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OIL PRICE EFFECTS IN THEORY AND PRACTICE

by

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I. INTRODUCTION

That increases in oil prices (and/or in the prices of other primary commodities) can upset the world economy has been amply demonstrated in the last ten years. What is not so clearly apparent, however, are the dimensions of the effects and the complex channels of interaction by which they operate.

Interest in modeling the channels through which disturbances are internationally distributed is by no means new. Indeed, starting with Metzler (1950), a vast literature has emerged in an attempt to model these channels of transmission. More recently, large oil price changes have led to modeling approaches with more emphasis on the role of relative price changes. The purpose of these models is to determine how oil price changes affect real income, prices, and employment in a small open oil importing economy, and how sensitive are these price effects to alternative policy responses and wage indexation schemes. However, one important limitation of these models is their partial equilibrium nature, i.e., the effects that oil price changes have on the domestic economy are assumed to be independent from the impacts that these price changes have on the rest of the world economy.[1]

Our purpose in this paper is to study -theoretically and empirically- the effects of oil price changes allowing for its feedback effects. We address the following questions:

-To what extent is income in developed and less developed economies affected by oil price changes? And how these income effects feedback to OPEC's oil exports?

-Can a greater recycling of oil revenues by OPEC offset the adverse impacts of oil price increases?

-What is the influence of oil price increases on the price of manufactures, and how increases in this price affect OPEC and other developing countries?

-How successful is a restrictive fiscal policy in combating the inflationary impacts of an increase in the price of oil, and what are the repercussions for the rest of the world?

-What are the financial transfers to developing countries required to offset the adverse impacts of oil price increases on economic growth?

Recognition of the international repercussions of oil price changes is important given that economic activity in different regions are linked through international trade. From the standpoint of oil importing economies, an increased recycling of OPEC's revenues, through greater imports, reduces the income transfer that arises out of higher oil prices. From OPEC's viewpoint, the international transmission of oil price effects is important in determining oil price strategies since oil price changes affect real income of the world economy, and thus OPEC's oil exports.

Although the question of international repercussion has been analyzed using large econometric models (e.g.,Project LINK, Federal Reserve's MCM, Fair's (1982) model), their complexity and heterogeneity often obscure the channels of interaction. There is some advantage to simplicity and transparency. In section II of this paper we formulate a three regions-three goods theoretical model of the world economy to highlight the channels by which the effects of an exogenous increase in the

price of oil are internationally transmitted.[2]

We obtain the comparative static results of an increase in the price of oil, as well as their sensitivity to fiscal policy responses. Also, we decompose the effect of an oil price increase on OPEC's exports into substitution and income effects, and show how the income effects raise -in absoulte terms- the price elasticity of OPEC's exports.

An empirical version of the theoretical model is econometrically estimated and used in section III to contrast the theoretical results with dynamic model simulations. In particular, we study the effects of oil price changes on the real income of oil importers (DC's and Non-OPEC LDC's) and the consequent feedback effect on their demand for oil and OPEC's exports. We then examine how sensitive are the effects of oil price changes to fiscal policy responses, greater recycling on the part of OPEC, and larger financial transfers to LDC's.

II. A THEORETICAL MODEL OF OIL PRICE EFFECTS

Our theoretical model, shown in Table 1, differs from those developed in the literature in that we consider three blocks of countries whose analytical structures are different from each other:

- -- the developed economies, whose GDP is determined from the demand side while the influence of supply enters through price determination;
- -- the OPEC countries, who recycle their oil revenue by purchasing manufactured goods from the developed economies, with no imports from the non-OPEC developing economies; and
- -- the non-OPEC developing economies, whose output is determined from the supply side using a production function.

The internationally traded goods we consider are:

Table 1

A Theoretical Model of a Three Region World Economy

Developed Countries

$$Y^d = C^d(Y^d) + E^d + B^d \quad (1)$$

$$B^d = X_m^d - [(P_o/P_m)M_o^d + (P_p/P_m)M_p^d] \quad (2)$$

$$M_o^d = M_o^d(P_o/P_m, Y^d) \quad (3)$$

$$M_p^d = M_p^d(P_p/P_m, Y^d) \quad (4)$$

$$P_m = \pi_o P_o + \pi_p P_p \quad (5)$$

Non-OPEC Developing Countries

$$Y^\ell = f(K^\ell, \bar{L}^\ell) \quad (6)$$

$$K^\ell = K_{-1}^\ell + I^\ell \quad (7)$$

$$I^\ell = i_0 + iM_m^\ell \quad (8)$$

$$M_m^\ell = (R + P_p M_p^d - P_o M_o^\ell)/P_m \quad (9)$$

$$M_o^\ell = M_o^\ell(P_o/P_o, Y^\ell) \quad (10)$$

OPEC

$$Y^o = F(K^o) \quad (11)$$

$$K^o = K_{-1}^o + I^o \quad (12)$$

$$I^o = b_0 + b\, M_m^o \quad (13)$$

$$M_m^o = \beta P_o X_o^o / P_m \quad (14)$$

EQUILIBRIUM CONDITIONS

$$X_m^d = M_m^o + M_m^\ell \quad (15)$$

$$X_o^o = M_o^d + M_o^\ell \quad (16)$$

$$X_p^\ell = M_p^d \quad (17)$$

Notation

1) Variables

M: imports

K: capital

L: labor

C: consumption plus investment

Y: GDP

P: prices

I: investment

B: trade account

E: exogenous variable

X: exports

R: Resource transfers

2) Superscripts

ℓ: Non-OPEC LDC's

o: OPEC

d: DC's

3) Subscripts

o: oil

p: raw materials

m: manufactures.

-- oil, exported by OPEC to both developed and non-OPEC developing economies;

-- raw materials, exported by non-OPEC developing economies to developed economies; and

-- manufactures, exported by developed to both OPEC and non-OPEC developing economies.

We consider three prices for the internationally traded goods:

-- the export price of manufactures of developed economies, which we determine endogenously,

-- the export price of raw materials, exogenously given; and

-- the price of oil.

Developed Economies

As mentioned earlier, real income (in terms of manufactures) is determined from the demand side as in equation (1). We assume that spending on consumption and investment, $C^d(Y^d)$, depends on the level of real GDP, Y^d. The term E^d represents exogenous variables such as government expenditures. The balance of payments, B^d in equation (2), equals the trade account since the only type of capital movements we recognize are those that compensate for the flow of goods. Notice also that the trade balance is expressed in terms of manufactures. In this way we recognize the terms-of-trade effect of changes in oil prices since oil imports are valued in terms of the exports of manufactured goods used to pay for them.

Exports of manufactures to both OPEC and non-OPEC LDC's depend on the terms of trade and export revenues of these last two blocks of countries. Oil imports, M_o^d in equation (3), and raw materials imports, M_p^d in equation (4), depend on terms of trade and real income.

The price of manufactures, P_m in equation (5), is assumed to be a linear function of the prices of raw materials and oil.[3] This is a simplification of a more realistic formulation in which the price of manufactures depends, in addition to the variables just mentioned, on the price of labor and excess capacity utilization. Our formulation can be derived from a production function with constant returns to scale while assuming zero profits.

Non-OPEC Developing Countries

Real income of Non-OPEC developing economies, Y^{ℓ} in equation (6), is determined using a production function with capital, K^{ℓ} and fixed labor, $\bar{L}^{\ell}$ as factors.[4] The capital stock is obtained by accumulation of net investment, which in turns depends on the amount of imports of capital goods. This relation between net investment and imports of capital goods can be derived by treating the aggregate capital stock as an aggregate of a domestic component and foreign component as suggested by McKinnon (1964) and Taylor (1979). Following their approach, we obtain equation (8).

It has been widely recognized that foreign exchange constraints play a role in determining output growth of developing economies.[5] In our model, foreign exchange constraints apply to imports of manufactures, M_m^{ℓ} in equation (9). In this way, if foreign exchange constraints are binding, then imports of manufactures will be limited, dampening capital accumulation and income growth. We deduct oil payments from the computation of foreign exchange resources, and assume that these countries use whatever is left over to finance imports of manufactures.[6] This implies that their trade account is in balance except for external credits and aid. Finally, oil imports, M_o^{ℓ} in equation (10), are determined as a function of terms of trade

and real income.

OPEC

OPEC's income determination is analogous to the case of non-OPEC developing countries. However, we assume that OPEC recycles a constant fraction β of their exports earnings via the purchase of manufactures from developed economies, as indicated by equation (14). Although the assumption of a constant value of β implies that OPEC's absorption capacity does not change over time, we use it because (1) it simplifies the comparative statics derivations, (2) we can study the effects of changes in β on the analytical solutions, and (3) it is relaxed in the empirical analysis.

II.1 The International Transmission of Oil Price Effects

To solve the model we begin by totally differentiating the system of equations (1) - (17). Using the equilibrium condition that world export supply of one commodity equals the world import demand for that commodity, we reduce the system from a seventeen equation system to a three differential equation system. In addition, we assume that initial prices are equal to 1. The resulting system of equations is:

$$\Gamma(\gamma_{ij})\ \underset{\sim}{dy} = \Omega(\omega_{sk})\ \underset{\sim}{dx}\ ,\ i,j=1,3;s=1,3;k=1,2;$$

where

$$\underset{\sim}{dy}' = (dY^d\ dY^\ell\ dY^o),$$

$$\underset{\sim}{dx}' = (dP_o\ \ dE^d).$$

The elements of Γ are:

$$\gamma_{11} = 1 - c^d + (1-\beta)\phi_o^d\ \eta_o^d > 0,$$

$$\gamma_{12} = (1-\beta)\phi_o^\ell \eta_o^\ell > 0,$$

$$\gamma_{13} = 0,$$

$$\gamma_{21} = -f'i\ \phi_p^d\ \eta_p^d < 0,$$

$$\gamma_{22} = 1 + \phi_o^\ell \eta_o^\ell f'i > 0,$$

$$\gamma_{23} = 0,$$

$$\gamma_{31} = -F'b\ \beta\ \phi_o^d \eta_o^d < 0,$$

$$\gamma_{32} = -F'b\ \beta\ \phi_o^\ell \eta_o^\ell < 0,$$

$$\gamma_{33} = 1.$$

The elements of Ω are:

$$\omega_{11} = -R\pi_o - (1-\beta)\left(M_o^\ell(1+\varepsilon_o^\ell - \pi_o) + M_o^d(1+\varepsilon_o^d)(1-\pi_o)\right) \lessgtr 0,$$

$$\omega_{12} = 1,$$

$$\omega_{21} = -f'i\left(R\pi_o + M_p^d(1+\varepsilon_p^d)\pi_o + M_o^\ell(1+\varepsilon_o^\ell - \pi_o)\right) \lessgtr 0,$$

$$\omega_{22} = 0,$$

$$\omega_{31} = F'b\beta\left(M_o^d(1+\varepsilon_o^d) + M_o^\ell(1+\varepsilon_o^\ell - \pi_o)\right) \lessgtr 0,$$

$$\omega_{32} = 0,$$

where the following notation has been used:

$$\phi_j^i \equiv M_j^i / Y^i, \quad \eta_j^i \equiv (1/\phi_j^i)(\partial M_j^i / \partial Y^i), \quad \varepsilon_j^i \equiv (P_j/M_j^i)(\partial M_j^i / \partial P_j),$$

$$F' \equiv \partial F/\partial K^o, \ f' \equiv \partial f/\partial K^\ell \ , \text{ for } i = d,o,\ell \text{ and } j = p,o,m.$$

Partitioning Γ as:

$$\Gamma = \begin{bmatrix} \Gamma_{11} & \vdots & \underset{\sim}{0} \\ \cdots & \vdots & \cdots \\ \Gamma_{21} & \vdots & 1 \end{bmatrix}, \text{ with } \quad \underset{\sim}{0}' = (0\ 0),\ \Gamma_{11} = (\gamma_{ij})\ i=1,2;j=1,2,$$

$$\Gamma_{21} = (\gamma_{31}\ \gamma_{32}),$$

we derive the impact of an increase in the price of oil on real income for each of the regions as:

$$d\underset{\sim}{Y} = \begin{vmatrix} \Gamma_{11}^{-1} & \underset{\sim}{0} \\ -\Gamma_{21}\Gamma_{11}^{-1} & 1 \end{vmatrix} \begin{Vmatrix} \omega_{11} & \omega_{12} \\ \omega_{21} & \omega_{22} \\ \omega_{31} & \omega_{32} \end{Vmatrix} \begin{vmatrix} dP_o \\ dE^d \end{vmatrix}. \quad (19)$$

We apply the "Correspondence Principle" (Samuelson 1947) in determining the direction of the impact of an oil price increase on the real income of oil importers. Following Metzler (1950), the model is stable if, and only if, all the principle minors of the Γ matrix are positive. This implies that the following conditions must hold:

$$\gamma_{11} = 1 - c^d + (1-\beta)\phi_o^d \eta_o^d > 0,$$

$$\det(\Gamma_{11}) = \overset{+}{\gamma}_{11}\overset{+}{\gamma}_{22} - \overset{+}{\gamma}_{12}\overset{-}{\gamma}_{21} > 0, \quad (20)$$

$$\det(\Gamma) = \det(\Gamma_{11}) > 0.$$

Examining these stability conditions we conclude that a sufficient condition for stability is that $1 - c^d > 0$, i.e., the marginal propensity to consume should be less than one.

Limiting our attention to oil importing economies, we derive the impact of an increase in the price of oil on developed economies as:

$$dY^d/dP_o = ((\overset{+}{\gamma}_{22}\overset{\pm}{\omega}_{11} - \overset{+}{\gamma}_{12}\overset{\pm}{\omega}_{21}) + \overset{+}{\gamma}_{22}(dE^d/dP_o))/\det(\Gamma) \underset{>}{<} 0. \quad (21)$$

For non-OPEC developing countries, the impact of an increase in the price of oil on their real income is:

$$dY^{\ell}/dP_o = ((\overset{+}{\gamma}_{11}\overset{\pm}{\omega}_{21} - \overset{-}{\gamma}_{21}\overset{\pm}{\omega}_{11}) - \overset{-}{\gamma}_{21}(dE^d/dP_o))/\det(\Gamma) \underset{>}{<} 0. \quad (22)$$

Equations (21) and (22) indicate that, in general, an increase in the price of oil need not be associated with a reduction in oil importers' real income. If we assume (1) no fiscal policy response to the change in oil prices and (2) price inelasticity, then we get

$$dY^d/dP_o = (\overset{+}{\gamma}_{22}\overset{-}{\omega}_{11} - \overset{+}{\gamma}_{12}\overset{-}{\omega}_{21})/\det(\Gamma) \gtrless 0 \ , \quad (23)$$

$$dY^{\ell}/dP_o = (\overset{+}{\gamma}_{11}\overset{-}{\omega}_{21} - \overset{-}{\gamma}_{21}\overset{-}{\omega}_{11})/\det(\Gamma) < 0. \quad (24)$$

The direction of the income effect of oil price changes remains ambiguous for developed economies, although it is unambiguously negative for Non-OPEC developing countries. In order to explain these results, we decompose the total effect of an oil price increase into direct and indirect effects. The direct effect is the transfer of real income from oil importing countries to OPEC. In the case of the DC's, this direct -and negative- effect takes the form of a deterioration of the real balance of payments, given the increased cost of oil imports in terms of manufactured goods. In the case of the LDC's, the transfer takes the form of reduced foreign-exchange availabilities, with subsequent indirect dynamic effects on output growth through the influence on imports of manufactured goods and investment.

The indirect effects of influence are through OPEC' recycling and increases in the export price of manufactures of DC's. An increase in oil prices raises oil revenues of OPEC who in turn recycles a fraction β in the form of imports of manufactures from DC's. This increase in OPEC's imports represents a stimulus to activity in the DC's--one which may not be offset by the direct negative effect. In turn, this stimulus to real activity in the DC's causes an increase in the imports of primary commodities from Non-OPEC LDC's, enlarging LDC's foreign resources which in

turn are used to purchase imports of manufactures from the DC's.

An increase in the price of oil, when translated into an increase in the price of manufactured goods, dampens the terms of trade deterioration of the DC's. This means a reduction in the value of their imports (assuming price inelasticity) in terms of manufactures, which has a positive impact on their real income. However, the increase in P_m dampens imports of manufactures of both OPEC and LDC's and thus adversely affects the GDP of the DC's. This adverse indirect effect of oil prices on DC's real income feeds back to both OPEC -in the form of lower oil imports- and to non-OPEC LDC's -in the form of lower imports of raw materials: the decline in exports of LDC's reduces their foreign exchange resources beyond the reduction due to the higher price of manufactures, and thus induces a decline in imports of capital goods and capital accumulation with a dampening effect on output growth.

Although the sign for dY^{ℓ}/dP_o is negative, the sign for dY^{d}/dP_o is ambiguous even in this simple model. This is because the direct effect of an increase in the price of oil -the transfer of real income to OPEC- could be offset by the indirect effects -increases in the price of manufactures and OPEC's recycling. In other words, whether an increase in oil prices is stagflationary or not is an empirical question which depends -to a large extent- on how these price increases affect the rest of the world economy, which in turn depends on the relative magnitudes of key parameters such as π_o, β, n_j^i, and ε_j^i.

Table 2 summarizes the comparative static results for alternative values of π_o and β assuming price inelasticity. For the case of developed economies, if there is no markup in oil prices and the value of the recycling coefficient is less than one, then an increase in oil prices

Table 2

Comparative Static Results of an Oil Price Increase

Summary of $\frac{dy^d}{dp_o}$ for DC's

β \ π_o	0	$0 < \bar{\pi}_o < 1$	1
0	-	?	?
$0 < \bar{\beta} < 1$	-	?	?
1	0	-	-

Summary of $\frac{dy^l}{dp_o}$ for LDC's

β \ π_o	0	$0 < \bar{\pi}_o < 1$	1
0	-	-	-
$0 < \bar{\beta} < 1$	-	-	-
1	-	-	-

results in a net transfer of real income to OPEC and therefore has a negative impact on DC's real income. However, oil price increases do not affect DC's real income if the initial transfer to OPEC is recycled back to DC's, i.e., if $\beta=1$. If the markup is greater than zero, then the impact of an oil price increase on the GDP of the DC's may be positive or negative given that an increase in π_0 reduces both exports of manufactures and the value of imports in terms of manufactures. Even though the $\text{sign}(\partial(dY^d/dP_0)/\partial\pi_0) = \Theta(\beta)$ is ambiguous in general, we find that $\Theta(1)<0$. That is, if OPEC recycles all their export revenues, then an increase in the markup of oil prices reduces real income of developed economies implying that oil price increases are stagflationary.

Positive impacts of oil price increases may appear on the surface to be counterintuitive. This possibility arises, nevertheless, because the direct effects of oil price increases may be offset by the indirect effects arising from the multiple channels of transmission. In particular, the increase in P_0 initially worsens the DC's trade account and thus their GDP. However, OPEC imports more manufactured goods, at a higher price, and thus it may offset the original income deterioration.

In contrast to the case of developed economies, the impact of oil price increases on the GDP of non-OPEC developing countries is negative for all values of β and π_0 between zero and one. Furthermore, there is an inverse relationship between the indexing parameter π_0 and the effect of an oil-price increase on Y^{ℓ}:

$$\text{sign}\left(\partial(dY^{\ell}/dP_0)/\partial\pi_0\right) < 0 \text{ for } \beta \in [0,1].$$

This result is reasonable since the available foreign exchange resources of the LDC's are reduced not only by the higher oil prices, but also by the corresponding increase in the price of manufactured goods. For

a given value of the markup coefficient, the impact of an oil price increase on LDC's real income is directly related to the recycling coefficient. This is because as β increases, OPEC imports more and this represents a stimulus to real income of DC's, which is then transmitted to developing countries in the form of more imports of raw materials.

In summary, our analysis indicates that the effect of an increase in oil prices on an oil importing economy depends critically on how the oil price increase affects the rest of the world economy. As a result, we find that an increase in the price of oil may have a negative or positive impact on the GDP of the DC's. It is important, however, to remember that no offsetting counterinflationary policy or capacity constraints have been assumed in the DC's so that the demand-side impacts can work out fully; we deal with the counterinflationary policies below.

II.2 Counterinflationary Policies and the Effect of Oil Prices on the World Economy

The previous comparative statics were derived under the assumption that government expenditures (E^d) do not respond to changes in oil prices.[7] For our purposes, we assume that an increase in the price of oil will increase the inflation rate, to which government economic policies are assumed to respond as:[8]

$$dE^d/dP_o = \psi\pi_o,$$

where we capture the influence of oil price increases on inflation by their effect on the price of manufactures. We assume that the response of government expenditures to changes in P_m is equal to ψ, $\psi<0$. The response of Y^d to changes in P_o is then equal to:

$$dY^d/dP_o = ((\gamma_{22}\omega_{11} - \gamma_{12}\omega_{21}) + \gamma_{22}\psi\pi_o)/\det(\Gamma),$$

$$= (dY^d/dP_o \,|\, dE^d=0) \quad + \gamma_{22}\psi\pi_o/\det(\Gamma). \quad (25)$$

The oil price multiplier allowing for fiscal policy responses can be decomposed into two terms. The first term captures the impact of oil price changes on real income assuming that fiscal policy does not respond to oil price changes. The second term captures the direct and indirect effects that fiscal policy changes have on domestic output. The direct effect is equal to the contractionary impact of a reduction in government expenditures in a closed economy. The indirect effects stem from the impact that fiscal policy changes have on DC's imports with the subsequent feedback to DC's exports and income.

From equation (25) we see that, even if oil prices have a positive impact on real income (given that the first term of equation (25) could be positive), a restrictive fiscal policy response to an oil price increase could offset the initial positive impact. In particular, if

$$\psi < -(\gamma_{22}\omega_{11} - \gamma_{12}\omega_{21})/(\pi_o\gamma_{22}) ,$$

then the effect of an increase in the price of oil coupled with a restrictive fiscal policy will reduce real income of developed economies.

