

NBER WORKING PAPER SERIES

THE REAL PRICE OF OIL AND THE 1970s
WORLD INFLATION

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Working Paper No. 629

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

February 1981

The research reported here is part of the NBER's research program in International Studies. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

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ABSTRACT

This paper shows that the effects on real income and the price level of the 1973-1974 oil price increase are quite ambiguous on both theoretical and empirical grounds. The theoretical analysis reviews standard results and extends them to analyze the steady-state equilibrium and endogenous monetary policy reaction functions. It is shown that standard models and parameter values imply trivial reductions in real income and ambiguously signed changes in the price level. It is noted, however, that other special models can rationalize empirical findings of large effects. Direct real-oil-price effects in an extended Barro-Lucas real income equation are estimated for eight countries. Although statistically significant and substantial direct effects are found for about half the countries, it is noted that these coincided with countries undergoing price decontrol during 1973-1974. Thus price-control biases in real GNP data provide an acceptable alternative explanation for the estimated effects. Simulation experiments in an international model illustrate the wide range of real income and price level effects which are consistent with the data. Further research is proposed to narrow the range of possible effects.

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THE REAL PRICE OF OIL AND THE 1970S WORLD INFLATION

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The increase in the real price of oil during 1973-1974 is widely believed to have been a major cause of inflation both in the United States and abroad. In part, this belief is based on a partial equilibrium (or adding-up) approach which explains the inflation rate as the weighted sum of the inflation rates of individual goods and services without making due allowance for the general equilibrium effects on factor prices of an increase in the relative price of an imported factor. But theoretically acceptable arguments can be made which attribute inflation -- or at least an upward price level shift -- to factors decreasing the real quantity of money demanded or increasing the nominal quantity of money supplied by the central banks. This paper reports an empirical investigation of the magnitude of these possible effects consistent with general equilibrium.

*The author acknowledges the able research assistance of Michael T. Melvin and Andrew A. Vogel and the generous support of the National Science Foundation (grants APR 78-13072 and DAR-7922874). The calculations were performed on the TROLL system at M.I.T. The research reported here is part of the NBER's research program in International Studies. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

First a theoretical analysis of the long-run and short-run effects of an oil-price change is presented in Section I. It is seen there that the long-run effect on real income and the real quantity of money demanded may be quite small if not negligible, particularly when real income is measured in terms of real GNP and money is deflated by the corresponding implicit deflator. While this result may be due to the use of a three-factor Cobb-Douglas production function in the context of a neoclassical growth model, it certainly illustrates that a long-run reduction of real GNP of even 1 or 2 percent is very much an empirical question. Short-run effects on real income and prices associated with shifts in aggregate demand and supply appear to be similar in magnitude to those for the long run. Central banks' reaction to the short-run real income and inflation effects may offset or reinforce these effects once monetary policy is allowed to be endogenous.

Tests of significance of oil-price variables in an extended Lucas-Barro real income equation are reported in Section II. The results are mixed and confounded by price control and decontrol programs which were widespread at nearly the same time as the 1973-1974 oil-price change. Much future work is required to definitively disentangle the effects of these two factors.

Section III reports simulation experiments on the effects of the 1973-1974 oil-price change. These experiments are conducted using the Mark IV Simulation Model presented in Darby (1980b). This model -- a simplified version of the Mark III International Transmission Model¹ -- is a quarterly macroeconomic model of the United States, United Kingdom, Canada, France, Germany, Italy, Japan, and the Netherlands. In addition to the basic Mark IV Model, an extended Mark IV-Oil Model is used which incorporates oil-price

variables in the real-income equations for those five countries for which the variables were found to be significant in Section II. Using the basic model, some notable effects are found as a result of induced movements in exports, exchange rates, money supplies, and the like. Stronger effects are simulated using the Mark IV-Oil Model, but the price-control caveat of Section II again applies.

The concluding section summarizes the results of this paper and suggests areas for future research as international data on the effects of the 1979-1980 oil-price increase come available.

I. Theory

The price level, measured in dollars per basket of goods, is the inverse of the price of money, goods per dollar. So it is convenient to classify the forces determining the price level according whether they influence the supply of or demand for money.

A standard (long-run) money-demand function explains the real quantity of money demanded m^d by real income y and the nominal interest rate R . The nominal quantity demanded M^d is the product of this real demand and the price level:

$$(1) \quad M^d = m^d(y, R) \cdot P$$

Equating money supply M^S to money demand and solving for the price level:

$$(2) \quad P = \frac{M^S}{m^d(y, R)}$$

That is, the price level equals the ratio of the nominal quantity of money supplied to the real quantity of money demanded.

Although the inflationary impact of an oil-price change is generally analyzed given an exogenously determined nominal money supply, this may be misleading or at least counterfactual. That is, to the extent that the oil-price change increases the price level and unemployment (at least temporarily) and decreases real income for a given nominal money supply, the inflationary effect would induce central banks to reduce M^S while the recessionary effect tends to increase M^S . Which effect is dominant would depend on the relative weights which the individual central bank puts on inflation and unemployment. In addition, other factors -- discussed below -- may influence central bank policy response to an oil-price change. With this warning, let us

proceed for now to analyze the effects of an oil-price change for an exogenous monetary policy.

Long-Run (Full Employment) Effects

Consider first the long-run effects of an oil price change on real output. For illustrative purposes suppose real output y is produced according to a 3-factor Cobb-Douglas production function using domestic capital k , labor ℓ , and imported petroleum ϕ :²

$$(3) \quad y = k^{\alpha} \ell^{\beta} \phi^{\gamma}$$

$$(4) \quad \alpha + \beta + \gamma = 1$$

Let us assume that output is produced by competitors who treat all prices as parametric including in particular the real price of oil θ .³ In equilibrium, one of the first order conditions requires that the marginal product of petroleum be equated to its real price:

$$(5) \quad \frac{dy}{d\phi} = \gamma k^{\alpha} \ell^{\beta} \phi^{1-\gamma} = \theta$$

It is straightforward to solve for the equilibrium usage of petroleum as a function of θ , k , and ℓ :

$$(6) \quad \phi = \left(\frac{\gamma}{\theta}\right)^{\frac{1}{\alpha+\beta}} k^{\frac{\alpha}{\alpha+\beta}} \ell^{\frac{\beta}{\alpha+\beta}}$$

If we now substitute this equilibrium ϕ into the production function (3) we obtain equilibrium real output as a function of the real price of oil and given, fully-employed resources of capital and labor:

$$(7) \quad y = \left(\frac{\gamma}{\theta}\right)^{\frac{\gamma}{\alpha+\beta}} k^{\frac{\alpha}{\alpha+\beta}} \ell^{\frac{\beta}{\alpha+\beta}}$$

Taking logarithms and differentiating, we find the elasticity of equilibrium output with respect to the real oil price for given capital and labor resources:

$$(8) \quad \left. \frac{d \log y}{d \log \theta} \right|_{k, \ell} = - \frac{\gamma}{\alpha + \beta} \equiv - \frac{\gamma}{1 - \gamma}$$

If for example, γ were on the order of 0.01, a 1 percent increase in the real oil price would decrease real output by only 0.01 percent (1 basis point) for given resources and given the assumptions of this illustration.⁴

The full, long-run equilibrium effect would be slightly larger due to a reduction in the steady-state capital-labor ratio for a given growth path of labor. To see this, suppose that saving and investment \dot{k} is a constant fraction σ of domestic factor income:

$$(9) \quad \dot{k} = \sigma(y - \theta\phi)$$

Dividing both sides of (9) by k and noting that $y - \theta\phi = (\alpha + \beta)y$,

$$(10) \quad \frac{\dot{k}}{k} = \sigma(\alpha + \beta) \frac{y}{k}$$

Thus the growth rate of capital is a fixed proportion of the output-capital ratio. In view of (7), this latter ratio is

$$(11) \quad \frac{y}{k} = \left(\frac{\gamma}{\theta}\right)^{\frac{\gamma}{\alpha + \beta}} \left(\frac{\ell}{k}\right)^{\frac{\beta}{\alpha + \beta}}$$

The simple neoclassical growth model can therefore be applied which, after tedious manipulations, yields the result that

$$(12) \quad \frac{d \log y}{d \log \theta} = - \frac{\gamma}{\beta}$$

This effect which allows for the (proportionate) reduction in the capital stock would be about a third larger than that in (8) for given resources

and a labor share equal to three quarters of value added. We should note that since income and capital fall proportionately in full steady-state equilibrium, there is no long-run effect on the real interest rate.⁵

A curiosity of national income accounting proves important in applying the analysis to empirical data. Gross national product is a value-added concept so that imported inputs are subtracted from total output to obtain GNP. This works fine for nominal GNP or Q:

$$(13) \quad Q = Py - (P\theta)\phi = P(1 - \gamma)y$$

So nominal GNP is simply the price of output P times real domestic factor income $(1 - \gamma)y$. However, in computing real GNP or q, imported inputs are valued at base-year relative prices $\bar{\theta}$:

$$(14) \quad q = y - \bar{\theta}\phi = (1 - \frac{\bar{\theta}}{\theta}\gamma)y$$

Thus measured real GNP rises relative to factor income $(1 - \gamma)y$ when the real oil price θ is increased. Nominal aggregate demand as measured by nominal GNP is not affected since there is an offsetting measurement error in the measured GNP deflator D:

$$D = \frac{Q}{q} = \frac{P(1 - \gamma)y}{(1 - \frac{\bar{\theta}}{\theta}\gamma)y}$$

$$(15) \quad D = \frac{1 - \gamma}{1 - \frac{\bar{\theta}}{\theta}\gamma} P$$

We can differentiate (14) to find the elasticity of real GNP with respect to the real oil price as:

$$(16) \quad \frac{d \log q}{d \log \theta} = \frac{\gamma\bar{\theta}}{\theta - \gamma\bar{\theta}} + \frac{d \log y}{d \log \theta}$$

For small changes in θ before the capital stock adjusts,⁶

$$(17) \quad \left. \frac{d \log q}{d \log \theta} \right|_{k, \ell, \theta \approx \bar{\theta}} = \frac{\gamma}{1 - \gamma} - \frac{\gamma}{1 - \gamma} = 0$$

Thus we see that in the neighborhood of the original oil price, the output effect is completely masked in measured GNP. However, for large changes in θ relative to $\bar{\theta}$ such as those occurring in 1973-1974, there would be a negative effect on measured real GNP.⁷ Using Δ for the change relative to base year prices we have

$$(18) \quad \Delta \log q = \log \left(\frac{1 - \frac{\bar{\theta}}{\theta} \gamma}{1 - \gamma} \right) + \frac{d \log y}{d \log \theta} \log (\theta / \bar{\theta})$$

where $\frac{d \log y}{d \log \theta}$ is from (8) or (12) depending on whether or not the capital stock is presumed to have adjusted.⁸ Note that the deflator is decreased

relative to the price of output by $\log \left(\frac{1 - \frac{\bar{\theta}}{\theta} \gamma}{1 - \gamma} \right)$ just as real GNP is increased relative to real factor incomes.

In summary, an increase in the real price of oil is predicted to decrease real output by the logarithmic change times $\frac{\gamma}{1 - \gamma}$ before capital adjusts or times $\frac{\gamma}{\beta}$ when capital is fully adjusted. However, such an oil price change will cause a partially offsetting overstatement of measured real GNP (and understatement of the GNP deflator).

Obviously the values of γ and β are of considerable interest. For current illustrative purposes, only petroleum imports will be considered.⁹ To the extent that petroleum imports are for resale to consumers rather than used in production they have no effect on output or measured GNP (real or nominal). Thus the ratio of the value of petroleum imports to GNP serves as an upper limit on γ . If we use pre-change U.S. data, this upper limit would be about 0.003 for 1970. In 1976, this share had risen to 0.02. This rise in the share could indicate inelastic consumer demand for imported petroleum products, a problem with the Cobb-Douglas production function, or

both. So while 0.003 should be an upper limit for γ if the Cobb-Douglas function is correct, 0.02 will also be considered as an upper-upper limit. Finally suppose that $\alpha/(\alpha + \beta)$ and $\beta/(\alpha + \beta)$ have their traditionally estimated values of 1/4 and 3/4. Then the multiplier $-\gamma/(1 - \gamma)$ is -0.003 or -0.020 depending on γ . The corresponding multipliers allowing for capital stock change are -0.004 and -0.027. The real price of a barrel of crude oil increased some 3.57 fold from 1973 I to 1974 I (a logarithmic increase of 1.273). This is surely an upper limit on $\theta/\bar{\theta}$ for all petroleum products. Table 1 presents estimates of the maximum effects on output and measured real GNP. We see that the maximum full adjustment effects on real output range from a decrease of 0.5 to 3.5 percent according to whether one takes a pre-change or post-change estimate of γ . For measured real GNP the corresponding decreases are only 0.3 to 2.0 percent. Even smaller changes correspond to the intermediate period corresponding to full-employment of resources but no adjustment of the capital stock.

Rasche and Tatom have long argued for much larger real-income effects of the oil-price change. They rely upon regression estimates of the quasi-production function (7) and find much larger values of γ than considered here. Part of that difference is illusory: They use a much broader energy price index which has a logarithmic increase of only 0.408 from 1972 to 1974¹⁰ compared to the 1.273 increase for a barrel of oil used here; so the larger elasticity is offset by a lower value of $\log(\theta/\bar{\theta})$. Further they do not take account of the biases in reported real GNP so that their estimates may refer to the output effect rather than the GNP effect. Finally, in their (1980) paper, they report an equation (6) in which they estimate the production function (3) directly (after taking logs) and also add

log θ separately. The estimated γ is 0.05 while the coefficient on log θ is -0.07. Using $\gamma = 0.05$, $\beta = 0.70$ (as reported), and $\log(\theta/\bar{\theta}) = 0.408$, we get an output change of -0.0215 with no capital adjustment and of -0.0291 with capital adjustment, which is in the same ball park as the figures in Table 1. It is the things other than in the production function -- captured in the log θ coefficient of -0.07 -- which permit such big estimates. These other things may have to do with cyclical factors, induced monetary policy, or fortuitous removal of price controls at roughly the same time as discussed below. Further the 0.05 estimate of γ may be biased upward if energy usage (relative to capital and labor) serves as an indicator of whether the economy is in a boom or recession. Thus the Rasche and Tatom conclusions may have weak empirical foundations.

This exercise has shown that even a huge change in the real price of oil such as in 1973-1974 may result in very small if not negligible effects on real output and especially upon measured real GNP. Different assumptions would result in different results, but the model used is surely a standard one in practice. Thus it would appear to be an empirical question as to whether the oil-price change had any significant long-run effect on measured real GNP.

We can now return to our original question of the long-run effect of the oil-price change on the real quantity of money demanded and hence, given the nominal money supply, on the price level. First we note that in long-run equilibrium real income is reduced by a constant fraction but the growth rate of real income is reduced only temporarily during the transitional period. Second we note that the real interest rate is unchanged. Under these conditions, in long-run equilibrium the real and nominal interest rate will be unchanged and the real quantity of money demanded will

behave similarly to real income -- a downward parallel shift in its growth path. The logarithmic downward shift will equal to the elasticity of real money demand with respect to real income times the logarithmic shift in real income. Thus, if this income elasticity is around 1 there will be a long-run increase in the price level equal to the long-run decrease in real income.¹¹ If during the early part of the adjustment period the price level effect exceeds this long-run effect, then the inflation rate must be reduced (*ceteris paribus*) below what it would otherwise be to reach long-run equilibrium.

Two problems may arise in econometric work based on real GNP as measured in the national income accounts. First, the reduction in measured real GNP will understate the output reduction which actually occurs. A second problem arises only if the income elasticity of the demand for money differs significantly from unity: Then the offsetting measurement errors in real GNP and the GNP deflator would cause an apparent shift in the money-demand function equal to the product of the measurement error and the difference of the elasticity from 1. This latter problem is a second-order matter which will not be pursued further in this paper.

Short-Run Effects

Short-run effects of the 1973-1974 oil-price shock have been analyzed in terms of induced shifts in aggregate demand and aggregate supply curves under the assumption that nominal wages are predetermined (or at least sticky) in the short run. As with the long-run analysis, the analysis of the short-run effects proceeds on the assumption that the government's monetary and fiscal policy is unaffected by the unexpected oil-price increase.

The aggregate demand effects of an oil-price shock can be viewed as analogous to that of an increase in taxes.¹² Assume for simplicity that in the short-run both producer and consumer demands for imported petroleum are perfectly inelastic. For producers, this means that higher import prices will be paid out of reduced quasi-rents, reducing private income. For consumers, higher oil prices would directly reduce expenditures on other consumption goods for given private income and these expenditures would be further reduced by the reduction of private income.¹³ Thus, at initial levels of real income and interest rates, aggregate expenditures would fall unless increased demand for exports by oil exporters equals or exceeds the induced reduction in consumption. When we allow for some elasticity of demand for imported oil and for increased exports of goods to oil producers, the plausible magnitude of these basically distributional effects is sharply reduced and could even be reversed.¹⁴ In what follows, we shall nonetheless consider the possibility of a small decrease in aggregate demand.

