

OIL PRICE INCREASE IN A TWO-SECTOR DEPENDENT ECONOMY MODEL

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This paper investigates the effects of a permanent increase in oil price on the accumulation of capital stock and the current account responses using a dynamic version of the two-sector dependent economy model developed by Brock and Turnovsky(1994), and Turnovsky and Sen(1995). For this purpose, oil, an imported intermediate input, is put into both sectors as a production factor. Then, we perform both long run steady state analysis and short run transitional dynamics in response to the unexpected rise in oil price. In the long run analysis, the value of capital stock at a new steady state is higher and thus current account deteriorates by making use of the negative relationship between capital stock and foreign traded bond. In addition, the consumption of two goods shows unclear responses even though they move in the same direction. The short run transitional dynamics is, however, too simple due to the constancy of the relative price of nontraded good at its steady state value; the relative price of nontraded good jumps up or down, but capital stock accumulates along the adjustment path, and thus the foreign traded bond (evolution of current account) moves in the opposite direction. This implies the current account may deteriorate during the adjustment period.

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I. INTRODUCTION

The drastic increase in world oil price has become a major obstacle to the efforts to get out of the severe economic recession in some non-oil producing countries. This oil price shock is due to both the reduction in supply by the OPEC agreements and the increase in world wide demand by the recovery of the world economy. As we experienced, the oil price shocks in the 1970s had

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tremendously affected those economies, which in turn gave hard times to the world economy for a long time. Oil, in most of the oil importing countries, is an important input as a production factor as well as a final consumption good. For this reason, oil price increase influenced the macroeconomic performances significantly by altering the investment and savings, which also affected the economy's current account.

Reflecting on the oil price shocks in the 1970s, Obstfeld(1980) and Sachs(1981) showed the reduced domestic investment due to the oil price increase might improve(lessen) current account surplus(deficit). In particular, Obstfeld(1980) derived the above results by the assumption of near-zero price elasticity of demand for oil. In addition, both Svensson((1984) and Marion(1984) analyze that the current account response is ambiguous to the permanent shock, while it deteriorates to the temporary shock. In Svensson((1984), he argues that the decrease in savings worsens the current account with no change in investment defining the current account as the difference between investment and savings. Besides, Marion(1984), with the introduction of nontraded sector as well as traded sector into the model provides that the effects on the current account of the oil price increase depend critically upon the difference in the relative production technology between the two sectors. Butlin(1985) explores the increase in the price of imported intermediate input has an ambiguous effect on the current account in an optimizing model with the rate of time preference and given world interest rate. And Matsuyama(1987), extending the Blanchard's open economy model, shows that the current account response is a combination of transfer payments abroad and capital taxation so that if the former effect dominates, the economy will run a current account deficit; if the latter dominates, it will run a current account surplus. With those outcomes, he criticized Obstfeld(1980)'s analysis.

More recently, Sen(1991) attacks the results of Svensson(1984) by showing that both permanent and temporary shock deteriorate the current account in an infinite time horizon model without capital mobility. Most of the previous works, however, do not explicitly consider nontraded sector which is significant in relation to the investment except for Marion(1984). But Marion(1984) employed a two-period model and hence dynamic adjustments of the economy were not possible to the external shock. In addition to such drawbacks, they did not introduce capital stock to the model, which thus made it difficult to analyze the effect on the capital stock accumulation together with current account response to such an external shock.

Based upon those observations, the current paper considers both traded and nontraded sector with capital stock being explicitly included to analyze the effects on capital stock and current account of a rise in the imported intermediate input price by employing dynamic version of dependent economy model. The dependent economy model, which was firstly introduced by Salter(1959) and Swan(1960), was developed into the dynamic model by Brock and Turnovsky (1994), and Turnovsky and Sen(1995) through Dornbusch(1974, 1980). The

dependent economy model differs from the small open economy model in that it includes nontraded sector as well as traded sector, and the relative price of nontraded good (real exchange rate) is endogenously determined by the domestic market equilibrium, while the price of traded good is exogenously given in the world market.

Then the model enables us to analyze the dynamic adjustments of real exchange, capital stock accumulation and the current account response to the external shock such as oil price increase. The reason why the model includes the nontraded sector is that nontraded goods such as structures, road and ports play an important role in the determination of investment and thus affect responses of current account. For simplicity, we assume nontraded good is used for both consumption and investment, but traded good is for consumption only.

The purpose of this paper, thus, is to show the dynamic adjustments of the economy in terms of capital stock accumulation and the response of current account in response to the oil price increase in a non-oil producing economy using a two-sector dependent economy model with an infinite time horizon. For this object, the imported intermediate input is put into both sectors as a production factor. Then we perform both steady state long run analysis and short run transitional dynamic analysis to analyze the effects of permanent oil price increase.

The rest of the paper is organized as follows: Section II describes the analytical framework and macroeconomic equilibrium in a reduced form. Besides, the short run responses of consumption, labor allocation across sectors and the optimal amount of oil are analyzed. Section III describes equilibrium dynamics. Then long run steady state analysis and short run transitional dynamics following a permanent increase in world oil price are analyzed in section IV and V, respectively. Section VI provides concluding remarks.

II. THE ANALYTICAL FRAMEWORK

The economy under consideration is inhabited by one single infinite lived agent, who provides one unit of inelastic labor supply at a competitive wage and accumulates capital stock for rental at a competitively determined rental price. We employ two standard neoclassical production functions to produce traded good using capital, labor and the imported input such as oil, $F(K_1, L_1, N_1)$, and nontraded good, $H(K_2, L_2, N_2)$. All three factors are mobile across the sectors. The capital stock accumulates over time, but fixed at a point of time, i.e., $K = K_1 + K_2$, while the labor supply is always fixed at one, $\bar{L} = L_1 + L_2 = 1$, abstracting from the population growth. For simplicity, any two inputs are cooperative as usually assumed, which implies the cross partials are positive, $F_{KL} > 0$, $F_{KN} > 0$, $F_{LN} > 0$ and $H_{KL} > 0$, $H_{KN} > 0$, $H_{LN} > 0$. This means that the production function is linear homogeneous in all three factors.

