the progressivity of the income tax system, raised the proportion of income taken in taxes. Federal tax receipts rose 12.6 percent from calendar year 1973 to 1974, compared to an 8.1 percent increase in nominal GNP and a 1.4 percent fall in real GNP. Personal income tax receipts rose by 15 percent, although personal income minus transfer payments (roughly equal to taxable income) rose by 8 percent.[20] This increase in the proportion of income taxed was the effect of inflation, and exerted a substantial drag on aggregate demand.

So far, we have focused on the determinants of consumption expenditure. Investment demand is reduced by higher interest rates, but a complete account requires a brief discussion of the marginal productivity of capital. Since a rise in energy prices lowers non-energy factor incomes, the average rate of return on the existing capital stock should fall, presumably lowering the demand for additional investment. Other effects depend upon the characteristics of the production process. If capital can be substituted for energy in production (capital-energy substitutability) then the demand for capital services will increase with a rise in energy prices. If capital use is associated with energy use, so that additional capital requires additional energy (capital-energy complementarity), then the demand for capital services falls with an increase in the price of energy.

Capital-energy substitutability or complementarity is an area of considerable controversy, and a problem which has important implications for the level of investment and medium-term economic growth. Econometric analyses seem to indicate that capital and energy are complements, while engineering, or 'process,' studies conclude that they are substitutes.[21] We shall not examine this

19. Frederic Mishkin, "What Depressed the Consumer? The Household Balance Sheet in the 1973-75 Recession," *Brookings Papers on Economic Activity*, #1 (1977), pp. 123-64.
20. U.S. Council of Economic Advisers, *1975 Economic Report*, pp. 61-62.
21. For a careful discussion of the evidence, *see* Ernest Berndt and David O. Wood, "Engineering and Econometric Interpretations of Energy-Capital Complementarity," *American Economic Review*, Vol. 69 (June 1979), pp. 342-54.

question in detail, other than to mention that certain industries (such as energy-producing industries) are obvious candidates for additional investment, and to raise the conjecture that energy is complementary to existing capital and substitutable with capital in prospective investment. Thus the energy usage or energy efficiency of a given type of capital good is nearly fixed, and energy-to-capital usage cannot be altered once one type of capital good (e.g., one type of refrigerator) is installed. But if types of capital goods (e.g., types of refrigerators) vary as to their initial cost and energy efficiency, as engineering studies suggest, or if the energy usage of the existing capital stock can be reduced by additional investment (e.g., additional insulation) then investment demand may be increased by the energy price rise.

Effects on Supply and Productivity

The empirical evidence that has been accumulated suggests strongly that prices are determined, at least in the short run, by a markup over unit costs.[22] If energy prices rise and other input prices do not fall, then domestic product prices will rise by approximately the proportion of energy in total costs. This causes the upward shift in the aggregate supply curve in Figure 2. If wages rise (because of indexing, or for other reasons described below), then the upward shift of the aggregate supply curve will be magnified.

If energy prices rise *relative* to the price of domestic output (if the OPEC producers pursue a policy of maintaining a higher real price of oil), then other factor returns must fall relative to the price of output and relative to the price of oil as well. This change in relative factor prices alters the desired input proportions, factor productivity and even desired output, as a simple example will show.

After the 1974 rise in oil prices, it was reported that oil tankers were running at slower speeds to conserve fuel oil. In this case, tankers were substituting capital services (ship days) and labor (crew days) for energy, and at the same time reducing their flow rate of output (ton-miles per day). As a result of the change in input proportions the average productivity of labor (ton-miles per crew day) and capital (ton-miles per ship day) both fell. These are the effects to be expected in general from changes in input proportions.

If production processes do allow some substitution of other inputs when energy becomes more expensive, then in general the productivity of those inputs which are substituted must fall. We will concentrate on labor, because the

22. *See for instance,* William D. Nordhaus, "Recent Developments in Price Dynamics," in *The Econometrics of Price Determination,* ed. Otto Eckstein (Federal Reserve Board, 1972) and Wynne Godley and William Nordhaus, "Pricing in the Trade Cycle," *Economic Journal,* 82 (September 1972), pp. 853-82. But *see also* Robert J. Gordon, "The Impact of Aggregate Demand on Prices," *Brookings Papers on Economic Activity,* #3 (1975), pp. 613-62.

capital stock is largely fixed and therefore always employed, and because the possibilities for substituting capital for energy appear to be limited in the short run. At a given level of output, with a rise in energy prices, the firm will substitute labor for energy inputs if possible. This will lower the average productivity of labor, since more labor is now being used to produce the same volume of output. The substitution will also lower the marginal product of labor, since the supply of other inputs is now spread more thinly across the labor employed, and each new laborer has fewer other inputs with which to work. For this reason, one would expect the equilibrium (full employment) real wage to fall in terms of the price of the domestic product.