II.3 Income Feedback Effects and the Price Elasticity of Oil Demand

Given that oil price changes affect real income of oil importers and that these income effects are transmitted to OPEC's exports, it seems natural to ask how is OPEC's pricing policy affected by the instability of the demand schedule due to the income feedback effects of oil price changes.[9] We address this question by considering the demand for oil that OPEC faces:

$$D^o = M_o^d + M_o^\ell \ .$$

The total effect of an increase in the price of oil on D^o is:

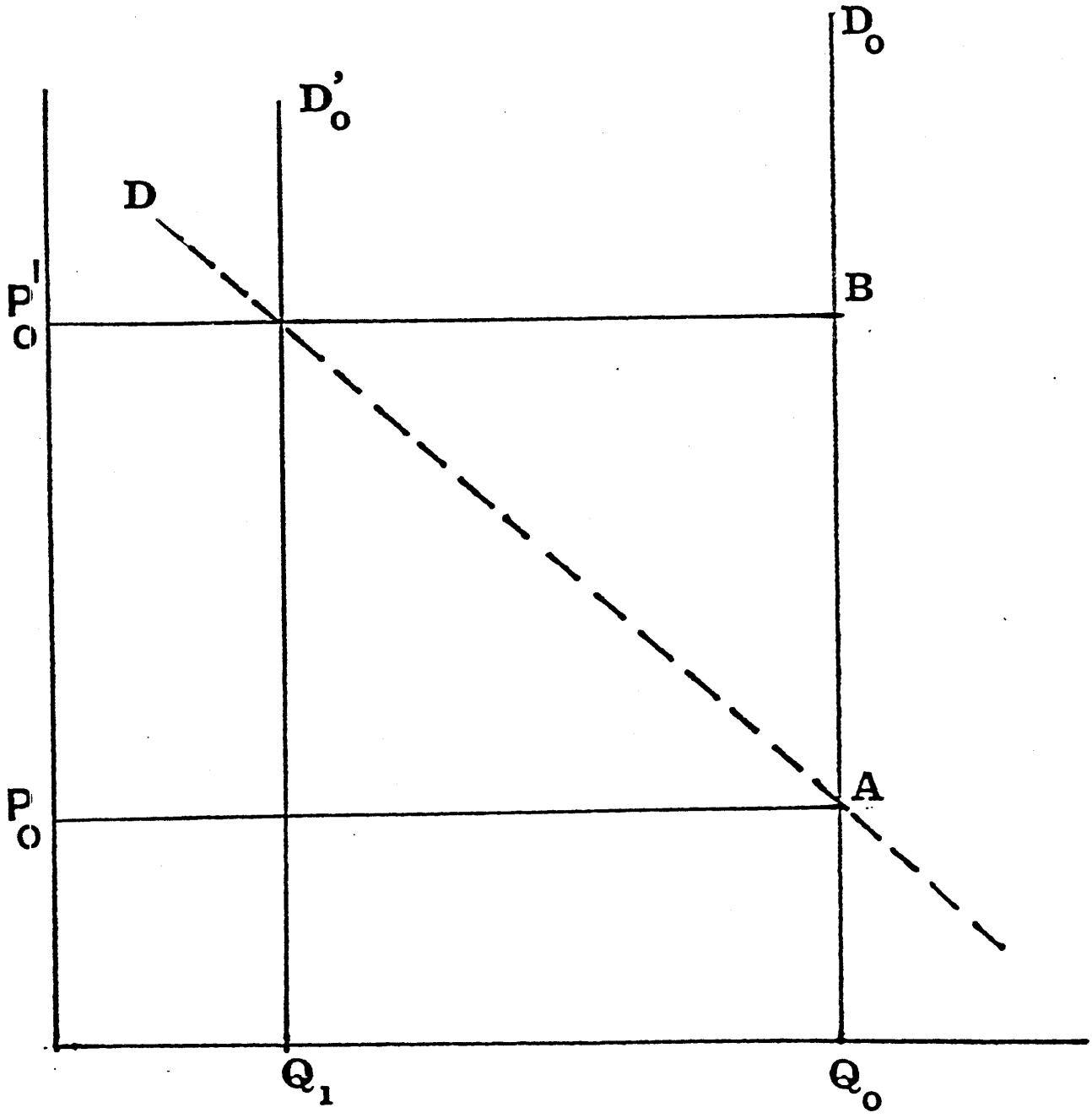
$$(26) \qquad dD^o/dP_o = [\ M_o^d\ \varepsilon_o^d(1-\pi_o) + M_o^\ell\ \varepsilon_o^\ell] +$$

$$+(\phi_o^d \eta_o^d \quad \phi_o^\ell \eta_o^\ell) \begin{bmatrix} \Gamma_{11}^{-1} & \tilde{0} \\ -\Gamma_{21}\Gamma_{11}^{-1} & 1 \end{bmatrix} \begin{bmatrix} \omega_{11} & \omega_{12} \\ \omega_{21} & \omega_{22} \\ \omega_{31} & \omega_{31} \end{bmatrix} \begin{bmatrix} \bar{1} \\ dE^d/dP_o \end{bmatrix},$$

where the first term represents the direct effect of oil price changes, and the second term represents the indirect, or income feedback effect. In Figure 1 we show the feedback effect of an increase in the price of oil on D^o, assuming that $\varepsilon_o^d = \varepsilon_o^\ell = 0$, and that the initial price-quantity combination is given by point A. The increase in the price of oil from P_o to P_o' raises OPEC's oil revenues (the area ABP_oP_o') only if the demand function D^o remains fixed. But as we have seen, the increase in the price of oil may reduce real income of oil importers (especially if followed by counterinflationary policies) shifting the demand for oil leftward to D'. As a result, OPEC's decision to increase oil prices might lead to a loss of oil revenues, even if the direct price elasticities (as seen by consumers) are equal to zero. This is because what matters for optimal price determination is the total price elasticity as seen by OPEC, which takes into account not only the substitution effects of an oil price increase but also the associated income effects. Furthemore, notice that the total price elasticity depends on the fiscal policy response in the DC's. In particular, a restrictive policy response reduces real income and therefore has the effect of increasing the (absolute value of) the total price

Figure 1

Effects of Oil Price Changes on Oil Revenues



elasticity.[10]

III. OIL PRICE EFFECTS IN PRACTICE

The theoretical results of section II have been derived under a number of assumptions that are not generally valid in practice. First, OPEC is not the only supplier of oil, and we should recognize that Non-OPEC LDC's supply oil to DC's, as well as manufactures. Second, the production side of oil importers determines -to a large extent- the behavior of the demand for oil, and this should be explicitly recognized. Third, dynamic effects are absent from the theoretical analysis and they need to be incorporated because of their crucial role in evaluating oil price effects. While it is true that these considerations can be incorporated in a theoretical model, the resulting analysis becomes quite cumbersome. In fact, even with the simpler model of section II, we find that the direction of oil price effects is not always unambigously determined. Thus we use model simulations to estimate the effects oil price changes while relaxing the assumptions implied in our theoretical analysis.

III.1 A Global Econometric Model of Oil Price Effects

In a compact form, the model has 52 equations, 16 of which are behavioral (see Marquez 1983 for a detailed description of the model). The parameters of the model are estimated using data for 1960-1979, although some of the relationships are estimated using data only up to 1977. The estimation method we use is OLS; the advantage of alternative parameter estimators such as 2SLS, 3SLS, and FIML need not hold for small samples such as ours (Mariano 1978). We now describe the main behavioral equations which are shown, in general form, in Table 3. Appendix A contains the estimated equations and the countries included in each country block.

Table 3

Main Behavioral Relations in

Global Econometric Model

Developed Economies

$$C^d = f(P_y^d\ Y^d / P_{con}^d) \quad (27)$$

$$I^d = f(Y^d, r^d) \quad (28)$$

$$M_r^d = f(P_r / P_m^d, Y^d) \quad (29)$$

$$\Delta\%P_m^d = f(\Delta\%P_r, \Delta\%P_\ell, \Delta\%P_{o,-1}, U_{-1}) \quad (30)$$

$$GY^d = f(L, [K, E(O,C)]) \quad (31)$$

$$O^d = f(P_o, P_c, P_\ell, P_k, GY^d) \quad (32)$$

$$\tilde{M}_o^d = O^d - O^s \quad (33)$$

$$\tilde{M}_o^d = \tilde{M}_o^d - X_o^\ell(P_o / P_c, GY^d) \quad (34)$$

$$M_o^d = (P_o^* / P_o)(\tilde{M}_o^d + \hat{X}_o^\ell) \quad (35)$$

OPEC

$$M_m^o = f(P_o / P_m^d(M_o^d + M_o^\ell)) \quad (36)$$

Non-OPEC Developing Countries

$$GY^\ell = f(K^\ell, O^\ell) \quad (37)$$

$$I^\ell = f(P_k^\ell / P_o, Y^\ell, R^\ell / P_m^d) \quad (38)$$

$$M_m^\ell = f(I_n^\ell, R^\ell / P_m^d) \quad (39)$$

$$X_m^\ell = f(P_m^d / P_m^\ell, Y^d) \quad (40)$$

$$O^\ell = f(P_k^\ell / P_o, GY^\ell) \quad (41)$$

$$\tilde{M}_o^\ell = O^\ell - O^{s,\ell} + \hat{X}_o^\ell \quad (42)$$

Developed Economies

Consumption, C^d in equation (27), depends on a distributed lag of nominal value added $P_y^d Y^d$ deflated by the consumption price index P_{con}^d ; the short run mpc is 0.47 and the long run income elasticity is one. Investment, I^d in equation (28), is a function of a distributed lag of real income as well as the long term nominal interest rate r^d; the short run mpi is 0.13 and the long run elasticity with respect to income is 1.18; the long run elasticity with respect to the interest rate is -0.20.

Imports of raw materials from Non-OPEC developing countries, M_r^d in equation (29), are a function of (i) present and past values of the price of raw materials, P_r, relative to the export price of manufactures of DC's, P_m^d, and (ii) real income of DC's Y^d; the long run relative price elasticity is -0.69 and the long run income elasticity is 0.63.

The inflation rate of the export price of manufactures, $\Delta\%P_m^d$ in equation (30), depends on (i) the rate of change of wages, $\Delta\%P_\ell$, with a coefficient of 0.3266; (ii) the inflation rate of oil prices, $\Delta\%P_o$, lagged one period with a coefficient of 0.09; (iii) the inflation rate of the price of raw materials with a coefficient of 0.34; and (iv) a measure of capacity of utilization, U, obtained as the difference between potential output and actual output.

Potential output, Y*, is estimated as a trend of actual output but we split the period of estimation in two subperiods: 1960-1972 and 1973-1979. The estimated growth rate for potential output for the period prior to 1973 is 4.7% and for the period after 1972 is 2.9%.

The demand for oil, O^d in equation (32), (in barrels) is derived as a

conditional demand function from a three level CES production function, equation (31), whose arguments are labor, L, capital, K, oil, O, and coal, C. In this way we account for both capital-energy substitution possibilitites and interfuel substitution possibilities. In addition, an aggregate measure of energy consistent with the structure of production can be derived. The conditional demand for oil depends on the prices of oil, coal, labor, and the rental price of capital as well as on gross output (value added plus oil imports) GY^d. We estimate a linearized version of this demand function with a distributed lag (4 periods) for prices and income, allowing for homogeneity of degree zero in prices. In estimating this relationship, we use switching regression with a split of the sample in 1972. The long run oil price elasticity declines from -0.27 to -.57. The long run coal price elasticity increases from 0.29 to 0.91. The estimated income elasticity declines from 1.70 to 1.34. The hypothesis of homogeneity of zero degree in prices cannot be rejected.

Total imports of oil, $\tilde{M}_o^d$ in equation (33), (in barrels) are equal to the difference between the demand for oil (in barrels) and the exogenously given supply of oil, O^s, (also in barrels). Imports of oil from OPEC, $\tilde{M}_o^d$ in equation (34), are equal to total imports of oil minus imports of oil from Non-OPEC LDC's, $\hat{X}_o^{\ell}$, which in turn depend on the price of oil relative to the price of coal as well as on real income of DC's. To link oil imports in barrels to oil imports in real value we use the identity between the value of oil imports given by the product of total oil imports in real terms, M_o^d, and the oil price index, P_o and the value of oil imports given by the product of the price of oil, P_o^*, (in dollars per barrel) and total imports of oil in barrels, $\tilde{M}_o^d$. We then solve from this identity for oil

imports in real terms as in equation (35).

OPEC

OPEC's real income is not determined in our empirical formulation. Instead, we analyze their the absorption capacity. For this we explain their imports of manufactures, M_m^O in equation (36), as a function of a distributed lag of oil revenues deflated by the export price of manufactures of DC's. The absorption elasticity in the first year is 0.31, 0.36 in the second year, and 0.04 after four years. The long run absorption elasticity is 0.98.

Non-OPEC Developing Countries

To determine gross output (value added plus oil imports in real terms), GY^{ℓ} in equation (37), we use a two level nested CES production function with capital, K^{ℓ}, and oil consumption, O^{ℓ}, as arguments. The parameters of this function are estimated in two steps by using the first order conditions for cost minimization and the production function itself. The short run elasticity of substitution between oil and capital is 0.05 and the long run elasticity is 0.73.

Following Coen (1971), we determine capital formation, I^{ℓ} in equation (38), as a function of the rental price of capital, P_k^{ℓ}, relative to the price of oil, and on gross output. In addition, we allow the speed of adjustment of capital formation to depend on the availability of foreign exchange resources in real terms, R^{ℓ}/ P_m^d . We find an inelastic response of investment with respect to changes in both income and relative prices. However, we find investment to be quite responsive to changes in foreign exchange reserves (an elasticity in excess of one).

Imports of manufactures, M_m^{ℓ} in equation (39), are derived using the fact that the capital stock is an aggregate between the domestic capital stock and the foreign capital stock with a non-zero elasticity of substitution. Following Marquez (1982), we obtain imports of manufactures as a function of net investment, I_n^{ℓ}, and foreign exchange reserves. Our results point to an elasticity of imports of manufactures with respect to investment of 0.8 and an elasticity with respect to (real) foreign exchange reserves in excess of one.

Exports of manufactures to DC's, X_m^{ℓ} in equation (40), depend on (i) the export price of manufactures of DC's relative to the export price of manufactures of LDC's, P_m^d / P_m^{ℓ}, and (ii) the real GDP of DC's. Oil consumption, O^{ℓ} in equation (41), is modeled as a conditional demand function derived from the production function (equation 37) and thus depends on relative factor prices and gross output GY^{ℓ}. Using the identity between world consumption (in barrels) and world oil production (in barrels), we derive imports of oil from OPEC, $\tilde{M}_O^{\ell}$,(in barrels) as the difference between LDC's oil demand and (exogenously given) oil supply, $O^{S,\ell}$ plus exports of oil of LDC's to DC's. Finally we link oil imports in barrels to oil imports in real value following the same steps as in equation (35) for DC's.

III.2 Dynamic Simulations of Oil Price Shocks

Our purpose here is to study the quantitative dimensions of oil price effects with model simulations using the estimated econometric model. The period for simulation is from 1973 to 1983, a total of eleven years which allows us to determine whether the model is dynamically stable.[11] We

are also interested in contrasting theoretical and empirical results. To estimate the quantitative effects of an oil price increase on the variables of interest, we use dynamic multipliers, which we define as:

$$m_{ijt} = (y^b_{it} - y^j_{it}) / y^b_{it} ,$$

where

y^b_{it} = base solution value for the ith endogenous variable at time t,

y^j_{it} = solution value for the ith endogenous variable at time t under the jth alternative scenario.

The alternative cases we consider are:

-Case I: An exogenous increase in the price of oil.

-Case II: An increase in the price of oil combined with counterinflationary policies in DC's.

-Case III: The same as Case II but with a higher respending by OPEC.

-Case IV: The same as Case II but allowing for increased lending to Non-oil LDC's.

In examining the response of the model to changes in exogenous variables, we need a base solution that can be used as a benchmark for comparisons. For this we extrapolate the exogenous variables outside the period of estimation [12]:

-- Domestic oil production in developed economies is assumed to grow at 1% per year;

-- Domestic oil production in Non-OPEC developing countries is assumed to grow at 2% per year (Daly-Griffin-Steele 1983, MacAvoy 1982).

-- Net capital flows to Non-OPEC developing countries are assumed to grow at 3% per year, in nominal terms.
-- Oil prices take their historical values.
-- Long term nominal interest rates are assumed to be 14% in 1982 and 10% in 1983.
-- Prices of raw materials are assumed to grow at 9%.
-- Nominal wages are assumed to grow at 10% per year.
-- Export prices of manufactures of developing economies are assumed to grow at 9% per year.
-- The exogenous components of total exports and imports are assumed to grow at rates such that the difference between exogenous exports and exogenous imports remains constant at their 1977 values.
-- Government real expenditures are assumed to grow at 0.9% per year.

Case I: An Increase in the Price of Oil

In this simulation we assume an increase of 10 percent in the price of oil in 1973, which then grows at the historical growth rate until 1983; we present our results in Table 4. A 10 percent increase in the price of oil reduces real income of developed economies by 0.5 percent in 1973, 1.2 percent in 1977 and 2.9 percent by 1983 (see Figure 2). This reduction in real income is due to an increase in the consumption price deflator which reduces real income available for consumption and therefore reduces consumption expenditures. The increase in the consumption deflator is not offset by the smaller increases in the GDP deflator. In addition, an increase in the price of oil raises exports of manufactures to OPEC and reduces oil imports representing an improvement in the real trade account

Table 4

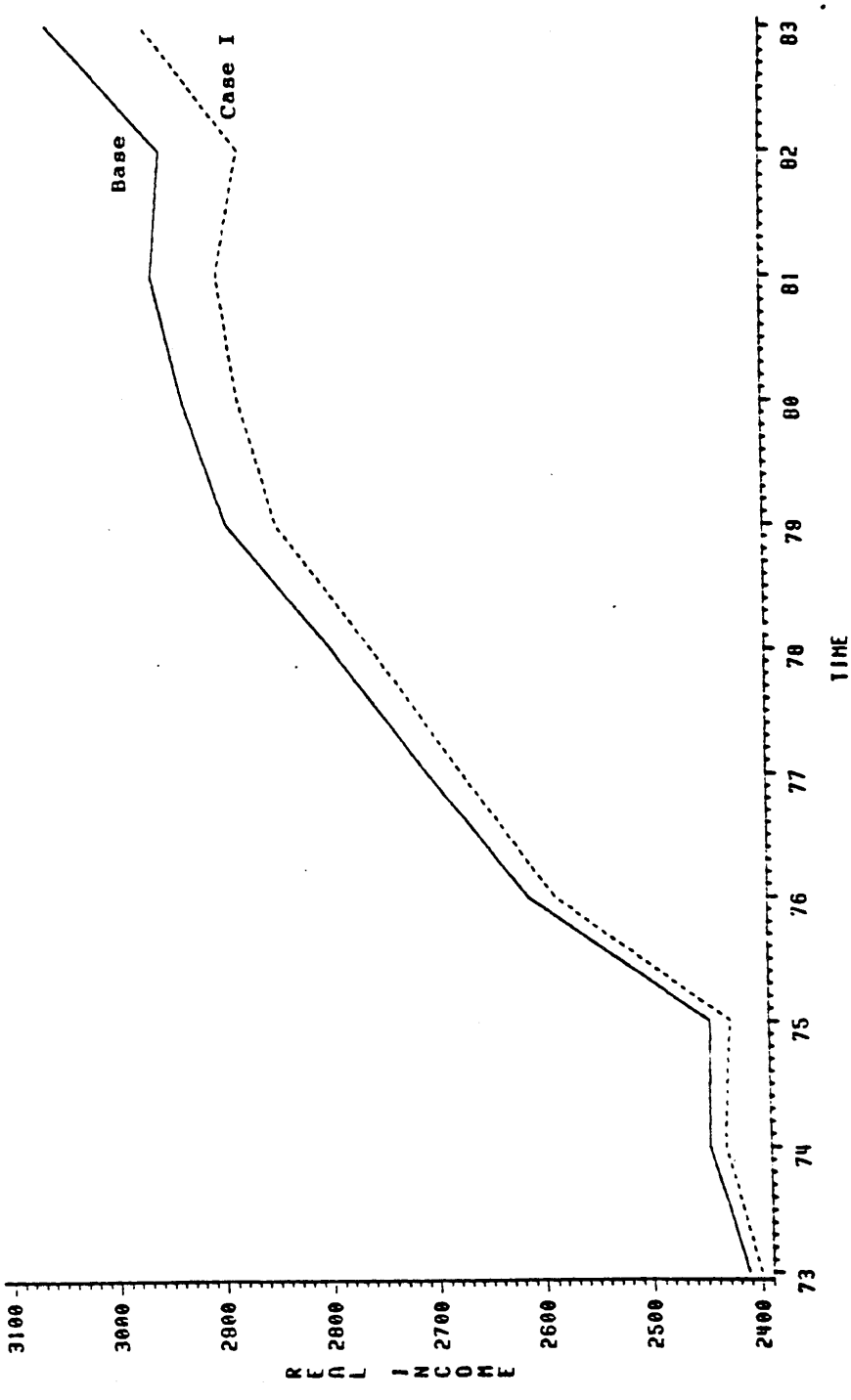
Dynamic Multipliers: Case I

	Y^d	Y^ℓ	$O^{d,d}$	$O^{d,\ell}$	$\tilde{M}_o^d$	$\tilde{M}_o^\ell$
1973	-.50	-.05	-1.42	-.74	-2.08	-2.21
1974	-.59	-.11	-4.33	-1.41	-6.23	-6.71
1975	-.76	-.23	-5.62	-2.04	-8.29	-8.91
1976	-.93	-.44	-6.37	-2.67	-8.99	-9.65
1977	-1.16	-.71	-6.62	-3.30	-9.24	-9.95
1978	-1.37	-.99	-6.88	-3.95	-9.55	-10.30
1979	-1.58	-1.26	-7.14	-4.60	-9.91	-10.70
1980	-1.81	-1.49	-7.41	-5.26	-10.88	-11.79
1981	-2.12	-1.69	-7.74	-5.92	-12.88	-14.18
1982	-2.52	-1.80	-8.16	-6.59	-15.08	-17.09
1983	-2.91	-1.83	-8.63	-7.25	-16.18	-18.80

	$\tilde{X}^o$	M_o^d	M_o^ℓ	X_o^ℓ	M_m^o	M_m^ℓ
1973	-2.08	-2.01	-1.30	-.76	2.36	-.02
1974	-5.86	-6.08	-2.39	-1.75	3.84	-.24
1975	-8.01	-8.04	-3.86	-2.51	3.77	-1.13
1976	-8.93	-8.80	-4.96	-2.58	1.88	-2.30
1977	-9.63	-9.09	-6.85	-2.83	.69	-2.33
1978	-10.05	-9.43	-7.74	-3.03	.11	-1.83
1979	-10.57	-9.80	-8.75	-3.29	-.25	-1.40
1980	-11.87	-10.61	-10.70	-4.20	-.71	-1.28
1981	-14.48	-12.17	-13.39	-5.65	-1.65	-1.03
1982	-17.32	-13.99	-15.48	-6.51	-3.08	-.39
1983	-18.71	-15.26	-16.19	-6.59	-4.53	.18

	X_m^ℓ	M_p^d	R^ℓ	R^ℓ/P_m^d	P_m^d	P_y^d
1973	-1.34	-.32	-1.54	-1.54	0.0	.32
1974	-1.58	-.27	-5.44	-6.18	1.24	.94
1975	-1.49	-.23	-7.38	-8.01	1.23	1.02
1976	-2.02	-.21	-4.88	-5.41	1.08	1.05
1977	-2.70	-.31	-2.55	-2.94	.87	1.08
1978	-3.36	-.55	-1.13	-1.34	.47	1.08
1979	-4.03	-.80	.19	.21	-.05	1.09
1980	-4.78	-1.09	3.94	4.24	-.77	1.09
1981	-5.76	-1.45	9.12	9.74	-1.69	1.05
1982	-6.99	-1.89	14.12	15.17	-2.90	.95
1983	-8.18	-2.36	8.95	10.37	-4.34	.78

