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WORLD EQUILIBRIUM WITH OIL PRICE INCREASES: AN INTERTEMPORAL ANALYSIS

Nancy Peregrim Marion

Lars E.O. Svensson

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ABSTRACT

This paper examines the effect of OPEC price increases on the welfare of a group of oil-importing industrial countries. It also studies how taxes or subsidies on oil imports or capital flows could alter the group's welfare. The analysis is conducted using a general-equilibrium model that describes the behavior of two actors, OPEC and the oil-importing bloc called Industria. The analysis is explicitly intertemporal and takes into account endogenous changes in saving, investment and employment.

We show that Industria's welfare is affected not only by direct oil terms of trade effect, but also by changes in the world rate of interest (intertemporal terms of trade effects) and, for rigid wages, changes in employment. Thus Industria gains from the intertemporal terms of trade effect if it is a net borrower and the world rate of interest falls. Precise conditions for whether the world rate of interest falls or rises are given.

We also show that Industria may gain from subsidizing oil imports rather than taxing them, in particular if wages are rigid, and that it may gain from restricting international capital mobility.

Nancy Peregrim Marion
Department of Economics
Dartmouth College
Hanover, New Hampshire 03755

(603) 646-2511

Lars E.O. Svensson
Institute for International
Economic Studies
S-10691 Stockholm, Sweden
46-8-16 30 75
and
National Bureau of Economic Research
(Visitor 1982-83)
1050 Massachusetts Avenue
Cambridge, MA 02138
(617) 868-3900

1. Introduction

This paper examines the effect of OPEC price increases on the welfare of a group of oil importers. It also studies how taxes or subsidies on oil imports or capital flows could alter the group's welfare.

The analysis is conducted using a general-equilibrium model that describes the behavior of two actors, OPEC and a large oil-importing bloc called Industria.[1/] The analysis is explicitly intertemporal and takes into account endogenous changes in saving, investment and employment.

There is by now an extensive literature on the macroeconomic effects of oil price increases. However, this literature mostly relies on a static, small-economy analysis that maintains fixed values for world interest rates and traded-goods prices when oil prices increase. Such a partial-equilibrium and nonintertemporal approach is limiting and could be misleading.[2/]

Two general-equilibrium models of the world economy within an intertemporal framework have been developed, one by Sachs (1982) and one by Dixit (1981), but their models and emphases differ from ours.

Sachs relies on a simulation model to analyze the effects of oil price increases on such variables as output and prices, capital accumulation, the real interest rate and employment. He also studies the scope for fiscal and monetary policies in moderating output declines. We rely on a theoretical construct rather than on a simulation model. Our use of the duality method, much inspired by Dixit and Norman (1980), allows us to use rather general specifications for preferences and

technology instead of special functional forms, and it makes for easily derived and interpreted results. Our focus is also different. We are concerned primarily with the welfare effects of oil price increases. Our calculations show that these welfare effects encompass more than just the loss of current income due to higher import bills. Of course, we, too, will be interested in how OPEC price increases change interest rates and employment, since those changes have implications for Industria's welfare. In addition, we are interested in how Industria might use specific tax/subsidy policies to improve its welfare.

Turning to Dixit's work, we note that his model contains an exogenously-given oil stock, competitive oil pricing by OPEC and the Hotelling rule which relates present and future oil prices to each other. The model is used to examine the effect of changes in the stock of oil on wages, interest and oil prices. It also offers a fascinating look at how the income distribution effects depend on the endowments of capital, labor and oil. Dixit assumes all oil revenues and nothing else is invested (hence present capitalists and workers save nothing) and that full employment prevails. In contrast, our model specifies exogenous oil prices, enabling us to distinguish between the impact of present and future oil price increases on a host of real variables, including production, consumption, saving, investment, employment and trade balances. We, too, are concerned about welfare effects, but our goal is to measure these effects taking into account the interactions between oil markets, international capital flows and employment variations.

Our results show that a rigorous calculation of Industria's changed welfare must take into account not only the lost income due to the decline in

Industria's present and future oil terms of trade, but the change in the real rate of interest. A fall in interest can improve Industria's welfare if it becomes a future net exporter of final goods to OPEC. This fall in interest, what we call an improvement in Industria's intertemporal terms of trade, can moderate the fall in welfare resulting from the deterioration in the oil terms of trade.

Since the analysis of welfare effects depends crucially on how the interest rate responds to oil price increases, the factors that influence its response are carefully examined. We find that the change in interest depends partly on the size of OPEC's present marginal propensity to consume relative to Industria's, on whether or not factors of production are "cooperative,"[3/] on how severely current production contracts and on the nature of the oil price increase-whether it is temporary, permanent or expected to occur in the future. We are able to qualify precisely under what conditions the interest rate might fall.[4/]

The welfare effects of oil price increases are calculated under conditions of both real wage flexibility and rigidity in Industria. We find that in the latter case, oil price increases unambiguously cause greater welfare losses since employment falls and the intertemporal terms of trade may improve very little or even worsen.

The model provides a rich variety of other results as well. For example, one can assess the effects of oil price increases on oil imports, consumption, investment, wages or employment, and the trade balances in the present and in the future. Among other things, it is shown that when factors are cooperative, permanent and future oil price increases have an uncertain impact in investment in Industria; they have a direct negative effect through

decreased profitability, but they also stimulate investment by inducing a fall in the rate of interest. If flexible, real wages fall in the present when there are OPEC price increases, but they may actually rise in the future, even if labor and oil are cooperative, should investment increase sufficiently due to the fall in interest.

In addition to assessing the effects of oil price increases, the paper examines the general-equilibrium effects of taxes or subsidies on oil imports and on capital flows. This analysis is motivated by the fact that for given oil prices, oil importers may be able to alter the intertemporal terms of trade in their favor. For instance, the oil-importing bloc can increase its welfare by subsidizing oil imports at present and taxing them in the future. It can also improve its welfare by imposing an impediment to international capital flows, namely taxing capital imports from OPEC.

