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THE ROLES OF THE TERMS OF TRADE AND NONTRADED-GOOD-PRICES IN EXCHANGE RATE VARIATIONS

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ABSTRACT

This paper demonstrates that disturbances to supplies or demands for internationally traded goods affect exchange-rates differently than do disturbances in markets for nontraded goods. The paper develops a stochastic two-country equilibrium model of exchange rates, asset prices, and goods prices, with two internationally traded goods and a nontraded good in each country. Optimal portfolios differ across countries because of differences in consumption bundles. Changes in exchange-rates, asset prices, and goods prices occur in response to underlying disturbances to supplies and demands for goods. We examine the ways in which responses of the exchange-rate are related to parameters of tastes and production shares, and we discuss conditions under which these exchange-rate responses are "large" compared to the responses of ratios of nominal price indexes.

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I. Introduction

The observation that exchange rate variability exceeds the variability of many ratios of nominal goods prices has evoked two types of explanations. First, the traditional explanation has been that the exchange rate, as an asset price, adjusts rapidly to new information that changes expectations of future nominal and real variables that are important in exchange rate determination. Nominal goods prices are viewed as less flexible and hence less responsive to this information. While many models have been developed with these characteristics, two important examples are Dornbusch (1976) and Mussa (1982). Second, recent work on equilibrium (flexible-price) models of exchange rates has indicated that real disturbances to the economy can lead to exchange rate changes that exceed changes in ratios of nominal prices of goods. Obstfeld and Stockman (1983) discuss this issue in a flexible-price version of a Mundell-Fleming model (Section 2) and in the context of Lucas's (1982) model. Analyses of the effects of real disturbances in these equilibrium models has, however, been limited to models that ignore nontraded goods (Stockman (1980), Lucas (1982)), or that ignore the terms of trade. Helpman and Razin (1982) include both nontraded goods and two imperfectly-substitutable traded goods in their model, but they limit their discussion to a specific (Cobb-Douglas) utility function and to a nonstochastic model.

This paper builds on Lucas (1982) and develops a stochastic rational-expectations maximizing model of a two-country world with two traded goods and a nontraded good in each country. The model includes a full array of financial assets, so optimal-portfolio problems and asset-pricing problems can be addressed with the model. The model is used to examine the effects of disturbances to supplies of goods or demands for goods on the exchange rate, the terms of trade, the relative prices of nontraded goods, asset prices, and nominal price levels. We examine the conditions under which exchange rate changes, that occur in response to realized values of the underlying stochastic disturbances, exceed changes in ratios of nominal goods prices. We develop implications of disturbances for a wider range of variables than have been considered in previous models of this type. The model reveals that the effects of real disturbances on exchange rates and ratios of goods prices depend on parameters of tastes and production shares.

II. The Model

Consider a world economy with two countries 1 and 2, each populated with an equal number of infinitely-lived representative households. Households in each country have the same tastes but receive different endowments of nonstorable consumption goods. At the beginning of period t a household in country 1 receives an endowment of x_t units of good X and z_t units of good Z, while a household in country 2 receives y_t units of good Y and z_t^* units of good Z^*. Goods X and Y are costlessly traded internationally, while Z and Z^* are only traded domestically. We assume that $\{x_t, y_t, z_t, z_t^*\}$ follows a stationary stochastic process.

Each country has a national currency, and nominal money supplies (in own-country per-capita terms) are m_t and n_t after being augmented at the beginning of the period by transfer payments, τ_{M_t} to households in country one and τ_{N_t}

to households in country 2. We assume that $\{\tau_{M_t}, \tau_{N_t}\}$ follows a stationary stochastic process.[1] Other assets available to households are discussed below.

The outcome of the stochastic process $s_t = \{x_t, y_t, z_t, z_t^*, \tau_{M_t}, \tau_{N_t}\}$ is known at the beginning of period t. The representative household in country 1 chooses consumption and asset stocks to maximize

$$E \sum_{t=0}^{\infty} \beta^t U(x_t^d, y_t^d, z_t^d) \tag{1}$$

where the expected value operator E indicates integration with respect to the conditional probability distribution of s_t, and x^d, y^d, and Z^d are demands for the two traded and (country 1) nontraded good. We assume that $U_{13} = U_{23} = 0$, $U_{11} < 0$, $U_{22} < 0$, and $U_{33} < 0$.

