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Exchange Rate Variability and Asset Trade

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## ABSTRACT

In popular discussions about the merits of different international monetary arrangements it is often maintained that increased exchange rate variability has a negative influence on international trade and foreign investment. This paper addresses a specific, but also a very basic, aspect of this general issue, namely the effect of exchange rate variability on capital flows and international portfolio diversification. More precisely, we examine how different monetary policies--and among those, policies that aim at stabilizing exchange rates--determine the risk characteristics of nominal assets, and how these risk characteristics in turn affect international portfolio composition and trade in assets, when international asset markets are incomplete.

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## 1. Introduction

In popular discussions about the merits of different international monetary arrangements it is often maintained that increased exchange rate variability has a negative influence on international trade and net capital flows. Yet there are few serious analyses in the international trade and finance literature of how exchange rate variability affects trade and capital flows. This paper addresses a specific, but also a very basic, question given this general issue, namely the effect of exchange rate variability on capital flows and international portfolio diversification in different assets. More precisely, we examine how different monetary policies--and among those, policies that aim at stabilizing exchange rates--determine the risk characteristics of nominal assets, and how these risk characteristics in turn affect international portfolio composition and trade in assets, when international asset markets are incomplete.

The motivation for our focus on nominal assets is evident. Monetary policy can exert a direct effect only on the risk structure of nominal assets and any effects on the risk structure of real assets must be indirect via some other non-neutrality. It is also evident that international asset markets must be incomplete for our analysis to be interesting. For if markets were complete the risk characteristics of nominal assets would not matter.

Previous literature in the macro tradition on international portfolio investment in monetary open economies has largely relied on the "portfolio balance" approach. That is, asset demand functions have been specified directly rather than being derived from a maximization problem given the risk-return characteristics of available assets. (See Branson and Hendersson (1985) for a survey of the portfolio balance approach.) Such an approach is

subject to the "Lucas critique", however, and since our purpose in this paper is precisely to investigate how different policy rules affect the trade pattern in assets, we cannot rely on a portfolio balance approach.

Previous literature in the finance tradition on international portfolio diversification has indeed derived asset demands from first principles, but it has typically assumed that the stochastic processes for asset returns and exchange rates are exogenously given and the dependence on monetary policies in general equilibrium has not been integrated (see for instance Fama and Farber (1979), Grauer, Litzenberger and Stehle (1976), and Kouri (1977)). Such an integration is undertaken in the general-equilibrium international asset pricing models of Lucas (1982), Stulz (1984) and Svensson (1985), but the focus in these papers is on prices and exchange rates and not on the trade pattern in assets; since a perfectly pooled equilibrium is assumed, the trade pattern is trivial.<sup>1</sup> A closer antecedent to the present paper is Helpman and Razin (1982) which uses a framework very similar to the one we will use. Their focus is on the optimality properties of different exchange rate regimes though, not on the associated trade patterns.

Svensson (1987) examines the effect of monetary policies on the trade pattern in nominal assets by adopting an "indirect" approach, which exploits the general Law of Comparative Advantage, as developed by Deardorff (1980) and Dixit and Norman (1980). The indirect approach first derives a correlation

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<sup>1</sup> That is, relative to autarky each country (in a two-country world) exports half of its assets and imports half of the other country's assets. Still, capital movements and correlations between key macro variables like investment, the current account, output, etc., can be studied, as in Stockman and Svensson (1987), but any current and capital account movements are due exclusively to revaluation of domestically based assets relative to foreign based assets, not to changes in the ownership of assets.

between the trade pattern in assets and autarky asset price differences, and then explains autarky asset price differences by differences in countries technologies, preferences, and monetary policies. This is convenient because it is not necessary to solve for the explicit equilibrium trade pattern; it is sufficient to solve for the simpler autarky equilibrium. But for our purpose the approach has the disadvantage that the results on the trade pattern are only in the form of correlations; there are in general no specific results on particular assets.

To get such specific results, we instead adopt a "direct" approach. That is, we solve explicitly for the trade equilibrium and examine the determinants of the aggregate capital account, as well as its composition into trade in distinct nominal bonds. We do this in a general equilibrium where price levels, exchange rates, and asset returns are determined by monetary policies. Most of the equilibria differ from the perfectly pooled equilibrium even when countries have identical preferences. We also consider equilibria when countries preferences differ, more precisely when attitudes to risk differ. Our approach relies to a considerable extent on a recent paper by Gordon and Varian (1987) which develops an intertemporal CAPM model of trade in risky assets between barter economies.<sup>2</sup>

A limitation of our analysis is that we postulate that international financial markets are incomplete, without attempting to integrate any reason

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<sup>2</sup> Gordon and Varian's (1986) focus is on the effect of taxes on prices of internationally traded assets. They demonstrate, among other things, a result similar to the optimum-tariff one, namely that asset terms-of-trade can be affected by taxation so as to improve national welfare.

Cole (1986) examines the effect of different kinds of assets (ex post securities, Arrow-Debreu securities, Helpman-Razin equities) on variance and covariance of key real variables, like output, consumption, and trade balance.

for that incompleteness--such as moral hazard, adverse selection or costly state verification--into the analysis. Instead we simply assume that, in addition to national monies, the only internationally traded assets are nominal bonds, denominated in each currency, and indexed bonds. In spite of outputs being random, we rule out trade in stocks and claims to national outputs by assumption.<sup>3</sup>

A new element in our paper is to apply, in the context of the international trade in assets, Selden's (1978) formulation of preferences. Selden's so called OCE (Ordinal Certainty Equivalence) approach allows a distinction between intertemporal preferences and attitudes towards risk, a distinction that is blurred in the usual expected utility framework.

The paper is organized in the following way. Section 2 presents the real aspects of the model and the general equilibrium. Section 3 presents the monetary aspects and the different policy rules for monetary policy that we will later consider. Section 4 examines the trade pattern in nominal bonds and indexed bonds for different policy configurations in the world economy. In particular, it examines the effects on the aggregate capital account and its composition of adopting policy rules in the form of exchange rate targets, that do limit exchange rate variability. Some conclusions and possible extensions are mentioned in Section 5. An appendix includes some technical details.

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<sup>3</sup> The restriction on trade in claims on national outputs is perhaps easier to defend than the restriction on trade in stocks, since the former partly captures the difficulty in trading claims to human capital. From the viewpoint of financial equilibrium, the explicit incorporation in our model of risk which is not directly marketable makes our analysis related to Mayers (1973) analysis of non marketable risk in the CAPM model.