The paper is organized as follows. Section 2 specifies how Industria and OPEC are modeled and how the world equilibrium is defined. In Section 3, the welfare effects on Industria are derived under assumptions of full employment, flexible wages and perfect capital mobility. Section 4 deals with the determination of the interest rate and Section 5 with the effect of OPEC price increases on the trade balance and on wages. Section 6 introduces rigid wages and variable employment. Section 7 considers the welfare effects of tariffs/subsidies on Industria's oil imports. Section 8 looks at the case where Industria restricts capital movements by taxing borrowing from OPEC. Section 9 presents some concluding comments.

2. Industria, OPEC and World Equilibrium

Consider a world of two countries, Industria and OPEC. There are two dates, indexed $t = 1$ and 2, which are called the present and the future. At each date final goods and oil are produced. Industria produces and exports the final goods, using as inputs imported oil and domestic capital and labor. Industria does not produce any oil, nor can it store oil. OPEC produces and exports only oil, at zero cost of production, to satisfy any quantity Industria demands. Both OPEC and Industria consume only final goods. At each date final goods and oil are traded at relative prices set by OPEC. The two countries can also borrow and lend from each other on a world credit market with an endogenously-determined rate of interest. In the present, neither country has inherited debt from the past.

Let us look at Industria, modeling first its production side. We let $x^t = f^t(k^t, \ell^t, z^t)$ denote its well-behaved concave production function at date t, where x^t is output of final goods, k^t the stock of capital, ℓ^t the employment level, and z^t the oil input. We shall represent the production side with the help of the GDP functions $Y^t(1, q^t, k^t, \ell^t)$, defined by $Y^t(1, q^t, k^t, \ell^t) = \max \{x^t - q^t z^t : x^t = f^t(k^t, \ell^t, z^t)\}$, where q^t is the price of oil in terms of final goods in period t. [5/] The first argument of the GDP functions, the price of final goods, is set equal to unity since we shall use final goods as the numeraire.

We let Y_1^t, Y_q^t, Y_k^t and Y_ℓ^t denote the partials of the GDP functions with respect to the arguments 1, q^t, k^t, and ℓ^t, respectively. Using standard properties of GDP functions, we know that under competitive conditions, final goods supply, demand for oil and the demand price for

labor in terms of final goods can be given by

$$(2.1) \qquad x^t = Y_1^t, \quad z^t = -Y_q^t, \quad \text{and } w^t = Y_\ell^t .$$

Next we specify Industria's investment behavior. Industria can use present final goods for investment in order to increase its future capital stock. Hence we have $k^2 = k^1 + i^1$, where i^1 is investment in the present and k^1 is the present capital stock, which is predetermined and exogenously given. There is no investment in the future.

Industria has access to a competitive world credit market with a final goods discount factor δ (one over one plus the final goods rate of interest). The equilibrium level of investment maximizes the excess of the present value of future GDP over the cost of present investment, i.e. the investment (demand) function $I^1(q^2, \delta, k^1, \ell^2)$ solves the optimization problem $\max_{i^1}\{\delta Y^2(1, q^2, k^1 + i^1, \ell^2) - i^1\}$. It follows that the investment function fulfills the first-order condition

$$(2.2) \qquad \delta Y_k^2(1, q^2, k^1 + I^1(q^2, \delta, k^1, \ell^2), \ell^2) = 1,$$

that is, the present value of the future marginal product of capital equals unity, the price of present investment goods.

Next we consider Industria's employment behavior. We assume initially that labor is fixed in total supply at each date and that flexible wages ensure a given (full) employment level ℓ^t at each date. This full employment assumption will be relaxed in Section 6.

This completes the discussion of the supply side. Let us now deal

with Industria's demand side. Regarding welfare and demand, we assume that Industria can be represented by a well-behaved utility function $U(c^1, c^2)$, where c^1 and c^2 are consumption of final goods in the present and future. We let $E(1, \delta, u)$ be the corresponding (present value) expenditure function defined by $E(1, \delta, u) = \min\{c^1 + \delta c^2 : U(c^1, c^2) > u\}$.[6/] The expenditure function gives the minimum present value of expenditure on consumption, measured in present final goods, required to reach a given utility level.

By standard properties of expenditure functions, the partials of the expenditure function with respect to its first two arguments are equal to the Hicksian compensated demand functions for present and future final goods. That is,

$$(2.3) \qquad c^1 = E_1 \quad \text{and} \quad c^2 = E_\delta \, .$$

Industria's intertemporal budget constraint can now be given by

$$(2.4) \qquad E(1, \delta, u) + I^1(q^2, \delta, \ell^2) = Y^1(1, q^1, \ell^1) + \delta Y^2(1, q^2, I(q^2, \delta, \ell^2), \ell^2),$$

where we have suppressed the given capital stock k^1. The budget constraint states that the present value of expenditure on consumption and investment equals the present value of GDP in the present and the future. It can be understood as expressing the welfare level u as an implicit function of oil prices, the discount factor, and employment levels. Given this welfare level, output of final goods, oil imports, wages and

consumption in the present and the future are given by (2.1) and (2.3), and present investment is given by the investment function.

The budget constraint can alternatively be written as equating the present value of expenditure on consumption to national wealth, W, defined as $W = (Y^1 - I^1) + \delta Y^2$, the sum of present GDP, net of investment, and the present value of future GDP.

