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John A. Tatom

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FEDERAL RESERVE BANK OF ST. LOUIS
Research Division
411 Locust Street
St. Louis, MO 63102

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ENERGY PRICES, ECONOMIC PERFORMANCE AND
MONETARY POLICY*

John A. Tatom
Senior Economist

Federal Reserve Bank of St. Louis
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Sharp increases in the prices of energy resources in 1974 and 1979-80 have had serious adverse effects on the world economy. The theoretical implications of these energy price changes have attracted considerable attention in recent years. In addition, some analysts have attempted to quantify the extent to which higher energy prices have adversely affected the level of prices, output, productivity, investment, and other economic developments. Nonetheless, considerable differences exist in theoretical approaches and these differences, in turn, have led to differences in conclusions as to the appropriate policy response to major changes in energy prices [see, for example, Gordon (1975) and (1979), Pierce and Enzler (1974), Hudson and Jorgenson (1974) and (1978), Mork and Hall (1979, a and b), Phelps (1978), and Brunner, Cukierman and Meltzer (1979)]. Rasche and Tatom (1977 a,b,c) have conducted several studies that, in addition to formulating a theoretical approach to the economic effects of energy price shocks, provide empirical evidence for the United States supporting their hypotheses. More recently, they (1981) have extended their analysis to five other countries: Canada, the United Kingdom, Germany, France and Japan. Energy price effects on output and productivity in these countries are shown to be comparable to those estimated for the United States.

This paper reviews the theory and evidence developed earlier and extends the empirical analysis to include the Netherlands. The theoretical analysis is summarized in the first section. Then the production function analysis for the United States is reexamined

and extended. In Section III the experience in the six foreign nations is analyzed. The implications of the 1979-80 energy price shock are briefly examined in section IV. Finally, monetary policy actions in all seven countries in 1974 and in 1979-80 are reviewed and contrasted with the theoretical conclusions concerning monetary policy.

I. THE ECONOMICS OF AN ENERGY PRICE SHOCK

A number of propositions about responses to energy price changes have been derived by Rasche and Tatom. Initially, a rise in the relative price of energy resources reduces the economic capacity of energy-using firms and raises their nominal product prices. At an aggregate level, natural and full-employment output are reduced and the general level of prices is raised. Given time to adjust the capital stock, firms will reduce the pace of investment in business plant and equipment, thereby adjusting such stocks to a lower desired capital-labor ratio. Thus, the growth rate of output will temporarily be affected beyond the period of the initial shock.

These results are easily explained. For the individual firm, a rise in the price of a variable factor raises the marginal and average cost of output. Where fixed capital and the variable resource are substitutes, economic capacity (the output rate at which short and long-run average cost are equal) declines. The extent of the decline in capacity output is the product of the share of the factor in total cost and the partial elasticity of substitution between the factor and fixed resources. Of course if this partial elasticity is unity, the elasticity of capacity output with respect to a rise in the variable factor price is simply the negative of its share in factor cost, and equals the elasticity of long-run average cost with respect to the variable factor

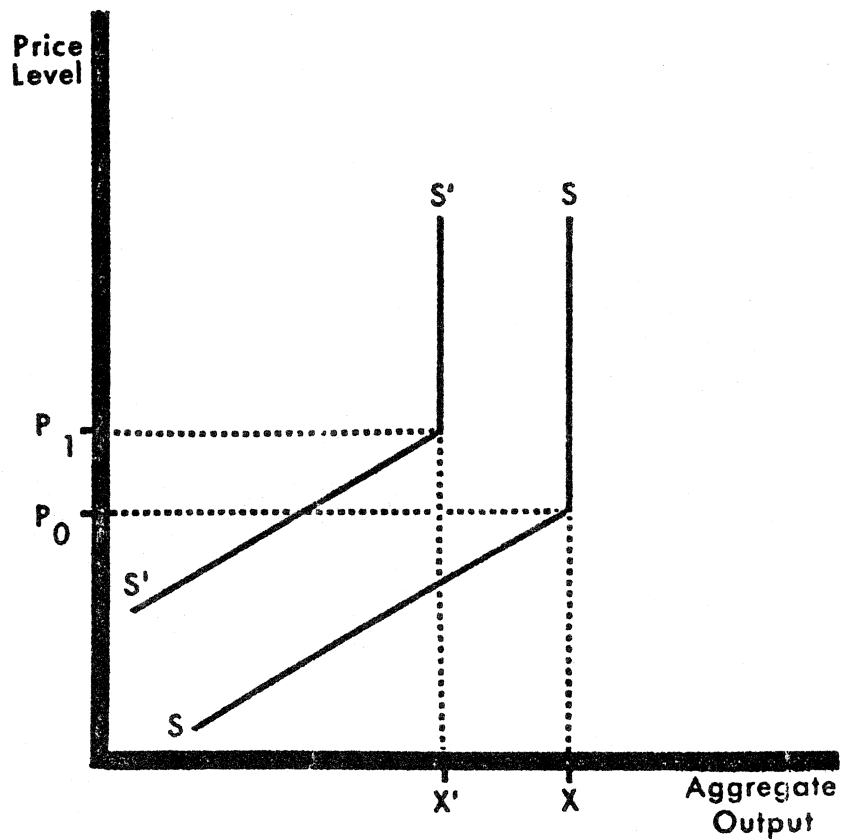
price. These results can be aggregated to yield the same conclusions for the economy's capacity and supply price.

The hypothesis concerning the macroeconomic effects of an increased relative price of energy have also been derived without reference to the capacity analysis. Such a derivation obscures some of the microeconomic detail of the adjustment, but is more straight-forward. Using a standard neoclassical aggregate production function (augmented to include energy resources) and assumptions about resource supply functions, the same results occur for the economy's aggregate supply curve. The principal assumption involved in such a derivation is that the economy is a price-taker in the world energy market.^{1/} The supply of capital goods is taken as given in the short run; in the long-run, it is assumed that the relative price of such goods, determined by supply conditions, is given. For simplicity, the supply of labor is assumed exogenous in both the short and long run.^{2/}

Under these conditions, the effect of a rise in the relative price of energy is to reduce energy use, output, and the relative prices of labor and capital services in the short-run. Essentially, a reduction in energy usage has the effect of reducing the average and marginal productivity of existing capital and labor. Over a longer period of time, the capital stock is reduced since the supply price of capital goods does not decline. The result is that the longer-run output loss and real wage decline are larger than the short run.

This model of aggregate supply, supplemented with the assumption of a money wage rate that is flexible only in an upward direction, yields the aggregate supply analysis provided by Rasche and Tatom (1977a, pp. 7-10). In particular, the aggregate supply curve SS in figure 1 is drawn

Figure 1
The Effect of a Higher Relative Price
of Energy on Aggregate Supply



given the supply of capital, the relative price of energy, a fixed money wage over the upward sloping portion, and a fixed supply of labor over the vertical portion. A rise in the relative price of energy shifts the aggregate supply curve upward and to the left to $S'S'$.

The size of the shift in aggregate supply can also be derived. In particular, the reduction in full-employment output, to X' , and the rise in the minimum price level associated with this output rate can be found. Recall the microeconomic results above. The elasticity of capacity output with respect to a change in the nominal price of energy is $s_e \sigma_{ke}$ (again assuming that the expenditure elasticity of capital is unity), where s_e is the share of energy resources in total cost and σ_{ke} is the partial elasticity of substitution between energy and capital. The elasticity of long-run average cost is s_e , holding other nominal factor prices unchanged. Since long-run average cost equals the nominal price at which each firm would choose to produce capacity output, a one percent rise in nominal energy prices raises the relative price of energy by $(1-s_e)$ percent. Equivalently, a one percent rise in the relative price of energy is associated with a

$(\frac{s_e}{1-s_e})$ percent increase in the price level and a $(\frac{s_e}{1-s_e} \sigma_{ke})$ decline in capacity output. If the partial elasticity of substitution between energy and capital is unity, then the elasticities of price and output are equal in magnitude and opposite in sign. The same results are derived directly for the aggregate supply model in Rasche and Tatom (1977b, p. 14-16) assuming that an aggregate Cobb-Douglas production function is an adequate approximation.

The size of the long-run output and capital stock reduction have also been derived for an economy with a Cobb-Douglas production function. While the short-run energy price elasticity of output is $(-\frac{s_e}{1-s_e})$, the long-run elasticity is $(-\frac{s_e}{s_1})$ where s_1 is the share of labor in output, under the assumption that the relative price of capital services is unaffected by a change in energy prices. The long-run elasticity equals $(1 + \frac{s_k}{s_1})$ times the short-run elasticity so that the output loss greater. The long-run energy price elasticities of the capital-labor ratio and real wage of labor equal that of output.^{3/}

The effect of an increase in the relative price of energy and the appropriate monetary policy response depends on aggregate demand as well as the aggregate supply shift. A standard view of aggregate demand is that it is negatively sloped and unit-elastic in the long-run. These conclusions follow simply when attention is focused upon the quantity theory of money. Given the nominal money supply, an increase in the price level will lead to a equiproportional decline in the level of real output at which the same quantity of money is demanded, unless velocity is affected by the price level. Velocity is not a function of the price level, if money is neutral. Over a short period, however, money may not be neutral.