## 2. The Real Economy

The economy is a monetary economy with cash-in-advance constraints in goods markets. However, from a presentational point of view, it is easier to postpone the discussion of monetary issues. Accordingly, this section abstracts entirely from monetary issues and deals only with the real economy, while money and monetary policy is introduced in the next section.<sup>4</sup>

We study a simple general equilibrium model of a world economy with two countries: the home country and the foreign country. Foreign variables and parameters are indexed with an asterisk \*. There are two time periods, 1 and 2. Period 1 and 2 variables and parameters are indexed with superscripts. In each period there is one perishable and internationally traded good, which is produced and consumed by both countries. Period 1 outputs are exogenous and certain, with home and foreign output denoted by  $y^1$  and  $y^{*1}$ . Period 2 outputs,  $y^2$  and  $y^{*2}$ , are also exogenous but uncertain. We call  $s = (y^2, y^{*2})$  the state (of the world). The state  $s$  is assumed to be bivariate normal, with means  $\bar{y}^2$  and  $\bar{y}^{*2}$ , variances  $\sigma_{hh}$  and  $\sigma_{ff}$ , and covariance  $\sigma_{hf}$ <sup>5</sup>.

As discussed in the introduction, international asset markets are assumed to be incomplete. In addition to the national moneys, there are only three internationally traded assets: one indexed bond, and nominal bonds denominated in home and foreign currency. The inclusion of the indexed bond is for

<sup>4</sup> The model is similar to the ones of Helpman (1981) (except it has uncertainty and only two periods), Helpman and Razin (1982) (except it has no uncertainty in period 1), Lucas (1982) (except it has possibly incomplete markets and only two periods), Persson (1982, 1984) (except it has uncertainty and only two periods), and Stockman (1983) (except it has cash in advance instead of money in the utility function).

<sup>5</sup> The assumption of normality is, as usual, problematic, since it implies that outputs can be negative with positive probability.

convenience: it greatly simplifies the solution of the model.

The indexed bond, denoted by subindex 0, has a state-dependent home-currency return of  $P^2(s)$  or a state-dependent foreign currency return of  $P^{*2}(s)$ ;  $P^2(s)$  and  $P^{*2}(s)$  being the home and foreign price level in state  $s$ . Its real return--the return in terms of the one good--is thus riskless and equal to unity in each state. The price of an indexed bond (in terms of the good) on the period 1 asset market is denoted by  $q_0$ .

The nominal bonds are discount bonds paying one unit of currency in each state. Their real returns are thus risky. The home (currency) bond has state-dependent real return  $d_m(s) = 1/P^2(s)$  and the foreign (currency) bond has real return  $d_n = 1/P^{*2}(s)$ . In the remainder of this section, we shall refer to the home and foreign bonds as the "risky assets". We let  $d(s)$  denote the return vector on the risky assets, that is  $d(s) = (d_m(s), d_n(s))$ . We shall later on--in section 3--make assumptions that make  $d_m$  and  $d_n$  jointly normally distributed. Further, we let  $\sigma$  denote the variance-covariance matrix of the risky asset returns and  $\sigma_{hd}$  and  $\sigma_{fd}$  denote the covariance (vectors) of home and foreign output with these returns. The asset prices of risky assets (in terms of the good) are denoted by  $Q_m$  and  $Q_n$  and  $Q$  is the asset price vector  $(Q_m, Q_n)$ .

Let us now, after these preliminaries, look at the decision problem of the representative consumer in the home country. There are no assets outstanding initially, so his only source of income in the first period is from home output. The home consumer owns the home firm and claims to output (shares) are not traded internationally by assumption. He can buy first period consumption  $c^1$  and trade on the international asset market. His imports, and thus his end-of-period holdings, of riskless indexed bonds are

denoted by  $z_0$ , and his imports of risky assets (home and foreign bonds), by  $z_m$  and  $z_n$ . Letting  $z$  denote the import vector of risky assets,  $(z_m, z_n)$ , we can write the consumer's period 1 budget constraint as

$$(2.1a) \quad c^1 + q_0 z_0 + Q' z = y^1,$$

where  $Q' z$  denotes the inner product  $Q_m z_m + Q_n z_n$ .

In period 2 he consumes in state  $s$  his income from period 2 output and the returns on his assets<sup>6</sup>

$$(2.1b) \quad c^2(s) = y^2 + z_0 + d(s)' z.$$

The consumer's preferences are formulated as a special case of Selden (1978, 1979). Following Selden's approach, we separate time preferences (intertemporal preferences) and risk preferences (attitude towards risk) of the consumer in the following way. The time preferences are given by the intertemporal and additively separable utility function

$$(2.2a) \quad U(c^1) + \beta U(\hat{c}^2),$$

where  $\beta$  is a discount factor,  $0 < \beta < 1$ , and where  $\hat{c}^2$  denotes the certainty equivalent of risky period 2 consumption. The risk preferences are given by the atemporal utility function  $V(c^2(s))$ , by which the certainty equivalent period 2 consumption is defined as

$$(2.2b) \quad V(\hat{c}^2) = E[V(c^2(s))],$$

where  $E$  is the expectations operator.<sup>7</sup> Further, we assume that there is

<sup>6</sup> Since outputs may be negative with positive probability by our assumption that outputs are normally distributed, we have a possibility of bankruptcy if consumption is constrained to be non-negative. We ignore this problem by letting consumption be negative if necessary.

<sup>7</sup> Selden (1978, 1979) does not restrict the time preferences to be additively separable. When the time preferences are additively separable, and the risk preferences coincide with the time preferences (in the sense that the functions  $U(\cdot)$  and  $V(\cdot)$  are identical), the preferences are identical to expected-utility von Neumann-Morgenstern preferences.

constant absolute risk aversion,

$$(2.2c) \quad V(c^2(s)) = -e^{-\gamma c^2(s)}, \quad \gamma > 0.$$

The specification in (2.2) and the assumption that outputs and asset returns are normally distributed imply

$$(2.3) \quad \hat{c}^2 = \bar{c}^2 - \gamma \sigma_{cc}^2 / 2,$$

where  $\bar{c}^2$  is the mean and  $\sigma_{cc}$  the variance of period 2 consumption. Thus, the exact expression for the "risk premium" depends only on the first two moments of period 2 consumption. Given the structure of the model, these moments satisfy

$$(2.4a) \quad \bar{c}^2 = \bar{y}^2 + z_0 + \bar{d}'z, \quad \text{and}$$

$$(2.4b) \quad \sigma_{cc}^2 = \sigma_{hh}^2 + z' \sigma z + 2 \sigma_{hd}^2 z.$$

The above specification of preferences and budget constraints leads to the following first-order conditions for the home country's imports of riskless assets (indexed bonds),

$$(2.5) \quad \beta U_c(\hat{c}^2) / U_c(c^1) = q_0,$$

and for the imports of risky assets (nominal bonds),

$$(2.6) \quad \bar{d} - \gamma \sigma_{hd} - \gamma \sigma z = q,$$

where  $q$  is the vector of relative asset prices  $q = (q_m, q_n) \equiv (Q_m/q_0, Q_n/q_0)$ .

