International Finance Discussion Papers

Number 247

December 1984

COOPERATIVE POLICIES AMONG THE NORTH, THE SOUTH, AND OPEC: AN OPTIMAL CONTROL APPROACH

by

Jaime Marquez
Peter Pauly

Cooperative Policies Among The North, The South, and OPEC:
An Optimal Control Application

Jaime Marquez
International Finance Division
Federal Reserve Board
Washington DC 20551

and

Peter Pauly
Economics Department
University of Pennsylvania
Philadelphia PA 19104

December 1984

While the benefits of a global policy coordination effort are known in theory, empirical estimates of the gains of such a move are difficult to come by casting doubts on whether global policy coordination will ever occur. In this paper we assess, empirically, the viability of cooperative policies among the North, the South, and OPEC. To this end we apply stochastic optimal control to a nonlinear stochastic dynamic econometric model of a three region world economy that highlights the channels of international transmission of oil price effects and the feedback effects of policy responses to oil price changes. Even if cooperative policies exist, and are implemented, not all the parties involved will benefit to the same extent. Thus we also examine the sensitivity of the distribution of income gains (or losses) between the North, the South, and OPEC to alternative specifications of the welfare function.

An earlier version of this paper was presented at the 5th IAEE Annual North American Meetings, June 1983, and the 4th IFAC/IFOR conference on The Modeling and Control of National Economies, June 1983. We are grateful to F. Gerard Adams, Matt Canzoneri, David Kendrick, Lawrence Klein, Peter Tinsley, Janice Shack-Marquez, Edward Green, Geoffrey Heal, and James Sweeny for their comments. We are also grateful to Gregory Chow for providing the software used in our analysis. Any remaining errors belong entirely to us. This paper represents the views of the authors 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.

I. INTRODUCTION

During the last ten years, we have witnessed a number of events which are bound to have a long lasting impact on the future course of the world economy. Since 1973, oil prices have increased by more than 1000 percent generating a significant income redistribution from oil importers to OPEC. These income transfers, and the associated policy responses, have hampered growth in developed economies from a historical average of 5 percent to an average of 2 percent for the 1974-1980 period. More recently, these countries have experienced negative growth rates. The developing countries, facing a sharp increase in their oil bill and a contraction in their export markets, managed to keep an annual average growth rate of 5 percent until 1980 by borrowing to unprecedented levels. However, the sharp increase in international interest rates slowed growth in these economies to less than one percent for the 1982-83 period. And their growth outlook seems closely linked to their ability to service their external debt, which crucially depends on the levels of international interest rates and thus on stabilization policies beyond their control. Economic performance in OPEC countries has not been as spectacular as previously thought. The worldwide recession and the dynamic effects of higher oil prices have induced a 50 percent decline in oil exports constraining considerably their ability to finance further growth. In view of the long lasting impacts of these turbulent developments, it seems reasonable to ask whether they could be avoided in the future by implementing coordinated policies among the major participating countries.

Although questions of international policy coordination have been receiving an increasing amount of attention in the literature,[1] so far the analyses have focused on policy coordination among the major developed countries. The possibility of policy coordination with other country blocks such as OPEC or the group of developing countries has received considerably less attention.[2] And yet two of the most significant developments of the last decade, the increase in oil prices and the unprecedented level of LDCs' debt, have had a significant impact on developed economies' growth outlook and therefore on the viability of policy coordination agreements among them. Ignoring the role played by OPEC and other developing countries in the world economy may be too great an abstraction to make.

The purpose of this paper is to address the issue of policy coordination among developed countries (the North), OPEC, and other developing countries (the South). We consider specific questions such as:

-- What are the paths for oil prices, government expenditures, interest rates, and resource transfers to LDCs consistent with a non-inflationary recovery of the world economy?

-- What are the optimal stabilization policy responses in industrial economies to changes in oil prices?

-- Can lower oil prices eliminate the need for higher capital transfers to LDCs? Can these capital transfers be avoided by coordinated expansionary fiscal policy in DCs?

-- What is the nature and sensitivity of the distribution of income gains (and losses) among DCs, OPEC, and non-OPEC LDCs to different coordinated policy mixes?

-- How different is the oil price path that maximizes growth for oil exporters from the oil price path that maximizes growth for oil importers?

The analysis begins in section II where we present a three-region econometric world model used to study the effects of exogenous oil price increases on worldwide economic activity and international trade. In section III we use model simulation to estimate the effects that changes in oil prices, and uncoordinated policy responses, have on each region's growth prospects. We find that a sustained increase in the price of oil deteriorates growth prospects for all countries and that this situation is only aggravated if (uncoordinated) restrictive policy responses are put in place. While in principle a worldwide recession, and the bleak prospects for the future, may justify a call for policy coordination on a global scale, empirical estimates of the benefits of such a policy move are hard to come by raising questions about its viability. Thus, in section IV we focus on the possibility of coordinating policies among the North, the South, and OPEC aimed at generating a sustained recovery of the world economy. This question is analyzed empirically by applying stochastic optimal control to the estimated econometric model.

The fact that cooperative policies may exist, and that they might be implemented, does not imply that all the parties involved will benefit to the same extent. As it turns out, the actual distribution of income gains is crucially dependent on the specification of the welfare function. Thus we also examine in section IV the sensitivity of the distribution of income gains (or losses) between DCs, OPEC, and non-OPEC LDCs to alternative specifications of the welfare function.[3] Finally, section V contains our conclusions.

II. A GLOBAL MODEL OF OIL PRICE EFFECTS

The model we use is simple but comprehensive; it is designed to analyze the international transmission of oil price effects, and its theoretical justification can be found in models developed by Taylor (1981) and Marquez (1983). The world economy is divided into three regions: (1) the North, which is represented here by the group of developed countries, DCs,(2) the OPEC countries, and (3) the South, which we characterize as the group of non-OPEC developing countries, LDCs. Economic activities in these different regions are linked to each other through international trade flows and prices.[4] The international trade flows we model are (1) oil, sold by OPEC to both DCs and LDCs; the latter also export oil to DCs; (2) manufactures, exported by the DCs to both OPEC and LDCs; and (3) manufactures and raw materials exported by the LDCs to DCs.

The model contains 37 equations, 15 of which are behavioral relationships. The parameters of the model are econometrically estimated using annual data for 1960-1979, although some of the relationships are estimated using data only up to 1977. The estimation method we use is OLS since the advantage of alternative parameter estimators such as 2SLS, 3SLS, and FIML hold only in large samples. For small samples such as ours, the choice of OLS might be justified (see Malinvaud 1970:569, Mariano 1978, and Judge et. al. 1982:638). We now describe the main behavioral equations which are shown, in general form, in Table 1 (an appendix to this paper, available upon request, contains all the equations of the model as well as a list of indicators of the dynamic simulation performance of the model inside and outside the estimation sample).

Table 1
Main Behavioral Relations in
Global Econometric Model

Developed Economies

$$C^d = C(P_y^d\ Y^d /\ P_{con}^d) \qquad (1)$$

$$I^d = I(Y^d,\ r^d) \qquad (2)$$

$$M_r^d = M(P_r /\ P_m^d\ ,\ Y^d) \qquad (3)$$

$$\Delta\% P_m^d = P(\Delta\% P_r,\ \Delta\% P_\ell,\ \Delta\% P_o,\ U) \qquad (4)$$

$$GY^d = G(L, [K, E(O, C)]) \qquad (5)$$

$$O^d = O(P_o,\ P_c,\ P_\ell,\ P_k,\ GY^d) \qquad (6)$$

$$\tilde{M}_o^d = O^d - O^s \qquad (7)$$

$$M_o^d = \tilde{M}_o^d - \tilde{X}_o^\ell(P_o /\ P_c,\ GY^d) \qquad (8)$$

$$X^d = M_m^\ell + M_m^o \qquad (9)$$

$$M^d = M_r^d + \tilde{M}_o^d + X_m^\ell \qquad (10)$$

$$Y^d = C^d + I^d + G^d + X^d - M^d \qquad (11)$$

OPEC

$$R^o = (P_o(\tilde{M}_o^d + \tilde{M}_o^\ell) /\ P_m^d) \qquad (12)$$

$$M_m^o = M_m^o(R^o) \qquad (13)$$

Non-OPEC Developing Countries

$$GY^\ell = g(K^\ell(K_f^\ell\ ,\ K_d^\ell),\quad O^\ell) \qquad (14)$$

$$I^\ell = I(\Delta(P_k^\ell /\ P_o),\ \Delta GY^\ell;\ R^\ell / P_m^d) \qquad (15)$$

$$M_m^\ell = m(I_n^\ell,\ R^\ell /\ P_m^d) \qquad (16)$$

$$O^\ell = f(\ P_k^\ell / P_o\ ,\ GY^\ell) \qquad (17)$$

$$\tilde{M}_o^\ell = O^\ell - O^{s,\ell} + \tilde{X}_o^\ell \qquad (18)$$

$$X_m^\ell = X(P_m^d /\ P_m^\ell,\ Y^d) \qquad (19)$$

$$R^\ell = P_m^\ell X_m^\ell + P_r M_r^d + P_o \tilde{X}_o^\ell - P_m^d M_m^\ell - P_o \tilde{M}_o^\ell + CF + R_{-1}^\ell \qquad (20)$$

Developed Economies

Private consumption, C^d in equation (1), is modeled following the permanent-income hypothesis. The measure of income we use is nominal value added, $P_y^d Y^d$, deflated by the consumption price index P_{con}^d; the estimate of the short run mpc is 0.47 and the estimated long run income elasticity is one. Investment, I^d in equation (2), is a function of a distributed lag of both real income and long term nominal interest rates[5] r^d; the estimate of the short run mpi is 0.13 and the estimated long run elasticity with respect to income is 1.18; the long run interest rate elasticity is -0.20. Imports of raw materials from LDCs, M_r^d in equation (3), depend on the price of raw materials, P_r, relative to the export price of manufactures of DCs, P_m^d , and on the real income of DCs, Y^d; the long run relative price elasticity is -0.69 and the long run income elasticity is 0.63.

The inflation rate of exports of manufactures, $\Delta\%P_m^d$ in equation (4), is modeled as a markup on factor prices while allowing for supply constraints. The factor prices considered are wages, raw materials, and oil. A one percent increase in the rate of change of nominal wages, $\Delta\%P_\ell$, raises the inflation rate by 0.33 percent, which is quite close to the effect of a one percent increase in the inflation rate of raw materials on $\Delta\%P_m^d$. A one percent increase in the inflation rate of oil prices, $\Delta\%P_o$, raises (with a lag) the inflation rate by 0.10 percent. Finally, capacity utilization U, measured as the difference between potential and actual output, is included as an explanatory variable to capture the effects of supply constraints on the inflation rate. A one percent increase in excess capacity lowers (with a lag) the inflation rate by 0.2 percent.

Potential output, Y^*, is estimated as a trend of actual output. We split the period of estimation into two subperiods--1960-1972 and 1973-1979--to allow for the possibility of structural changes that might have taken place after the first oil shock in 1973. The estimated growth rate for potential output prior to 1973 is 4.7% and 2.9% for the period afterwards. A Chow test for the null hypothesis of structural parameter stability could not be accepted.