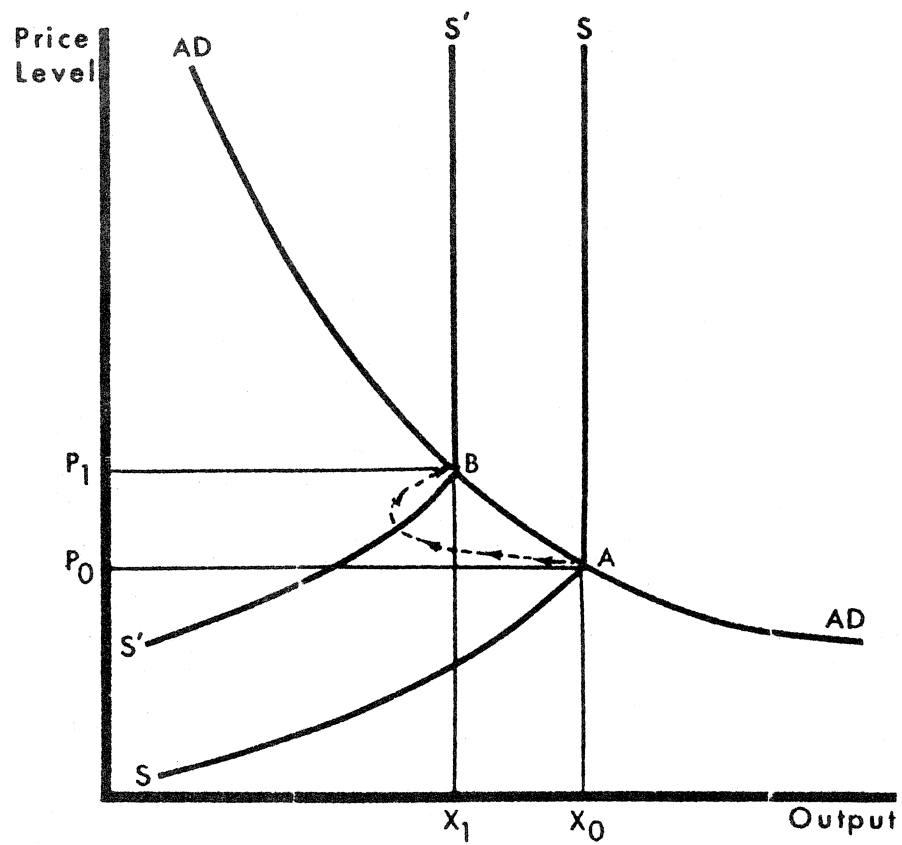
For example, an increase in the price level may lead to a real balance effect, temporarily reducing the demand for real money balances (velocity will be temporarily higher). In this case, the instantaneous aggregate demand curve is price-level inelastic so that the shift in the

aggregate supply curve above will lead to temporary overshooting of the price level at output X' . Full-employment is maintained at output X' , but the price level increases by more than described above, temporarily. If aggregate demand is unit elastic as shown in figure 2, nominal spending demand would be unaffected by the rise in the price level to P_1 and supply-demand equilibrium occurs at point B. This case is consistent with the view that the money stock determines the position of the aggregate demand curve and that, along the curve, total spending is fixed. Of course, if the aggregate demand curve were price-level elastic, then unemployment would occur and the price level would not rise as high as P_1 ; aggregate demand would equal supply along the upward sloping section of the supply curve S' .

The economy may not adjust instantaneously to point B, even if point B is the new equilibrium. For example, price rigidities due to costly information or other transactions costs can keep nominal prices from adjusting quickly. The immediate incentive to cut production and employment indicated by the leftward shift in the aggregate supply curve need not be accompanied immediately by the price level adjustment sufficient to ensure the maintenance of full employment. In this event, disequilibrium GNP will be dominated by the reduction in output before the equilibrium B (and full-employment) is achieved. Consequently, output and prices can move along an adjustment path such as that indicated by the arrow in figure 2. Evidence for the U.S. is consistent with this adjustment process and the hypothesized independence of GNP to energy price changes, once the adjustment is completed [see Tatom (1981a)].

Figure 2

The Effect of a Higher Relative Price of Energy on Output and the Price Level



What can monetary policy do to affect the outcome of an increase in the relative price of energy? Ignoring price rigidities, the appropriate response in the unit-elastic aggregate demand case is to maintain existing policy. In this case, the economy instantly adjusts to point B with minimal price level impact and no effect on unemployment. If aggregate demand is temporarily price-level inelastic, the temporary overshooting of the price level can be avoided by temporarily reducing the money stock, then restoring money to its original desired path. In this case, the inelastic aggregate demand curve is transitory and a given inelastic aggregate demand curve would rotate to the left reaching point B. The extra price surge would ultimately be eliminated without a reduction in the money supply. The policy of reducing and increasing money requires an extreme degree of fine-tuning based on perfect knowledge of the lagged adjustment process, so a neutral policy (optimal ignoring the transition) is a low-cost short-run strategy. The adoption of an accomodative monetary policy^{4/} would, of course, shift the aggregate demand curve to the right, worsening the price level result with no effect on output, except where aggregate demand is price elastic, a possibility that is difficult to rationalize on theoretical or empirical grounds.

If there are price-level rigidities, transitional unemployment may result from a rise in the relative price of energy. This occurs if the supply effect is sufficiently dominant, so that actual output temporarily declines more than potential output. On the other hand, even with price level rigidities, the rise in excess demand can as readily lead to reductions in unemployment. During the transition to equilibrium at point B in figure 2, a policy change to speed adjustment to the

short-run equilibrium would require even more detailed knowledge of disequilibrium dynamics than the simple "go-stop" policy mentioned above. So long as the transition period is brief, and/or the transitory employment impacts are low, it would appear unduly risky to alter the course of policy. For example, in the U.S., an optimal policy response appears to require a sequence of sharp switches from restraint to stimulus to restraint in order to counter the disequilibrium adjustment to an energy price shock (Tatom, 1981a). Such policy shifts are themselves a source of instability rendering the optimality of this course doubtful.

Finally, output can decline more than from X to X' in figure 2, with a permanent decline in employment in one important case. For the economy to produce along the vertical segment of $S'S'$ requires that the real wage of workers decline so as to provide the incentive for employers to continue employment of the existing labor force. If the real wage is not allowed to fall, then fewer workers will be employed and the output level X' will not be achieved [see Gray (1976)]. In effect, potential employment will be reduced since it is determined by the real wage and marginal productivity of labor. Potential output will be lower than X' . So long as the real wage is maintained, the equilibrium unemployment rate is higher.

Under a fixed real wage assumption, the shift from point A in figure 2 due to a rise in the relative price of energy will be higher and to the left of B along a rectangular hyperbola to account for the rise in nominal wages induced by higher energy prices.^{5/} Prices will tend to rise and potential output will tend to fall more than they would if real wages are altered to reflect the lost productivity. The conclusions above for monetary policy are the same, however. Unfortunately, the

policy problem is more frustrating, since unemployment will be higher. It is important to note, however, that just as printing money cannot alleviate the scarcity of energy resources indicated by their higher relative price, so too it cannot alleviate the scarcity of employment created by the maintenance of a real wage set too high to provide full-employment of existing resources.^{6/}

II. THE U.S. EVIDENCE

Direct evidence of the effect of a higher relative price of energy can be obtained from production function estimates. Suppose that output depends upon the use of labor, capital, and energy resources. Assume that energy resources are sufficiently variable so that the first-order condition for its profit-maximizing employment rate holds. Using a Cobb-Douglas production function, the production function may be approximated as:

$$(1) \ln X_t = \beta_0 + \beta_1 \ln h_t + \beta_2 \ln k_t + \beta_3 \ln P_t + \beta_4 t$$

where X_t is output, h_t is hours of all persons, k_t is utilized capital employment, P_t is the relative price of energy, and t is time.

For the Cobb-Douglas case, the β coefficients in (1) have the following interpretation:

$$(2) \quad \beta_1 = \frac{\alpha}{1-\gamma}; \beta_2 = \frac{\beta}{1-\gamma}; \beta_3 = \frac{-\gamma}{1-\gamma}; \beta_4 = \frac{r}{1-\gamma};$$

where γ is the output elasticity of energy, α is the output elasticity of labor, β is the output elasticity of capital, and r is the trend rate of

growth of productivity. Tatom (1979a, pp. 171-173) indicates an alternative specification for equation (1) when the true production function is better approximated by a translog function. Using quarterly data for the private business sector over the period 1955:1-1977:4, the Cobb-Douglas restriction cannot be rejected. Rasche and Tatom (1981) discuss the purported rejection of these restrictions by others.

Rasche and Tatom (1977c) provide evidence that β_3 is significantly negative, as the theory suggests. In that study, annual data for the private business sector were used for the period 1949-75. The estimate for β_3 was -13.60 percent ($t = 5.66$). The results indicated estimates for α of 64.9 percent, β of 23.1 percent, γ of 12.0 percent, and r of 1.6 percent with standard errors of 5.2 percent for α and β , 2.10 percent for γ , and .2 percent for the time trend. The estimate of α was not significantly different from the share of labor in total factor cost. Also, it was shown that the omission of energy from the estimated equation resulted in a significant structural change in the estimate after 1973, a shift that could be rejected when energy is included in the estimation.

Finally, an examination of the potential biases due to the Cobb-Douglas assumption was conducted. The primary result was to show that if the implicit price elasticity of energy demand is too high, then the estimate of the output elasticity of energy would be biased downward and that of labor would be biased upward. Because of the consistency of the estimated output elasticity of labor with the share of labor, we concluded that these biases could not be substantial. Moreover, such biases would not affect the interpretation of β_3 as an unbiased measure of the effect of a higher relative price of energy on output.