Characterizing the features of traded good, the traded sector is relatively capital intensive and the nontraded sector relatively labor intensive, and capital and labor are better substitutes for oil than each other.¹ In addition, the relative price of nontraded good, which is a real exchange rate, is determined by the market equilibrium condition for nontraded good. But the price of imported oil is exogenously given at p . Besides that oil has no sufficient substitutes lead to a low price elasticity of demand considering non-oil producing countries as Obstfeld(1980) assumed. As noted in the above, the traded good is consumed domestically and abroad, but the nontraded good is used for consumption and investment.

In addition to the accumulation of capital stock, the representative agent accumulates foreign traded bonds (b) which pay the fixed world interest rate (\bar{r}). In this model, the role of the government is just to maintain the balanced budget.

Then we have the following instantaneous budget constraint of representative agent expressed in terms of traded good.

$$\dot{b} = F(K_1, L_1, N_1) + \sigma H(K - K_1, 1 - L_1, N - N_1) + \bar{r}b - x - \sigma y - \sigma I - pN \quad (1)$$

where σ is the relative price of nontraded good; and x, y denote the consumption levels of traded and nontraded good, respectively.

In addition, the capital stock accumulates without depreciation according to

$$\dot{K} = I \quad (2)$$

The resource constraints are as follows.

$$K = K_1 + K_2, \quad L = L_1 + L_2 = 1, \quad N = N_1 + N_2 \quad (3)$$

The representative agent's problem is to choose the consumption of two goods (x, y), the allocation of capital stock, labor and oil between the two sectors ($L_1, L_2, K_1, K_2, N_1, N_2$), the optimal amount of oil (N) and foreign bond holding (b) to maximize the intertemporal utility function.

$$\text{Max} \int_0^{\infty} U(x, y) e^{-\beta t} dt \quad (4)$$

subject to equation (1), (2) and the initial conditions; $b(0) = b_0, K(0) = K_0$. We assume that the instantaneous utility function is strictly concave, i.e., $U_{xx} < 0, U_{yy} < 0$ and the two goods are Edgeworth complementary, so that $U_{xy} > 0$. The

¹ We have the following factor intensity rankings, $a_{KF}/a_{KH} > a_{NF}/a_{NH} > a_{LF}/a_{LH}$, as discussed by Jones and Easton (1983), where a_{ij} denotes the input of factor i required to produce a unit of output in the j th sector. Factor intensity reversals are assumed not to occur.

rate of time preference of the agent (β) is a constant which, in a perfect capital mobility, must be equal to the given world interest rate to ensure the steady state. In order for solving the standard intertemporal optimization problem, we set up the following Lagrangian.

$$L = e^{-\beta t} [U(x, y) + \lambda(-\dot{b} + F(K_1, L_1, N_1) + \sigma H(K - K_1, 1 - L_1, N - N_1) + \bar{r}b - x - \sigma y - \sigma \dot{K} - \rho N)] \quad (5)$$

where λ is a Lagrange multiplier associated with domestic bond holding. The usual optimality conditions for consumption are

$$U_x(x, y) = \lambda \quad (6a)$$

$$U_y(x, y) = \sigma \lambda \quad (6b)$$

Equation (6a) and (6b) describe the usual marginal rate of substitution conditions for consumers. And the following efficiency conditions in production should be satisfied.

$$F_K(K_1, L_1, N_1) = \sigma H_K(K - K_1, 1 - L_1, N - N_1) \equiv r^k \quad (6c)$$

$$F_L(K_1, L_1, N_1) = \sigma H_L(K - K_1, 1 - L_1, N - N_1) \equiv w \quad (6d)$$

$$F_N(K_1, L_1, N_1) = \sigma H_N(K - K_1, 1 - L_1, N - N_1) = \rho \quad (6e)$$

where r^k and w denote rental price of capital and the real wage rate, respectively. These equations assert that the marginal products of capital, labor and oil must be equal across the sectors to determine the allocation of each factor across the two sectors. And the optimal amount of oil is determined by equation (6e) at a given world price.

In addition, the dynamic variables evolve according to

$$\dot{\lambda} = \lambda(\beta - \bar{r}) \quad (6f)$$

$$\dot{\sigma} = \bar{r}\sigma - r^k \quad (6g)$$

where r^k is the rental price of capital which is determined by that the marginal product of capital and labor between the two sectors must be equal. The equality of β and \bar{r} at steady state implies $\dot{\lambda} = 0$ everywhere. Thus λ , the marginal utility of wealth in the form of foreign traded bond is always constant at its steady state value, i.e., $\bar{\lambda} = \tilde{\lambda}$ ($\tilde{\lambda}$ is a steady state value, which will be determined below). Finally, we need to impose the transversality conditions to satisfy the agent's intertemporal budget constraint.

$$\lim_{t \rightarrow \infty} \lambda b e^{-\beta t} = \lim_{t \rightarrow \infty} \lambda \sigma K e^{-\gamma t} = 0 \tag{6h}$$