Repeating an exactly analogous argument for the foreign country, leads to analogous first-order conditions

$$(2.5*) \quad \beta^* U_c^*(\hat{c}^{*2}) / U_c^*(c^{*1}) = q_0, \quad \text{and}$$

$$(2.6*) \quad \bar{d} - \gamma^* \sigma_{fd} - \gamma^* \sigma z^* = q.$$

We can now study equilibrium prices and quantities in the first-period asset markets. Equilibrium in the markets for risky assets requires world imports of both assets to be zero, viz

$$(2.7) \quad z + z^* = 0,$$

which together with the first order conditions (2.6) yields

$$(2.8) \quad q = d - \gamma^W \sigma_{wd}.$$

Here,  $\gamma^W \equiv 1/(1/\gamma + 1/\gamma^*)$  is a measure of the world-wide absolute rate of risk aversion and  $\sigma_{wd}$  is the covariance (vector) between world output,  $y^W = y^2 + y^{*2}$ , and the returns on risky assets. The equilibrium (relative) prices on risky assets are thus determined in a very simple way. Using the expression (2.8) together with the first-order conditions, we can solve for the equilibrium import vector of risky assets (nominal bonds) as

$$(2.9) \quad z = \sigma^{-1}(a\sigma_{fd} - a^*\sigma_{hd}),$$

where  $a \equiv (1/\gamma)/((1/\gamma) + (1/\gamma^*))$  and  $a^* \equiv (1/\gamma^*)/((1/\gamma) + (1/\gamma^*))$  are normalized measures of risk aversion. The equilibrium import of risky assets thus depends on the attitudes towards risk in the two countries, on the risk properties of the assets, and on the covariance between asset returns and outputs.

It is slightly more complicated to represent equilibrium in the market for riskless assets (indexed bonds). To do that, let us define "certainty equivalent risky period 2 income (net of indexed bonds)"  $\hat{x}^2$  by

$$(2.10) \quad \hat{x}^2 \equiv \hat{c}^2 - z_0.$$

We can express  $\hat{x}^2$  as

$$(2.11a) \quad \hat{x}^2 = \hat{y}^2 + \hat{d}'z - \gamma\sigma_{cc}/2,$$

where the variance of second-period consumption, given equilibrium in the markets for risky assets, satisfies

$$(2.11b) \quad \sigma_{cc} = \sigma_{hh} - a(2-a)\sigma_{hd}^2\sigma^{-1}\sigma_{hd} + 2a^*2\sigma_{hd}^2\sigma^{-1}\sigma_{fd} + a^*2\sigma_{fd}^2\sigma^{-1}\sigma_{fd}.$$

Next, define the "demand price function"  $\tilde{q}_0(z_0)$  implicitly by

$$(2.12) \quad q_0 = \frac{\beta U_c(z_0 + \hat{x}^2)}{U_c(y^1 - q_0(z_0 + q'z))},$$

with  $\hat{x}^2$  given by (2.11) and  $z$  given by (2.9). Thus,  $\tilde{q}_0(z_0)$  is the demand price for riskless assets given equilibrium in the markets for risky assets. It is easy to show that the condition for  $\tilde{q}_0(\cdot)$  to be downward sloping is

$$(2.13) \quad U_c^1/U_{cc}^1 < q_0(z_0 + q'z),$$

where  $U_c^1$  denotes  $U_c(y^1 - q_0(z_0 + q'z))$ , etc. The left-hand side of the inequality is proportional to the intertemporal substitution effect and the right-hand side is proportional to the income or "terms-of-trade" effect. Thus, only a strongly positive income effect--due to a large total asset export--can make  $\tilde{q}_0(\cdot)$  positively sloped. The foreign demand price for indexed bonds  $\tilde{q}_0^*(z_0^*)$  is similarly defined. Then,  $\tilde{q}_0^*(\cdot)$  is downward sloping under the same condition that  $q_0$  is downward sloping, only that the left-hand side is replaced by  $U_c^{*1}/U_{cc}^{*1}$  with  $U_c^{*1} = U_c(y^{*1} - q_0(z_0 + q'z))$ , etc. We assume that condition (2.13) and its foreign analog are fulfilled.

Since  $z_0^* = -z_0$  in equilibrium, the condition for equilibrium in the market for riskless assets can be written as

$$(2.14) \quad \tilde{q}_0(z_0) = \tilde{q}_0^*(-z_0).$$

This condition can be solved for the equilibrium home country import of indexed bonds. Under the assumptions about the slopes of the demand price functions, the equilibrium is unique.

We note that we can write the budget constraint (2.1a) as

$$(2.15) \quad (c^1 - y^1) + q_0(z_0 + q'z) = 0,$$

and interpret it as a period 1 balance-of-payments-constraint. The first term is the current account deficit and the second is the capital account deficit, consisting of the value of indexed bonds import  $q_0 z_0$  and of nominal bonds import  $q_0 q'z = Q'z$ .

### 3. Money and Monetary Policy

We introduce money by postulating cash-in-advance constraints in goods markets. Our way of modeling these constraints follows closely the approach pioneered by Helpman (1981) and used in many subsequent papers in international finance. A similar formulation to the one we will use here, also in the context of a two-period uncertainty model, has recently been used by Svensson (1987), and we refer the reader to that paper for a detailed discussion on the institutional setting. The implications of money market equilibrium (with binding liquidity constraints) and goods market equilibrium is that the period 1 price levels in the home and foreign countries obey the simple quantity-theory equations

$$(3.1) \quad P^1 = M^1/y^1, \text{ and}$$

$$(3.1^*) \quad P^{*1} = N^1/y^{*1},$$

where  $M^1$  and  $N^1$  denote the home and foreign period 1 money supply. The period 1 exchange rate follows from the law-of-one-price,

$$(3.2) \quad e^1 = P^1/P^{*1}.$$

Similarly, the period 2 state-dependent price levels satisfy

$$(3.3) \quad P^2(s) = M^2(s)/y^2, \text{ and}$$

$$(3.3^*) \quad P^{*2}(s) = N^2(s)/y^{*2},$$

and the state-dependent period 2 exchange rate is given by

$$(3.4) \quad e^2(s) = P^2(s)/P^{*2}(s).$$

The above simplistic formulation is obviously very restrictive. But it is also very useful from a modeling point of view. Since outputs are exogenous, monetary policy in the two countries will determine the price levels and the exchange rate in each state. This means that once monetary policy is formulated, the risk-return properties of home and foreign currency bonds are also determined and can be taken as given in the real equilibrium

that we studied in the previous section. The real returns on home and foreign bonds are by equations (3.3) simply given by

$$(3.5) \quad d_m(s) = 1/P^2(s) = y^2/M^2(s) \text{ and} \\ d_n(s) = 1/P^{*2}(s) = y^{*2}/N^2(s).$$

The resulting recursivity of the model simplifies the analysis considerably. If, for instance, money demand would depend on consumption instead of on output, the recursivity would break down.