Let us now look at OPEC. We assume that OPEC sets oil prices q^1 and q^2 and supplies the world market (Industria) with the amount of oil it demands. Since we disregard any costs of producing oil, as well as oil's exhaustibility, OPEC wealth, W^o, is simply the present value of total oil output, $q^1z^1 + \delta q^2z^2$. With regard to welfare and demand, as for Industria, we let OPEC be represented by the expenditure function $E^o(1, \delta, u^o)$, where u^o is OPEC's welfare level, and the partials E^o_1 and E^o_δ are OPEC's consumption at the two dates, with

$$(2.5) \qquad c^{o1} = E^o_1 \text{ and } c^{o2} = E^o_\delta.$$

OPEC's intertemporal budget constraint is

$$(2.6) \qquad E^o(1, \delta, u^o) = q^1z^1 + \delta q^2z^2 \equiv W^o,$$

which states that the present value of OPEC's consumption expenditure equals the present value of oil output at the two dates, i.e. OPEC's wealth. The budget constraint expresses OPEC's welfare level as an implicit function of oil prices, the discount factor, and Industria's oil imports.

Let us next look at a world equilibrium, where the oil market and the final goods market clear at each date. Due to Walras' Law, we can disregard one of the market equilibria, and we choose to disregard the future final goods market. Consequently, a world equilibrium can be represented by the two countries' budget constraints, (2.4) and (2.6); equilibrium in the oil markets at the two dates,

$$(2.7) \qquad -y_q^1 = z^1 \text{ and } -y_q^2 = z^2,$$

where Industria's oil demand equals OPEC's supply; and equilibrium in the present final goods market,

$$(2.8) \qquad E_1 + E_1^o + I^1 = y_1^1 = x^1,$$

where world consumption and investment of present final goods equal Industria's supply. For exogenous oil prices q^1 and q^2 and given (full) employment levels ℓ^1 and ℓ^2, equations (2.4) and (2.6) - (2.8) determine the two countries' welfare levels, u and u^o, the discount factor δ, and Industria's oil imports, z^1 and z^2.

Industria's trade balances in the present and the future, b^1 and b^2, can also be calculated since they are merely the excess of GDP over domestic absorption at each date. We find that

$$(2.9) \qquad b^1 = y^1 - E_1 - I^1 \text{ and}$$

$$b^2 = y^2 - E_\delta .^{7/}$$

From (2.4) and the homogeneity of the expenditure function it follows that trade is balanced over time in present value terms, but not necessarily at each date, i.e.

$$(2.10) \qquad b^1 + \delta b^2 = 0.$$

3. Welfare Effects

Let us first look at the effects of oil price increases on Industria's welfare under conditions of wage flexibility and constant (full) employment levels at each date. Differentiating the budget constraint (2.4) and manipulating terms, we find that the change in Industria's welfare, du, is given by

$$(3.1) \qquad E_u du = -z^1 dq^1 - \delta z^2 dq^2 + b^2 d\delta,$$

where E_u is the partial of the expenditure function with respect to the welfare level and represents the inverse of the marginal utility of wealth, which is positive. The expression $E_u du$ can be interpreted as a wealth-equivalent welfare change.

Equation (3.1) indicates that Industria's welfare is affected by changes in the oil terms of trade that occur each period, $-z^1 dq^1$ and $-\delta z^2 dq^2$, and by changes in the intertemporal terms of trade, $b^2 d\delta$. Oil price increases deteriorate Industria's oil terms of trade and worsen its welfare, but they may improve the intertemporal terms of trade, for instance if the discount factor increases (the rate of interest falls) and Industria

has a future trade surplus (and hence a deficit - a net debtor position - in the present). We also note that the degree of substitutability in production between oil, capital and labor has no direct (first-order) effect on Industria's welfare.

Equation (3.1) provides a rigorous measure of the general-equilibrium effects on the rest of the world of oil price increases, in contrast to many studies which merely evaluate these effects by looking at the changed oil bill. We see that the change in the intertemporal terms of trade must also be included in the calculation, since it has an important effect on Industria's welfare as well.

4. The Discount Factor

In order to determine more completely the effects of oil price increases on Industria's welfare, we must examine the determinants of the endogenous change in the discount factor. Since the present final goods market always clears, we know that any disturbance which creates an incipient excess supply of present final goods must lead to an increase in the discount rate (a fall in the real rate of interest) to stimulate present spending.

To make the discussion clearer, we first look at the effect on the discount factor of a temporary oil price increase, where only the present oil price increases ($dq^1 > 0$ and $dq^2 = 0$). We next examine the effect of a future oil price increase ($dq^1 = 0$, $dq^2 > 0$). Given the model's linearity, we then also know the effect on the discount factor of a permanent oil price increase, where both present and future oil prices

increase (dq^1, $dq^2 > 0$).

To calculate the effect on the discount factor of a temporary oil price increase, we differentiate the market equilibrium conditions for oil and present final goods, (2.7) and (2.8). After some substitutions and manipulations,[8] we get

$$(4.1) \qquad d\delta = [\underset{(-)}{x_q^1} + (\underset{(+)}{C_w^1} - \underset{(+)}{C_w^{o1}})z^1 - \underset{(-)}{C_{wq}^{o1}z_q^1}]dq^1/A \gtrless 0,$$

where $A > 0$ is required for stability.[9]

According to (4.1), a temporary oil price increase has an uncertain impact on the discount factor. The ambiguity arises because the oil price increase reduces both production and consumption of present final goods.

The bracketed expression in (4.1) can be viewed as the change in the excess supply of present final goods due to the exogenous increase in present oil prices. The first term in brackets is the production effect. It tends to lower excess supply. The reason is straightforward. An increase in today's oil price reduces the demand for oil inputs, since the own price substitution effect is always negative, and reduced oil inputs depress current output since oil has a positive marginal product.[10]

The second term in brackets reflects a transfer effect in consumption. Industria reduces its consumption of present final goods because it faces a deterioration in today's oil terms of trade. OPEC, meanwhile, increases its consumption. If, consistent with the empirical regularities of the 1970s, we assume that Industria's marginal propensity to consume present

goods out of wealth exceeds OPEC's ($C_W^1 > C_W^{o1}$), there is a net drop in world consumption of present final goods. This transfer effect tends to increase excess supply.