The conditional demand for oil, 0^d in equation (6), is derived from a three level CES production function, equation (5), whose arguments are labor, L, capital, K, oil, 0, and coal, C. Thus capital-energy and interfuel substitution possibilities are both taken into account. This conditional demand for oil depends on the prices of oil, coal, labor, and the rental price of capital as well as on gross output,[6] GY^d. We estimate a linearized version of this demand function with a distributed lag (4 periods) for prices and income with a sample split in 1972. The long run oil price elasticity declines from -0.27 to -0.57. The long run coal price elasticity increases from 0.29 to 0.91. The estimated income elasticity declines from 1.70 to 1.34. These changes in the parameter estimates turned out to be quite significant as a Chow test for the null hypothesis of parameter stability could not be accepted. Finally, the hypothesis of homogeneity of degree zero in prices cannot be rejected.

DCs' total imports of oil, $\tilde{M}_0^d$ in equation (7), are equal to the difference between oil demand and the exogenously given oil supply, 0^s. OPEC is assumed to be the swing producer, and therefore imports of oil from OPEC, $\hat{M}_0^d$ in equation (8), are equal to total oil imports minus oil imports from LDCs, $\hat{X}_0^{\ell}$, which in turn depend on the price of oil relative to the price of coal and on gross output of DCs. Finally, total exports, X^d, total imports, M^d, and real income are determined in equations (9), (10), and (11) respectively.[7]

OPEC

The only behavioral relation we model for OPEC is their absorption of oil revenues. For this we relate their imports of manufactures, M_m^o in equation (13), to a distributed lag of real oil revenues, R^o, which are defined in equation (12). 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

Gross output, GY^ℓ in equation (14), is determined using a two level nested CES production function with capital, K^ℓ, and oil consumption, O^ℓ, as arguments in the first nest. The parameters of this function are estimated using the first-order conditions for cost minimization; the estimated elasticity of substitution between oil and capital is 0.05 in the short-run and 0.73 in the long-run.

Capital formation, I^ℓ in equation (15), is modeled as a function of changes in the rental price of capital, P_k^ℓ, relative to the price of oil and on gross output changes. However, we amend this neoclassical formulation to allow for a non-constant speed of adjustment. In particular, we model this speed as a direct function of the availability of foreign exchange reserves in real terms, R_{-1}^ℓ / P_m^d, since it seems reasonable to expect that the availability of financial resources will determine how much investment can take place in a given year (see Coen 1971). We find investment to be quite responsive to changes in foreign exchange reserves (an elasticity in excess of one), although not quite as responsive with respect to changes in relative prices and real income.

Imports of manufactures, M_m^ℓ in equation (16), are derived from the second nest of the production function, where the economy-wide capital stock is modeled as an aggregate of a domestically made capital component, K_d^ℓ, and a foreign made capital component, K_f^ℓ, with a positive (but finite) elasticity of substitution. Following Marquez (1984), the optimal level of the foreign capital stock is proportional to the optimal level of the economy-wide capital stock, and by taking time derivatives, we obtain imports of manufactures as a function of net investment, I_n^ℓ. We assume, again, a lagged adjustment model for imports with the speed of adjustment of manufacture imports directly related to the availability of foreign exchange reserves. Our empirical results for manufacture imports point to an import elasticity of 0.8 with respect to net investment and an elasticity in excess of one with respect to (real) foreign exchange reserves.

The conditional demand for oil, O^ℓ in equation (17), is derived from the first level of the (two level CES) production function, and it depends on relative factor prices and gross output, GY^ℓ. Oil imports, $\tilde{M}_o^\ell$, are assumed to come from OPEC only, and they are derived using the identity between world oil consumption and world oil production, equation (18). This identity establishes that LDCs' oil imports are equal to LDCs' oil demand minus (the exogenously given) oil supply, $O^{s,\ell}$, plus the amount of oil exports of LDCs to DCs.

Finally, exports of manufactures to DCs, X_m^ℓ in equation (19), depend on the export price of manufactures of DCs relative to the export price of manufactures of LDCs, P_m^d/P_m^ℓ, and on the real GDP of DCs. Our estimates point to an income elasticity of 2.7 and a (relative) price elasticity of 0.7 . Nominal foreign exchange reserves, R^ℓ, are determined, in equation (20), as the balance of payments plus foreign exchange reserves lagged one period.

III. THE ANATOMY OF OIL PRICE EFFECTS

There is little doubt that oil price increases, and the associated policy responses, have a significant impact on the outlook of the world economy.[8] In this paper the effects of oil price increases are decomposed into direct and indirect effects. More specifically, the direct effect is the transfer of real income from oil importers to OPEC, which in the case of the DCs 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 LDCs, the transfer takes the form of a reduction in foreign exchange resources, which has subsequent indirect dynamic effects on output growth through the influence on capital good imports and investment.

The indirect effects of oil price increases operate, in our model, through OPEC's revenue recycling and increases in manufactures' export price. An increase in oil prices raises oil revenues of OPEC who in turn recycles a fraction of it to import manufactures from DCs. This increase in OPEC's imports represents a stimulus to activity in the DCs--one which may offset the direct negative effect. In turn, this stimulus to real activity in the DCs increases exports of LDCs, enlarging their foreign exchange resources and thus allowing greater capital good imports and faster output growth.

Increases in the price of manufactures, induced by higher oil prices, have an ambiguous impact on DCs' real income. On the one hand, there is a dampening of the initial terms of trade deterioration, which reduces the value of DCs' imports (in terms of manufactures) stimulating their real income. On the other hand, the increase in P_m^d reduces the purchasing power of export revenues of both OPEC and LDCs with an adverse effect on DCs' exports and GDP. For developing countries, the increase in P_m^d also has an ambiguous impact on real income. On the one hand it reduces the purchasing power of existing foreign exchange reserves with an adverse effect on capital accumulation and output growth. On the other hand, it stimulates LDCs' exports and thus increases foreign exchange reserves.

On the whole, the above discussion suggests that whether an increase in oil prices is stagflationary or not depends, to a large extent, on the strength of the direct effects relative to the indirect effects of these price increases. For developed economies, 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 which operate through both increases in the price of manufactures and the recycling activities of OPEC. For developing countries, the strong and adverse direct effect--the increase in the real oil bill--could be aggravated by the associated increases in the price of manufacture imports. But these adverse effects may be offset by the beneficial effects of OPEC's recycling. In practice, whether the direct effects are offset by the indirect effects depends on the relative magnitudes of key parameters such as the markup on oil prices, demand price elasticities, OPEC's recyling activities, and economic policy reactions.

Model simulations are needed to quantify the total--direct and indirect--effect of an oil price increase. To this end, we have simulated the model of section II for the period 1973-1983 under three alternative noncooperative scenarios:[9]

I. A sustained ten percent increase in the price of oil.

II. A sustained ten percent increase in the price of oil coupled with a restrictive fiscal policy.

III. The same as case II in conjunction with an increase in aid to developing countries.

Table 2 contains the dynamic income multipliers for each of these cases.

The results from case I suggest that a permanent 10 percent increase in the price of oil reduces real income for all country blocs considered here. More specifically, the DCs experience an annual average real income loss of 1.5 percent, while real income in LDCs falls by an annual average of 1.0 percent. OPEC's terms-of-trade improvement raises their real income only temporarily. The dynamic effects of higher oil prices on oil demand, and the ensuing worldwide recession are transmitted to OPEC as a significant decline in their oil exports reducing their real income by an average of 0.3 percent per year.[10]

A restrictive fiscal policy response to the oil price increase only exacerbates the real income losses, as the results from case II indicate. Here the annual average income loss for DCs is 3.7 percent, 0.8 percent for OPEC, and 1.5 percent for the remaining developing countries. This worldwide recession is initiated by the cutback in aggregate demand in DCs, which reduces exports of both OPEC and LDCs and thus the revenue to

Table 2

Dynamic Income Multipliers for
Oil Price Shocks, Fiscal Policy Responses
and Transfer Policies
1973-1983

	DCs			OPEC			Non-OPEC LDCs		
	I	II	III	I	II	III	I	II	III
1973	-0.5	-0.5	-0.5	7.9	7.9	7.9	-0.05	-0.05	-0.05
1974	-0.6	-1.4	-1.4	2.9	2.3	2.3	-0.1	-0.1	-0.1
1975	-0.8	-2.0	-1.8	0.8	-0.4	-0.2	-0.2	-0.2	0.01
1976	-0.9	-2.4	-1.7	-0.1	-1.4	-0.8	-0.4	-0.5	0.8
1977	-1.2	-3.0	-1.5	-0.5	-2.0	-0.5	-0.7	-0.8	2.6
1978	-1.4	-3.5	-1.4	-0.6	-1.9	0.2	-1.0	-1.3	5.1
1979	-1.6	-4.1	-1.5	-0.6	-1.4	1.1	-1.3	-1.7	8.0
1980	-1.8	-4.7	-1.6	-1.1	-1.4	1.3	-1.5	-2.2	11.0
1981	-2.1	-5.4	-1.8	-2.8	-2.9	0.8	-1.7	-2.7	13.9
1982	-2.5	-6.4	-2.1	-4.4	-4.2	0.7	-1.8	-3.2	16.6
1983	-2.9	-7.2	-2.5	-4.4	-2.8	1.8	-1.8	-3.5	19.0
Average Effect	-1.5	-3.7	-1.6	-0.3	-0.8	1.3	-1.0	-1.5	7.0

Dynamic multipliers are computed as

$$m_{ijt} = (y^b_{it} - y^j_{it}) * 100/y^b_{it}$$

where y^b_{it} is the base solution for the i^{th} variable at time t,

y^j_{it} is the solution for the i^{th} endogenous variable at time t under the j^{th} alternative simulation, j = I, II, III.

Simulation I: 10 percent shock to oil prices in 1973, which grows at historical rates afterwards.

Simulation II: As simulation I, but with a cut in government purchases in 1974 of 8 US$ billion, 2 percent of total purchases;

Simulation III: Same as simulation II, but allowing greater capital transfers tranfers from OPEC to non-OPEC LDCs, by an annual average of US $24 billion.

finance their imports from DCs. In turn, this decline in DCs' exports reduces their real income even more, with subsequent adverse effects on OPEC and LDCs' real income.

Table 2 also displays the regional output effects of an increase in capital transfers to LDCs. For concreteness' sake, we assume that OPEC increases its aid flows to LDCs in each year by 50 percent of net capital transfers to LDCs of that year. The simulation results for this scenario indicate that the effects of an exogenous increase in capital transfers to developing countries more than offset the adverse income effects of both higher oil prices and restrictive fiscal policies, resulting in an average income gain of 7 percent per year. However, the transfers needed to achieve these income gains are quite substantial. This increase in income is possible because of the rapid growth of investment which can be afforded by the increase in financial resources. Furthermore, the rapid growth in developing countries has beneficial spillover effects on OPEC and developed countries. In particular, given the low elasticity of substitution between oil and capital, the increase in capital accumulation stimulates oil demand which raises OPEC's oil exports increasing OPEC's real income by 1.3 percent on average. At the same time, the increase in LDCs' capital accumulation raises exports of manufactures by DCs and thus reduces DCs' average income loss by 2.1 percentage points.