Maximization of (1) is subject to both a budget constraint and finance constraints of the kind previously used in Stockman (1980), Lucas (1980, 1982), Helpman (1981), and Helpman and Razin (1982, 1983). These require goods purchased in period t to be paid for with money that is either carried over from t-1 or is acquired in period t from dividends or sales of assets. Money acquired from sales of endowments in period t is not collected until the end of the period and cannot be used for purchases until t+1. We also assume that all purchases of goods must be paid for with the seller's currency. This assumption is altered in Section V, where we extend the analysis of Helpman and Razin (1983) on the role of different monetary mechanisms.[2]

Formally, let m_t and n_t denote the quantities of money that the representative household in country one obtains during trading in t from one of three sources: (1) the money carried over from t-1, (2) the money received as a "dividend" or "interest payment" on an asset the household owns, or (3) the money received from selling an asset that the household owned at the beginning of t. Let α_t denote the vector of (noncurrency) assets the household owns at the beginning of period t, q_t the vector of these asset prices in t measured in units of good X, and δ_t the vector of dividends or interest payments measured in units of X that these assets pay in t. Also let p_{x_t} and p_{z_t} be the nominal prices of X and Z in terms of the money of country one, let P_{y_t} and P_{z_t} be the money--two prices of Y and Z^* and let e be the price of money two in terms of money one. Then the household's balance sheet (in country one) is

$$\frac{\tilde{m}_{t-1}}{P_X} + e_t \frac{\tilde{n}_{t-1}}{P_X} - \frac{m_t}{P_X} - e_t \frac{n_t}{P_{X_t}} + \alpha_t'(q_t+\delta_t) - \alpha_{t+1}'q_t = 0 \qquad (2)$$

where

$$\tilde{m}_t \equiv m_t - p_{X_t} x_t^d - p_{Z_t} z_t^d \geq 0, \qquad (3)$$

$$\tilde{n}_t \equiv n_t - P_{Y_t} y_t^d \geq 0, \qquad (4)$$

and, in the absence of asset trades, the household would own two assets: its endowment from nature and a stream of transfers (taxes) from the home government, which pay in t for all t,

$$P_{X_{t-1}} x_{t-1} + P_{Z_{t-1}} z_{t-1} \qquad (5)$$

and

$$\tau_{M_t} \qquad (6)$$

Equation (2) describes the asset transactions of the household at t. The first two terms show money held but not spent in t-1; the second two terms were defined above, and represent money that can be used to buy goods in period t, as required by (3) and (4). The last two terms in (2) give the value of initial assets plus dividends or interest, and the assets chosen in t that the household will have in t+1.

We follow Helpman (1981) and Lucas (1982) in restricting our attention to an equilibrium in which the (default-free) one-period nominal interest rate in each currency is positive. Then there is an interest-cost to choosing m_t and n_t larger than expenditures $P_{X_t} x_t^d + P_{Z_t} z_t^d$ and $P_{Y_t} y_t^d$, while there is no corresponding benefit.[3] So $\tilde{m}_t = \tilde{n}_t = 0$, and (2) becomes simply

$$x_t^{'}(q_t+\delta_t) - x_t^d - \frac{P_{Z_t}}{P_{X_t}} \cdot Z^d - e_t \frac{P_{Y_t}}{P_{X_t}} y_t^d - \alpha_{t+1}^{'} q_t = 0 \qquad (2')$$

As a consequence,

$$M_t = P_{X_t} x_t + P_{Z_t} z_t \qquad (7)$$

and

$$N_t = P_{Y_t} y_t + P_{Z_t}^* z_t^* \qquad (8)$$

Maximization of (1) subject to (2') yields the first-order conditions

$$U_1(x_t^d, y_t^d, z_t^d) = \lambda_t \qquad (9)$$

$$U_2(x_t^d, y_t^d, z_t^d) = \lambda_t \frac{P_{Y_t}}{P_{X_t}} e_t \qquad (10)$$

$$U_3(x_t^d, y_t^d, z_t^d) = \lambda_t \frac{P_{Z_t}}{P_{X_t}} \qquad (11)$$

$$\beta E\left(\frac{q_{it+1}+\delta_{it+1}}{q_{it}} \lambda_{t+1}\right) = \lambda_t \quad \text{(for all i)} \qquad (12)$$

where q_i and λ_i are the i^{th} elements of q and δ. (12) takes the form of the Euler equations estimated by Hansen and Singleton (1982, 1983).