Finally, the last term in brackets shows the fall in OPEC income and consumption caused by Industria's reduced oil imports.

We conclude that a temporary oil price increase will cause an incipient excess supply of present final goods and <u>increase</u> the discount factor if the drop in world consumption dominates the drop in production.

Les us next look at the effect on the discount factor of a <u>future</u> oil price increase. Again, differentiating the market equilibrium conditions and manipulating, we get

$$(4.2) \qquad d\delta = [\underset{(-)}{-I_q^1} + (\underset{(+)}{C_W^1} - C_W^{o1})\delta z^2 - \underset{(-)}{C_W^{o1}}(\underset{(+)(-)}{z_q^2 + z_k^2 I_q^1})]dq^2/A > 0.$$

An increase in the future oil price creates an incipient excess supply of present final goods since it lowers consumption and investment but does not affect production. Consequently, the discount factor must <u>increase</u>.

The bracketed expression in (4.2) is the change in the excess supply of present final goods (at constant discount factor) caused by the increase in the future oil price. It is positive. The reasons are several. First, investment demand for present final goods falls if capital and labor are cooperative. This follows because a future oil price increase will lower future oil inputs, which under the cooperative assumption will decrease the future marginal product of capital and hence present

investment.[11]

Second, there is a transfer effect due to the change in the future oil terms of trade. It leads to reduced consumption for present final goods by the same argument used for a temporary oil price increase.

Third, there is a drop in OPEC consumption due to the fall in future oil imports. A future increase in oil prices reduces the demand for future oil inputs directly and also has an indirect effect. If oil and capital are cooperative, investment falls and future oil demand will fall because the marginal product of oil will be less with a smaller future capital stock.[12]

Hence, the fall in both investment and consumption give rise to an incipient excess supply of present final goods, so the discount factor must <u>increase</u> in response to the higher future oil price.

In order to determine the effect on the discount factor of a <u>permanent</u> oil price increase, we merely sum the right-hand sides of (4.1) and (4.2). All terms contribute to creating an incipient excess supply except the production effect. If the latter is dominated, the discount factor <u>rises</u> for a permanent oil price increase.

Henceforth, we assume that a rise in the discount factor is the 'normal' case, both for temporary and permanent oil price increases, and we know that the discount factor unambiguously rises for a future oil price increase.

Our analysis of how the discount factor responds to permanent oil price increases supports some of the simulation results obtained by Sachs (1982), but it offers a richer understanding of the phenomena at hand. Since it is based on an analytical general-equilibrium model, one

that incorporates the supply side and capital accumulation as well as the demand side and a general specification of preferences, we can easily isolate the various pressures on the discount factor when oil prices change. We see that these pressures arise from both the supply and demand sides of the market for present final goods. Moreover, the final outcome depends importantly on our assumptions that (1) capital and oil are cooperative and that (2) OPEC's marginal propensity to consume present final goods is less than Industria's.

Taking into account our knowledge about the effects of oil price increases on the discount factor, we can say something further about the change in Industria's welfare. If Industria is initially a net borrower from OPEC, and will thus have a future trade surplus ($b^2 > 0$), Industria will get an intertemporal terms of trade gain in welfare when oil prices increase which can moderate its static oil terms of trade losses.

5. The Trade Balance and Wage Response

We can use our results about the effects of oil price increases on the discount factor and Industria's welfare to calculate the change in Industria's present trade balance. We merely differentiate (2.9), which after some manipulations yields

$$(5.1) \qquad db^1 = -z^1 dq^1 - C_W^1 (-z^1 dq^1 - \delta z^2 dq^2 + b^2 d\delta)$$
$$-E_{1\delta} d\delta - I_q^1 dq^2 - I_\delta d\delta \gtrless 0.$$

Oil price increases have an uncertain impact on Industria's trade balance because they may reduce its absorption as well as its GDP. The first term on the right-hand side of (5.1) is the fall in GDP caused by the deterioration in Industria's oil terms of trade. It worsens the trade balance. The second term represents the change in Industria's consumption caused by its changed welfare. If oil price increases reduce Industria's welfare, its consumption of present final goods will decline, improving the trade balance. The third term is an intertemporal consumption substitution effect. It worsens the trade balance since the rise in the discount factor increases Industria's consumption of present final goods. The last two terms show the total change in investment, which may rise or fall when oil and capital are cooperative. We conclude that a necessary and sufficient condition for Industria's trade balance to deteriorate is for the drop in GDP and the rise in absorption due to the increase in the discount factor to dominate.

We also note that the smaller is OPEC's marginal propensity to consume in the present and the smaller is OPEC's intertemporal substitution in consumption, the more likely it is that Industria's present trade balance will deteriorate.[13/] Indeed, in the limiting case where OPEC consumes nothing in the present, Industria's trade balance unambiguously deteriorates. We can best see this by observing that OPEC's trade balance is the negative of Industria's, and in the limiting case where OPEC's present consumption is zero, OPEC's trade balance is merely $b^{ol} = q^1 z^1$. Diferentiating b^{ol} gives

$$(5.2) \qquad db^{ol} = -db^1 = z^1 dq^1 + q^1 dz^1,$$

which is positive if OPEC's oil revenues increase in the present. Thus in this limiting case, both a temporary and a permanent oil price increase deteriorate Industria's trade balance, whereas a future oil price increase has no impact. Indeed, in the limiting case, the present trade balance is independent of the discount factor.