Greatly simplified, our three simulation exercises replicate the effects of the three stylized facts of the last decade: higher oil prices, restrictive policy responses, and increased resources to LDCs. And what we find is that, unless transfers to LDC's keep growing (at an unsustainable growth rate), the setting of oil prices and stabilization policy responses completely independent of each other leaves everyone worse off. And it is precisely in this state of "low equilibrium" levels of income growth where the gains from policy coordination among the different country blocs are highest (Johansen 1982).

IV. COOPERATIVE POLICIES AMONG THE NORTH, THE SOUTH, AND OPEC

Formulation of the Problem

While the benefits of a global policy coordination effort are known in theory, empirical estimates of the gains of such a move are difficult to come by casting doubts on whether global policy coordination will ever occur. In this section we assess, empirically, the viability of cooperative policies among DCs, OPEC, and LDCs. In effect, we reverse the focus of analysis of the previous section, and ask now what are the implications for oil prices, stabilization policies in DCs, and transfers to LDCs if a sustained recovery of the world economy is to materialize.

We begin our analysis by making the (strong) assumption that economic policies in DCs, OPEC, and LDCs, are determined in a cooperative setting. This assumption amounts to postulating a social welfare function which is used to evaluate the desirability of alternative coordinated policy mixes (for details see Niehans 1968, Oudiz and Sachs 1984). Furthermore, we assume that this welfare function is quadratic in deviations from a given set of targets. To derive the optimal coordinated policy "mix", we minimize the expected cost of not achieving the given set of growth targets for each of the regions considered here, subject to the behavioral constraints and identities embodied in the econometric model of section II:[11]

$$\min E(W) = E\{\sum_{t=1}^{T} (\underset{\sim}{y}_t^* - \underset{\sim}{d}_t)' K (\underset{\sim}{y}_t^* - \underset{\sim}{d}_t)\} \qquad (21)$$

$$\text{subject to } \underset{\sim}{y}_t = \underset{\sim}{f}(\underset{\sim}{y}_t, \underset{\sim}{y}_{t-1}, \underset{\sim}{x}_t, \underset{\sim}{x}_{t-1}, \underset{\sim}{z}_t, \underset{\sim}{\theta}) + \underset{\sim}{e}_t \ , \qquad (22)$$

where

$\underset{\sim}{y}_t$ = column vector of endogenous variables,

$\underset{\sim}{f}$ = vector of functions,

$\underset{\sim}{x}_t$ = column vector of controllable exogenous variables or instruments,

$\underset{\sim}{z}_t$ = vector of non-controllable exogenous variables,

$\underset{\sim}{\theta}$ = vector of parameters,

$\underset{\sim}{e}$ = vector of random errors, $\underset{\sim}{e} \sim N(\underset{\sim}{0}, \Omega)$,

Ω = estimated covariance matrix,

$\underset{\sim}{y}_t^{*'} = (\underset{\sim}{y}_t' \vdots \underset{\sim}{x}_t')$,

K = positive semidefinite diagonal matrix of weights,

$\underset{\sim}{d}_t$ = column vector of desired values for targets and instruments.

The cooperative policy vector is obtained as the solution of the first-order conditions for the above minimization problem which, in our case, takes the form of a <u>linear feedback rule</u>:

$$\underset{\sim}{x}_t = G_t(\underset{\sim}{\theta}, \Omega, \underset{\sim}{d}_t, K) \underset{\sim}{y}_{t-1}^* + g_t \ . \qquad (23)$$

The cooperative policy mix $\underset{\sim}{x}_t$, as derived here, is conditional on the (estimated) parameters of the model, $\underset{\sim}{\theta}$ and Ω, the desired values for instruments and targets, $\underset{\sim}{d}_t$, and the weights in the welfare function, K.

The policy mix at a point in time depends on the effects of past policy decisions as summarized in y^*_{t-1}, with the weights in the linear feedback rule being updated recursively by a set of matrix Riccati equations. Moreover, the policy mix can be modified over time as information about the behavior of the endogenous variables becomes available. Notice that since a stochastic framework is being used, x_t attempts not only to minimize the $\| x_t - d_t \|$ but also to minimize the covariance matrix of deviations between y_t and Ey_t.[12]

By combining the expression for the cooperative policy vector with the econometric model, we obtain an "enlarged" econometric model where cooperative policies, as represented by equation (23), and the behavior of the world economy, as represented by equation (22), are determined simultaneously:

$$y_t = f(y_t, y_{t-1}, x_t, x_{t-1}, z_t, \theta) + e_t , \tag{22}$$

$$x_t = G_t(\theta, \Omega, d_t, K)y^*_{t-1} + g_t. \tag{23}$$

The solution algorithm for this problem is explained in full detail in Chow (1975, 1981).[13] Greatly simplified, it begins with equation (22) and an initial policy path for x_t, $\{x^1\}_t$, to determine the effects of the given policy path on the endogenous variables, $\{y^1\}_t$. These effects are then used (with a lag of one period) in equation (23) to obtain a second policy path $\{x^2\}_t$ which, by using equation (22), generates a second path for the economic activity targets, $\{y^2\}_t$. This second round of effects is, in turn, used to update the previous policy path and so on. This iterative process between $\underset{\sim}{x}_t$ and $\underset{\sim}{y}_t$ continues until $\|\{\underset{\sim}{x}^s\}_t - \{\underset{\sim}{x}^{s-1}\}_t\| \to 0$, where s is the sth iteration.

Experimental Design

The first step in empirically implementing our analysis is to parametrize the social welfare function. In this paper we use the following parametrization:

$$\min E(W) = E\{\sum_{t=1982}^{1990} \sum_{i=1}^{4} w_i (Y_{it} - a_{it})^2 + \sum_{t=1982}^{1990} \sum_{j=1}^{4} m_j (X_{jt} - r_{jt})^2\},$$

where we have assumed the following form for the K matrix in the welfare function, equation (21):

$$K = \left|\begin{array}{c:c} T & 0 \\ \hdashline 0 & I \end{array}\right|, \quad T = \left|\begin{array}{c:c} W & 0 \\ \hdashline 0 & 0 \end{array}\right|, \quad I = \left|\begin{array}{c:c} M & 0 \\ \hdashline 0 & 0 \end{array}\right|, \quad W = \delta_{ij} w_i, \quad M = \delta_{ij} m_i, \quad i = 1 \ldots 4,$$

and δ_{ij} is the Kronecker product.

The target variables we consider are:

Y_1 = growth rate for real oil revenues of OPEC, $\Delta\%R^o$;

Y_2 = growth rate of DCs, $\Delta\%Y^d$;

Y_3 = growth rate of LDCs, $\Delta\%Y^\ell$; and

Y_4 = inflation rate of manufacture exports of DCs, $\Delta\%P_m^d$.

The policy instruments we use are:[14]

X_1= growth rate for oil prices, $\Delta\%P_o$;

X_2= long term nominal interest rate of DCs, r^d;

X_3= real government expenditures in DCs, G^d; and

X_4= nominal net capital transfers to LDCs,[15] CF,

and thus $\underset{\sim}{x}_t' = (X_{1t}, X_{2t}, X_{3t}, X_{4t})$.

Our choice of target variables is particularly useful in analyzing the implications of a sustained recovery of the world economy for oil prices, stabilization policies, and transfers to LDCs. In addition, it lends itself to the study of the distribution of income gains arising from changes in the bargaining position of each country. The inflation rate of manufacture exports, a proxy for the overall inflation rate, is also included in the welfare function to capture policy makers' concern with allocative inefficiencies and distributional effects of high and uncertain inflation rates (Niehans 1968, Cukierman 1983).

With our choice of policy instruments we can examine the type of policy mix--fiscal, and (only indirectly) monetary--that can be implemented by developed economies in order to achieve a non-inflationary growth path for the world economy.[16] Also, it is possible to study the financial requirements of developing countries resulting from a sustained target growth. Finally, we determine the optimal price of oil from a cooperative policy point of view, and examine how it might differ from OPEC's optimal price when considered in isolation.

The desired values for the growth and inflation targets (the a's) are shown in Table 3. To determine these values we postulate a transition of the world economy from a 'no-growth' path to a 'high-growth' path with reduced inflation. The desired growth rate for developed economies is assumed to increase steadily from 2.5 percent in 1982 to 5.8 percent in 1989 and 1990. For developing countries, the desired growth rate increases from four percent in 1982 to seven percent for the period 1987-1990.[17] Real oil revenues of OPEC, R^o, are targeted to grow at one percent during 1982 and 1983. These growth rates are small relative to the standards of the 1970's, but they are ambitious given the sharp declines in real oil revenues for the 1982-1983 period. We increase this desired growth rate from four percent in 1984 to ten percent in 1989 and 1990. Finally, the desired inflation rate for manufacture exports steadily declines from seven percent in 1982 to five percent in 1985 and thereafter.

The desired values for the instruments (the r's) are also shown in Table 3. Nominal oil prices are targeted to have a zero growth rate in 1982, a decline of 15 percent in 1983, and a six percent increase for the 1984-1990 period implying a one percent increase in real oil prices for this last period.[18] Long term nominal interest rates, r^d, are targeted to decline from 14 percent in 1982 to eight percent by 1986, remaining at this level until 1990. For government expenditures we assume an average annual growth rate of only 0.9 percent reflecting the concern of current administrations over increasing government budget deficits. Nominal capital transfers to LDCs are assumed to grow at an 11.2 percent growth rate per year.[19] Government expenditures and capital transfers enter into the welfare function as indices with 1982=1.0 to avoid the problems that arise from interactions between the units of measurement of the instruments and the weights in the welfare function.

Ideally, we would like to obtain a set of weights that would

Table 3

Base Optimal Control Solution
Desired Values for Targets and Instruments
(1982-1990)

Targets

	$\Delta\%Y^d$	$\Delta\%R^o$	$\Delta\%Y^\ell$	$\Delta\%P_m^d$
1982	2.5	1.0	4.0	7.0
1983	3.4	1.0	4.8	6.5
1984	4.0	4.0	5.5	5.5
1985	4.3	6.0	6.0	5.0
1986	4.8	7.0	6.5	5.0
1987	5.2	8.0	7.0	5.0
1988	5.5	9.0	7.0	5.0
1989	5.8	10.0	7.0	5.0
1990	5.8	10.0	7.0	5.0

Instruments

	$\Delta\%P_o$	r^d	G^d	CF
1982	0.0	14	1.0	1.0
1983	-15.0	11	1.01	1.11
1984	6.5	10	1.02	1.23
1985	6	10	1.03	1.37
1986	6	8	1.04	1.52
1987	6	8	1.05	1.70
1988	6	8	1.06	1.87
1989	6	8	1.07	2.08
1990	6	8	1.08	2.31

CF is defined as nominal net capital transfers to developing countries, which are estimated at $52.7 billion in 1982. G^d is defined as government purchases in 1970 prices and 1970 exchange rates, with a value of $450.9 billion in 1982.

ensure the existence of both the welfare function we have postulated and its associated coordinated policies. However, this is such a formidable task that only in very small models can one actually derive the appropriate set of weights (see Oudiz and Sachs 1984). In this paper we take a more pragmatic approach and begin with an initial set of weights, which are then changed to examine the effects of different (quadratic) welfare functions on cooperative policy mixes. We start with an egalitarian welfare function, i.e., $w_i = 1$ for $i=1,\ldots,4$, which implies that the tradeoffs between targets that may arise here are due only to the behavioral constraints embedded in our model, to the stochastic structure (as represented by Ω), and to the values given to the instruments' weights.