Monetary policies in the home and foreign country determine the period 1 and period 2 money supplies. In the subsequent study of risk and asset trade, we shall distinguish a few benchmark policy rules for period 2 monetary policies. The benchmark policy rules all have the property that the target variable is stabilized in the sense of becoming state-independent.

The first policy rule is when the government pursues a monetary or a nominal GDP target. In our model, this requires that the money supply is made state-independent. It follows from (3.3) that under such a target, the home government sets

$$(3.6) \quad M^2(s) = M^2, \text{ for all } s,$$

where  $M$  is the target for nominal GDP. As can be seen from (3.3), this results in home nominal GDP,  $P^2(s)y^2$ , being constant across states of the world. Analogously, foreign nominal GDP targeting requires

$$(3.6^*) \quad N^2(s) = N^2, \text{ for all } s.$$

Under the second policy rule, the government pursues an inflationary target. From (3.3), this policy requires the home government to set the second-period money supply in a state-dependent way, namely

$$(3.7) \quad M^2(s) = (1+\pi)P^1y^2, \text{ for all } s,$$

where  $\pi$  is the chosen inflation target. Hence the implicit period 2 price

level target is  $P^2(s) = P^2 = (1+\pi)P^1$  for all  $s$ . (In our framework, an inflation target and a period 2 price level target are equivalent.) A foreign inflation target implies

$$(3.7*) \quad N^2(s) = (1+\pi^*)P^{*1}y^2, \text{ for all } s.$$

Finally, the governments may adopt exchange rate targets. Here, we must distinguish whether the two governments do or do not coordinate their policies. An uncoordinated exchange rate target adopted by the home government, from (3.3) and (3.4) requires it to set the money supply in the following, state-dependent way

$$(3.8) \quad M^2(s) = \bar{e}N^2(s)y^2/y^{*2}, \text{ for all } s,$$

where  $\bar{e}$  is the target value of the period 2 exchange rate. If instead the two governments agree to coordinate their policies and adopt a coordinated exchange rate target  $\bar{e}$ , they have one remaining degree of freedom. The remaining degree of freedom is used to set the world money supply  $H^2(s) \equiv M^2(s) + \bar{e}N^2(s)$ , which is possibly state dependent. From (3.3) and (3.4), it follows that, given the world money supply  $H^2(s)$ , the two individual money supplies must be set according to

$$(3.9) \quad M^2(s) = H^2(s)y^2/y^{*2}, \text{ for all } s, \text{ and}$$

$$(3.9*) \quad N^2(s) = H^2(s)y^{*2}/\bar{e}y^2, \text{ for all } s.$$

Each country's money supply has to be set in proportion to that country's share in world output in state  $s$ . The coordinated exchange rate target can be associated with either a world nominal GDP target or a world inflation target. A world nominal GDP target implies

$$(3.10) \quad H^2(s) = H^2 \text{ for all } s,$$

which results in a constant world nominal GDP,  $P^2(s)y^w = H^2$  for all  $s$ . A world inflation target, with an implicit period 2 world price level target

$P^2(s) = P^2 = P^1(1+\pi)$  for all  $s$ , implies

$$(3.11) \quad H^2(s) = P^2 y^w \quad \text{for all } s.$$

That is, world money supply is set proportional to world output.

In this model it does not matter whether the governments undertake open market operations or foreign exchange interventions to affect price levels and exchange rates. The only thing that matters is the resulting effect on money supplies. There are two reasons for this. First, there is Ricardian equivalence, since consumers have rational expectations and are as long-lived as the economy, and since lumpsum net transfers are available. Second, the transactions structure is such that each country's representative consumer chooses to begin period 2 with zero holdings of the other country's currency. Then any seigniorage collected by each government is a tax on their own citizens only. See Svensson (1987) for further discussion of this. The consequence for our analysis is that we need only consider monetary policies in terms of direct money supply rules.

This completes the specification of the different possible rules for monetary policy. As we shall see in the next section, the risk properties of the available nominal bonds hinge crucially upon which combination of policy rules that the two countries adopt.

#### 4. Asset Trade

In this section we shall examine the aggregate capital account and the underlying trade pattern in nominal bonds and indexed bonds for the different stylized policy rules mentioned in section 3. In particular, we shall compare the trade pattern in nominal and indexed bonds ( $z_m$ ,  $z_n$ , and  $z_0$ ) and the

capital account deficit ( $q_0(z_0 + q'z)$ ) in a situation when the home and foreign country pursues specified monetary policies, and in a situation when the home country instead adopts an uncoordinated exchange rate target. At the end we shall also discuss what happens when the two countries adopt a coordinated exchange rate target.

a) Home Exchange Rate Targ vs. Home Nominal GDP target  
with a Foreign Nominal GDP Target

We start with the situation when the home and foreign countries both have an individual nominal GDP target, as given by equations (3.6). Substitution of equations (3.6) into the real return expressions (3.5) reveals that with these policy rules the expected return vector  $\bar{d}$  and the variance/covariance matrix  $\sigma$  are given by

$$(4.1) \quad \bar{d} = \begin{bmatrix} \bar{y}^2 \\ \bar{y}^{*2} \end{bmatrix} \quad \text{and} \quad \sigma = \begin{bmatrix} \sigma_{hh} & \sigma_{hf} \\ \sigma_{hf} & \sigma_{ff} \end{bmatrix}.$$

In other words, home and foreign nominal bonds become equivalent to claims to home and foreign output, respectively. We denote this circumstance by

$$(4.2) \quad m=h \quad \text{and} \quad n=f.$$

In the interest of brevity, we shall somewhat imprecisely refer to claims to home and foreign outputs as home and foreign stocks. Substitution of (4.1) into (2.9) immediately gives the trade pattern in nominal bonds, namely

$$(4.3) \quad z_m = -\alpha^* < 0 \quad \text{and} \quad z_n = \alpha > 0.$$

The home country exports home bonds and imports foreign bonds. Since home and foreign bonds are equivalent to home and foreign stocks, the home country diversifies its portfolio by effectively trading home stocks for foreign stocks. In equilibrium the home country then holds a portfolio of both home and foreign stocks.

