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Trade in nominal assets and net international capital flows

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Abstract

Nominal assets play a major role in international financial markets, while trade in indexed bonds is limited. As a result, agents are exposed to both price and exchange rate uncertainty. Nonetheless, previous research on net capital flows has assumed the presence of a risk-free vehicle to intertemporal asset trade. In this paper we develop a general equilibrium intertemporal model with trade limited to nominal bonds and equity. We find that exposure to nominal risk dampens net capital flows, thus making economies effectively more closed.

JEL classification: F32; F41

1. Introduction

What determines the size of net international capital flows? This has long been a central question in international macroeconomics. It has been addressed extensively in the context of models that assume the existence of an asset providing a risk-free vehicle to intertemporal asset trade.[1] This approach abstracts from the reality that

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[1] Models of intertemporal asset trade developed in the early 1980s generally assume a small open economy, deterministic framework: Obstfeld (1982), Sachs (1982) and Svensson and Razin (1983), and Persson and Svensson (1985) are examples (Frenkel and Razin, 1992 analyze a two-country general equilibrium version). Subsequently, stochastic small open economy models with trade in a risk-free bond were developed. Examples are Greenwood (1983), Zeira (1987) and Mendoza (1991), and Cardia (1991). Recently general equilibrium stochastic open economy models with trade limited to risk-free bonds have been developed by Baxter and Crucini (1995), Devereux and Saito (1997), Kollmann (1995, 1996) and van Wincoop (1996). Two-country general equilibrium models with complete markets, such as Backus, Kehoe and Kydland (1992), implicitly assume the existence of a risk-free bond as well.

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Nomenclature

P	price level in the second period
S	nominal exchange rate in the second period
M_i	money supply in period i
e_i	total endowment in period i
e_{iL}	labor endowment in period i
e_{iK}	capital endowment in period i
$\bar{e}_{2K}$	expectation of e_{2K} in period 1
$\tilde{e}_1$	e_{1L}+earnings from claims on e_{1K}
q_K	period 1 price of period 2 claim on H-country equity
q	period 1 price of H-country nominal bond with payoff in period 2
$\mathbf{q}$	asset price vector=$(q, q^*, q_K, q_K^*)'$
r	risk-adjusted real asset return
b_H	holdings of H-country nominal bonds
b_F	holdings of F-country nominal bonds
k_H	holdings of H-country equity claims
k_F	holdings of F-country equity claims
$\underline{k}_H$	holdings before period 1 on period 2 H-country equity claims
$\underline{k}_F$	holdings before period 1 on period 2 F-country equity claims
$\mathbf{w}$	vector of asset holdings
$\bar{\mathbf{w}}$	vector of asset supplies
$\mathbf{w_0}$	vector of initial asset positions
$\mathbf{d}$	vector of real asset payoffs = $(\frac{1}{p}, \frac{1}{p*}, e_{2K}, e_{2K}^*)'$
$\mathbf{\Sigma}$	variance-covariance matrix of asset payoffs
c_1	period 1 consumption
$\hat{c}_2$	risk-adjusted period 2 consumption
$\bar{c}_2$	expected second period consumption
β	discount factor
ρ	intertemporal elasticity of substitution
γ	degree of absolute risk aversion
θ	$U'(c_1)c_1/U'(\hat{c}_2)\hat{c}_2$

trade in nominal assets is important and trade in indexed bonds is limited. Borrowers and lenders are exposed to price uncertainty and, particularly in the international context, to exchange rate uncertainty. Our goal is to understand the macroeconomic implications of this nominal risk within a tractable general equilibrium framework. We develop an incomplete markets model with trade limited to nominal bonds and a real asset (equity) with a risky payoff. We find that nominal risk reduces net international capital flows. This barrier to intertemporal asset trade therefore makes economies effectively more closed, particularly for a high degree of nominal risk.

This result is consistent with preliminary evidence that exchange rate uncertainty reduces net capital flows.

Existing open economy models that explicitly introduce nominal uncertainty are mostly concerned with asset pricing, and are not suitable for studying net international capital flows.[2] This literature, based on Lucas (1982), develops stochastic monetary general equilibrium models of exchange rate determination,[3] but generally assumes that asset markets are complete. Individuals can therefore perfectly hedge nominal risk. Stockman and Svensson (1987) study net capital flows, but find that the perfect pooling assumption implies that these flows are only due to a change in the valuation of existing assets, not to a change in asset holdings themselves. Because such valuation effects are usually not measured in the national accounts, they argue that the current account would be zero if the standard national accounts definition were adopted.