Figure 2


REAL INCOME OF DC'S
BILL. OF U.S. DOLLARS
Base
Case I
REAL INCOME
3100
3000
2900
2800
2700
2600
2500
2400
73
74
75
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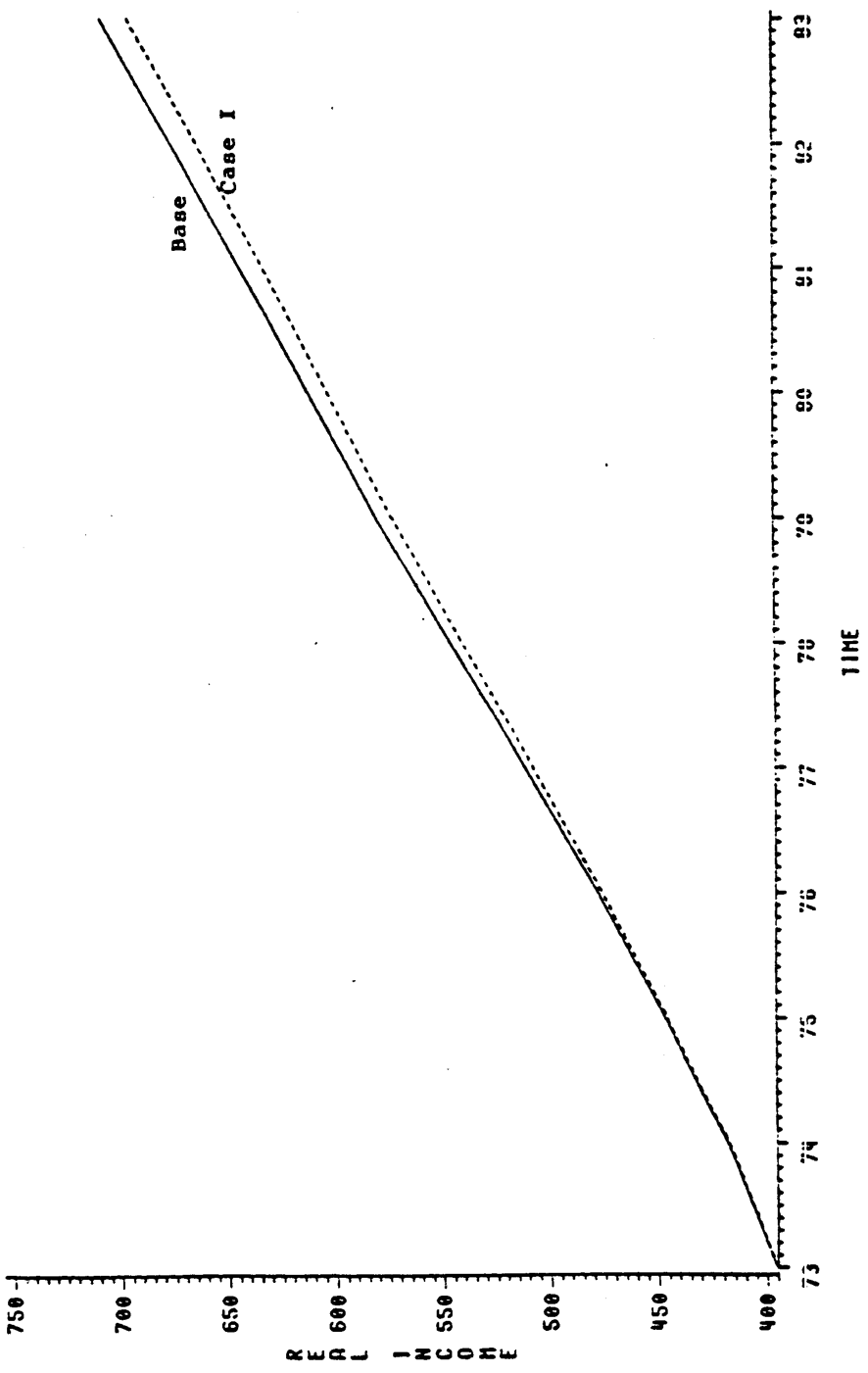
81
82
83
TIME

Figure 3


REAL INCOME OF LDC'S
BILL. OF U.S. DOLLARS
Base
Case I
REAL INCOME
750
700
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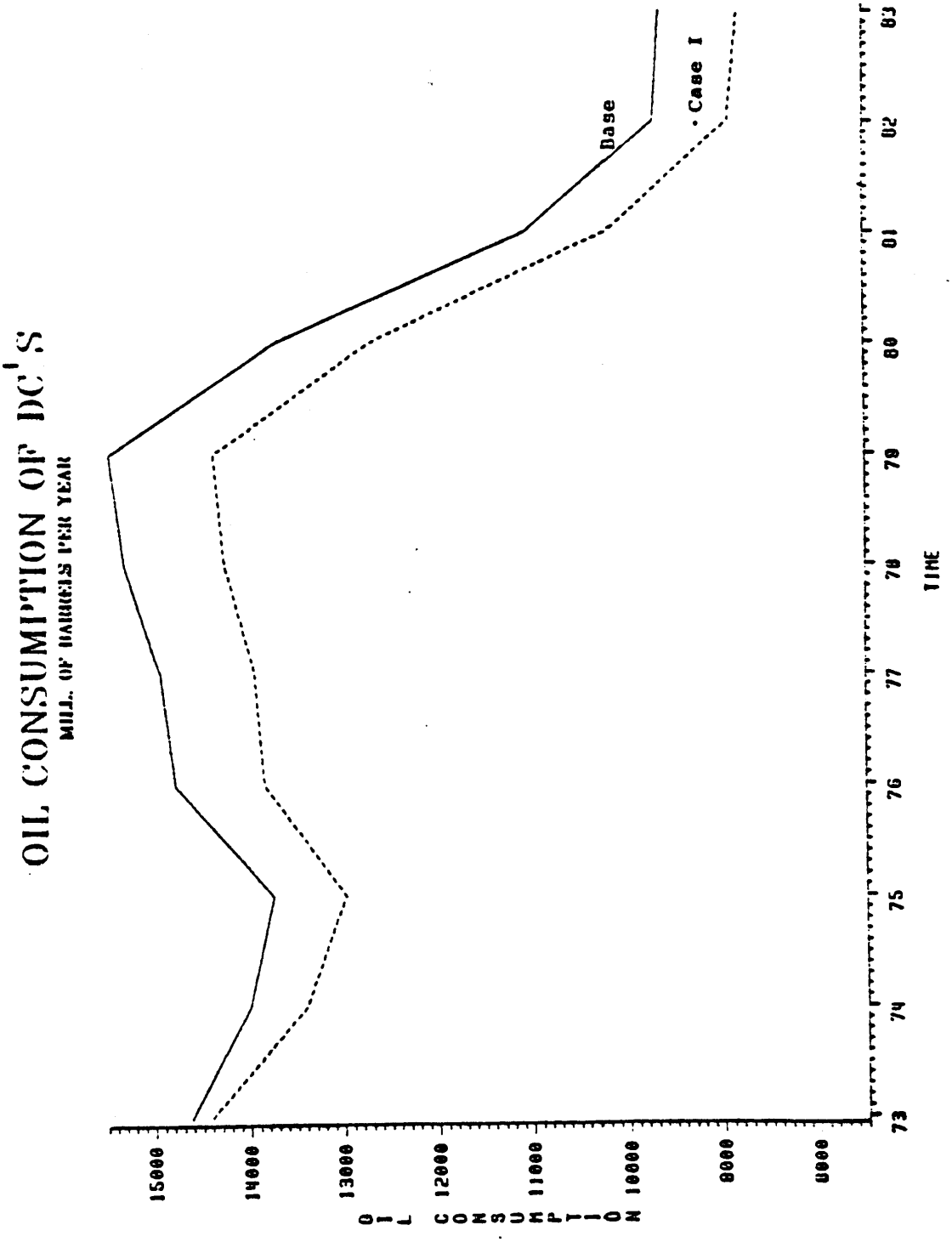
TIME

Figure 4


OIL CONSUMPTION OF DC'S
MILL. OF BARRELS PER YEAR
Base
Case I
OIL CONSUMPTION
15000
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13000
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10000
9000
8000
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83
TIME

Figure 5

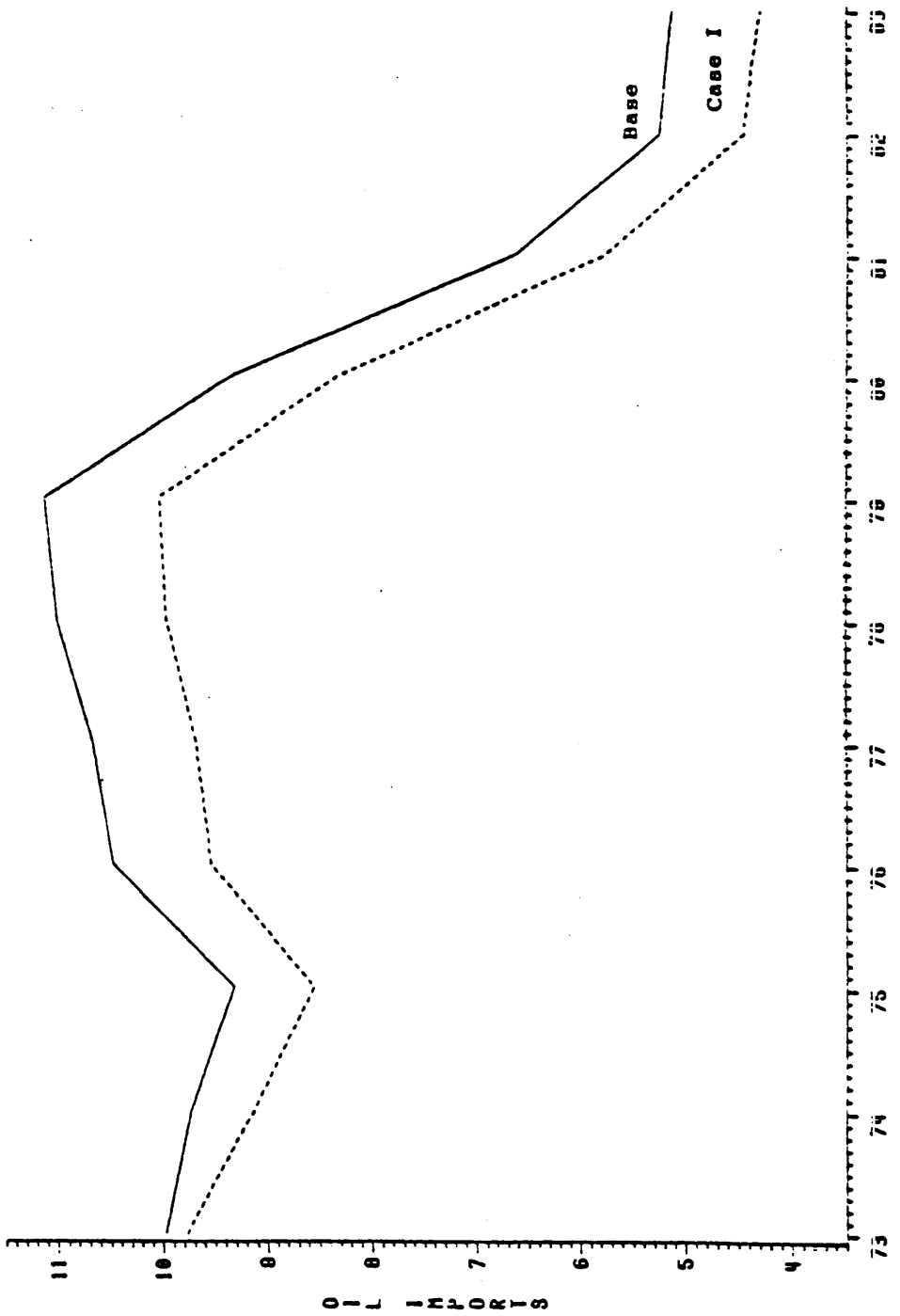
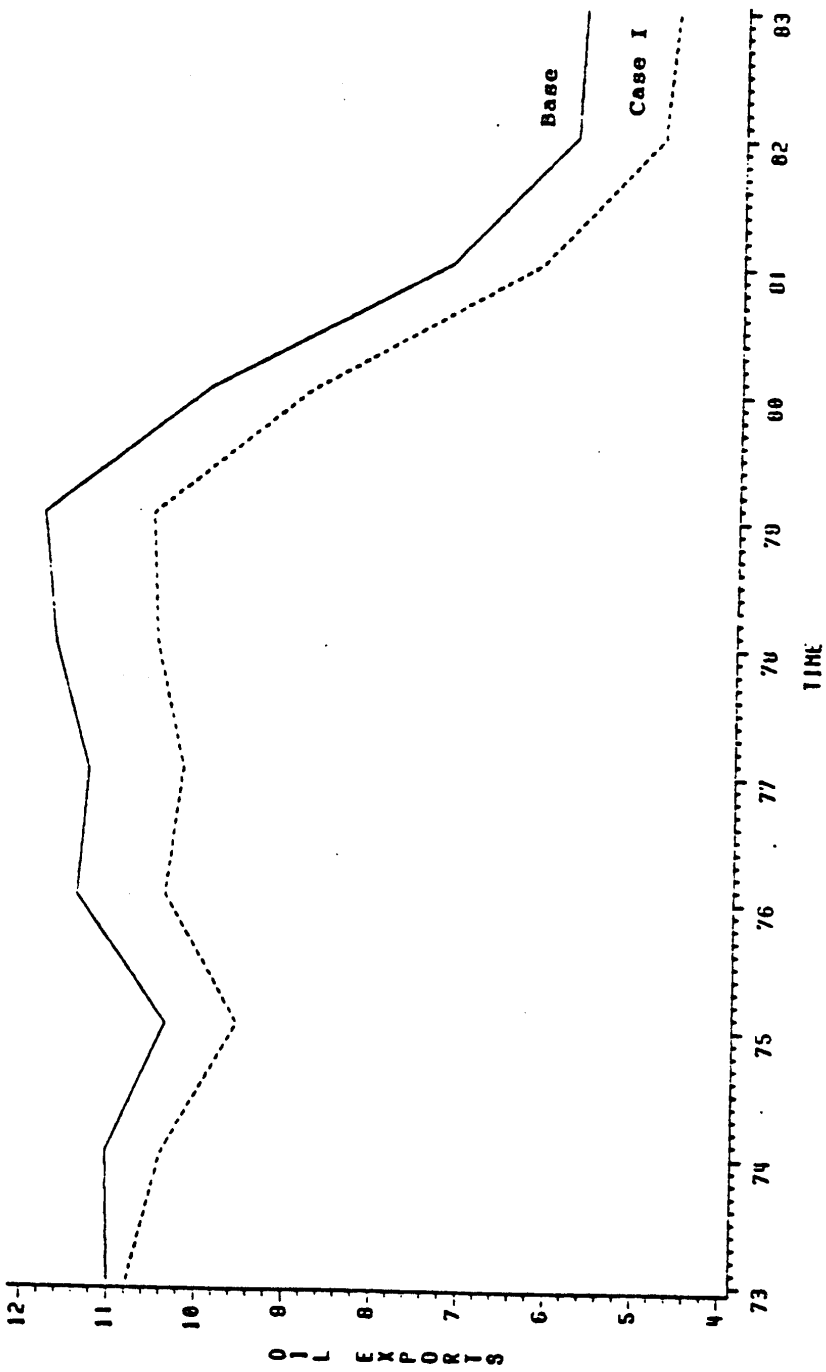

OIL IMPORTS OF DC'S
BILL. OF BARRELS PER YEAR
Base
Case I
OIL IMPORTS
TIME

Figure 6


OIL EXPORTS OF OPEC
BIL. OF BARRELS PER YEAR
Base
Case I
OIL EXPORTS
12
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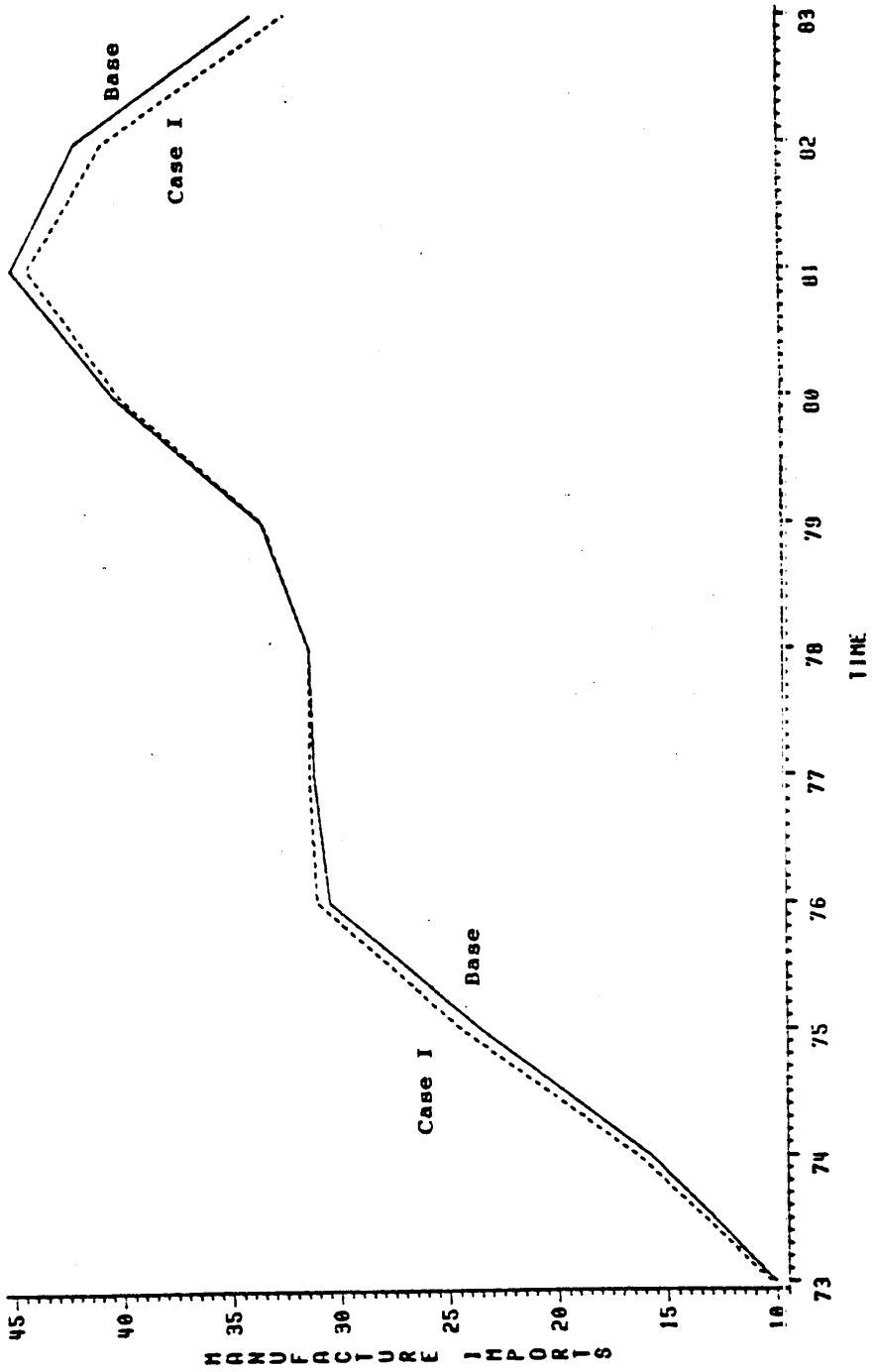
TIME

Figure 7


REAL IMPORTS OF MANUFACTURES OF OPEC
BIL. OF U.S. DOLLARS
MANUFACTURE IMPORTS
45
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TIME
Base
Case I
Case I
Base

and therefore a stimulus to real income. However, our results imply that the improvement in the trade account is not strong enough to offset the reduction in consumption leading to a net deterioration of DC's real income.

Real income in Non-OPEC developing countries also deteriorates as a result of an increase in the price of oil, which reduces not only nominal holdings of foreign exchange resources, but also their real purchasing power due to the increase in the export price of manufactures of DC's. This decline in real foreign exchange reserves adversely affects imports of manufactures, capital formation and the capital stock, which in turn dampens output growth. In addition, the increase in oil prices reduces oil consumption in LDC's by 0.7 percent in 1973, by 3.3 percent in 1977 and by 7.25 percent in 1983. The decline in the capital stock and in oil consumption adversely affects production in Non-OPEC LDC's with respect to the baseline case by 0.05 percent in 1973, 0.7 percent in 1977, and 1.8 percent in 1983 (see Figure 3).

The sustained increase in oil prices reduces oil consumption of developed economies (Figure 4) by an annual average of 6.4 percent with respect to the base solution. This in turn reduces oil imports of DC's (Figure 5) and oil exports of OPEC (Figure 6). The initial reduction in OPEC's oil exports (in bbY) is 2.1 percent, which gives a total price elasticity of -0.21. However, as the dynamic effects of higher oil prices work themselves out, we find that the total price elasticity (in absolute value) increases to 0.56 in 1974, and to 1.0 in 1978. In other words, it takes six years to move from the inelastic portion of the oil demand curve faced by OPEC to the elastic zone.

Price increases beyond the point where the demand is elastic result in more than proportionate reductions in oil consumption leading to a

decline in oil revenues. This decline in revenues results in a reduction of OPEC's imports of manufactures of 0.25 percent in 1979, after an average increase of 2.1 percent above the baseline solution for the previous six years (Figure 7). Although OPEC's real income is not determined in our empirical model, a reduction in imports of manufactures slows the development process in OPEC. This suggests that a sustained 10 percent increase of oil prices over the base solution may not be in OPEC's best long run interest.

Case II: Higher Oil Prices and Restrictive Fiscal Policy Response

One of the consequences of an increase in the price of oil is an increase in the inflation rate in oil importing countries. The response of economic policies in developed economies to the inflation generated by the two oil price shocks has been, in general, restrictive[13] (i.e., $\psi<0$). For this reason we investigate the impacts of a reduction in real government spending on real income, prices, and international trade. In particular, we reduce real government expenditure by US$ 8 billions (approximately two percent of real government expenditures) from 1974 to 1983 as a response to the 10 percent increase in the price of oil. The delayed response of fiscal policy may be justified on the basis that the budget appropriation process operates with a lag of a year. Table 5 contains the dynamic multipliers for Case II; Figures 8 to 13 contrast the results of the base solution to the present case.