Finally, let us also examine the wage response to oil price increases when the discount factor also increases. Differentiating (2.2), we find that for $dq^t > 0$, $d\delta > 0$,

$$(5.3) \qquad dw^1 = Y^1_{\ell q} dq^1 < 0, \text{ and}$$

$$(5.4) \qquad dw^2 = \underset{(-)}{Y^2_{\ell q}} dq^2 + \underset{(+)}{Y^2_{\ell k}} dI^1 = \underset{(-)}{Y^2_{\ell q}} dq^2 + \underset{(+)(-)}{Y^2_{\ell k} I^1_q} dq^2 + \underset{(+)(+)}{Y^2_{\ell k} I^1_\delta} d\delta \gtrless 0$$

We see from (5.3) that the present wage unambigously falls if labor and oil are cooperative ($Y^1_{\ell q} < 0$), which we have always assumed.[14/] We see from (5.4) that the change in future wages is ambiguous. The future oil price increase, at constant discount factor, unambiguously decreases future wages, directly when labor and oil are cooperative ($Y^2_{\ell q} < 0$) and indirectly through a decrease in investment, if capital and oil, and labor and capital are cooperative ($Y^2_{\ell k} > 0$, $I^1_q < 0$).[15/] However, an increase in the discount factor, at constant oil prices, increases investment, which increases wages if capital and labor are cooperative. We hence note the interesting possibility that the future wage rate could be pushed up by an oil price increase, in spite of labor and oil being cooperative.

6. Rigid Wages and Variable Employment

So far we have assumed flexible wages and full employment in Industria. In this section we shall examine the consequences of rigid real wages and changes in employment (unemployment) in the present, with flexible wages and full employment in the future.

If the present wage is fixed in terms of present final goods, the level of employment is given by the condition that the demand price for labor, Y_ℓ^1, equals the wage, w^1. This condition determines the present employment function $L^1(w^1, q^1, k^1)$, which hence fulfills

$$(6.1) \qquad Y_\ell^1(1, q^1, k^1, L^1(w^1, q^1, k^1)) = w^1.$$

The change in the present employment level in response to an oil price increase will be given by

$$(6.2) \qquad d\ell^1 = L_q^1 dq^1 < 0.$$

Employment falls under our assumption that labor and oil are cooperative, and we note that this variation in employment is due to rigid wages.[16/]

To examine the effects on welfare, the discount factor, the trade balance, etc., when wages are rigid, we could now go through the same exercise as in Sections 3-5, taking into account that employment is now endogenous. However, a simpler way to understand how variable employment alters our earlier results is to find the effects, at constant oil prices, of the change in employment given by (6.2). The effects of changes in oil prices with endogenous changes in employment will simply be the sum of the effects of oil price changes at full employment and the effects of the employment change at constant oil prices.

Hence, let us differentiate our system with constant oil prices

and with full employment in the future, but with present employment falling by $d\ell^1$ as in (6.2). Differentiating the budget constraint (2.4), we get

$$(6.3) \qquad E_u du = b^2 d\delta + \underset{(-)}{w^1 d\ell^1} .$$

Industria's welfare is directly influenced by the decrease in present GDP, $w^1 d\ell^1$, which we call the (wealth equivalent) employment effect (on welfare). Industria's welfare is also influenced by a change in the intertemporal terms of trade, but since oil prices are constant, there are no static oil terms of trade effects.

In order to determine completely the employment effect on welfare, we must determine its effect on the discount factor. Hence, we differentiate the equilibrium conditions for the oil markets and the present final goods market, (2.7) and (2.8), to get

$$(6.5) \qquad d\delta = \underset{(+)}{[x_\ell^1} - C_w^1 w^1 - \underset{(+)}{C_w^{o1} q^1 z_\ell^1}] d\ell^1/A < 0.$$

Equation (6.5) indicates that a fall in employment decreases the discount factor.[17/] The reason is that supply of final goods falls in the present only, whereas the drop in world consumption of final goods is spread over both periods. Hence the discount factor must decrease to prevent any excess demand.

It follows that Industria faces a deterioration in its intertemporal

terms of trade. Combined with the adverse employment effect, Industria's welfare unambiguously deteriorates when employment falls.

If we try to determine the change in Industria's present trade balance by differentiating (2.9), it appears ambiguous, since the fall in employment will worsen it but the decrease in the discount factor will improve it. If we look instead at OPEC's present trade balance, where $b^{o1} = q^1 z^1 - E_1^o$, we see that it changes by

$$(6.6) \qquad db^{o1} = -db^1 = q^1 z_\ell^1 d\ell^1 - C_W^{01}(-b^2 d\delta + q^1 z_\ell^1 d\ell^1 + \delta q^2 z_k^2 I_\delta^1 d\delta) - E_{1\delta}^o d\delta \ .$$

The drop in Industria's employment reduces Industria's demand for oil inputs (oil and labor are cooperative) and consequently OPEC's oil production falls by $q^1 z_\ell^1 d\ell^1$. If OPEC's marginal propensity to consume in the present and its intertemporal substitution in consumption are both small, or if OPEC consumes no final goods in the present, then the production effect dominates, and OPEC's trade balance worsens while Industria's improves.

Combining our results of a fall in present employment at constant oil prices with our previous results of an increase in oil prices at full employment, we can make the following statement: a given oil price increase causes a smaller rise in the discount factor when wages are rigid in the present period rather than flexible. The discount factor may even remain unchanged or decrease.[18/] When present wages are rigid, a given oil price also causes a greater drop in Industria's welfare, and

its trade balance is likely to deteriorate less.

7. Tariffs/Subsidies on Oil Imports

As we have shown in Sections 3 and 4, oil price increases change Industria's welfare by altering the oil terms of trade and the intertemporal terms of trade. Recognizing this, Industria may wish to pursue tariff policies that alter the terms of trade in its favor. Since OPEC fixes the relative price of oil at each date, Industria can do nothing about turning the oil terms of trade in its favor. However, it may be able to improve its intertemporal terms of trade through specific tariff policies. In this section, we consider the welfare consequences of Industria imposing tariffs or subsidies on oil imports under the restrictive assumption that OPEC does not retaliate. In the next section, we examine the consequences of Industria imposing a tax on capital imports.