A couple of papers focus more explicitly on asset trade in the presence of an incomplete markets, general equilibrium, setup with nominal uncertainty. Svensson (1989) considers a two-country monetary model in which there is only trade in nominal bonds. The model is used to make qualitative predictions about the pattern of trade. However, there are no specific results on the magnitude of particular asset holdings and net capital flows. Persson and Svensson (1989) study a similar model and analyze the risk characteristics of the real return on nominal bonds under different assumptions about monetary policy. The model is then used to compute the capital account when one country is more risk averse than the other. But for analytical convenience Persson and Svensson still allow for trade in an indexed bond, which implies that individuals can fully hedge nominal risk.

Our strategy is to use a tractable model that allows for an analytical study of the relationship between nominal risk and net capital flows. To this end, we build on the framework developed by Persson and Svensson (1989), which is a two-period, two-country endowment economy. But we introduce different tradable assets: nominal bonds and equity.

An alternative strategy would be to obtain a numerical approximation to the solution of a more complicated infinite horizon model. This would allow us to introduce a production economy and richer dynamics. While such an endeavor is a potentially fruitful direction for future research, we believe our approach has several advantages. First, the model can be seen as an extension to the familiar two country, two-period endowment economy without uncertainty (e.g. Frenkel and Razin, 1992). Second, we obtain an explicit analytical solution by considering a marginal deviation from a symmetric equilibrium. The familiar expression for net capital flows in a risk-free world is modified with one extra term capturing nominal risk exposure. Third, because we are able to solve the model analytically, the mechanisms at work are

[2] Even less applicable for our purpose are the many deterministic open economy models with trade in nominal bonds. Helpman and Razin (1984) is an example. See Obstfeld and Rogoff (1996), chapter 8, for an overview.

[3] See for example Svensson (1985), Hodrick (1989), Stockman and Svensson (1987) and Backus, Gregory and Telmer (1993).

more transparent. Finally, we believe our model can provide a benchmark to interpreting results based on models with more complicated dynamics, and various other extensions.[4]

In our basic framework, as well as in most open-economy monetary models, Purchasing Power Parity (PPP) is assumed. This implies that the exchange rate is equal to the ratio of price levels and that exchange rate risk cannot be distinguished from relative inflation risk. In an attempt to disentangle the two sources of nominal risk, exchange rate and inflation risk, we examine an extension of the benchmark model where information about foreign monetary policy is imperfect. We show in this framework that exchange rate risk per se reduces net capital flows.

The remainder of the paper is organized as follows. The model is introduced in Section 2. In Section 3 we compute net capital flows resulting from various sources of asymmetry. Section 4 examines an extension with asymmetric information about monetary policy that emphasizes the role of exchange rate uncertainty. The final section concludes and discusses directions for future work.

2. The model

Since the model description is notation intensive, we supply a table with a list of all variables and their definitions.

There are two countries, H and F, with representative individuals living for two periods. Nominal and real variables are indicated with upper and lower case letters, respectively, and F-country variables are denoted by an asterisk. Before examining the individuals' optimal behavior, we describe the structure of the goods and asset markets.

2.1. Goods and asset markets

We consider a simple one-good endowment economy. H- and F-country residents receive a stochastic endowment of e_i and e_i^* at the beginning of period i. We assume that only a proportion of the endowment is traded and so we break up the endowment in two random components:

$$e_i = e_{iL} + e_{iK}$$

We refer to e_{iL} and e_{iK} as the labor and capital endowment. Markets are incomplete because there is only trade in claims on capital endowments (equity). In the first period, residents from both countries can sell claims on their second-period capital

[4] It is also worth pointing out that findings based on a numerical approximation of the solution to an infinite horizon economy can be deceiving. In particular, when using standard linearization techniques the approximated linear decision rules do not depend on uncertainty at all. For example, Kim (1996) uses a general equilibrium infinite horizon two-country setup with only nominal bonds. He can only solve for the approximated linear decision rules, where consumption depends on expected endowments and not on uncertainty about future endowments.

endowments. Normalizing the supply of equity to one, these claims have a real payoff of e_{2K} and e^*_{2K}, with a period-one price of q_K and q^*_K.