The extent of substitution possibilities and the effect of the rise in energy prices on labor demand and labor productivity have been the area of some recent controversy. Robert Rasche and John Tatom argue that there is considerable substitutability of labor and energy in production, with a consequent impact on labor demand and average labor productivity.[23] Rasche and Tatom estimate a Cobb-Douglas production function for the output of the U.S. private business sector in terms of inputs of capital, labor and energy:

$$Y = Ae^{rt} K^{1-a-B} L^{a} E^{B}$$

The estimates that they find are $a = .65$ and $B = .12$, which, if the Cobb-Douglas form is correct, should also be the shares of labor and energy in total costs. The Cobb-Douglas form imposes considerable substitutability between energy and labor, and the change in labor demand in production would be $\frac{B}{a+B}$ times the change in the relative price of labor. From 1972 to 1977 the price of energy relative to labor rose by 78 percent;[24] this would indicate an increase in labor demand at a constant level of output of about 12 percent, and a corresponding fall in the average productivity of labor.

Rasche and Tatom's conclusions of considerable substitution possibilities for energy and the substantial effect of a rise in energy prices on productivity have been challenged by both George Perry and Edward Denison.[25] The challenges have been on two grounds. Rasche and Tatom did not have information on energy inputs, and instead used an equilibrium energy demand relationship involving relative prices. Their 12 percent estimate of energy's share in total costs is much higher than the 4 to 5 percent which others have found. This would overstate the effect on labor demand considerably. (Substitution for $B = .05$ and $a = .70$ would reduce the increase in labor demand at constant output to

23. Robert Rasche and John Taton, "Energy Resources and Potential GNP," *Federal Reserve Bank of St. Louis Review* (June 1977), pp. 10-24.
24. Wholesale price index, fuels, power and related products, divided by average hourly earnings in manufacturing adjusted for overtime and inter-industry shifts. Council of Economic Advisers, *Economic Report of the President 1979.*
25. *See* Perry, "Potential Output," and E. Denison, "Explanations of Declining Productivity Growth," *Survey of Current Business,* Vol. 59 (August 1979), pp. 1-24.

5.2 percent.) Perry and Denison also argue that the Cobb-Douglas function overstates the degree of substitutability between labor and energy.

Perry builds a time series of business fuel consumption per unit of output and estimates that it fell by 10.2 percent between 1973 and 1976, while the price of energy rose relative to output by 57 percent over the same period. He then estimates the trend of energy use per unit of output from 1949 to 1973, and attributes one-half to two-thirds of the 10.2 percent reduction to trend changes. Much of the rest he attributes to elimination of non-productive energy use, and concludes that possibilities for substitution away from energy toward labor, and therefore possibilities of a fall in the average product of labor, are quite limited.

The calculation of energy input is an important step in the right direction, but Perry probably errs in his calculation of the trend effect. Energy use per unit of GNP can be easily calculated, and this ratio did fall steadily in the post-war period, until about 1965. But then a sharp reversal occurred. Energy consumption rose by 5 percent annually from 1965 to 1970 while GNP grew by 3.2 percent per year. The reasons for this reversal are not completely understood, but much of the change can be attributed to the failure of electricity generation to improve its energy conversion ratio after 1965.[26] Therefore it is not clear what, if anything, should be subtracted from (or added to) the 10.2 percent decline in business energy use per unit of output, but it appears much more likely that possibilities for substitution of labor for energy exist in the short run.

Other econometric estimates indicate some possibilities for substitution, but lower than those of a Cobb-Douglas function. Berndt and Wood estimate a partial elasticity of substitution between labor and energy of .65 which, if energy's share in costs were 5 percent, would indicate an increase in labor demand per unit of output of $(.78) \cdot (.05) \cdot (.65) = 2.54$ percent. Edward Hudson and Dale Jorgenson, using a sectoral model which emphasizes energy, find that real GNP fell by 3.2 percent from 1972 to 1976 due to the increase in energy prices, while labor demand declined by only 0.6 percent (or 0.5 million jobs), and "as a consequence, productivity growth fell substantially over the period 1972-1976."[27] The increase in labor demand per unit of output comes from two sources in their model: the substitution of labor for energy in each sector; and the shift in final demand from energy–intensive toward labor–intensive industries.