For macroeconomic equilibrium, defining:

$$k_i = \frac{K_i}{L_i} \quad n_i = \frac{N_i}{L_i} \quad i=1,2, \quad N_1 = \alpha N, \quad N_2 = (1-\alpha)N$$

$$F\left(\frac{K_1}{L_1}, 1, \frac{N_1}{L_1}\right) \equiv f(k_1, n_1), \quad f_i > 0, \quad f_{ij} > 0, \quad f_{ii} < 0, \quad f_{ij} f_{jj} - f_{ij}^2 > 0. \quad (i \neq j)$$

$$H\left(\frac{K_2}{L_2}, 1, \frac{N_2}{L_2}\right) \equiv h(k_2, n_2), \quad h_i > 0, \quad h_{ij} > 0, \quad h_{ii} < 0, \quad h_{ij} h_{jj} - h_{ij}^2 > 0. \quad (i \neq j)$$

with the assumption of $k_1 > k_2$ and $n_1 > n_2$ enables us to summarize the static part of macroeconomic equilibrium by the following set of relationship with $\lambda = \bar{\lambda}$:

$$U_x(x, y) = \bar{\lambda} \tag{7a}$$

$$U_y(x, y) = \sigma \bar{\lambda} \tag{7b}$$

$$f_k(k_1, n_1) = \sigma h_k(k_2, n_2) \equiv r^k \tag{7c}$$

$$f_n(k_1, n_1) = \sigma h_n(k_2, n_2) = p \tag{7d}$$

$$f(k_1, n_1) - k_1 f_k(k_1, n_1) - n_1 f_n(k_1, n_1) \\ = \sigma [h(k_2, n_2) - k_2 h_k(k_2, n_2) - n_2 h_n(k_2, n_2)] \equiv w \tag{7e}$$

and resource constraints:

$$K = k_1 L_1 + k_2 (1 - L_1) \tag{7f}$$

$$N = n_1 L_1 + n_2 (1 - L_1) \tag{7g}$$

The last two equations (7f) and (7g) govern the resource allocation between the two sectors together with $\bar{L} = 1 = L_1 + L_2$.

Equations (7a) and (7b) describe the usual optimality conditions for consumers, (equality of marginal rate of substitution between two goods and the relative price of nontraded good). For the static part of equilibrium, we can solve equations (7a) and (7b) for short-run responses in the following way.

$$x = x(\bar{\lambda}, \sigma), \quad x_{\bar{\lambda}} < 0, \quad x_{\sigma} < 0 \tag{8a}$$

$$y = y(\bar{\lambda}, \sigma), \quad y_{\bar{\lambda}} < 0, \quad y_{\sigma} < 0 \tag{8b}$$

Then, using the efficiency conditions in production, equations (7c) - (7e), we may solve k_1, k_2, n_1 and n_2 with respect to σ, p .

$$k_1 = k_1(\sigma, p); \quad k_2 = k_2(\sigma, p); \quad n_1 = n_1(\sigma, p); \quad n_2 = n_2(\sigma, p) \quad (9)$$

Expressions for the partial derivatives of equation (9) are reported in the Appendix. The relative price effects appearing in equation (9) are complicated. In general, those effects depend upon the relative sectoral intensities of production in capital stock, i.e., $k_1 > k_2$, or $k_1 < k_2$. But, they also depend upon the complementarity or substitutability of capital with oil in production as similarly discussed in Brock and Turnovsky (1994).²

Utilizing the solutions of equation (9), we can easily derive the solutions for the rental price of capital and for the wage rate in terms of σ and p .

$$\begin{aligned} r^k &= r^k(\sigma, p), & w &= w(\sigma, p) \\ \frac{\partial r^k}{\partial \sigma} &= \frac{-h}{k_1 - k_2} < 0, & \frac{\partial r^k}{\partial p} &= \frac{-\sigma(n_1 - n_2)}{k_1 - k_2} < 0 \end{aligned} \quad (10a)$$

$$\frac{\partial w}{\partial \sigma} = \frac{k_1 h}{k_1 - k_2} > 0, \quad \frac{\partial w}{\partial p} = \frac{\sigma k_1 (n_1 - n_2)}{k_1 - k_2} - \sigma n_1 \begin{matrix} \geq 0 \\ < 0 \end{matrix} \quad (10b)$$

The partial derivatives shown in the above equation indicate that the rental price of capital and the wage rate both depend critically upon the relative sectoral intensities of production in capital stock. The increase in the relative price of nontraded good raises the wage rate by attracting more labors from the traded sector and thus lowers the rental price of capital since more capital is released if and only if traded sector is relatively capital intensive, i.e., $k_1 > k_2$.

The solutions of equation (9) immediately enable us to solve the labor allocation by making use of equation (7f).

$$\begin{aligned} L_1 &= \frac{K - k_2(\sigma, p)}{k_1(\sigma, p) - k_2(\sigma, p)} \equiv L_1(K, \sigma, p), & \frac{\partial L_1}{\partial K} &= \frac{1}{k_1 - k_2} > 0, \\ \frac{\partial L_1}{\partial \sigma} &= \frac{-1}{k_1 - k_2} \left(L_1 \frac{\partial k_1}{\partial \sigma} + (1 - L_1) \frac{\partial k_2}{\partial \sigma} \right) < 0, \\ \frac{\partial L_1}{\partial p} &= \frac{-1}{k_1 - k_2} \left(L_1 \frac{\partial k_1}{\partial p} + (1 - L_1) \frac{\partial k_2}{\partial p} \right) \begin{matrix} \leq 0 \\ > 0 \end{matrix} \end{aligned} \quad (11)$$

Having determined the sectoral labor allocation, it also follows that the optimal amount of oil is determined from equation (7g), that is,

² Brock and Turnovsky (1994) analyzes two types capitals, structure and equipment, in a dependent economy model, where both capitals are mobile across sectors. Thus the response of intensities depends upon the complementarity or substitutability of structure with equipment in production.

$$N = n_1(\sigma, p)L_1(K, \sigma, p) + n_2(\sigma, p)(1 - L_1(K, \sigma, p)) \equiv N(K, \sigma, p)$$

$$\frac{\partial N}{\partial K} = \frac{n_1 - n_2}{k_1 - k_2}, \quad \frac{\partial N}{\partial \sigma} = (n_1 - n_2) \frac{\partial L_1}{\partial \sigma} + \left(L_1 \frac{\partial n_1}{\partial \sigma} + (1 - L_1) \frac{\partial n_2}{\partial \sigma} \right) \quad (12)$$