The equilibrium of the economy requires that total world demand for assets and traded goods equal their supplies and that demands and supplies for the nontraded goods Z and Z^* be equated within each country. There are obviously many possible equilibria, depending on the initial distribution of wealth (as well as the set of available assets). We follow Lucas (1982) in discussing an equilibrium in which wealth is equal in the two countries and any assets can be traded as long as they pay dividends or interest, physically, in currencies rather than goods (which would introduce barter and undermine the assumed monetary economy).

This economy has an equilibrium with the following characteristics. Consumptions are $\frac{x_t}{2}$, $\frac{y_t}{2}$, and z_t. There is an asset α_t that is a claim to $P_t x_t$ units of money one in period t, $P_{X_{t+1}} x_{t+1}$ units of money one in t+1, and so on forever. The interest payment on this asset in terms of X is thus $\delta_{X_t} = x_t$. An asset α_Y pays $P_{Y_t} y_t$ units of money two in period t, for all t, so $\delta_{Y_t} = \frac{e_t P_{Y_t}}{P_{X_t}} y_t$.

Finally, there are assets α_Z and α_{Z*} that are claims to infinite streams of money one and money two, respectively, in the amounts $P_{Z_t} Z_t$ and $P^*_{Z_t} z^*_t$, so $\delta_{Z_t} = \frac{P_{Z_t}}{P_{X_t}} z_t$ and $\delta_{Z*_t} = e_t \frac{P_{Z*t}}{P_{x_t}} z^*_t$. The representative household in country one owns assets $\frac{1}{2}\alpha_X$, $\frac{1}{2}\alpha_Y$, and α_Z, while the representative household in country two owns $\frac{1}{2}\alpha_X$, $\frac{1}{2}\alpha_Y$ and α_{Z*}.

Equilibrium prices are determined by substituting these allocations in (7)-(12). Prices of goods are

$$P_{X_t} = \frac{M_t}{x_t + \dfrac{U_3(\frac{x_t}{2},\frac{y_t}{2},z_t)}{U_1(\frac{x_t}{2},\frac{y_t}{2},z_t)} z_t} \tag{13}$$

$$P_{Y_t} = \frac{N_t}{y_t + \dfrac{U_3(\frac{x_t}{2},\frac{y_t}{2},z_t^*)}{U_2(\frac{x_t}{2},\frac{y_t}{2},z_t^*)} z_t^*} \tag{14}$$

$$P_{Z_t} = \frac{M_t}{\dfrac{U_1(\frac{x_t}{2},\frac{y_t}{2},z_t)}{U_3(\frac{x_t}{2},\frac{y_t}{2},z_t)} x_t + z_t} \tag{15}$$

$$P_{Z*_t} = \frac{N_t}{\dfrac{U_2(\frac{x_t}{2},\frac{y_t}{2},z_t^*)}{U_3(\frac{x_t}{2},\frac{y_t}{2},z_t^*)} y_t + z_t} \tag{16}$$

while the exchange rate is given by

$$e_t = \frac{M_t}{N_t} \frac{U_2(\frac{x_t}{2},\frac{y_t}{2},z_t)y_t + U_3(\frac{x_t}{2},\frac{y_t}{2},z_t^*)z_t^*}{U_1(\frac{x_t}{2},\frac{y_t}{2},z_t)x_t + U_3(\frac{x_t}{2},\frac{y_t}{2},z_t)z_t} \tag{17}$$

The vector of asset prices $q_t^{'} = (q_{X_t}, q_{Y_t}, q_{Z_t}, q_{Z*_t})$ had i^{th} element

$$q_{it} = \sum_{j=1}^{\infty} \beta^j E\delta_{it+j} \frac{U_1(\frac{x_{t+j}}{2}, \frac{y_{t+j}}{2}, z_{t+j})}{U_1(\frac{x_t}{2}, \frac{y_t}{2}, z_t)} \tag{18}$$

where δ_{it} is the i^{th} of $\delta_t^{'} = (\delta_{x_t}, \delta_{y_t}, \delta_{Z_t}, \delta_{Z*_t})$.