The aggregate supply effect would appear more substantial and has been analyzed on varying assumptions by Bruno and Sachs (1979), Hudson and Jorgenson (1978), Mork and Hall (1979), Norsworthy, Harper, and Kunze (1979), Phelps (1978), and Rasche and Totom (1977a, 1980). Following the latter authors, suppose that the short-run conditions underlying the aggregate supply curve are fixity of the capital stock, the nominal wage W , and the real price of oil. Using the aggregate production function (3), one can readily derive output as

$$(19) \quad y = \left(\frac{Y}{\theta}\right)^{\frac{\gamma}{\alpha}} \left(\frac{BP}{W}\right)^{\frac{\beta}{\alpha}} k$$

On comparing (19) and (7), we note that for a given price level there is a much greater output effect with nominal wages fixed than when labor is assumed

to be at its natural unemployment rate. Specifically

$$(20) \quad \left. \frac{d \log y}{d \log \theta} \right|_{k,W} = -\frac{\gamma}{\alpha} + \frac{\beta}{\alpha} \frac{d \log P}{d \log \theta}$$

Note that the elasticity of the aggregate supply curve is

$$(21) \quad \frac{d \log y}{d \log P} = \frac{\beta}{\alpha}$$

It is convenient to plot aggregate supply and demand curves in terms of $\log y$ and $\log P$ so that slopes and elasticities have a simple correspondence. The logarithmic aggregate supply curve corresponding to equation (19) is

$$(22) \quad \log y = \left[\frac{\beta}{\alpha} \log (\beta/W) + \frac{\gamma}{\alpha} \log \gamma + \log k \right] - \frac{\gamma}{\alpha} \log \theta + \frac{\beta}{\alpha} \log P$$

This is plotted as S in Figure 1 for given values of k , W , and the base-year relative price of oil $\bar{\theta}$. The slope of S is the inverse (α/β) of the elasticity of aggregate supply. An aggregate demand curve D is also drawn to determine short-run output and the price level, \bar{y} and \bar{P} .¹⁵

As can be seen in equation (22) an increase in the real price of oil shifts the aggregate supply curve horizontally by $-\frac{\gamma}{\alpha} \log (\theta/\bar{\theta})$ as illustrated in Figure 2.¹⁶ This can alternatively be described as an upward shift equal to minus the slope of S times the horizontal shift

$$(23) \quad \left(-\frac{\alpha}{\beta}\right) \left(-\frac{\gamma}{\alpha} \log (\theta/\bar{\theta})\right) = \frac{\gamma}{\beta} \log (\theta/\bar{\theta})$$

If any shift in the aggregate demand curve is negligible, the new equilibrium output and price level are y and P . The short-run displacement in output from that corresponding to the base real oil price $\bar{\theta}$ is

$$(24) \quad \Delta \log y = \frac{-1}{\frac{\alpha}{\beta} - \frac{1}{\eta_D}} \frac{\gamma}{\beta} \log (\theta/\bar{\theta})$$

where η_D is the elasticity of the aggregate demand curve so that α/β and $1/\eta_D$ are the slopes of the aggregate supply and demand curves respectively. Suppose that the aggregate demand curve is unit elastic ($\eta_D = -1$), then

$$(25) \quad \Delta \log y = - \frac{\gamma}{1-\gamma} \log (\theta/\bar{\theta})$$

which is identical to the long-run effect implied by (8) before the capital stock adjusts. The increase in the price level,

$$(26) \quad \Delta \log P = \frac{1}{\eta_D} \Delta \log y = \frac{\gamma}{1-\gamma} \log (\theta/\bar{\theta}),$$

reduces real wages just sufficiently to maintain employment at the natural level. Thus, absent a shift in the aggregate demand curve, employment rises or falls (and output is greater or less than the given-capital long-run level indicated by (25)) according to whether the elasticity of aggregate demand is smaller or greater than 1 in absolute value. If aggregate demand were inelastic, increased employment would lessen the short-run decline in output. In Darby (1976c, pp. 161-163) I have argued that short-run and hence transitory movements in output will induce much less than proportionate movements in money demand, which suggests that the short-run aggregate demand curve is in fact elastic.¹⁷ This would imply a short-run reduction in employment, which would accentuate the initial fall in output predicted by the full-employment analysis.¹⁸ Once expected nominal wages are reduced, this difference would disappear. In addition, the aggregate demand curve may shift to the left as previously argued if there is a distributional effect due to faster decreases in consumer spending than increases in oil-exporter spending, this is illustrated in Figure 3.

Again it must be emphasized that these calculations are only illustrative of the sort of effects which might be expected. If, for example, we assumed partial adjustment of nominal wages to their equilibrium values, the aggregate supply curve would be less elastic and the output change would be more closely tied to the change in the given-capital long-run level of output.¹⁹

The aggregate demand curve is derived using our price level equation (2) so the short-run price level effect

$$(28) \quad \Delta \log P = \frac{1}{\eta_D} \Delta \log y$$

is valid for the short-run period in which IS-LM analysis is applicable. If $-1/\eta_D$ is less than the long-run elasticity of demand for money with respect to output, the short-run increase in the price level would be less than that associated with an equal long-run decrease in output.

Note that the same accounting problems in relating output and the price level to real GNP and the deflator apply in the short run as in the long run.

Endogenous Monetary Policy

The time has now come to consider possible effects of the oil shock upon monetary policy. Suppose that we can write the money supply reaction function of the monetary authorities as

$$(29) \quad \log M = \log M^* + h_y \log (y/y^*) + h_p \log (P/P^*) + \epsilon_M$$

In logarithms, actual money equals expected money as predicted by lagged variables systematically affecting central bank behavior plus negative

coefficients times the innovations in output and the price level and a random disturbance.²⁰ Write the semi-reduced forms for output and the price level as:

$$(30) \quad y = f(k, W, \theta, M, M^*, \epsilon_y)$$

$$(31) \quad P = \pi(k, W, \theta, M, M^*, \epsilon_p)$$

Denote the real-oil-price and money elasticities of these equations by f_θ , f_M , π_θ , and π_M . Then taking the log changes in equations (29) through (31) and solving for $\Delta \log M$ yields

$$(32) \quad \Delta \log M = \frac{h_y f_\theta + h_p \pi_\theta}{1 - h_y f_M - h_p \pi_M} \Delta \log \theta$$

We have seen above that f_θ is negative and π_θ is positive while h_y and h_p are both negative. Whether money is increased, decreased, or left unchanged by the central bank depends both on the relative sizes of the output and price effects and upon the relative aversion of the central bank to recession and inflation. The denominator of (32) allows for attenuation of money changes to the extent that there are within-period (positive) responses in output and prices. Finally, the price level effect is obtained by substituting (32) into the log-change form of (31):

$$(33) \quad \Delta \log P = \left(\pi_\theta + \frac{(h_y f_\theta + h_p \pi_\theta) \pi_M}{1 - h_y f_M - h_p \pi_M} \right) \Delta \log \theta$$

Here π_θ is the value of $\frac{\Delta \log P}{\Delta \log \theta}$ such as is computed in (28) for a given nominal money supply and the ratio term is the additional (ambiguously signed) effect due to endogenous nominal money supply changes.

Simulation experiments which allow for such endogenous movements in the nominal money supply are reported below in Section III. It is perhaps understandable why most analyses assume that the ambiguously signed change in nominal money must be negligible and proceed on that basis. One can at least explain the effect if the central bank were to hold money supply unchanged.

Conclusions from Theory

Considering first the results of our analysis conditional upon a given monetary policy, with resources at their natural employment levels, the output elasticity with respect to the real price of oil is $-\gamma/(1 - \gamma)$ before capital adjusts and $-\gamma/\beta$ with full capital adjustment. The parameter γ , the value share of oil imports used in producing domestic output, may be quite small, certainly less than 0.02 for the United States for example. The labor share β is on the order of 0.7 to 0.8, so the long run elasticities vary from about γ to 1.3γ or 1.4γ . In the short-run, unemployment will increase slightly (if aggregate demand is elastic), but the short-run output elasticity seems to lie in the same range as for the long-run. The price level is shifted up in the long-run by the long-run income elasticity of money demand (around 1) times the output elasticity. In the short-run the price level shifts less than in proportion to output since the short-run aggregate demand curve is elastic.

These shifts in the levels of output and prices affect their growth rates only during the transitional period. They may be reinforced or offset by endogenous money supply reactions of the central bank. These reactions depend on the relative aversion of the central bank to decreases in output and increases in prices and so are ambiguous in sign a priori.

Biases in the calculation of real value-added imply smaller elasticities in absolute value for real GNP and the implicit price deflator than for real output and the price level. Indeed, an increase in the real oil price of the size which occurred in 1973-1974 implies that the logarithmic change in real GNP would be less than half that for output.

II. Tests for Structural Change in the Real-Income Equation

The behavior of the real price of oil is dominated by a downward secular trend from the 1950s until the early 1970s as illustrated for the United States in Figure 4. There was a small upward movement in 1971-1972, but the major increase occurred in the second quarter of 1973 and especially the first quarter of 1974. Widespread recessions in 1973-1975 provide the major empirical evidence in support of a large real-income effect of oil price increases. However, several alternative hypotheses focus on other major events occurring roughly coincidentally.

The first of these alternative hypotheses points to the final breakdown of pegged exchange rates in 1973 which permitted (previously) nonreserve countries to regain control of their money supplies and to stop the inflation imported from the United States. In the United States, meanwhile, the Fed reduced money supply growth in mid 1973 and again in mid 1974. The average reduction in the growth rate of the money supply in the eight countries in our sample exceeded 5 percentage points. Obviously any estimate of the effect of oil-price changes must account for the effect of these restrictive monetary shocks.

A second alternative hypothesis points to the widespread adoption of price controls, following the U.S. lead in August 1971, and their subsequent dismantling in the period 1973-1975. Such controls may have caused overstatement of real GNP (and understatement of the GNP deflator) compared to true values.²¹ When the controls were relaxed during 1973-1975, measured real income fell back to its true value giving an illusion of a deeper recession than was actually occurring or the occurrence of a recession when there was none. Although it is possible to develop corrected estimates for

real GNP and the deflator using physical unit series such as employment, car-loadings, and components of the industrial production indices, that is a very large job. The present paper will only examine whether estimated effects of oil-price changes appear to be larger in those countries with coincident price control relaxation. If so, future research will be indicated to disentangle these oil and price control effects.

In examining the empirical data, it is also important to note that the normal or natural growth rate of output has declined generally in the post-war period. In the late 1940s, after a decade and a half of depression and war, the world capital-labor ratio was very low relative to its balanced-growth or steady-state value.²² As the capital stock approaches its steady-state level, the growth rates of capital and hence real income decline toward their steady-state values. If we were to impose a constant natural growth rate, a spurious negative coefficient might be estimated for oil to account for slowing growth in the 1970s.

The real GNP equations of the Mark III International Transmission Model provide a convenient starting place for estimating the effect on output of changes in the real price of oil.²³ These equations were derived, following Barro (1978), by combining a standard Lucas (1973) aggregate supply function with an aggregate demand function with nominal money, real government spending, and real exports as arguments. Specifically, they express the rational-expectations/natural-rate approach as

$$(34) \quad \log y_t - \log y_{t-1} = a_1 - a_2(\log y_{t-1} - \log \bar{y}_{t-1}) + \sum_{i=0}^3 a_{3+i} \hat{M}_{t-i} \\ + \sum_{i=0}^3 a_{7+i} \hat{g}_{t-i} + \sum_{i=0}^3 a_{11+i} \hat{x}_{t-i} + \varepsilon_t$$

where the time subscripts are made explicit, \bar{y}_t is the natural-employment level of real output in quarter t , and \hat{M}_t , \hat{g}_t , and \hat{x}_t are the innovations in

the aggregate demand variables $\log M_t$, logarithm of real government expenditures for goods and services, and exports divided by GNP, respectively.²⁴

Thus in the absence of innovations or stochastic disturbance ε_t , $\log y_t$ adjusts toward its natural level at the rate a_2 per quarter. Innovations in the determinants of aggregate demand affect $\log y_t$ with an unconstrained four-quarter distributed lag to allow for any inventory adjustment lags.

To estimate the effect of the real oil price, it remains to specify $\log \bar{y}_t$ appropriately. A form which allows for both declining natural output growth as just discussed and for an oil price effect is

$$(35) \quad \log \bar{y}_t = b_1 + b_2 t + b_3 t^2 + b_4 \log \theta_t$$

A positive b_2 and negative b_3 implies a declining natural growth rate. The parameter b_4 estimates the full long-run value of $\frac{d \log y}{d \log \theta}$. If the expression (35) were simply substituted in equation (34), an oil price change would implicitly be assumed to have no immediate effect and then a partial adjustment effect at the rate a_2 per quarter. This is inconsistent with the analysis of Section I in which it was shown that the short-run effect is similar in magnitude to the long-run effect.²⁵ So, as with the aggregate demand variables, a four quarter distributed lag on the first difference of $\log \theta$ to capture a rapid short-run adjustment process.

Substituting equation (35) in (34) and adding the short-run adjustment process yields the estimating equation

$$(36) \quad \log y_t = a_1 + a_2(b_1 - b_2) + (1 - a_2)\log y_{t-1} + a_2 b_2 t + a_2 b_3 (t - 1)^2 \\ + a_2 b_4 \log \theta_{t-1} + \sum_{i=0}^3 a_{3+i} \hat{M}_{t-i} + \sum_{i=0}^3 a_{7+i} \hat{g}_{t-i} + \sum_{i=0}^3 a_{11+i} \hat{X}_{t-i} \\ + \sum_{i=1}^4 c_i (\log \theta_{t+1-i} - \log \theta_{t-i}) + \varepsilon_t$$

This equation has been estimated using the 1957-1976 quarterly data set and instruments for the eight countries in the Mark III International Transmission Model. The regressions are based on the two-stage-least-squares-principal-components (2SLSPC) technique because of the large number of predetermined variables in the model.²⁶ The coefficients of the aggregate demand variables are not at issue here, are substantially the same as those discussed in Darby and Stockman (1980), and so are omitted for the sake of brevity from the present discussion.²⁷

The regression results are summarized in Table 2. The coefficient of $\log \theta_t$ is negative in every case although only 4 of the t-statistics meet conventional levels of significance. The implicit estimate of the long-run oil effect is reported in the ninth column as ranging from a 2 basis point decrease in real income per percentage point increase in the real price of oil for the U.S. to 19 basis points for Japan. Table 3 indicates the implied long-run reduction in real income for the eight countries based on the 1973I-1976IV increase in the real price of oil. Rasche and Tatom (1980, Table 7) prepared similar estimates for their model (discussed in Section I) based on 1973-1977 energy price increases, and those estimates are reported for comparison. Despite some differences in detail, the calculations here tell broadly the same story as that of Rasche and Tatom. However, this strong story does not do so well under closer examination.

Let us first consider the possibility that the share of imported oil in total output is so small that any effects are in fact negligible. This is tested by computing the F statistic for the hypothesis that all the oil coefficients are zero ($H_0: a_2 b_4 = c_1 = c_2 = c_3 = c_4 = 0$). As reported in Table 2, only five of the countries have any statistically significant oil

effect at the 5 percent level²⁸ and for one of these (the United States) the significant response is due to short-run movements which might be related to various panic policy responses, briefly adopted here and abroad, to the temporary OPEC embargo at the end of 1973. Further, the significant French effects imply that French income was higher throughout 1973 as a result of rising oil prices and so does not support the hypothesis.

Since experience indicates that the French, Italian, and Japanese data may be quite unreliable,²⁹ let us focus on the results for the United States, United Kingdom, Canada, Germany, and the Netherlands. Of these five, the F statistic is insignificant for Canada and Germany and significant for the United States, United Kingdom, and the Netherlands. Interestingly these three countries with significant F statistics all removed general price controls coincidentally with the 1973-1974 oil price increase while Canada and Germany had no price controls during the relevant period.³⁰ If, as I have argued elsewhere (1976a, 1976b), the decontrol process results in the elimination of overstatement of real GNP built up during the control period, then the spurious drop in reported real GNP relative to true GNP will be captured as part (or all!) of the effect of the coincidental increase in real oil prices. Certainly the pattern of significant oil effects only where simultaneous decontrol occurred strongly indicates the value of research to formulate real GNP estimates unbiased by price-control evasions which overstate quantities and understate prices.

In summary, these empirical results give a rather ambiguous answer to the question of whether or not a large increase in the real price of oil will reduce significantly real income for given nominal money supplies, real government spending, and real exports. Such a reduction is estimated for half the cases, but this may be a spurious result due to the simultaneous removal of price controls in those countries.