The level of imported intermediate input is determined by capital stock evolving over time, the relative price of nontraded good and the exogenously given p . The partial effects of oil depend not only upon the relative sectoral intensities of production in capital stock but also upon the relative sectoral intensities of production in oil. The first partial derivative in equation (12) implies that the level of oil will increase when capital stock rises, i.e., $\partial N / \partial K > 0$ (N and K are complements) if and only if the relevant sector is relatively intensive both in capital and oil. For example, if traded sector uses both capital stock and oil more intensively than nontraded sector ($n_1 > n_2$ and $k_1 > k_2$), the partial response ($\partial N / \partial K$) implies that the two inputs are complements. Otherwise, we will have $\partial N / \partial K < 0$, which means the two inputs are substitutes (these definitions of complements and substitutes are followed from Brock and Turnovsky (1994)). In case of $k_1 > k_2$ only, the two inputs (K, N) may or may not be complements depending upon the sectoral intensities of oil. If we assume that traded sector uses oil more intensively than nontraded sector ($n_1 > n_2$), the two inputs move in the same direction (complements). If $n_1 < n_2$, the two inputs represent substitutes according to the definitions in the above.

Following from the determination of sectoral labor allocation and the level of oil, we can immediately determine its sectoral allocation between the two sectors using the definition of sectoral allocation factor (α).

$$\alpha = \frac{n_1(\sigma, p)L_1(K, \sigma, p)}{N(K, \sigma, p)} \equiv \alpha(K, \sigma, p), \quad \frac{\partial \alpha}{\partial K} = \frac{(1 - \alpha)n_1 + \alpha n_2}{N(k_1 - k_2)} > 0 \quad (13)$$

Since we started with the solutions of factor intensities, we can easily determine the allocation factor in terms of capital stock, the relative price of nontraded good and p . The response of sectoral allocation factor (α) depends only upon the sectoral intensities of production in capital stock regardless of the relative ratios of oil to labor in two sectors when the capital stock changes with σ and p held constant. This can be explained by the technological relationship between oil and capital in production function. This is contrast to the response of the level of oil to the change in capital stock where the response depends upon both intensities of capital and oil. This contrast arises in the fact that the allocation factor (α) is defined to be the amount of oil assigned to the traded sector. With $k_1 > k_2$, the output of traded sector rises as capital stock increases

(which will be shown in the below), and therefore the sector needs more oil to raise the output regardless of relative sectoral intensities of oil. The relative price effect is ambiguous, though. At the same time, we may solve for domestic outputs of two goods (Y^F , Y^H) as follows:

$$\begin{aligned}
 Y^F &= f(k_1(\sigma, p), n_1(\sigma, p))L_1(K, \sigma, p) \equiv Y^F(K, \sigma, p), \\
 \frac{\partial Y^F}{\partial K} &= \frac{f}{k_1 - k_2}, \\
 \frac{\partial Y^F}{\partial \sigma} &= f \frac{\partial L_1}{\partial \sigma} + \left(f_k \frac{\partial k_1}{\partial \sigma} + f_n \frac{\partial n_1}{\partial \sigma} \right) L_1, \\
 \frac{\partial Y^F}{\partial p} &= f \frac{\partial L_1}{\partial p} + \left(f_k \frac{\partial k_1}{\partial p} + f_n \frac{\partial n_1}{\partial p} \right) L_1
 \end{aligned} \tag{14a}$$

$$\begin{aligned}
 Y^H &= h(k_2(\sigma, p), n_2(\sigma, p))(1 - L_1(K, \sigma, p)) \equiv Y^H(K, \sigma, p), \\
 \frac{\partial Y^H}{\partial K} &= -\frac{h}{k_1 - k_2} \\
 \frac{\partial Y^H}{\partial \sigma} &= -h \frac{\partial L_1}{\partial \sigma} + \left(h_k \frac{\partial k_1}{\partial \sigma} + h_n \frac{\partial n_1}{\partial \sigma} \right) (1 - L_1), \\
 \frac{\partial Y^H}{\partial p} &= -h \frac{\partial L_1}{\partial p} + \left(h_k \frac{\partial k_1}{\partial p} + h_n \frac{\partial n_1}{\partial p} \right) (1 - L_1)
 \end{aligned} \tag{14b}$$

The output of traded sector (Y^F) will rise when the capital stock increases if and only if the sector is relatively capital intensive ($k_1 > k_2$). In this case, the output of nontraded sector is reduced. The result is consistent with the traditional Rybczynski theorem in international trade theory. In addition, we can determine the signs of partial derivatives with respect to σ and p employing the Stolper-Samulesion theorem as well as the Rybczynski theorem. Then we have $Y^F_\sigma < 0$, $Y^F_p < 0$ and $Y^H_\sigma > 0$, $Y^H_p < 0$. Thus the partial effects of the outputs of two sectors depend critically upon the sectoral intensities of capital.

Finally, the description of dynamic equations completes the macroeconomic equilibrium. Utilizing the solutions of static part and the outputs of two sectors, we can express the dynamic structure of the economy in the following ways:

$$\dot{K} = Y^H(K, \sigma, p) - y(\bar{\lambda}, \sigma) \tag{15a}$$

$$\dot{\sigma} = \bar{r}\sigma - r^k(\sigma, p) \tag{15b}$$

$$\dot{b} = Y^F(K, \sigma, p) + \bar{r}b - x(\bar{\lambda}, \sigma) - pN(K, \sigma, p) \tag{15c}$$

Equation (15a), the equilibrium in the nontraded goods market, describes the accumulation of capital stock, which is equal to any amount in excess of consumption of nontraded good. Equation (15b) just rewrites the arbitrage

condition (6g), combining it with (7c). The final equation specifies the economy's current account. The rate of accumulation of traded bond equals the excess of the domestic output of traded good over domestic consumption, plus interest earned on net foreign assets and the payments on the imported intermediate input.