Let t^1 and t^2 denote the tariffs/subsidies per unit oil import in the present and future, respectively. With q^1 and q^2 denoting the relative prices of oil at the two dates, Industria's domestic relative prices of oil at the two dates will be $(q^1 + t^1)$ and $(q^2 + t^2)$. Positive values for t^1 and t^2 signify import tariffs, negative values import subsidies. Not to burden our terminology too much, let us henceforth refer to t^1 and t^2 as (net) tariffs only, implicitly interpreting negative values as subsidies.

Let the initial situation be one of zero tariffs, and assume flexible wages and full employment. If Industria then imposes small tariffs, the

welfare effects can be calculated by differentiating a modified budget constraint for Industria that takes tariff revenues into account.[19/] We find that

$$(7.1) \qquad E_u du = b^2 d\delta,$$

that is, Industria's welfare change depends only on the change in its intertemporal terms of trade.

To find the effect of tariffs on the discount factor, we first make the simplifying assumption that OPEC consumes only in the future. Then, by differentiating modified market equilibrium conditions, we get[20/]

$$(7.2) \qquad d\delta = [x_q^1 dt^1 - I_q^1 dt^2]/\tilde{A},$$

still assuming zero initial tariffs.

We see that a small tariff increase on oil imports in the present period reduces output by $x_q^1 dt^1$ but has no effect on demand. Hence the discount factor must fall to prevent any excess demand for present final goods. Consequently, Industria will suffer a deterioration in its intertemporal terms of trade and a welfare loss if it taxes present oil imports. Somewhat surprisingly, Industria should <u>subsidize</u> rather than tax oil imports in the present to improve its welfare.

Regarding changes in future tariffs, note that a small increase would decrease investment ($I_q^1 dt^2 < 0$) when oil and capital are cooperative, and the discount factor would have to increase to maintain equilibrium

in the market for present final goods. A tax on future oil imports thus improves Industria's welfare. Hence, under the restrictive assumption that oil prices are exogenous, Industria should subsidize present oil imports and tax future ones.

Let us also briefly look at these issues when there are rigid wages and variable employment in the present. The change in employment given a change in the present tariff is

$$(7.3) \qquad d\ell^1 = \underset{(-)}{L_q^1} dt^1.$$

A small subsidy ($dt^1 < 0$) increases employment whereas a small tariff decreases it. From the analysis in Section 6 it follows that a subsidy which increases employment improves Industria's welfare. We conclude that rigid wages in the present provide a separate case for Industria to subsidize its present oil imports.

8. Restricted Capital Mobility

So far we have assumed that there is perfect mobility of financial capital between Industria and OPEC, in the sense that the two countries have access to the same competitive world credit market with the same rate of interest. We shall now deal with the case when there are some impediments to international capital movements. We again assume full employment and that OPEC consumes only in the future.

We choose to represent the impediments to international capital mobility by having Industria impose a small tax on interest payments to

OPEC. This tax draws a wedge between Industria's home rate of interest, r^I, and the world, i.e. OPEC's, rate of interest, r, such that $r^I > r$. Equivalently, the tax draws a wedge, $\tau > 0$, between OPEC's discount factor, δ, and Industria's, $\delta - \tau$. [21] We assume that the tax revenues are distributed to Industria's consumers in a lumpsum way. Then, assuming full employment and an initial zero tax level, we differentiate a modified budget constraint with respect to a small tax ($d\tau > 0$), getting $E_u du = b^2 d\delta$.[22] That is, Industria's welfare change depends only on changes in the intertemporal terms of trade.

Differentiating a modified market equilibrium condition with respect to a small tax ($d\tau > 0$) gives [23]

$$(8.1) \qquad d\delta = [\underset{(+)}{\Sigma_{\perp\delta}} d\tau + \underset{(+)}{I^1_\delta} d\tau]\, \tilde{A}^{-1} > 0.$$

The small tax on interest paid to OPEC reduces Industria's absorption of present final goods. Under the restrictive assumption that oil prices remain unchanged, it follows that the world discount factor increases and Industria's welfare indeed improves when it imposes a small tax on interest payments. [24]

When wages are rigid and employment is variable in the present, the imposition of a tax on interest has no effect on employment. Consequently, we conclude that Industria can improve its welfare by taxing capital imports even when present wages are rigid.

We might ask whether we can rank oil tariffs/subsidies and capital import taxation in terms of their effect on Industria's welfare. For full

employment, we might compare the right-hand sides of (7.2) and (8.1). Without further specifying the parameters it cannot be said which policy would have a larger effect on the discount factor and hence on welfare, although intuition might lead us to think that capital import taxation would be a more direct way of influencing the discount factor. Note, though, that if there are presently rigid wages, a present oil subsidy, in contrast to capital import taxation, does affect employment and have an additional influence on Industria's welfare. If the employment effect is strong enough, subsidies on present oil imports will have a larger effect on Industria's welfare than taxes on capital imports.

9. Concluding Remarks

Under the assumption that factors of production are cooperative, we have shown that OPEC price increases deteriorate Industria's oil terms of trade but they may improve its intertemporal terms of trade if interest rates fall and Industria is a net borrower in the present. We have also established precise conditions under which interest rates may, in fact, fall. The analysis also indicates that OPEC price increases may increase or decrease present investment in Industria, that Industria's trade balance is likely to deteriorate, that current wages will fall but future wages may rise or fall depending on the change in investment.

If wages are rigid in Industria, oil price increases decrease employment when factors are cooperative. The fall in the rate of interest is then reduced or even reversed compared to the case with flexible wages. Industria's welfare deteriorates more and its trade

balance deteriorates less.

We have also shown that for given oil prices, oil importers can improve their welfare by subsidizing present oil imports and taxing future oil imports or by taxing capital imports from OPEC.