The substitution of labor for energy may be the key to the recent changes in productivity growth, the topic examined by Denison:

26. *See* Joel Darmstadter, "Energy," in *Population, Resources, and the Environment,* ed. Commission on Population Growth and the American Future (Washington, D.C.: GPO, 1972).
27. Edward A. Hudson and Dale W. Jorgenson, "Energy Prices and the U.S. Economy 1972-1976," Harvard Institute for Economic Research, Discussion Paper #637, pp. 1, 29.

> The growth rate of National Income Per Person Employed (NIPPE) fell from 2.43 percent in 1948-1973 to -.54 percent in 1973-1976 . . . . According to my estimates there is no unexplained retardation in the rate of growth of productivity until 1974, and the drop in the rate that started at that time was abrupt and large. I consider this timing an important clue in any attempt to unravel the mystery surrounding the productivity slowdown.[28]

Denison rejects the rise in energy prices as the explanation for the productivity break, based largely on Perry's results. As I have said above, I find Perry's estimates inconclusive, and consider the question still open.

One may be tempted to conclude that since greater substitutability of labor for energy in production involves a greater fall in labor productivity, the more substitutability one has, the worse off one becomes. This conclusion would be incorrect. The above discussion on demand effects stressed the distinction between output and income that goes to domestic factors. The smaller the substitution possibilities, the greater the fall in income received by non-energy factors of production when energy prices rise. It is the desire to produce at lower cost that leads to substitution in production, and in the U.S., substitution leads to a reduction in payments to (largely foreign) energy.

The substitution of labor for energy can also play an important social role, by cushioning the unemployment effects of the fall in output. Because substitution possibilities exist, the effects of the rise in energy prices and reduction in output can be spread across the labor force. More people can continue to work, but each is paid slightly less in real terms because of the fall in productivity, just as one could share unemployment by reducing hours and dividing up the available work.

Rasche and Tatom and others have noted that employment has recovered much faster from the 1974-1975 recession than from previous ones. This is an indication that labor substitution (taking place with some lag) alleviated the unemployment effects of the recession.[29]

Effects on Potential Output and Growth

If firms use less energy to produce their output, then when all other inputs (capital, labor) are fully employed, the level of total output will be reduced, just as conservation of fuel in our tanker example lowered the transportation output of the ship. If one defines potential output as the output of cost-minimizing firms when all domestic resources are fully employed, then poten-

28. Edward Denison, "Explanations of Declining Productivity Growth," pp. 4-5.
29. Robert Rasche and John Tatom, "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," *Federal Reserve Bank of St. Louis Review* (May 1977), pp. 2-12.

tial output falls as a result of the increase in the relative price of imported energy. (The reader is reminded once more, however, of the distinction between output and income when energy prices change.)

Calculations of potential, or "high employment" output have conventionally been made using an empirical relationship between employment and the rate of growth of output known as Okun's law. Substitution in production would alter the relationship between labor and output, and thus affect the calculation of potential output. This would have important implications for analyzing fiscal policy, since fiscal policy is determined by government expenditures and receipts at potential output, rather than at current output. It would also have important implications for determining how close the economy is to full utilization, and therefore to inflation (although in this case the rate of unemployment is an alternative, and preferable, measure).

Rasche and Tatom, along with Perry, examine the issue of potential output and reach opposing conclusions. Rasche and Tatom find potential output increased by only 6 percent from 1973 to 1976, while the Council of Economic Advisers' measure indicates that potential output rose by 11 percent[30] during this period. Perry finds essentially no change in the estimate of potential output due to the rise in energy prices since, for the reasons reviewed above, he finds essentially no substitution away from energy.

The extent to which potential output dropped due to the rise in the relative price of energy is one issue. An equally important issue is what will happen to the path, or growth rate, of potential output. An increase in energy's relative price leads to a fall in the real return on capital, and therefore a lower demand for investment. In addition, if capital and energy are complements, then the rise in energy prices lowers the demand for capital services in production and further depresses the rate of return on the existing capital stock. As the labor force grows, the labor intensity of production will increase. This will raise the marginal product of capital, and raise investment demand. Thus investment will recover from a rise in energy prices but only after a period of slow growth in output and productivity. If there is no future change in the relative price of energy, then the previous rate of output growth will be restored. Models which assume a rising real price of energy produce a permanently lowered output growth rate.