The reduction in government expenditures adversely affects real income of developed economies in the first year beyond the recessionary effects of oil price increases without much success in reducing the price level. The combined effects of higher oil prices and restrictive fiscal policies result in a real income path for DC's below the baseline case by 1.4 percent in 1974, 3 percent in 1977, and 7 percent in 1983, with an

Table 5

Dynamic Multipliers: Case II

	Y^d	Y^ℓ	$O^{d,d}$	$O^{d,\ell}$	$\tilde{M}_o^d$	$\tilde{M}_o^\ell$
1973	-.51	-.05	-1.42	-.74	-2.08	-2.21
1974	-1.36	-.11	-4.83	-1.41	-6.94	-7.40
1975	-1.95	-.23	-6.67	-2.04	-9.83	-10.42
1976	-2.44	-.48	-7.91	-2.69	-11.14	-11.80
1977	-3.01	-.83	-8.62	-3.37	-12.04	-12.74
1978	-3.54	-1.26	-9.30	-4.10	-12.91	-13.66
1979	-4.07	-1.72	-9.97	-4.87	-13.84	-14.65
1980	-4.66	-2.21	-10.67	-5.69	-15.65	-16.59
1981	-5.39	-2.70	-11.47	-6.57	-19.09	-20.49
1982	-6.35	-3.15	-12.48	-7.51	-23.05	-25.39
1983	-7.24	-3.54	-13.56	-8.50	-25.42	-28.62

	$\tilde{X}^o$	M_o^d	M_o^ℓ	X_o^ℓ	M_m^o	M_m^ℓ
1973	-2.08	-2.01	-1.30	-.76	2.36	-.02
1974	-6.49	-6.70	-2.76	-2.49	3.65	-.24
1975	-9.39	-9.40	-4.63	-3.90	3.15	-1.28
1976	-10.94	-10.77	-6.14	-4.48	.74	-2.95
1977	-12.30	-11.64	-8.63	-5.17	-.94	-3.43
1978	-13.26	-12.51	-9.88	-5.79	-1.91	-3.38
1979	-14.34	-13.41	-11.34	-6.47	-2.58	-3.48
1980	-16.48	-14.92	-14.04	-7.99	-3.34	-3.87
1981	-20.48	-17.58	-17.78	-10.31	-4.75	-3.79
1982	-25.06	-20.80	-21.02	-12.04	-6.93	-3.22
1983	-27.74	-23.23	-22.60	-12.68	-9.21	-2.84

	X_m^ℓ	M_p^d	R^ℓ	R^ℓ/P_m^d	P_m^d	P_y^d
1973	-1.34	-.32	-1.54	-1.54	.00	.32
1974	-3.62	-.76	-6.97	-7.69	1.24	.94
1975	-4.61	-.99	-10.96	-11.46	1.01	.98
1976	-6.05	-1.24	-9.94	-10.17	.49	.95
1977	-7.69	-1.65	-10.72	-10.60	-.30	.88
1978	-9.30	-2.23	-13.56	-13.01	-1.41	.76
1979	-10.93	-2.87	-12.43	-11.36	-2.96	.59
1980	-12.73	-3.60	-7.62	-5.87	-5.08	.35
1981	-14.92	-4.48	-3.53	-.96	-7.64	-.01
1982	-17.64	-5.56	-.87	2.63	-10.91	-.47
1983	-20.19	-6.65	-5.54	-1.26	-14.63	-1.06

Figure 8

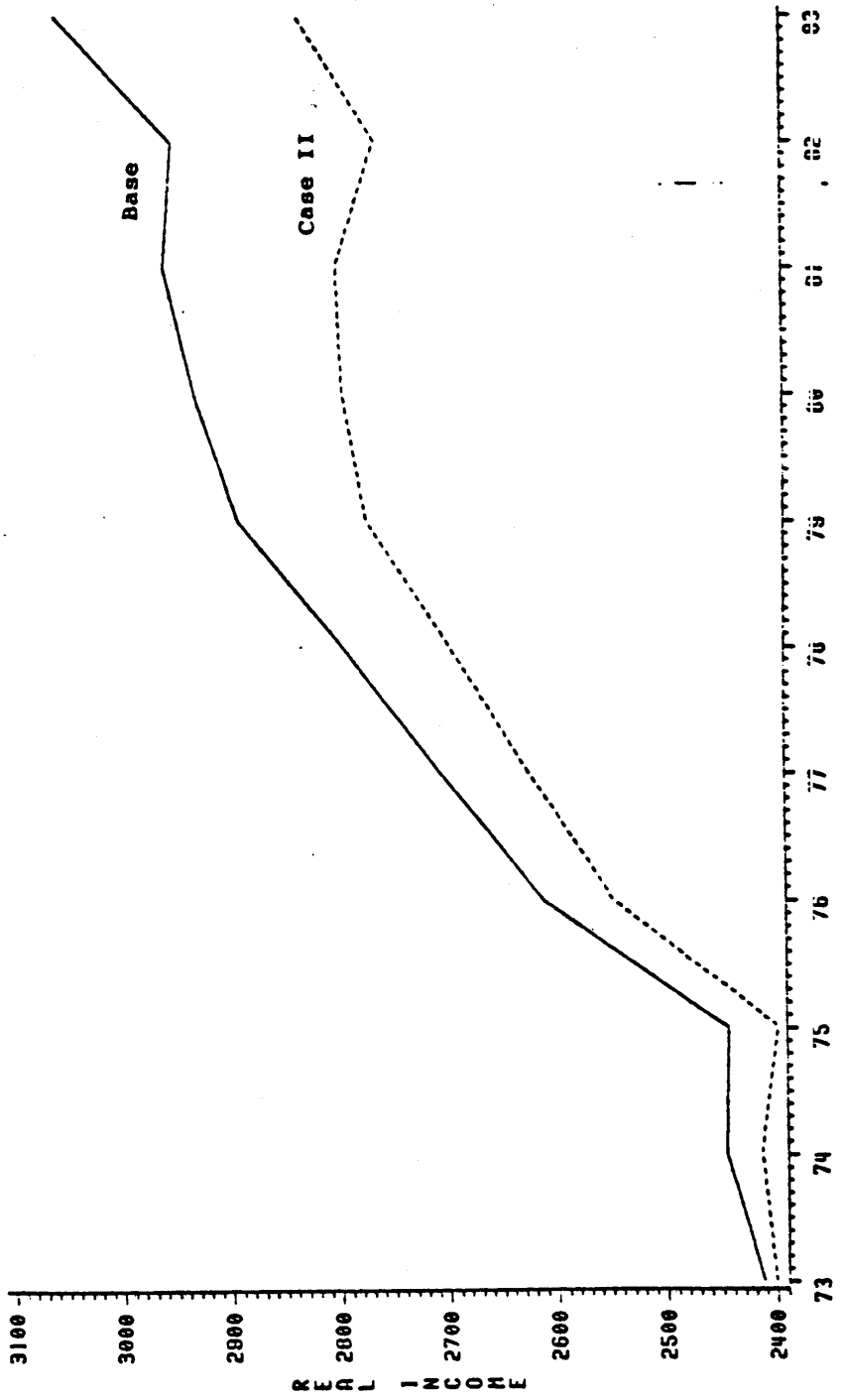
REAL INCOME OF DC'S
BIL. OF U.S. DOLLARS
Base
Case II
REAL INCOME
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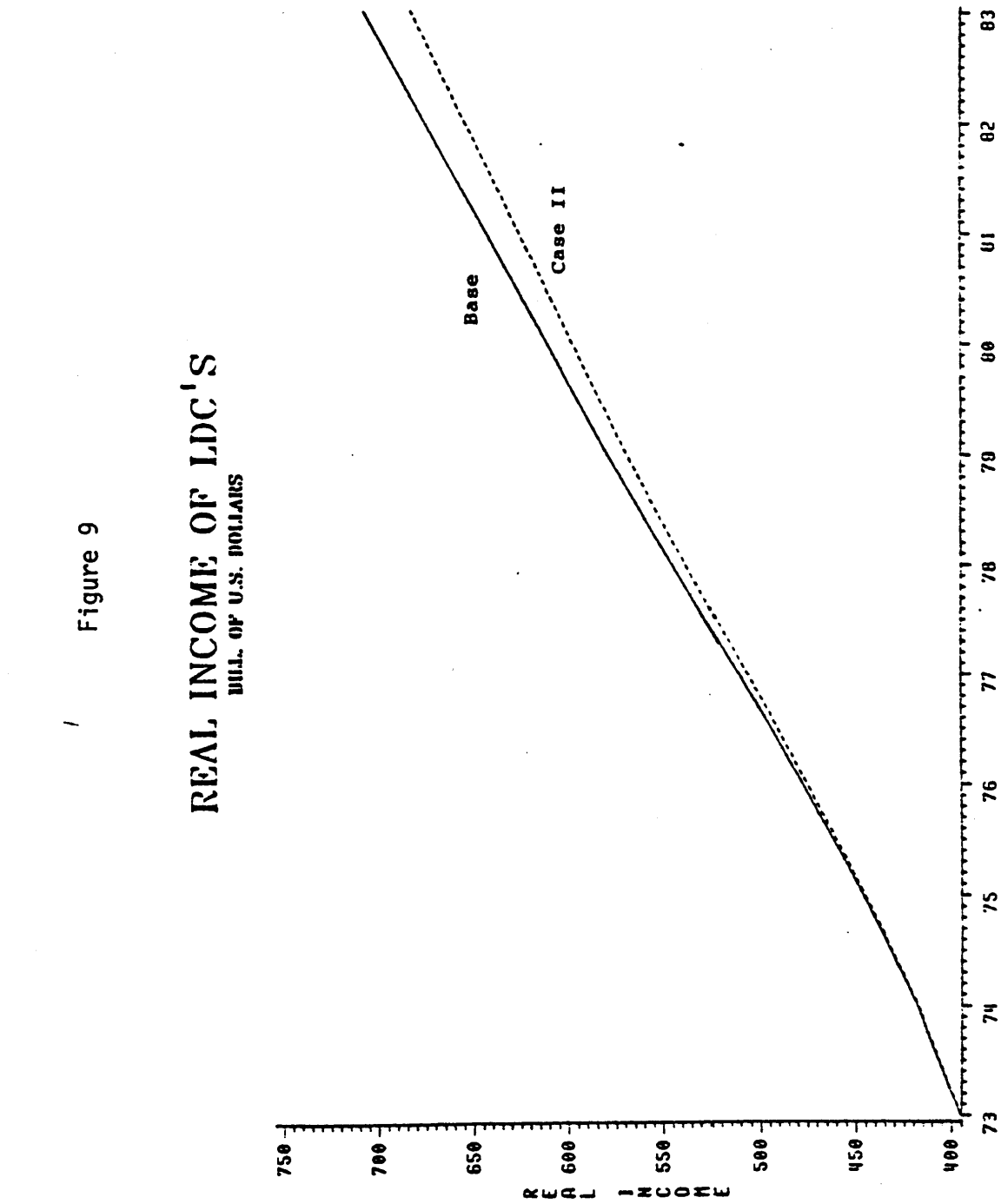
Figure 9


REAL INCOME OF LDC'S
BILL. OF U.S. DOLLARS
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Case II
REAL INCOME
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Figure 10

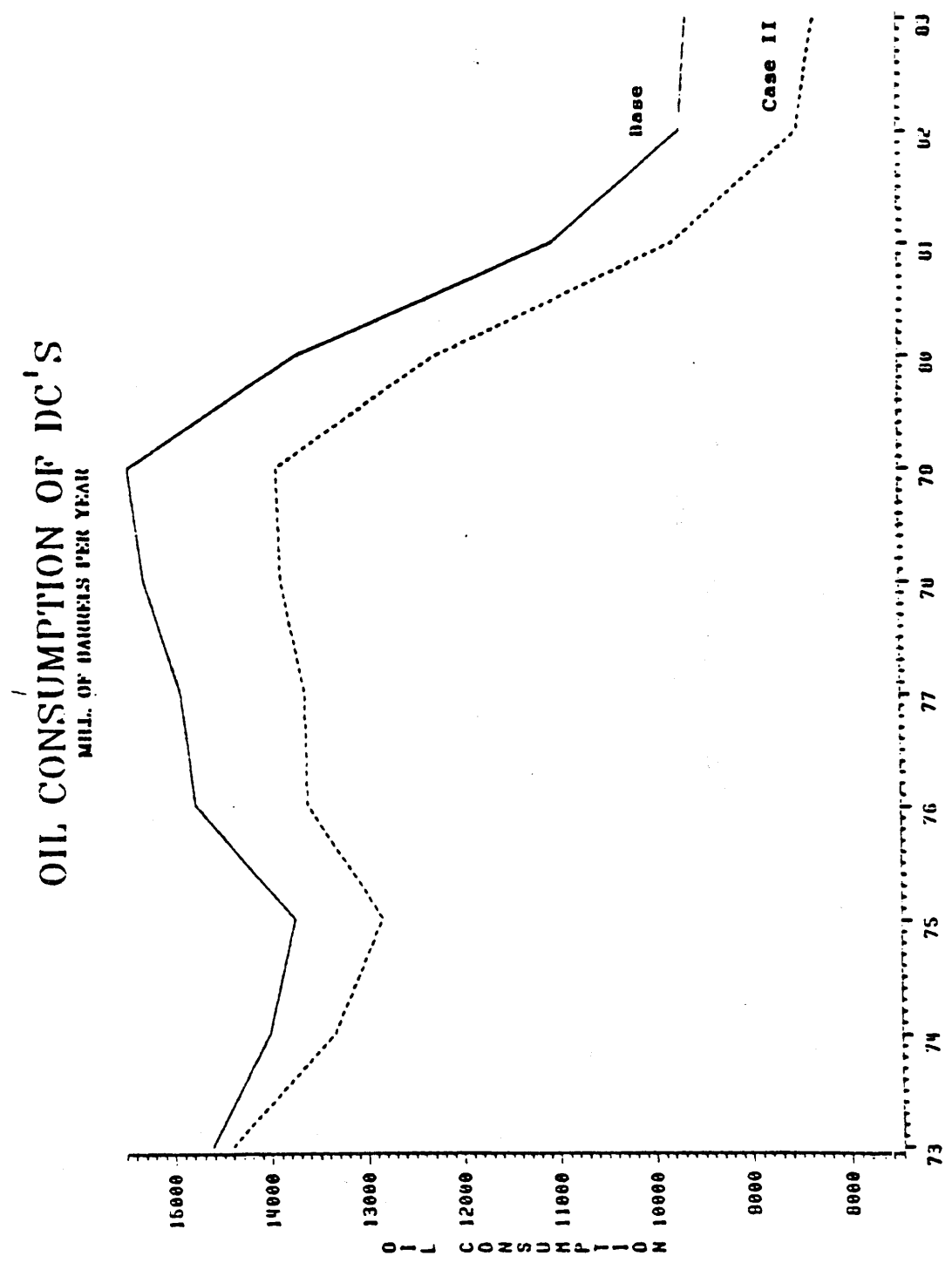
OIL CONSUMPTION OF DC'S
MILL. OF BARRELS PER YEAR
Base
Case II
OIL CONSUMPTION
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Figure 11

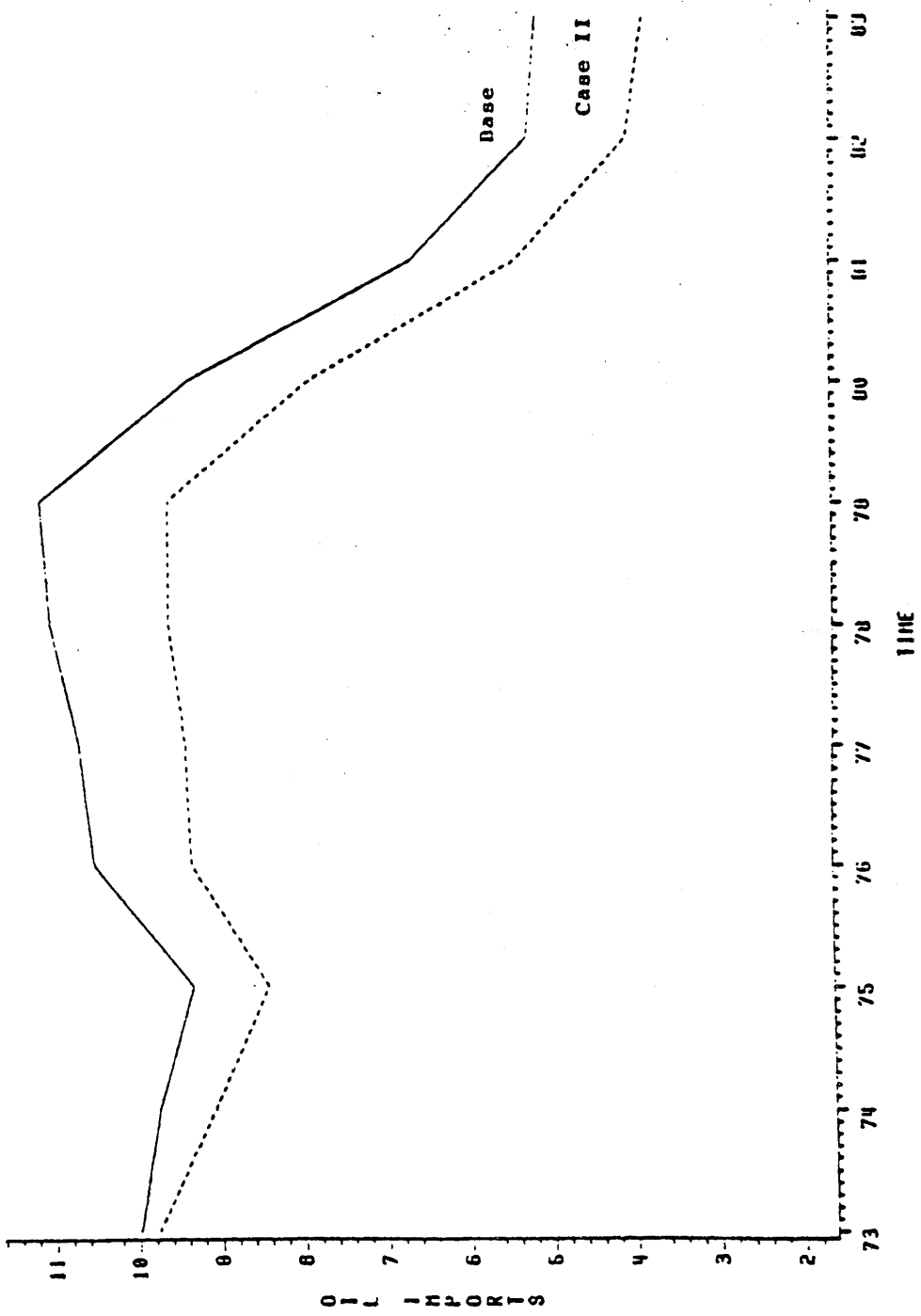
OIL IMPORTS OF DC'S
BILL. OF BARRELS PER YEAR
Base
Case II
OIL IMPORTS
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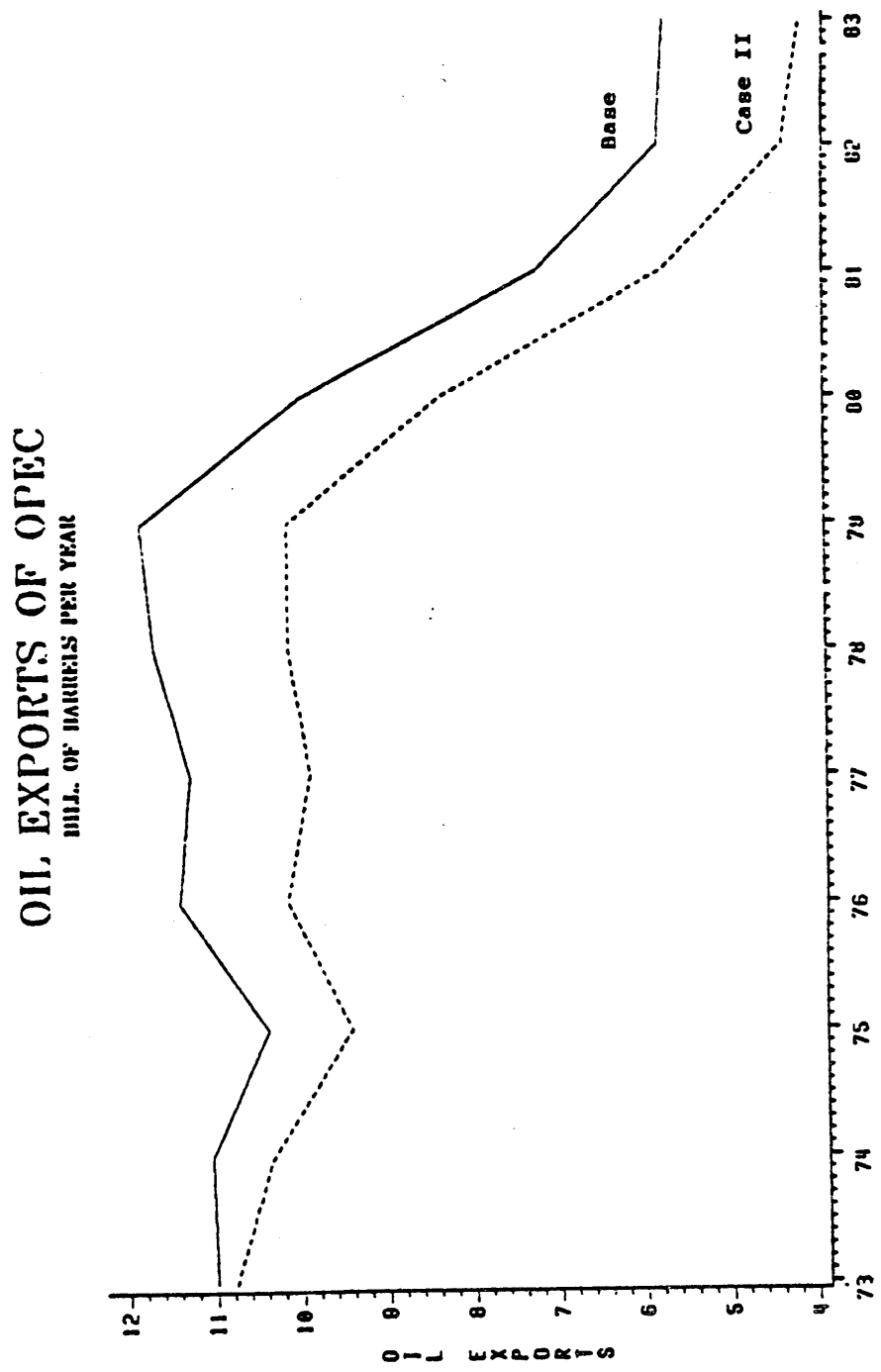
Figure 12


OIL EXPORTS OF OPEC
BILL. OF BARRELS PER YEAR
Base
Case II
OIL EXPORTS
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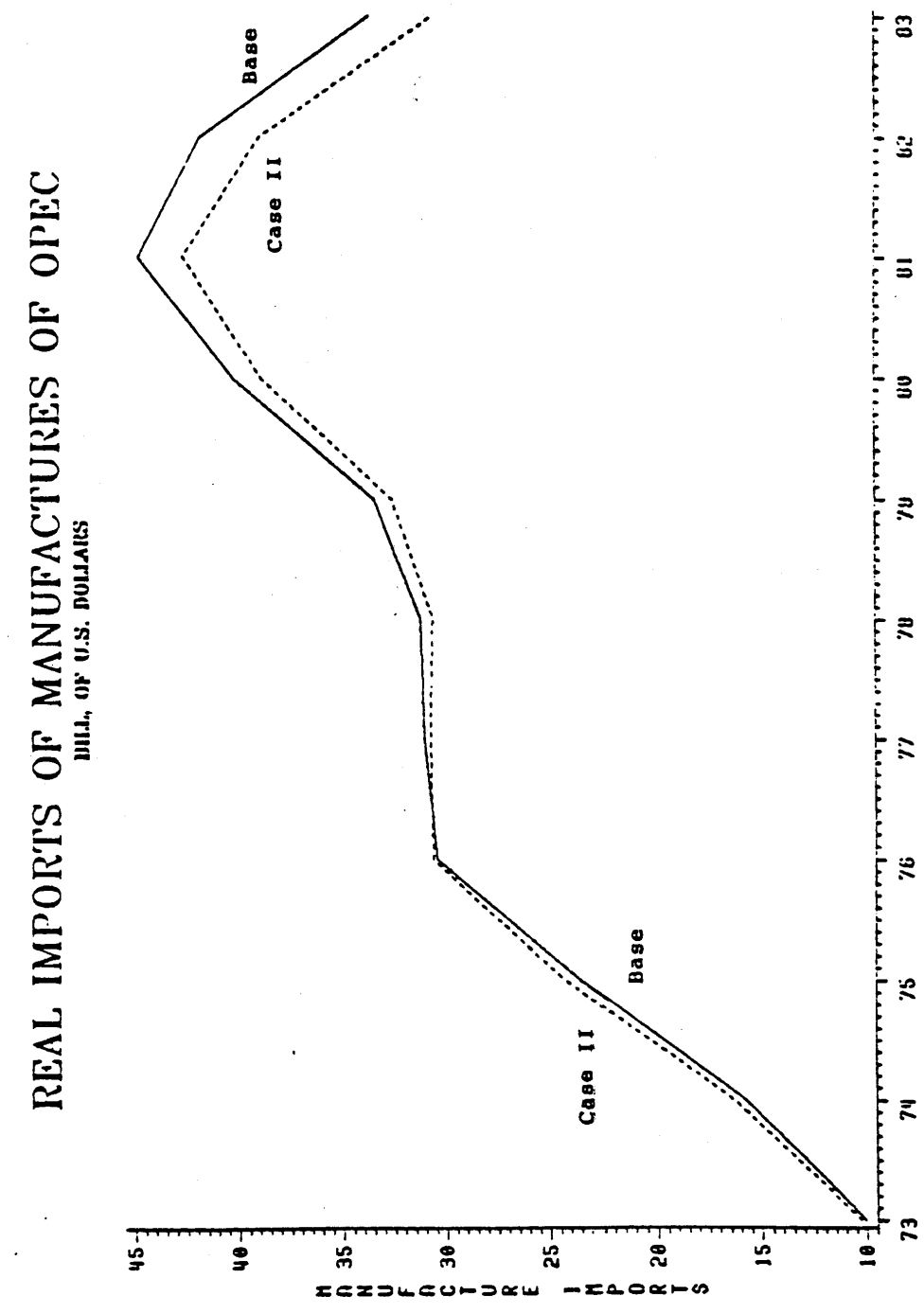
TIME

Figure 13


REAL IMPORTS OF MANUFACTURES OF OPEC
BIL., OF U.S. DOLLARS
MANUFACTURE IMPORTS
45
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Base
Case II
Case II
Base
73
74
75
76
77
78
79
80
81
82
83
TIME

average reduction of 3.7 percent per year (see Figure 8).

