

## REAL SHOCKS AND EQUILIBRIUM REAL EXCHANGE RATE IN A SPECIFIC GOODS MODEL\*

HEE-HO KIM · JANGHWAN PARK\*\*

*We have explored a specific goods model of exchange rate determination to investigate various shocks effects on the real exchange rate. Changes in the equilibrium real exchange rate facilitate the required changes in the traded and nontraded goods prices to maintain equilibrium in the international goods markets as well as domestic markets. Likely the goods prices changes, changes in the real exchange rate depend on the sources of disturbances and market conditions. In particular, how real shocks affect the real exchange rate depends on the factor intensity of goods production and shares of consumption and production of tradable good by home and abroad.*

JEL Classification: F1, F3

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### I. INTRODUCTION

A major explanation of exchange rate determination is purchasing power parity (PPP). It is well-known, however, that the exchange rate has departed from its PPP level over prolonged periods. One interpretation is that these departures are a disequilibrium phenomenon; i.e., they occur because of wide spread violations of the law of one price, violations which are observed as a result of slow adjustment in the markets involved. This has been the typical disequilibrium approach (Frankel(1993), Meltzer(1993), and Krugman(1992)). It implies concepts of “overvaluation” and “undervaluation” of the exchange rate.

An alternative interpretation is the equilibrium view of exchange rate

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\*\* Correspondence: Hee-ho Kim, Department of Economics, Kyungpook National University, San-Gyuk Dong 1370, Buk-Gu, Tae-Gu, S.Korea 702-701, Tel) 82-53-950-5438, e-mail: kimhh@knu.ac.kr

determination (Stockman (1987), Edwards (1990), Neary (1988), Connolly and Devereux (1992), Stein (1996) and Kim (2002)). In this approach, the real exchange rate behavior reflects not the importance of a sluggish price adjustment but rather the influence of permanent real shocks. The exchange rate is always at an equilibrium value. Shocks to the system may change the equilibrium value, even when the law of one price holds and the goods markets clear continuously. Such shocks might include both monetary shocks and non-monetary shocks.

We employ an equilibrium model to reveal how certain real shocks such as resource endowment changes, technology changes, trade balance and tariff changes affect the exchange rate. The analysis focuses on the real exchange rate of PPP version.<sup>1</sup>

### Isomorphism

In the present model there are two countries, both consuming the same tradable good, and each consuming a nontradable or country-specific good. In each country the two goods can be thought of as being used to produce national welfare, as represented by national expenditure. Each national expenditure is produced with two inputs, one being the internationally traded good and the other the country-specific or nontradable good.

This model form, it turns out, is isomorphic to the two-good, three-input specific factor model of Jones (1971), Neary (1978), and others. In the two-good specific factor model (also known as a version of the Ricardo-Viner model), each good is produced with two factors, including one factor used only to produce that good and one factor common to both goods. In our "specific goods" model, there are three goods and two national expenditure bundles. Each national expenditure is composed of two goods, including one good produced and consumed only domestically (a non-traded good), and one good common to both countries (the traded good). The two national expenditure levels in the specific goods model correspond to the two goods in the specific factors model. Likewise, the three goods in the specific goods model correspond to the three factors in the specific factors model. In the specific goods model, two of the three goods are specific to particular countries, just as two of the three factors in the specific factors model are specific to particular goods. Because of this match in form with the specific factors model, it will be possible to borrow the solutions of that model almost directly for the specific goods model.

Among the variables of interest in the specific factors model are the prices of two goods, and the ratio between those prices. In the specific goods model the corresponding variables are the price levels of the two countries (i.e. the prices

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<sup>1</sup> By the PPP definition, the real exchange rate is the nominal rate adjusted for changes in the price levels in the two countries involved. There are several alternative definitions, chief among them being the price of the tradables relative to the nontradables. See Edwards (1990).

of national consumption levels). More importantly, the price ratio corresponds to the PPP real exchange rate. Thus the model provides a ready connection between the real exchange rate and other important variables of the model (individual goods prices and output levels). The model can also be extended to analyze effects of the net trade balance.

This paper is organized into five sections. This introduction is the first. Development of the simple specific goods model comprises the second. This version, labeled below the "simple" model, treats goods endowments as exogenous. The third provides comparative statics model results. In a subsequent section, more detail will be added to the supply aspects of the model along with factor markets and production. Summary and conclusion are in the last section.

## II. THE SIMPLE SPECIFIC GOODS MODEL

The specific goods model can be outlined in its simplest form with five equations (1) through (5).

$$s_{11}P_1 + s_{T1}P_T = \Pi_1 \quad (1)$$

$$s_{22}P_2 + s_{T2}P_T = \Pi_2 \quad (2)$$

$$C_1/C_{T1} = f_1(P_T/P_1) \quad (3)$$

$$C_2/C_{T2} = f_2(P_T/P_2) \quad (4)$$

$$C_{T1} + C_{T2} = X_{T1} + X_{T2} = X_T \quad (5)$$

Equations (1) and (2) define price levels for the two countries.  $P_1$  and  $P_2$  are prices of the non-traded goods of countries 1 and 2, and  $P_T$  is the price of the traded good. In keeping with the equilibrium approach to exchange rate determination, we assume operation of the law of one price; it implies equality of the tradable price in the two countries.  $\Pi_i$  is the price level in country  $i$ ,  $s_{ii}$  is the ratio of non-traded good production to real national output in country  $i$ , and  $s_{Ti}$  is the ratio of traded good production to national output in country  $i$ .

Equations (3) and (4) indicate demand conditions in the two countries. Each represents the ratio of goods consumption as function of the price ratio.  $C_i$  and  $C_{Ti}$  are the consumptions of non-traded and traded goods of country  $i$ . Finally, equation (5) is the adding up condition for the traded good, with consumption levels of that good in the two countries equaling production levels in the two

countries.  $C_{Ti}$  and  $X_{Ti}$  are the consumptions and productions of traded goods for country  $i$ , while  $X_T$  is the total production of world economy.