Substitution of (4.2) in (2.8) gives the equilibrium prices (relative to indexed bonds) of home and foreign bonds,

$$(4.4) \quad q_m = q_h = \bar{y}^2 - \gamma^W \sigma_{wh} \quad \text{and} \quad q_n = q_f = \bar{y}^{*2} - \gamma^W \sigma_{wf}.$$

Here,  $q_h$  and  $q_f$  denote the (hypothetical) prices of home and foreign stocks and  $\sigma_{wh}$  and  $\sigma_{wf}$  denote the covariance between world period 2 output,  $y^{W2} = y^2 + y^{*2}$ , and home and foreign output, respectively. We use (4.3) and (4.4) to compute  $Z$ : the aggregate trade in nominal bonds

$$(4.5) \quad Z \equiv q'z = \alpha q_f - \alpha^* q_h = \alpha q_w - q_h,$$

where  $q_w = q_h + q_f$  is the (hypothetical) price (relative to the indexed bond) of claims to world period 2 output. We see that the home country effectively holds a share  $\alpha$  of claims to home output (the term  $\alpha q_w$ ), and that the aggregate trade in nominal bonds is the difference between that portfolio and an endowment consisting of home stocks (the term  $q_h$ ). This is of course an example of a familiar mutual-fund result in the CAPM model.

Numerous asymmetries between countries can be examined. In order to restrict the number of cases we limit the differences between countries to period 2 outputs being imperfectly correlated, and to attitudes towards risk. Let us therefore assume that the countries have the same period 1 output, and that the marginal probability distribution of their period 2 output is the same, but that their period 2 output may be less than perfectly correlated. More specifically, unless otherwise stated, we now assume

$$(A1) \quad y^1 = y^{*1}, \quad \bar{y}^2 = \bar{y}^{*2}, \quad \text{and} \quad \sigma_{hh} = \sigma_{ff}.$$

It follows directly from (A1) that  $\sigma_{hf}$ , the covariance between home and foreign period 2 output, is bounded by  $-\sigma_{hh} \leq \sigma_{hf} \leq \sigma_{hh}$ .

We shall also assume, unless otherwise stated, that the countries have the same time preferences, that is the same subjective discount factor and

intertemporal utility function,

$$(A2) \quad \beta = \beta^* \text{ and } U(\cdot) = U^*(\cdot).$$

Finally, we shall assume either that the two countries have the same absolute risk aversion,

$$(A3a) \quad \gamma = \gamma^* \text{ (that is, } \alpha = \alpha^* = 1/2\text{)},$$

or that the home country is more risk averse,

$$(A3b) \quad \gamma > \gamma^* \text{ (that is, } \alpha^* > 1/2 > \alpha\text{)}.$$

Under assumption (A1) we have  $q_h = q_f$  and hence

$$(4.6) \quad Z = (\alpha - \alpha^*)q_h.$$

It follows directly from (4.6) and (4.3) that when the countries have the same risk aversion, (A3a), aggregate trade in nominal bonds is zero and the home country effectively exports and imports exactly half of the home and foreign stocks,

$$(4.7) \quad Z = 0 \text{ and } z_m = -z_n = -1/2.$$

This is of course the familiar perfectly pooled equilibrium.

When the home country is more risk averse, (A3b), the home country in the aggregate exports nominal bonds, imports less of foreign bonds, and exports more of home bonds,

$$(4.8) \quad Z < 0, z_m < -1/2, \text{ and } 0 < z_n < 1/2.$$

Let us next examine the determinants of the trade in indexed bonds,  $z_0$ . Obviously, when the countries have the same risk aversion, there is zero trade in indexed bonds,

$$(4.9) \quad z_0 = 0,$$

since the countries are assumed to have the same intertemporal preferences.

It follows that the capital account is balanced,

$$(4.10) \quad q_0(z_0 + Z) = 0.$$

When the home country is more risk averse, indexed bonds are imported by the home country,

$$(4.11) \quad z_0 > 0.$$

We can show (4.11) by comparing the home and foreign demand price for indexed bonds when no indexed bonds are traded, that is,  $\tilde{q}_0(0)$  and  $\tilde{q}_0^*(0)$ , from (2.12) with

$$(4.12) \quad \begin{aligned} \tilde{q}_0(0) &= \beta U_c(\hat{x}^2)/U_c(y^1 - \tilde{q}_0(0)Z) \quad \text{and} \\ \tilde{q}_0^*(0) &= \beta U_c(\hat{x}^{*2})/U_c(y^1 + \tilde{q}_0^*(0)Z), \end{aligned}$$

where we have exploited (A2) and  $Z^* = -Z$ . From the definitions of  $\hat{x}^2$  and  $\hat{x}^{*2}$ , we have  $\hat{x}^2 - \hat{x}^{*2} = (\alpha - \alpha^*)(\bar{y}^W - \gamma^W \sigma_{WW}/2) < 0$ , where  $\sigma_{WW}$  is the variance of world output. Further, by (4.8)  $y^1 - \tilde{q}_0 Z > y^{*1} + \tilde{q}_0^* Z$ . Since  $U_c(\cdot)$  is decreasing, it follows that  $\tilde{q}_0(0) > \tilde{q}_0^*(0)$ , which implies  $z_0 > 0$  by (2.13).

Intuitively, the more risk averse home country has a lower certainty equivalent risky period 2 income ( $\hat{x}^2 < \hat{x}^{*2}$ ). Absent trade in indexed bonds, the home country has higher period 1 consumption, since it is a net exporter of risky assets. Intertemporal substitution and equal time preferences then implies that the home country imports indexed bonds to increase period 2 consumption and decrease period 1 consumption.

What can we say about the capital account deficit  $q_0(z_0 + Z)$  when the home country is more risk averse? Indexed bonds are imported, whereas nominal bonds are exported. What is the net? Let us make the additional assumption that the intertemporal preferences are homothetic, that is,

$$(A4) \quad U(c^1) + \beta U(\hat{c}^2) \text{ is homothetic}$$

(which is equivalent to assuming that  $U(\cdot)$  is CES, that is, the intertemporal elasticity of substitution is constant). Then it can actually be demonstrated (see the Appendix) that there is a capital account deficit,

$$(4.13) \quad q_0(z_0 + Z) > 0.$$

The import of indexed bonds dominates over the export of nominal bonds. The home country's higher risk aversion leads it to save more than the foreign country, which translates into positive net foreign investment.