Oil demand in the DC's is below the baseline case by five percent in 1974, 10 percent in 1980 and 13 percent by 1983, with an annual average reduction of 8.8 percent over the 11 year period (Figure 10). This decline in oil demand in the DC's results in a reduction in their total oil imports and oil exports of OPEC (Figures 11 and 12). For this last variable we find a reduction of 6.5 percent in 1974, 9.4 percent in 1975 and 28 percent by 1983, with an annual average reduction of 15 percent with respect to the baseline. Naturally, these reductions in oil exports of OPEC imply a substantial increase in (the absolute value) of the total price elasticity which increases from 0.7 in 1974 to 2.8 by 1983. This adversely affects OPEC's oil revenues and therefore their imports of manufactures from DC's by 1 percent in 1979, 5 percent in 1981 and 9 percent in 1983 (see Figure 13).

The reduction in real income of developed economies also adversely affects real income in Non-OPEC developing economies. In particular, exports of manufactures of LDC's to DC's fall by 4 percent in 1974, by 10 percent in 1978 and by 20 percent in 1983, with an annual average reduction of 9.8 percent with respect to the baseline case. Similarly, exports of raw materials of LDC's to DC's fall with respect to the baseline case by an annual average of 2.8 percent.[14] The overall decline in exports of LDC's, coupled with reduced real foreign exchange resources dampens imports of manufactures, capital accumulation and real income of Non-OPEC LDC's by 0.11 percent in 1974, 1.7 percent in 1979 and by 3.5 percent in 1983 with an average annual reduction of 1.5 percent with respect to the baseline case (Figure 9).

Case III: Higher Absorption by OPEC

A remedial tool that frequently has been suggested is for OPEC to spend a larger fraction of their oil revenues on imports of manufactures. Hooper and Tryon (1982) have found that increasing OPEC's recycling by 50 percert in nominal terms eliminates the output losses due to higher oil prices in 1982 for Japan and Germany; similarly, Adams and Marquez (1983) have found that a higher absorption capacity for OPEC offsets the negative effects of oil price increases. Here we assume an increase of 33 percent in OPEC's absorption capacity in real terms, in addition to the assumptions of Case II. This scenario amounts to an increase in the recycling coefficient β of section II, and as we saw then, increases in β reduce the negative impact of oil prices. We increase OPEC's imports of manufactures in real terms by US$ 3 billions in 1973, US$ 10 billions in 1976 and US$ 16 billions in 1982 with an annual average increase of US$ 10.7 billions. The results for this case are shown in Table 6 and are depicted in Figures 14 to 19.

We find that an increase of 33 percent in OPEC's imports of manufactures, a demand stimulus to developed economies, does not completely offset the negative effects of higher oil prices and counterinflationary policies on real income of developed economies (Figure 14), although the higher recycling on the part of OPEC does offset the adverse effects of counterinflationary policies.[15]

Real income of Non-OPEC developing countries is above the levels for Case II. This is because OPEC's increased recycling stimulates real income of DC's, which in turn induces an increase in LDC's exports of both manufactures and raw materials to DC's by annual averages of 8 percent (9.8 for Case II minus 1.8 for Case III) and 2.5 percent respectively. This increase in exports increases foreign exchange reserves, which stimulate imports of manufactures, capital formation and real income of Non-OPEC developing countries. Nevertheless, the higher recycling of OPEC does not completely offset the negative impacts of higher oil prices and restrictive

Table 6

Dynamic Multipliers: Case III

	Y^d	Y^ℓ	$U^{d,d}$	$U^{d,\ell}$	$\tilde{M}_o^d$	$\tilde{M}_o^\ell$
1973	-.20	-.05	-1.22	-.74	-1.79	-1.93
1974	-.74	-.11	-4.31	-1.41	-6.20	-6.67
1975	-.76	-.21	-5.62	-2.03	-8.28	-8.90
1976	-.76	-.42	-6.26	-2.66	-8.82	-9.51
1977	-.89	-.69	-6.39	-3.28	-8.92	-9.64
1978	-1.00	-.97	-6.51	-3.92	-9.03	-9.79
1979	-.95	-1.21	-6.54	-4.56	-9.08	-9.88
1980	-.83	-1.41	-6.48	-5.20	-9.50	-10.42
1981	-.69	-1.54	-6.33	-5.83	-10.54	-11.83
1982	-.66	-1.57	-6.22	-6.43	-11.50	-13.39
1983	-.81	-1.45	-6.27	-7.01	-11.76	-14.10

	$\tilde{X}^o$	M_o^d	M_o^ℓ	X_o^ℓ	M_m^o	M_m^ℓ
1973	-1.82	-.18	-1.14	-.47	32.24	-.02
1974	-5.83	-6.04	-2.41	-1.81	35.65	-.17
1975	-7.99	-8.03	-3.85	-2.51	37.74	-.93
1976	-8.80	-8.67	-4.85	-2.43	34.74	-2.31
1977	-9.32	-8.80	-6.61	-2.51	32.98	-2.36
1978	-9.56	-8.96	-7.40	-2.58	32.34	-1.71
1979	-9.77	-9.05	-8.19	-2.56	36.05	-1.09
1980	-10.56	-9.38	-9.77	-3.02	34.79	-.77
1981	-12.27	-10.15	-11.86	-3.77	35.16	-.27
1982	-13.98	-10.97	-13.34	-3.94	36.85	.72
1983	-14.60	-11.45	-13.67	-3.66	39.35	1.76

	X_m^ℓ	M_p^d	R^ℓ	R^ℓ/P_m^d	P_m^d	P_y^d
1973	-.55	-.13	-.99	-.99	.00	.32
1974	-1.96	-.35	-5.39	-6.17	1.32	.95
1975	-1.45	-.21	-7.65	-8.30	1.28	1.03
1976	-1.55	-.08	-4.69	-5.24	1.13	1.06
1977	-1.96	-.12	-1.47	-1.92	.99	1.10
1978	-2.35	-.28	1.12	.82	.69	1.12
1979	-2.31	-.34	3.48	3.34	.34	1.15
1980	-2.13	-.37	8.55	8.57	-.06	1.21
1981	-1.85	-.39	16.77	16.96	-.48	1.26
1982	-1.87	-.47	26.33	26.67	-.87	1.30
1983	-2.35	-.66	21.27	21.73	-1.27	1.32

Figure 14

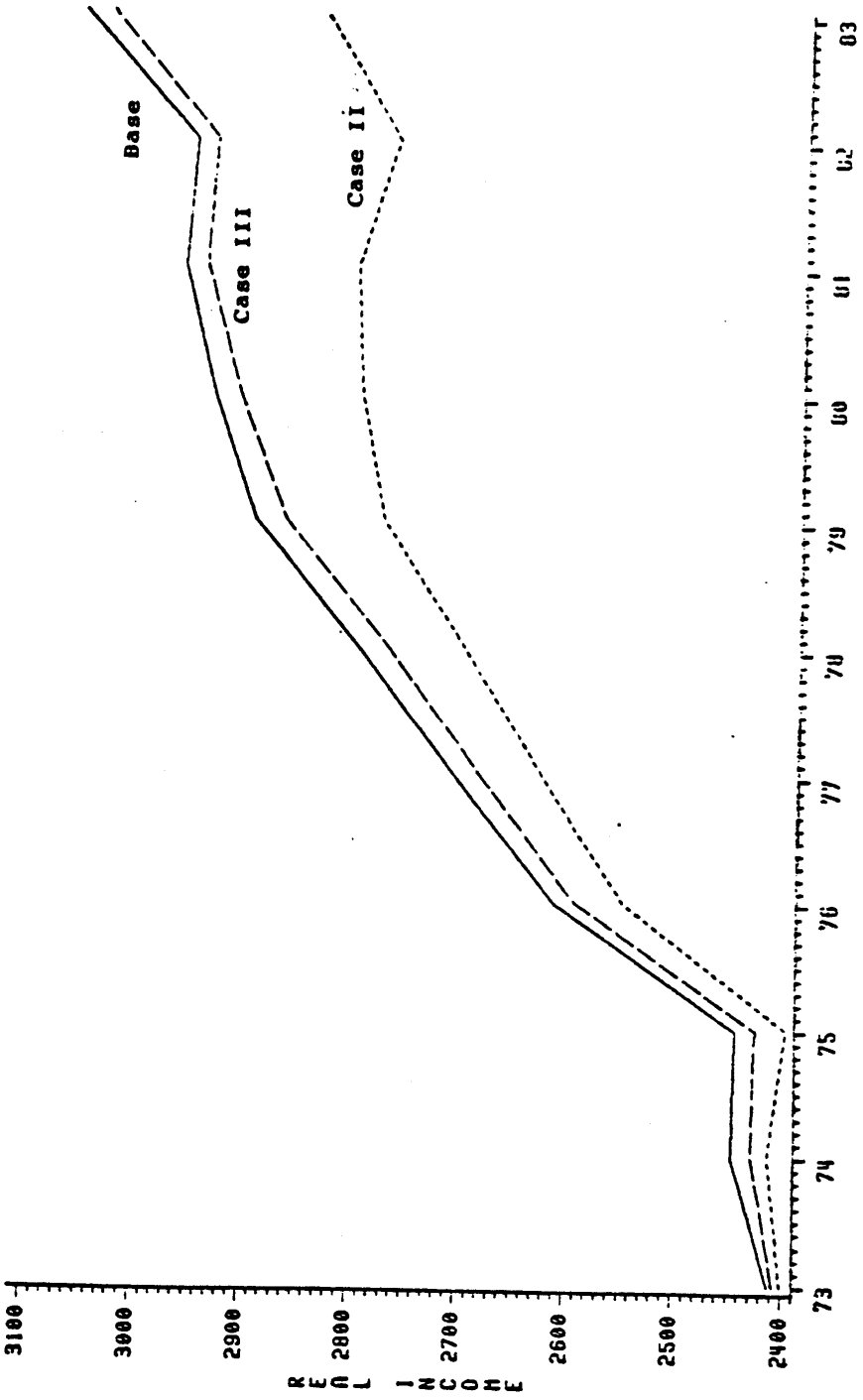

REAL INCOME OF DC'S
BILL. OF U.S. DOLLARS
Base
Case III
Case II
REAL INCOME
3100
3000
2900
2800
2700
2600
2500
2400
73
74
75
76
77
78
79
80
81
82
83
TIME

Figure 15

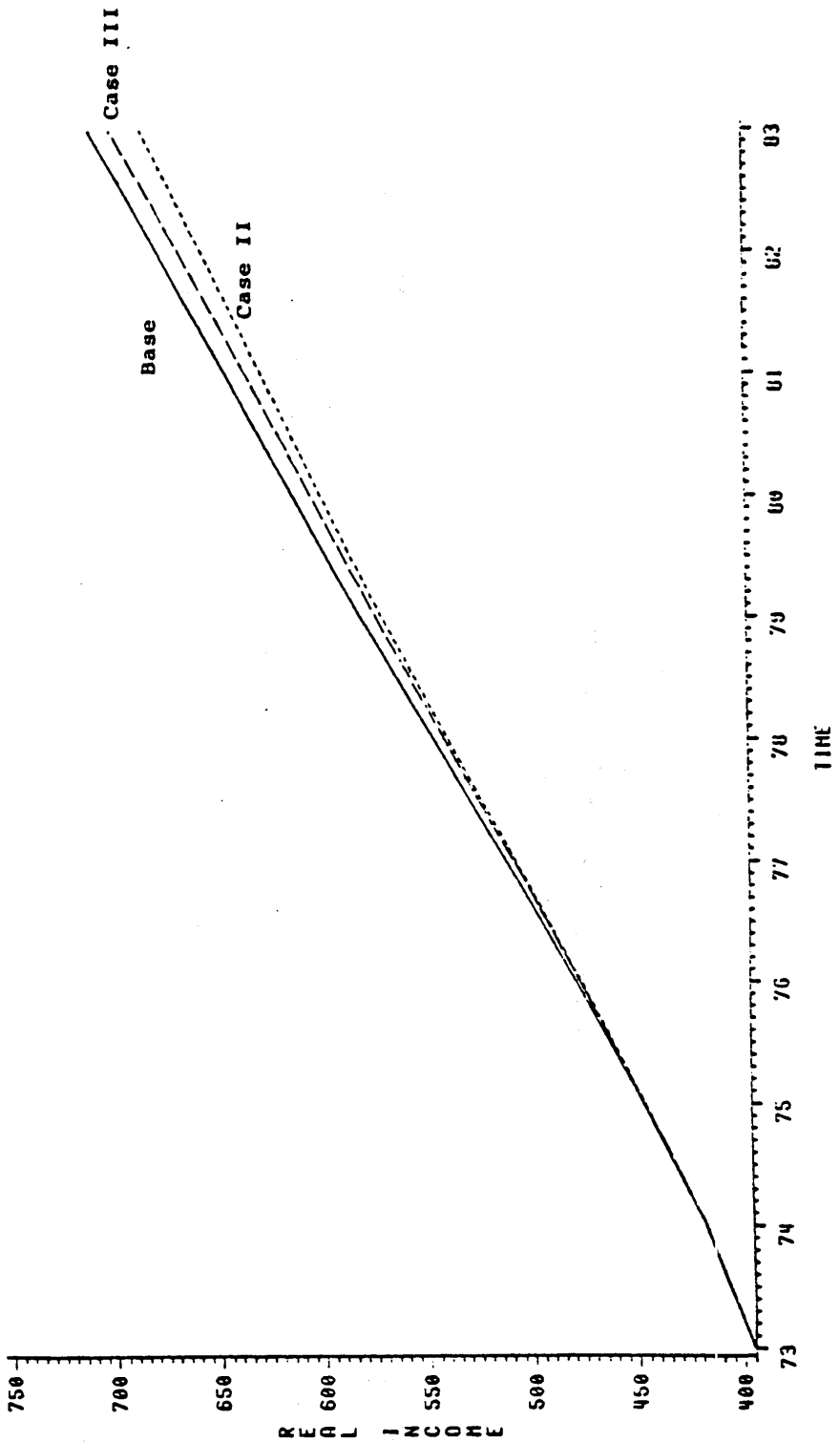

REAL INCOME OF LDC'S
BILL. OF U.S. DOLLARS
Case III
Case II
Base
REAL INCOME
750
700
650
600
550
500
450
400
73
74
75
76
77
78
79
80
81
82
83
TIME

Figure 16

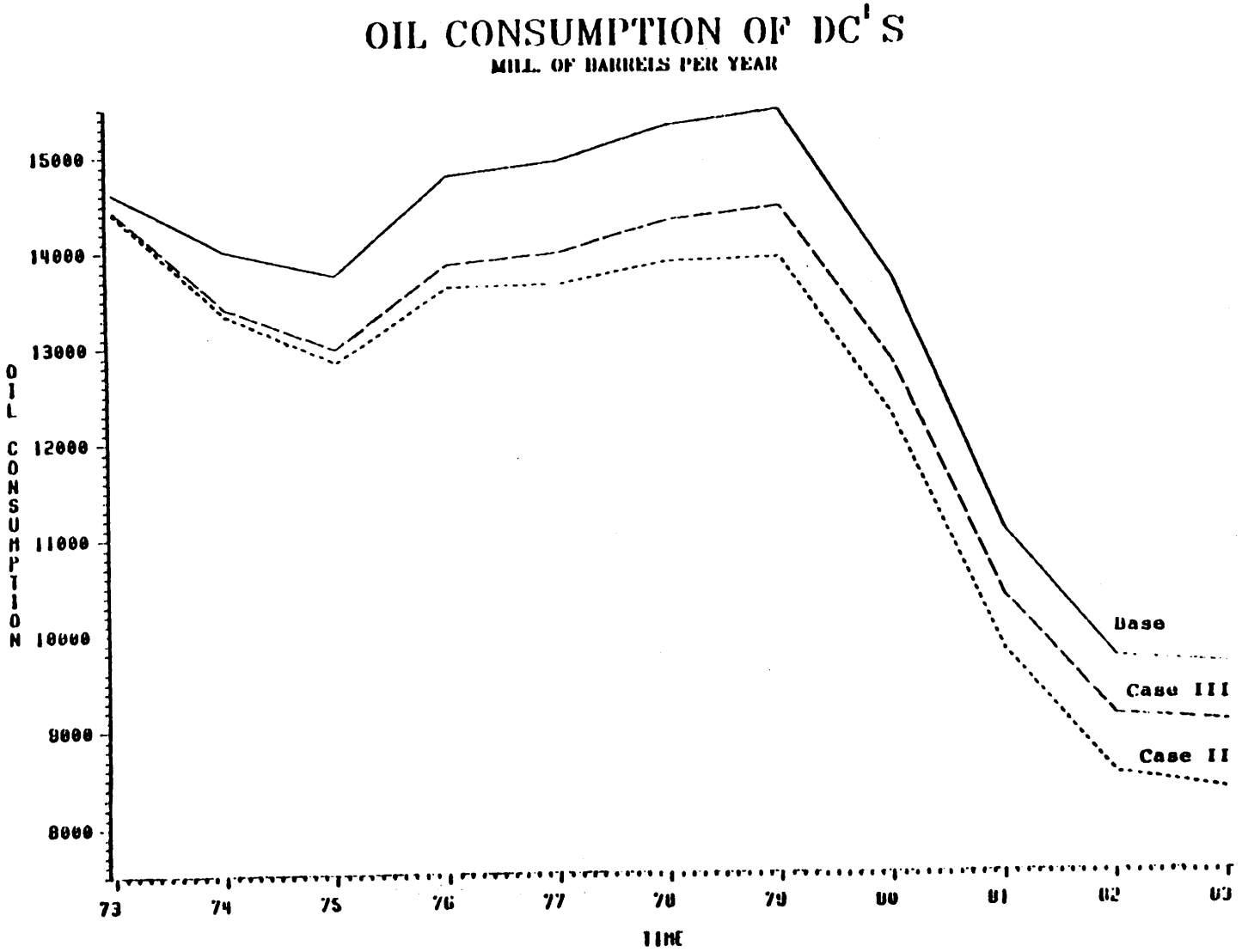

OIL CONSUMPTION OF DC'S
MILL. OF BARRELS PER YEAR
OIL CONSUMPTION
15000
14000
13000
12000
11000
10000
9000
8000
73
74
75
76
77
78
79
80
81
82
83
TIME
Base
Case III
Case II

Figure 17

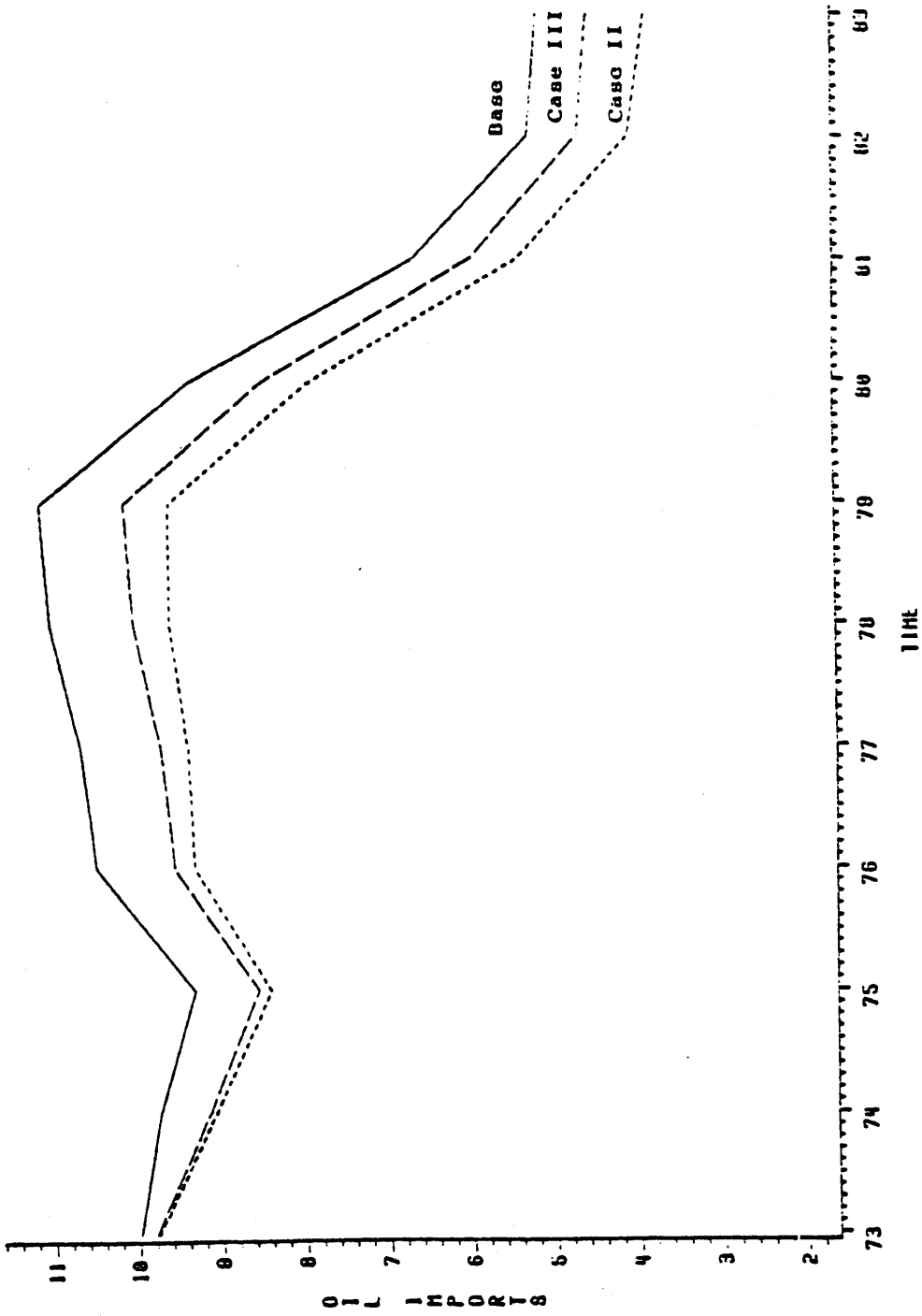

OIL IMPORTS OF DC'S
BIL. OF BARRELS PER YEAR
Base
Case III
Case II
OIL IMPORTS
11
10
9
8
7
6
5
4
3
2
73
74
75
76
77
78
79
80
81
82
83
TIME