The choice of values for the instruments' weights (the m's) is complicated by the fact that the iterative algorithm to solve for $\underset{\sim}{x}_t$ (closed loop) is sensitive to the values of instruments' weights, especially low values (similar findings are reported by Klein and Su 1980, Bellman 1961). To get around this problem, we recognize that policy changes are costly and thus are not likely to be frequent or to result in large deviations from historical standards (Klein 1983). Thus large weights are given to both real government expenditures of DCs ($m_3=99999$) and nominal net capital transfers to LDCs ($m_4=1500$), effectively constraining the instruments. Interest rates are assigned a weight $m_2=20$, and oil prices are assigned a weight $m_1=4.5$. While it is true that this choice of weights is arbitrary, we examine below the sensitivity of our results to changes in these weights.

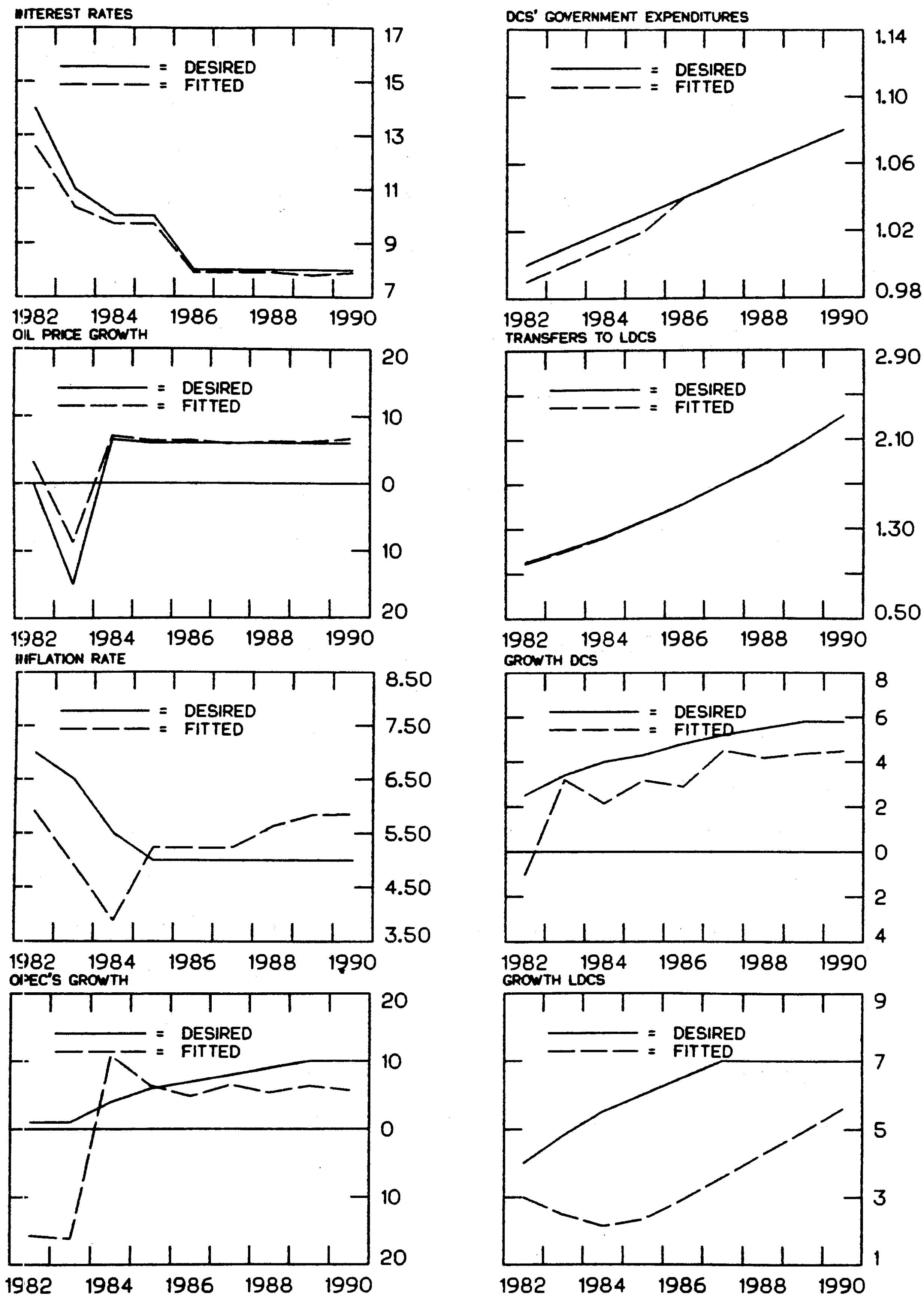
Empirical Results

Although the notion of cooperation among the major country blocs has a good deal of appeal in theory, it remains to be seen whether it is viable in practice or whether the outcome is worth the effort. Our purpose here is to examine these empirical questions with the econometric model of section II for the period 1982-1990, given the targets and weights described above.[20]

Figure 1 displays the cooperative policy paths consistent with a sustained recovery of the world economy. In particular, we find that nominal oil prices increase by 3.2 percent in 1982, <u>decline</u> by 8.8 percent in 1983, and increase in 1984 by seven percent; nominal oil price growth remains in the six percent range for the 1985-1990 period. The path for optimal real government expenditures in DCs shows an average growth of 1 percent per year while optimal nominal capital transfers grow at an average of 10 percent per year. Finally, interest rates fall from 13 to 8 percent. As Figure 1 shows, these last three instruments exhibit virtually no deviations from their desired values.

The growth outlook consistent with the above cooperative macro policies is shown in Figure 1. Growth in developed economies, after experiencing a decline of one percent in 1982, shows a steady increase from 3.2 percent in 1983 to 4.5 percent in 1990. Non-OPEC developing countries exhibit positive growth for the entire planning period starting with a three percent growth rate in 1982, which increases to 5.6 percent by 1990; their (nine year) average annual growth rate is 3.5 percent.[21] OPEC's real oil revenues decline sharply in 1982 and 1983 (16 percent in each year) because of both the recession in developed countries and the decline in oil prices. However, these revenues increase by 10.8 percent in 1984, and 6.5 percent in 1985, with an annual average growth rate of 5.8 percent for the period 1986-1990. The inflation rate, $\Delta\%P^d_m$, decreases from 5.9 percent in 1982 to 3.9

Figure 1
Mean Fitted Values for Targets and Instruments: Baseline Solution



percent in 1984, but rises again to 5.8 percent by 1990. The initial decline in $\Delta\%P_m^d$ is due to both the fall in oil prices in 1983 and the reduction in economic activity of DCs in 1982.

The overall picture that emerges from applying optimal control to our (albeit very simple) model is that it is feasible to achieve relatively high growth rates for developed, OPEC, and non-OPEC developing countries for the remainder of this decade, <u>provided</u> international policy cooperation results in (1) nominal oil prices growing at an average of six percent per year, (2) nominal capital transfers to non-OPEC developing countries growing at 10.0 percent per year, (3) long term interest rates declining to 8.0 percent, and (4) real government expenditures continuing their (modest) expansionary path. Recall, however, that these results are conditional on the weighting scheme for the welfare function chosen a priori. We now analyze the sensitivity of our results to changes in these weights.

<u>The Distribution of Income Gains or Moving Along the Contract Curve</u>

One of the characteristics of the optimal control solutions shown in Figure 1 is the divergence between desired and fitted (mean) paths for the target growth rates. Furthermore, this divergence is not uniform across targets, which means that even though there are cooperative policies capable of restoring a sustained recovery to the world economy, not all countries benefit equally from this increase in world output. This unequal gain distribution, or the extent to which growth in one country takes place at the expense of growth in another country ("welfare tradeoffs") is crucially dependent on the weights used in the welfare function. And an interesting question that arises in this context is the sensitivity of the tradeoffs among the different targets to changes in the parameters in the welfare function.

More formally, a welfare tradeoff is said to occur when an improvement in the performance of the ith target implies a deterioration in the performance of another target variable. One useful measure of the performance of a given target, relative to its desired values, is:

$$W_i = \left(1/9 \sum_{t=1982}^{1990} (Y_{it} - a_{it})^2\right)^{1/2}, \ i=1,2,3,$$

where W_i is a measure of the average deviation of the fitted (mean) value of target variable Y_i from its desired value a_i. Therefore, the smaller is W_i, the smaller is the "welfare" loss of the ith country bloc. In this context, a welfare tradeoff is defined as a situation where a decrease in W_i entails a simultaneous increase in W_j for $j \neq i$.

A distinct type of tradeoff that arises in our formulation is the degree of substitutability among different instruments in achieving a specific target. In particular, a desired growth path for LDCs could be achieved with alternative policy mixes for capital transfers and government expenditures in DCs. Thus it is conceivable that an expansionary fiscal policy in DCs, by raising exports of developing countries, could reduce the amount of capital transfers, or aid, needed to support a target growth rate for LDCs. While presumably, the expansionary effect of direct transfers to LDCs is larger, the DCs should prefer conventional expansionary fiscal policy since it avoids the direct transfer of resources. The question is what is the extent to which these two policies can substitute for each other.

In the remainder of this paper we study the response of the distribution of income gains among OPEC, developed countries and non-OPEC developing countries to changes in (1) the weights given to the targets, and (2) the weights attached to fluctuations in the instruments, particularly oil price changes, real government expenditures, and nominal capital transfers to LDCs.

Case I: Greater Weight to OPEC's Revenue Growth Target

We begin the sensitivity analysis by increasing the weight given to OPEC's growth target from one to ten while leaving unchanged all the remaining weights. Intuitively, an increase in a target's weight means that deviations of this target from its desired path are now more costly. Thus, the coordinated policy mix is changed to reduce, even further, deviations of this target from its desired path. Table 4 presents the welfare losses for each country bloc and the average growth rate for oil prices corresponding to various combinations of weights; Figure 2 depicts the results of Table 4, while Figure 3 contains the (mean) paths of targets and instruments for selected weights.

An increase in the weight of OPEC's revenue target reduces its welfare losses by 3.9 percentage points with respect to the base solution. This reduction is possible because the resulting cooperative policy allows an increase in the average growth rate of oil prices of 3.8 percentage points. At the same time, this new policy mix that affords a reduction in OPEC's welfare losses induces an increase in welfare losses to both developed and developing economies by 0.6 and 0.1 percentage points respectively. Consequently, if the OPEC countries have enhanced bargaining power in determining coordinated policies, then they may be able to reduce

TABLE 4

Case I: Greater Weight for OPEC's Revenue Growth Target

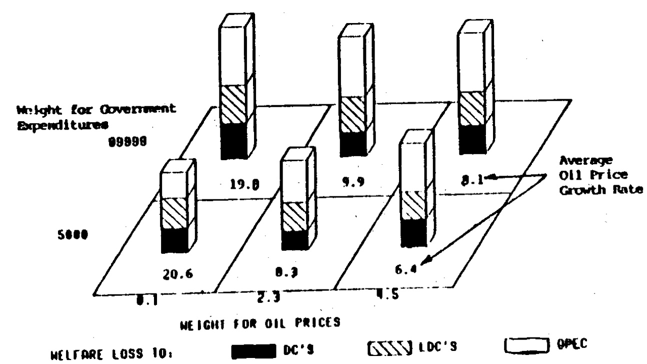
Weights		Welfare Losses[b]			
m_1	m_3	DC's	OPEC	LDCs	$\Delta\%P_0^a$
4.5	99999	2.3	4.8	2.8	8.1
2.3	99999	2.0	4.9	3.0	9.9
0.1	99999	3.0	4.8	3.2	19.8
4.5	5000	2.3	4.0	2.3	6.4
2.3	5000	1.6	3.5	2.4	8.3
0.1	5000	2.0	2.1	2.6	20.6
Base Solution		1.7	8.7	2.7	4.3

[a] Average growth rate, 1982-1990.