Let us next consider the situation when the foreign country still pursues a nominal GDP target, but the home country instead pursues an (uncoordinated) exchange rate target, as specified in (3.8). It follows from (3.5) that home nominal bonds then get the same risk characteristics as foreign nominal bonds so that these two assets become perfect substitutes. Foreign nominal bonds have, as before, risk characteristics equivalent to foreign stocks. In addition to the indexed bonds, there is now effectively only one risky asset, namely foreign stocks. We denote this by

$$(4.14) \quad m = n = f.$$

Since home and foreign nominal bonds are perfect substitutes, only aggregate trade in them matters, and the particular composition of aggregate trade into trade in home and foreign bonds is irrelevant. In terms of the real model in Section 2, we must then regard the trade vector of risky assets  $z$  as one-dimensional. It is straightforward to verify, that all the expressions in Section 2 still hold when the relevant vectors and matrices are reinterpreted as scalars, however. For example, expected dividends and the variance of dividends on risky nominal bonds are given by the scalars

$$(4.15) \quad d = \bar{y}^{*2} \text{ and } \sigma = \sigma_{ff}.$$

Using (4.15) in (2.8) and (2.9) we directly get

$$(4.16) \quad z = z_f = \alpha - a^* \sigma_{hf} / \sigma_{ff} \text{ and } q = q_f = \bar{y}^{*2} - \gamma^W \sigma_{wf},$$

where  $z$  denotes aggregate trade in nominal bonds.

Under assumption (A3a), equal risk aversion, we have

$$(4.17) \quad z = (1 - \sigma_{hf}/\sigma_{ff})/2 \geq 0,$$

where  $z$  is nonnegative by (A1); recall that  $\sigma_{hf} \leq \sigma_{ff} = \sigma_{hh}$  under (A1). The home country diversifies its portfolio by importing the single risky asset, nominal bonds. It follows, of course, that aggregate trade in nominal bonds is nonnegative,

$$(4.18) \quad Z = qz \geq 0.$$

It is easy to show that the import of nominal bonds is financed by export of indexed bonds,

$$(4.19) \quad z_0 < 0.$$

What about the capital account? Under assumption (A4), homotheticity, it can indeed be shown (see the appendix) that the capital account is balanced,

$$(4.20) \quad q_0(z_0 + Z) = 0.$$

If instead the home country is more risk averse, (A3b), we see from (4.16) that it is no longer clear that the home country unambiguously imports nominal bonds. If  $\alpha^* \sigma_{ff} < \alpha \sigma_{hf}$ , we have  $z < 0$ , that is, the home country exports nominal bonds. The closer  $\sigma_{hf}$  to  $\sigma_{ff}$  and the larger  $\alpha^*$  relative to  $\alpha$ , the more likely is  $z < 0$ . If this indeed happens, nominal bonds (equivalent of foreign stocks) is a bad hedge for home output risk and it is better for the home country to insure itself by importing indexed bonds, which import is financed by export of nominal bonds. With regard to the aggregate capital account, it can be shown (see the appendix) that under (A4), homotheticity,

$$(4.21) \quad \text{sgn } q_0(z_0 + Z) = \text{sgn } (\gamma - \gamma^*)[(1+z)^2 \sigma_{ff}/2 + \alpha^*(\sigma_{ff} + \sigma_{hf})z].$$

We see that if  $z > 0$ , the capital account is definitely in deficit. But if  $z < 0$ -because, as explained above,  $\sigma_{hf}$  is positive and close to  $\sigma_{ff}$  and  $\alpha^* \gg \alpha$ -the capital account may instead be in surplus. In the latter case, a change from a nominal GDP target to an exchange rate target thus causes the

capital account to change sign.

In summary, a change from a nominal GDP rule to an exchange rate rule, when the foreign country has a nominal GDP rule, clearly implies a different composition of the capital account. If the two countries have the same risk aversion, the aggregate capital account is unchanged at zero. But if the home country is more risk averse, the capital account may change from deficit to surplus.

b) Home Exchange Rate Target vs. Home Inflation Target  
with a Foreign Nominal GDP Target

We next look at the case when the foreign country pursues a nominal GDP target, but the home country has an inflation target. Then home bonds are perfect substitutes for indexed bonds, whereas foreign bonds remain equivalent to foreign stocks,

$$(4.22) \quad m = 0, n = f.$$

It follows that the effective availability of assets is equivalent to the case in (a) when the home country follows an exchange rate rule. Assume now that the home country instead shifts to an exchange rate target. That makes risky nominal home and foreign bonds perfect substitutes,

$$(4.23) \quad m = n = f.$$

Therefore, under our assumption that there are indexed bonds, the same array of assets is effectively available, namely indexed bonds and risky nominal foreign bonds. It follows that the equilibrium is effectively the same, as when the home country pursues an inflation target, although the denomination of the traded assets may change.

c) Home Exchange Rate Target vs. Home Inflation Target

with a Foreign Inflation Target

When the home and foreign countries initially pursue inflation targets, home and foreign bonds are both equivalent to indexed bonds. There is effectively only one asset traded, the indexed bond. In our notation

$$(4.24) \quad m = n = 0.$$

When the countries have the same risk aversion, it follows (since the two countries are equal in all other respects) that there is no trade and the capital account is balanced,

$$(4.25) \quad z_0 = 0.$$

When the home country is more risk averse, we have

$$(4.26) \quad \hat{x}^2 - \hat{x}^{*2} = -(\gamma - \gamma^*)\sigma_{hh}/2 < 0,$$

(we have used (A1)). Absent trade in indexed bond, the certainty equivalent period 2 consumption is lower in the home country. It follows that the home country will import indexed bonds,

$$(4.27) \quad z_0 > 0,$$

and there will be a capital account deficit.

When each country pursues an inflation target, the exchange rate is constant. Hence it makes no difference if the home country instead pursues an exchange rate target.

d) Home Exchange Rate Target vs. Home Nominal GDP Target

with a Foreign Inflation Target

When the foreign country pursues an inflation target and the home country pursues a nominal GDP target, the situation is of course the mirror image of the one discussed under b) above. That is,

$$(4.28) \quad m = h, \quad n = 0.$$

The trade pattern in assets is determined by the same conditions as when the home country has an exchange rate target under a).

If the home country instead pursues an exchange rate target, we have

$$(4.29) \quad m = n = 0,$$

that is, the availability of assets is equivalent to the one discussed under c) above.

If the two countries are equally risk averse, (A3a), the adoption of an exchange rate target does not change net foreign investment: it follows from the results above that the capital account stays at zero. However, gross trade in assets is different. While the home country trades (exports or imports) nominal bonds for indexed bonds with an inflation rule, gross trade is indeterminate and may very well be zero with an exchange rate rule.