Figure 18

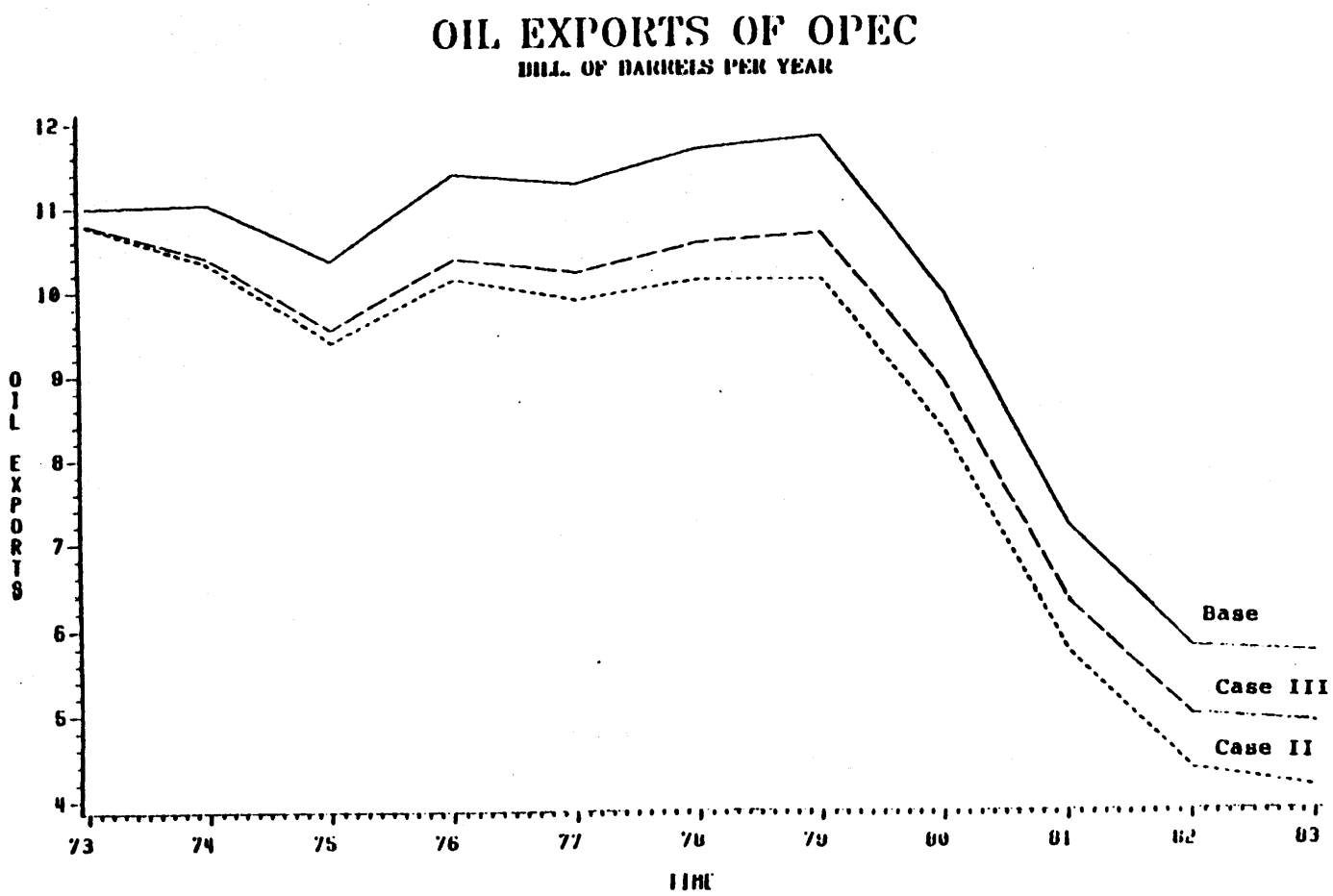
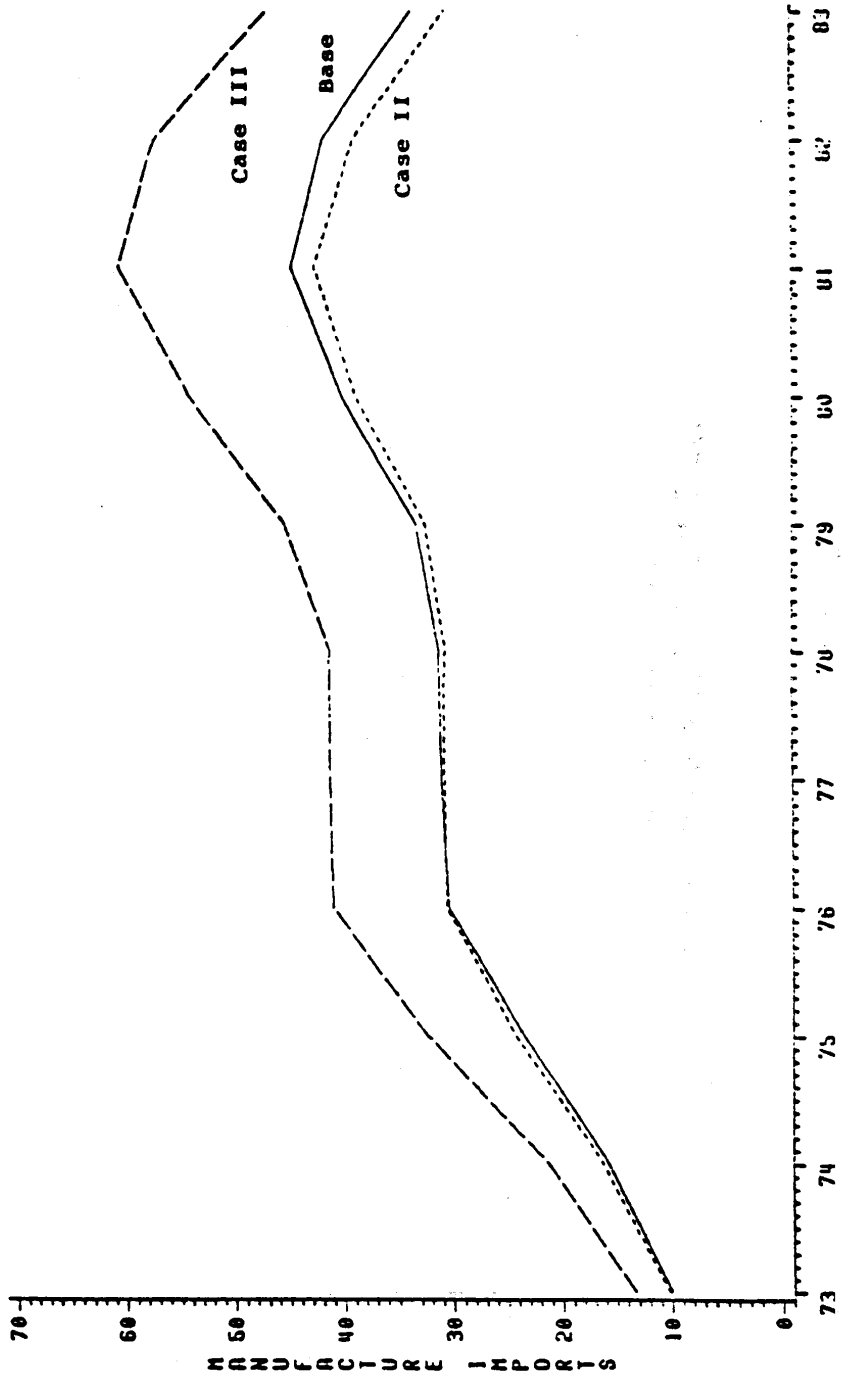

OIL EXPORTS OF OPEC
BILL. OF BARRELS PER YEAR
OIL EXPORTS
12
11
10
9
8
7
6
5
4
73
74
75
76
77
78
79
80
81
82
83
TIME
Base
Case III
Case II

Figure 19


REAL IMPORTS OF MANUFACTURES OF OPEC
BILL. OF U.S. DOLLARS
Case III
Base
Case II
MANUFACTURE IMPORTS
70
60
50
40
30
20
10
0
73
74
75
76
77
78
79
80
81
TIME

fiscal policy on real income of LDC's, since the path for Y^{ℓ} is still below the baseline case by 0.05 percent in 1973, 1 percent in 1978 and 1.45 percent in 1983 with an annual average reduction of 0.9 percent (Figure 15).

The increase in OPEC's recycling also has a feedback effect on DC's oil consumption and thus on OPEC's oil exports. In particular, oil exports of OPEC are now below the baseline case by an annual average of 7.9 percent, in contrast to an average reduction of 15 percent in Case II (Figure 18). Obviously, the smaller reduction in oil exports of OPEC helps to finance part of the increase in imports of manufactures.

Case IV: Increased Lending to Non-OPEC Developing Economies

Another way of offsetting the burden that higher oil prices have on Non-OPEC developing countries is through an increase in the level of capital transfers by OPEC to these countries. We assume that OPEC transfers to these countries an amount equal to 50 percent of the net capital transfers of that year, in each year, from 1974-1983. This implies a nominal transfer of US$ 18 billions in 1974, and an annual average nominal transfer of US$ 24 billions. Table 7 contains the results for Case IV which are also shown in Figures 20 to 25.

Figure 20 shows that the increased lending to Non-OPEC LDC's by OPEC does not offset the impacts of higher oil prices and counterinflationary policies on DC's real income, although it does represents an improvement over Case II.

The main beneficiary of this financial transfer is the group of Non-OPEC developing countries. Even though income of LDC's is below the baseline case for 1973 and 1974, we find that the positive effect on real income increases from 0.004 percent in 1975 to 19 percent in 1983 (see

Table 7

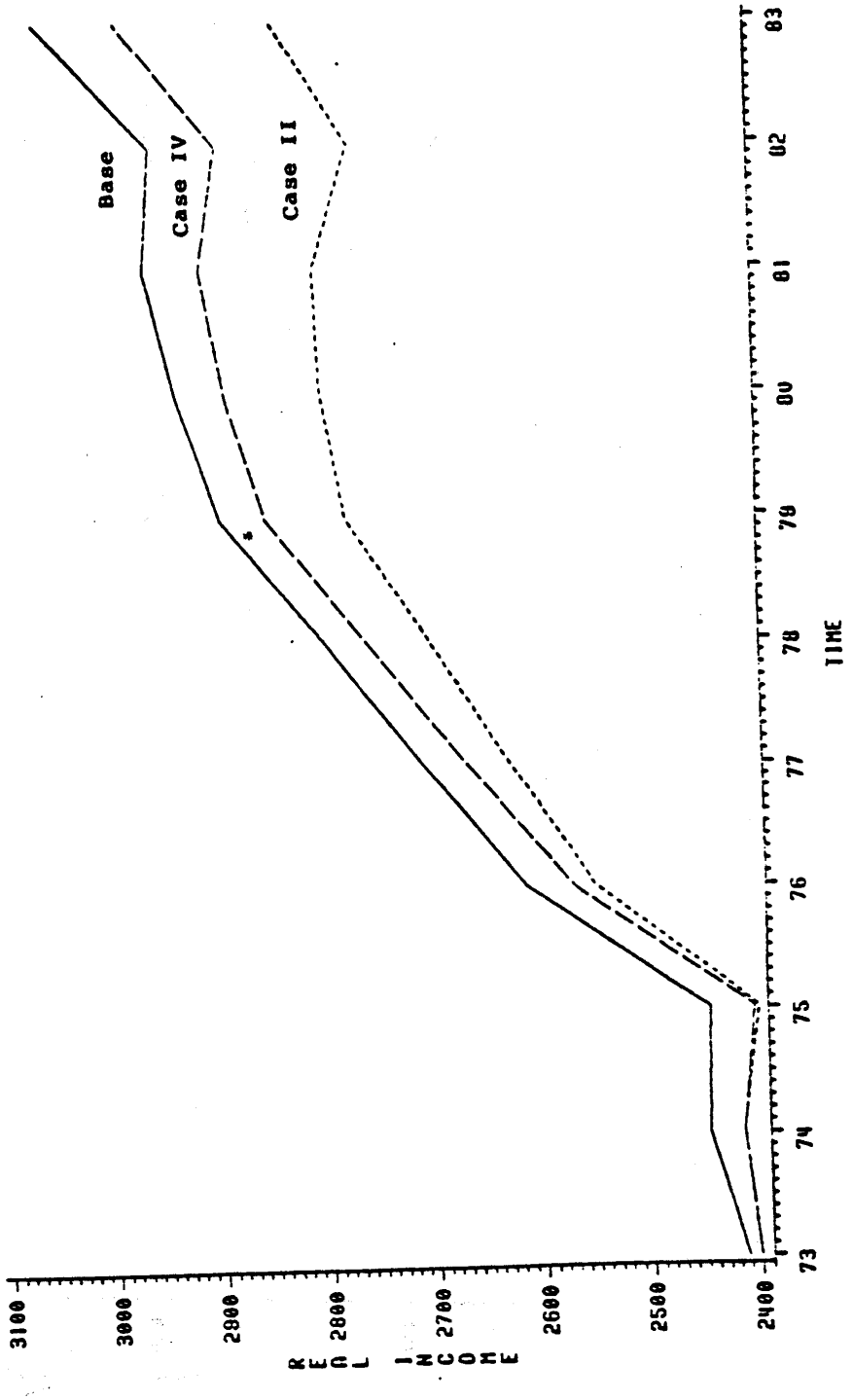
Dynamic Multipliers: Case IV

	Y^d	Y^ℓ	$O^{d,d}$	$O^{d,\ell}$	$\tilde{M}_o^d$	$\tilde{M}_o^\ell$
1973	-.50	-.05	-1.42	-.74	-2.08	-2.21
1974	-1.36	-.11	-4.83	-1.41	-6.94	-7.40
1975	-1.76	.01	-6.55	-2.02	-9.66	-10.26
1976	-1.65	.84	-7.35	-2.53	-10.35	-11.03
1977	-1.50	2.60	-7.34	-2.85	-10.25	-10.99
1978	-1.42	5.11	-7.24	-2.92	-10.05	-10.83
1979	-1.47	8.00	-7.21	-2.71	-10.00	-10.82
1980	-1.58	11.02	-7.26	-2.23	-10.65	-11.58
1981	-1.79	13.94	-7.44	-1.51	-12.37	-13.68
1982	-2.12	16.62	-7.74	-.59	-14.31	-16.29
1983	-2.49	18.96	-8.14	.49	-15.27	-17.83

	$\tilde{X}^o$	M_o^d	M_o^ℓ	X_o^ℓ	M_m^o	M_m^ℓ
1973	-2.08	-2.01	-1.30	-.76	2.36	-.02
1974	-6.49	-6.70	-2.76	-2.49	3.65	-.24
1975	-9.23	-9.26	-4.50	-3.72	3.20	3.06
1976	-10.17	-10.06	-5.43	-3.66	1.03	15.17
1977	-10.47	-10.04	-6.65	-3.48	-.11	24.14
1978	-10.25	-9.91	-6.44	-3.26	-.29	25.84
1979	-10.14	-9.91	-6.07	-3.25	-.07	24.75
1980	-10.70	-10.42	-6.10	-3.95	.13	23.51
1981	-12.07	-11.73	-6.17	-5.23	-.02	21.19
1982	-13.32	-13.34	-5.33	-5.96	-.44	19.43
1983	-13.46	-14.47	-3.60	-5.99	-.74	18.34

	X_m^ℓ	M_p^d	R^ℓ	R^ℓ/P_m^d	P_m^d	P_y^d
1973	-1.34	-.32	-1.54	-1.54	.00	.32
1974	-3.62	-.76	36.49	35.43	1.24	.94
1975	-4.14	-.88	85.13	84.10	1.01	.98
1976	-3.99	-.73	90.37	89.83	.55	.96
1977	-3.78	-.67	96.17	96.15	.03	.94
1978	-3.75	-.79	97.84	98.31	-.53	.91
1979	-4.07	-1.00	68.58	69.38	-1.16	.90
1980	-4.48	-1.24	43.59	44.63	-1.96	.88
1981	-5.21	-1.55	27.60	28.85	-2.86	.84
1982	-6.24	-1.93	7.02	8.37	-4.01	.75
1983	-7.36	-2.35	-16.76	-15.43	-5.31	.61

Figure 20


REAL INCOME OF DC'S
BIL. OF U.S. DOLLARS
Base
Case IV
Case II
REAL INCOME
3100
3000
2900
2800
2700
2600
2500
2400
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74
75
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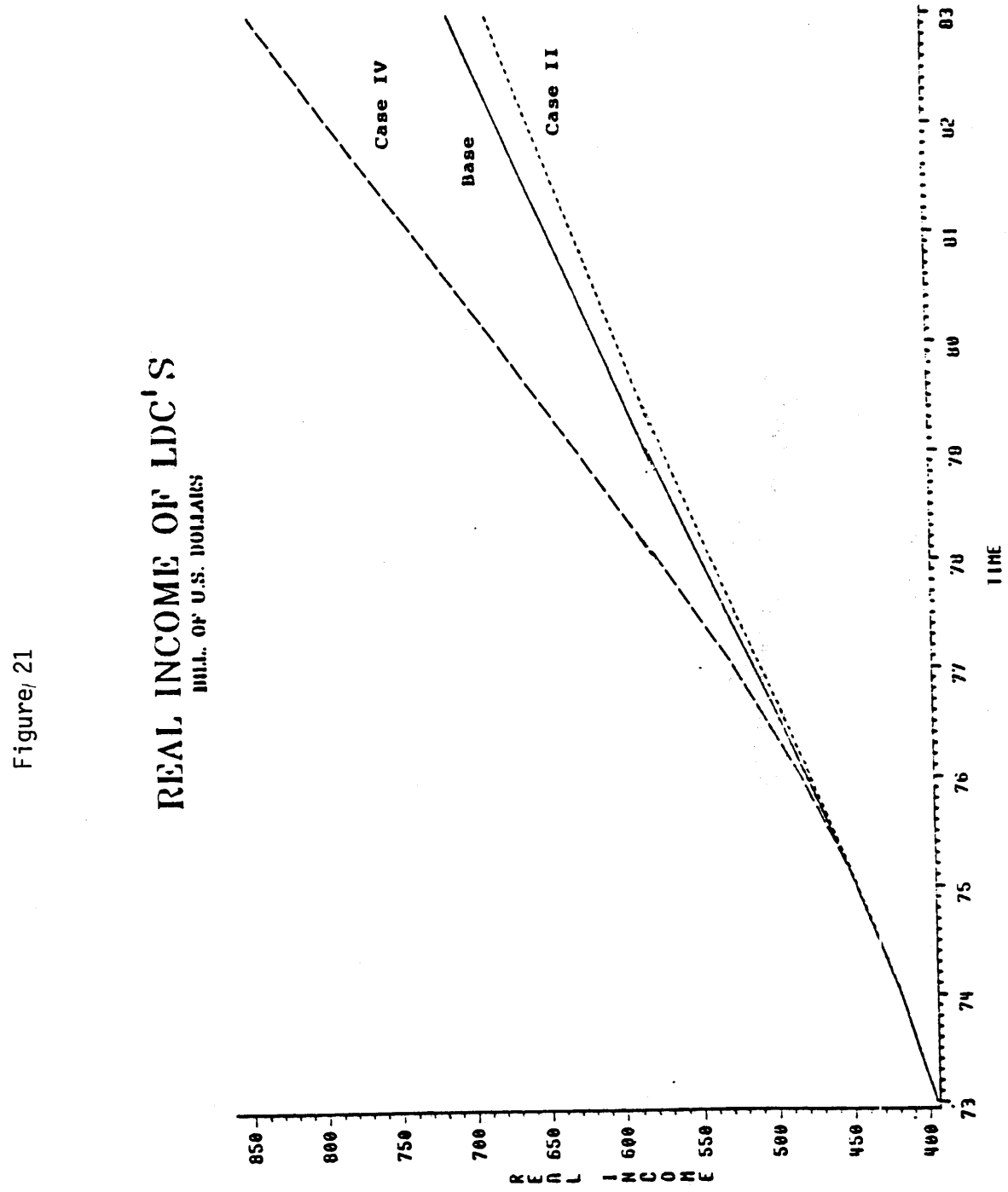
81
82
83
TIME