We should also mention some limitations of the analysis. Since our model is designed to concentrate on certain general-equilibrium interrelationships, especially the effects of oil price increases or tax policies on Industria's welfare, a two-country framework is adequate. However, in focussing on just two blocs - OPEC versus the oil importers - the model abstracts from intra-bloc differences. Some implications of these intra-bloc differences are analyzed in Dixit (1981) and in Marion and Svensson (1982). Our model also ignores the special feature of oil as an exhaustible resource and the nature of OPEC's pricing decision. The relative price of oil in terms of final goods is treated as exogenous. While this is acceptable given the questions being asked, the welfare implications of changes in oil prices that are optimally set by OPEC need to be studied as well.

While these issues provide important areas for further research, the principal concern of this paper is to analyze some important general-equilibrium interrelationships in detail and so to increase our understanding of the effects of oil price increases and tax policies on important macroeconomic variables. In spite of including endogenous international capital flows, capital accumulation in Industria, and an endogenous world rate of interest, we have nevertheless been able to derive fairly clear-cut results, both under conditions of full employment and unemployment. Our analysis has also made explicit the precise qualifications of these results.

FOOTNOTES

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1/ Calling the oil-importing bloc Industria is inspired by Calvo and Findlay (1978).

2/ For explicitly intertemporal but partial-equilibrium analyses of the effects of oil price increases, see Bruno (1982), Marion (1981), Obstfeld (1980), Sachs (1981) and Svensson (1981). For a general-equilibrium analysis within the monetary approach to the balance of payments and hence without an explicitly intertemporal framework, see Schmid (1976).

3/ Throughout our analysis we will maintain the assumption that capital, labor and oil are cooperative in Industria, in the technical sense that their cross partials in the production functions are positive. This assumption makes sense for this level of aggregation, and it is not very restrictive. The definition of cooperation is different from the usual definitions of complementarity or substitutability in production which make reference to the sign of the partial of the demand for a factor with respect to the price of another factor at a given output level. See Berndt and Wood (1979) for a thorough discussion of such

Hicksian complementarity/substitutability between energy and other factors. Factors can be Hicksian substitutes yet cooperative in our sense. This is indeed the case with the specific separable technologies discussed by Berndt and Wood where $x = f[g(k, e), h(\ell, m)]$ and $f(\cdot)$, $g(\cdot)$ and $h(\cdot)$ are linearly homogenous, e is the energy input, and m is the input of non-energy materials.

A frequent assumption in the literature is weak separability between oil and a capital-labor composite factor. Then we have $x = f[v(k, \ell), z]$, where $f(\cdot)$ and $v(\cdot)$ are linearly homogenous. It is readily checked that in this case capital, labor and oil are cooperative in our sense.

4/ There is evidence that world interest rates fell during the 1973-1979 period. See Sachs (1981, pp. 223-35).

5/ See Dixit and Norman (1980) or Varian (1978) for a discussion of the properties of GDP, or revenue, functions.

6/ See Dixit and Norman (1980) or Varian (1978) for a discussion of the properties of expenditure functions.

7/ As can be seen from inspection of (2.9), Industria's present trade surplus is equal to GDP (Y^1) minus domestic absorption ($E_1 + I^1$). Alternatively, the trade surplus represents the excess of domestic saving ($Y^1 - E_1$) over investment (I^1). Furthermore, since $Y^1 = x^1 - q^1 z^1$, we can write the trade surplus as exports ($x^1 - E_1 - I^1$) minus imports ($q^1 z^1$). Since there is no initial debt and hence no interest payments in the present, the present trade surplus is also equal to the current-account surplus and represents the net accumulation of foreign assets.

8/ In the differentiation we use (3.1) and we also use (2.6) to get $E_u^o du^o = z^1 dq^1 + \delta z^2 dq^2 - b^2 d\delta + q^1 dz^1 + \delta q^2 dz^2$. We define C_W^1 as Industria's marginal propensity to consume present final goods out of wealth, where $C_W^1 = E_{1u}/E_u$. We define OPEC's MPC as C_W^{o1}, where $C_W^{o1} = E_{1u}^o/E_u^o$. We assume that consumption is normal in both periods, so that $0 \leq C_W^1, C_W^{o1} \leq 1$.

9/ Here A is the derivative of world excess demand for present goods with respect to the discount factor. If oil prices are given, oil markets are always in equilibrium, and the discount factor adjusts to clear the market for present final goods, then a necessary and sufficient condition for stability is $A > 0$. That is, a rise in the discount factor (a fall in the rate of interest) increases excess world demand for present final goods (decreases net saving). Note that A is given by $E_{1\delta} + E_{1\delta}^o + I_\delta^1 + (C_W^1 - C_W^{o1})b^2 + C_W^{o1}\delta q^2 z_k^2 I_\delta^1$. The first three terms represent the intertemporal substitution effects and the investment effect of a discount factor change. They are all positive. (The consumption cross substitution effects are positive since there are only two consumer goods, present and future final goods.) The investment substitution effect is positive since $I_\delta^1 = -Y_k^2/\delta Y_{kk}^2 > 0$; investment always increases with the discount factor. The fourth term is a transfer effect. It is positive under the plausible assumptions that Industria has a current trade deficit (and hence a surplus in the future, with $b^2 > 0$), and that OPEC's marginal propensity to consume present final goods is less than Industria's ($C_W^1 - C_W^{o1} > 0$). The last term is also positive since an increase in investment due to an increase in the discount factor ($I_\delta^1 > 0$) leads to an increase in future oil imports ($z_k^2 I_\delta^1 d\delta > 0$)

under our assumption that capital and oil are cooperative. Hence all terms are indeed positive, and there is no conflict between the assumption of stability and our other assumptions.