III. Simulation Experiments

To assess the effects of the 1973-1974 oil price increase on real income -- and ultimately the price level -- we must allow for induced changes in nominal money supplies and real exports aside from any possible direct effects such as examined in Section II. To take account of these indirect effects, one must resort to a simulation model of some sort, and this section reports results from the Mark IV Simulation Model described in Darby (1981).³¹ The results of any one simulation model cannot be taken too seriously except as they illustrate the possible importance of channels not inconsistent with the data which might otherwise be overlooked. So with a spirit of healthy scepticism, let us turn to the specific experiments.

To assess the effects of the oil price increase we compare the results from simulating the model in one case with the actual real price of oil and in another case with the real price of oil held constant at the 1973 I price. The assumed difference in the logarithm of the real price of oil ($\log(\theta/\bar{\theta})$) is plotted in Figure 5. The dynamic simulations begin in 1973 II and continue for two years thereafter.³²

In view of the mixed evidence for direct oil price effects on real income as reported in Section II, the basic Mark IV model does not incorporate such effects. An alternative simulation model, the Mark IV-Oil, was therefore estimated. It differs from the basic Mark IV model only in the addition to the real income equations of the variables listed in Table 2 above for those 5 countries for which the oil variables were significant (United States, United Kingdom, France, Japan, and the Netherlands). These five equations are listed with their estimated coefficients in Table 4.

Figures 6 through 10 illustrate the simulation results for the five countries with reliable data. Each figure displays the simulated effect of

the oil price increase on six major macroeconomic variables for one country. The effect is estimated as the difference between the simulation values based on the actual real price of oil and the values based on a constant post-1973 I price. The effects simulated by the basic Mark IV model are plotted with a square while those for the Mark IV-Oil are plotted with a diamond.

Examining first Figure 6 for the United States, we see a considerable difference depending on whether or not direct oil price effects appear in the real income equation. In the basic Mark IV Model without those effects, the simulated effect of the oil price increase is to increase real income by stimulating exports. The price level rises a bit to a peak effect of 2.5 percent, despite the slight decrease in nominal money supply, because the large rise in interest rates (due to increased exports) dominates the income effect to produce a significant decline in the real quantity of money demanded. That is, the denominator in equation (2) above falls by more than the numerator. The situation is much different for the Mark IV-Oil Model with direct real income effects: Real income -- following a brief initial increase -- is reduced by up to 3 2/3 percent at the trough. This reduction is caused both by the direct real income effects and -- in the second year -- by the reversal of real export growth. The price level increase is almost double that simulated in the basic model although simulated nominal money is only a little higher. This is so because of much lower simulated y which would much reduce $m^d(y,R)$ and hence increase $P = M^S/m^d(y,R)$ as compared to the basic Mark IV Model simulations.

The simulated effects for the United Kingdom (see Figure 7) tell a story similar to that for the United States. The main differences lie in the simulated behavior of the nominal money stock and interest rates in the

Mark IV-Oil Model. Because the estimated U.K. money-supply reaction function is responsive to unemployment but not inflation increases, unlike the U.S., falling output induces substantial increases in nominal money. In the U.S. Mark IV-Oil simulations the downward pressure on the interest rate due to lower exports was roughly offset by upward pressure from increased inflationary expectations. Inflationary expectations are much less important in the estimated U.K. interest rate equation; so the lower level of exports in the Mark IV-Oil Model case is reflected in lower interest rates. Nonetheless, the much higher nominal money supply and lower real income dominate the somewhat lower interest rates in increasing $P = M^S/m^d(y,R)$. A minor difference between the U.S. and U.K. simulations appears in the scaled balance of payments variable: For the U.S., this variable largely represents intervention by other countries while for the U.K. it mainly represents minimal net intervention in the floating exchange market by the British government.

The Canadian sectors of the basic Mark IV Model and of the Mark IV-Oil Model are identical since the oil variables were found insignificant in the Canadian real income equation in Section II. The differences in the simulated effects thus represent the effects on Canada of lower foreign real income in the Mark IV-Oil case. Thus the peak real income is only about 2 percent in this case compared to about 3 2/3 percent with the basic model and so, given the small simulated movements in nominal money and interest rates, prices fall a bit less than in the basic model.

Like Canada, no direct oil-price effects are included in the German real-income equation. The German real-income equation does display an anomalous cumulative negative impact of higher exports, however, so real income is lower with the higher estimated exports in the basic Mark IV Model. Since more than complete real crowding out of increased export expenditures is inconsistent with a priori notions, the German simulations are viewed as uninformative for

this experiment.

The Netherlands real income equation in the Mark IV-Oil Model includes direct oil effects and the real income simulation yields results similar to although much larger than those obtained for the U.S. and U.K. The price effects differ, however, for several reasons: (1) There is an anomolous, insignificant, but negative coefficient on transitory income in the real money demand equation; thus lower simulated real income implies higher simulated real money demand. (2) The estimated interest rate coefficient in the real money-demand function has the right sign but is trivial in magnitude. (3) Nominal money is trivially lower in the Mark IV-Oil case due to some simulated balance-of-payments effects. Thus the price effects simulated for the Netherlands occur only because of coefficients which are consistent with the data but not standard a priori notions.

These simulation results illustrate the large difference it makes whether or not we take at face value the estimated real-oil-price effects in the real income equations. We cannot say whether or not the 1973-1974 increases in real oil prices caused price level increases on the order of 0 to 3 percent or of 4 to 8 percent and upwards. Similarly real income effects might range from slightly positive to about -10 percent for the countries examined here. It is both the sorrow and challenge of our nonexperimental science that other things were not held constant when the oil price change occurred. One factor which may explain the estimated real income effects in 1973-1974 was identified in Section II: the coincidental removal of price controls in those countries for which real effects were found. Only much further research can show whether the large simulated effects in the Mark IV-Oil Model have a basis in reality or are the result of other changes -- such as price decontrol -- occurring in the same period.

IV. Conclusions

The effects on real income and the price level of the 1973-1974 increases in the real price of oil are the subject of strongly held but diverse opinions.³³ Unfortunately the results of this paper indicate that a wide range of opinions is indeed consistent with the data. Perhaps we should not be surprised that with effectively one degree of freedom it is difficult to have much confidence in estimates of both an oil price coefficient and its standard error.

The Iranian hostage crisis of 1979-1980 will provide us data soon on a second major move in the real price of oil. But these data are unlikely to resolve the empirical question. It seems to this author that a more fruitful avenue may be to develop quantitative measures of the biases in official real output data due to price controls and then see what oil-price effects are estimated using these corrected data. This approach is feasible because price controls were generally imposed much before the oil price change. Thus historical relationships between labor input, electricity production, carloadings, and other physical unit series can be used to estimate the biases up to the oil price change.

If this paper has demonstrated that the effects of the real-oil-price increases in 1973-1974 remain an open question and thus stimulates research towards answering it, then the author will be amply recompensed for having to report such inconclusive conclusions.

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Footnotes

¹See Darby and Stockman (1980) for details.

²A fuller specification would include a factor $e^{\delta+\tau t}$ on the right hand side, but it simplifies the notation without loss to choose labor units such that the e^{δ} is eliminated and to incorporate technical progress τ into our measurement of labor in efficiency units. The basic results (8) and (12) below are stated in Tatom (1979a, pp. 10-11) and Rasche and Tatom (1980) starting from the same production function (3). Their longest-run results (12), however, are derived from the simple assertion that the marginal product of capital is fixed in the long-run by supply conditions rather than as the result of a growth analysis as is done below. Their assertion -- although it is correct in this case -- is generally false. They erroneously interpret the gross "rental price of capital" which is equated to the marginal product of capital as "the relative price of capital" (e.g., Tatom (1979a, pp. 10-11)) and argue that this will equal its fixed supply price in the long-run. In the appendix to Rasche and Tatom (1980), they instead have attempted to relate changes in output to changes in capacity of individual firms, but this seems to neglect the fact that the number of firms is not fixed.

In the main body of the paper they present evidence supportive of the usage of a Cobb-Douglas production function of this form (3). Kopcke (1980) argues that it is improper to include energy as an argument in the aggregate production function since energy is itself an intermediate product produced by capital and labor. This objection does not apply to imported petroleum which is produced by foreign labor and capital. Care must be taken, as seen below, however in going from the domestic output concept appropriate to the

production function (3) to the value-added concept of real GNP. Unfortunately this last step has not been made in the three-factor analyses of the effects of oil-price changes.

³This assumption is arguable also. For example, Phelps (1978) treated the quantity of imported oil ϕ as determined exogenously; the nominal price of oil is assumed fixed by Mork and Hall (1979) and by Berner, et al., (1977) in their Multi-Country Model. Rasche and Tatom (1980) argue persuasively that neither of these representations capture the meaning of OPEC's ability to set an optimal real price of oil.

⁴The value of γ is discussed at some length below. To the extent that capital is in the form of existing machines which cannot be readily modified and which require fixed petroleum inputs, the quasi-rents of existing machines will fall without any reduction in output or petroleum usage. A possibly offsetting factor would be the premature obsolescence of machines on which the quasi-rents fall below zero. Neither of these factors is operative in full long-run equilibrium discussed immediately below, and are taken as negligible on net here.

⁵Before capital adjusts, but with resources fully employed the marginal product of capital $\alpha k^{\alpha-1} \ell^{\beta} \phi^{\gamma}$ falls (slightly) with ϕ and hence so does the real interest rate.

⁶That is $\theta \approx \bar{\theta}$ so that $\frac{\gamma \bar{\theta}}{\theta - \gamma \theta} \approx \frac{\gamma}{1 - \gamma}$.

⁷Although $\frac{d \log q}{d \log \theta} = 0$ initially as seen at (17) as θ increases, the positive RHS term in (16) decreases while the negative RHS is unchanged. The negative effect is yet greater if capital is allowed to adjust.

⁸Note that the first RHS term in (18) is approximately equal (for small γ) to $\gamma\left(1 - \frac{\bar{\theta}}{\theta}\right)$ which illustrates that as θ becomes large the adjustment for imported inputs in measured GNP becomes trivial and all output is included in measured GNP.

⁹It is possible to apply the analysis to energy more generally, but the increase in γ is largely offset by a reduced logarithmic change in θ .

¹⁰Rasche and Tatom (1980), Table 6.

¹¹A formal solution to this problem is presented in Darby (1979, Chap. 5).

¹²This tax analysis is given little if any weight in recent analyses. Rasche and Tatom (1980), for example, term it "the 1974 view" and belief that aggregate demand shifts were important appears to have been an ephemeral phenomenon. It is included here for the sake of completeness.

¹³The exact amount of these reductions depends on consumer expectations, but the direction is unambiguous.

¹⁴There is no long-run effect on output or interest rates via this channel unless differences between foreign and domestic propensities to save cause a shift in the domestic investment-output ratio.

¹⁵The aggregate demand curve is derived by solving the IS relationship for R and substituting in equation (2).

¹⁶A negative sign indicates a shift to the left.

¹⁷Purvis (1975) displays the correct formula for η_D which is

$$\eta_D = \frac{-1}{\frac{\partial \log m^d}{\partial \log y} + \psi \frac{\partial \log m^d}{\partial \log R}}$$

where ψ is $\frac{d \log R}{d \log y}$ or the elasticity of the interest rate with respect to output on the IS curve. For a normal negatively sloped IS curve, $\psi \frac{\partial \log m^d}{\partial \log R}$ will be positive but insufficient to bring the denominator of η_D up to 1 if short-run interest elasticity of money demand is small and the IS curve is rather flat as argued by Hall (1977).

Rasche and Tatom (1980) make a convoluted version of Gamb's error (which Purvis corrected) to conclude that the aggregate demand curve was inelastic. Rather than accept the implication of increased employment, they repeat their (1977a) assumption that nominal wages rise freely once the natural unemployment rate is reached. I can see no justification for this appendage to a basic search view of the labor market. It is of course irrelevant if $\eta_D < -1$ or the aggregate demand curve shifts to the left sufficiently to reduce employment despite an inelastic aggregate demand curve.

¹⁸If the elasticity of aggregate demand is less than -1 but greater than $-\frac{\beta}{\beta - \alpha}$ (about -1.5), the short-run effect will be greater than the full-employment effect for a given capital stock but less than the long-run effect allowing for capital adjustment. That is, in the absence of significant shifts in aggregate demand, the long-run effects with full capital adjustment such as calculated in Table 1 exceed the short-run effects unless $\eta_D < -\beta/(\beta - \alpha) \approx -1.5$.

¹⁹More wage flexibility implies less employment variation, so output would be lower than indicated by equation (24) if $\eta_D > -1$ and less if $\eta_D < -1$.

²⁰The lack of a term in the balance of payments implies that we are either dealing with a reserve country (the U.S.), a freely floating country,

or with a country which can and does sterilize balance of payments effects in the relevant period; see Darby (1980). By the time of the first oil shock (1973-1974) this is probably a reasonable characterization although current balance of payment effects will also be present for some countries in the simulations reported in Section III below.

²¹See Darby (1976a, 1976b).

²²Even for the relatively unscathed United States, capital grew by only about 0.4 percent per annum from 1929 through 1948 compared to a normal growth rate of 3.2 percent; see Christensen and Jorgenson (1978, p. 56). This implies that by 1948 the actual U.S. capital stock was less than 60 percent of the steady-state capital stock.

²³See Darby and Stockman (1980) for a description of the model.

²⁴The scaling of exports as a fraction of income rather than in logarithmic terms was done to permit application of the balance-of-payments identity in the model. In the results reported here all the innovations are defined as residuals from optimal ARIMA processes applied to $\log M_t$, $\log g_t$, and $(X/Y)_t$, respectively.

²⁵Immediately after an increase in the real oil price, the capital stock is greater than in full long-run equilibrium while labor utilization is less. The net effect depends on the elasticity η_D of the aggregate demand curve, but approximates the full long-run effect on plausible assumptions.

²⁶The only current endogenous variables in equation (36) are \hat{M}_t , \hat{g}_t , \hat{x}_t , and $\log \theta_t$. Time t and government spending shocks are exogenous in the model, but \hat{M}_t and \hat{x}_t are endogenous. The price of oil in base-year dollars

is exogenous so $\log \theta_t$ is exogenous for the U.S. For the other seven countries endogenous movements in the purchasing power ratio make the real price of oil in base-year domestic currency units endogenous, but they are dominated by movements in the U.S. real price.

²⁷To the extent these aggregate demand variables were correlated with any significant oil variables added here, their numerical values were of course affected. However, the general pattern and conclusions remained unaltered from the earlier discussion cited in the text.

²⁸Only France is significant at the 1 percent level.

²⁹See discussions in Darby and Stockman (1980) and Darby (1981).

³⁰The United States took the lead in imposing price controls in August 1971 which Darby (1976a, 1976b) argues led to an increasing overstatement of real GNP (and understatement of the deflator) through the first quarter of 1973. Controls were then relaxed in phases through the third quarter of 1974 with progressive elimination of overstatement in real GNP. That is, real income growth was overstated from 1971III through 1973I and then understated from 1973II through 1974IV. According to Parkin in Shenoy (1978, pp. 150-151) the United Kingdom followed a similar pattern with controls instituted with a freeze in November 1972, peaking in their effect on the data with the end of Stage II in August 1973, and eventually abandoned entirely after the Conservative loss of February 1974. Shenoy (1978, pp. 132-135) reports a similar albeit more complex pattern for the Netherlands beginning also with a 1972 price freeze. Carr (1976, p. 40) points out that Canada was free of general price controls until October 1975, too late to cause any biases in the oil-price coefficients. West Germany imposed no

price controls on the ground that such policies distract attention from the real problems; Shenoy (1978, pp. 138-141).

³¹The Mark IV Simulation Model is a simplified simulation version of the Mark III International Transmission Model described in Darby and Stockman (1980). The main simplifications involve (1) deletion of insignificant variables except where they are required a priori to permit international transmission and (2) combining variables to reduce multicollinearity where a priori hypotheses on equality of coefficients were not rejected by the data. The resulting model is thus both consistent with the data and tractable for simulation. The Mark IV Model exists in versions corresponding to pegged and floating exchange rates, but only the latter (Mark IV-FLT) is used in this paper.

³²In a dynamic simulation, the input series are the exogenous variables plus the initial conditions (endogenous variables at the beginning of the simulation). The values of endogenous variables within the simulation period are assigned their predicted values. As is common for a large model with few exogenous variables, the cumulative errors in the endogenous variables eventually take the simulation off track. For the Mark IV Simulation Model, this dynamic instability is not a significant difficulty until after the first two years.

³³Taking two of the best studies for the long-run U.S. real-income effect as examples: Nosworthy, Harper, and Kunze (1979, p. 412) report an average reduction in productivity growth of 0.18 percent per annum for 1973-1978 which implies a total reduction in real income of 0.9 percent. By contrast, Rasche and Tatom (1980), as reported in Table 3 above, estimate a 7.0 percent long-run effect.