Table 1 shows recent estimates of equation (1) for three overlapping periods: 1949-73, 1949-75, and 1949-78. The first two periods are shown because they were examined in the 1977 study. The third period updates the original estimates. In the first two periods, slight changes arise because of minor data revisions. However, none of the major conclusions have changed because of these revisions, nor does the addition of the three additional observations change the results.

The other tests discussed in 1977 were also performed. In particular, it is still the case that without the energy price term, there is a structural break after 1973 that is not present when energy prices are taken into account. It is also the case that we cannot reject the hypothesis that the output elasticity of hours equals the share of labor in each of the three sample periods. The only noteworthy change concerns the possibility of a slowing in the time trend beginning in 1967. This hypothesis was supported in the 1977 paper. When equation (1) was reestimated including such a shift, it was not highly significant; for the 1947-73 period the t-statistic is -1.96, but for the 1949-75 and 1949-78 periods the t-statistic is only 1.5. In the earlier study, a decline of .5 percent per year was significant in the period 1949-75, $t = -2.18$).

It is interesting that the coefficient on the relative price of energy does not rise as the sample period lengthens. Some analysts emphasize the hypothesis that energy is inelastically demanded so that as the relative price of energy rises, energy's share in cost would be expected to increase. Thus, successive increases in the relative price of energy should have greater and greater impacts on output and

TABLE 1

Production Function Estimates
for the U.S. Private Business Sector

| | <u>1949-73</u> | <u>1949-75</u> | <u>1949-78</u> |
|----------------|--------------------|--------------------|--------------------|
| β_0 | 1.5947% (4.83) | 1.5925% (10.96) | 1.5566% (12.35) |
| β_1 | 0.6634 (11.25) | 0.7414 (12.14) | 0.7287 (12.37) |
| β_2 | 0.3366 (5.71) | 0.2586 (4.24) | 0.2713 (4.61) |
| β_3 | -0.1273 (-1.90) | -0.1134 (-4.81) | -0.1085 (-5.50) |
| β_4 | 0.0153 (7.22) | 0.0181 (9.77) | 0.0177 (9.89) |
| $\hat{\alpha}$ | 58.8 (8.59) | 66.6 (12.88) | 65.7 (13.14) |
| $\hat{\beta}$ | 29.9 (5.76) | 23.2 (4.09) | 24.5 (4.46) |
| $\hat{\gamma}$ | 11.3 (2.14) | 10.2 (5.36) | 9.8 (6.10) |
| r | 1.36 (5.76) | 1.63 (10.34) | 1.60 (10.60) |
| \bar{R}^2 | 0.97 | 0.96 | 0.96 |
| S.E. | 0.0079 | 0.0092 | 0.0091 |
| D.W. | 1.68 | 1.45 | 1.64 |
| $\hat{\rho}$ | .66 (4.31) | .59 (3.72) | .57 (3.74) |

prices.^{7/} In effect, these analysts would claim that it becomes more and more difficult to substitute the use of labor and capital to economize on energy costs. The estimates of β_3 , however, do not support this hypothesis.

There are other sources of U.S. evidence on the energy price hypothesis. Tatom (1979a) derives the size of the reduction in the desired capital-labor ratio predicted by the theory for each one percentage point increase in the relative price of energy. The evidence shows that (1) a sharp decline relative to trend did occur from 1973-78 and (2) the decline was of the magnitude indicated by the theory. Moreover, the short-run and long-run effects of a rise in the relative price of energy account for all of the dismal performance of U.S. productivity from 1973-78 [(see Tatom (1979b)]. Karnosky (1976) provides evidence suggesting that energy price increases produced a once-and-for-all jump in the level of prices during 1974. Meyer and Rasche (1980) discuss a price equation which provides direct evidence that the effect of a higher relative price of energy produces an increase in the GNP deflator that is essentially the same as the output elasticity from the production function, a result predicted by the theory above.^{8/} The size and significance of permanent impacts on U.S. prices and potential output have also been established using a reduced form approach for determining GNP, prices and real output [see Tatom (1981a)]. Finally, simple experiments with Okun's Law relationships indicate that during periods of a rapidly rising relative price of energy, either potential output slows or the historical relationship between real GNP growth and changes in the unemployment rate breaks down.^{9/}

The empirical analysis of the hypothesis has been criticized by others and the criticisms have been addressed elsewhere. See, for example, Tatom (1979 b and c), DeLeeuw (1977), Perry (1977), and Denison

(1979). A primary criticism is the use of the Cobb-Douglas function, in part because of the high level of the implied responsiveness of energy use to changes in its price. The potential biases have been examined before (Rasche and Tatom, 1977b) and no evidence of such bias in the estimates has been found. On the other hand, we have questioned (1977a) the extent to which the capital stock estimates based on replacement cost measure the market value of the capital stock following an energy price shock. It is unclear to what extent the energy price coefficient measures the output loss due to economic obsolescence of the capital stock rather than that due to energy use, but of no significance for the theoretical conclusions or the empirical evidence provided.

III. THE FOREIGN EXPERIENCE

Rasche and Tatom (1977a, b, c) strongly supported the hypothesis that the productivity experience in the United States, subsequent to 1973, was dominated by the sharp increase in the real price of energy resources. The analysis above suggests that the data from the United States experience that has become available since then is consistent with the hypothesis. However, as Denison (1979) has noted, the "productivity problem" of the 1970's is not a phenomenon that is unique to the United States. Fortunately for the hypothesis, if there is in fact a world market in energy, neither is the energy shock unique to the United States. The purpose of this section is to discuss the results of attempts to replicate the tests with data from other industrialized countries.

A World Energy Market?

Given the domination of the world energy scene by OPEC, questioning the existence of a world energy market may strike many as foolish. On the other hand, numerous countries, including obviously the U.S., have expended great resources over the past seven years discussing "energy policies", the major thrust of which appears to be how to insulate parts or all of the domestic market from price developments on the world market. Even if one is prepared to argue that such measures are bound to fail in the long run, there always exists the possibility that such efforts could have produced major differences in the impact across countries in a six year period.

The data on wholesale prices of energy in various countries over the past two decades is presented in table 2. All of the indices have been renormalized to a base period of 1970 for comparison. At first glance, there is an amazing similarity in the behavior of the price indices, except in Germany where the energy shock would appear to have been considerably smaller, though not inconsequential. Part of the impact is concealed in table 2 by the rapid adjustment of exchange rates that has occurred in recent years, which in turn reflects different policy responses to the original energy shock. In table 3, the prices of energy are deflated by output prices for each country; the similarity there is even more striking.

A casual review of the record for the U.S. and the six foreign countries is supportive of the view that all countries have shared a similar adverse impact due to energy price developments in the seventies. Tables 4 and 5 show real output growth rates and the rate of price increase, respectively, for each of the seven countries from 1960

TABLE 2
Energy Prices in Various Countries
(1970 = 100.0)

| | U.S. ^{1/} | CANADA ^{2/} | UK ^{3/} | GERMANY ^{4/} | JAPAN ^{4/} | FRANCE ^{5/} | NETHERLANDS ^{6/} |
|----|--------------------|----------------------|------------------|-----------------------|---------------------|----------------------|---------------------------|
| 60 | 90.5 | 97.1 | 79.6 | 90.2 | 98.9 | 78.0 | 97.6 |
| 61 | 91.5 | 97.0 | 77.9 | 89.3 | 98.6 | 78.0 | 91.4 |
| 62 | 91.1 | 96.3 | 77.5 | 90.2 | 100.0 | 78.7 | 91.7 |
| 63 | 90.7 | 93.5 | 79.6 | 90.2 | 99.8 | 80.1 | 94.6 |
| 64 | 88.2 | 93.7 | 81.0 | 90.2 | 98.9 | 79.4 | 88.8 |
| 65 | 89.9 | 92.1 | 86.4 | 92.0 | 100.2 | 79.4 | 84.7 |
| 66 | 92.1 | 92.3 | 89.8 | 92.9 | 99.5 | 80.1 | 90.4 |
| 67 | 94.2 | 93.2 | 91.8 | 94.7 | 99.8 | 80.8 | 90.7 |
| 68 | 93.1 | 95.2 | 95.2 | 99.7 | 100.7 | 83.8 | 90.7 |
| 69 | 95.0 | 97.1 | 94.6 | 90.1 | 98.6 | 88.5 | 85.6 |
| 70 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 71 | 107.5 | 110.1 | 107.9 | 109.2 | 107.4 | 110.8 | 114.7 |
| 72 | 111.7 | 113.1 | 111.9 | 113.6 | 107.4 | 113.4 | 104.2 |
| 73 | 126.5 | 129.1 | 113.5 | 122.9 | 111.5 | 117.6 | 119.8 |
| 74 | 196.1 | 175.6 | 144.3 | 155.1 | 185.3 | 170.7 | 155.2 |
| 75 | 230.8 | 202.3 | 193.7 | 177.7 | 225.7 | 191.6 | 214.6 |
| 76 | 250.1 | 231.5 | 227.2 | 199.7 | 247.9 | 210.5 | 282.2 |
| 77 | 284.6 | 269.3 | 257.5 | 195.7 | 265.7 | 232.9 | 293.3 |
| 78 | 303.7 | 303.3 | 292.7 | n.a. | 250.3 | n.a. | 290.6 |

^{1/}Wholesale price index (Producers Price Index) for fuel, related products and power.

^{2/}Industry selling price index for petroleum and coal products industry.

^{3/}Wholesale price of fuel.

^{4/}Wholesale price of fuel and energy.

^{5/}Wholesale price of fuel and power.