If the home country is more risk averse, (A3b), the situation with an inflation rule is not exactly the mirror image of b), since now the more risk averse home country can effectively trade its own stocks (rather than the other country's stocks as in b)). The more risk averse home country will always export its stocks, hence

$$(4.30) \quad z = z_h < 0 \text{ and } Z = qz < 0.$$

By symmetry one can derive an analog to (4.21),

$$(4.31) \quad \operatorname{sgn} q_0(z_0 + Z) = \operatorname{sgn} (\gamma - \gamma^*)[(1-z_h)^2 \sigma_{hh}/2 - \alpha(\sigma_{hh} + \sigma_{hf})z_h].$$

It follows from (4.30) and (4.31) that the capital account is in deficit,

$$(4.32) \quad q_0(z_0 + Z) > 0.$$

There is import of indexed bonds, and that dominates over export of risky home nominal bonds.

With the exchange rate rule, there is also a capital account deficit, as under c) above.

e) Coordinated Exchange Rate Targets

Let us finally consider two cases of coordinated exchange rate targets. The first one is trivial, namely when both countries, in addition to the common exchange rate target, pursues a world inflation target instead of individual inflation targets. It is easy to see that the asset availability in this case is equivalent to the one under c) above when both countries have individual inflation targets and the home country shifts to an individual exchange rate target. As under c) asset trade is thus unaffected by the change to a common exchange rate target.

The other case is when the home and foreign countries adopt a world nominal GDP target in addition to the common exchange rate target. Then home and foreign bonds are perfect substitutes for risky claims to world output,

$$(4.33) \quad m = n = w,$$

with expected dividends and variance

$$(4.34) \quad \bar{y}^w 2 = \bar{y}^2 + \bar{y}^{*2} \text{ and } \sigma_{ww} = \sigma_{hh} + 2\sigma_{hf} + \sigma_{ff}.$$

Using this and (A1) in (2.9), we have

$$(4.35) \quad z = z_w = (\alpha - \alpha^*) \sigma_{hw} / \sigma_{ww} = (\alpha - \alpha^*) / 2.$$

When the countries have the same risk aversion, there is obviously no trade in either risky nominal bonds or indexed bonds, and a balanced capital account:

$$(4.36) \quad z = z_0 = 0.$$

It is natural to compare this outcome with the outcome when the two countries initially pursue individual nominal GDP targets, which is the first case analyzed under a). There the capital account was also balanced, but there was gross trade in nominal bonds: the home country exporting home bonds and importing foreign bonds.

When the home country is more risk averse, (A3b), the adoption of a common exchange rate target makes the home country export risky nominal bonds

$$(4.37) \quad z < 0$$

(unless home and foreign output are perfectly negatively correlated).

What about trade in indexed bonds, and the sign of the capital account? We know from the case discussed under heading c), that in the absence of trade in risky assets, there would be import of indexed bonds, and a capital account deficit. Indeed, it can be shown (see appendix) that indexed bonds are imported,

$$(4.38) \quad z_0 > 0,$$

and that indexed bonds import dominates over nominal bonds export so that that capital account is in deficit,

$$(4.39) \quad q_0(z_0 + Z) > 0.$$

In this case adopting an exchange rate target for monetary policies would not cause a reversal of the capital account.

## 5. Conclusions

We have investigated how different monetary policies affect the risk-return characteristics of nominal assets and how this in turn affects real decisions--savings and portfolio allocations--in an incomplete markets setting. With regard to the main question, how less exchange rate variability influences trade in assets and net foreign investment, our results indicate that one should not hope for any unambiguous conclusions. Depending on the initial policies at home and abroad, a monetary policy aiming at reduced exchange rate variability may imply very different effects on the trade pattern in assets. Net foreign investment may, on the one extreme, not be

affected at all, or on the other extreme, change sign: from positive to negative, or from negative to positive.

Nevertheless, we believe that the general question that we have addressed--how real trade is affected by monetary and exchange rate policy in an uncertain world with incomplete markets--is worth pursuing further. We can think of a number of extensions of the simplistic framework in this paper. Within the context of our model, we assumed the existence of indexed bonds throughout the analysis. This was mostly for analytical convenience; the model becomes much harder to solve if there are no indexed bonds. Unfortunately, the assumption that indexed bonds are traded is not innocuous; it does affect the results in several of the cases that we considered. But we do believe that an extension without indexed bonds is feasible, however, and that such an extension is both well motivated and interesting. Well motivated because international trade in indexed bonds is not empirically significant, and interesting because without indexed bonds savings and portfolio decisions can not be separated at all.

The trade patterns and capital accounts discussed in our model are relative to autarky. Discussions of capital movements meaning changes in portfolios over time requires a framework with several periods, which raises many well known technical difficulties.<sup>8</sup> Also, the comparisons between different policy regimes are of course comparisons of different equilibria with given regimes, not analysis of changes over time in equilibria from changes over time in policy. A proper analysis of the latter is also associated with well known difficulties. It may be that one can make some

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<sup>8</sup> See Dumas (1986) for a model where portfolio adjustment takes place over time.

progress on the effect of policy changes by analyzing our model with arbitrary (instead of zero) initial portfolios, and then letting the initial portfolios represent the steady-state portfolios in particular policy regimes.

The model could be extended to include investment in physical capital, so as to make possible a richer analysis of the link between exchange rate risk and foreign investment.<sup>9</sup> One could also include more than one good and analyze the connection between exchange rate risk and foreign (atemporal) trade.<sup>10</sup> For exchange rate risk to be associated with relative price risk--which seems to be what many people suggesting an adverse affect of exchange rate risk on trade have in mind--one has to incorporate predetermined or "sticky" goods prices, however.

Since the agents are optimizing and there are well-defined utility levels, it is tempting to use the model to discuss optimality of monetary policies. This should be done with great care, though, since with this setup with incomplete markets there is an inherent bias against exchange rate stabilizing policy, since such policy generally reduces the number of available assets and hence reduces the scope for risk-sharing. Of course, it should also be remembered that our model does not incorporate the underlying frictions that make international financial markets incomplete. Any normative analysis would therefore rest on shaky foundations.

One may, of course, also criticize our positive analysis on the same grounds. Put differently, the criticism of the portfolio balance approach for

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<sup>9</sup> Gordon and Varian (1986) do include physical investment in their real one-good model of asset trade.

<sup>10</sup> Grossman and Razin (1985) discuss how real trade flows are affected by uncertainty in a Ricardian trade model where asset (stock) markets are incomplete.

not including individual maximization and thus being subject to the "Lucas Critique", can be made of our own analysis for not including the reasons why markets are incomplete. Given the well known difficulties to come up with a satisfactory explanation for the existence of nominal contracts, we suspect that an attempt to derive the asset structure from first principles would violate the starting point for our whole analysis, namely the absolute preponderance of nominal contracts in international financial markets.