These equations can be differentiated in log form to find out the equilibrium real exchange rate in the system. Let the “^” symbol over each variable denote the percentage change. Then from (1) and (2) we get:

$$\phi_{11} \hat{P}_1 + \phi_{T1} \hat{P}_T = \hat{\Pi}_1 \quad (6)$$

$$\phi_{22} \hat{P}_2 + \phi_{T2} \hat{P}_T = \hat{\Pi}_2 \quad (7)$$

The terms  $\phi_{ii}$  and  $\phi_{Ti}$  are the shares of two goods in national expenditure. Note that this derivation depends on the envelope theorem property that:

$$\phi_{ii} \hat{s}_i + \phi_{Ti} \hat{s}_{Ti} = 0$$

where the national consumption in country  $i$  is composed of the optimal combination of  $C_i$  and  $C_{Ti}$ . From equations (3) and (4) come:

$$\hat{C}_1 - \hat{C}_{T1} = \eta_1 (\hat{P}_T - \hat{P}_1) \quad (8)$$

$$\hat{C}_2 - \hat{C}_{T2} = \eta_2 (\hat{P}_T - \hat{P}_2) \quad (9)$$

where  $\eta_1$  and  $\eta_2$  are elasticities of substitution between pairs of goods in consumption. From (5) we get:

$$\varphi_{T1} \hat{C}_{T1} + \varphi_{T2} \hat{C}_{T2} = \hat{X}_T = \mu_{T1} \hat{X}_{T1} + \mu_{T2} \hat{X}_{T2} \quad (10)$$

with  $\varphi_{Ti}$  and  $\mu_{Ti}$  being the shares of consumption and production of the tradable by country  $i$ . Using (8) and (9) above we can convert (10) to :

$$\varphi_{T1} \eta_1 \hat{P}_1 + \varphi_{T2} \eta_2 \hat{P}_2 - \{\varphi_{T1} \eta_1 + \varphi_{T2} \eta_2\} \hat{P}_T = \hat{X}_T - \varphi_{T1} \hat{C}_1 - \varphi_{T2} \hat{C}_2$$

Combining this with (6) and (7) yields equilibrium prices:

$$\begin{aligned} \hat{P}_1 = \frac{1}{\Delta} \left\{ \left[ \varphi_{T1} \frac{\eta_1}{\phi_{11}} + \frac{1}{\phi_{11}} \varphi_{T2} \frac{\eta_2}{\phi_{22}} \right] \hat{\Pi}_1 - \frac{\phi_{T1}}{\phi_{11}} \varphi_{T2} \frac{\eta_2}{\phi_{22}} \hat{\Pi}_2 \right. \\ \left. + \frac{\phi_{T1}}{\phi_{11}} [\hat{X}_T - \varphi_{T1} \hat{C}_1 - \varphi_{T2} \hat{C}_2] \right\} \end{aligned} \quad (11)$$

$$\begin{aligned} \hat{P}_2 = \frac{1}{\Delta} \left\{ \left[ \varphi_{T2} \frac{\eta_2}{\phi_{22}} + \frac{1}{\phi_{22}} \varphi_{T2} \frac{\eta_1}{\phi_{11}} \right] \hat{\Pi}_2 - \frac{\phi_{T2}}{\phi_{22}} \varphi_{T1} \frac{\eta_1}{\phi_{11}} \hat{\Pi}_1 \right. \\ \left. + \frac{\phi_{T2}}{\phi_{22}} [\hat{X}_T - \varphi_{T1} \hat{C}_1 - \varphi_{T2} \hat{C}_2] \right\} \end{aligned} \quad (12)$$

$$\hat{P}_T = \frac{1}{\Delta} \left\{ \varphi_{T1} \frac{\eta_1}{\phi_{11}} \hat{\Pi}_1 + \varphi_{T2} \frac{\eta_2}{\phi_{22}} \hat{\Pi}_2 - [\hat{X}_T - \varphi_{T1} \hat{C}_1 - \varphi_{T2} \hat{C}_2] \right\} \quad (13)$$

where  $\Delta = \varphi_{T1} \frac{\eta_1}{\phi_{11}} + \varphi_{T2} \frac{\eta_2}{\phi_{22}}$ . These equations are the solutions presented in Jones (1971). In that work, the equations represent the three factor prices as functions of output prices and factor endowments. In the present context, the equations indicate how the three goods prices change as functions of changes in national price levels and in total world consumption (=production) of each of the three goods. We can add to these three the solutions for  $\hat{C}_{T1}$  and  $\hat{C}_{T2}$ . First, use (11)-(13) to get relative prices in each country as a function of the national price levels and total production levels.

$$\hat{P}_1 - \hat{P}_T = \frac{1}{\Delta \phi_{11}} \left\{ \varphi_{T2} \frac{\eta_2}{\phi_{22}} (\hat{\Pi}_1 - \hat{\Pi}_2) + [\hat{X}_T - \varphi_{T1} \hat{C}_1 - \varphi_{T2} \hat{C}_2] \right\} \quad (14)$$

$$\hat{P}_2 - \hat{P}_T = \frac{1}{\Delta \phi_{22}} \left\{ \varphi_{T1} \frac{\eta_1}{\phi_{11}} (\hat{\Pi}_2 - \hat{\Pi}_1) + [\hat{X}_T - \varphi_{T1} \hat{C}_1 - \varphi_{T2} \hat{C}_2] \right\} \quad (15)$$

Then, use (8) and (9) to compute consumption levels of the traded good in each country.

$$\hat{C}_{T1} = \frac{\eta_1}{\Delta \phi_{11}} \left\{ \varphi_{T2} \frac{\eta_2}{\phi_{22}} (\hat{\Pi}_1 - \hat{\Pi}_2) + \left[ \hat{X}_T + \varphi_{T2} \frac{\phi_{11} \eta_2}{\phi_{22} \eta_1} \hat{C}_1 - \varphi_{T2} \hat{C}_2 \right] \right\} \quad (16)$$

$$\hat{C}_{T2} = \frac{\eta_2}{\Delta \phi_{22}} \left\{ \varphi_{T1} \frac{\eta_1}{\phi_{11}} (\hat{\Pi}_2 - \hat{\Pi}_1) + \left[ \hat{X}_T - \varphi_{T1} \hat{C}_1 + \varphi_{T1} \frac{\phi_{22} \eta_1}{\phi_{11} \eta_2} \hat{C}_2 \right] \right\} \quad (17)$$

These four equations indicate domestic relative prices and domestic tradables consumptions as functions of the real exchange rate (defined as the strength of the foreign currency,  $R = \frac{\Pi_1}{\Pi_2}$ ) and of production levels. In this section we treat production levels as exogenous. Later the supply aspect of the model will be enhanced.