Effects on Inflation

If wages and other factor returns were fully flexible, there would be no necessity for a rise in the general price level with a change in the nominal price

30. *Ibid.*, p. 20.

of energy. Other factor returns could fall sufficiently to allow product prices to fall; this would maintain the same level of a composite price index. If other prices do not fall, then a rise in the price of energy relative to other prices can be accomplished only through a rise in the general price level. Much of the extraordinarily high rate of inflation in 1974 can be described in this fashion, as an adjustment to the rise in oil prices in the first quarter.

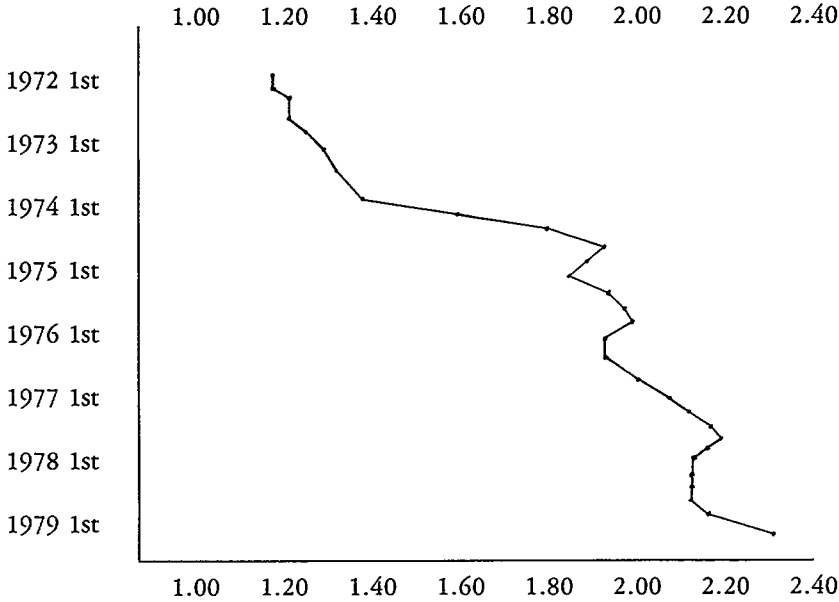
One can draw a logical distinction between the impact effect of the rise in energy prices on the prices of other goods, and any inflationary *process* which may or may not arise from the relative price change. In practice it is difficult to maintain this distinction, for the cost increases caused by the rise in energy prices may take some time to pass completely through into the prices of other goods. Prices of direct energy use (e.g., gasoline) and goods with a very high energy or petroleum content (e.g., petrochemicals, fertilizers) would rise quickly. Prices of other goods might respond to increases in costs from direct energy use in production, but the response to the increased energy costs of intermediate good inputs would be slower. Cost increases in the production of capital goods would be the slowest to pass through into costs of finished consumer goods.

The adjustment time would depend to a greater extent on how quickly energy prices facing energy users rose. For the industrial countries, the relative price of energy rose very quickly and reached its highest point in the first quarter of 1974 (Figure 1). From then until 1979, inflation and the depreciation of the dollar lowered the relative price of energy for Europe and Japan, easing the adjustment to the 1974 rise.

In the United States, prices paid for energy did not rise by the full extent of the OPEC price increase, because price controls on domestic oil and gas production kept prices down, and because the necessity for rate hearings delayed the increase in electricity prices. Over time, average prices for energy increased as cost pass-throughs in electric generation were allowed, as price controls on natural gas production were relaxed, as more of United States oil production passed into uncontrolled categories, and as the United States imported a higher fraction of its total energy use, for which it paid the higher world price.

The wholesale price index for fuels, power and related products relative to the GNP deflator (a general index of goods and services prices) is plotted in Figure 4. In contrast to the relative price of oil for the industrial countries shown in Figure 1, the relative price of energy in the United States rises continuously through the period. Because this kind of adjustment in energy prices took place in the United States, the OPEC price increases in 1974 were translated into a higher *rate* of inflation in the United States in the latter half of the 1970s.

Figure 4
United States Wholesale Price Index, Fuels and Power
Relative to the GNP Deflator



Source: Citibank Database.

Empirical evidence suggests strongly that prices, even in the short run, are determined largely by unit costs of production. Since roughly two-thirds of costs are labor costs, an inquiry into the effects of the oil price rise in initiating an inflationary process must emphasize the labor market.