To verify that this is an equilibrium, note that the first order conditions for utility maximization with these prices are satisfied at the consumptions $\frac{x_t}{2}$, $\frac{y_t}{2}$, and z_t (z_t^* for households in country two), and asset holdings $\frac{1}{2}\alpha_x$, $\frac{1}{2}\alpha_y$, and α_z (α_{z*} for country two). Demands and supplies of goods are equated, since supplies are x_t, y_t, z_t, and z_t^*. Demands and supplies for assets are also equated. The asset α_x pays as interest each period just enough money one to purchase x_t goods. The asset α_Z pays each period just enough money one to purchase z_t goods. By (7), these assets pay M_t, exactly the supply of money (per capita) each period. Thus α_X is a claim to a share of the money stock equal to the share of X, in GNP of country one, while α_Z is a claim to the rest of M. Similarly, assets α_Y and α_{Z*} together pay N_t each period.

Each household in country one owns exactly enough assets to finance consumption out of his interest payments. Interest from $\frac{1}{2}\alpha_Y$ finances consumption $\frac{x_t}{2}$, that from $\frac{1}{2}\alpha_Y$ finances $\frac{y_t}{2}$, and $\alpha_z(\alpha_{Z*})$ finances $z_t(z_t^*)$. From the budget constraint, then, each household can just afford to maintain its asset holdings over time.

Portfolios differ across countries because of the existence of nontraded goods. Each household attempts to eliminate risk of changes in prices and endowments, but the world economy as a whole cannot eliminate it. Instead, asset prices reflect the risk. However, no household in country one has an incentive to either buy or sell asset α_z^* (and vice versa), as can easily be verified from the first-order conditions and the budget constraint. If a household in country one owned some α_z^* and less of another asset, it would incur unnecessary risk in consumption.

Note that (17) implies that the exchange rate equals the ratio of money supplies multiplied by the (inverse) ratio of gross national products, measured in terms of the same good. Since GNPs do not consist of the same bundle of goods, a change in relative goods prices changes the exchange rate for any given levels of money supplies and GNPs.

Nominal prices of goods are each equal to the ratio of money supplies to GNP measured in terms of that good, reflecting the unit-velocity result. Note that the equilibrium collapses to that of Lucas (1982) when outputs of nontraded goods are identically zero.

III. Characteristics of the Equilibrium

The probability distribution on the stochastic process $\{x_t, y_t, z_t, z_t^*, \tau_{M_t}, \tau_{N_t}\}$ induces a probability distribution on the exchange rate. Given the realizations of the other random variables, a higher realization of x_t changes the exchange rate by

$$\hat{e}/\hat{x} = \frac{x}{2U_1U_2}[s_Y U_{12} U_1 - s_X U_{11} U_2] - s_X \tag{19}$$

where a hat (^) denotes percentage change, where s_Y is the share of Y in the GNP of country two, s_X is the share of X in the GNP of country one, and the functions U_1, U_2, U_{11} and U_{12} are evaluated at $(\frac{x}{2},\frac{y}{2},z)$. Note that (19) involves not only properties of the utility function that affect elasticities of demands for goods (as in the traditional "elasticities" approach to exchange rates) but also production shares.