^{6/}Purchase Price of Primary Energy by Industry.

TABLE 3

The Relative Price of Energy in Seven Nations
(1970 = 100)

| | U.S. | UK | GERMANY | FRANCE | CANADA | JAPAN | NETHERLANDS |
|------|-------|-------|---------|--------|--------|-------|-------------|
| 1960 | 115.5 | 114.4 | 125.1 | 119.9 | 117.8 | 110.5 | 144.6 |
| 61 | 116.1 | 107.9 | 119.2 | 115.8 | 117.2 | 109.4 | 133.6 |
| 62 | 114.4 | 104.7 | 115.5 | 118.8 | 115.3 | 112.4 | 131.0 |
| 63 | 113.0 | 104.6 | 112.7 | 106.9 | 110.8 | 110.5 | 130.2 |
| 64 | 108.5 | 105.0 | 109.6 | 101.8 | 110.0 | 109.3 | 114.8 |
| 65 | 108.7 | 107.1 | 108.4 | 99.1 | 106.9 | 110.1 | 104.4 |
| 66 | 108.0 | 107.8 | 105.4 | 97.2 | 103.2 | 107.2 | 106.5 |
| 67 | 107.3 | 107.9 | 106.2 | 94.8 | 100.9 | 105.0 | 103.8 |
| 68 | 102.1 | 107.4 | 110.1 | 94.5 | 100.9 | 105.8 | 100.8 |
| 69 | 99.5 | 102.2 | 96.3 | 93.5 | 100.5 | 102.0 | 89.1 |
| 1970 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 71 | 103.1 | 99.1 | 101.7 | 105.0 | 107.3 | 108.7 | 90.1 |
| 72 | 103.3 | 93.7 | 100.2 | 101.1 | 104.6 | 107.6 | 95.4 |
| 73 | 110.6 | 87.8 | 102.9 | 97.2 | 108.6 | 98.1 | 113.8 |
| 74 | 155.3 | 97.1 | 121.9 | 127.0 | 128.2 | 127.6 | 142.3 |
| 75 | 166.9 | 101.8 | 130.5 | 125.8 | 131.0 | 151.9 | 171.5 |
| 76 | 172.3 | 102.3 | 142.2 | 125.9 | 139.4 | 158.1 | 169.0 |
| 77 | 185.5 | 109.4 | 134.6 | 127.7 | 143.7 | 164.8 | 159.8 |

TABLE 4

Output Growth in Seven Countries

| | 1960-73 | 1974 | 1975 | 1976-78 ^{1/} |
|----------------|----------------------------|------|------|-----------------------|
| Canada | 5.4 (1.8) | 3.6 | 1.3 | 3.9 (1.5) |
| France | 5.9 (0.9) | 2.8 | 0.3 | 3.6 (0.9) |
| Germany | 4.8 (2.3) | 0.4 | -1.9 | 3.7 (1.3) |
| Japan | 10.7 (3.0) | -0.6 | 1.4 | 5.8 (0.6) |
| Netherlands | 5.1 ^{2/} (1.7) | 3.6 | -1.8 | 3.5 (1.9) |
| United Kingdom | 3.3 (1.9) | -1.5 | -1.7 | 2.7 (1.0) |
| United States | 4.0 (1.9) | -1.4 | -1.3 | 4.9 (0.9) |

^{1/} Average of annual rate of increase in GNP (GDP in France and the UK) standard deviation in parentheses.

^{2/} 1961-73.

SOURCE: "International Economic Conditions," Federal Reserve Bank of St. Louis.

TABLE 5

The Rate of Increase in Prices in Seven Countries

| | 1960-73 | 1974 | 1975 | 1976-78 ^{1/} |
|----------------|----------------------------|------|------|-----------------------|
| Canada | 3.5 (2.1) | 15.3 | 10.7 | 7.8 (1.7) |
| France | 4.4 (1.8) | 11.6 | 13.1 | 9.6 (0.8) |
| Germany | 4.2 ^{2/} (2.0) | 6.8 | 6.7 | 3.6 (0.4) |
| Japan | 5.5 (1.9) | 20.1 | 8.6 | 5.3 (0.5) |
| Netherlands | 5.9 ^{2/} (2.3) | 9.2 | 11.2 | 6.9 (1.8) |
| United Kingdom | 4.8 (2.9) | 17.0 | 27.7 | 11.9 (1.8) |
| United States | 3.3 (1.7) | 9.7 | 9.6 | 6.2 (1.1) |

^{1/} Average of annual rate of increase in GNP deflator (GDP deflator for UK) standard deviation in parentheses.

^{2/} 1960-73.

SOURCE: "International Economic Conditions," Federal Reserve Bank of St. Louis.

to 1978. In 1974-75, the growth rate of real GNP fell sharply in each of the countries (table 4). In 1974, the rate of increase of prices rose sharply in each of the seven countries. In some cases the increased pace of price increases was reflected in the 1975 data, but subsequently the inflation pace abated in all seven countries.^{10/}

The conclusion from this review is that many countries have been exposed to a change in the relative price of energy of roughly the same order of magnitude. Given this conclusion, our hypothesis that the change in the price of energy has been a major factor in the productivity experience in the U.S. should be replicable in the experience of other countries. The estimates for these countries are discussed individually below.

Canada

The Canadian data are the most complete and the most comparable to the U.S. data of any of the countries studied. The Canadian equivalent to the Private Business Sector concept in the U.S. data is the concept of Commercial Industries. Data exist for this sector on real GDP at factor cost, employment, and hours of work annually since 1946. Data on the net real stock of nonresidential structures and machinery and equipment were graciously provided by Statistics Canada.^{11/} The major difficulty encountered is that there does not exist a deflator for the commercial industries sector. The approximation to the deflator for this sector employed here is the deflator for all sectors excluding the public administration and defense sector and the community services sector.

The sample period for the Canadian regression is 1956-78. The starting point was determined by the availability of the industry selling price index for the petroleum and coal products industry.^{12/} Starting at this point necessitated some decision on a capacity utilization series, since the quarterly capacity series published by Statistics Canada starts in 1961. The annual averages of the published capacity utilization series were extrapolated backward using the following regression of capacity on the unemployment rate, a time trend, and a dummy variable to compensate for the 1966 change in the Canadian unemployment rate definitions:

$$(9) \quad CU = 38.94 + 1.00 * TIME - 3.61 * UR - 4.01 DUM$$

$$(10.94) \quad (.20) \quad (.47) \quad (1.94)$$

$$R^2 = .84 \quad SEE = 1.88 \quad D.W. = 1.17$$

where CU is capacity utilization (on a base of 100), UR is the unemployment rate (in percent), T is a time trend starting at 46 in 1946 and DUM is a dummy variable assuming a value of 1.0 in 1966 and subsequent years. The numbers in parenthesis under the estimated regression coefficients in this and subsequent regressions are the estimated standard errors.

Using these data, the following Cobb-Douglas production function was estimated for Canadian Commercial Industries:

$$(10) \quad \ln X = 2.07 + .76 \ln h + .24 \ln k - .11 \ln P + 0.27 TIME$$

$$(.26) \quad (.08) \quad (.08) \quad (.04) \quad (.004)$$

$$R^2 = .991 \quad D.W. = 2.04 \quad SEE = .012 \quad \rho = .51$$

where h is total hours worked in commercial industry, k is the beginning of period capital stock multiplied by the capacity utilization rate, and

p is the relative price of energy. This result is very similar to the results obtained for the United States. The implied output elasticities of labor, capital and energy are .61, .27, .12, respectively. For comparison, the share of labor in total commercial industries in 1971, base year for the real GDP data and hence the only year for which we can obtain an accurate measure of the share, is .594. Therefore, the labor share implied by the functional form and the estimated parameter values seem to be very consistent with the actual labor share data.

Needless to say, the sample period for this regression is relatively short. Taken individually, the ultimate test of the hypothesis for Canada will have to wait until the data are available to extrapolate through the 1979-80 experience. Collectively, this independent replication of the U.S. result considerably strengthens the proposition.

Other Countries

The data base available on which to test the proposition for other countries is even more limited than that of Canada. The best consistent set of published data that we were able to find is the National Accounts of OECD countries which covers only the period 1960-77.^{13/} For both Germany and the United Kingdom, Gross Domestic Product by industry of origin is available in current and constant currency units from 1960 on. Earlier OECD and national publications that provide data for the 1950's do not provide the information in a consistent accounting framework, and in the case of Germany, exclude both the Saarland and West Berlin. The OECD accounts measure that most

closely approximates the private business sector concept for the United States is the Gross Domestic Product originating in all industries plus imputed bank services charges, less imputed rent for owner occupied housing.^{14/} In the German case, neither the OECD nor the Statistisches Bundesamt publishes a separate series on the imputed rent for owner occupied dwellings. Thus, in this case, the output measure includes imputed rental income.

Germany

The remaining data series for Germany were constructed from a variety of sources. The major items to note are that there are several choices for an hour of work measure, and lacking any information with which to choose between two of these, regressions using different measures are presented. Second, the only measure of capacity utilization that we have been able to obtain for Germany is the Wharton index.^{15/} After some experimentation with this index, it was concluded that it is inappropriate to apply the strict restriction of the Cobb-Douglas form to the independent variable in the form of utilized capital stock per total hours worked. Consequently, in addition to this variable, an additional regressor is added, the log of the Wharton capacity utilization rate.