## Appendix

We first derive a general expression for the capital account under the assumptions (A2) and (A4), that time preferences in the two countries are equal and homothetic. Then we use this expression to verify the statements in (4.13), (4.20) and (4.21).

From the budget constraints, (2.1a), and the definitions of  $\hat{x}^2$  and  $\hat{x}^{*2}$ , (2.10), it follows that

$$(A.1) \quad c^1 + q_0 \hat{c}^2 = y^1 - q_0 Z + q_0 \hat{x}^2$$

$$(A.1^*) \quad c^{*1} + q_0 \hat{c}^{*2} = y^{*1} + q_0 Z + q_0 \hat{x}^{*2},$$

where the RHS of each equation is a measure of "certainty equivalent wealth" in the country. By (A2) and (A4), we have

$$(A.2) \quad c^1 = y^1 - q_0(z_0 + Z) = \frac{y^1 - q_0 Z + q_0 \hat{x}^2}{y^1 + y^{*1} + q_0(\hat{x}^2 + \hat{x}^{*2})} (y^1 + y^{*1});$$

that is the home country's period 1 consumption as a share of world period 1 output equals the share of the home country's certainty equivalent wealth in world certainty equivalent wealth. Using  $y^1 = y^{*1}$  by our symmetry condition (A1), it is straightforward to rewrite (A.2) as

$$(A.3) \quad q_0(z_0 + Z) = \frac{q_0 y^1}{2y^1 + q_0(\hat{x}^2 + \hat{x}^{*2})} [2Z - (\hat{x}^2 - \hat{x}^{*2})].$$

The sign of the capital account is thus determined by the expression within square brackets.

First consider the case (4.2):  $m = h$ ,  $n = f$ . Under assumption (A1), it follows from (4.4) and (4.5) that

$$(A.4) \quad Z = (\alpha - \alpha^*) q_h = (\alpha - \alpha^*) (\bar{y}^2 - \gamma^w \sigma_{wh}).$$

Also, as discussed under (4.12)

$$(A.5) \quad \hat{x}^2 - \hat{x}^{*2} = (\alpha - \alpha^*) (\bar{y}^w 2 - \gamma^w \sigma_{ww}/2) = (\alpha - \alpha^*) (2\bar{y}^2 - \gamma^w \sigma_{wh})$$

here the last equality follows since  $\sigma_{ww} = \sigma_{hh} + \sigma_{ff} + 2\sigma_{hf} = 2(\sigma_{hh} + \sigma_{hf}) = 2\sigma_{wh}$ . Thus, we get

$$(A.6) \quad 2Z - (\hat{x}^1 - \hat{x}^{*2}) = (a^* - a)\gamma^w \sigma_{wh}.$$

Substituting (A.6) into (A.3) proves (4.13)

Consider next the case (4.14):  $m = n = f$ . Then, using (4.15) and the definition (2.4), the variances of consumption fulfill

$$(A.7) \quad \sigma_{cc} = \sigma_{hh} + z^2 \sigma_{ff} + 2z\sigma_{hf} \quad \text{and}$$

$$(A.7^*) \quad \sigma_{c^*c^*} = \sigma_{ff} + z^2 \sigma_{ff} - 2z\sigma_{ff}.$$

From (A.7) and the definitions of  $\hat{x}^2$  and  $\hat{x}^{*2}$ , one can, after some manipulations, derive

$$(A.8) \quad \hat{x}^2 - \hat{x}^{*2} = 2z(\bar{y}^{*2} - \gamma^w \sigma_{wf}) - \frac{\gamma - \gamma^*}{2} (1+z)^2 \sigma_{ff} - \frac{\gamma - \gamma^*}{\gamma + \gamma^*} (2z\sigma_{wf}).$$

The expression for  $q_f = q$  in (4.16) and the definition of  $a^*$  imply that (A.8) can be rewritten as

$$(A.9) \quad \hat{x}^2 - \hat{x}^{*2} = 2Z - (\gamma - \gamma^*)((1+z)^2 \sigma_{ff}/2 - a^*z\sigma_{wf}).$$

It follows that

$$(A.10) \quad 2Z - (\hat{x}^2 - \hat{x}^{*2}) = (\gamma - \gamma^*)((1+z)^2 \sigma_{ff}/2 - a^*z\sigma_{wf}),$$

which together with (A.3) proves (4.2) and (4.21).

Finally it is easy to verify that if the conditions in the text are fulfilled,  $q_0(z_0 + Z)$  may well be negative in this case. To see this substitute the equilibrium value of  $z$  from (4.16) into (4.21). As an example let the critical parameter values be  $\gamma = 2$ ,  $\gamma^* = 1$  and  $\sigma_{hf} = 7\sigma_{ff}/8$ . Straightforward calculations show that  $q_0(z_0 + Z) = -1/8$ .

Let us also consider the case  $m = n = w$  and demonstrate (4.38) and (4.39). Under (A1) we have

$$(A.11) \quad \bar{d} = \bar{y}^{w2} = 2\bar{y}^2, \quad \sigma = \sigma_{ww} = 2(\sigma_{hh} + \sigma_{hf}), \quad \text{and} \quad \sigma_{hw} = \sigma_{fw} = \sigma_{hh} + \sigma_{hf}.$$

It follows from (2.8) and (2.9) that

$$(A.12) \quad q = q_w = 2\bar{y}^2 - 2\gamma^w(\sigma_{hh} + \sigma_{hf}) \text{ and}$$

$$(A.13) \quad z = z_w = (\alpha - \alpha^*)/2.$$

This and some algebra gives

$$(A.14) \quad 2Z - (\hat{x}^2 - \hat{x}^{*2}) = (\gamma - \gamma^*)(\sigma_{hh} + \sigma_{hf})[\sigma_{hh}/2(\sigma_{hh} + \sigma_{hf}) - z^2].$$

We have  $z^2 \leq 1/4$  by (A.13) ( $z^2 < 1/4$  for  $\gamma > 0$  and  $\gamma^* > 0$ ), and we have

$$\sigma_{hh}/2(\sigma_{hh} + \sigma_{hf}) \geq 1/4 \text{ by } \sigma_{hf} \leq \sigma_{hh} \quad (\sigma_{hh}/2(\sigma_{hh} + \sigma_{hf}) > 1/4 \text{ for } \sigma_{hf} < \sigma_{hh}).$$

Hence, for either positive absolute risk aversion or home and foreign output less than perfectly correlated, we get

$$(A.15) \quad 2Z - (\hat{x}^2 - \hat{x}^{*2}) > 0,$$

and this together with (A.3) implies (4.38) and (4.39).

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