Figure 21


REAL INCOME OF LDC'S
BILL. OF U.S. DOLLARS
Case IV
Base
Case II
REAL INCOME
850
800
750
700
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600
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500
450
400
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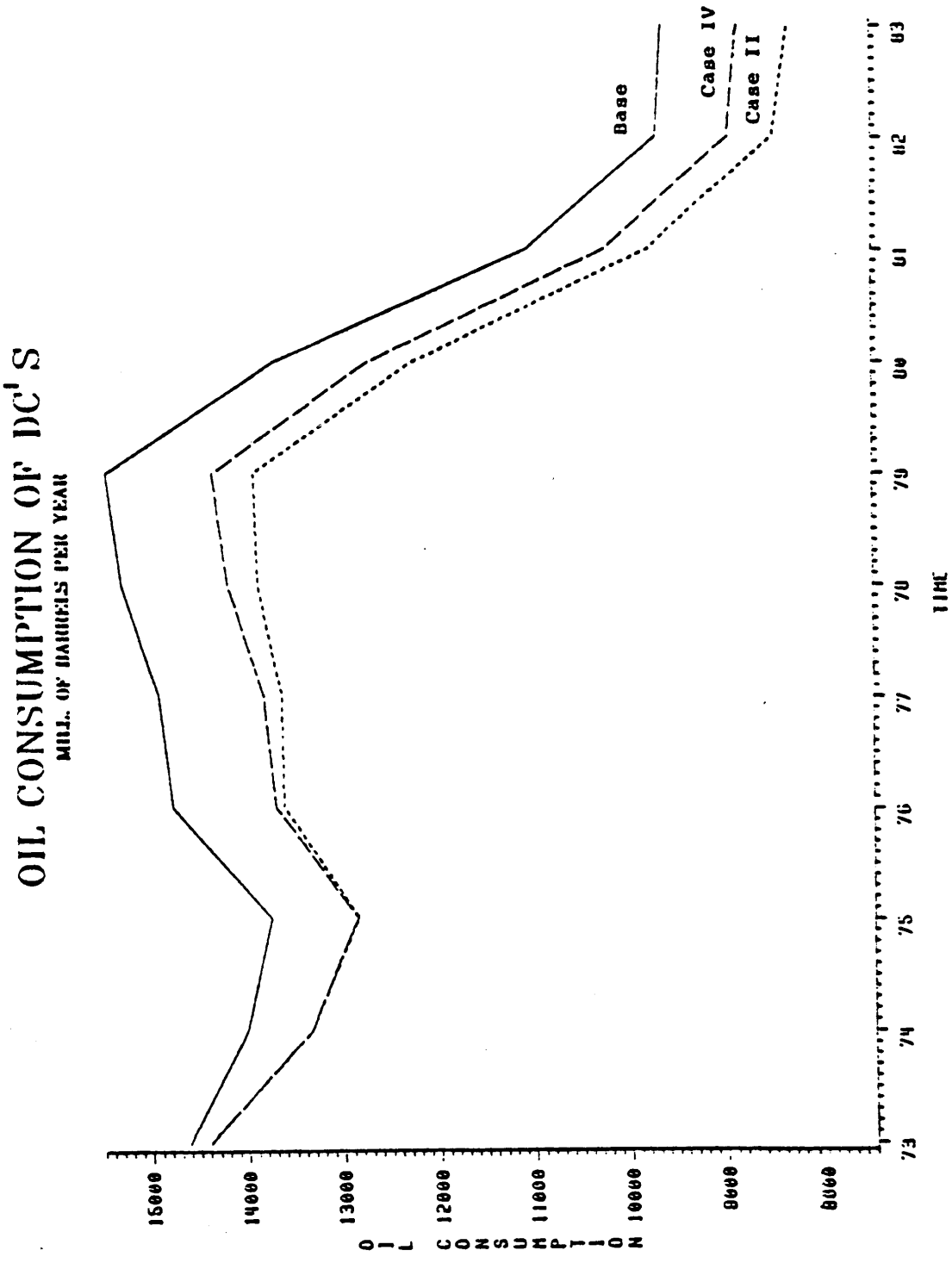
82
83
TIME

Figure 22


OIL CONSUMPTION OF DC'S
MILL. OF BARRELS PER YEAR
Base
Case IV
Case II
15000
14000
13000
12000
11000
10000
9000
8000
OIL CONSUMPTION
73
74
75
76
77
78
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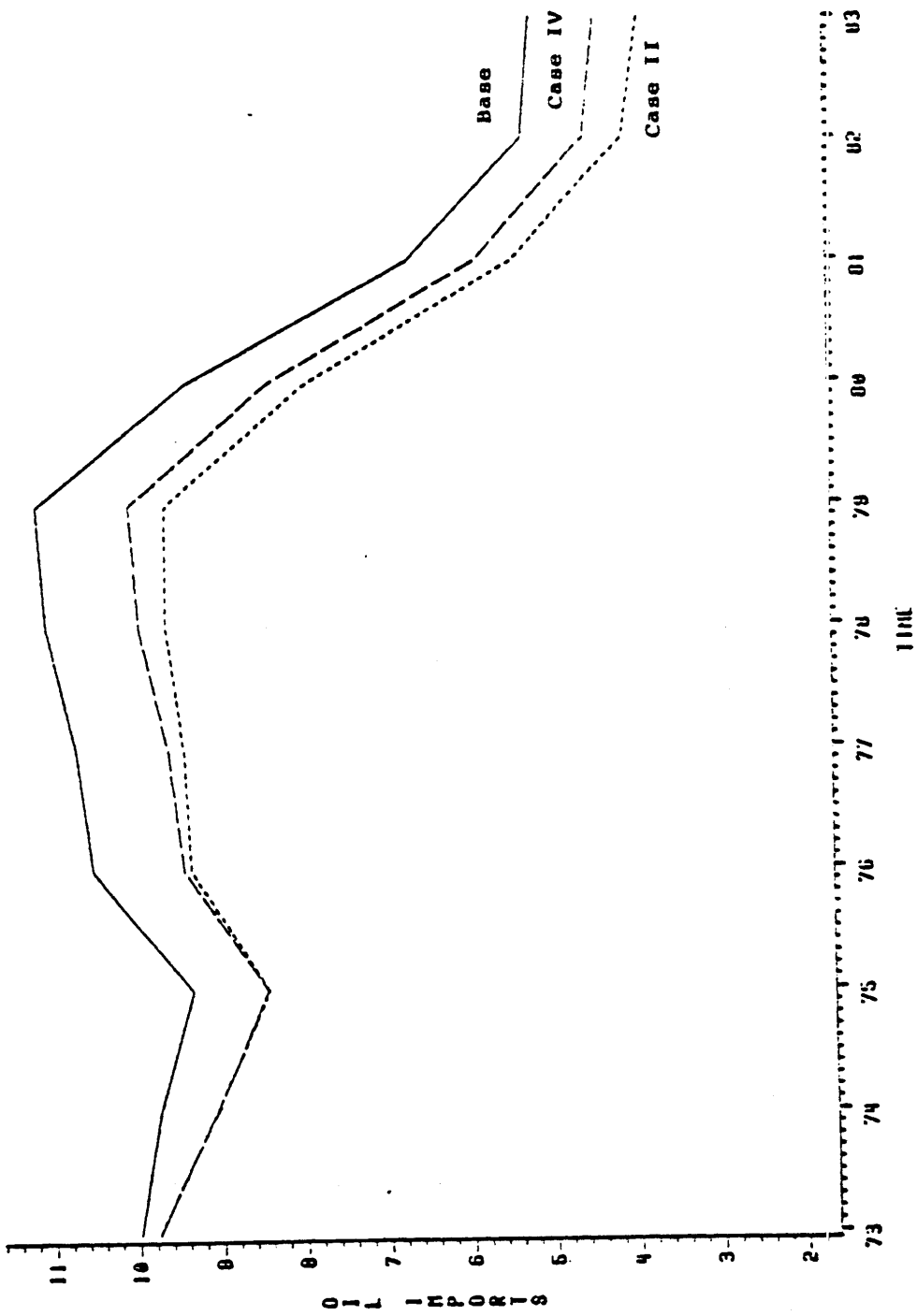
80
81
82
83
TIME

Figure 23


OIL IMPORTS OF DC'S
MILL. OF BARRELS PER YEAR
Base
Case IV
Case II
OIL IMPORTS
11
10
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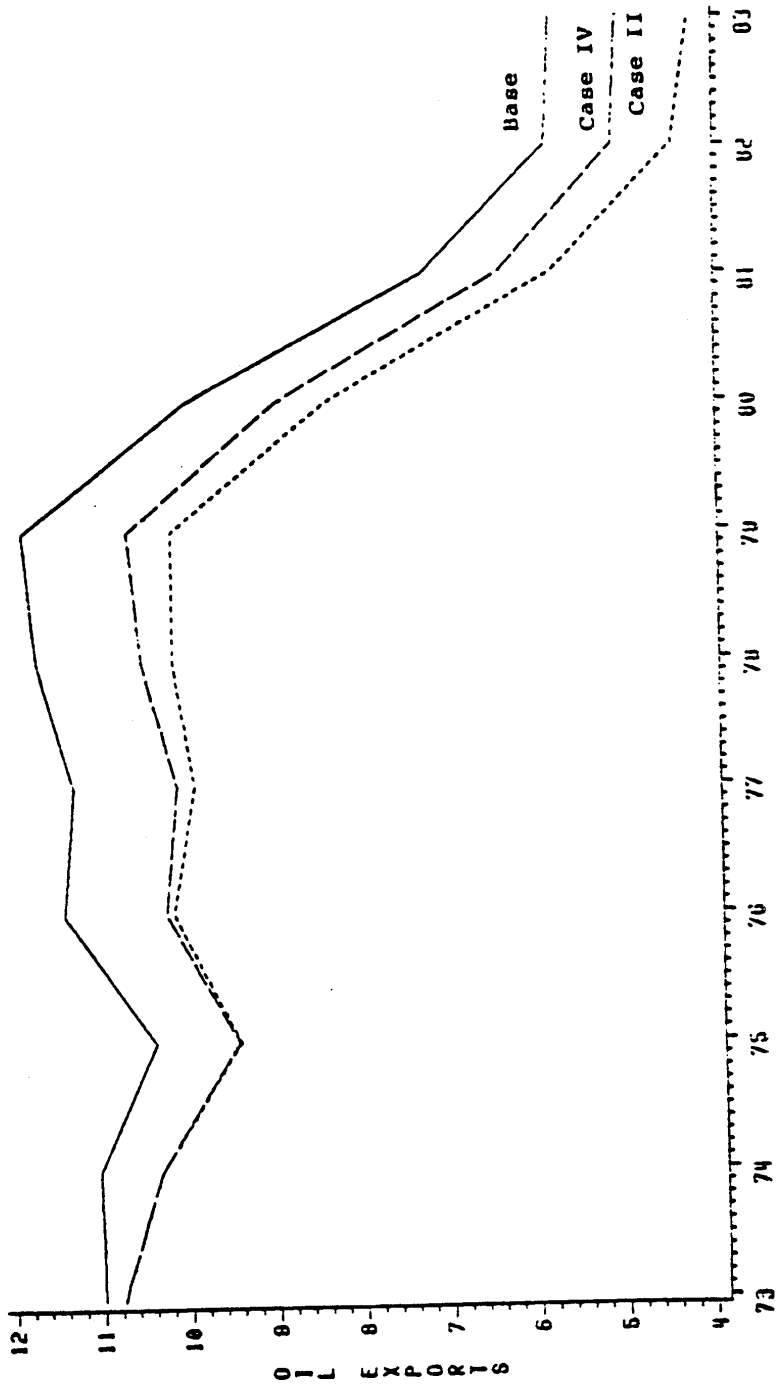
81
82
83
TIME

Figure 24


OIL EXPORTS OF OPEC
BILL. OF BARRELS PER YEAR
OIL EXPORTS
12
11
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77
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TIME
Base
Case IV
Case II

Figure 25

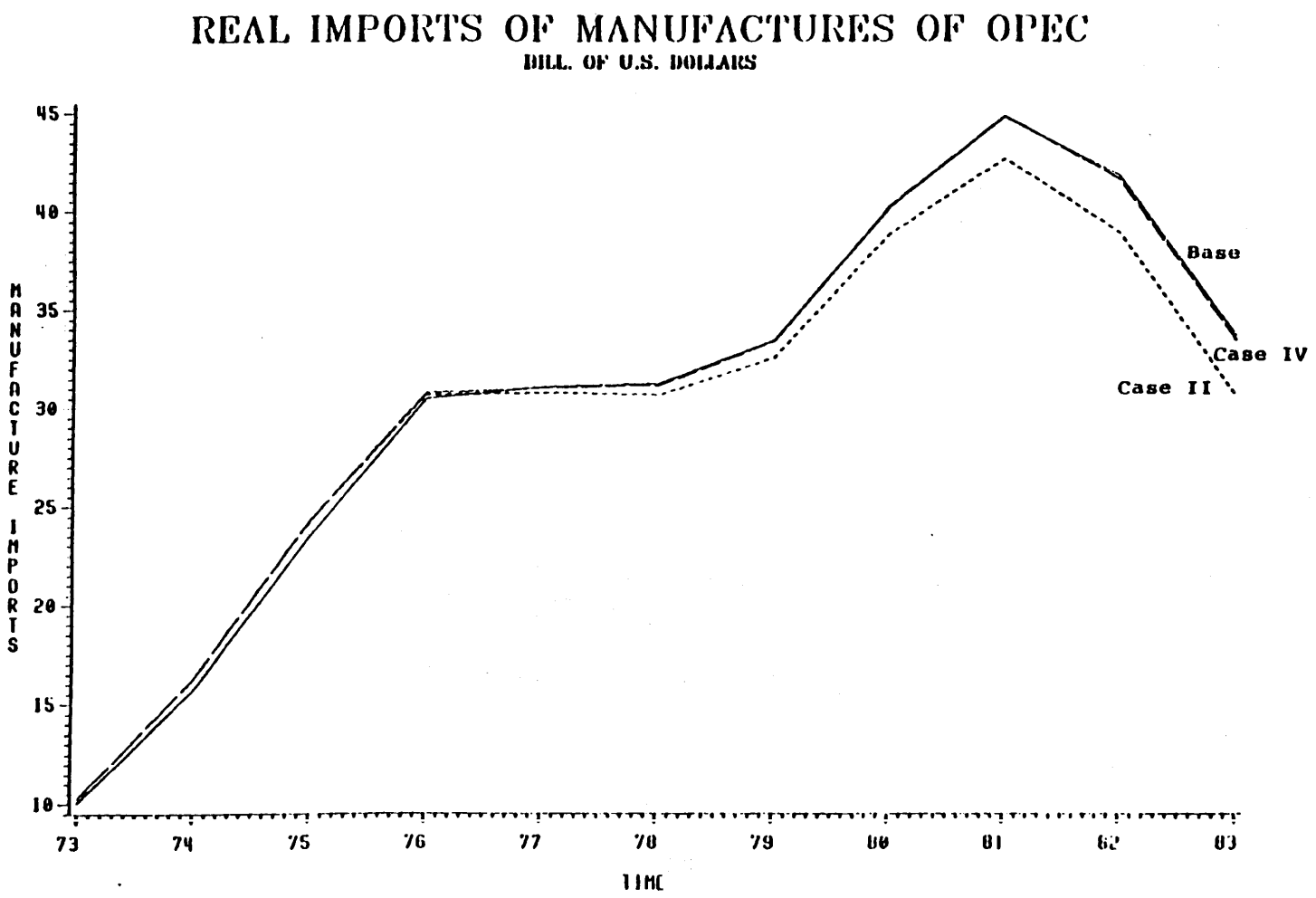
REAL IMPORTS OF MANUFACTURES OF OPEC
BILL. OF U.S. DOLLARS
MANUFACTURE IMPORTS
45
40
35
30
25
20
15
10
73
74
75
76
77
78
79
80
81
82
83
TIME
Base
Case IV
Case II

Figure 21). This is because, the increase in capital transfers enlarges foreign exchange reserves enabling a 16 percent average increase in the amourts of capital goods imports, which increases capital formation and, therefore, output growth.

Increases in real income of LDC's, together with their positive impact on DC's real income, stimulate oil demand and OPEC's oil exports. This increase in OPEC's oil exports represents a rightward shift of their export demand schedule which reduces (in absolute value) the total oil price elasticity from 2.7 for Case II to 1.3 for this case. Nevertheless, OPEC's exports are below the baseline solution by an annual average of 10 percent with a total price elasticity greater than one which implies that increases in oil prices will result in losses of oil export revenues.

VI. CONCLUSIONS

In this paper we have developed a three-region world model to study the channels through which oil price changes are internationally transmitted. The direct channel of transmission is the transfer of real income from oil importers to OPEC. This direct, and adverse, effect of oil price increases may be offset by the indirect effects, which arise only in a multicountry setting. These indirect effects operate through both OPEC's recycling and markups in oil prices. The relative importance of these international transmission channels depends on the values of certain key parameters such as:

-- the (ceteris paribus) import price elasticities of DC's and LDC's, ε_o^d and ε_o^ℓ,

-- the absorption capacity of OPEC, β;

-- the markup coefficient of manufactures prices on the price of

oil, π_o;

-- the response of fiscal policy to the increase in the price of oil; and

-- the volume of international trade.

We estimate the theoretical model using data for 1960-1979. We find that a 10 percent increase in the price of oil reduces real income of developed economies by 0.5 percent in the first year, by 1 percent for the second year, and by 2.9 percent after eleven years. Real income of developing economies is also adversely affected by an increase in oil prices.

Counterinflationary policies are effective in reducing the price level after being imposed for as long as seven years. These policies, however, reduce real income of both developed and less developed economies below the already reduced income levels arising from higher oil prices.

Although a 33 percent increase in OPEC's absorption capacity does not completely offset the recessionary effects of higher oil prices and of counterinflationary policies, there is an improvement in real income of developed and developing countries over the results of Case II.

Higher capital transfers from OPEC to Non-OPEC developing countries raises real income for the latter group of countries above the values for the base solution; real income of developed economies is above the values taken in Case II, but still below the values for the base solution.

Our empirical analysis provides valuable insights into the quantitative dimensions of the feedback effects that oil prices have on the oil demand that OPEC faces. Using the notion of total price elasticity, which accounts for the direct effects of oil price increases on oil demand, and the feedback effects that occur through the international transmission

channels, we find that the long run total price elasticity for OPEC's oil demand may be -in absolute terms- as low as 0.2 or as high as 2.8 depending on whether one allows for counterinflationary policies. The fact that the price elasticity may increase as a result of policy responses to changes in oil rices is crucially important for OPEC pricing strategies. An oil price path that does not allow for such policy responses may lead to a significant loss in revenues, contrary to what may be expected by OPEC.

Endnotes

* This paper is based on my dissertation at the University of Pennsylvania. I am grateful to F. Gerard Adams, Lawrence Klein, Peter Pauly, Wilfred Ethier, Lance Taylor, Albert Ando, Kenneth Rogoff, and Thomas Glaessner for their comments and criticisms. Any remaining errors are my own. This paper represents the views of the author and should not be interpreted as reflecting the views of the Board of Governors of The Federal Reserve System or other members of its staff.

1 Schmid (1976), Findlay and Rodriguez (1977), Bruno and Sachs (1979), and Solow (1980). An important exception is Taylor (1981). I am became aware of Taylor's paper after completing this research; I am grateful to Lance Taylor for pointing this paper to me.

2 One important assumption here is the exogeneity of oil prices since it implies that oil importers are small economies. Marquez (1983) relaxes the small country assumption and applies (closed loop) optimal control to the model developed in this paper to determine optimal oil prices.

3 Equation (5) postulates a strictly proportional relation between commodity prices and the price of manufactures. Adams (1979) has shown that the inclusion of a constant intercept is relevant for taking capacity constraints into consideration. However, the inclusion of a constant term does not affect our results here because in the process of differentiation the constant term drops out.

4 The assumption of fixed labor may be justified since what is relevant for production decisions is not just the number of man-hours, but the number of effective man-hours which captures education and experience of the labor force. However, education is a process that takes place only gradually and for our purposes it can be left out.

5 For earlier analyses, see Chenery and Strout (1966), McKinnon (1964); for a more recent analysis, see Taylor (1979).

6 We also studied the case where only a fraction γ of foreign exchange resources is used to finance manufacture imports. The analytical solutions, equations (23) and (24), represent the limiting cases of the general solutions as $\gamma \to 1$. We choose to use $\gamma=1$ so as to give the LDC's all the leverage possible to finance their growth.

7 In principle, <u>if</u> prices were perfectly flexible, then it might not be necessary to alter economic policies in response to a change in the price of oil. Other prices would decrease leaving the overall inflation rate unchanged. However, there is substantial statistical and theoretical evidence pointing to a positive relationship between relative price changes (a change in oil prices) and the overall inflation rate (Fischer 1981, Cukierman 1982, and Marquez and Vining 1984).

8 A more general formulation would be:

$$dE^d/dP_o = \alpha(dE^d/dP_m)(dP_m/dP_o) + (1-\alpha)(dE^d/dY^d)(dY^d/dP_o),$$

i.e., government policies respond to inflation and to recession (see Marquez 1983).

9 These conclusions also extend to the dynamic case where oil is considered as a non-renewable resource (see Marquez 1983).

10 This suggests that the price elasticity relevant for OPEC's pricing strategies is no longer a constant parameter but rather is an endogenous variable as pointed out by Stiglitz (1976); see also Marquez (1983).

11 The model is stable if a sustained change in one of the exogenous variables induces a change in the endogenous variables such that this change does not explode as time passes (Klein 1983).

12 For the period 1973-1979 we use actual values of the exogenous variables, but for the period 1980-1983 we employ the assumptions used in the LINK meetings of September 1982 and March 1983.

13 Sachs (1982), Blinder (1979), Lehment (1982), Shigera (1982), Vangrevelinger (1982).

14 We notice that the reduction in exports of raw materials is of smaller magnitude than the reduction in exports of manufactures. This result can be explained in terms of the differences in income elasticities for these two types of exports. As we recall, exports of manufactures are income elastic whereas exports of raw materials are income elastic, which then implies that exports of manufactures will fall more than raw materials exports after a decline in DC's real income.

15 This can be readily seen by the increase in the real income multipliers from -7 percent in 1983, for Case II, to -0.8 percent for Case III.

REFERENCES

Adams, F. G. (1979). "Must High Commodity Prices Depress The World Economy? An Application of a World Model System." Journal of Policy Modeling. Vol. 1, No.2: 201-215.

Adams, F.G., and J.R. Marquez (1983). "A Global Model of Oil Price Impacts." In F.G. Adams and B. Hickman (eds.) Global Econometrics: Essays in Honor of Lawrence R. Klein. Cambridge: MIT Press.

Blinder, A. (1979). Economic Policy and the Great Stagflation. New York: Academic Press.

Bruno, M., and J. Sachs (1979). "Macroeconomic Adjustments with Import Price Shocks: Real and Monetary Aspects." The Maurice Falk Institute for Research in Economics. Discussion Paper 793, Jerusalem, Israel.

Chenery, H. and A. Strout (1966). "Foreign Assistance and Economic Development." American Economic Review. Vol. 56, No.4: 679-733.

Coen, R. (1971). "The Effect of Cash Flow in the Speed of Adjustment." In G. Eromm (ed.) Tax Incentives and Capital Spending. Washington, D.C.: Brookings Insitution

Cukierman, A. (1982). "Relative price Variability and Inflation. A Survey and Further Results." Paper prepared for the November 1982 Carnegie-Rochester Conference on Public Policy.

Daly, G., J. Griffin, and H. Stele (1983). "The Future of OPEC: Price Level and Cartel Stability." The Energy Journal Vol. 4, No. 1: 65-78.

Fair, Ray (1982). "Estimated Output, Price, Interest Rate, and Exchange Rate Linkage Among Countries." Journal of Political Economy Vol. 90, No. 3: 507-535.

Findlay, R., and C. A. Rodriguez (1977). "Intermediate Imports and Macroeconomic Policy under Flexible Exchange Rates." Canadian Journal of Economics. Vol. 10, No.2: 208-217.

Fischer, S. (1981). "Relative Shocks, Relative Price Variability, and Inflation." Brookings Papers on Economic Activity. No. 2: 381-441.