TABLE 1

Illustrative Calculations of Maximum Long-Run
Effect of 1973-1974 Real Oil Price Increase

	<u>No Capital Adjustment</u>		<u>Full Capital Adjustment</u>	
	$\gamma = 0.003$	$\gamma = 0.02$	$\gamma = 0.003$	$\gamma = 0.02$
change in log output ($\Delta \log y$)	-0.0038	-0.0260	-0.0051	-0.0346
change in measured real GNP ($\Delta \log q$)	-0.0017	-0.0114	-0.0029	-0.0200
difference ($\Delta \log q - \Delta \log y$ $\equiv \Delta \log P - \Delta \log D$)	0.0022	0.0146	0.0022	0.0146

TABLE 2

2SLSPC Regression Estimates of Oil-Price Effects in Real Income Equation (36)

Country	Adjustment Coefficient a_2	Coefficient of										Long-run Oil Effect $a_2 b_4 / a_2$	F(5,59) Statistic	R^2	S.P.E. [D-W]	h
		$a_2 b_2$	$(t-1)^2$ $a_2 b_3 \times 10^6$	$\log \theta_{t-1}$ $a_2 b_4$	$\Delta \log \theta_t$ c_1	$\Delta \log \theta_{t-1}$ c_2	$\Delta \log \theta_{t-2}$ c_3	$\Delta \log \theta_{t-3}$ c_4								
United States	0.180 (0.049) 3.656	0.00196 (0.00058) 3.349	-3.215 (3.389) -0.949	-0.0038 (0.0052) -0.732	-0.021 (0.011) -1.897	-0.022 (0.011) -2.074	-0.009 (0.010) -0.092	-0.018 (0.011) -1.650	-0.021	2.54*	0.9984	0.0082	-0.53			
United Kingdom	0.448 (0.112) 3.985	0.00284 (0.00095) 2.978	2.449 (6.089) 0.402	-0.0253 (0.0093) -2.717	-0.047 (0.018) -2.602	0.025 (0.017) 1.489	0.019 (0.016) 1.127	0.007 (0.017) 0.433	-0.057	3.32*	0.9943	0.0120	1.10			
Canada	0.171 (0.070) 2.446	0.00203 (0.00080) 2.529	1.293 (5.283) 0.245	-0.0081 (0.0073) -1.097	-0.005 (0.016) -0.304	0.004 (0.015) 0.273	-0.010 (0.015) -0.642	-0.004 (0.016) -0.260	-0.047	0.49	0.9982	0.0121	-3.40			
France	0.613 (0.120) 5.089	0.00892 (0.00173) 5.163	-1.977 (7.316) -0.270	-0.0581 (0.0168) -3.455	0.038 (0.021) 1.823	0.083 (0.026) 3.167	0.062 (0.024) 2.576	0.009 (0.023) 0.373	-0.095	4.40**	0.9976	0.0159	[2.33]			
Germany	0.176 (0.080) 2.205	0.00236 (0.00116) 2.035	-5.581 (6.748) -0.827	-0.0068 (0.015) -0.456	0.002 (0.026) 0.074	0.013 (0.020) 0.678	0.022 (0.019) 1.187	-0.010 (0.020) -0.492	-0.039	0.56	0.9975	0.0131	0.26			
Italy	0.260 (0.083) 3.127	0.00404 (0.00145) 2.785	-11.474 (6.440) -1.782	-0.0092 (0.0073) -1.252	0.010 (0.014) 0.749	0.005 (0.015) 0.333	0.010 (0.015) 0.617	0.001 (0.014) 0.073	-0.035	0.54	0.9982	0.0120	-2.02			
Japan	0.206 (0.082) 2.529	0.00485 (0.00179) 2.711	-2.244 (6.043) -0.371	-0.0393 (0.0178) -2.205	-0.048 (0.018) -2.711	0.007 (0.020) 0.345	0.014 (0.018) 0.788	0.010 (0.018) 0.562	-0.191	2.27*	0.9994	0.0135	-1.74			
Netherlands	0.334 (0.087) 3.850	0.00284 (0.00083) 3.418	11.646 (7.465) 1.560	-0.0394 (0.0138) -2.862	-0.027 (0.016) -1.672	0.035 (0.019) 1.839	0.018 (0.018) 0.967	0.009 (0.017) 0.534	-0.118	2.38*	0.9981	0.0122	1.59			

Notes: 1. Period: 1957I-1976IV. Standard errors are reported in parentheses below coefficient estimates, t-statistics are below the standard errors. The biased Durbin-Watson statistic is reported in square brackets in those cases in which Durbin's h cannot be computed (is imaginary). Coefficient estimates for the constant and the aggregate demand shocks (a_3, \dots, a_{14}) are not reported for brevity's sake.

2. Note that the reported coefficient estimates for t^2 are multiplied by 10^6 .

3. In the headings the symbol Δ is used for first differences rather than deviations from the base year.

4. The F(5,59) statistic is for the test of the hypothesis that $a_2 b_4 = c_1 = c_2 = c_3 = c_4 = 0$. The 0.05 significance level (indicated by *) requires $F > 2.23$. The 0.01 significance level (indicated by **) requires $F > 3.34$.

TABLE 3

Implied Estimates of Long-Run Decrease in Real GNP
due to 1973I-1976IV Increases in Real Price of Oil

Country	$\frac{d \log q}{d \log \theta}$ ^a	$\log \theta_{1976IV}$ $-\log \theta_{1973I}$	Long-Run Decrease in q ^b	Rasche-Tatom Long-Run Estimate ^c
United States	-0.021	1.2119	-2.5%	-7.0%
United Kingdom	-0.057	1.2749	-7.3%	-3.5%
Canada	-0.047	1.1045	-5.2%	-4.4%
France	-0.095	1.1477	-10.9%	-4.1%
Germany	-0.039	1.1101	-4.3%	-1.9%
Italy	-0.035	1.3995	-4.9%	NA
Japan	-0.191	1.1402	-21.8%	-17.1%
Netherlands	-0.118	0.9856	-11.6%	NA

Notes: a. This is the ratio of the estimated values of $a_2 b_4$ to a_2 from Table 2.

b. Product of the previous two columns.

c. From Rasche and Tatom (1980), Table 7, for 1973-1977 energy-price increases.

TABLE 4

Alternative Real-Income Equations for Mark IV-Oil Model

EQUATION FORM

$$\begin{aligned} \log y_j = & \alpha_{j1} + \alpha_{j2} \log y_{j,t-1}^P + (1-\alpha_{j2}) \log y_{j,t-1} + \sum_{i=0}^3 \alpha_{j,3+i} \hat{M}_{j,t-i} \\ & + \sum_{i=0}^3 \alpha_{j,7+i} \hat{g}_{j,t-i} + \sum_{i=0}^3 \alpha_{j,11+i} \hat{x}_{j,t-i} + \alpha_{j,20} t \\ & + \alpha_{j,21} (t-1)^2 + \alpha_{j,22} \log \theta_{j,t-1} + \sum_{i=0}^3 \alpha_{j,23+i} \log(\theta_{j,t-1} / \theta_{j,t-i-1}) + \epsilon_j \end{aligned}$$

Note: The country index is j , $\log y_j^P$ is permanent income, and $\log \theta_j \equiv \log E_j + \log P^{RO}$ where E_j is the exchange rate and P^{RO} is the index of the real price of a barrel of Venezuelan oil in 1970 U.S. dollars.

COEFFICIENTS

Coefficient Name	Values by Country (j)				
	United States	United Kingdom	France	Japan	Netherlands
α_{j1}	-0.0016	-0.0148	0.0843	0.2335	0.0668
α_{j2}	0.1472	0.4631	0.5351	0.2116	0.2869
α_{j3}	0.8335	-0.1410	-0.2414	--	0.1542
α_{j4}	0.4271	--	--	--	0.0679
α_{j5}	--	--	--	0.2211	-0.0676
α_{j6}	0.9220	--	--	--	-0.1044
α_{j7}	--	0.1464	0.0487	--	0.0625
α_{j8}	0.1320	--	--	--	-0.0239

TABLE 4 (Continued)

Coefficient Name	United States	United Kingdom	France	Japan	Netherlands
$\alpha_{j,9}$	0.0960	0.0959	0.0531	--	0.0222
$\alpha_{j,10}$	0.0852	--	--	-0.0536	0.0398
$\alpha_{j,11}$	1.4624	--	-0.1536	-0.8258	0.0352
$\alpha_{j,12}$	1.0743	0.5147	--	--	-0.0231
$\alpha_{j,13}$	--	--	--	-0.6406	0.1660
$\alpha_{j,14}$	--	--	--	-0.8563	-0.0236
$\alpha_{j,20}$	0.0005	0.0005	0.0007	0.0006	-0.0004
$\alpha_{j,21}$	-0.0000	-0.0000	-0.0000	-0.0000	+0.0000
$\alpha_{j,22}$	0.0003	-0.0188	-0.0447	-0.0351	-0.0307
$\alpha_{j,23}$	-0.0187	-0.0294	0.0089	-0.0481	-0.0269
$\alpha_{j,24}$	-0.0231	0.0236	0.0500	0.0018	0.0257
$\alpha_{j,25}$	-0.0064	0.0213	0.0402	0.0104	0.0096
$\alpha_{j,26}$	-0.0200	0.0073	0.0084	0.0024	0.0032

Note: The Mark IV-Oil Model differs from the Mark IV-FLT Simulation Model only in these five equations. A coefficient for a suppressed variable (t statistic less than 1 in absolute value; $\alpha_{j,3}$ through $\alpha_{j,14}$ only) is indicated by --.

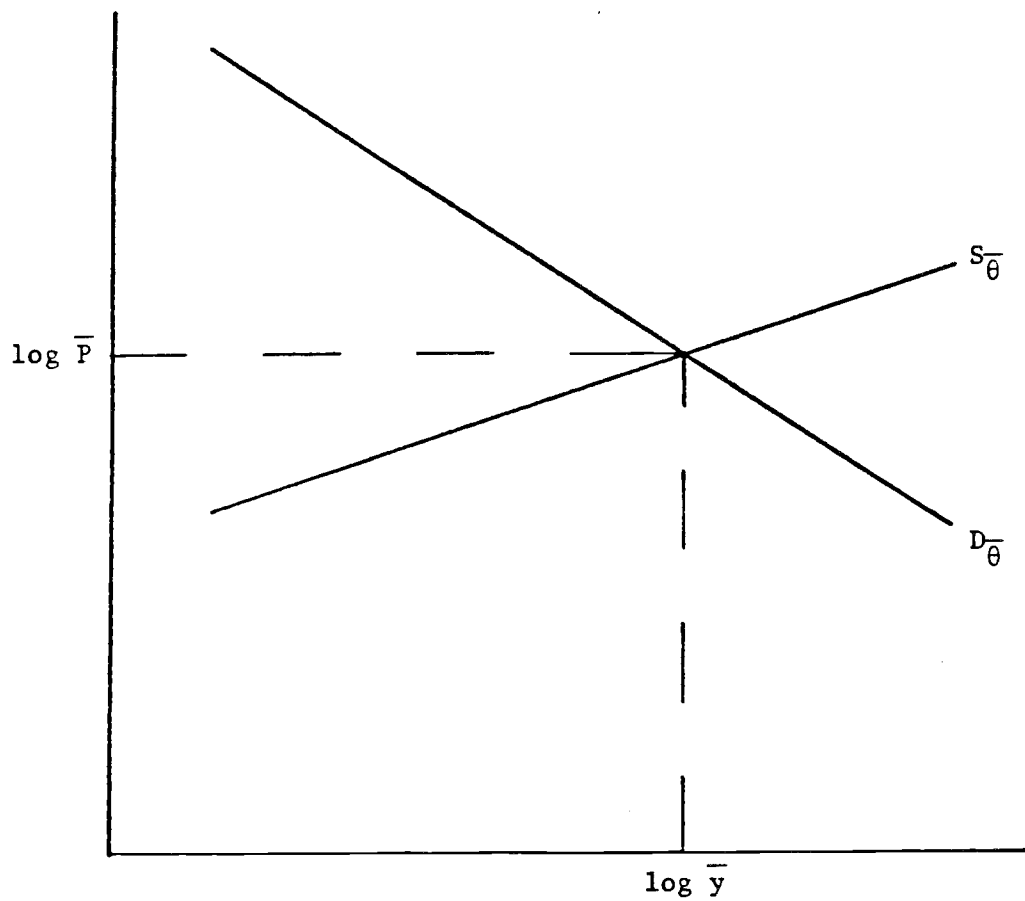


Figure 1

Determination of Base Output and Price Level.

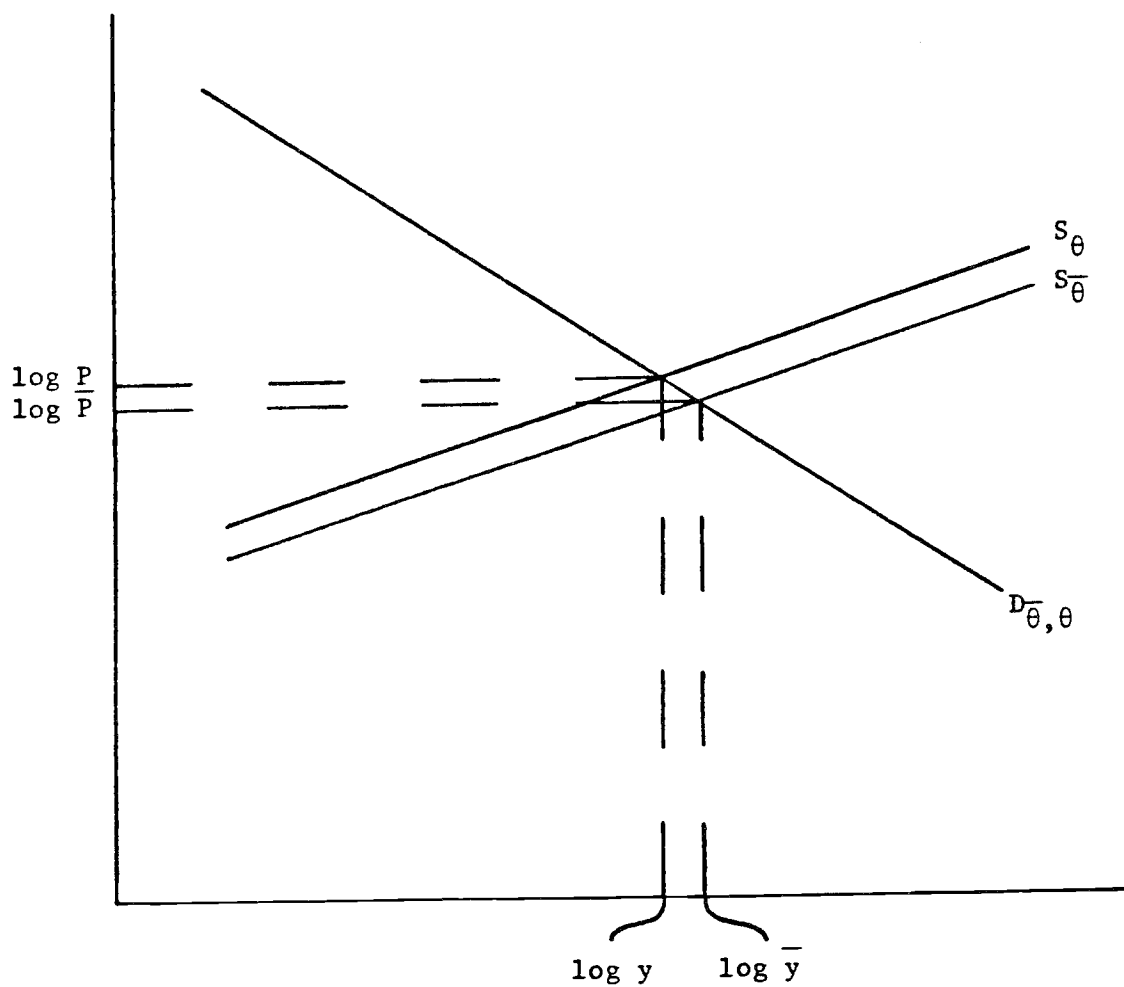


Figure 2

Determination of Change in Output and Price Level
from Base Values with No Aggregate-Demand Shift