The first regression, using an index of weekly hours of Arbeiter in der Industrie published in the Statistisches Jahrbuch is:

$$(11) \quad \ln X = -4.22 + .77 \ln h + .23 \ln k - .04 \ln P - .11 \ln CAPW + .037 \text{ TIME} \\ \quad \quad \quad (.31) \quad (.09) \quad \quad (.09) \quad \quad (.02) \quad \quad (.05) \quad \quad (.006)$$

$$R^2 = .998 \quad D.W. = 2.31 \quad SEE = .0066 \quad \rho = .17$$

while a second regression, using an index of hours per week in German

manufacturing published in the OECD Main Economic Indicators is:

$$(12) \ln X = -3.87 + .68 \ln h + .32 \ln k - .05 \ln P - .16 \ln CAPW + .031 \text{ TIME}$$

$$(.35) (.10) \quad (.10) \quad (.02) \quad (.06) \quad (.006)$$

$$\bar{R}^2 = .998 \quad D.W. = 2.28 \quad SEE = .0076 \quad \rho = .06$$

The second of these two regressions, though it has a slightly higher standard error of estimate, would seem to be the more satisfactory. Both equations are characterized by what appears to be relatively high output elasticities of hours worked. In the first equation the implied labor share is .74, while in the second it is .65. This result appears to be similar to earlier studies of Germany that used Cobb-Douglas production functions, completed prior to the increase in energy prices.^{16/}

In both equations the estimated coefficient on the relative price term is considerably smaller than that found for either the U.S. or Canada; roughly, only one half as large as in the latter cases, but in both cases the "t" ratio on this variable is in excess of 2.0. This smaller coefficient is consistent with the notion, certainly true at the retail level, that historically energy has been relatively more expensive in Germany than it has been in North America.

Again, in all fairness it should be remembered when judging these estimates in isolation that there are very few degrees of freedom. Second, these results, in contrast to those that we have reported for the U.S. and Canada, reflect some degree of data mining. Thus, the true test of the particular case will require some post-sample experience. Nevertheless, it is somewhat surprising, and testimony to the strength of the hypothesis, that any effect of the relative price term showed up at all in the German data. The German productivity data, measured on the concept used, do not exhibit the plunge in 1974 that is characteristic

of other countries. In addition, as noted in table 3, there is considerably less variation in the relative price term for Germany than for other countries. This appears in large part due to the strong currency position of the DM in the 1970's, which in turn has resulted from the resistance of the German monetary authorities to inflationary policies.

United Kingdom

The data for the United Kingdom indicate the same type of sharp decline in productivity trends in the private economy in 1974 that characterizes the United States and Canada. Furthermore, it is apparent that standard Cobb-Douglas production functions such as those estimated by the OECD using data prior to this time, no longer meaningfully describe productivity developments in the United Kingdom.^{17/} Obtaining a meaningful Cobb-Douglas production function even after allowing for the relative price of energy inputs proved somewhat troublesome.

The difficulty, surprisingly, was not in obtaining an estimate of the relative price coefficient that was significant and consistent with the other countries examined. The estimate of this coefficient in various experiments was remarkably constant and of the order $-.10$. Instead, the common characteristic of the various equations estimated was that as data points were added beyond around 1971, the estimated coefficient of the capital-labor ratio tended to rise rapidly, and the estimated coefficient of the time trend tended to fall sharply. It is not difficult to produce estimates of the former that exceed one and of the latter than are less than zero. The data seem to suggest that the time trend that was present in the 60's dropped dramatically in the

70's. A reading of the various OECD annual surveys for the United Kingdom during the 70's suggests the same interpretation. Those surveys tend to focus discussion on the manufacturing sector alone, and suggest 1970 as a watershed. A number of time trends that terminate at various years in the early 1970's were examined. There do not appear to be large difference among these equations; the ones reported here have a time trend that proceeds through 1972 and terminates in 1973, approximately coincidental with the introduction (November 1972) of stage I of price and income controls. The estimated relationship for the period 1960-77 is:

$$(13) \quad \ln X = 4.38 + .56 \ln h + .44 \ln k - .09 \ln P - .014 T72 - .11 \ln CAPW$$

$$(.64) (.08) \quad (.08) \quad (.06) \quad (.004) \quad (.08)$$

$$R^2 = .993 \quad D.W. = 2.04 \quad SEE = .0089 \quad \rho = .17$$

where T72 is a time trend that ends after 1972. In this equation, the implied labor share is .52, which compares with an actual labor share in the private economy during the early to mid 1970's that ranged from .64 to .70.^{18/} Furthermore, the implied output elasticity of capital at .40 compares favorably with that of 1973 OECD study at .38 over a sample period that did not involve the period of inflation in energy prices. Other than 1975, when the equation has a relatively large overestimate of productivity, it tracks the post-1972 period extremely well. The estimated coefficient of the relative price of energy at -.09 is somewhat smaller in absolute value than results that obtained in North America, but larger in absolute value than found in the German data. It is also the case that the significance of this estimated coefficient is lower than reported for other countries.

France

In the case of France as well as Japan and the Netherlands, the required data on gross domestic product was not available in the OECD statistics. In these three countries production functions are estimated for the manufacturing sector.^{19/} Data on capital services are also difficult to obtain. The manufacturing capital stock estimates were kindly provided by Jacques Artus.^{20/} The Wharton Index of capacity utilization is used to measure capital employment. (See footnote 15). The measure of the relative price of energy was found by deflating the wholesale price index for fuel and power by the Gross Domestic Product deflator for France. The sample period is 1959-1977 due to data limitations.

The estimated production function for France is:

$$(14) \quad \ln X = -1.89 + 0.73 \ln h + 0.27 \ln k - 0.11 \ln P + .040 t$$

| | | | | |
|-------|-------|-------|-------|---------|
| (.88) | (.12) | (.12) | (.05) | (.0076) |
|-------|-------|-------|-------|---------|

$$R^2 = .997 \quad SEE = .0140 \quad D.W. = 1.96 \quad \rho = .65$$

The implied energy elasticity of output is 10.1 percent, while that for labor is 66.0 percent. When the capacity utilization measure is included, as a separate variable, it is not significant and does not affect the other coefficients.

Japan

A production function for the manufacturing sector is estimated for Japan. Indices for output and hours are obtained from the Offices of Productivity and Technology, U.S. Bureau of Labor Statistics. The capital stock series is that constructed by Jacques Artus. The Operating

Ratio in Manufacturing from 1959 to 1977 was obtained using data from the Bank of Japan, Economic Statistics Annual (1977 and various prior issues), and Economic Statistics Monthly (September 1979). The ratio was constructed (1970 = 100) by chaining available series that are based on alternative base years, since the reported series using this base year could only be found for 1967-76. Other reported series with different base years were available for overlapping periods so that the series could be extrapolated. The wholesale price of fuel and energy is available in the Japan Statistical Yearbook and is rebased to 1975 = 100. To measure the relative price of energy in the manufacturing products (all commodities, 1970 = 100), from the Economic Statistical Annual. The latter series is available from 1967-78, but the wholesale price index for all manufactured commodities is available from 1959 to 1978. Using twelve overlapping years, the producer price index was extrapolated back to 1959 using a log-linear regression.

In addition to data limitations, the appropriate specification of the production function is a serious problem for Japan. This has been noted by other analysts. For example, in The Measurement of Domestic Cyclical Fluctuations the authors note problems in estimating the production function which arise due to "labor hoarding" in Japan, and lagged adjustment of output to factor inputs. In that study, lagged output and lagged hours are included to capture these effects.

In the estimation of the manufacturing production function for Japan, both variables were included and they are significant. A constant term is not significantly different from zero, so it is omitted. The

estimated equation (OLS) for 1959-77 is:

$$(15) \quad \ln X_t = 0.524 \ln X_{t-1} + 0.121 \ln k_t + 0.875 \ln h_t - 0.577 \ln h_{t-1} \\ (0.096) \quad (0.051) \quad (0.226) \quad (0.252) \\ + 0.551 \ln CAP_t + 0.026 T - 0.114 \ln P_t \\ (0.136) \quad (0.010) \quad (0.065)$$

$$\bar{R}^2 = 0.99$$

$$SEE = 0.0155$$

$$D.W. = 1.59$$

The production function parameters are found by equating $\ln X_t$ with $\ln X_{t-1}$ and $\ln h_t$ with $\ln h_{t-1}$. When this is done the output elasticity of the relative price of energy is 0.239 and its standard error is 0.081. This estimate is larger than the coefficient on the relative price of energy in the other five countries. The estimate of the implied output elasticity of energy is 19.3 percent (s.e. = 0.075). The operating ratio is significant in the equation. The estimates of the output elasticity of labor and capital are 0.77 and 0.31, respectively.

We have some misgivings about this production function estimate, primarily because of the quality of the capital stock and utilization data used in the estimation. In addition, this equation is estimated with very few degrees of freedom (12) because the constant returns to scale restriction does not hold and because of the dynamic structure of the equation. The equation is stable, however, unlike more simple production functions. The equation above was estimated over the period ending in 1973 and yielded essentially the same results. An F-test ($F_{4,12} = 1.63$), on the addition of the 1974-77 observations, indicates that the hypothesis of structural change can be rejected. Again, however, this test has a very small number of degrees of freedom.

Netherlands

The growth rate of output per hour in manufacturing declined sharply in the Netherlands following the surge in world energy prices in 1974-75. From 1960-73 the trend growth rate in output per hour was 7.6 percent, but this fell to a 4.8 percent rate from 1973-78. This decline is less significant than in some other nations but is supportive of the theory nonetheless.^{21/} As in many other nations, real nonresidential fixed investment slowed as well. From 1965 to 1973, capital formation was at a 4.5 percent rate; from 1973 to 1976, this rate declined to -2.3 percent.