### III. REAL SHOCKS EFFECTS ON THE REAL EXCHANGE RATE IN THE SIMPLE SPECIFIC GOODS MODEL

#### 1. Trade balance effect

Under a flexible rate regime the real exchange rate would be endogenous. The trade balance would then be exogenous, fixed by the nation's savings and investment decisions. The following section presents an analysis of that case. This system of equations will allow us to see how real shocks affect the real exchange rate. Let trade balance for country 1 be  $N$ . Since trade balance,  $N = X_T - C_T$  and  $X_T$  is exogenous, treating  $C_T$  as exogenous will have the effect of making  $N$  exogenous: that is the assumption made below. To further simplify, it will be helpful to normalize by letting the price level in country 1 ( $\Pi_1$ ) be fixed, so that  $\hat{\Pi}_1 = 0$ ; i.e., let goods in country 1 be the numeraire. Normalization of price level does not really imply sticky price. It just utilizes the theoretical assumption of monetary neutrality. Then the real exchange rate ( $R = 1/\Pi_2$ ) can be treated as endogenous to the system. Changes in the real exchange rate depend on four prices movements of goods and foreign price level derived by real shocks, adhering to law of one price and a normalized price level at home. Solution for  $\hat{R}$  in terms of the exogenous variables is:<sup>2</sup>

$$\hat{R} = -\hat{\Pi}_2 = \frac{\Delta\phi_{11}\phi_{22}}{\phi_{T2}\eta_1\eta_2} \hat{C}_T - \frac{\phi_{22}}{\phi_{T2}\eta_2} \hat{X}_T - \frac{\phi_{11}}{\eta_1} \hat{C}_1 + \frac{\phi_{22}}{\eta_2} \hat{C}_2 \quad (18)$$

It is clear from this transformation that it is reasonable to treat either the real exchange rate or trade balance as endogenous, and the other as exogenous. Given the nature of this model, both cannot reasonably be endogenous.<sup>3</sup> In (18), net exports of the home country and the real exchange rate are directly related. Net exports of the home country (by decreasing  $C_T$ ), holding the other exogenous variables constant, increase the dollar-dominated price level of the foreign country and decrease  $R$ . Such an event could come about from an increase in foreign demand for current consumption of the tradable, or from a decrease in home demand for that consumption. In either case, the initial change implies an increase in excess demand for the tradable, an increase in its price, a spillover increase in the foreign nontradable price, and an overall increase in the

<sup>2</sup> Studies by Meltzer (1993) and Zhou (1995) have devoted to investigating the effects of real shocks to the exchange rate.

<sup>3</sup> An alternative would be to model international borrowing and lending, either with a multiperiod consumer optimization problem or with a portfolio balance approach. Both add complexities without being fully satisfying, so the simpler approach of treating either the exchange rate or the trade balance as exogenous is adopted here. See Backus (1993) for a reference.

foreign price level. At home the tradables price rises; since the price level is held constant by assumption, the nontraded price must fall. (equations (11), (12), and (13) can be used to see what happens to the three prices).

These results are equivalent to the transfer problem in the literature such as Jones (1970). Traditionally, a transfer to home would appreciate the real value of the home currency when the Marshall-Lerner condition holds. Our result indicates that a transfer out of home (net export) would depreciate the home currency value.

From (18) we can also how the real exchange rate is affected by changes in goods production. An increase in home production of the tradable lowers its price, thereby having the opposite effects from the net export increase. An increase in home production of the nontraded good, on the other hand, raises  $P_T$ ; an initial excess supply lowers  $P_1$ , implying a relative increase in  $P_T$ , a positive cross effect on  $P_2$ , and thus an increase in  $\Pi_2$  and a decrease in  $R$ . An increase in production of the nontraded good abroad has the opposite set of effects. Finally, an increase in  $X_T$  lowers the real exchange rate.

## 2. Tariff effect

In addition to the shocks described above, the model can be used to analyze price distortions. In particular, let the home country be a net importer of the tradable and let  $\tau$  be a tariff factor ( $=1+\text{tariff}$ ) which it imposes on imports. Then  $P_T = \tau P_T^*$ . Reworking (16) to include a tariff we get:

$$\begin{aligned} \hat{C}_T = \frac{\eta_1}{\Delta\phi_{11}} \left\{ \varphi_{T2} \frac{\eta_2}{\phi_{22}} (\hat{\Pi}_1 - \hat{\Pi}_2) + \left[ \hat{X}_T + \varphi_{T2} \frac{\phi_{11}\eta_2}{\phi_{22}\eta_1} \hat{C}_1 \right. \right. \\ \left. \left. - \varphi_{T2} \hat{C}_2 \right] - \frac{\varphi_{T2}\phi_{T1}\eta_2}{\phi_{22}} \hat{\tau} \right\} \end{aligned} \quad (19)$$