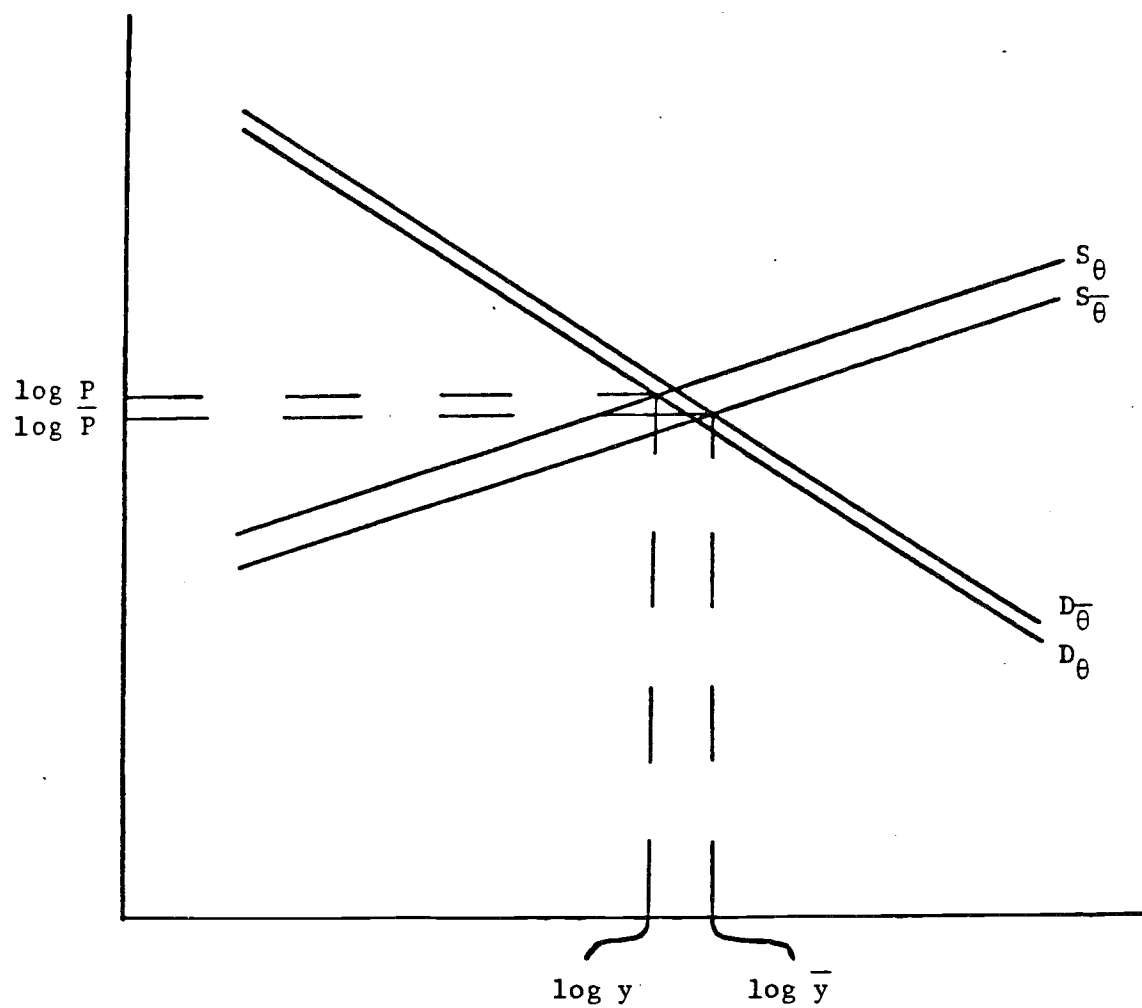


Figure 3

Determination of Changes in Output and Price Level
from Base Values with Shift in Aggregate Demand

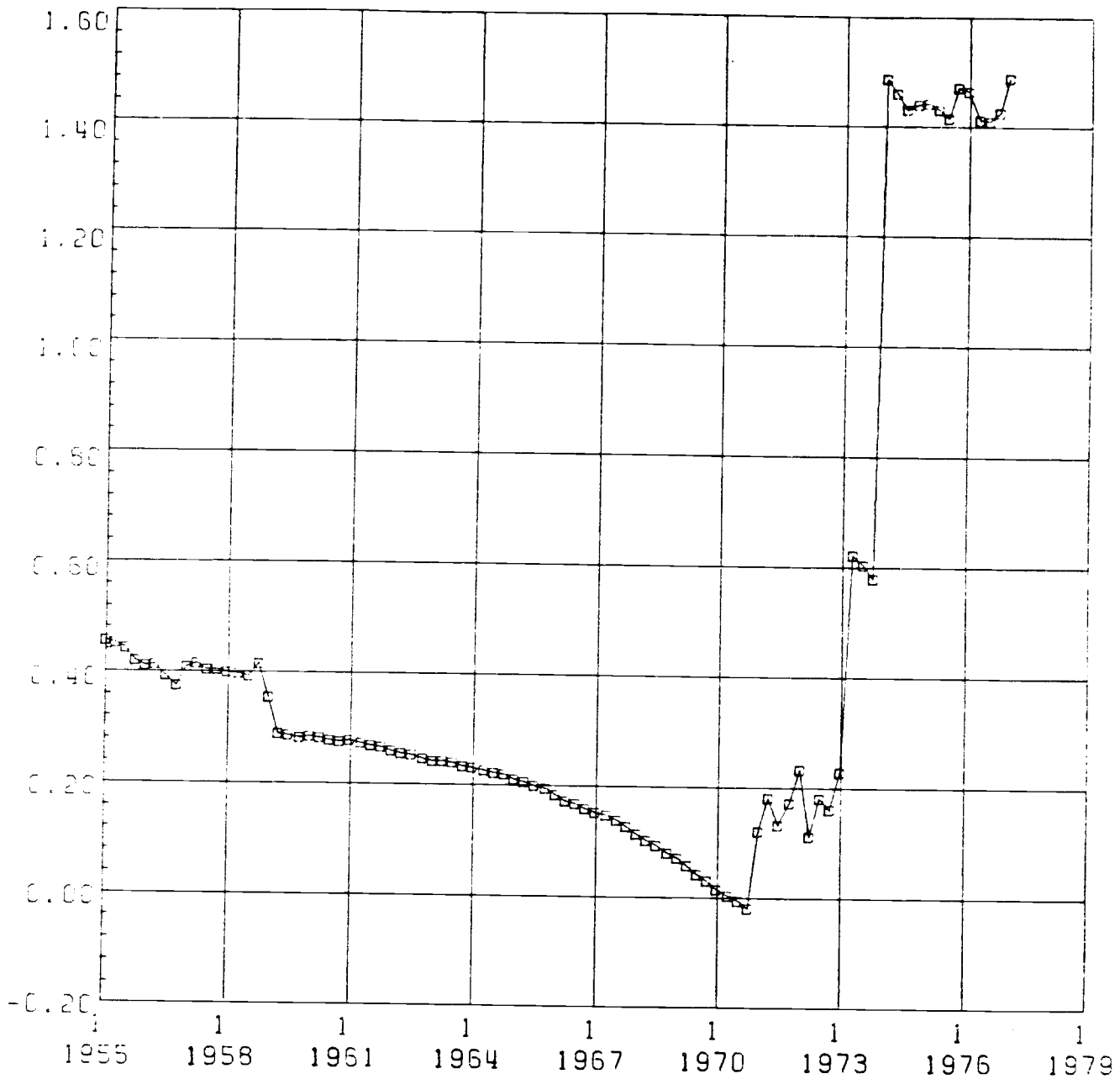


Figure 4

The Logarithm of the United States Real Price of Imported Oil

Source: The dollar price index of Venezuelan crude oil is taken from various issues of International Financial Statistics and rebased to 1.00 in 1970. This is then deflated by the U.S. GNP deflator (1970 = 1.00) to obtain θ ($\theta_{1970} = 1.00$).

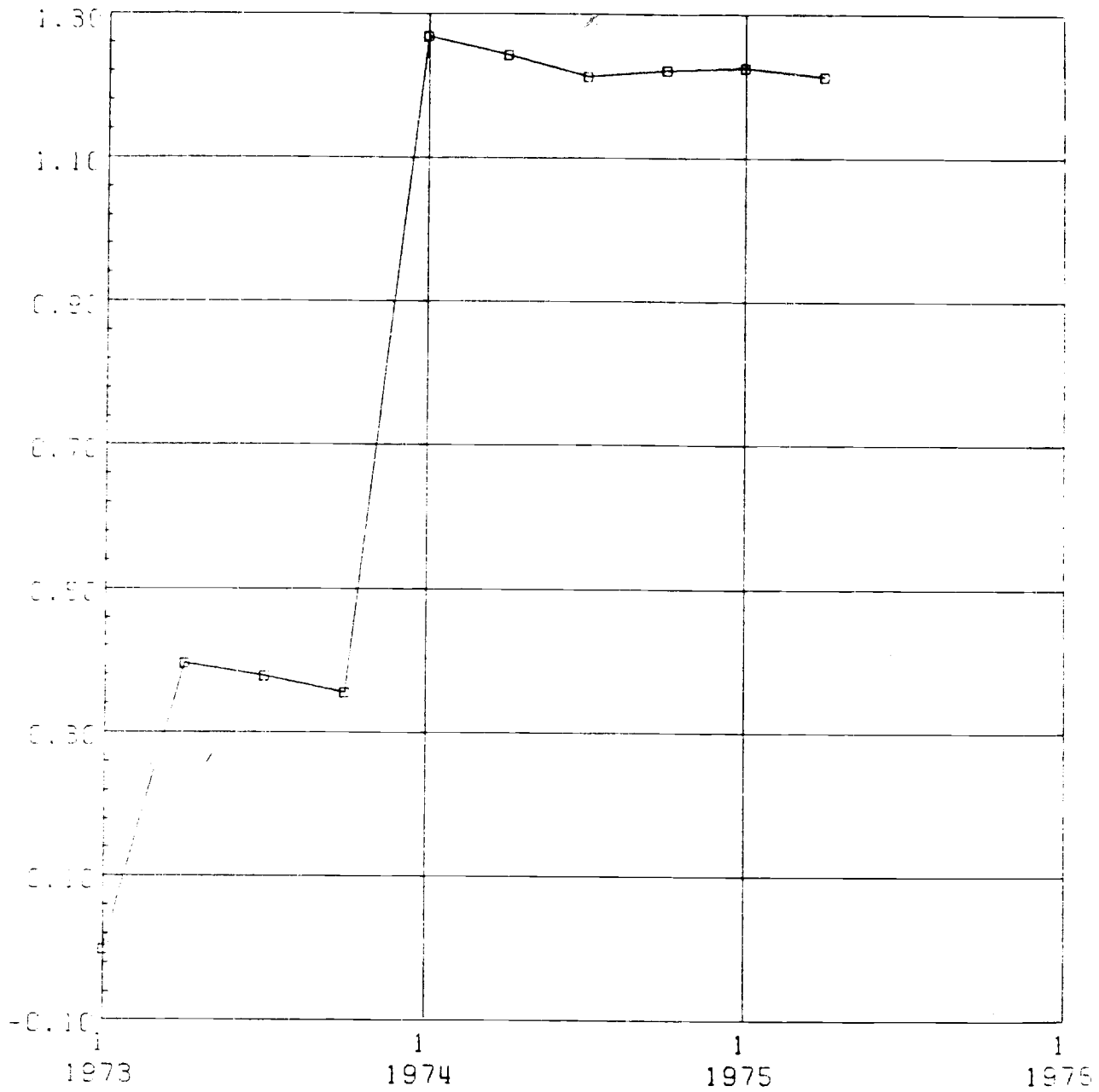
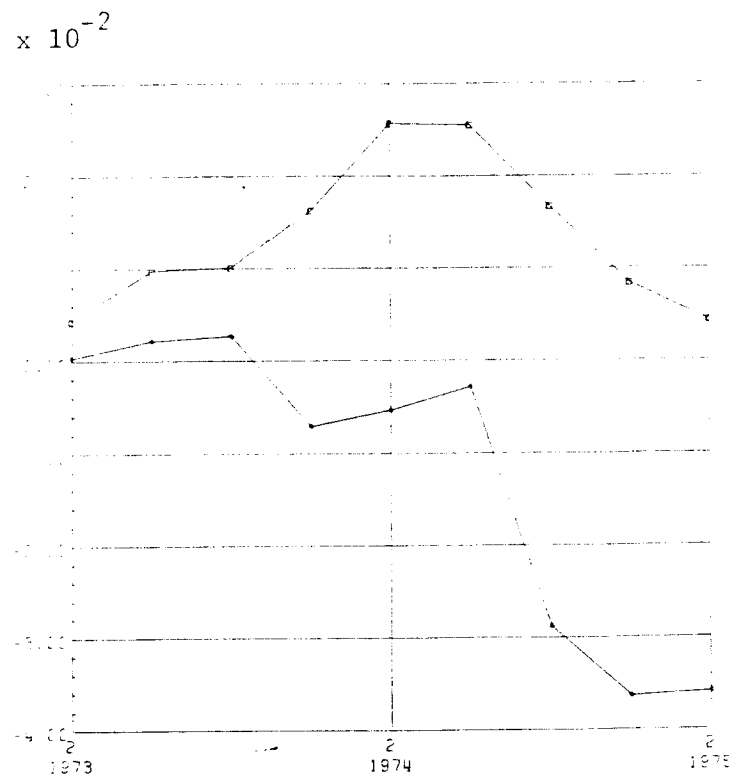
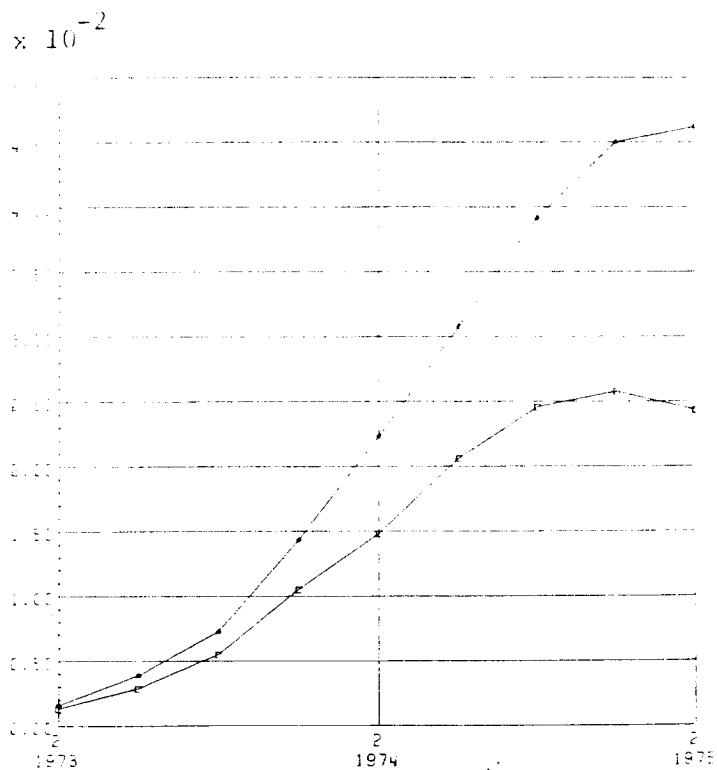


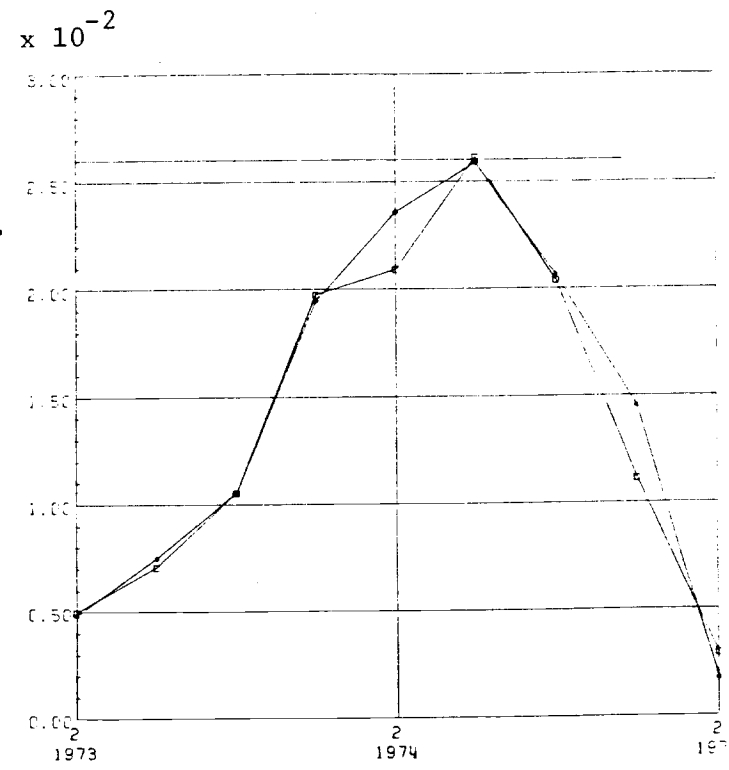
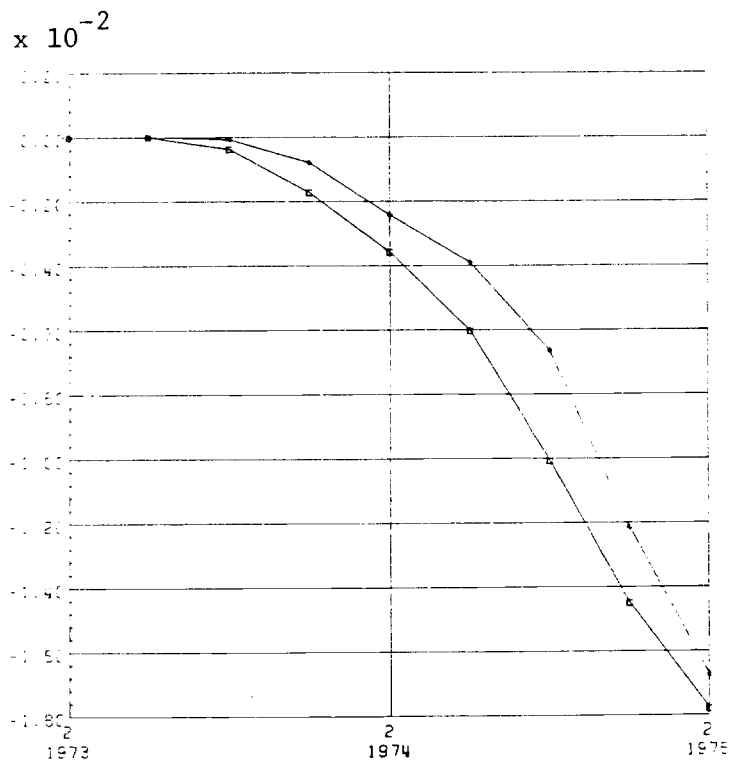
Figure 5