In estimating a production function for the Netherlands, special consideration is given for the importance of energy in output. In particular, the contribution to trend growth due to breakthroughs in the natural gas sector beginning in 1964 are included. In a closed economy, major innovations in the supply of energy resources would be expected to be mirrored in energy prices. In an open economy, however, this effect is more limited and energy price developments alone cannot capture the contribution of innovations to productivity.

Data for output and hours in the manufacturing sector are used with Artus' estimate of the Netherlands' stock of capital in manufacturing. To measure the employment rate of capital, a proxy variable is used. It is assumed that the utilization rate of capital, c_t , is a log-linear function of the employment rate, measured as actual employment divided by potential employment. This measure is extremely crude and may well capture other cyclical influences than simply variations in capital employment.^{22/} The relative price of energy used

here is constructed by deflating the purchase price of primary energy by the price deflator for enterprise sector output.^{23/} The sample period for the manufacturing production function is 1955-78. A constant term is not significantly different from zero, so it is omitted. The estimated equation is:

$$(16) \quad \ln X = \frac{0.57}{(.01)} \ln h + \frac{0.43}{(.01)} \ln K + \frac{0.021_t}{(.002)} \\ + \frac{0.024}{(.003)} T76 + \frac{3.29}{(.72)} \ln c - \frac{0.10}{(.02)} \ln P$$

t

$$\bar{R}^2 = 0.94 \quad \text{S.E.} = 0.0156 \quad \text{D.W.} = 2.00 \quad \rho = 0.31$$

where T76 is a time trend that begins in 1964 and ends in 1975. The timing of this trend corresponds to the period of rapid expansion of energy output in the Netherlands; the trend is truncated in 1975 due to the new energy policy.^{24/} The major shortcoming of equation (16) is the relatively low estimate of the output elasticity of hours (0.52). The coefficient on the relative price of energy is essentially the same as that observed in many other countries and is significantly negative.

An attempt was made to estimate a production function for the enterprise sector in Holland. Several major aspects of these data cloud the credibility of such estimates. First, net capital stock estimates were constructed following Magnus (1979) procedure that assumed a 3 percent depreciation rate for structures, a 6 percent depreciation rate for machines, and a 10 percent depreciation rate for transport equipment. The implied depreciation rate for the net capital stock in Holland averages about 5.42 percent for the period 1950-78. This rate is very low when compared to the U.S.. The implicit depreciation rate in the U.S. net capital stock data is about 10 percent [see Rasche and Tatom (1977c)] while structures investment has been a larger component of

nonresidential fixed investment in the U.S. than it is in Holland. For example, in the U.S. nonresidential fixed investment in structures averages at 31 percent of the total from 1974-78 while it was only 22 percent of the total in Holland. To the extent that the depreciation rate is too low, the growth of the net capital stock is likely to be overestimated.

A second questionable aspect of the Netherlands data concerns the behavior of the relative price of energy series used above for the manufacturing sector and in estimates for the enterprise sector. Since this series is based on the purchase price of primary energy by industry, the covered energy component is narrower than in most of the other countries examined here. The relative price series is more U-shaped than for other countries and more volatile. The most noteworthy curiosity is that from 1975-78 the relative price of energy was sharply lower (12.5 percent, on average) than it had been throughout the 1950s. From 1950-57 the relative price of energy rose 27 percent, a pattern which is not apparent in other nations. Subsequently, the relative price of energy declined at a 9 percent annual rate from 1957 to 1965. After 1965, the pattern of energy price developments (see table 3) is comparable to the experience in other nations. Finally, an hours of employment series was not available so that number of persons employed (E) was used as the measure of labor input.^{25/}

The enterprise sector production function for the Netherlands estimated over the same period (1955-78) as for the manufacturing sector

is:

$$(17) \quad \ln X = 0.74 \ln h + 0.26 \ln K + 0.017 t \\ \quad \quad \quad (.001) \quad \quad (.001) \quad \quad (.001) \\ \quad \quad \quad + 0.023 T76 + 2.23 \ln c - 0.035 \ln P \\ \quad \quad \quad (.002) \quad \quad (.40) \quad \quad (.012)$$

$$\bar{R}^2 = 0.90 \quad S.E. = 0.010 \quad D.W. = 2.25 \quad \rho = -0.26$$

An insignificant constant term is omitted. The output elasticity of the relative price of energy (-0.035) is much lower for the enterprise sector than for manufacturing or for other nations, but it is statistically significant ($t = -2.80$). The implied output elasticity of labor employment is 71.7 percent, an estimate that appears consistent with the share of labor in the enterprise sector [see OECD (1980, p. 16)]. When the beginning of the sample period is varied from 1950 to 1960, there is marked stability in the coefficient estimates from 1952 onward, but the energy price coefficient is smaller and not significant for sample periods beginning in 1950 or 1951. Apparently from 1950-52, the relative price of energy series shows an increase of 17 percent that is not reflected in output developments.

When the second time trend is not truncated in 1976, the standard error of the equation estimate rises but the magnitude and t -ratio for the energy price term also increases. For the same sample period (1955-78), the estimated equation is:

$$(18) \quad \ln X = 0.74 \ln h + 0.25 \ln K + 0.017 t \\ \quad \quad \quad (.002) \quad \quad (.002) \quad \quad (.002) \\ \quad \quad \quad + 0.022 T2 + 2.14 \ln c - 0.06 \ln P \\ \quad \quad \quad (.003) \quad \quad (.57) \quad \quad (.02)$$

$$\bar{R}^2 = 0.84 \quad S.E. = 0.0128 \quad D.W. = 2.05$$

The output elasticity of employment is 69.8 percent and except for the energy price coefficients, the other coefficients remain quite stable as well. This stability is again noteworthy when the beginning of the sample period is varied from 1950-60, except for the energy price coefficient which has a t-statistic of only about -1.1 for sample periods beginning in 1950-51. The size of the energy price coefficient remains 0.6 to 0.7 for the sample periods that begin after 1952. Equations with the unbroken post-1963 time trend (T2), yield estimates of the energy price coefficient that are more in line with the manufacturing estimate and the estimates for other countries. It is not clear why the break in the energy-related trend makes such a difference in the enterprise sector estimate but not in the manufacturing sector.

The data for the Netherlands are generally consistent with the evidence from other countries and the order of magnitude of the energy price effect is similar, especially for the manufacturing sector. Some puzzling differences in the estimates for the enterprise sector and in the energy price data for the Netherlands, especially in the early 1950s, remain for further investigation.

The Energy Price Effect on Productivity: 1973-77

The similarity of the movements in the relative price of energy in table 3 is quite striking. From 1973-77, the relative price of energy rose ($\Delta \ln$) by about 52 percent in the U.S. and Japan. In the other five countries the relative price of energy rose 22 percent (U.K.) to 34 percent (Netherlands).

Using these increases and the equation estimates above, it is possible to estimate the loss in output and productivity in each country

due to energy price developments. The manufacturing sector results (equation 16) are used for the Netherlands. These effects are summarized in table 6. The short-run effect of an increase in energy prices is measured given employment of capital and labor. Over a longer period, the capital-labor ratio falls due to an energy price increase, so the long-run effect is measured including these reductions.

The largest productivity loss for the 1973-77 period is estimated to have occurred in Japan, where the effect was more than twice as large as in the U.S. The smallest loss occurred in Germany. Real energy price changes in Canada, France and the U.K. had similar effects on productivity with the immediate effect being a 2-3 percent loss, while including the adjustment of the capital stock, the loss is 3.5 to 4.4 percent.^{26/}

IV. THE 1979-80 ENERGY PRICE SHOCK

In 1979-80, the relative price of energy surged upward again due to major changes in OPEC production and world petroleum prices. In the United States, the average price of crude oil rose from \$12.93 per barrel in December 1978 to \$23.63 in December 1979. By November 1980, this price had risen further to \$29.79 per barrel. Because of the close relation of energy prices to crude oil prices, the relative price of energy rose 28.9 percent from the fourth quarter of 1978 to the fourth quarter of 1979 and increased an additional 13.2 percent by the fourth quarter of 1980. The total increase over these eight quarters of 42.1 percent is essentially the same as the increase that occurred from III/1973 to III/1974 in the United States. Consequently, the effects on U.S. output and productivity would be expected to be comparable.