As we expect, *ceteris paribus*, an increase in  $\tau$  causes a reduction in the consumption and imports of the tradable. This occurs even with the exchange rate treated as exogenous and held constant. It is also evident that if we treat  $C_T$  and the trade balance as exogenous instead, the tariff would have a positive effect on the real exchange rate. This would occur because the tariff would drive down the price of tradable abroad. Cross price effects would result in a drop in  $P_2$  as well.  $\Pi_2$  would thus decline and the real exchange rate would rise. This result confirms with the literature such as Edwards and Ostry (1990) indicating that a rise in tariff will appreciate the real exchange rate.<sup>4</sup>

In addition to the analysis of real exchange rate determination, the specific

<sup>4</sup> See Edwards and van Wijnbergen (1987) and Connolly and Devereux (1992) for the reverse effect of tariff on the real exchange rate.

goods model can be used to examine the trade balance determination under a fixed exchange rate system. In a fixed exchange rate regime, central banks would control the exchange rate and price levels and thus real exchange rate. In consequence, however, they would not control the trade balance. In general, the real exchange rate chosen by the banks would imply a set of relative prices leading to a non-zero trade balance. The version of the model described below reflects that feature.

In this version of the model, an increase in the real exchange rate would be accompanied by a decrease in the relative price of the tradable good on country 1 (home country) and an increase in the relative price of the tradable good in country 2 (foreign country). It would also involve an increase in tradables consumption at home and a decrease abroad. The four equations also indicate that an increase in total production (=total consumption) of the tradable or one of the nontradables would affect relative prices and individual consumption levels  $C_{T1}$  and  $C_{T2}$ . For example, an increase in production and consumption of the nontradable abroad would decrease consumption of the tradable at home and increase it abroad. Increased nontradable production abroad would result through income effects in higher tradables consumption there. The relative price of tradables would be bid up. This relative price effect would tend to lower tradables consumption at home. All this would occur even holding the real exchange rate constant. The analogy of these results with the specific factors model is strong. In that model the equations would explain relative factor prices within each industry and division of non-specific factor between the two industries.

An interesting feature is that consumption levels do not depend on the distribution of tradables production between the two countries. Whatever that distribution is, international borrowing or lending will occur to allow the chosen consumption pattern. National budget constraints are not included in the model. That is, some level of the real exchange rate would allow those constraints to be met, but there is no assurance that the authorities would choose that exchange rate level.

If we know  $X_{T1}$  and  $X_{T2}$ , production of the tradable in the two countries, we can compute the trade balance ( $N$ ), measured in quantity units. Then differentiate the trade balance  $dN = dX_{T1} - dC_{T1}$ . Because  $N$  can change sign, percentage changes here would be confusing; therefore the analysis is in terms of normal differentials. The following effects on  $N$  apply:

$$\frac{dN}{d(\Pi_1/\Pi_2)} = - \frac{(\Pi_1/\Pi_2)C_{T1}}{\Delta} \left[ \frac{\varphi_{T2}\eta_1}{\phi_{11}} \right] \left[ \frac{\eta_2}{\phi_{22}} \right] < 0 \quad (20a)$$

$$\frac{dN}{dX_{T1}} = \frac{\varphi_{T2}\eta_2/\phi_{22}}{\Delta}, \quad 0 \leq \frac{dN}{dX_{T1}} \leq 1 \quad (20b)$$



$$\frac{dN}{dX_{T2}} = -\frac{\varphi_{T1}\eta_1/\phi_{11}}{\Delta}, \quad -1 \leq \frac{dN}{dX_{T2}} \leq 0 \quad (20c)$$

$$\frac{dN}{dC_1} = -(C_{T1}/C_1) \frac{\varphi_{T2}\eta_1\eta_2/\phi_{22}}{\Delta} < 0 \quad (20d)$$

$$\frac{dN}{dC_2} = (C_{T1}/C_2) \frac{\varphi_{T2}\eta_1/\phi_{11}}{\Delta} > 0 \quad (20e)$$

In (20a) we see that a rise in the real exchange rate, which would decrease domestic competitiveness, would reduce the domestic trade balance as well.<sup>5</sup> An increase in tradables production at home would increase the balance, though by only a fraction of the production increase. Likewise, an increase in tradable production abroad would decrease the home trade balance, though again by only a fraction of the increase in foreign production of the tradable. An increase in home (foreign) production of nontradables would decrease (increase) the balance. More nontradables production in a country increases demand for the tradable as well, thus worsening that country's balance of trade.

#### IV. THE SPECIFIC GOODS MODEL WITH PRODUCTION

The previous form of the model treated production of goods as exogenous. A more fundamental model would go a step farther and treat production levels as functions of underlying resource availability and exogenous shocks. The model here treats each good as being produced with two factors, labor and capital, under the constant return to scale and according to a given level of technology. Firms maximize profits under perfectly competitive conditions and in the absence of externality. Labor and capital are perfectly mobile domestically (though completely immobile internationally), so that each factor's reward is the same in both sectors of the economy. The nontraded goods are more labor intensive than the tradable at every factor price ratio. It also includes technology change as a source of exogenous changes. In each country there are two goods. Thus it is the Heckscher-Ohlin two factor, two good model grafted to the specific goods model.

Technology change in the model is represented as augmentation of a factor or factors in an industry. It is necessary to distinguish between actual units of inputs and effective units. Let  $l_i = t_{Li}L_i$ , where  $L_i$  is labor used in good  $i$  production,  $l_i$  is effective or technology-augmented units, and  $t_{Li}$  is a technology factor which initially equals 1 and increases through time. Similar definitions can be applied to capital, so that  $k_i = t_{Ki}K_i$ .

<sup>5</sup> See Svensson and Razin (1983), Sen and Turnovsky (1989) for the relationship between real transfer and relative prices.