We can rewrite (19) as

$$\hat{e}/\hat{x} = -s_X(1+\varepsilon) + s_Y\varepsilon_2 \tag{20}$$

where ε is the elasticity of marginal utility of X with respect to consumption of X, $\frac{U_{11}}{U_1}\frac{x}{2}$ and ε_2 is the elasticity of the marginal utility of Y with respect to consumption of X, $\frac{U_{12}}{U_2}\frac{x}{2}$. The relative price of X in terms of Y, the terms of trade, falls by

$$\widehat{(P_X/eP_Y)}/\hat{x} = \varepsilon - \varepsilon_2 \tag{21}$$

This change in the terms of trade occurs partly through a change in the exchange rate and partly through changes in the domestic nominal price of X,

$$\hat{P}_X/\hat{x} = -s_X(1+\varepsilon) + \varepsilon \tag{22}$$

and in the foreign nominal price of Y,

$$\hat{P}_Y/\hat{x} = (1-s_Y)\varepsilon_2 \tag{23}$$

Nominal prices of domestic and foreign nontraded goods change by

$$\hat{P}_Z/\hat{x} = -s_X(1+\varepsilon) \tag{24}$$

and

$$\hat{P}_{Z*}/\hat{x} = -s_Y\varepsilon_2 \tag{25}$$

Random fluctuations in output of X can produce changes in the exchange rate that are larger in magnitude (in percentage terms) than changes in the ratio of national price levels. This tendency of exchange rates to vary more than ratios of nominal goods prices has been one of the most persistent regularities observed under flexible exchange rates.

Let

$$V_1 \equiv |\hat{e}/\hat{x}| - |\hat{P}_X/\hat{x} - \hat{P}_Y/\hat{x}| \tag{26}$$

be the absolute percentage change in the exchange rate in excess of the absolute percentage change in the ratio of export prices when the output of X rises. We wish to examine the circumstances under which V_1 is positive, which would imply greater variability in exchange rates, as x fluctuates over time, than in P_X/P_Y. It is easy to verify, using (21), that if (20) is negative, then $V_1 < 0$. If (20) is positive, however, V_1 can be positive. If (20) is positive, which requires

$$\varepsilon < \varepsilon_2 \frac{s_Y}{s_X} - 1, \tag{27}$$

and if also

$$\varepsilon_2 \frac{1-s_Y}{1-s_X} + \frac{s_X}{1-s_X} < \varepsilon \tag{28}$$

then $V_1 > 0$. In that case, (22) exceeds (23). Alternatively, if (27) holds, $s_X > \frac{1}{2}$ and also

$$\varepsilon < \varepsilon_2 \frac{1-2s_Y}{1-2s_X} + \frac{2s_X}{1-2s_X} \tag{29}$$

then $V_1 > 0$. In Lucas' (1982) model, $\varepsilon_2 = 0$, $s_X = 1$, so the conditions (27) and (29) reduce to $\varepsilon < -2$, in which case $V_1 > 0$. Finally, if (27) holds,

$s_X < \frac{1}{2}$, and (29) does not hold, then $V_1 > 0$. The point is that various combinations of output shares and demand elasticities are consistent with greater variability in exchange rates than in ratios of nominal goods prices.

These calculations can also be made easily with price indexes.

Define GNP price deflators by

$$\xi = P_X^{s_X} P_Z^{1-s_X} \tag{30}$$

$$\xi^* = P_Y^{s} P_{Z*}^{1-s_Y}$$

It is easy to see that $\hat{\xi}/\hat{x} = -s_X$ while $\hat{\xi}^*/\hat{x} = 0$. Then, in absolute value terms, the percentage response of e to a rise in x exceeds the percentage response of ξ/ξ^* if either (20) is negative and

$$\frac{s_Y}{s_X}\varepsilon_2 < \varepsilon < \varepsilon_2 \tag{31}$$

or if (20) is positive and

$$\varepsilon < \frac{s_Y}{s_X}\varepsilon_2 - 2. \tag{32}$$

Similar calculations can be performed for consumer price indexes, and for changes in the output of nontraded goods. Note that

$$\hat{e}/\hat{z} = -(1-s_X)(1+\varepsilon_3), \tag{33}$$

where $\varepsilon_3 \equiv U_{33}Z/U_3$, so that the sign of the effect on the exchange rate of a change in the output of nontraded goods depends on the size of ε_3. A related condition, for a model with money introduced through the utility function, is discussed in Obstfeld and Stockman (1983).