TABLE 6
The Estimates of Output and Productivity
Losses in Seven Nations
Due to Energy Price Developments
(1973-77)

| | US | UK | GERMANY | FRANCE | CANADA | JAPAN | NETHERLANDS |
|--------------------------------|---------|---------|---------|---------|---------|---------|-------------|
| Esti- mation Period | 1949-78 | 1960-77 | 1960-77 | 1959-77 | 1956-78 | 1959-77 | 1955-78 |
| Energy Price Elasticity: | | | | | | | |
| Short- Run | -0.10 | -0.09 | -0.05 | -0.11 | -0.11 | -0.24 | -0.10 |
| Long- Run | -0.14 | -0.16 | -0.07 | -0.15 | -0.16 | -0.33 | -0.17 |
| 1973-77 Price Increase | 51.7 | 22.2 | 26.9 | 27.4 | 28.0 | 51.9 | 33.9 |
| Short- run Loss | -5.2 | -2.0 | -1.3 | -3.0 | -3.1 | -12.5 | -3.5 |
| Long- run Loss | -7.0 | -3.5 | -1.9 | -4.1 | -4.4 | -17.1 | -5.9 |

Using the 1949-78 U.S. production function estimate, actual hours and utilized capital stock changes for the private business sector, and the 42 percent increase in energy prices yields a forecast drop of private business sector output of 0.3 percent from IV/1978 to IV/1980. The actual change in output over this period was 0.6 percent, not significantly different from the forecast. Using the actual changes over each four quarter period, the estimated output changes from IV/1978 to IV/1979 is 0.7 percent while output actually rose 1.4 percent and from IV/1979 to IV/1980 the estimated rise in output is -1.0 percent while the actual change is -0.8 percent. These errors are less than the standard error of the annual equation in table 1. The 42 percent rise in energy prices in the U.S. from IV/1978 to IV/1980 accounts for a reduction in PBS output growth of 4.6 percent.^{27/}

Of course the decline in output growth and productivity was further aggravated by severe monetary restraint in early 1980 as well as the temporary effects of a credit control program. However, these effects are reflected in cyclical movements in hours of employment and utilization of capital resources. Actual productivity developments in 1979-80 included an adverse cyclical component as well as the permanent component due to energy price developments.

The 1979-80 energy price increase again took place in an international market so that the adverse impact on potential output and productivity would be expected to show up in output and price developments in other countries. Moreover, for some time to come, it is likely that investment in business plant and equipment will continue the stagnant pace of 1973-78 in the absence of policy changes removing existing disincentives for capital formation. While the effect of this

slow pace of capital formation on productivity growth is large relative to that of the initial energy price change (40-50 percent as large), it appears to be spread over a longer period of time that it is less disruptive.

V. The Monetary Policy Experience In Seven Countries

It is not easy to characterize the policy response to the international energy shock in 1974 for the seven countries above. First, delineating the direction of change of monetary actions can be a matter of considerable disagreement among economic policy analysts. Second, monetary actions over time reflect actions and reactions to a host of economic developments at any point in time, not simply a reaction to a shock such as an energy price change.

Table 7 shows the annual rate of growth of the money stock over various periods for each of the seven countries. Since the truly dramatic rise in the world's relative price of energy began in IV/1973, growth rates over four quarter periods around IV/1973 as well as the three year trend rate of growth up to IV/1973 are given. Policy actions in any year can be viewed relative to the trend rate of money stock growth over a longer period in the past, or relative to the year before, with conflicting conclusions about the direction of policy. Also, focusing on money stock growth over a four quarter period may mask significant shifts in monetary actions over shorter periods within the four quarter interval that have important real effects.

Comparing money stock growth for the year ending IV/1973 to the three years ending IV/1973 reveals what policy had been prior to the oil price shock. Generally, policy actions were restrictive in 1973. Most

TABLE 7

Growth Rates of the Money Stock In Seven Nations

| | <u>IV/1972- IV/1973</u> | <u>IV/1970- IV/1973</u> | <u>IV/1973- IV/1974</u> | <u>IV/1974- IV/1975</u> |
|----------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| United Kingdom | 6.5 | 11.5 | 10.9 | 19.2 |
| Japan | 19.9 | 24.3 | 11.1 | 10.9 |
| Canada | 12.0 | 14.4 | 6.4 | 21.0 |
| Germany | 0.8 | 9.3 | 10.6 | 15.3 |
| France | 7.5 | 11.6 | 13.6 | 12.8 |
| Netherlands | 0.8 | 11.4 | 9.9 | 21.0 |
| United States | 6.2 | 7.1 | 5.1 | 4.5 |

countries were reacting to the explosive monetary growth of the early seventies as well as boom conditions and rising inflation rates.^{28/} The reduction in monetary growth in 1973 was sharpest in the Netherlands, Germany and the United Kingdom.

Comparing 1974 developments to the prior trend rate yields a more diverse pattern. Restraint was clearly implemented in Japan, Canada, and the United States and, to some extent, in the Netherlands and United Kingdom. Germany and France, on the other hand, accelerated monetary growth rates in 1974.

The annual figures mask the extent of significant monetary restraint in some countries. The Japanese and Canadian data show strong recessionary monetary actions. In the U.S., closer inspection shows that beginning in mid-1974, stronger restraint was applied than is evident in the comparison of 1974 to the prior trend. From the third quarter of 1974 to the first quarter of 1975, the money stock grew at only a 3.3 percent rate, well below the 7.1 percent trend rate. Based on prior experience with recessions in the U.S., this restraint was strongly recessionary. In the U.K., which appears to have pursued slight restraint for the year 1974 as a whole, the rate of money stock growth was only 6.1 percent from the end of 1973 to the third quarter of 1974. Indeed in all of the countries, periods of two or more consecutive quarters of money stock growth that was less than half the three year trend figure, may be found between mid-1973 and the first quarter of 1975. The lowest annual money growth rate for a two quarter period in each country was: U.K., IV/1973-II/1974, -0.3 percent; Germany, II/1973-IV/1973, -1.2 percent; Japan, II/1974-IV/1974, 6.8 percent; Canada, II/1974-IV/1974, -1.7 percent; France, II/1974-IV/1974, 3.7

percent; Netherlands, I/1973-III/1973, -7.4 percent; and the United States, III/1974-I/1975, 3.3 percent.

The result of the extreme monetary restraint exercised in each country, at least temporarily, was the world-wide recession on top of the decline in output associated with the energy shock. The degree of temporary restraint (measured by the trend rate less the slowest two-quarter money growth rate in each country) was greatest in the Netherlands, Japan, Canada and the United Kingdom. The restraint was least in the United States, but even there, it was sufficient to induce a sharp run-up in the unemployment rate.

In the last column of table 7, the rates of growth of the money stock in 1975 are given. These are included to indicate the transient nature of the earlier restraint in most cases. Sharp accelerations occurred in 1975 (as compared to 1974) in the Netherlands, U.K., Germany and Canada. France continued the rapid average rate of growth averaged in 1974. Only Japan and the U.S. maintained or lowered the slower money growth rates of 1974 during 1975.

Data on 1979-80 monetary actions are given in table 8. In the U.S., changes in the definitions of monetary aggregates, the October 6, 1979 change in policy procedures, and two major announcements of intentions to slow the growth of monetary aggregates (November 1978 and October 1979) have led to considerable confusion over the direction of monetary policy. Recent growth rates for the money stock measure M1B are shown for the United States. The growth rate of the money stock in 1979 was essentially unchanged from that in 1978. During both years, the rate of money growth was above the trend rate for the three years ending in the fourth quarter of 1978. In 1980, this growth rate fell to roughly

TABLE 8
Growth Rates of the Money Stock in Seven Countries

| | <u>IV/77-IV/78</u> | <u>IV/75-IV/78</u> | <u>IV/78-IV/79</u> | <u>IV/79-III/80^{1/}</u> |
|-------------|--------------------|--------------------|--------------------|----------------------------------|
| U.K. | 16.7 | 16.1 | 10.1 | 1.2 |
| Japan | 12.3 | 10.9 | 5.6 | -0.5 |
| Canada | 11.0 | 7.9 | 4.9 | 6.2 |
| Germany | 13.5 | 10.1 | 4.4 | 1.5 |
| France | 11.7 | 10.3 | 10.6 | 8.5 |
| Netherlands | 3.2 | 8.1 | 5.0 | 1.2 |
| U.S. | 8.2 | 7.4 | 8.0 | 7.3 |

^{1/} Except in the U.S where the growth rate is for the period ending IV/1980, and the U.K. and France for the period ending II/1980.

the 1975-78 trend. From the fourth quarter of 1979 to the second quarter of 1980, however, M1B grew at a 1.8 percent rate, a strongly recessionary pace in light of the rapid expansion over the previous few years.

Only the Netherlands had a rate of money growth in 1978 that was less than the trend rate for the period ending in the fourth quarter of 1978. In 1979-80, however, all the countries listed in table 8, except for the U.S. and France, had money growth rates that were sharply below the 1975-78 trend rates of growth. France, like the U.S., did slow the growth rate sharply in some quarters. From the third quarter of 1979 to the first quarter of 1980, the money stock in France expanded at only a 5.3 percent rate.

Each of the seven countries appear to have repeated the tight policies associated with the 1974 experience. The recessionary direction of money stock growth is easily discerned in the last two columns of table 8 for the U.K., Japan, Germany, and the Netherlands. This direction is also clear from data on two-quarter periods for the U.S. and France above. Finally, in Canada the growth rate of money stock slipped to only 1.6 percent from IV/1979 to II/1980.

Some restraint in the growth rate of monetary aggregates was to be expected in 1979 and 1980 in the seven nations because of the procyclical policies which were followed during the recent expansion, especially in the latter portion, and the consequent acceleration in underlying inflation rates. Unfortunately, the restraint in 1974 and 1979-80 appears to go well beyond a gradual reduction. It will be even more unfortunate if the recent episode of monetary restraint is as transitory as that following the first energy shock. Comparing the three year rate of growth in tables 7 and 8 reveals that only Japan, Canada,

and the Netherlands made significant progress in reducing the trend rate of growth following their restraint and recessionary experience of 1974-75. These trend rates were not much changed in the United States, Germany or France; in the U.K. the trend rate rose sharply.

VI. CONCLUSION

Energy price increases have had a profound effect on the world economy since 1973. Sharp increases in the price of energy relative to output prices, especially in 1974 and again in 1979-80, have reduced economic capacity in the seven countries examined. The reexamination of the U.S. data reveals that the quality of the original results has not deteriorated over time, and that the estimates explain 1979-80 productivity developments very well. The estimates for other countries reinforce the hypotheses. The energy price effects are significant and similar across countries. In the manufacturing sector in Japan the effect appears to be larger than elsewhere, while the effects in Germany and the Netherlands are smaller. The differences in output elasticities are not large, however.