Let  $w$  and  $r$  be the factor prices for actual (rather than effective) labor and capital, and let  $a_{ji}$  be the input/output ratio for the  $j_{th}$  input used in the  $i_{th}$  good in country 1. The specific goods model can be extended to consider production by using equilibrium conditions in competitive markets and factor restrictions. The first two equations below are equilibriums in competitive markets, while the last two equations are labor/capital restrictions.

$$a_{L1}w + a_{K1}r = P_1$$

$$a_{LT}w + a_{KT}r = P_T$$

$$a_{L1}X_1 + a_{LT}X_T = L$$

$$a_{K1}X_1 + a_{KT}X_T = K$$

Differentiation of equilibrium conditions in the competitive markets leads to :

$$\theta_{L1}(\hat{w} - \hat{t}_{L1}) + \theta_{K1}(\hat{r} - \hat{t}_{K1}) = \hat{P}_1 \quad (21a)$$

$$\theta_{LT}(\hat{w} - \hat{t}_{LT}) + \theta_{KT}(\hat{r} - \hat{t}_{KT}) = \hat{P}_T \quad (21b)$$

where  $\theta_{ji}$  is the cost share of factor  $i$  for good  $j$ . This differentiation relies on the envelope theorem result that:  $\theta_{Li}\hat{\alpha}_{Li} + \theta_{Ki}\hat{\alpha}_{Ki} = 0$ ,  $i=1, T$  for country 1 (with a similar result for country 2). The  $\alpha$ 's indicate factor/output ratios in terms of effective factor unit,  $\alpha_{ji} = a_{ji} + t_{ji}$  for factor  $j$  used in good  $i$ . Similarly, differentiating labor and capital restrictions in country 1 yields:

$$\lambda_{L1}\hat{X}_1 + \lambda_{LT}\hat{X}_T = \hat{L} - \lambda_{L1}(\hat{\alpha}_{L1} - \hat{t}_{L1}) - \lambda_{LT}(\hat{\alpha}_{LT} - \hat{t}_{LT}) \quad (22a)$$

$$\lambda_{K1}\hat{X}_1 + \lambda_{KT}\hat{X}_T = \hat{K} - \lambda_{K1}(\hat{\alpha}_{K1} - \hat{t}_{K1}) - \lambda_{KT}(\hat{\alpha}_{KT} - \hat{t}_{KT}) \quad (22b)$$

where  $\lambda_{Li} = \frac{L_i}{L}$  and  $\lambda_{Ki} = \frac{K_i}{K}$ . Using the elasticity of substitution between factors for good  $i$  ( $\sigma_i = \frac{\partial(\frac{k_i}{j_i})}{\partial(\frac{w}{r})} \frac{(\frac{w}{r})}{(\frac{k_i}{j_i})} = \frac{\hat{\alpha}_{k_i} - \hat{\alpha}_{l_i}}{\hat{w} - \hat{r}}$ ) and following Jones (1971), we can use (21) and (22) to obtain equilibrium expressions for production of the two goods. For country 1, these are:

$$\begin{aligned}\hat{X}_1 = & \frac{1}{|\lambda|} \{ \lambda_{LT}(\hat{K} + \lambda_{K1}\hat{t}_{K1} + \lambda_{KT}\hat{t}_{KT}) - \lambda_{KT}(\hat{L} + \lambda_{L1}\hat{t}_{L1} + \lambda_{LT}\hat{t}_{LT}) \\ & - \frac{\lambda_{KT}\delta_L + \lambda_{LT}\delta_K}{|\theta|} [(\hat{P}_1 + \theta_{L1}\hat{t}_{L1} + \theta_{K1}\hat{t}_{K1}) \\ & - (\hat{P}_T + \theta_{LT}\hat{t}_{LT} + \theta_{KT}\hat{t}_{KT})] \} \end{aligned} \quad (23a)$$

$$\begin{aligned}\hat{X}_T = & \frac{1}{|\lambda|} \{ \lambda_{K1}(\hat{L} + \lambda_{L1}\hat{t}_{L1} + \lambda_{LT}\hat{t}_{LT}) - \lambda_{L1}(\hat{K} + \lambda_{K1}\hat{t}_{K1} + \lambda_{KT}\hat{t}_{KT}) \\ & + \frac{\lambda_{K1}\delta_L + \lambda_{L1}\delta_K}{|\theta|} [(\hat{P}_1 + \theta_{L1}\hat{t}_{L1} + \theta_{K1}\hat{t}_{K1}) \\ & - (\hat{P}_T + \theta_{LT}\hat{t}_{LT} + \theta_{KT}\hat{t}_{KT})] \} \end{aligned} \quad (23b)$$

Here  $|\lambda| = \lambda_{K1} - \lambda_{L1}$  and  $|\theta| = \theta_{L1} - \theta_{LT}$  indicate factor intensity conditions.  $|\lambda|$  is negative and  $|\theta|$  is positive if the nontraded goods are labor-intensive. Here  $\delta_L = \lambda_{L1}\theta_{K1}\sigma_1 + \lambda_{LT}\theta_{KT}\sigma_T$ ,  $\delta_K = \lambda_{K1}\theta_{L1}\sigma_1 + \lambda_{KT}\theta_{LT}\sigma_T$ . The expressions in (23) indicate supply behavior in the home country. A similar set of equation (21), (22), and (23) can be defined for the foreign country. A last equation will be the trade balance equation. That equation is :

$$\mu_T \hat{X}_T - \varphi_T \hat{C}_T = (N/X_T) \hat{N} \quad (24)$$

This equation is expressed in physical quantity units of the traded good. A positive value of  $N$  signifies positive net exports from the home country.

With equations (6) through (10), plus (23a) and (23b) for the home country and for the foreign country, as well as (24), we have a system of 10 equations with 10 unknowns. Here, because of the focus of this paper, the exchange rate is treated as endogenous and the trade balance as exogenous. This system of equations will allow us to see how both endowment changes and technology changes affect the real exchange rate, output levels, prices, etc.

Differentiating this system gives us a detailed picture of how major aspects of the economy, including the real exchange rate, are affected by long term trends in endowments and technology. In the following sections, we treat how supply shocks affect the economic system. The trade balance effect on the real exchange rate in the specific goods model with production appears in the appendix.