[b] Welfare losses are defined as the square root of the mean of square deviations of the target variable from its desired values. $m_1 \equiv$ weight of oil prices in the welfare function, $m_3 \equiv$ weight for government expenditures in the welfare function.

Figure 2

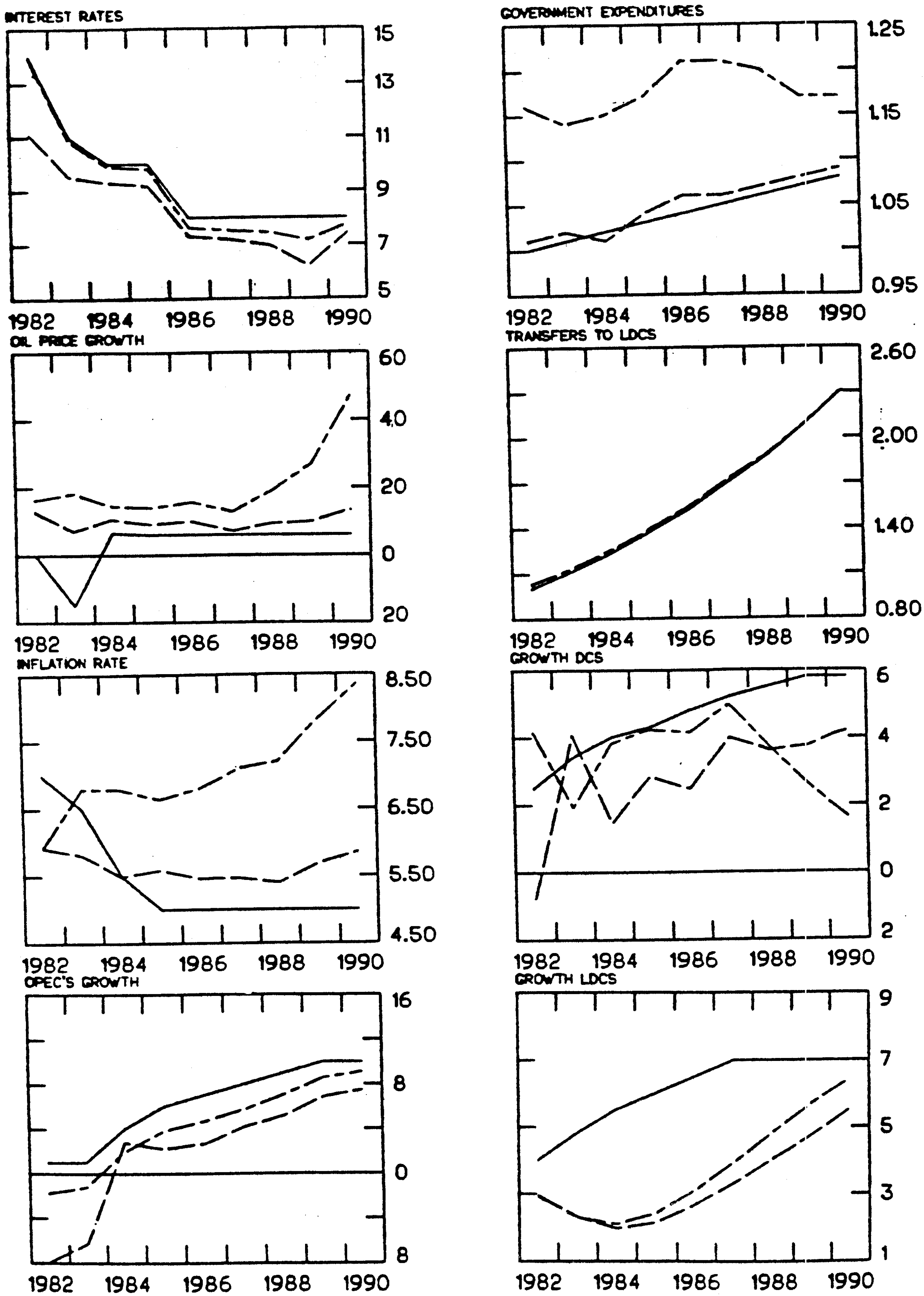
SENSITIVITY OF WELFARE LOSSES TO CHANGES IN INSTRUMENT WEIGHTS CASE I



The height of each column associated with a particular combination of instruments' weights represents the sum of all regions welfare losses for the same weight configuration. Each segment of a given column represents welfare losses for a specific region.

Figure 3
Mean Fitted Values for Targets and Instruments: Case I

Desired Path ———; (m_1=2.3, m_3=99999)- - - -; (m_1=0.1, m_3=5000)— — — —



their welfare losses only by inducing an increase in welfare losses to the other countries.

The efficacy of alternative instruments in achieving OPEC's growth target can be examined by varying the instruments' weights in the welfare function. Intuitively, the smaller the value of the weight for a given instrument the more willing we are to use that instrument to improve OPEC's growth target. A reduction in the weight of oil prices' growth from 4.5 to 0.1 raises the average growth rate of oil prices by 11.7 percentage points, inducing further increases in welfare losses to both DCs and LDCs--by 1.3 and 1.5 percentage points respectively--while reducing OPEC's welfare losses even further. The increases in welfare losses of DCs and LDCs are not more pronounced because as oil prices accelerate, the optimal fiscal policy response becomes more expansionary and thus tends to offset the adverse effects of increases in oil prices on income growth (see Figure 3).

That the optimal fiscal policy response to higher oil prices might be an expansion of government expenditures is a plausible result given that the overriding consideration in our specification is the sustainability of a given growth path. Experimentation (not shown) with a higher weight for inflation leads to a decline in government expenditures. In addition, the expansionary policy response to higher oil prices is consistent with previous historical attempts at international coordination of macropolicies. For instance, the "locomotive" and "convoy" strategies that were tried during the seventies were a clear response to the higher oil prices (see Sachs 1979:270). Furthermore, Oudiz and Sachs have found (Oudiz and Sachs 1984:41) that the optimal fiscal policy response in the U.S. to an exogenous increase in the price of oil is an expansion of government expenditures.[22]

The influence on OPEC's growth target of alternative DCs' fiscal policies is examined here by lowering the cost of fluctuations in this instrument from 99999 to 5000. The results point to a rather expansionary fiscal policy leading to an unambiguous reduction in welfare losses for each bloc of countries. This "Pareto" improvement is possible, in our model, because the optimal response of government expenditures in developed economies is rather expansionary, exceeding its target by an annual average of $US 55 billion, whereas the optimal fiscal policy response with a large weight exceeds its target only by an average of $US 8.6 billion. This expansionary fiscal policy raises OPEC's oil exports which, when combined with the higher oil prices, explains the reduction in welfare losses to OPEC. Similarly, we find a substantial reduction in welfare losses to LDCs despite (1) increases in the average growth rate of oil prices, and (2) virtually no deviations of capital transfers from their desired values. Again, this result can be explained by the stimulative effect of higher government expenditures in DCs on exports of LDCs, which increases their foreign exchange reserves and thus eliminates the need for higher capital transfers. Therefore, the expansionary fiscal policy serves as a substitute instrument for capital transfers to LDCs.[23]

That a highly expansionary policy may be beneficial to all the parties involved should not come as a surprise. In the present context, it implies that individuals are willing to consider their holdings of government debt as part of their wealth without realizing that the increased debt service may call for increased taxes in the future. Since it is quite unlikely that individuals will sustain such a view indefinitely, it seems clear that such an expansionary move will not be observed in reality. This forward-looking expectation element is absent from our model and is one avenue for future research.

Case II: Greater Weight to DCs Growth Target

We now examine the response of the policy mix to an increase in the weight of DCs' growth target from one to ten while leaving all the other targets with a weight of one. The results are shown in Table 5 and are depicted in Figure 4. Figure 5 exhibits the (mean) paths of targets and instruments for selected weight combinations.

In general, the initial impact of an increase in the weight for DCs' growth target is to change the cooperative policy mix towards a higher level of government expenditures in DCs. However, as we saw in Case I, if the overriding consideration is the sustainability of a given growth path, then it is entirely conceivable to find a direct relation between movements in oil price changes and movements in optimal real government expenditures in DCs. Consequently, the beneficial effects of an increase in government expenditures on DCs' income are offset by the adverse effects of the oil price increase that immediately follows. This offsetting effect requires an even larger expansion of government expenditures to counteract the negative effects of higher oil prices and to achieve the desired growth target. However, any further increase in government expenditures is followed by another round of oil price increases which again increases further government expenditures. The net effect of this process is an increase in welfare losses to DCs and LDCs but a reduction in welfare losses to OPEC who clearly benefit from the increase in oil prices. This adverse result on DCs' welfare losses arises because the increase in oil prices is of a greater magnitude than the increase in government purchases, which in turn is

TABLE 5

Welfare Tradeoffs
Case II: Greater Weight for DC's Growth Target

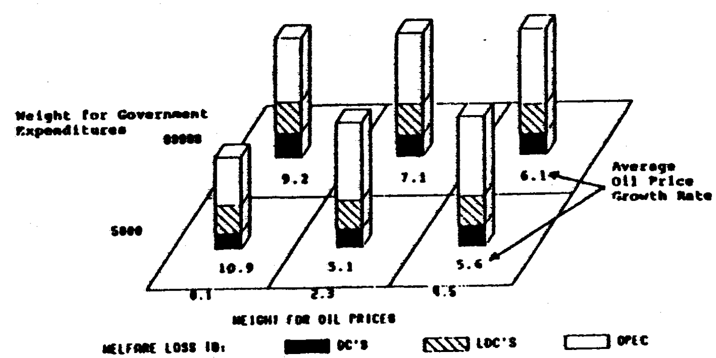
Weights		Welfare Losses[b]			
m_1	m_3	DC's	OPEC	LDCs	$\Delta\%P_0^a$
4.5	99999	2.2	7.8	3.1	6.1
2.3	99999	2.3	7.4	3.2	7.1
0.1	99999	2.6	6.6	3.2	9.2
4.5	5000	3.0	8.3	3.1	5.6
2.3	5000	2.0	8.1	3.0	5.1
0.1	5000	1.6	5.0	3.0	10.9
Weight for DC's Growth = 200					
4.5	5000	0.6	7.6	2.5	5.2
Base Solution		1.7	8.7	2.7	4.3

[a] Average growth rate, 1982-1990.

[b] Welfare losses are defined as the square root of the mean of square deviations of the target variable from its desired values.
$m_1 \equiv$ weight of oil prices in the welfare function, $m_3 \equiv$ weight for government expenditures in the welfare function.