Hooper, P. and R. Tryon (1982). "Macroeconomic and Exchange Rate Effects of an Oil Price Shock Under Alternative OPEC Investment Scenarios." In K. Clinton (ed.) Proceedings of the Fifth Pacific Basin Central Bank Economist's Conference: Supply Side Shocks, the Balance of Payments, and Monetary Policy (Bank of Ottawa).

Klein, L. (1983). Lectures in Econometrics, Amsterdam: North Holland.

Lehment, H. (1982). "Economic Policy Response to the Oil Price Shocks of 1974 and 1979." European Economic Review Vol. 18, Nos. 1/2: 235-242.

MacAvoy, P. (1982). Crude Oil Prices as Determined by OPEC and Market Fundamentals. Cambridge: Ballinger Publishing Co.

Mariano, R. (1978). "Commodity Market Modeling: Methodological Issues and Control Theory Applications." In F. G. Adams and J. Behrman (eds.) Econometric Modeling of World Commodity Policy. Lexington: Lexington Books.

Marquez, J. (1982). "Foreign Exchange Constraints, Investment Demand, and Imports of Manufactures in LDCs." Center for Analysis of Developing Economies, Discussion Paper 82-47, Philadelphia: University of Pennsylvania.

Marquez, J. (1983). "The International Transmission of Oil Price Effects and the Derivation of Optimal Oil Prices." Ph.D. dissertation, University of Pennsylvania, Philadelphia.

Marquez, J. and D. Vining (1984). "Inflation and Relative Price Behavior: A Survey of the Literature" in M. Ballabon Economic Perspectives Vol. 3: 1-56. Hardwood Academic Publishers, New York (forthcoming).

McKinnon, R. (1964). "Foreign Exchange Constraints in Economic Development and Efficient Aid Allocation." Economic Journal. Vol. 74, No.294: 387-409.

Metzler, L. (1950). "A Multiple-Region Theory of Income and Trade." Econometrica. Vol. 18, No.4: 329-354.

Sachs, J. (1982). "The Oil Shocks and Macroeconomic Adjustment in the United States." European Economic Review Vol. 18, Nos. 1/2: 243-248.

Samuelson, P. (1947). Foundations of Economic Analysis. Cambridge: Harvard University Press.

Schmid, M. (1976). "A Model of Trade in Money, Goods, and Factors." Journal of International Economics. Vol. 6, No.4: 347-362.

Shigehara, K. (1982). "Absorption of the Two Oil Shocks. The Japanese Case." European Economic Review Vol. 18, Nos. 1/2: 249-261.

Solow, R. (1980). "What to Do (Macroeconomically) When OPEC Comes?" In S. Fischer (ed.) Rational Expectations and Economic Policy. Chicago: National Bureau of Economic Reserach.

Solow, R. (1974). "The Economics of Resources or the Resources of Economics." American Economic Review. Vol. 54, No. 2: 1-14.

Stiglitz, J. (1976). "Monopoly and the Rate of Extraction of Exhaustible Resources." American Economic Review. Vol. 66, No. 4: 655-661.

Taylor, L. (1979). Macro Models for Developing Countries. New York: McGraw-Hill.

Taylor, L. (1981). "South-North Trade and Southern Growth: Bleak Prospects from the Stucturalist Point of View." Journal of International Economics Vol. 11: 589-602.

Vangrevlinghe, G. (1982). "Absorption of the Two Oil Shocks. The French Case." European Economic Review Vol. 18, Nos. 1/2: 263-266.

APPENDIX A

GLOBAL ECONOMETRIC MODEL

I. Developed Economies

Consumption Function.

$$C^d_t = \underset{(0.222)}{10.185} + \underset{(6.19)}{0.4681}(P^d_{yt} Y^d_t / P^d_{con,t}) + \underset{(1.85)}{0.2376} C^d_{t-1}$$

$\bar{R}^2 = 0.98$ D.W. = 1.6

S.S.E. = 10.3 Rho = 0.69 h=0.97

Period of estimation: 1960-1977

Private Gross Investment

$$I^d = \underset{(0.094)}{4.31703} + \underset{(2.768)}{0.25636} \sum_{i=0}^{2} \omega_i Y^d_{t-i} - \underset{(-3.697)}{13.1547} r^d_{t-1}$$

$\bar{R}^2 = 0.875$ D.W. = 0.952

S.S.E. = 17.529 Rho = 0.399847

$\omega_0 = 0.5$ $\omega_1 = 0.3$ $\omega_2 = 0.2$

Period of estimation: 1960-1979

Imports of Raw Materials

$$\ln M_r^d = \left(\sum_{i=0}^{3} \phi_i \ln (P_r/P_m^a)_{t-i} \right) \underset{(9.41)}{+ 0.6306 \ln (Y^a)} \underset{(-0.24)}{- 0.078}$$

$\bar{R}^2 = 0.923$ D.W. = 2.35 S.S.E. = 0.00168

$\phi_0 = -0.1384$ (-3.08) $\quad \phi_2 = -0.2076$ (-2.24)

$\phi_1 = -0.2076$ (-3.62) $\quad \phi_3 = -0.1384$ (-0.24)

$$M_r^d = \exp(\ln M_r^d)$$

Demand for Oil

$$\ln O^{d,d} = \omega_\ell^\nu \sum_{i=0}^{3} \gamma_i \ln (P_\ell^a)_{t-i} + \omega_c^\nu \sum_{i=0}^{3} \gamma_i \ln (P_c^a)_{t-i} +$$

$$\omega_k^\nu \sum_{i=0}^{3} \gamma_i \ln (P_k^a)_{t-i} + \omega_o^\nu \sum_{i=0}^{3} \gamma_i \ln (P_o)_{t-i}$$

$$\mu_y^\nu \sum_{i=0}^{3} \phi_i \ln GY^d + A^\nu$$

$\bar{R}^2 = 0.99$ D.W. 2.93 S.S.E. 0.000137

$\gamma_0 = 0.2$ $\gamma_1 = 0.5$ $\gamma_2 = 0.2$ $\gamma_3 = 0.1$

$\phi_0 = 0.5$ $\phi_1 = 0.2$ $\phi_2 = 0.175$ $\phi_3 = 0.125$

$$A^1 = \underset{(-0.358)}{-0.871} \qquad \omega_o^1 = \underset{(-1.6)}{-0.272} \qquad \omega_c^1 = \underset{(1.60)}{0.292}$$

$$\omega_\ell^1 = \underset{(-0.53)}{-0.3069} \qquad \omega_k^1 = \underset{(0.732)}{0.2872} \qquad \mu_y^1 = \underset{(3.23)}{1.704}$$

$$A^2 = \underset{(0.30)}{0.8779} \qquad \omega_o^2 = \underset{(-3.5)}{-0.57} \qquad \omega_c^2 = \underset{(4.11)}{0.908}$$

$$\omega_\ell^2 = \underset{(-0.694)}{-0.2382} \qquad \omega_k^2 = \underset{(-0.64)}{-0.0995} \qquad \mu_y^2 = \underset{(2.165)}{1.335}$$

$\nu = 1$ if $t < 1972$, $\nu = 2$ if $t > 1972$.

Period of estimation: 1960-1979.

$$<O^{d,a} = \exp(\ln O^{a,a}).$$

Total Imports of Oil, Barrels

$$\tilde{M}_o^d = (O^{d,d} - O^{s,a})/1000$$

Imports of Oil from OPEC, Barrels

$$\tilde{M}_o^a = \tilde{M}_o^d - \tilde{X}_o^\ell$$

Imports of Oil from OPEC, Real Terms

$$M_o^d = \underset{(61.9)}{1.715}\ \tilde{M}_o^d$$

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

Imports of Oil from Non-OPEC, Barrels

$$\ln \tilde{X}_o^\ell = \underset{(-2.7)}{-18.076} + \underset{(1.036)}{0.5084} \sum_{i=0}^{1} w_i \ln (P_k^d/P_o)_{t-i}$$

$$+ \underset{(1.983)}{1.8649} \sum_{i=0}^{1} w_i \ln(P_c^d/P_o)_{t-i} + \underset{(-2.1)}{2.2232} \sum_{i=0}^{1} w_i \ln(P_\ell^d/P_o)_{t-i}$$

$$\underset{(2.64)}{1.542}\ \ln GY_t^d + \underset{(2.65)}{0.7712}\ \ln GY_{t-1}^d$$

$$w_0 = 0.6 \quad w_1 = 0.4$$

$$\bar{R}^2 = 0.824 \quad D.W. = 3.03 \quad S.S.E. = 0.199$$

$$\tilde{X}_o^\ell = \exp(\ln \tilde{X}_o^\ell)$$

Imports of Oil from Non-OPEC, Real Terms

$$X_o^\ell = \underset{(49.63)}{1.680}\ \tilde{X}_o^\ell$$

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

Export Price of Manufactures

$$P^{d}_{mt} = P^{a}_{m,t-1} \ (1 + \Delta\% \ P^{d}_{mt})$$

Potential Output

$$\ln GY^{*d} = \underset{(54.79)}{(4.34508} + \underset{(39.327)}{0.047173} \ T) \ D +$$

$$\underset{(23.986)}{(5.576778} + \underset{(9.784)}{.0299922} \ T)(1 - D)$$

$$D = \begin{cases} 1 \text{ if } T \leq 1972 \\ 0 \text{ if } T > 1972 \end{cases}$$

$\bar{R}^2 = 0.99$, D.W. = 1.357, S.S.E. = 0.0002618

Period of estimation: 1960-1979

$$GY^{*d} = \exp(\ln GY^{*d})$$

Excess Capacity

$$U = \frac{GY^{*d} - GY^{d}}{GY^{*d}}$$

Consumption Price Deflator

$$\ln P^{d}_{con,t} = \underset{(11.4)}{1.596} + \underset{(4.98)}{0.1008}(0.75 \ln P_{ot} + 0.25 \ln P_{o,t-1}) + \underset{(11.72)}{0.557} \ln P^{d}_{\ell t}$$

$\bar{R}^2 = 0.99$ D.W. = 2.27

S.S.E. = 0.0242 Rho = 0.217

Period of estimation: 1960-1977

$$P_{con,t} = \exp(\ln P_{con,t})$$

Value Added Price Deflator

$$\ln P^{d}_{yt} = \underset{(-2.2)}{-0.662} + \underset{(23.69)}{1.0005} \ln P^{d}_{cont} + \underset{(4.62)}{0.1853} \ln P^{d}_{mt} - 0.05 \ln P_{ot}$$

$\bar{R}^2 = 0.99$ D.W. = 2.028 S.S.E. = 0.000043

Period of estimation: 1960-1977

$$P^{d}_{yt} = \exp(\ln P^{d}_{yt})$$

Total Exports

$$X^{a} = M^{\ell}_{m} + M^{o}_{m} + X^{a}_{exo}.$$

Total Imports

$$M^d = M_o^d + X_o^\ell + X_m^\ell + M_r^d + M_{exo}^d$$

Inflation Rate of Manufactured Goods

$$\Delta\% P_{mt}^d = \underset{(0.3)}{0.9741} + \underset{(1.5)}{0.0904}\ \Delta\% P_{o,t-1}$$

$$+ \underset{(0.85)}{0.327}\ \Delta\% P_{\ell t}^d + \underset{(3.02)}{0.349}\ \Delta\% P_{rt} - \underset{(-0.2)}{0.162}\ U_{t-1}$$

$\bar{R}^2 = 0.47$ D.W. = 1.095 S.S.E. = 4.66

Period of estimation: 1960-1979

Value Added

$$Y^d = C^d + I^d + G^d + X^d - M^d$$

Growth Rate of Domestic Product

$$\Delta\% Y^d = (\ln (Y^d) - \ln (Y^d)_{t-1})\ 100$$

Gross Domestic Product

$$GY^d = Y^d + M_o^d + X_o^\ell$$

II. OPEC

Imports of Manufactures

$$\ln M_m^o = \sum_{i=0}^{3} \psi_i \ln \left(\frac{P_o}{P_m^a}\right)\left(M_o^a + M_o^\ell\right)_{t-i} \underset{(29.7)}{-\ 2.986}$$

$\psi_0 = 0.3058$ (8.91) $\quad \psi_2 = 0.2732$ (10.42)

$\psi_1 = 0.3613$ (11.63) $\quad \psi_3 = 0.0416$ (1.07)

$\bar{R}^2 = 0.998$ D.W. = 2.467 S.S.E. = 0.00108

Period of estimation: 1965-1977

$$M_m^o = \exp(\ln M_m^o)$$

Total Imports of OPEC, Real Terms

$$M^o = M_m^o + M_{exo}^o.$$

Total Exports of Oil, Barrels

$$\tilde{X}^o = \tilde{M}_o^a + \tilde{M}_o^\ell$$

Total Exports of Oil Real Terms

$$X^o = M_o^a + M_o^\ell + X_{exo}^o$$

III. LESS DEVELOPED ECONOMIES

Gross Output

$$\ln GY^{\ell} = \underset{(-1.026)}{-0.829817} + \underset{(8.9637)}{1.00092} \ln Z^{\ell}$$

$\bar{R}^2 = 0.8545$ D.W. = 0.8343

S.S.E. = 0.0129048 Rho = 0.882091

$$Z^{\ell} = [(1-\phi)(K^{\ell})^{-\rho} + \phi(O^{d,\ell})^{-\rho}]^{-1/\rho}$$

$\phi = 0.01$ $\rho = 0.360434$

$$GY^{\ell} = \exp(\ln GY^{\ell})$$

Demand for Oil, Barrels

$$\ln O^{d,\ell} = \underset{(-0.869)}{(-0.140789} + \underset{(1.5472)}{0.10951} [\ln (GY^{\ell}) + \log(\phi^{1/\rho}(1 + (\frac{1-\phi}{\phi})^{\sigma} (P_O/P_K^{\ell})^{\sigma-1})^{1/\rho})]$$

$$+ \underset{(17.48)}{0.954486} \log(O^{d,\ell})_{t-1})$$

$\bar{R}^2 = 0.956$ D.W. = 2.389 S.S.E. = 0.0658495

$\rho = 0.3604$ $\phi = 0.01$ $\sigma = 0.7351$

$$O^{d,\ell} = \exp(\ln O^{d,\ell})$$

Rental Price of Capital

$$P_K^{\ell} = P_{m,t-1}^{d} \left(3 + 3.3 \left(\frac{P_m^{d}}{P_{m,t-1}^{d}}\right)\right)$$

Imports of Oil from OPEC, Barrels

$$\tilde{M}_O^{\ell} = O^{d,\ell} + \tilde{X}_O^{\ell} - O^{s,\ell}$$

Imports of Oil from OPEC, Real Terms

$$M_O^{\ell} = \underset{(53.6)}{1.6979}\ \tilde{M}_O^{\ell}$$

$\bar{R}^2 = 0.99$ Period of Estimation: 1960-1977

Gross Investment Demand

$$I^{\ell} = \underset{(-1.8897)}{-6.19586} + \underset{(0.3040)}{0.0673201} \sum_{i=0}^{3} \omega_i \, \Delta GY_{t-i}^{\ell}$$

$$+ \underset{(3.16)}{1.01661} \sum_{i=1}^{2} \phi_i \, (R^{\ell}/P_m^{d})_{t-i}$$

$\bar{R}^2 = 0.99$ D.W. = 2.11 S.S.E. = 2.639

$\omega_0 = 0.5$ $\omega_1 = 0.3$ $\omega_2 = 0.2$ $\phi_1 = 0.3$ $\phi_2 = 0.7$

$\delta = 0.033$

$$\Delta GY_t^{\ell} = GY_t^{\ell} - (1-\delta)\, GY_{t-1}^{\ell}$$

Net Investment

$$I^{\ell}_{n,t} = I^{\ell}_{t} - \delta K^{\ell}_{t-1}$$

$\delta = 0.033$

Capital Stock

$$K^{\ell}_{t} = I^{\ell} + (1-\delta)K^{\ell}_{t-1}$$

$\delta = 0.033$

Imports of Manufactures

$$M^{\ell}_{m} = \underset{(-1.96)}{-2.25458} + \underset{(3.67)}{0.536848} \sum_{i=1}^{2} \omega_i \, (R^{\ell}/P^{d}_{m})_{t-i} + \sum_{i=0}^{2} \phi_i \, GY^{\ell}$$

$$\bar{R}^2 = 0.987 \quad D.W. = 2.444 \quad S.S.E. = 1.0163$$

$$\phi_0 = \underset{(7.192)}{0.02052} \quad \phi_1 = \underset{(7.192)}{0.02737} \quad \phi_2 = \underset{(7.192)}{0.02052};$$

$$\phi_0 + \phi_1 + \phi_2 = 0.068414$$

$$\omega_1 = 0.3 \quad \omega_2 = 0.7$$

Value Added

$$Y^{\ell} = GY^{\ell} - M^{\ell}_{o}$$

Growth Rate of Value Added

$$\Delta\% \; Y^{\ell} = (\ln Y^{\ell}_{t} - \ln Y^{\ell}_{t-1}) * 100$$

Exports of Manufactures to Developed Economies

$$\ln X^{\ell}_{m} = \underset{(-20.82)}{-18.2776} + \underset{(23.47)}{2.6796} \ln Y^{d} + \underset{(2.45)}{0.6966} \ln (P^{d}_{m}/P^{\ell}_{m})$$

$$\bar{R}^2 = 0.984 \quad D.W. = 1.28 \quad S.S.E. = 0.005$$

Period of Estimation: 1960-1977

$$X^{\ell}_{m} = \exp(\ln X^{\ell}_{m})$$

Total Exports of Developing Economies

$$X^{\ell} = M^{d}_{r} + X^{\ell}_{m} + X^{\ell}_{exo.} + X^{\ell}_{o}$$

Total Imports of Developing Economies

$$M^{\ell} = X^{d} + X^{o} + X^{\ell} - M^{o} - M^{a}$$

Foreign Exchange Reserves, Nominal Terms

$$R^{\ell} = R^{\ell}_{t-1} + \$X^{\ell} - \$M^{\ell} + CF_{t}$$

Total Exports of Developing Economies, Nominal Terms

$$\$X^{\ell} = P_m^{\ell} X_m^{\ell} + P_r M_r^{d} + \$X_{exo.} + P_o X_o^{\ell}$$

Total Imports of Developing Economies, Nominal Terms

$$\$M^{\ell} = P_m^{d} M_m^{\ell} + P_o M_o^{\ell} + \$M_{exo.}$$

NOTATION

Endogenous Variables

C^d: Consumption expenditure of DC's; billions of $US; 1970 prices and exchange rates.

I^d: Gross domestic private investment of DC's; billions of $US; 1970 prices and exchange rates.

Y^d: Value added of DC's; billions of $US; 1970 prices and exchange rates.

GY^d: Gross output, defined of value added (Y^d) plus total oil imports.

P^d_{yt}: Value Added Price Deflator.

P^d_{cont}: Consumption Price Deflator.

M^d_r: Imports of intermediate products other than oil (SITC # 0-1 + SITC # 2 + SITC # 4).

P^d_m: Export price index of manufactures of DC's; 1970 = 100.

$O^{d,d}$: Demand for oil of DC's; millions of barrels/year

X^l_o: Exports of oil of LDC's to DC's in 1970 prices; billions of $US (SITC # 3).

$\tilde{M}^d_o$: Imports of oil of DC's from OPEC; billions of barrels/year.

U: excess capacity in DC's, percentage

$\tilde{\tilde{M}}^d_o$: Imports of oil of DC's; billions of barrels/year.

$\tilde{X}^l_o$: Exports of oil of LDC's to DC's; billions of

barrels/year.

GY^{*d}: Potential output of DC's; billions of $US, 1970 prices and exchange rates.

X^d: Total exports of DC's; billions of $US, 1970 prices.

M_m^ℓ: Imports of manufactures of LDC's from DC's; billions of $US, 1970 prices (SITC # 5-9).

M^d: Total imports of DC's; billions of $US, 1970 prices.

X_m^ℓ: Exports of manufactures of LDC's to DC's; billions of $US, 1970 prices (SITC # 5-9).

M_o^ℓ: Imports of oil by LDC's from OPEC; billions of $US, 1970 prices (SITC # 3).

M^o: Total imports of OPEC; billions of $US, 1970 prices.

X^o: OPEC's total exports; billions of $US, 1970 prices.

$O^{d,\ell}$: Demand for oil of LDC's; billions of barrels/year.

GY^ℓ: LDC's gross domestic output, billions of $US, 1970 prices and exchange rates = value added plus oil imports.

P_K^ℓ: Rental price of capital, LDC's, 1970 = 100.

Y^ℓ: value added of LDC's; billions of $US, 1970 prices and exchange rates.

$\tilde{M}_o^{\ell}$: Oil imports of LDC's from OPEC; billions of barrels/year.

I^{ℓ}: Gross investment of LDC's; billions of $US, 1970 prices and exchange rates.

I_n^{ℓ}: Net investment of LDC's; billions of $US, 1970 prices and exchange rates.

K^{ℓ}: Capital stock of LDC's; billions of $US, 1970 prices and exchange rates.

$\$X^{\ell}$: Total value of exports of LDC's; billions of $US, current value.

R^{ℓ}: Foreign exchange reserves of LDC's; billions of $US, current value.

X^{ℓ}: Total exports of LDC's; billions of $US, 1970 prices.

M^{ℓ}: Total imports of LDC's; billions of $US, 1970 prices.

$\$M^{\ell}$: Total imports of LDC's; billions of $US, current value.

$\tilde{X}^{o}$: Total exports of oil by OPEC; billions of barrels/year.

M_o^d: Imports of oil of DC's from OPEC; in 1970 prices; billions of $US (SITC # 3).

M_m^o: Imports of manufactures of OPEC from DC's; 1970 prices; billions of $US (SITC#5-9).

Exogenous Variables

P_k^d: Index of rental price of capital of DC's; 1970 = 100

r^d: Nominal long term interest rate percent per year of DC's.

P_r: Import price index of intermediate products; 1970 = 100.

P_ℓ^d: Price index of labor of DC's; 1970 = 100.

P_o: Price index of oil; 1970 = 100.

P_q^d: Price index of new capital goods of DC's; 1970 = 100.

$O^{s,a}$: Domestic supply of oil, DC's; millions of barrels/year.

X_{exo}^d: Remaining exports of DC's not explained in the model; billions of $US, 1970 prices.

M_{exo}^d: Imports of DC's not explained by the model.

G^d: Government expenditure of DC's; billions of $US, 1970 prices and exchange rates.

M_{exo}^o: OPEC's imports not explained in the model; billions of $US, 1970 prices.

X_{exo}^o: OPEC's exports not explained by the model.

$O^{s,\ell}$: Domestic oil supply of LDC's; billions of barrels/year.

P_m^ℓ: LDC's export price index of manufactures; 1970 = 100.

X^{ℓ}_{exo}: Exports of LDC's not explained by the model; billions of $US, 1970 prices.

CF: Net capital flows to LDC's; billions of $US, current value.

$\$X_{exo}$: LDC's exports not explained by the model; billions of $US, current value.

$\$M_{exo}$: LDC's imports not explained by the model; billions of $US, current value.

P^{d}_{c}: Price index of coal of DC's; 1970 = 100.