III. EQUILIBRIUM DYNAMICS

The dynamic structure of the economy is simply block recursive. Thus \dot{K} and $\dot{\sigma}$ constitute the core dynamics and \dot{b} is solved by substituting the solutions of K and σ into b . Linearizing \dot{K} and $\dot{\sigma}$ around the steady state makes two linear differential equations system.

$$\begin{pmatrix} \dot{K} \\ \dot{\sigma} \end{pmatrix} = \begin{pmatrix} Y_K^H (Y_\sigma^H - y_\sigma) \\ 0 \quad (\bar{r} - r_\sigma^k) \end{pmatrix} \begin{pmatrix} K - \tilde{K} \\ \sigma - \tilde{\sigma} \end{pmatrix}. \quad (16)$$

The system represents a saddle point with eigenvalues $\mu_1 < 0$ and $\mu_2 > 0$, since the determinant of coefficient matrix is negative, $Y_K^H(\bar{r} - r_\sigma^k) < 0$. Therefore, the stable solutions for K and σ are given by

$$K(t) = \tilde{K} + (K_0 - \tilde{K}) e^{\mu_1 t} \quad (17a)$$

$$\sigma(t) = \tilde{\sigma} \quad (17b)$$

To determine the dynamics of the economy's current account, we linearize equation (15c) around steady state to get

$$\dot{b} = [Y_K^F - pN_K](K - \tilde{K}) - [Y_\sigma^F - x_\sigma - pN_\sigma](\sigma - \tilde{\sigma}) + \bar{r}(b - \tilde{b}) \quad (18)$$

The coefficients in equation (18) are evaluated at steady state. Substituting the solutions of K and σ into equation (18), we obtain:

$$\dot{b} = \bar{r}b - \bar{r}\tilde{b} + \Omega(K_0 - \tilde{K}) e^{\mu_1 t}$$

where $\Omega \equiv [Y_K^F - pN_K]$ describes the effects of the change in capital stock on the output of traded sector and the amount of payments of imported intermediate input. Assuming that the economy starts out with an initial stock of traded bond $b(0) = b_0$, the solution to b is:

$$b(t) = \tilde{b} + \frac{\Omega(K_0 - \tilde{K})}{\mu_1 - \bar{r}} e^{\mu_1 t} + [b_0 - \tilde{b} - \frac{\Omega}{\mu_1 - \bar{r}}(K_0 - \tilde{K})] e^{\bar{r}t}. \quad (19)$$

Making the solution consistent with intertemporal budget constraint, we obtain:

$$b_0 - \tilde{b} = \frac{\Omega}{\mu_1 - \tilde{r}} (K_0 - \tilde{K}) \quad (20)$$

Then, the solution becomes:

$$b(t) = \tilde{b} + \frac{\Omega(K_0 - \tilde{K})}{\mu_1 - \tilde{r}} e^{\mu_1 t} = \tilde{b} + \frac{\Omega}{\mu_1 - \tilde{r}} (K(t) - \tilde{K}). \quad (21)$$

Equation (21) describes the relationship between the holding of foreign traded bond and the accumulation of capital stock. Here, it is important to determine the sign of Ω . Ω reflects the effects of the change in capital stock on the output of traded sector and the amount of payments of imported intermediate input. Since the traded sector is relatively capital intensive and the two inputs are cooperative (K, N) , both the output of traded sector and the imports of intermediate input increase. While either sign is possible, we assume that the former effects dominate the latter effects. Thus we have $\Omega > 0$.³ With $\Omega > 0$, equation (21) represents a negative relationship between the accumulation of capital stock and the holding of foreign traded bond. Note that equation (20) describes the steady state relationship between the stock of foreign traded bond and capital stock, in which steady state values (\tilde{K}, \tilde{b}) depend upon the initial values (K_0, b_0) . This implies that the temporary shock produces permanent effects.⁴

For steady state equilibrium, the dynamic variables should stop to evolve, i. e., $\dot{K} = \dot{\sigma} = \dot{b} = 0$. With $\sigma = \tilde{\sigma}$, the steady state equilibrium of the economy is given by the following set of equations:

$$U_x(\tilde{x}, \tilde{y}) = \tilde{\lambda} \quad (22a)$$

$$U_y(\tilde{x}, \tilde{y}) = \tilde{\sigma}\tilde{\lambda} \quad (22b)$$

³ Since the sign of Ω depends upon both the output response of traded good (Y^F) and the response of imported intermediate input (N) to the change in capital stock (K), which in turn rely on the factor intensities being assumed as the traded sector is relatively intensive both in capital stock and intermediate input ($k_1 > k_2$ and $n_1 > n_2$), Ω will be either positive or negative. Then, with the assumption of $n_1 > n_2$ as discussed following Jones and Easton (1983), Ω becomes positive in case of $k_1 < k_2$. While Ω will be either signs depending upon the relative magnitudes as pointed out in the above, in case of $k_1 > k_2$. Thus assuming that the output effect is greater than the input effect associated with the change in the capital stock leads to $\Omega > 0$. The opposite case of $\Omega < 0$ results in quite unrealistic outcomes of the non-oil producing economies where the deterioration of current account was observed from the past two oil shocks in the 1970s.