Figure 4

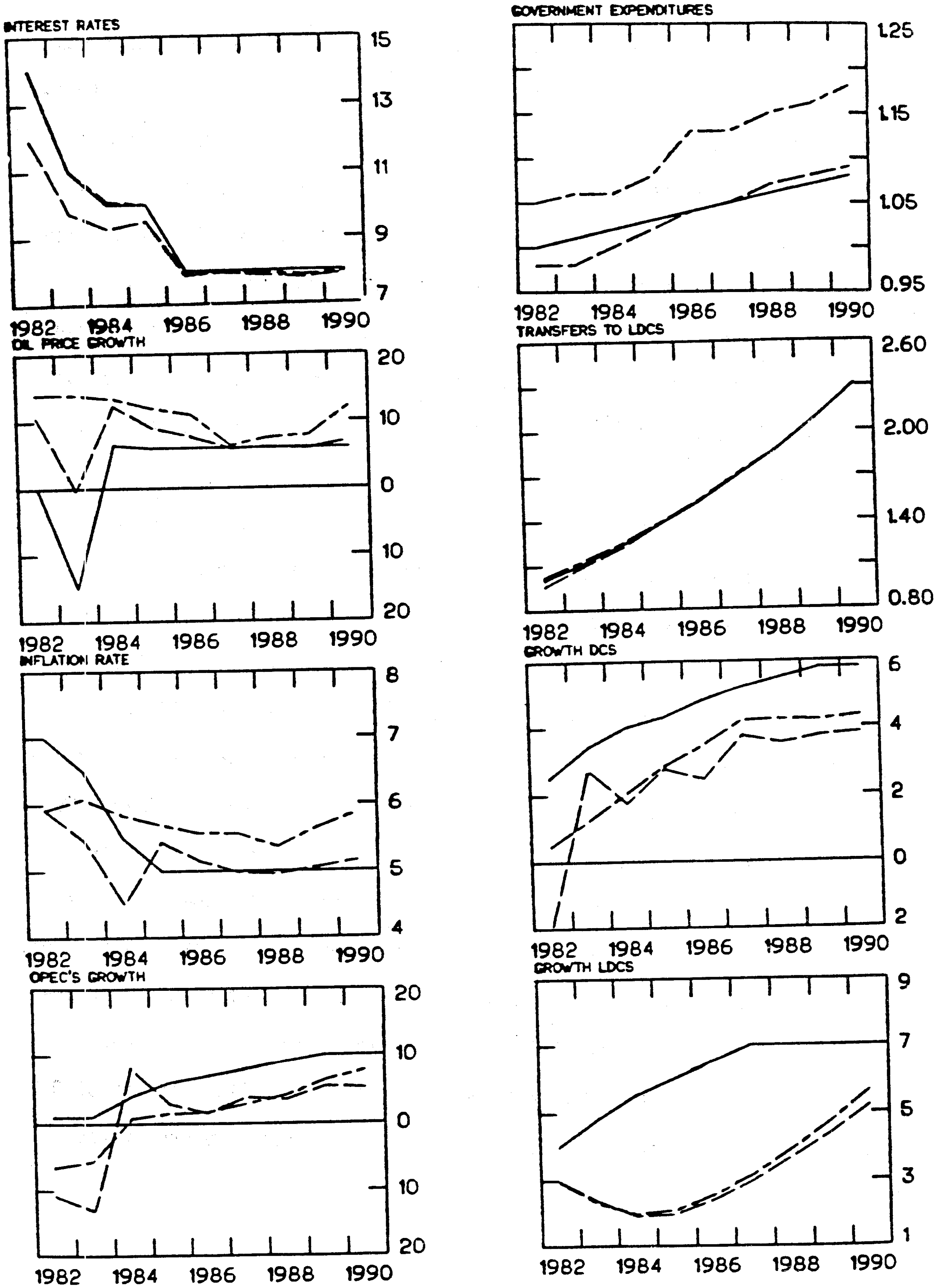
SENSITIVITY OF WELFARE LOSSES TO CHANGES IN INSTRUMENT WEIGHTS CASE II



The height of each column associated with a particular combination of instruments' weights represents the sum of all regions welfare losses for the same weight configuration. Each segment of a given column represents welfare losses for a specific region.

Figure 5
Mean Fitted Values for Targets and Instruments: Case 2

Desired Path ——; (m_1=2.3, m_3=99999)– – –; (m_1=0.1, m_3= 5000)— – — –



explained by the large weight differential between these two instruments.

In order to eliminate the influence of a large weight differential on the welfare tradeoffs, we reduce the weight of government expenditures from 99999 to 5000. As a result, we find that this weight reduction leads to declines in welfare losses of 1.0 percentage points for DCs (2.6 minus 1.6) and of 1.6 percentage points for OPEC with almost no effect on LDCs' welfare losses despite an increase of 1.7 percentage points in the average growth rate of oil prices. These last results suggest that the adverse effect of higher oil prices on both DCs' and LDCs' growth are being offset by the stimulative effects of increases in government expenditures of DCs, given that fluctuations in this instrument now have attached a lower cost (see Figure 5).

We also examine the impacts of further increases in the weight for DCs' growth target. In effect, this amounts to raising the cost of deviations in DCs' growth target from their desired path relative to the cost of deviations in the instruments from their desired paths. Thus we consider an increase in the weight of DCs' growth target from 10 to 200, while keeping the weights for oil prices and government expenditures at 4.5 and 5000 respectively. Our results indicate that when the weight for DCs equals 200, their welfare losses decline by 1.1 percentage points with respect to the base solution. There is also a similar decline in OPEC's welfare losses despite a decline in the average oil price growth rate. This implies that OPEC's reduction in welfare losses arises out of the increase in the volume of oil exports induced by the higher growth in developed economies. Finally, the LDCs experience a decline in welfare losses of 0.2 percentage points because the effects of higher government expenditures (higher growth in DCs) and lower oil price growth are transmitted to them via international trade, enlarging their foreign exchange resources, which affords faster capital accumulation and enhances output growth. Notice that this faster output growth does not call for capital transfers above the targeted levels. Thus, once again, we find that increases in DCs' government expenditures and lower oil prices serve as substitute instruments for capital transfers to LDCs.

Case III: Greater Weight to LDCs Growth Target

We now examine the effect on coordinated policies of an increase in the weight of LDCs' growth target from one to ten while keeping the weights for the other targets equal to one. We also reduce the cost attached to fluctuations in capital transfers from 1500 to 100. Our results are shown in Table 6 and depicted in Figure 6; Figure 7 displays the mean paths for targets and instruments for selected weight combinations.

An increase in the weight of LDCs' growth target reduces their welfare losses by an average of 1.1 percentage points with respect to the base solution for all the combinations of weights considered here. More specifically, reducing the weight for oil prices from 4.5 to 0.1, while keeping the fiscal policy weight unchanged, does not increase welfare losses to LDCs despite a 7 percentage points increase in the annual average growth rate of oil prices. Growth in LDCs is isolated from the adverse effects of higher oil prices by the increase in capital transfers, which now exceed their (already high) targets by an annual average of $US 19.5 billion.

Although fiscal policy can, in principle, serve as an instrument to promote growth in LDCs, we find that LDCs' welfare losses are fairly

TABLE 6

Welfare Tradeoffs
Case III: Greater Weight for LDC's Growth Target

Weights		Welfare Losses[c]				
m_1	m_3	DC's	OPEC	LDCs	$\Delta\%P_0^a$	ΔCF^b
4.5	99999	1.6	8.6	1.6	4.3	12.1
2.3	99999	1.7	7.8	1.6	5.1	13.4
0.1	99999	2.6	5.6	1.6	11.4	19.5
4.5	5000	1.9	8.7	1.6	3.8	14.3
2.3	5000	1.8	7.9	1.5	4.6	14.8
0.1	5000	2.0	4.8	1.5	11.4	17.7
Base Solution		1.7	8.7	2.7	4.3	0.2

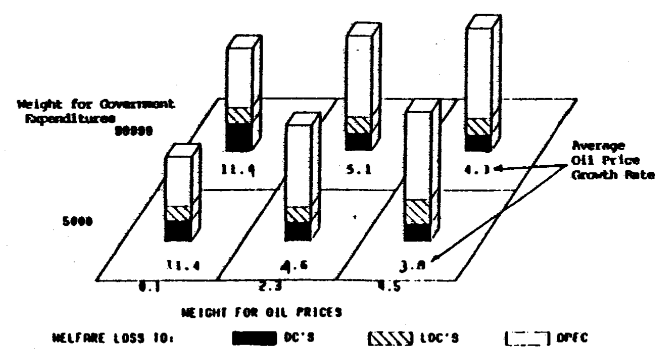
[a] Average growth rate, 1982-1990.

[b] Average deviation from target, 1982-1990, billions of $US.

[c] Welfare losses are defined as the square root of the mean of square deviations of the target variable from its desired values.
m_1 ≡ weight of oil prices in the welfare function, m_3 ≡ weight for government expenditures in the welfare function.