IV. Changes in Demands for Goods

Although we have discussed changes in supplies of goods, certain changes in demand can be analyzed easily. Suppose that one or both governments impose lump-sum taxes on their own households and use the proceeds to buy $g_t \equiv (g_{X_t}, g_{Z_t}, g_{Z^*_t})$ units of the goods (X,Y,Z,Z^*). Let g_t follow a stationary stochastic process. Moreover, suppose that government spending either does not enter household's utility functions or that it enters in an additively-separable way (i.e. household utility in country one would be $U(x^d_t, y^d_t, z^d_t) + W(g_t)$). Denote total supplies of goods by $x^T_t \equiv x_t + g_{X_t}$, $y^T_t \equiv y_t + g_{Y_t}$. If governments buy only goods produced in their own countries, then the government in country one levies a tax in t of $\ell_t = P_{X_t} g_{X_t} + P_{z_t} g_{Z_t}$ on households in country one. Since τ_{M_t} remains the gross transfer payment $\tau_{M_t} - \ell_t$ (which may be negative) is the net transfer payment in (6). Also, with this new notation, (5) becomes $P_{X_{t-1}} x^T_{t-1} + P_{Z_{t-1}} z^T_{t-1}$. Then it is easy to verify that the equilibrium described above is unaffected. Consumptions of $\frac{x_t}{2}$, $\frac{y_t}{2}$, and z_t (or z^*_t) now refer to half (or all) of the net supplies remaining after government spending has been subtracted. The description of asset stocks held by households in each country is also unaffected, though the interpretation is now different because the terms x_t, y_t, etc. refer to net supplies. Intuitively, households faced with stochastic taxes and government spending diversify away this additional risk to the extent it is possible. So when the government of country one raises spending on X, the effects are borne equally in both countries.[4] When that spending is on the nontraded good, however, the full cost is borne by domestic residents. The effects on prices (including the exchange rate) of an increase in government spending on any good are identical to the effects of a decrease in supply, so all the results derived above can be applied to these demand disturbances.[5]

V. Alternative Asset Trades

The assets α_X, α_Y, α_Z and α_{Z*} could be replaced by another, equivalent, set of assets. Note that α_x is a claim to a payment of money one in every period, where the payment in t is the share of X in country one's GNP at t times the supply of money one at t. This equals the receipts from selling X and Z in period t-1, $P_{X_{t-1}} x_{t-1} + P_{Z_{t-1}} z_{t-1}$, plus the current tranfer payment τ_t, minus the receipts that <u>will</u> be obtained at the end of period t from selling z_t, $P_{Z_t} z_t$. In Lucas' (1982) model without nontraded goods $P_{Z_t} z_t = 0$ so that equities (e.g. a claim to $P_{X_{t-1}} X_{t-1}$ units of money one paid in period t) combined with a single indexed nominal claim (to transfer payments) were the only assets that households need to trade in equilibrium. Here, however, this menu of assets would have to be supplemented with an additional asset that pays $P_{Z_t} z_t$ in period t, so that it is indexed not to the price P_{z_t} but to receipts $P_{Z_t} z_t$. The set of assets $\{\alpha_x, \alpha_Y, \alpha_Z, \alpha_{Z*}\} \equiv \tilde{\alpha}$ could, therefore, be replaced by assets that pay in t, $\{P_{X_{t-1}} X_{t-1}, P_{Y_{t-1}} y_{t-1}, \tau_{M_t}, \tau_{N_t}, P_{Z_{t-1}} z_{t-1}, P_{Z*_{t-1}} z^*_t, P_{Z_t} z_t, P_{Z*_t} z^*_t\}$. The last two assets are futures contracts on the dividends paid by the equities on nontraded goods: they pay, in t, the dividends that those equities will pay in t+1. If this menu of assets replaces the menu of assets $\tilde{\alpha}$ then the equilibrium can be replicated with asset shares $(\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},-\frac{1}{2})$ for country one households and shares $(\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2},-\frac{1}{2},\frac{1}{2})$ for country two households. With this asset structure an increase in τ_{M_t} is paid to households in both countries. Households in country one will pay the greater "inflation tax" because the price of domestic nontraded goods rises but the (money-two) price of Z^* is unchanged. However, the other assets assure that this increase in M_t does not result in a redistribution of wealth. Similarly, this asset structure prevents wealth redistribution from changes in outputs of traded or nontraded goods. Obviously, there are many other asset structures that could also duplicate $\tilde{\alpha}$.