⁴ The dependence of steady state values on the initial conditions is the source of the temporary policy change having permanent effect. This is emphasized by Sen and Turnovsky (1989), and Turnovsky and Sen (1991).

$$Y^H(\tilde{K}, \tilde{\sigma}, p) = \tilde{y} \quad (22c)$$

$$\tilde{r}\tilde{b} = \tilde{x} + pN(\tilde{K}, \tilde{\sigma}, p) - Y^F(\tilde{K}, \tilde{\sigma}, p) \quad (22d)$$

$$\tilde{b} - b_0 = \frac{\Omega}{\mu_1 - \tilde{r}} (\tilde{K} - K_0). \quad (22e)$$

The above five equations jointly determine the steady state values of \tilde{x} , \tilde{y} , $\tilde{\lambda}$, \tilde{K} , and \tilde{b} .

IV. THE LONG RUN RESPONSE OF CURRENT ACCOUNT

The dynamics of the system involves forward-looking behavior. Thus the short run transition is determined in part by the long run steady state. Therefore, we will start with the long run analysis. The long run effects of the increase in the imported intermediate input (oil) are analyzed and then discussed in turn. Some important results are summarized as follows.

1. Stock of capital: $\frac{d\tilde{K}}{dp} = \frac{1}{D} [Y_p^H(\tilde{\sigma}U_{xy} - U_{yy}) + A(\tilde{\sigma}U_{xx} - U_{yx})]$
2. Stock of foreign traded bond: $\frac{d\tilde{b}}{dp} = \frac{\Omega}{\mu_1 - \tilde{r}} \frac{d\tilde{K}}{dp}$
3. Relative price of nontraded good: $\frac{d\tilde{\sigma}}{dp} = \frac{1}{Y_\sigma^H} (\frac{d\tilde{y}}{dp} - Y_K^H \frac{d\tilde{K}}{dp} - Y_p^H)$

where $D \equiv Y_K^H(U_{yy} - \tilde{\sigma}U_{xy}) + A_{44}(U_{yx} - \tilde{\sigma}U_{xx}) > 0$,

$$A_{44} \equiv \frac{\mu_1 \Omega}{\mu_1 - \tilde{r}} > 0, \quad A \equiv Y_p^F - pN_p - \tilde{N}.$$

As shown in the above, the response of capital stock to the increase in the imported intermediate input depends upon the sign of A . Utilizing the nature of oil in the non-oil producing countries (no sufficient substitutes), however, we can decide its sign in a restrictive case assuming a low price elasticity of demand (ε_p) following Obstfeld(1980), i.e., $0 < \varepsilon_p < 1$. Then we have $A < 0$.⁵ Thus the stock of capital at a new steady state is higher. The reason for this outcome is that the output of nontraded good rises according to equation (14) so that the investment may increase due to the relative magnitudes in changes, even though its consumption shows ambiguous response (either rise or fall).⁶ Having determined the sign of $d\tilde{K}/dp$, we can easily determine the sign of $d\tilde{b}/dp$. This implies the current account deteriorates in response to the unexpected increase in oil price despite of the higher level of capital stock in the dynamic

⁵ With the assumption of a low price elasticity of demand, we can determine the sign of A in the following way. $A \equiv Y_p^F - pN_p - \tilde{N} = Y_p^F - \tilde{N} - (\frac{p}{N} \frac{\partial N}{\partial p})N = Y_p^F - \tilde{N}(1 + \varepsilon_p)$. If $0 < \varepsilon_p < 1$ in absolute values, then we have $A < 0$.

⁶ The investment may rise because of different magnitudes in changes of $Y_p^H > \tilde{y}_p$ in absolute values.

version of dependent economy model. This outcome is consistent with Sen(1991), but contrast with Obstfeld (1980) and Sachs(1981).⁷

From equation (22c), we can derive the response of relative price of nontraded good, which is not clear due to the ambiguity of consumption of two goods. The steady state levels of consumption of both goods are unclear, but the ratio of two goods is positive, i.e., $d\tilde{x}/d\tilde{y} = -(U_{yy} - \tilde{\sigma}U_{xy})/(U_{yx} - \tilde{\sigma}U_{xx}) > 0$. This means that the consumption of both goods moves in the same direction (either both increase or decrease) in response to the external price shock. Despite we can not determine all signs of long-run responses, the following two points should be emphasized. First, the current account may deteriorate in a restrictive case where the price elasticity of demand is low, which is consistent with the previous outcomes (Sen(1991)), but there is a negative relationship between the steady state values of capital stock and foreign traded bond(evolution of current account). Second, the consumption of both traded and nontraded goods moves in the same direction regardless of the ambiguity of long-run responses.

V. SHORT RUN TRANSITIONAL DYNAMICS

In this section, the short-run transitional dynamics in response to the permanent increase in imported intermediate input (oil) will be analyzed. Due to the constancy of the relative price of nontraded good at its steady state value, it is not worthwhile to analyze the temporary shock in addition to the permanent shock. The stable path in $K-\sigma$ space is represented in Figure 1. The initial response of the relative price of nontraded good (σ) is given by

$$\frac{d\sigma(0)}{dp} = \frac{d\tilde{\sigma}}{dp} \begin{matrix} < \\ > \end{matrix} 0 \quad (23)$$