## 1. Endowment Changes

In this section, the effects of labor and capital endowment changes are considered. This takes us beyond the goods themselves to the underlying determinants of supply. Three cases will be considered - an increase in the home capital endowment (which can also be interpreted as an increase in the

capital/labor ratio), a simultaneous increase of home labor and capital endowments by equal percentages, and a simultaneous increase in endowments of labor and capital, and trade balance by equal percentages.

#### Increase in capital

First we analyze the case of an increase in the home endowment of capital. Using the set of equations described above, we find the following set of changes:

$$\frac{\hat{P}_1}{\hat{K}} = \frac{\phi_T[\mu_T\lambda_{L1} + \varphi_T\lambda_{LT}]}{|\lambda|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25a)$$

$$\frac{\hat{P}_T}{\hat{K}} = -\frac{\phi_{11}[\mu_T\lambda_{L1} + \varphi_T\lambda_{LT}]}{|\lambda|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25b)$$

$$\frac{\hat{P}_2}{\hat{K}} = -\frac{\phi_{11}[\mu_T\lambda_{L1} + \varphi_T\lambda_{LT}]}{|\lambda|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25c)$$

$$\frac{\hat{R}}{\hat{K}} = \frac{\phi_{11}[\mu_T\lambda_{L1} + \varphi_T\lambda_{LT}]}{|\lambda|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25d)$$

$$\frac{\hat{X}_1}{\hat{K}} = \frac{\mu_T\delta_{L1} - \varphi_T\lambda_{LT}\eta_1|\phi|}{|\lambda||\phi|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25e)$$

$$\frac{\hat{X}_T}{\hat{K}} = \frac{\varphi_T[\delta_L + \lambda_{L1}\eta_1|\phi|]}{|\lambda||\phi|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25f)$$

$$\frac{\hat{C}_T}{\hat{K}} = \frac{\mu_T[\delta_L + \lambda_{L1}\eta_1|\phi|]}{|\lambda||\phi|[\varphi_T(A - \eta_1) + \mu_TB]} \quad (25g)$$

$$\frac{\hat{X}_2}{\hat{K}} = \frac{\hat{X}_{T2}}{\hat{K}} = \frac{\hat{C}_{T2}}{\hat{K}} = 0 \quad (25h)$$

where

$$A = \frac{\lambda_{KT}\delta_L + \lambda_{LT}\delta_K}{|\lambda||\phi|}, \quad B = \frac{\lambda_{K1}\delta_L + \lambda_{L1}\delta_K}{|\lambda||\phi|}, \quad A^* = \frac{\lambda_{KT}^*\delta_L^* + \lambda_{LT}^*\delta_K^*}{|\lambda^*||\phi^*|},$$

$$B^* = \frac{\lambda_{K2}^*\delta_L^* + \lambda_{L2}^*\delta_K^*}{|\lambda^*||\phi^*|}.$$

$A$ 's and  $B$ 's are all negative if the nontraded goods are labor intensive ( $|\lambda| < 0$ ).

The main story of interest here is the effect of  $K$  on  $R$ , the real exchange

rate. As is evident from equation (25d), if the traded good is capital (labor) intensive ( $|\lambda| < 0$ ), the effect is unambiguously positive (negative). As the capital stock (or the capital/labor ratio) increases, relative prices at home are altered. This in turn changes the real exchange rate and the purchasing power parity relationship between the two countries. If the tradable is capital intensive, the equilibrium level of the foreign price level would fall relative to the domestic price level and the real exchange rate rises. In the case of a long-term change, this would imply a gradual shifting of PPP between the two countries.

It is notable that relative prices in the foreign country do not change. The assumption of a constant trade balance implies that the foreign country is sealed off from the home economy. The shift of relative prices at home alters the real exchange rate, but has no effect on relative prices or production abroad.

Quantity shifts at home depend on factor intensity relationships. In the extreme case of fixed relative prices ( $\eta_1 = \infty$ ), the usual Rybczynski results hold. If the tradable is capital intensive, then  $X_T$  increases and  $X_1$  decreases. However, these movements are altered by the presence of price changes. If the tradable is capital intensive, then  $P_1$  rises and  $P_T$  falls. These movements tend to counteract the Rybczynski effects on  $X_1$  and  $X_T$  production. Resources are attracted into  $X_1$  and out of  $X_T$  production. That effect is larger, the larger is  $\delta_L$  (the larger are the elasticity of substitution terms  $\sigma_1$  and  $\sigma_T$ ). The larger  $\delta_L$  implies greater substitutability between factors and an easier shift of resources between the two goods. The overall effects are ambiguous for  $X_1$ . In the case of  $X_T$ , production is discouraged but not enough to overcome the Rybczynski effects. For the two goods taken together, there is an upward bias in production, since factors have been enhanced.

#### Increase in capital and labor

The previous case concerned a disproportionate increase in one factor endowment. Equations (26) indicate results of an increase in both  $K$  and  $L$  of the same percentage. In these equations .

$$\frac{\hat{P}_1}{\hat{F}} = - \frac{\phi_T(\mu_T - \varphi_T)}{[\varphi_T(A - \eta_1) + \mu_TB]} \quad (26a)$$

$$\frac{\hat{P}_T}{\hat{F}} = \frac{\hat{P}_2}{\hat{F}} = \frac{\hat{\Pi}_1}{\hat{F}} = \frac{\phi_{11}(\mu_T - \varphi_T)}{[\varphi_T(A - \eta_1) + \mu_TB]} \quad (26b)$$

$$\frac{\hat{R}}{\hat{F}} = - \frac{\phi_{11}(\mu_T - \varphi_T)}{[\varphi_T(A - \eta_1) + \mu_TB]} \quad (26c)$$

$$\frac{\hat{X}_1}{\hat{F}} = 1 + \frac{A(\mu_T - \varphi_T)}{[\varphi_T(A - \eta_1) + \mu_TB]} \quad (26d)$$

$$\frac{\hat{X}_T}{\hat{F}} = 1 - \frac{A(\mu_T - \varphi_T)}{[\varphi_T(A - \eta_1) + \mu_TB]} \quad (26e)$$

$$\frac{\hat{C}_T}{\hat{F}} = \frac{\mu_T}{\varphi_T} \frac{\hat{X}_T}{\hat{F}} \quad (26f)$$

$$\frac{\hat{X}_2}{\hat{F}} = \frac{\hat{X}_{T2}}{\hat{F}} = \frac{\hat{C}_{T2}}{\hat{F}} = 0 \quad (26g)$$