The 1979-80 experience in other countries will provide an important test of the hypotheses developed here. The estimates for other countries have more limited degrees of freedom and, in most cases, the quality of the data used here is not as good as that for the United States. Casual information on slowing growth in other nations and accelerations in measured inflation rates around the world, however, indicates that the estimates are likely to remain quite stable when the 1979-80 data are available.

It may well be the case that restrictive monetary policies are most palatable in the face of surges in the inflation rate, even when the surges are temporary. The macroeconomic theory of real energy price effects indicates that such surges in inflation are indeed temporary and

carry with them little or no effect on the utilization of other resources. Consequently, the appropriate policy response is a neutral one. The policymaking environment in 1974, as well as in 1979-80, is complicated by the rapid growth of money stocks in the immediately prior period in most of the nations examined. Thus some move toward slowing monetary growth rates is necessary and to be expected as a move toward restoring price stability. Unfortunately in both 1974 and 1979-80, monetary actions in the seven countries examined here were very restrictive. Consequently, the permanent output and productivity loss due to energy price effects was compounded by temporary cyclical losses.

The theory and evidence provided here is of greater importance for the possibility of using aggregate demand policy to recover the productivity losses associated with real energy price increases. These losses are permanent and arise from aggregate supply changes, not from cyclical weakness in aggregate demand. Consequently, it is not possible to escape the adverse effects of energy price shocks by stimulative demand management policies.

FOOTNOTES

*The author is Senior Economist, Federal Reserve Bank of St. Louis. This paper draws liberally from Rasche and Tatom (1981), as well as from their other work cited in the references. The views expressed here are not necessarily those of Robert H. Rasche or the Bank. The theoretical foundations of this paper and a consideration of alternative theoretical approaches are discussed in detail by Rasche and Tatom (1981).

¹The relevant assumptions for the production function are positive marginal products, diminishing marginal productivity, and that the increased use of any factor will augment the marginal productivity of the others.

²These are the assumptions used by Tatom (1979b). The model could be complicated by changing the resource supply assumptions but this would have no effect on the qualitative results so long as two features are preserved, the reduction in energy employment and the failure of the relative price of capital goods to decline by the extent of the energy-induced short-run decline in output per unit of capital.

³It is likely that the supply price of capital goods rises relative to that of aggregate output, further reducing the desired capital-labor ratio and output. These effects are discussed by Tatom (1979b).

⁴A policy of no change in the money stock (or no change in a targeted growth rate of monetary aggregates due to energy price shocks) is characterized here as a neutral policy. An "accomodative" policy, in this view, is one which attempts to increase the money stock in order to restore the initial level of full-employment output, an impossible task according to this analysis. Cagan (1980) assesses policy by its tolerance of price level impacts so that our "neutral" policy is "accomodative." From his viewpoint, a "neutral" policy in the face of an energy price shock would require that the money supply be reduced in proportion to the decline in output, so as to leave the path of the price level undisturbed. Such a policy ignores nominal wage rigidities and is "restrictive" if judged in terms of the short-run employment and output effects instead of price level effects.

⁵The Council of Economic Advisers discusses the optimal policy response to an increase in the relative price of energy in the Economic Report of the President 1980, pp. 103-104. Their analysis recognizes the shift upward in the "tail" of the aggregate supply curve due to an energy price increase as well as consequent price-level induced wage increases. Unfortunately, in this discussion they fail to recognize the leftward shift in the vertical portion in either case. Thus, they conclude that a practical policy is to "accomodate" the energy price shift, presumably by shifting aggregate demand outward to the initial level of output at the higher price level, but not to accomodate the subsequent wage increase. Elsewhere, (p. 89), the CEA appears to accept the view that a substantial leftward shift in the vertical portion of such an aggregate supply curve occurred in 1974 (although they do not explicitly cite energy developments as the reason).

⁶This is an appropriate point to indicate that the analysis of a rise in the relative price of energy is the same as that of an attempt to increase the real wage of labor above that indicated by competitive labor markets. The typical analysis of such "cost-push inflation" differs from that presented here only to the extent that it does not recognize the decline in potential output which accompanies the price level response. Also, the case of energy is somewhat more interesting since it is easier to conceive of the possibility that an artificially higher relative price can be ratified by reducing the supply of the resource.

⁷Mork and Hall (1979b, p. 34), among others, have suggested that this hypothesis may be important for the analysis of the 1979-80 energy price increase.

⁸The equation relates the rate of change in prices to the growth rate of the money stock over the last twenty quarters, a distributed lag in the relative price of energy and dummy variables for the price control period and subsequent "catch-up."

⁹As the CEA notes the Economic Report of the President (1980, p. 89), real GNP grew only 0.8 percent during the quarters of 1979 but the unemployment rate did not change (fourth quarter to fourth quarter). The implication is that potential output growth was about the same as that of real GNP.

¹⁰Tatom (1979c) has shown that the growth rate of productivity declined sharply in 1974 and/or 1975 relative to the 1960-73 trend in eleven countries. Real nonresidential fixed investment slowed sharply in 1973-78 in all eleven countries, again relative to the prior trend.

¹¹The data are those used on Brox and Cluff, Canadian Statistical Review, January 1979. We appreciate the efforts of Mr. Harold Brown of Statistics Canada in providing us with these data and answering other questions concerning the Canadian statistics.

¹²We subsequently located Dominion Bureau of Statistics data on wholesale prices of petroleum and coal for years prior to 1956. We have not attempted to extend the sample backwards by splicing the two series together.

¹³National Accounts of the OECD Countries, 1960-77, Volume II, detailed tables. OECD, Paris, 1979.

¹⁴That is, total GDP less GDP originating in households and nonprofit institutions and less government production of services.

¹⁵We have constructed a series by compiling the most recently revised numbers that appear in various issues of the Wharton Quarterly.

¹⁶See OECD, "The Measurement of Domestic Cyclical Fluctuations," Paris, July 1973, P. 29 for a quarterly Cobb-Douglas production function for the entire German economy over the period 1960-71. The estimated output elasticities for labor and capital in this study are .69 and .31, respectively, and the time trend is estimated as .032 (per annum).

¹⁷For the OECD estimates on quarterly data over the period 55 through 71, see OECD, "The Measurement of Domestic Cyclical Fluctuations," Paris, July 1973, p. 38. In the March 1978 "Economic Survey of the United Kingdom," the OECD reports: "the decline in manufacturing investment since 1970, structural changes in demand and output, and the rapid rate of obsolescence associated with the marked rise in energy prices make difficult the estimation of the underlying growth rate of potential GDP in recent years," p. 35.

¹⁸See Statistical Office of the European Community, Eurostat: National Accounts ESA, 1977 for a breakdown of compensation of employees in the UK by sector.

¹⁹While this experiment is more limited in coverage, it may be representative. Tatom (1979c) presents an estimate of the annual U.S. production function for the manufacturing sector. He was not able to reject the hypothesis that the energy price effect on manufacturing productivity is the same as that for the private business sector.

²⁰These series are updated estimates from Jacques Artus, "Measures of Potential Output in Manufacturing for Eight Industrial Countries, 1955-78," International Monetary Fund Staff Papers (March 1977), pp. 1-35.

²¹In countries where indexing prevents real wages from declining to reflect the loss in productivity, a larger reduction in employment will tend to occur. Data on output per worker or per hour would not be expected to reflect the productivity loss indicated by the production function estimates for such countries.

²²This method has been used in estimating U.S. production functions by J.K. You (1979). Unfortunately it is a poor measure of capital employment as compared to the Federal Reserve Board's capacity utilization rate, see Tatom (1981b). It is used here primarily to remove cyclical influences.

²³All data, other than manufacturing sector output, hours, and capital stock, were supplied by Edward Bomhoff, including data to extend the series for the capital stock in the enterprise sector and nominal energy prices prepared originally by Magnus (1979).

²⁴See OECD (1980). The equation estimate is little changed if the trend beginning in 1964 is not truncated. In that case, the standard error of the equation rises to 1.91 percent; the energy price coefficient is -0.10 ($t = 2.97$).

²⁵An attempt to measure hours using a series on cumulative reductions in hours that begins in 1960 was made but the resulting estimates were generally inferior to those reported here.

²⁶The long-run effect ignores the indirect effect of an increase in the supply price of new capital goods relative to other output due to a higher relative price of energy. This effect would further reduce the desired capital-labor ratio resulting in even larger reductions in the capital stock and productivity. See Tatom (1979b) for a discussion of this effect.

²⁷When the annual production function in table 1 is reestimated over the 1949-79 period, no significant change occurs. The hours coefficient is 0.7103 (14.95), capital coefficient, 0.2897 (6.10), relative price of energy, -0.1169 (-6.58), time trend 1.72 percent (10.66), and constant 1.58 (14.04). The standard error of estimate is 0.0090, adjusted R^2 is 0.94, Durbin-Watson statistic is 1.76, and ρ is 0.58. The implied estimate of γ is 10.5 percent.

²⁸Another view of monetary policy actions in this period which emphasizes these reactions may be found in Stanley W. Black, "Policy Responses to Major Disturbances in the 1970s and Their Transmission through International Goods and Capital Markets," Weltwirtschaftliches Archiv, Band 114, Heft 4, 1978, pp. 614-641.

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