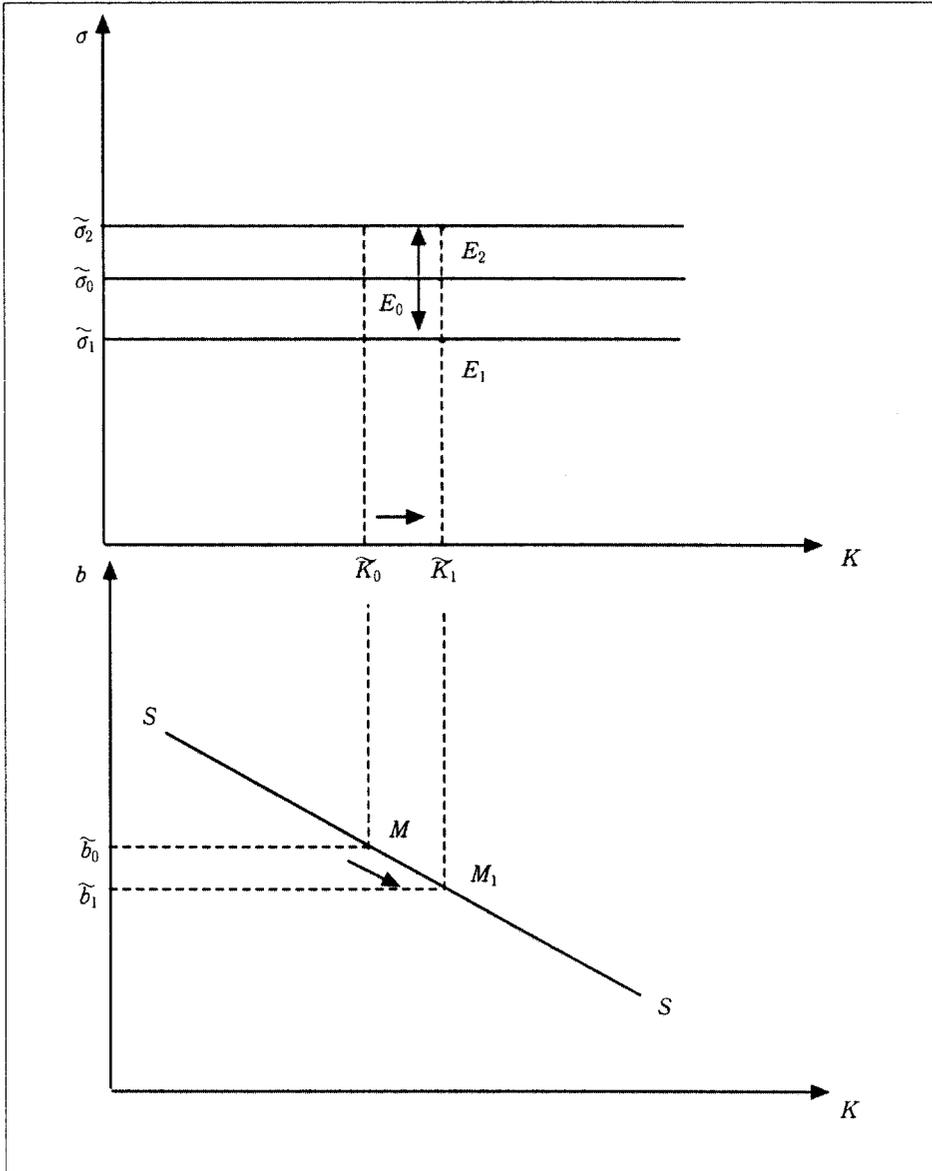
Since the long-run response of σ is not clear, the initial impact effect is also unclear. Suppose that the economy initially lies on the stable path at E with \tilde{K}_0 and $\tilde{\sigma}_0$ in Figure 1. If an unexpected permanent increase in oil price hits the economy, the horizontal stable path shifts either upward or downward due to unclear response of steady state values of σ . At the same time, the value of capital stock may rise gradually to the new steady state due to the higher level of capital stock at a new steady state. Thus we can consider two different new equilibria such as E_1 and E_2 at a new steady state. In case of E_1 , the relative price of nontraded good falls to the rise of oil price, but E_2 represents the opposite case.

Nevertheless, E_1 and E_2 both indicate capital stock at a new steady state rises as the shock hits the economy. As shown in Figure 1, the relative price

⁷ Obstfeld(1980) and Sachs(1981) show that the oil price increase will improve the current account by reducing the investment. Then, the capital stock will fall at a new steady state.

of nontraded good may either jump up or down in accordance with its long run responses, while the capital stock rises gradually following the stable path (SS) so that the current deteriorate during the adjustment path. This also implies that the response of current account depends negatively upon the response of capital stock regardless of the change in the relative price of nontraded good.

[Figure 1] The Increase in the Imported Intermediate Input



VI. SUMMARY AND CONCLUDING REMARKS

This paper investigates the effects of a permanent increase in oil price on the accumulation of capital stock and the current account responses using a dynamic version of the two-sector dependent economy model developed by Brock and Turnovsky(1994), and Turnovsky and Sen(1995). For this purpose, we perform both long run steady state analysis and short run transitional dynamics in response to the unexpected external shock. Since the model contains nontraded sector as well as traded sector with capital stock being included, the relative price of nontraded good is determined by the domestic market equilibrium, but the price of traded good is exogenously given in the world market. Assuming that capital and labor are better substitutes for oil than each other, and traded sector is capital intensive, while nontraded sector is labor intensive following Jones and Easton(1983), the dynamics of relative price of nontraded good is degenerate. For simplicity, investment is determined by the excess of the output of nontraded good over its consumption and traded good is used for consumption only.

The main outcomes are as follows. In the long run analysis, the value of capital stock at a new steady state is higher in response to the unexpected permanent increase in oil price, and thus current account deteriorates by making use of the negative relationship between capital stock and foreign traded bond. This outcome can be explained by the fact that the investment is simply determined by the excess of the output of nontraded good over its consumption according to the market equilibrium condition, not by the agent's optimization behavior assuming a low price elasticity of demand of oil. This result is consistent with Sen(1991), but is contrast with Obstfeld(1980) and Sachs(1981), though. In addition, the consumption of two goods shows unclear responses even though they move in the same direction. The paper considers only a permanent change in oil price due to the constancy of σ at its steady state value. Thus the short run transitional dynamics is too simple; the relative price of nontraded good jumps up or down, but capital stock accumulates along the adjustment path, and then the foreign traded bond moves in the opposite direction. This implies the current account may deteriorate during the adjustment period.