In a closed economy, one would expect an increase in production of each good equal to the overall increase in factor endowments. Prices would not change. In this open economy model, those effects are modified to the extent the net trade balance is nonzero. If the home country is a net exporter ( $\mu_T - \varphi_T > 0$ ), then the nontradable price increases and the tradable price decreases. Because of these price shifts, production of the tradable increases less than the mean and production of the nontradable increases more. The real exchange rate increases somewhat and purchasing power parity between the two countries is altered accordingly.

#### Increase in capital and labor, plus increase in $N$

If, in addition to an increase in the two factors of production, the net trade balance  $N$  is allowed to increase by the same percentage, then the economy acts essentially like the closed economy model. Relative prices, as well as the real exchange rate, do not change. Both goods at home increase by the same proportion as the endowment changes. Purchasing power parity relationships are unaffected. This "neutral" story is as we would expect, given the neutral nature of the shocks.

## 2. Technology improvement

A major potential source of shock to the real exchange rate is technological change. This section contains analysis of Hicks biased technical change of the capital-augmenting variety in the tradables industry.<sup>6</sup> We consider an increase in  $t_{KT}$ . Changes in the endogenous variables are:

$$\frac{\hat{P}_1}{\hat{t}_{KT}} = \frac{\phi_T[(\mu_T \lambda_{L1} + \varphi_T \lambda_{LT})(\lambda_{KT}/|\lambda|) + \theta_{KT}(\mu_TB + \varphi_TA)]}{[\varphi_T(A - \eta_1) + \mu_TB]} \quad (27a)$$

$$\frac{\hat{P}_T}{\hat{t}_{KT}} = \frac{\hat{P}_2}{\hat{t}_{KT}} = \frac{\hat{\Pi}_2}{\hat{t}_{KT}} = \frac{\mu_{11}}{\varphi_T} \frac{\hat{P}_1}{\hat{t}_{KT}} \quad (27b)$$

<sup>6</sup> See Stockman and Svensson (1987) for the effect of productivity shocks on the real exchange rate in the economy without investment.

$$\frac{\hat{R}_1}{\hat{t}_{KT}} = \frac{\phi_{11}[(\mu_{T1}\lambda_{L1} + \varphi_{T1}\lambda_{LT})(\lambda_{KT}/|\lambda|) + \theta_{KT}(\mu_{T1}B + \varphi_{T1}A)]}{[\varphi_{T1}(A - \eta_1) + \mu_{T1}B]} \quad (27c)$$

$$\frac{\hat{X}_1}{\hat{t}_{KT}} = \frac{\mu_{T1}\lambda_{KT}/|\lambda||\phi| - \varphi_{T1}\eta_1[\theta_{KT}A + \lambda_{LT}\lambda_{KT}/|\lambda|]}{[\varphi_{T1}(A - \eta_1) + \mu_{T1}B]} \quad (27d)$$

$$\frac{\hat{X}_{T1}}{\hat{t}_{KT}} = \frac{\varphi_{T1}[\lambda_{KT}/|\lambda||\phi| + \eta_1(\theta_{KT}B + \lambda_{L1}\lambda_{KT}/|\lambda|)]}{[\varphi_{T1}(A - \eta_1) + \mu_{T1}B]} \quad (27e)$$

$$\frac{\hat{C}_{T1}}{\hat{t}_{KT}} = \frac{\mu_{T1}[\lambda_{KT}/|\lambda||\phi| + \eta_1(\theta_{KT}B + \lambda_{L1}\lambda_{KT}/|\lambda|)]}{[\varphi_{T1}(A - \eta_1) + \mu_{T1}B]} \quad (27f)$$

$$\frac{\hat{X}_2}{\hat{t}_{KT}} = \frac{\hat{X}_{T2}}{\hat{t}_{KT}} = \frac{\hat{C}_{T2}}{\hat{t}_{KT}} = 0. \quad (27g)$$

If the tradable good is capital intensive, then the effect of the technology shock is an increase in  $P_1$  and a decrease in  $P_T$ , and  $\pi_2$ . The real exchange rate increases and purchasing power parity between the two countries is altered so that the foreign price level declines relative to the domestic price. If the tradable is labor intensive, then the price effects become ambiguous. The first term in square brackets in the numerator of (27a) above is positive, while the second term is negative. If the first term prevails, then the technology shock decreases the real exchange rate. The first term is more likely to be dominant, the smaller are the production elasticities of substitution  $\sigma_1$  and  $\sigma_T$ . These offsetting effects on  $\pi_2$  and  $R$  occur when capital effectiveness increases for the labor intensive good.

Production levels also evidence some ambiguity. If the tradable is capital intensive ( $|\lambda| < 0$ ), then the effect of  $t_{KT}$  on  $X_1$  is ambiguous and the effect on  $X_{T1}$  is positive. If the opposite intensity relationship holds, then the effects of  $t_{KT}$  on  $X_1$  and  $X_{T1}$  are ambiguous. In each case, the ambiguity arises for the good which is not capital intensive. Production of the other good moves in the way expected from the Rybczynski considerations. It is interesting to note, however, that fixing domestic relative prices (by letting  $\eta_1$  approach infinity) does not result in simple Rybczynski production effects. Rather, the technology change reduces the price of effective capital in the tradables sector and thereby causes a reshuffling of factors between the two industries independent of goods prices.