VI. Buyers' Currencies

We have assumed that all purchases are made with seller's currencies. We now follow Helpman and Razin (1983) and examine how the equilibrium differs if buyers' currencies are used for all purchases. If we let x_t^d and y_t^d denote the traded-good demands of the country one household, and x_t^{*d} and y_t^{*d} those of the country two household, (3) and (4) are replaced by

$$m_t \geq P_{X_t} x_t^d + e_t P_{Y_t} y_t^d + P_{Z_t} z_t^d \tag{34}$$

for the former and

$$n_t \geq \frac{P_{X_t}}{e_t} x_t^{*d} + P_{Y_t} y_t^{*d} + P_{Z*_t} z_t^{*d} \tag{35}$$

for the latter. The analogues to (5') and (6')

$$\hat{m}_{t-1} = \frac{1}{2} P_{X_t} x_t + P_{Z_t} z_t + \tau_{M_t} \tag{36}$$

$$\hat{n}_{t+1} = \frac{1}{2} \frac{P_{X_t}}{e_t} x_t \tag{37}$$

so (2') becomes

$$\frac{P_{X_{t-1}}}{2P_{x_t}}x_{t-1} + \frac{P_{Z_{t-1}}z_t}{P_{Z_t}} + \frac{\tau_{M_t}}{P_{X_t}} + \frac{e_t P_{X_{t-1}}x_t}{2e_{t-1}P_{X_t}} + \alpha_t'(q_t+\delta_t)$$

$$- x_t^d - \frac{P_{Z_t}}{P_{X_t}} z_t^d - e_t \frac{P_{y_t}}{P_{X_t}} y_t^d - \alpha_{t+1}' q_t = 0. \tag{38}$$

As Helpman and Razin note, the arbitrage conditions now have the form

$$P_{X_t} = e_{t+1} \bullet P_{X_t}^* \tag{39}$$

Where $P_{X_t}^*$ is the price of X in money two. Since (34) and (35) hold as equalities when short-term nominal interest rates are positive,

$$e_{t+1} = \frac{M_t}{N_t} \frac{\frac{x_t}{2} + \frac{U_2}{U_1}\frac{y_t}{2} + \frac{U_{3*}}{U_1} z_t^*}{\frac{x_t}{2} + \frac{U_2}{U_1}\frac{y_t}{2} + \frac{U_3}{U_1} z_t} \tag{40}$$

where all the U_i are evaluated at $(\frac{x_t}{2},\frac{y_t}{2},z_t)$ except U_{3*} which is evaluated at $(\frac{x_t}{2},\frac{y_t}{2},z_t^*)$.

In the absence of nontraded goods, (40) would collapse to the ratio of money supplies because spending in the two countries would be equal. Nominal goods prices, previously given in (13)-(16), now become ratios of money to spending rather than to income.

Equilibrium consumptions of $(\frac{x_t}{2},\frac{y_t}{2},z_t)$ and $(\frac{x_t}{2},\frac{y_t}{2},z_t^*)$ are maintained with four nonmoney assets, a_x, a_y, a_Z, and a_Z^*, where each asset is a claim to an infinite stream of payments of the receipts from selling the corresponding good in t-1 (e.g. $x_{t-1}P_{X_{t-1}}$), paid in t. Thus, the assets are all pure equities. The country one household chooses to own shares $(\frac{1}{2},\frac{1}{2},1,0)$ while the country two household chooses $(\frac{1}{2},\frac{1}{2},0,1)$. Since households in country one sell, on average, half of their endowments of X to households in country two for money two, they begin each period t with $\frac{x_{t-1}P_{X_{t-1}}}{2e_t}$ units of money two. Similarly, households in country two begin period t with $\frac{y_{t-1}P_{Y_{t-1}}e_t}{2}$ units of money one. The nonmoney assets commit each country one household to pay $\frac{x_t P_{X_{t-1}}}{2e_t}$ units of money two to country two households in t and entitle it to receive $\frac{y_{t-1}P_{Y_{t-1}}e_t}{2}$ units of money one. It is straightforward to verify that this an equilibrium.