The model, however, has the following limitations. First, the constancy of relative price of nontraded good at its steady state value makes the dynamic adjustments too simple, which in turn results in less sufficient outcomes. Second, the investment is not optimally chosen, in stead determined by the excess of the output of nontraded good over its consumption, which makes the model feasible and tractable, but lacks of rationality.

APPENDIX

1. Partial Effects of Factor Intensities

Using equations (7c) - (7e), we obtain

$$\begin{pmatrix} f_{kk} & f_{kn} & -\sigma h_{kk} & -\sigma h_{kn} \\ f_{nk} & f_{nn} & 0 & 0 \\ 0 & 0 & \sigma h_{nk} & \sigma h_{nn} \\ \left(\begin{matrix} -k_1 f_{kk} \\ -n_1 f_{nk} \end{matrix} \right) & \left(\begin{matrix} -k_1 f_{kn} \\ -n_1 f_{nn} \end{matrix} \right) & \left(\begin{matrix} \sigma k_2 h_{kk} \\ \sigma n_2 h_{nk} \end{matrix} \right) & \left(\begin{matrix} \sigma k_2 h_{kk} \\ \sigma n_2 h_{nk} \end{matrix} \right) \end{pmatrix} \begin{pmatrix} dk_1 \\ dn_1 \\ dk_2 \\ dn_2 \end{pmatrix} = \begin{pmatrix} h_k d\sigma \\ 0 \\ -h_n d\sigma \\ (h - k_2 h_k - n_2 h_n) d\sigma \end{pmatrix}$$

That is,

$$k_1 = k_1(\sigma, p), \quad n_1 = n_1(\sigma, p), \quad k_2 = k_2(\sigma, p), \quad n_2 = n_2(\sigma, p)$$

with the following properties

$$\frac{\partial k_1}{\partial \sigma} = \frac{-hf_{nn}}{(k_1 - k_2)F} > 0, \quad \frac{\partial k_1}{\partial p} = \frac{-\sigma}{(k_1 - k_2)F} [(k_1 - k_2)f_{kn} + (n_1 - n_2)f_{nn}] \frac{\leq}{>} 0$$

$$\frac{\partial n_1}{\partial \sigma} = \frac{hf_{kk}}{(k_1 - k_2)F} > 0, \quad \frac{\partial n_1}{\partial p} = \frac{\sigma}{(k_1 - k_2)F} [(k_1 - k_2)f_{kk} + (n_1 - n_2)f_{nk}] \frac{\leq}{>} 0$$

$$\frac{\partial k_2}{\partial \sigma} = \frac{-[h + (k_1 - k_2)h_k]h_{nn} + (k_1 - k_2)h_n h_{kn}}{\sigma(k_1 - k_2)H} > 0,$$

$$\frac{\partial k_2}{\partial p} = \frac{-(k_1 - k_2)h_{kn} + (n_1 - n_2)h_{nn}}{(k_1 - k_2)H} \frac{\leq}{>} 0$$

$$\frac{\partial n_2}{\partial \sigma} = \frac{[h + (k_1 - k_2)h_k]h_{nk} - (k_1 - k_2)h_n h_{kk}}{\sigma(k_1 - k_2)H} > 0,$$

$$\frac{\partial n_2}{\partial p} = \frac{(k_1 - k_2)h_{kk} + (n_1 - n_2)h_{nk}}{(k_1 - k_2)H} \frac{\leq}{>} 0$$

where $F = f_{kk}f_{nn} - f_{kn}^2 > 0$, $H = h_{kk}h_{nn} - h_{kn}^2 > 0$.

2. Long Run Analysis

Using equations (22a) - (22e) and substitution of equation (22e) into (22d), we obtain

$$\begin{pmatrix} U_{xx} & U_{xy} & -1 & 0 \\ U_{yx} & U_{yy} & -\tilde{\sigma} & 0 \\ 0 & 1 & 0 & -Y_K^H \\ 1 & 0 & 0 & -A_{44} \end{pmatrix} \begin{pmatrix} d\tilde{x} \\ d\tilde{y} \\ d\tilde{\lambda} \\ d\tilde{K} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ Y_p^H dp \\ A \end{pmatrix}$$

where $A_{44} \equiv \frac{\mu_1 \Omega}{\mu_1 - r} > 0$, $A \equiv Y_p^F - pN_p - \tilde{N}$. If we solve the above system, we get the following long run results.

1. Stock of capital: $\frac{d\tilde{K}}{dp} = \frac{1}{D} [Y_p^H (\tilde{\sigma} U_{xy} - U_{yy}) + A (\tilde{\sigma} U_{xx} - U_{yx})]$
2. Stock of foreign traded bond: $\frac{d\tilde{b}}{dp} = \frac{\Omega}{\mu_1 - r} \frac{d\tilde{K}}{dp}$
3. Relative price of nontraded good: $\frac{d\tilde{\sigma}}{dp} = \frac{1}{Y_\sigma^H} (-\frac{d\tilde{y}}{dp} - Y_K^H \frac{d\tilde{K}}{dp} - Y_p^H)$
4. Consumption of traded good: $\frac{d\tilde{x}}{dp} = \frac{1}{D} [(U_{yy} - \tilde{\sigma} U_{xy}) (A Y_K^H - A_{44} Y_p^H)]$
5. Consumption of nontraded good: $\frac{d\tilde{y}}{dp} = \frac{-1}{D} [(U_{yx} - \tilde{\sigma} U_{xx}) (A Y_K^H - A_{44} Y_p^H)]$

where $D \equiv Y_K^H (U_{yy} - \tilde{\sigma} U_{xy}) + A_{44} (U_{yx} - \tilde{\sigma} U_{xx}) > 0$.

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