Logarithmic Increase in U.S. Real Price of Oil from 1973 I



(a) Price level -- $\log P_{US}$

(b) Real Income -- $\log y_{US}$

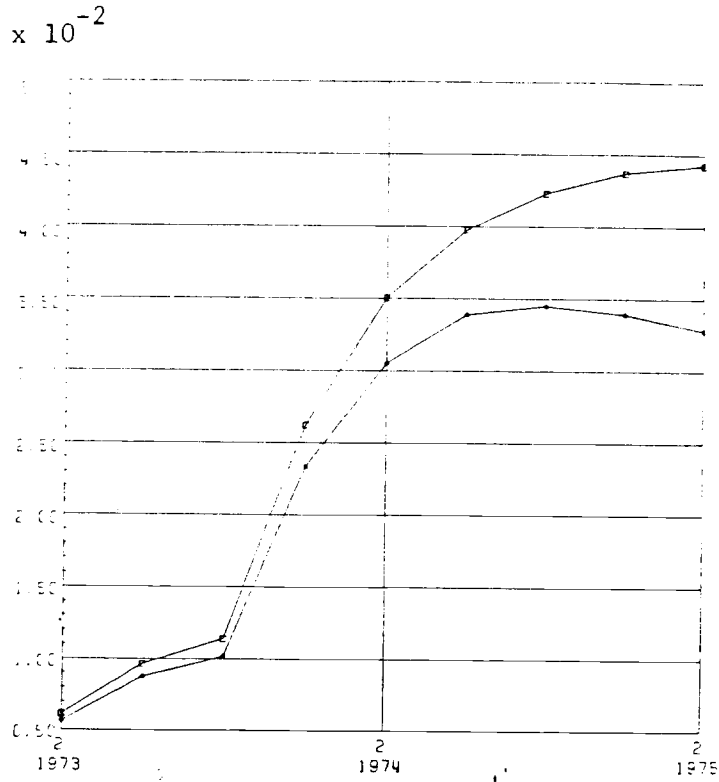


(c) Nominal Money -- $\log M_{US}$

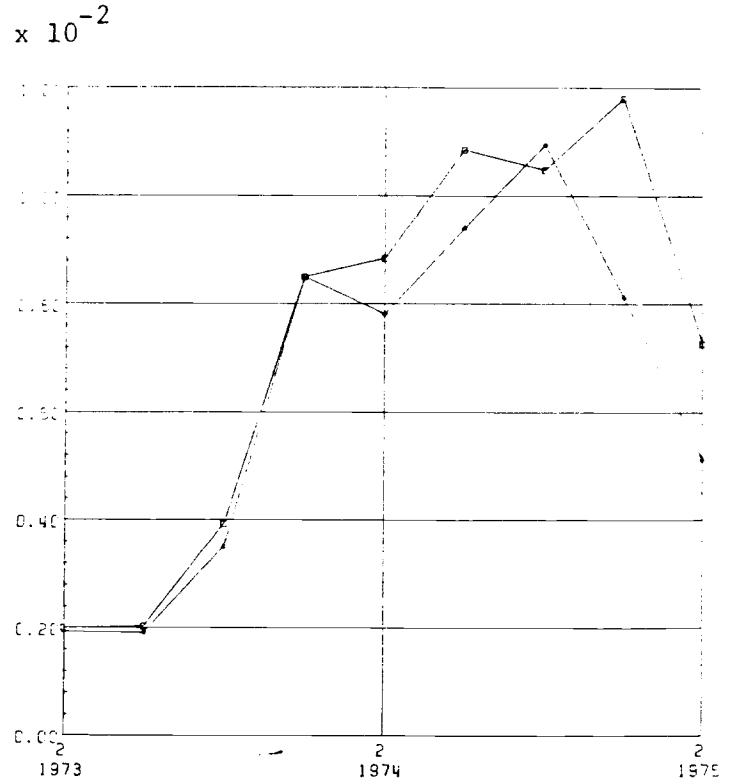
(d) Short-Term Interest Rate -- R_{US}

FIGURE 6

Simulated Effects in the United States of the 1973-1975 Increase in the Real Price of Oil

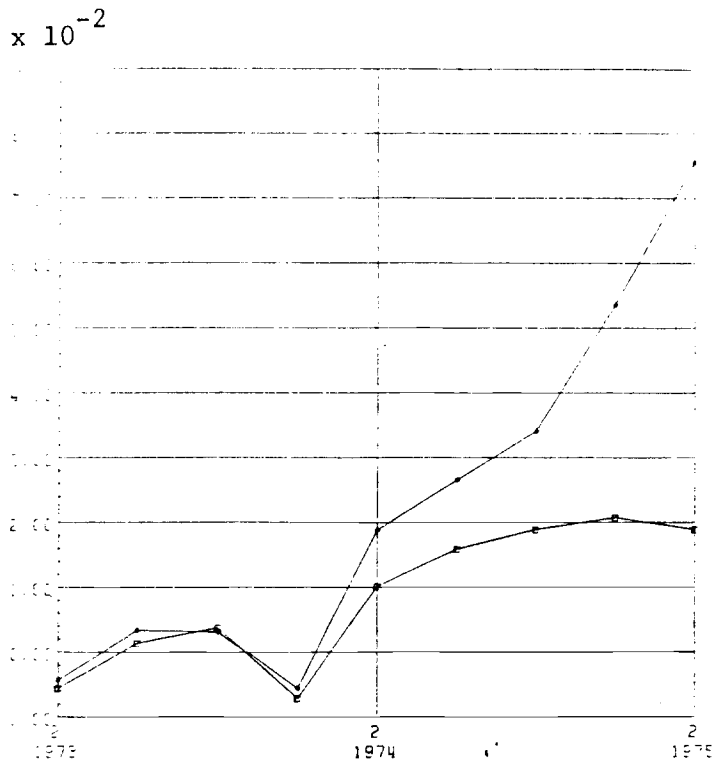


(e) Scaled Exports -- (X/Y)_{US}

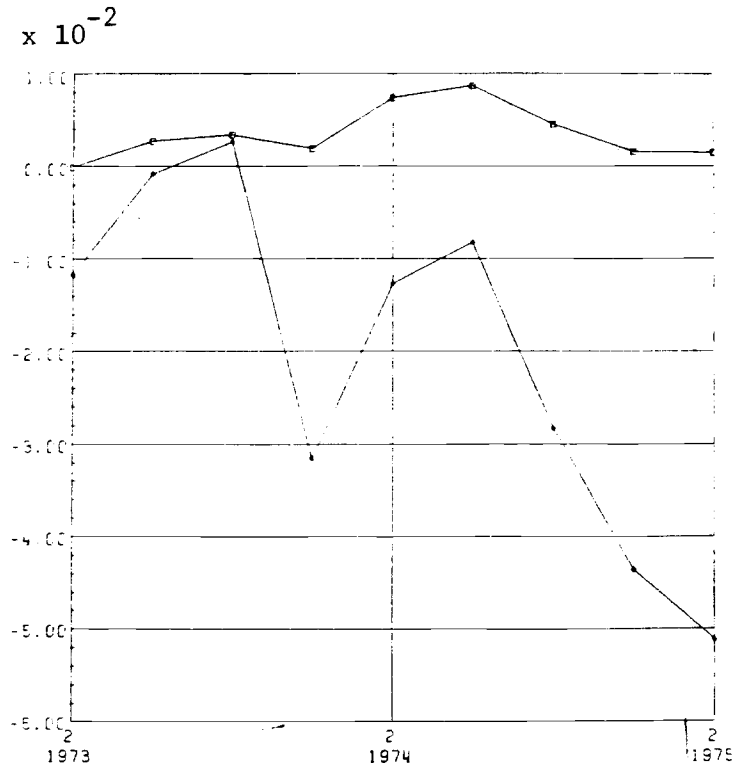


(f) Scaled Balance of Payments -- (B/Y)_{US}

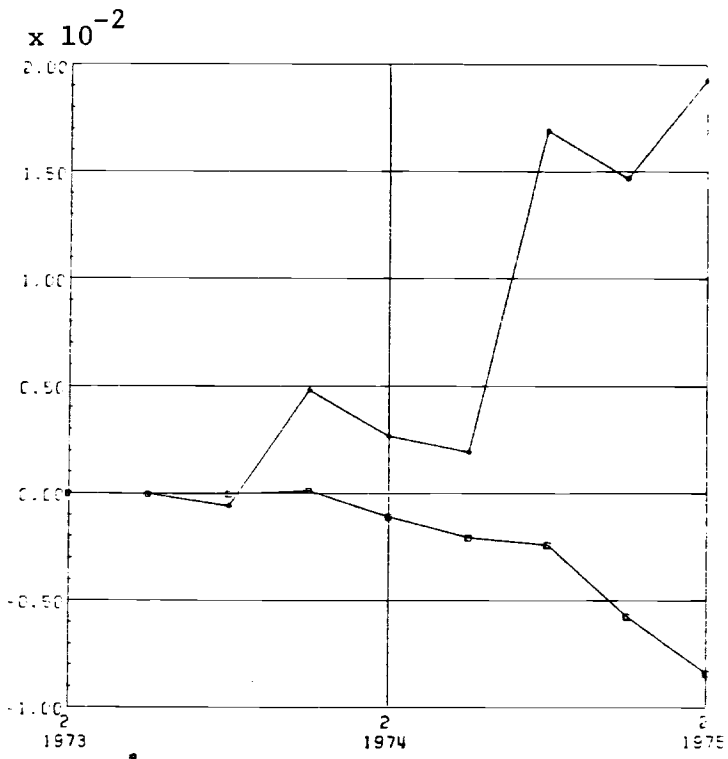
Key:
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 • Effects simulated using Mark IV-Oil Model



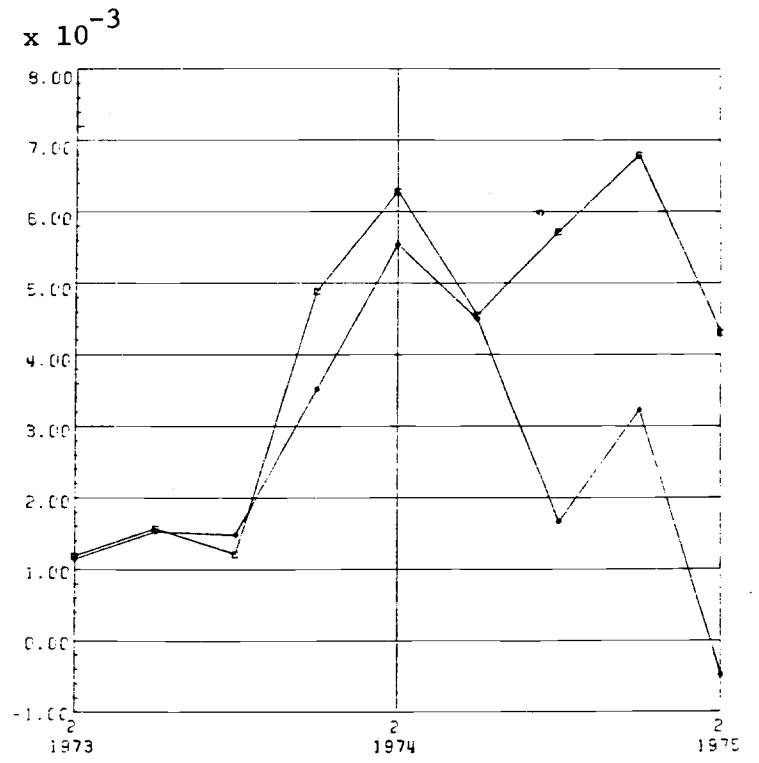
(a) Price Level -- $\log P_{UK}$



(b) Real Income -- $\log y_{UK}$



(c) Nominal Money -- $\log M_{UK}$

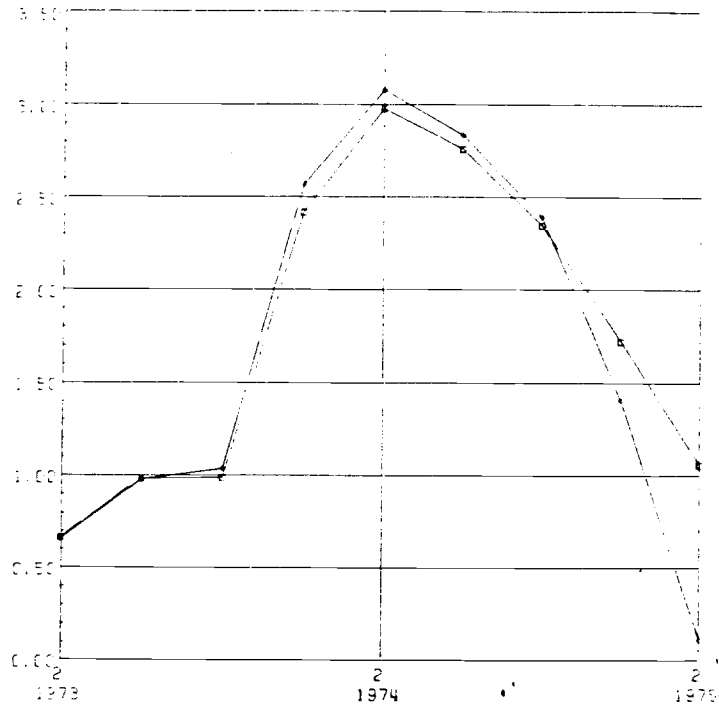


(d) Short-Term Interest Rate -- R_{UK}

FIGURE 7

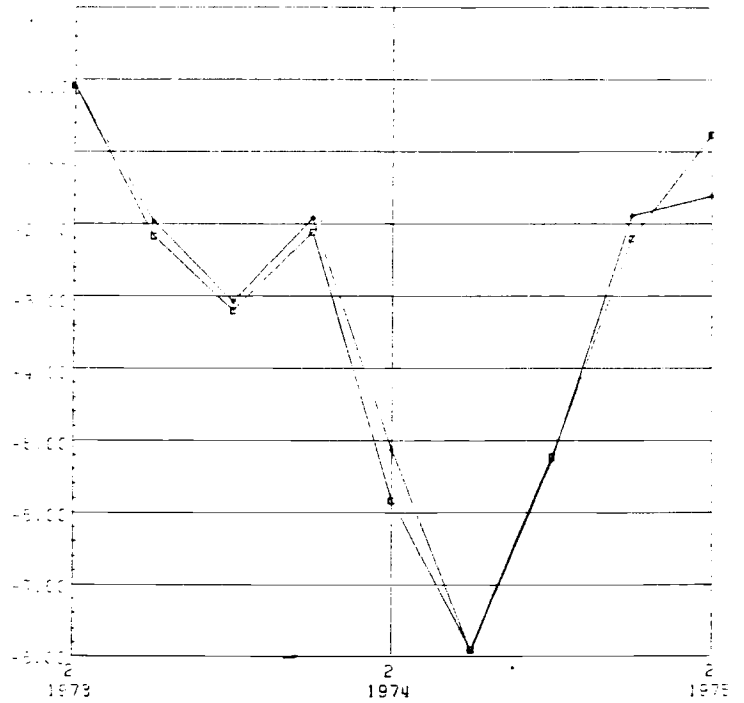
Simulated Effects in the United Kingdom of the 1973-1975 Increase in the Real Price of Oil