Figure 6

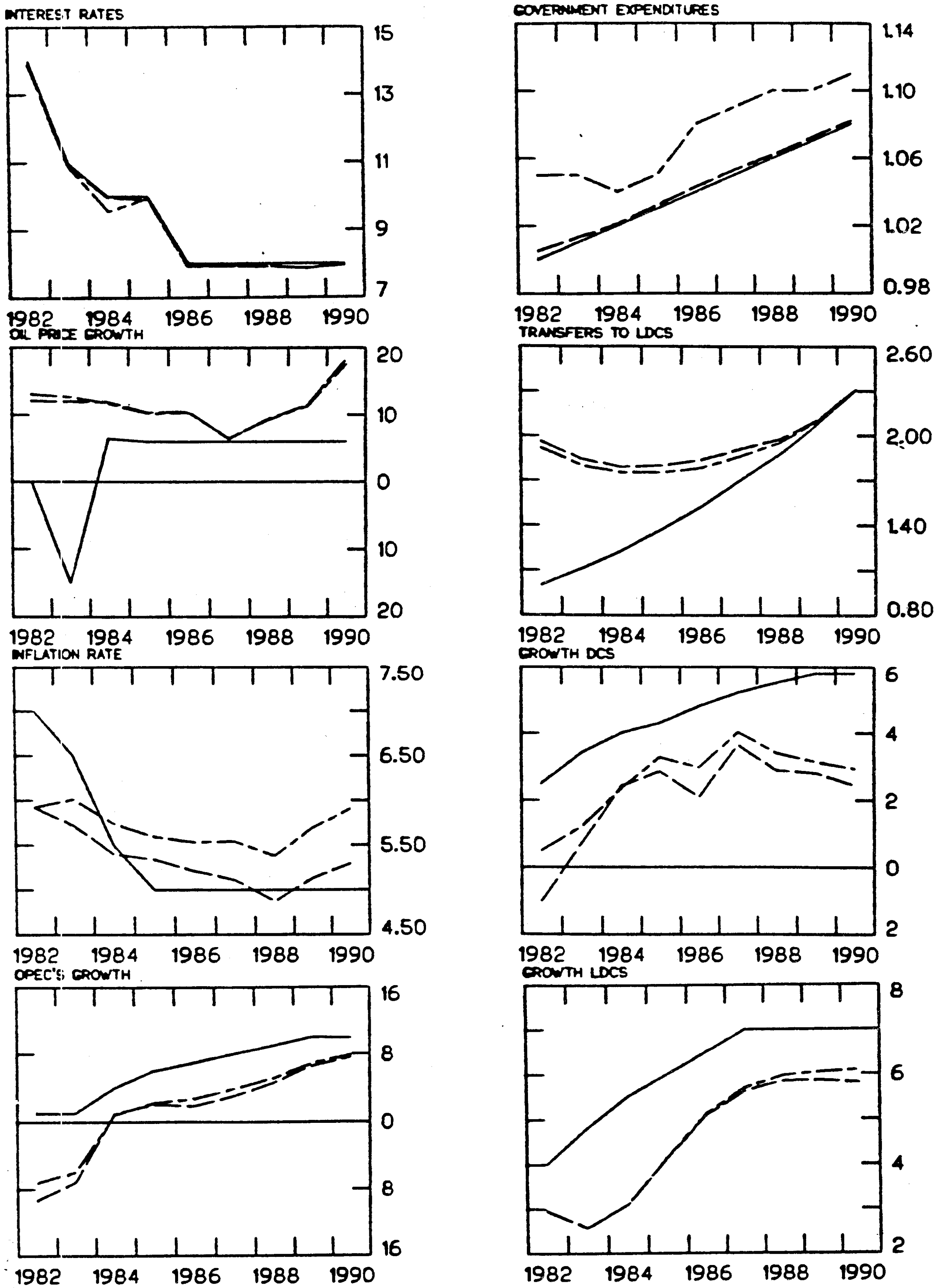
SENSITIVITY OF WELFARE LOSSES TO CHANGES IN INSTRUMENT WEIGHTS CASE III



The height of each column associated with a particular combination of instruments' weights represents the sum of all regions welfare losses for the same weight configuration. Each segment of a given column represents welfare losses for a specific region.

Figure 7
Mean Fitted Values for Targets and Instruments: Case 3

Desired Path ——; (m_1=0.1, m_3=99999)- - - -; (m_1=0.1, m_3= 5000)— — — —



insensitive to changes in fiscal policy's weight. This means that there are, in our model, other more efficient instruments to promote growth in LDCs. In contrast, however, welfare losses for DCs and OPEC are quite sensitive to changes in fiscal policy's weight. In particular, given a weight of 4.5 for oil prices, a reduction in the weight on government expenditures from 99999 to 5000 raises welfare losses to both DCs and OPEC. This is because with a weight of 4.5, oil prices tend to follow their target values quite closely, which include a fall in oil prices. As noticed earlier, there exists in the context of our analysis a positive association between oil prices and government expenditures. Thus a decline in oil prices leads to a fall in government spending and this latter decline generates the adverse effects on DCs and OPEC. We also notice that, despite the decline in the average growth rate of oil prices, there is an increase in the amount of capital transfers to LDCs. This increase in transfers is necessary to offset the impact of lower government expenditures in DCs on the LDCs, since the beneficial aspects of lower oil prices are being offset by the reduction in growth of DCs.

In contrast to the previous situation, a reduction in the weight of government expenditures from 99999 to 5000, coupled with a reduction in the weight of oil prices to 0.1, results in significant reductions in welfare losses for both DCs and OPEC despite a decline in average capital transfers to LDCs and unchanged oil prices. This result arises because DCs' government expenditures are now substantially (and unrealistically) higher, increasing exports of LDCs and their foreign exchange receipts which allows a small reduction in the average increase in capital transfers (see Figure 7).

Evaluation of Sensitivity Analysis Results

Several interesting results emerge from the sensitivity analysis performed so far. First, although instrument instability did not materialize for the weights we have used, there are cases where small weight values result in paths for instruments that are not entirely consistent with the policy environment where these instruments are determined. In other words, even though a policy mix might be efficient, it may lack credibility when compared to historical standards. To be specific, we find that in order to accelerate economic growth in LDCs, capital transfers would have to exceed their (already high) targets by an annual average of $US 20 billion in some cases. Given today's current financial situation for some developing countries, it seems unlikely that such large transfers will take place.[24] Second, there are certain combinations of weights (see Figures 3, 5, 7) which lead to rather expansionary fiscal policies, implying myopic behavior on the part of individuals. This is an area where more work is clearly needed.

Third, the results suggest that certain instruments can substitute for each other in supporting a given target growth path. More specifically, either lower oil prices or higher government expenditures reduce the need for capital transfers to developing countries. On the other hand, we find a complementary relationship between government expenditures and oil price growth, provided growth considerations override inflationary considerations.

Fourth, we find that the "ceteris paribus" oil price path consistent with OPEC's best interests is higher than the oil price path consistent with either DCs' or LDCs' best interests. The measurement of ceteris paribus oil price paths in our context is difficult because other instruments are changing at the same time as all oil prices do. Thus we assume that ceteris paribus can be (approximately) obtained when instruments have their highest weight. Table 7 displays the sensitivity of welfare tradeoffs for cases I and II, along with changes in the average growth rate for oil prices for each of the weighting schemes we have considered here. We see that an increase in the average growth rate of oil prices is unambiguously associated with a reduction in OPEC's welfare losses and with increases in welfare losses for both DCs and LDCs. This finding clearly indicates the existence of conflicting interests among the three blocs of countries included in our model, and calls for an extension of our analysis to allow for non-cooperative policy design.[25]

V. CONCLUSIONS

Our first purpose in this paper has been to study empirically the possibility of developing cooperative policies among the North, the South, and OPEC, consistent with a non-inflationary reactivation of the world economy.

To this end we use a nonlinear stochastic dynamic econometric model for a three region world economy that highlights the channels of international transmission of oil price effects and the feedback effects of policy responses to oil price changes. Applying stochastic optimal control to an estimated version of this model, we find that if (1) oil prices grow at six percent per year which means roughly constant real oil prices, (2) government expenditures grow at 0.9 percent per year, and (3) capital transfers to developing countries grow at 10 percent per year, then it is feasible to achieve a non-inflationary recovery of the world economy.

Our results are very much dependent on the structure of the model used, the period for parameter estimation, the specification of the welfare

Table 7

Impact of Acceleration in Oil Price
Changes on World Income Distribution.

Average Effects
1983-1990

Case I

m_1	m_3	DCs	OPEC	LDCs	$\Delta(\Delta\%P_0)$
4.5	99999	0.6	-3.9	0.1	3.8
2.3	99999	0.3	-3.8	0.3	5.6
0.1	99999	1.3	-3.9	0.5	15.5

Case II

m_1	m_3	DCs	OPEC	LDCs	$\Delta(\Delta\%P_0)$
4.5	99999	0.5	-0.9	0.4	1.8
2.3	99999	0.6	-1.3	0.5	2.8
0.1	99999	0.9	-2.1	0.5	4.9

Case I: Greater weight to OPEC's revenue target.

Case II: Greater weight to DC's growth target.

Entries for a particular weighting scheme represent deviations of welfare losses from welfare losses for the base solution.

function, and quite importantly, on the assumption of cooperation among the three country blocs considered here. Clearly, more research is needed in each of these areas. Furthermore, capital flows are not being modeled here, and no allowance is made for endogeneity of exchange rates. Taking into account the above considerations, the sensitivity analysis we have performed suggests the following conclusions: (1) if growth is the overriding concern of authorities, then there is a positive relationship between the optimal response of government expenditures and optimal oil price changes; (2) low oil prices and expansionary fiscal policy in DCs reduce the need for net capital transfers to developing countries; (3) there exists a conflict of interests between oil importers and oil exporters since the oil price path that reduces OPEC's welfare losses is higher than the oil price path required to reduce welfare losses for both DCs and LDCs.

ENDNOTES

*An earlier version of this paper was presented at the 5th IAEE Annual North American Meetings, June 1983, and the 4th IFAC/IFOR conference on The Modeling and Control of National Economies, June 1983. We are grateful to F. Gerard Adams, Matt Canzoneri, David Kendrick, Lawrence Klein, Peter Tinsley, Janice Shack-Marquez, Edward Green, Geoffrey Heal, and James Sweeny for their comments. We are also grateful to Gregory Chow for providing the software used in our analysis. Any remaining errors belong entirely to us. This paper represents the views of the authors 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] See Niehans (1968), Hamada (1979), Johansen (1982), Canzoneri and Gray (1983), Rogoff (1983), and Oudiz and Sachs (1984). However, these analyses have been characterized by deterministic, static, two-country models, with little or no empirical content (an exception is Oudiz and Sachs 1984). Our approach is more empirically oriented and thus we use a three-country, stochastic, dynamic model.

[2] There is a considerable amount of work analyzing the possibilities for policy coordination between the North and the South. Suffice to mention the work of the UNCTAD for the last twenty years. For the academic literature, see Bhagwati (1977), Cline (1979) and Johnson (1967). The possiblities for policy coordination between OPEC and the North have been analyzed by Adelman (1984), who cites the Teheran agreement of 1971 as a failure of such arrangements. However, conclusions reached by focusing on only two country blocs are conditional on the third country bloc which is left out. Thus it seems that a more realistic approach to the problem of policy coordination is to include the North, the South, and OPEC. Taylor (1981) has examined this issue from a theoretical standpoint, and the present paper could be seen as an empirical implementation of Taylor's work.

[3] As a corollary of our analysis, we offer an approach to determining oil prices which is different from the classical wealth maximization approach developed in the literature (Hotelling 1931, Dasgupta and Heal 1979). We recognize that OPEC faces not only the problem of allocating oil production through time (the classical approach), but also a tradeoff between exploiting the direct price inelasticity of oil demand on the one hand, and avoiding the income feedback effects of oil price increases on the other. This tradeoff arises only in a more general equilibrium model such as the one developed below. See Marquez and Pauly (1984) for an analysis of the implications of these tradeoffs for OPEC's pricing policy.

[4] Financial links also exist among these three blocks of countries, and there have been several attempts at modeling these financial links. For instance Sachs (1983a) develops a model that captures both trade and financial links. However, he assumes the parameter values for his relationships casting some doubts on the generality of his results. Minford (1984) uses a model with both trade and financial linkages coupled with rational expectations. Some of his parameters are assumed and some are estimated; yet "full dynamic simulation tests have not yet been possible." (Minford 1984:7). Clearly,

the absence of financial links is a limitation of our model. However, the ongoing modeling effort still suggests the existence of tradeoffs between a reasonably sized model including most of the relevant linkages, reliability of parameter estimates, technical limitations of numerical optimization algorithms, and model validation.

[5]The theoretically correct specification should use the real interest rate. This specification, however, yielded the wrong sign in estimation, and thus could not be used. This sign reversal could be due to the combination of our (large) level of aggregation and a positive variance in the distribution of inflationary expectations, or to the non-neutrality of the distributuion of the inflation rate with respect to changes in relative prices. This non-neutrality arises when the one-good assumption of most macro models is removed. See Cukierman (1983), and Sachs (1983b:260-261) who examines the effects of this non-neutrality in the distribution of relative price changes on the labor market.

[6]Gross output is defined as real value added plus oil imports in real terms.

[7]Developed countries also export to DCs. These intra DCs trade flows cancel each other out in equation (11); trade flows between DCs and Centrally Planned Economies are treated exogenously.