10/ In terms of the GDP function we have $z_q^1 = Y_{qq}^1 \leq 0$ by convexity of the GDP function in prices, and $x_q^1 = Y_{1q}^1 = -qY_{qq}^1 = qz_q^1 \leq 0$ since by zero homogeneity of Y_q in prices, $Y_{ql} + qY_{qq} = 0$. In terms of the production function we have $z_q^1 = 1/f_{zz} \leq 0$ and $x_q^1 = f_z/f_{zz} \leq 0$ since $f_{zz} \leq 0$.

11/ We have, by differentiating (2.2), $I_q^1 = -Y_{kq}^2/Y_{kk}^2 = -f_{kz}^2/(f_{zz}^2 f_{kk}^2) < 0$ if $f_{kz}^2 > 0$.

12/ We have $z_k^2 = -Y_{qk}^2 = -f_{kz}^2/f_{zz}^2 > 0$, if $f_{kz}^2 > 0$.

13/ OPEC's present trade balance is $b^{ol} = q^1 z^1 - E_1^o$. Differentiating, we find that

$$db^{ol} = \underset{(+)}{(z^1 dq^1 + q^1 dz^1)} - C_W^{ol}\underset{(+)}{(z^1 dq^1 + \delta z^2 dq^2 - b^2 d\delta + q^1 dz^1 + \delta q^2 dz^2)} - \underset{(+)\,(+)}{E_{1\delta}^o d\delta}.$$

The smaller is C_W^{ol} and $E_{1\delta}^o$, the more likely it is that $db^{ol} > 0$ and hence $db^1 < 0$.

14/ We have $Y_{\ell q}^1 = f_{\ell z}^1/f_{zz}^1 < 0$ if $f_{\ell z}^1 > 0$. An increase in the oil price reduces oil inputs which reduces the marginal product of labor.

15/ We have $Y_{\ell k}^2 = f_{\ell k}^2 - f_{\ell z}^2 f_{kz}^2/f_{zz}^2 > 0$ if $f_{\ell z}^2$, $f_{kz}^2 > 0$.

16/ Note that by differentiating (6.1), $L_q^1 = -Y_{\ell q}^1/Y_{\ell\ell}^1 < 0$ if $Y_{\ell q}^1 < 0$.

17/ The proof is as follows. The present GDP function fulfills $Y^1 = x^1 - q^1 z^1$. Hence $w^1 = Y_\ell^1 = x_\ell^1 - q^1 z_\ell^1 > 0$, and we get $x_\ell^1 - w^1 - q^1 z_\ell^1 = 0$. Since $0 < C_W^1 < 1$ and $0 < C_W^{ol} < 1$ and w^1, $z_\ell^1 > 0$,

we get $x^1_\ell - C_w w^1 - C^{ol}_w q^1 z^1_\ell > 0$. Since we are investigating the case of an employment decrease, $d\ell^1 < 0$.

18/ Sachs' (1982) simulation results also indicate that real wage rigidity may reduce or even reverse the fall in short-term interest rates caused by an oil price increase.

19/ The budget constraint is $E(1, \delta, u) + I^1(q^2 + t^2, \delta) = Y^1(1, q^1 + t^1) + \delta Y^2(1, q^2 + t^2, I^1(q^2 + t^2, \delta)) + t^1 z^1 + \delta t^2 z^2$, where the last two terms represent the tariff revenues. Differentiation gives $E_u du + b^2 d\delta + t^1 dz^1 + \delta t^2 dz^2$. By assumption, $t^1 = t^2 = 0$ initially.

20/ Differentiating the market equilibrium conditions gives $\tilde{A} d\delta = x^1_q dt^1 - I^1_q dt^2 - C^1_w (t^1 z^1_q dt^1 + \delta t^2 z^2_q dt^2 + \delta t^2 z^2_k I^1_q dt^2)$. The terms in parentheses drop out by the assumption of zero initial tariffs. The term $\tilde{A}$ equals $E_{1\delta} + I^1_\delta + C^1_w b^2 + C^1_w \delta t^2 z^2_k I^1 > 0$.

21/ It can be shown that $\tau = (r^I - r)\delta/(1 + r^I)$. Having Industria impose a tax on interest payments to OPEC is formally equivalent to imposing a (present value) tax τ per unit of future net exports, b^2. The tax decreases the relative price between future and present final goods, i.e. the discount factor, from δ to $\delta - \tau$, and gives rise to (present value) tax revenues τb^2. What we have here is just an intertemporal example of Lerner's classic theorem on the equivalence between import and export taxes. In our framework, taxing present capital imports, $-b^1$, is equivalent to taxing the corresponding future capital exports, b^2. We refer to Marion and Svensson (1981) for details.

22/ The budget constraint is $E(1, \delta - \tau, u) + I^1(q^2, \delta - \tau) = Y^1(1, q^1) + (\delta - \tau)Y^2(1, q^2, I^1(q^2, \delta - \tau)) + \tau b^2$, where the last term is the present value of the tax revenues. Differentiating gives

$E_u du = b^2 d\delta + \tau db^2$. But $\tau = 0$ initially.

23/ Here, $\tilde{A} = E_{1\delta} + I^1_\delta + (1 - (\tau/\delta))C^1_W b^2 > 0$. The term $-(\tau/\delta)C^1_W b^2$ is due to the fact that an increase in the discount factor causes a change in the future trade balance which leads to a negative tax revenue effect on welfare that reduces excess demand. This is the analogue of the usual "tariff multiplier" in standard trade theory. Since $\delta - \tau > 0$, the term $(1 - (\tau/\delta))$ is clearly positive, hence so is $\tilde{A}$.

24/ In a somewhat different context, Dixit (1981) shows that a tariff levied by the oil-importing country on present oil imports with the aim of cutting back its oil dependence reduces the present value price of future goods (δ) and harms the oil importer if it remains a net exporter of industrial goods in the future, i.e. if $b^2 > 0$.

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