$\times 10^{-2}$



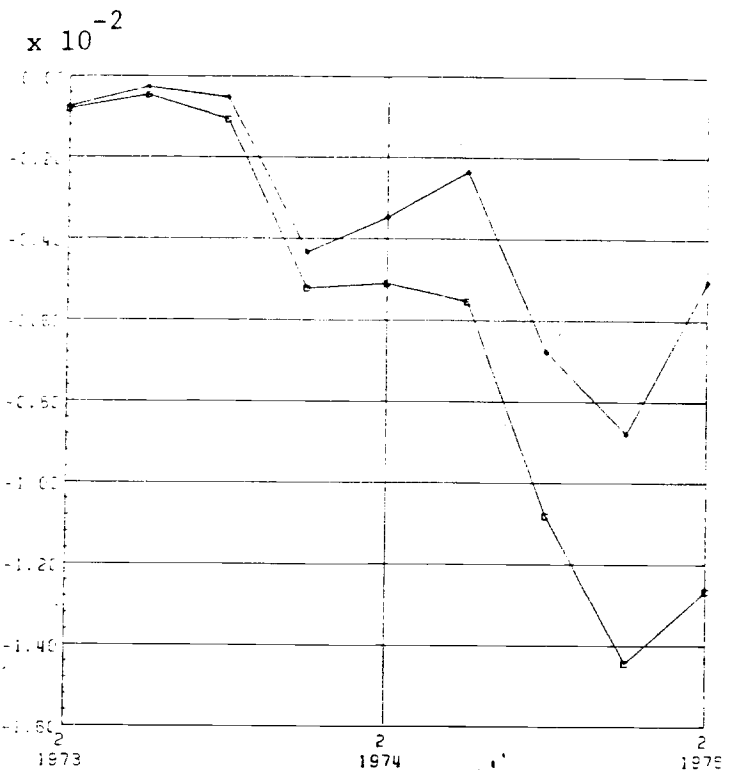
(e) Scaled Exports -- $(X/Y)_{UK}$

$\times 10^{-5}$

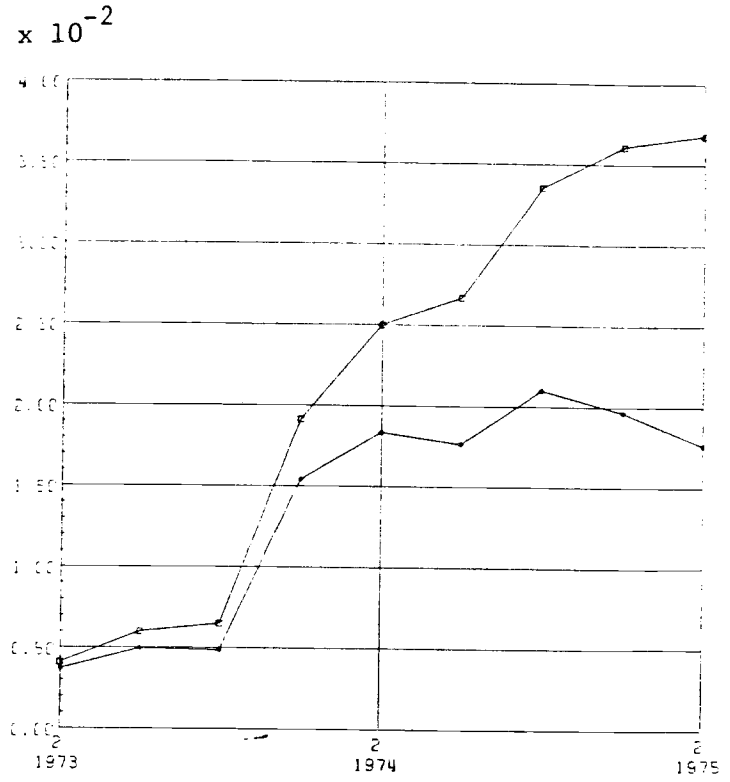


(f) Scaled Balance of Payments -- $(B/Y)_{UK}$

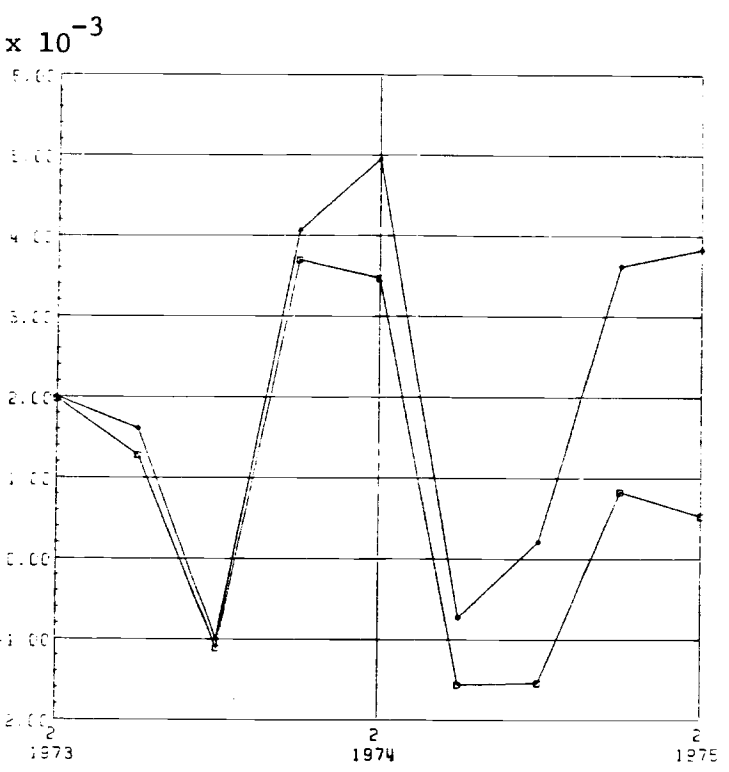
Key:
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 ◻ Effects simulated using Mark IV-Oil Model



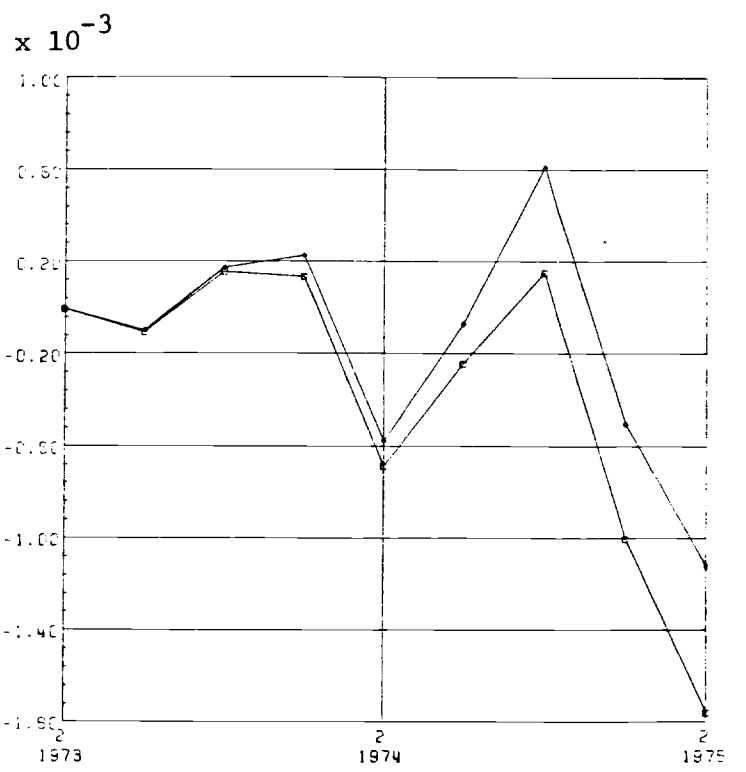
(a) Price Level -- $\log P_{CA}$



(b) Real Income -- $\log y_{CA}$



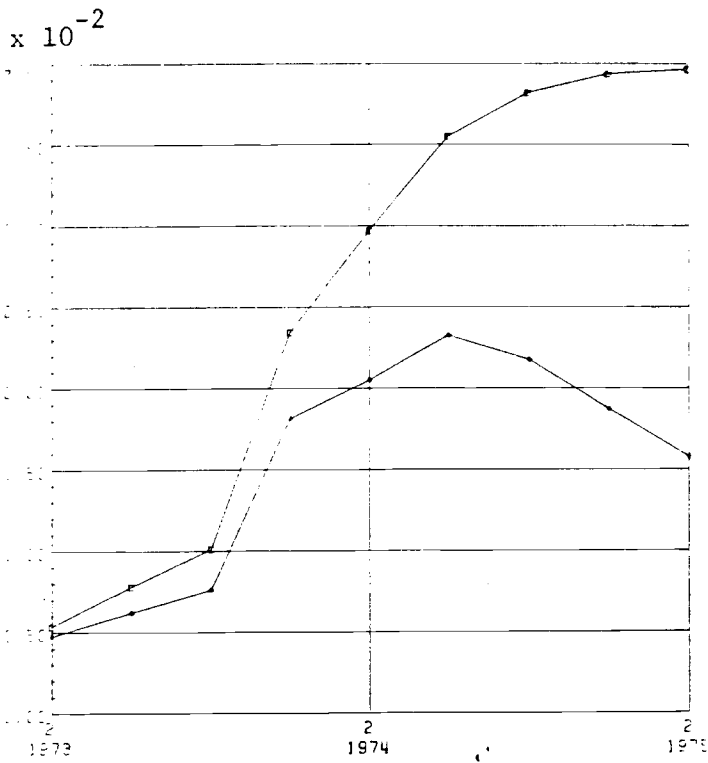
(c) Nominal Money -- $\log M_{CA}$



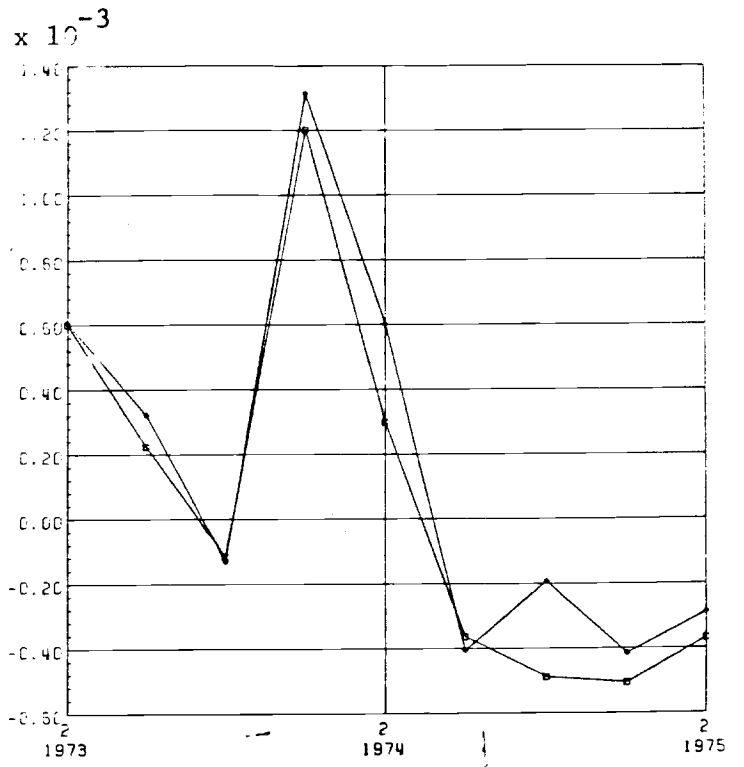
(d) Short-Term Interest Rate -- R_{CA}

FIGURE 8

Simulated Effects in Canada of the 1973-1975 Increase in the Real Price of Oil

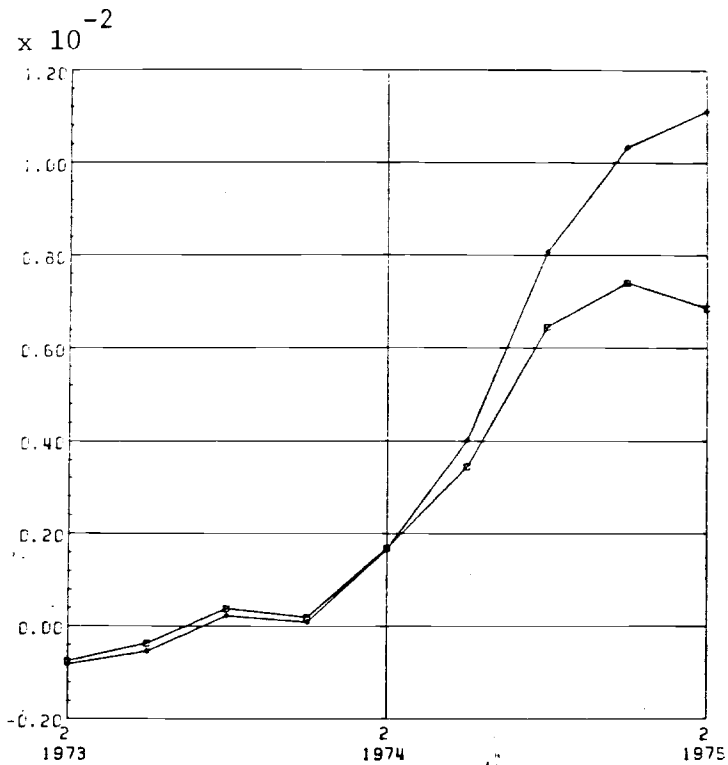


(e) Scaled Exports -- $(X/Y)_{CA}$

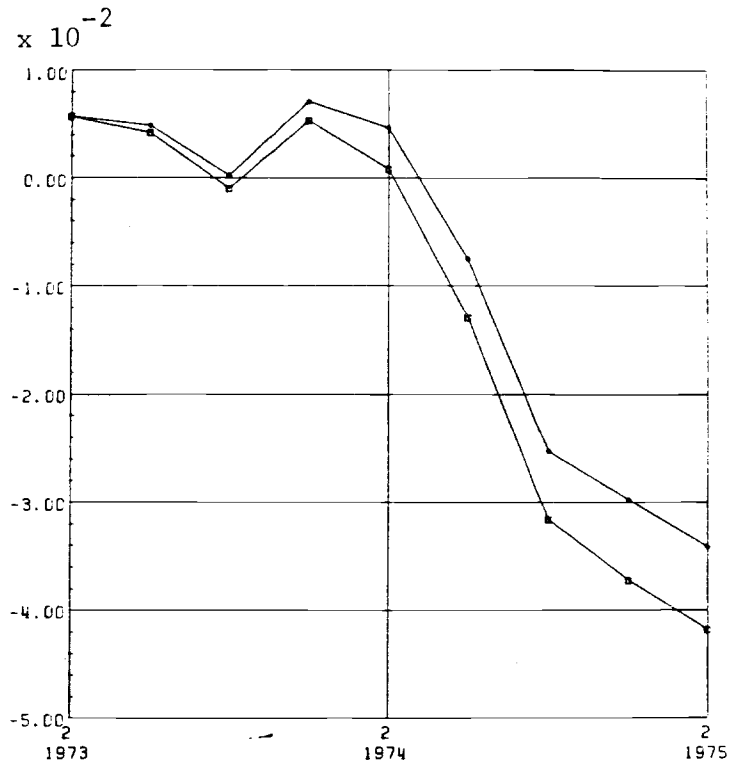


(f) Scaled Balance of Payments -- $(B/Y)_{CA}$

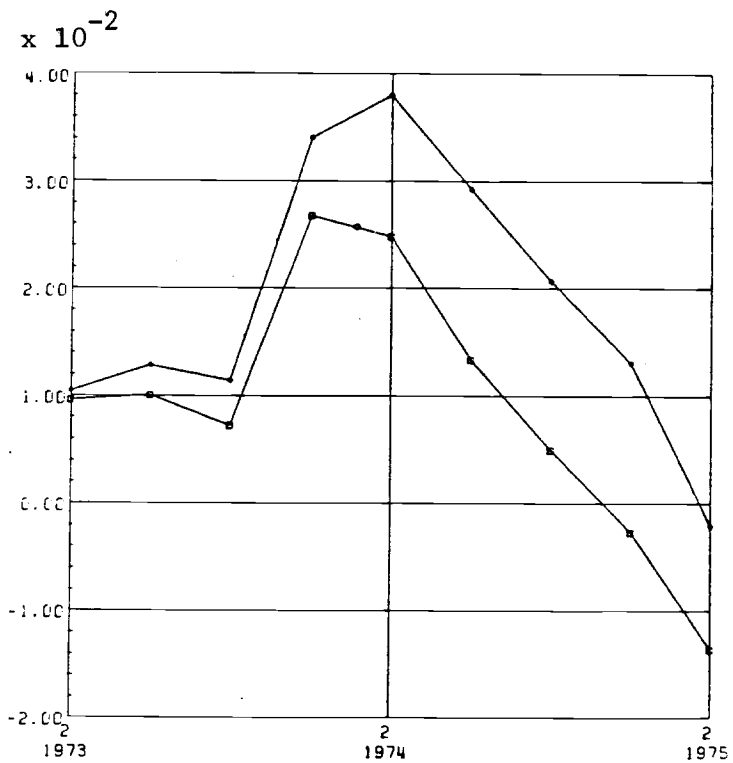
Key:
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 ◻ Effects simulated using Mark IV-Oil Model