The macroeconomic theory of wage determination goes back to A.W. Phillips, who found a long-term relation between the unemployment rate and wage increase in England. The theoretical foundations of the Phillips curve were refined by E.S. Phelps and Milton Friedman, who argued that real, and not nominal, wages were at issue in the bargaining and wage determination process. While unemployment might affect the path of wages, inflation that was expected by all parties in the bargaining process would result in equivalent wage increases.

In a simple macroeconomic model with a single commodity price there is no difficulty in defining "the real wage." A rise in energy prices complicates the definition, for the energy price increase is a change in relative prices, or a "terms-of-trade" change, which introduces at least two goods into the real wage definition.

The domestic producer is interested in his cost of labor relative to the price of his product, and defines the real wage in this fashion. We argued above that a rise in the price of energy relative to the price of the product would require a fall in the wage relative to the product price. For the producer the real wage, in terms of current wages and prices, is now too high.

The wage earner is concerned with his wage in terms of the goods he buys, including energy. For the wage earner, with the rise in energy prices, the current real wage is too low.

To illustrate this point, consider the price changes which occurred in the United States. Between 1973 and 1974, the implicit deflator for personal consumption expenditures (a consumption basket index) rose by 10.81 percent while the GNP deflator (a domestic product price index) rose by only 9.66 percent — a difference of 1.15 percentage points. If no substitution away from energy in production is assumed, it is possible to net out the increased production expenditure for energy, as Robert J. Gordon has done. His GNP price index net of food and energy rises by 7.1 percent from 1973 to 1974, or 3.7 percentage points less than that of the personal consumption deflator.[31]

The question of which real wage definition controls the wage-setting process is therefore crucial for determining whether a rise in the relative price of energy initiates a round of wage-price inflation.[32] There are reasons for believing that changes in the real wage, defined in terms of a consumption price index, determine at least a part of wage changes, and therefore that an increase in the relative price of energy leads to a round of inflation.

The most straightforward reason for thinking that the consumption real wage determines wage change is wage contract indexation, almost all of which is done on the basis of a consumption price index. Of the 9.7 million workers the Labor Department estimates are covered by major collective bargaining agreements, some 5.8 million (60 percent) have contracts with escalator clauses.[33] Most cost-of-living adjustments are based on changes in the Consumer Price Index, the most common of which is a 1 cent per hour increase for each 0.3 or 0.4 percentage point change in the CPI.[34] Indexation is much more widespread in Europe (with the exceptions of France and Germany) than in the United States or Japan, and would therefore make adjustment to a rise in the

31. This series was graciously provided by the author for my work on a previous paper: Robert Dohner, "Real Wage Resistance and U.S. and U.K. Wage Equations," (Massachusetts Institute of Technology, 1979, unpub.).
32. Of course the monetary authority must ultimately "validate" the price increase. The failure of the money stock to rise would lead to price increases and a *fall* in output. I think the view that monetary authorities have this much independence, and do not react to unemployment, is misplaced.
33. Douglas R. LeRoy, "Scheduled Wage Increase and Escalator Provisions in 1978," *Monthly Labor Review* (January 1978), Table 4.
34. *Ibid.*, p. 7.

relative price of energy more difficult.[35] There is also reason to believe that wage changes respond to the consumption price index even in those cases where there are not explicit indexation clauses, either because wage setting follows the pattern of major agreements, or because consumption price changes are issues in the bargaining process.

Should wages rise because of the rise in energy prices, the aggregate supply curve in Figure 3 would shift up further, since rising wage costs increase the supply price at any level of output. Prices would rise, lowering the real wage, and output would fall, raising unemployment. This wage-price spiral would continue until unemployment and disappointed real wage expectations reconcile labor to a new, lower real wage. The policy authorities would be faced with a difficult choice, since a policy of encouraging demand could prolong the inflation process.

The empirical evidence on this kind of wage adjustment process is mixed. Lawrence Klein attributes wage increases in Britain and Scandinavia after 1973 to the rise in oil prices.[36] In contrast Robert J. Gordon, using lagged changes in a price index net of food and energy, and lagged change in a consumer price index, finds that the consumer price index changes do not help to explain U.S. wage inflation. Gordon concludes:

> None of the 1973-1974 inflation in food and energy prices 'got into' wages, and all pre-1971 wage equations that allow any influences of food and energy prices drastically over-predict the cumulative 1971-1976 wage increase.[37]