An increase in output of the country one export good in t affects nominal goods prices in t and the exchange rate in t+1:

$$\hat{P}_X/\hat{x} = -\omega_x(1+\varepsilon) - \omega_y\varepsilon_2 + \varepsilon, \tag{41}$$

$$\hat{P}_Y/\hat{x} - \varepsilon_2 - \omega_x^*(1+\varepsilon) - \omega_y^*\varepsilon_2 \tag{42}$$

$$\hat{P}_Z/\hat{x} = -\omega_x(1+\varepsilon) - \omega_y\varepsilon_2 \tag{43}$$

$$\hat{P}_{Z*}/\hat{x} = -\omega_x^*(1+\varepsilon) - \omega_y^*\varepsilon_2 \tag{44}$$

and

$$\hat{e}_{t+1}/\hat{x} = (\omega_x^*-\omega_x)(1+\varepsilon) - \omega_y(1-\frac{\omega_X^*}{\omega_X})\varepsilon_2. \tag{45}$$

The variation in the exchange rate may exceed the variation in ratios of goods prices as x varies, though with different timing. For example, any combination of elasticities and shares for which (45) is positive (such as $\varepsilon > -1$, $\omega_x^* > \omega_x$, and $\varepsilon_2 = 0$) will result in a larger impact of a change in output of X on the exchange rate than on the ratio of export prices, P_X/P_Y. The relative responses of the exchange rate and other price ratios can be computed as in Section 3. Similarly, it is straightforward to calculate the responses of the exchange rate and nominal goods prices to changes in the output of nontraded goods.

VII. Conclusions

This paper has discussed a stochastic rational expectations model of a 2-country world equilibrium with two traded goods that are imperfect substitutes and a nontraded good in each country. Disturbances to supply and demand for any of these goods lead to changes in relative prices: the contemporaneous terms of trade, the relative price of nontraded goods, and intertemporal relative prices (real interest rates). These disturbances also cause changes in exchange rates, which under certain conditions are "large" relative to the responses of some other prices.

The model permits a wide array of financial assets, though it implies a unit velocity of money. Svensson (1983) has made some progress in relaxing that assumption while maintaining tractability. As in Lucas (1982) there are no wealth redistributions from any disturbances. Whether one views this as a substantial cost depends on whether one thinks that these redistributions are, in the real world, large and important for prices. The absence of wealth redistributions means that, as in Helpman (1981) and Lucas (1982), pegged and flexible exchange rate systems lead to identical allocations (though, perhaps trivially, different prices).

The conditions under which an increase in supply or decrease in demand for the domestic exportable good appreciates or depreciates domestic currency depend on parameters of preferences and on production shares. The conditions under which exchange rates vary more than various price ratios in response to real disturbances also depend on these parameters and shares, but often the conditions require inelastic demands for goods or asymmetries across countries. Although higher variability of exchange rates than price ratios can be explained by this model, the unit income elasticity of the demand for money in the (buyer's currency) model remains restrictive, working against higher exchange rate volatility (compare, e.g., Section 2.1 of Obstfeld and Stockman (1984)). Further work on the roles of the terms of trade and nontraded goods prices in exchange rate changes should proceed with models which, like Svensson's (1983), can relax this assumption.

Footnotes

1. The stochastic process is restricted so that money supplies are always positive. Similarly, endowments are strictly positive.
2. Helpman and Razin also consider investment and a nonstationary equilibrium, which we do not consider here. However, they consider a model with only one good.
3. In contrast, planned expenditure is uncertain when asset decisions are made in the model proposed in Stockman (1980), and money holdings are chosen to exceed the expected value of expenditure.
4. The effects on utility may differ if government spending affects (in an additively-separable way) utility only in the home country.
5. The analysis is easily extended to a case in which the domestic government purchases the foreign export good.

   The effects of demand disturbances that originate in disturbances to preferences can be analyzed easily only if shocks to preferences affect the marginal utility of the nontraded good but leave the mrginal utility of the traded goods unchanged.

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