## V. SUMMARY AND CONCLUSION

We have explored a specific goods model of exchange rate determination to

investigate the various shocks effects on the real exchange rate. Real shocks such as factor endowment changes, technology change, tariff changes, trade balance, and demand changes were considered. Changes in the equilibrium real exchange rate facilitate the required changes in the traded and nontraded goods prices to maintain equilibrium in the international markets as well as domestic goods markets. Likely the goods prices changes, changes in the real exchange rate depend on the sources of disturbances and market conditions. In particular, how real shocks affect the real exchange rate depends on the factor intensity of goods production and the shares of consumption and production of tradable good by home and abroad.

If the nontraded good is labor intensive, an exogenous increase in the net trade balance raises the price of tradable goods abroad and the foreign price level. The real exchange rate definitely falls in response to the increase in the net exports. As the capital stock increases, relative prices at home are altered. This in turn changes the real exchange rate and the purchasing power parity relationship between the two countries. If the tradable is capital intensive, the equilibrium level of the foreign price level would fall relative to the domestic price level and the real exchange rate rises. Quantity shifts at home depend on factor intensity relationships. In the extreme case of fixed relative prices, the usual Rybczynski results hold. However, these movements could be altered by the presence of price changes.

The effect of the capital augmenting technology change is an increase in the real exchange rate if the tradable good is capital intensive. However, if the tradable is labor intensive, the price effects become ambiguous. Production levels also evidence some ambiguity. An increase in tariff causes a reduction in consumption of tradable. Then the prices of tradable and nontradable goods fall abroad through cross price effect. The foreign price level declines and the real exchange rate increases.

Policy implications drawn from the equilibrium view are quite different from those of the disequilibrium model. Chief among them is that the real exchange rate is not exploitable by the government. The real exchange rate is endogenous variables determined in the economy. Changes in the exchange rate imply equilibrium value changes in the model. This implies that the foreign exchange market intervention as well as change in the exchange regime would fail to control the equilibrium real exchange rate. If any, the alternative policies would be suggested to directly affect the exchange rate in the system through real effects. The fiscal policies such as taxation and government expenditure and subsidies intriguing investment will be better policy instruments than foreign exchange market intervention in that these policies can affect the equilibrium value of the real exchange rate.



## APPENDIX

**Trade balance effects on the real exchange rate in the specific goods model with production**

Price effects of an increase in the balance are:

$$\frac{\hat{P}_1}{\hat{N}} = \frac{\phi_{11}(\mu_{T1} - \varphi_{T1})}{\varphi_{T1}(A - \eta_1) + \mu_{T1}B} \quad (28a)$$

$$\frac{\hat{P}_T}{\hat{N}} = -\frac{\phi_{11}(\mu_{T1} - \varphi_{T1})}{\varphi_{T1}(A - \eta_1) + \mu_{T1}B} \quad (28b)$$

$$\frac{\hat{P}_2}{\hat{N}} = -\frac{\phi_{T2}(\mu_{T1} - \varphi_{T1})}{\varphi_{T2}(A^* - \eta_2) + \mu_{T2}B^*} \quad (28c)$$

$$\frac{\hat{R}}{\hat{N}} = \frac{\hat{\Pi}_2}{\hat{N}} = -\frac{\phi_{11}(\mu_{T1} - \varphi_{T1})}{\varphi_{T1}(A - \eta_1) + \mu_{T1}B} + \frac{\phi_{22}(\mu_{T1} - \varphi_{T1})}{\varphi_{T2}(A^* - \eta_2) + \mu_{T2}B^*} \quad (28d)$$

Quantity changes are following:

$$\frac{\hat{X}_1}{\hat{N}} = -\frac{A(\mu_{T1} - \varphi_{T1})}{\varphi_{T1}(A - \eta_1) + \mu_{T1}B} \quad (28e)$$

$$\frac{\hat{X}_{T1}}{\hat{N}} = \frac{B(\mu_{T1} - \varphi_{T1})}{\varphi_{T1}(A - \eta_1) + \mu_{T1}B} \quad (28f)$$

$$\frac{\hat{X}_2}{\hat{N}} = \frac{A^*(\mu_{T1} - \varphi_{T1})}{\varphi_{T2}(A^* - \eta_2) + \mu_{T2}B^*} \quad (28g)$$

$$\frac{\hat{X}_{T2}}{\hat{N}} = -\frac{B^*(\mu_{T1} - \varphi_{T1})}{\varphi_{T2}(A^* - \eta_2) + \mu_{T2}B^*} \quad (28h)$$

$$\frac{\hat{C}_{T2}}{\hat{N}} = -\frac{(A - \eta_1)(\mu_{T1} - \varphi_{T1})}{\varphi_{T1}(A - \eta_1) + \mu_{T1}B} \quad (28i)$$

$$\frac{\hat{C}_{T2}}{\hat{N}} = \frac{(A^* - \eta_2)(\mu_{T1} - \varphi_{T1})}{\varphi_{T2}(A^* - \eta_2) + \mu_{T2}B^*} \quad (28j)$$

The effects of trade balance on the real exchange rate, prices, and production depends on the factor intensity of goods production and the shares of consumption and production of the tradable good by home and abroad. Any

exogenous increase in trade balance is equivalent to real transfer out of home to abroad in terms of the tradable good. An increase in the net trade balance lowers the supply of the tradable good at home. The relative price of tradable goods there must rise, inducing an increase in home tradables production and a decrease in home nontradables production. Overall expenditure declines in the home country, as does consumption of each individual good there. The supply of the tradables increases abroad. This induces a decline in the relative price of the tradables, a resulting decrease in tradables production and decrease in nontradables production. Consumption of each good as well as overall expenditure increases. The price of the tradables rises relative to the nontradable price at home, and therefore it rises also relative to the home price level, which is numeraire. Since the tradables price abroad rises relative to the numeraire, but declines relative to the foreign nontradable, the foreign price level overall must rise even more. Therefore the real exchange rate definitely falls in response to the increase in the net exports.

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