In another paper, I investigated an alternative model where rates of wage change are determined by previous values of the real wage.[38] The real wage (defined in terms of a consumption price index) does affect wage determination in the United States and the United Kingdom, and equations with lagged real wage terms better explain (in out-of-sample predictions) the behavior of wages in 1974 and 1975. Jeffrey Sachs, in reviewing the trend of real wages after the oil price rise, finds that real wage growth slowed in the United States, providing some scope for demand policies, but that wage growth squeezed profits in Europe and Japan, limiting the scope for increasing output. The effect of the oil price rise in spurring wage inflation is an important and unsettled issue, but the preliminary results, I think, indicate some effect of energy price rises in in-

35. Anne R. Braun, "Indexation of Wages and Salaries in the Developed Economies," IMF Staff Papers 23 (1976), Table 1, p. 238. Braun argues that indexation schemes are designed to protect the lowest-paid worker and therefore have a heavy weighing on foodstuffs and other commodities, making them respond more to commodity price changes.
36. Lawrence Klein, "Disturbances to the International Economy," in *After the Phillips Curve*, ed. Federal Reserve Bank of Boston, Conference Series #19, pp. 84-107.
37. Robert J. Gordon, "Can the Inflation of the 1970s Be Explained?," *Brookings Papers on Economic Activity* 1 (1977), pp. 253-79.
38. *See* Dohner, "Real Wage Resistance."

creasing inflation beyond that required for the energy price adjustment. A more careful modeling of the effects of energy price increases on the wage process would require more explicit attention than macroeconomics has traditionally paid to the institutional arrangements which govern wage change.[39]

Conclusion

If the implications of the analysis are gloomy, it is because the effects of a rise in the relative price of oil are rather gloomy, and impose difficult adjustments upon the consuming countries. The rise in the relative price of oil lowers the real income of the consuming countries, since more of their output is needed to pay for the now more expensive oil. This fall in real income must be distributed among domestic factors of production; and if the factors are unwilling to accept a reduction in their real income, then inflation occurs to reconcile the inconsistent claims on (now lower) national income. The fact that energy use is more expensive affects production decisions, decreasing both output and productivity.

If the relative price of oil rises to a higher level and stays there, then the adjustment is eventually completed. Prices no longer rise because of the rise in the relative price of energy, and incomes begin to grow through investment and technological advance. If the relative price of energy falls due to inflation in the consuming countries, then the adjustment is eased or reversed until the next round of energy price increases. If the relative importance of energy falls on account of substitution over time away from energy use in production or consumption, the effects of the rise in energy's relative price can be permanently moderated.

I will close with a few remarks about economic analysis. The oil price change is a difficult analytical problem because it involves a substantial relative price shift. Traditional macroeconomic models do not describe these effects because the aggregation in those models assumes that relative price shifts do not take place. Recent theoretical models by Gordon (1975), Phelps (1978) and Solow (1979), and by Bruno and Sachs (1979) and Dohner (1978) for open economies have been developed for this purpose, with the substantial benefit of hindsight.[40] Distinctions among output, income, and real income, and the precise definition of real magnitudes (e.g., the real wage) are all extremely important.

39. Jeffrey Sachs, "Wages, Profits, and Macroeconomic Adjustment in the 1970s: A Comparative Study," *Brookings Papers on Economic Activity* (1979, forthcoming).
40. *See* Robert J. Gordon, "Alternative Response of Policy to External Supply Shocks," *Brookings Papers on Economic Activity* 1 (1975), pp. 183-206; Edward Phelps, "Commodity-Supply Shock and Full-Employment Monetary Policy," *Journal of Money, Credit and Banking* 10 (May 1978), pp. 206-21; Robert Solow, "What to Do (Macroeconomically) When OPEC Comes," paper prepared for the NBER Conference on Rational Expectations and Economic Policy, Bald Peak, New Hampshire, 1979; Bruno and Sachs, "Supply vs. Demand Approaches"; and Dohner, "Terms of Trade Changes."

There is also reason to distrust the implications of econometric models, which have been estimated for periods of near constancy in relative prices. One example might be the econometric finding of capital-energy complementarity. With labor a large share of costs, and energy a small and perhaps declining share of costs over much of the postwar period, techniques may have developed to substitute labor for capital, with little regard for energy use.[41] Thus it is not surprising that additional capital use was associated with additional energy use, or that capital and energy would appear as complements in the postwar period. Higher energy prices may well encourage future techniques which substitute capital for energy.

Experience with higher relative prices for energy will improve econometric models, as well as theory. But higher energy prices are so new that econometrics should not substitute for good judgment in analyzing the economic effects of higher energy prices.

41. *See* Clark Bullard, "Discussion," *American Economic Review,* Vol. 68 (May 1978), p. 125.