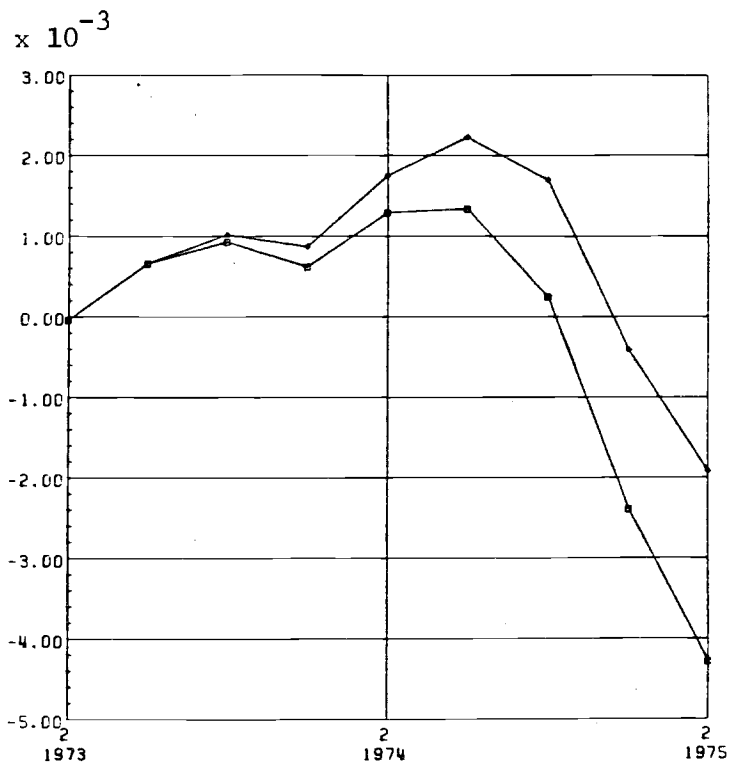
(a) Price Level -- P_{GE}



(b) Real Income -- $\log y_{GE}$



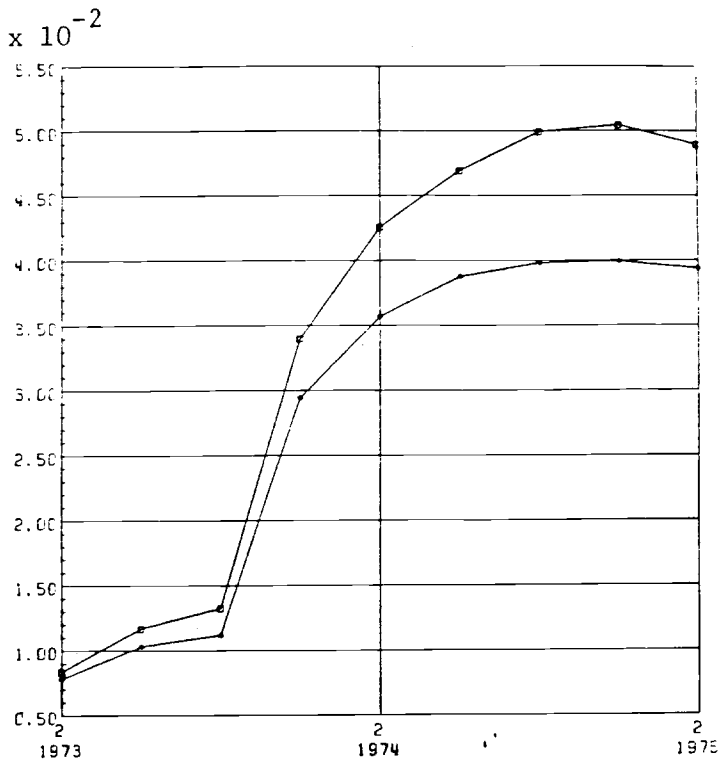
(c) Nominal Money -- $\log M_{GE}$



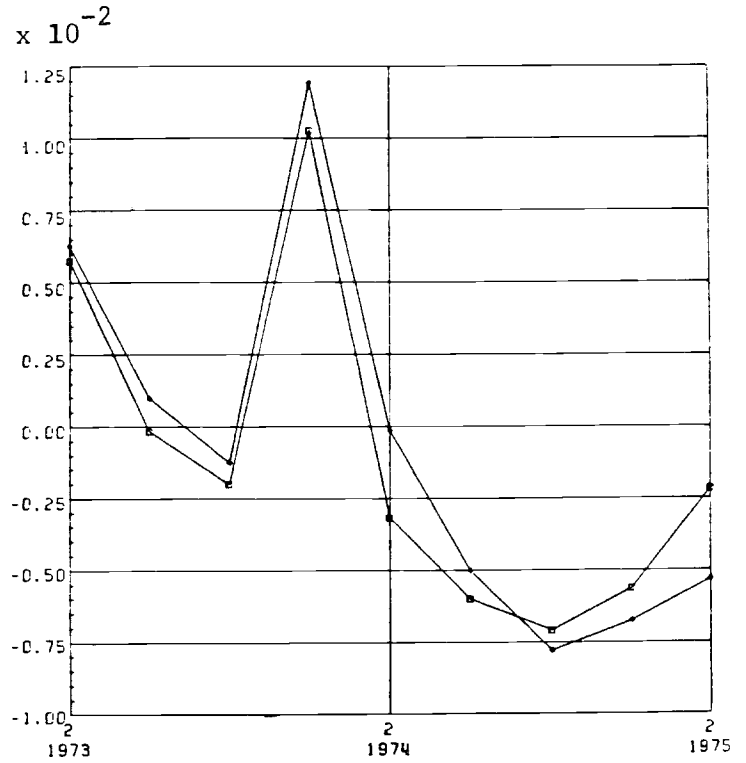
(d) Short-term Interest Rate -- R_{GE}

FIGURE 9

Simulated Effects in Germany of the 1973-1975 Increase in the Real Price of Oil

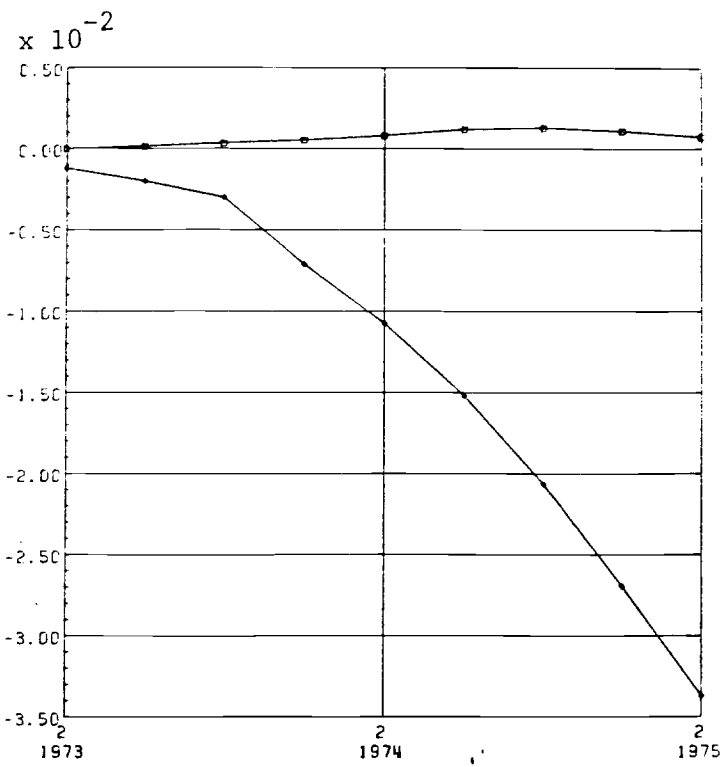


(e) Scaled Exports -- $(X/Y)_{GE}$

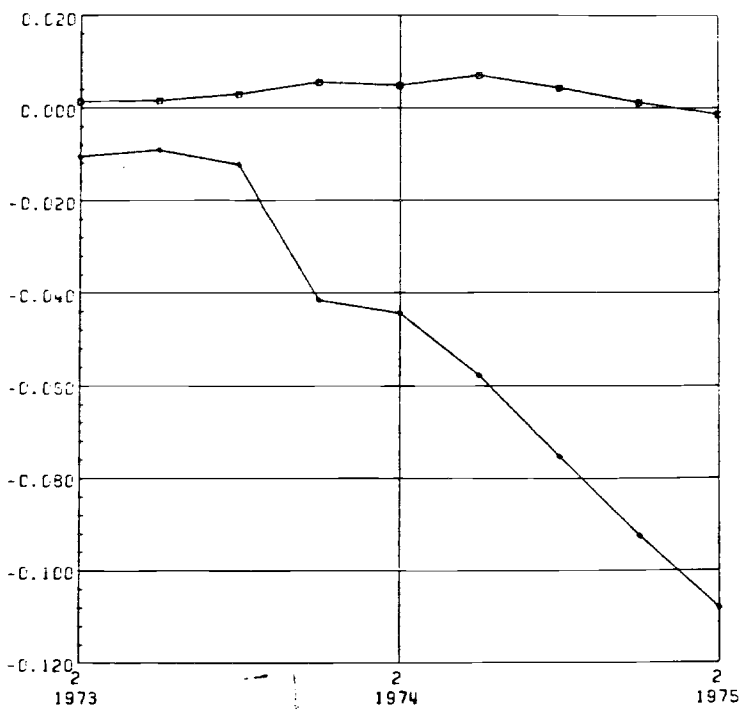


(f) Scaled Balance of Payments -- $(B/Y)_{GE}$

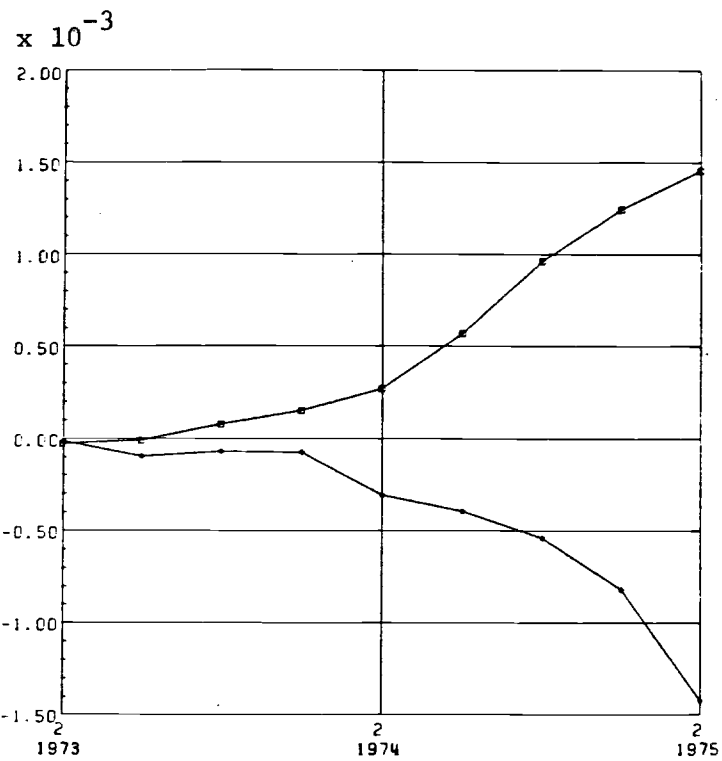
Key:
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 ◻ Effects simulated using Mark IV-Oil Model



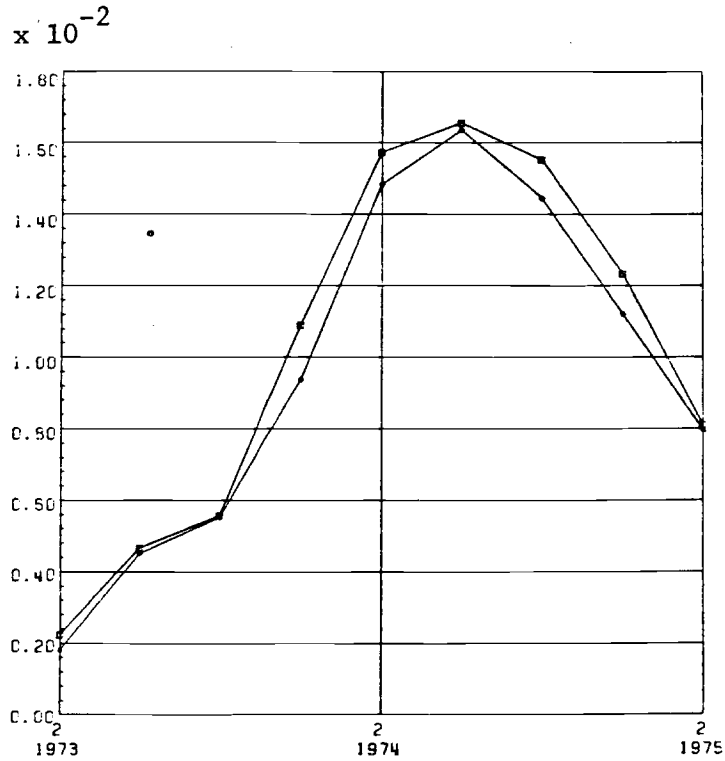
(a) Price Level -- log P_{NE}



(b) Real Income -- log y_{NE}



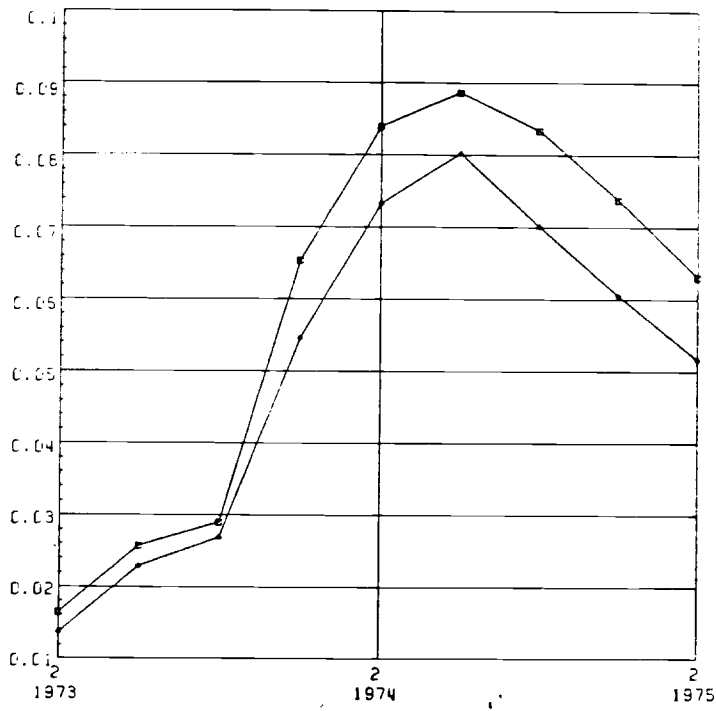
(c) Nominal Money -- log M_{NE}



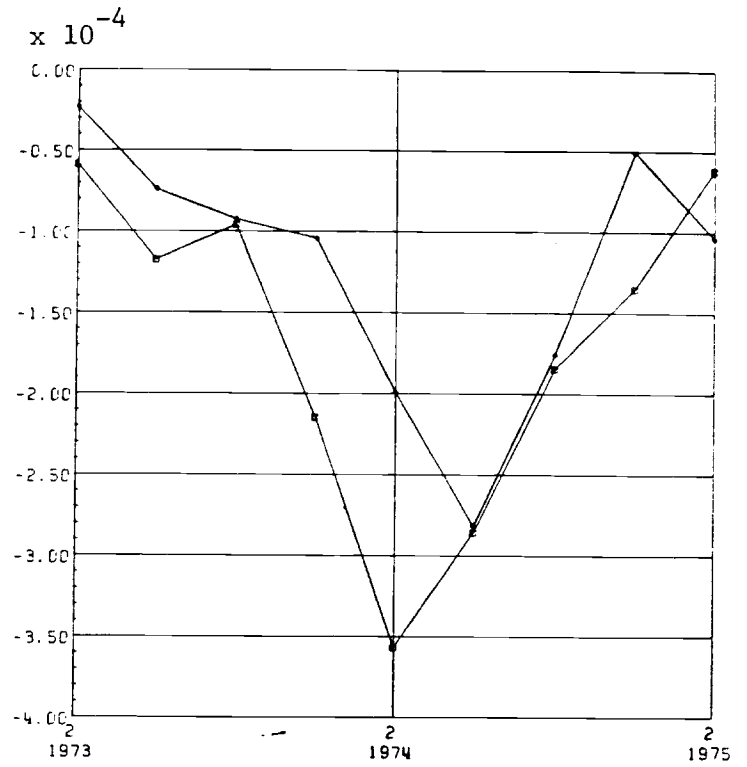
(d) Short-Term Interest Rate -- R_{NE}

FIGURE 10

Simulated Effects in the Netherlands of the 1973-1975 Increase in the Real Price of Oil



(e) Scaled Exports -- $(X/Y)_{NE}$



(f) Scaled Balance of Payments -- $(B/Y)_{NE}$

Key: ◻ Effects simulated using basic Mark IV Model
 ◉ Effects simulated using Mark IV-Oil Model