[8]See Marquez (1983), Fried and Schultze (1975), Nordhaus (1980), MacAvoy (1982), and Griffin and Teece (1982). In this paper we are considering increases in the price of oil for expositional purposes. We have found that in general the effects of oil price changes are almost symmetrical. Nonetheless, empirical results suggest the existence of a lower threshold for oil prices for debt-riden countries (Mexico, Nigeria, Venezuela) below which oil price changes are no longer symmetrical.

[9]We use historical values as the baseline simulation.

[10]OPEC's real GDP can be approximated by OPEC's real oil revenues. This approximation works best for analyses with long term horizons such as ours, and for the large oil producers which account for most of OPEC trade and for which oil revenues represent a sizeable fraction of GDP.

[11]For computational purposes, we need to express the model in its state-space representation. This is accomplished by redefining variables with lags of order greater than one as new variables. As a result, the state-space representation of the model has variables with lags of order no greater than one. The size of the model, in its state-space representation has 101 equations.

[12]In effect, the original number of targets is increased by the number of variances and covariances that has to be minimized.

[13]In order to be fair, we should point out that optimal control applications are not problem free. In particular, Kydland and Prescott (1977) argue that policies derived using optimal control need not be optimal if agents have rational expectations. The main problem is, as they indicate, the absence of a mechanism inducing future policymakers to take into account the effects of today's policymakers' decisions on today's agents' decisions. However, the issue is far from resolved since Chow (1981) shows how to apply optimal control theory allowing for rational expectations.

[14]Notice that the number of targets exceeds the number of instruments, given that we have to minimize the variances of the deviations between the actual and the expected value for each target. In effect, there are eight targets and four instruments. The variance-covariance matrix Ω is estimated using the OLS residuals.

[15]Although capital transfers to non-OPEC LDCs can hardly be considered a variable under their control, developed countries do benefit from such transfers as the simulation results from case III indicate. Capital transfers here are net of amortization and interest payments, and thus they represent "new money". There are, in principle, several sources of capital transfers: OPEC cumulated unspent oil revenues (as in scenario III), debt relief (Kenen 1977), and profit sharing from seabed activities (Cooper 1977). Nevertheless, these capital transfers have traditionally been a source of political controversies and ethical considerations (see Bhagwati 1977, Cooper 1977, and Kenen 1977).

[16]Implicitly we are assuming the monetary authorities carry out open market operations with a corresponding effect on the interest rate.

[17]A similar target growth rate is found in the United Nations Development Report (United Nations 1982).

[18]Real oil prices are defined here as nominal oil prices relative to the export price of manufactures of developed countries.

[19]This the growth rate corresponding to the "high-case scenario" of the World Bank Report for 1982 (World Bank 1982:35). More recently, Terrel (Terrel 1984:759) has estimated that in order to restore a sustained growth to developing countries, transfers should grow at a rate of 6 percent per year starting from a base of $40 billion transfers for the period 1983 and 1984. The discrepancy in estimates is due to the lower target growth rate of Terrel's analysis.

[20]Cooperative policies derived for the period 1973-1983 (not shown) indicate that growth for each region could have been higher than historical growth rates. However, we do not find this kind of exercise very informative since one can always do better with hindsight. From the point of view of evaluating cooperative policies between the three country blocks considered here, an extrapolation into the future seems more relevant, especially when combined with a sensitivity analysis as we do here.

[21]This is average growth rate is higher than the "high scenario" target growth rate for developing economies (3.3%) of the 1982 report of the World Bank (World Bank 1982:37). This seemingly small difference in growth rates results in significant differences in the levels of real income after 9 years.

[22]They also find that Japan and Germany reduce government spending in response to an increase in the price of oil. However, Oudiz and Sachs point out that, becauses of the large size of the U.S. in the world economy, the U.S. plays a very influential, and asymmetrical, role in the world economy. Thus it is entirely conceivable to observe, at our (OECD) aggregate level, a positive association between government spending and oil prices. Finally,

Burbidge and Harrison (1984) have found, using Vector Autoregressive simulations, that an increase in the price of oil leads to increases in the money supply in the U.S., Japan, and the U.K., which is clearly an expansionary response to the oil price shock.

[23]While it is true that an increase of one dollar in exports can offset a one dollar decline in foreign aid while keeping foreign exchange reserves constant, it is also true that an increase in exports may enhance domestic activities to a greater extent than aid. These domestic considerations make the notion of substitutability a subtle one, and its analysis is beyond the scope of the present paper.

[24]Another instance of unrealistic instrument paths' is the case of greater weight to OPEC's growth target using a low weight for government expenditures. Under these circumstances, these expenditures exceed their targeted values by an annual average of $55 billion in real terms. Again, given today's concern with government budget deficits, it seems unlikely that such an expansion of government expenditures will materialize.

[25]One way of relaxing the assumption of cooperation is, for instance, to include in the welfare function only OPEC's targets and instruments and have reaction functions for DCs and LDCs. A second approach is to have a welfare function for each of the players who have conflicting objectives (Pindyck 1977). Alternatively, one could examine the implications for growth of Cournot-Nash and Stackbelger solutions (see Canzoneri and Gray 1983). Notice that we have not dealt with the (difficult) problem of policy coordination in the face of uncertainty about the underlying economic structure. Using a highly stylized version of the model used in this paper, we have examined cooperative pricing policies in a Bayesian framework allowing for learning about the structure. The results, while preliminary, are available upon request.

References

Adelman, M. (1984). "International Oil Agreements," The Energy Journal, Vol.5, No.3:1-10.

Bellman, R. (1961). Adaptive Control Processes: A Guided Tour, Princeton: Princeton University Press.

Bhagwati, J. (Ed.) (1977). The New International Economic Order: The North-South Debate, Cambridge: MIT Press.

Burbidge, J. and A. Harrison (1984). "Testing for the Effects of Oil-Price Rises Using Vector Autoregressions," International Economic Review, Vol.25, No.2:459-484.

Canzoneri, M. and J. Gray (1983). "Two Essays on Monetary Theory in an Interdependent World," International Finance Discussion Paper No. 219, Board of Governors of the Federal Reserve System.

Chow, G. (1975). Analysis and Control of Dynamic Systems, New York: John Wiley.

Chow, G. (1981). Econometric Analysis by Control Methods, New York: John Wiley.

Cline, W. (Ed.) (1979). Policy Alternatives for a New International Economic Order. An Economic Analysis, New York: Praeger.

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

Cooper, R. (1977). "The Ocean as a Source of Revenue," chapter 4:105-124, in J. Bhagwati (ed.).

Cukierman, A. (1983). "Relative Price Variability and Inflation: A Survey and Further Results," Carnegie-Rochester Conference Series on Public Policy, No.19, Autum, Amsterdam: North-Holland.

Dasgupta, P. and G. Heal (1979). Economic Theory and Exhaustible Resources, Oxford: Cambridge-Nisbet.

Fried, E. and C. Schultze (Eds.) (1975). Higher Oil Prices and The World Economy, Washington D.C.: Brookings Institution.

Griffin, J. and D. Teece (Eds.) (1982). OPEC Behavior and World Oil Prices, London: George Allen and Unwin.

Hamada, K. (1979). "Macroeconomic Strategy and Coordination Under Alternative Exchange Rates," in Dornbusch and Frenkel (eds.) International Economic Policy: Theory and Evidence, Baltimore: Johns Hopkins University Press.

Hotelling, H. (1931). "The Economics of Exhaustible Resources," The Journal of Political Economy, Vol.39, No.2:137-175.

Johansen, L. (1982). "A Note on the Possibility of an International Equilibrium with Low Levels of Economic Activity," Journal of International Economics, Vol.13, Nos.3/4:137-175.

Johnson, H. (1967). Economic Policies Towards Less Developed Countries, Washington D.C.: Brookings Institution.

Judge, G., R. Carter Hill, W. Griffiths, H. Lutkepohl, and T. Lee (1982). Introduction to the Theory and Practice of Econometrics, New York: John Wiley.

Kenen, P. (1977). "Debt Relief as Development Assistance," chapter 2:50-80, in J. Bhagwati (ed.).

Klein, L. (1983). "Economic Policy Formulation: Theory and Implemetation (Applied Econometrics in the Public Sector,)" in Handbook of Econometrics, Vol.2, forthcoming.

Klein, L. and V. Su (1980). "Recent Economic Fluctuations and Stabilization Policies: An Optimal Control Approach," in L. Klein, M. Nerlove, and S. Tsiang (eds.), Quantitative Economics and Development, New York: Academic Press.

Kydland, F. and E. Prescott (1977). "Rules Rather Than Discretion: The Inconsistency of Optimal Plans," The Journal of Political Economy, Vol.85, No.3:473-491.

MacAvoy, P. (1982). Crude Oil Prices As Determined By OPEC and Market Fundamentals, Cambridge: Ballinger.

Malinvaud, E. (1970). Statistical Methods of Econometrics, Amsterdam: North-Holland.

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. (1983). "The International Transmission of Oil Price Effects and The Derivation of Optimal Oil Prices," Ph.D. dissertation, Philadelpia: University of Pennsylvania.

Marquez, J. (1984). "Foreign Exchange Constraints and Growth Possibilities in LDCs," Journal of Development Economics, forthcoming.

Marquez, J. and P. Pauly (1984). "OPEC's Pricing Policy and The International Transmission of Oil Price Effects," Energy Economics, Vol.6, No.4:267-275.

Minford, P. (1984). "The Effects of American Policies--A New Classical Interpretation," manuscript, University of Liverpool, England.

Niehans, J. (1968). "Monetary and Fiscal Policies in Open Economies Under Fixed Exchange Rates: An Optimizing Approach," The Journal of Political Economy, Vol.76, No.4:893-920.

Nordhaus, W. (1980). "Oil and Economic Performance in Industrial Economies," Brooking Papers on Economic Activity, No.2:341-401.

Oudiz, G. and J. Sachs (1984). "Macroeconomic Policy Coordination Among The Industrial Countries," Brookings Papers on Economic Activity, No.1:1-64.

Pindyck, R. (1977). "Optimal Economic Stabilization Policies Under Decentralized and Conflicting Objectives," IEEE Transactions on Automatic Control, Vol. ac-22, No.4:517-530.

Rogoff, K. (1983). "Productive and Counterproductive Cooperative Monetary Policies," International Finance Discussion Paper No.233, Board of Governors of The Federal Reserve System.

Sachs, J. (1979). "Wages, Profits and Macroeconomic Adjustment: A Comparative Study," Brookings Papers on Economic Activity, No.2:269-319.

Sachs, J. (1983a). "Energy and Growth Under Flexible Exchange Rates," in J. Bhandari and B. Putnam (eds.) Economic Interdependence and Flexible Exchange Rates, Cambridge: MIT Press.

Sachs, J. (1983b). "Real Wages and Unemployment in the OECD Countries," Brookings Papers on Economic Activity, No.2:255-289.

Taylor, L. (1981). "South-North and Southern Growth. Bleak Prospects from the Structuralist Point of View," Journal of International Economics, Vol.11, No.4:589-602.

Terrel, H. (1984). "Bank Lending to Developing Countries: Recent Developments and Some Considerations for the Future," Federal Reserve Bulletin, Vol.70, No.10:755-763.

United Nations (1982). Trade and Development Report, 1982, New York: United Nations.

World Bank (1982). World Development Report, New York: Oxford University Press.