In the first period, individuals can invest in domestic and foreign nominal discount bonds, in domestic and foreign claims on endowments, and in domestic money. The H- and F-country nominal bonds have a price of q and q^* in terms of period 1 goods. Their period 2 payoff is one unit of the local currency. Hence, the real payoffs on the domestic and foreign nominal bonds for H-country residents are $\frac{1}{P}$ and $\frac{S}{P}$, where P and S denote the second period price level and nominal exchange rate. With one tradable good Purchasing Power Parity (PPP) holds, and the real payoffs are the same for F-country residents: $\frac{1}{SP^*}=\frac{1}{P}$ and $\frac{1}{P^*}=\frac{S}{P}$ where P^* is the F-country price level in period 2.

Let b_H and b_F denote the quantities of domestic and foreign nominal bonds held by individuals of country H and k_H, k_F equity holdings. The vector $\mathbf{w}$ of asset holdings is defined by $\mathbf{w}'=(b_H,\ b_F,\ k_H,\ k_F)$. Similarly, foreign asset holdings are described by $\mathbf{w}^{*\prime}=(b^*_H,b^*_F,k^*_H,k^*_F)$. Nominal bonds are assumed to be in zero net supply, while equity supplies are equal to one. Consequently, the market clearing conditions are given by

$$\mathbf{w}+\mathbf{w}^*=\bar{\mathbf{w}}, \tag{1}$$

where $\bar{\mathbf{w}}'=(0,0,1,1)$. We also denote by $\mathbf{w_0}$ the vector of initial asset positions by H-country residents, which is equal to $(0,0,\bar{k}_H,\bar{k}_F)'$, where $\bar{k}_H$, $\bar{k}_F$ are claims by domestic residents on second-period capital endowments before asset trade takes place during period one. We assume $\bar{k}_H+\bar{k}_F=1$.

Money is introduced through a standard cash-in-advance constraint, assuming that the seller's currency is always used (the S-system in Helpman and Razin, 1984). As in Lucas (1982), the asset market opens after prices are known, so that money market equilibrium conditions are

$$M_i=P_ie_i, \tag{2}$$

$$M^*_i=P^*_ie^*_i \tag{3}$$

for i=1, 2. The seigniorage revenue obtained from money creation is returned to individuals through a lump-sum transfer.

The price levels are $P_i=M_i/e_i$ and $P^*_i=M^*_i/e^*_i$. When consumption and investment decisions are made during period 1, first-period endowments and money supplies are known, but those in the second period are unknown.[5] For convenience, we normalize the money supply to be equal to the endowment in the first period in both countries, so that first-period price levels are equal to one. Hence we denote $P_1=P^*_1=1$, $P_2=P$, and $P^*_2=P^*$.

[5] It is feasible to also allow for a stochastic money demand velocity. For example, Bohn (1990) assumes that all money is held through account balances and that a stochastic fraction ν of checks deposited experiences a technical delay in clearing. This leads to money demand equal to νPe. But for the analysis that follows it does not matter whether shocks originate on the demand or supply side of the money market.

We impose symmetry by assuming that the vector of domestic payoffs $\left(\frac{1}{P},e_{2K},e_{2L}\right)$ has the same variance as the vector of foreign payoffs $\left(\frac{1}{P^*},e^*_{2K},e^*_{2L}\right)$ and that they have a symmetric covariance. We also assume $E\left(\frac{1}{P}\right)=E\left(\frac{1}{P^*}\right)=1$, $E(e_{2K})=E(e^*_{2K})=\bar{e}_{2K}$, and $E(e_{2L})=E(e^*_{2L})=\bar{e}_{2L}$.

2.2. The consumer maximization problem

Define the asset price vector by $\mathbf{q}'=(q,q^*,q_K,q^*_K)$ and the vector of asset payoffs by $\mathbf{d}'=\left(\frac{1}{P},\frac{1}{P^*},e_{2K},e^*_{2K}\right)$. First- and second-period budget constraints for H-country residents are:

$$c_1=\tilde{e}_1-(\mathbf{w}-\mathbf{w_0})'\mathbf{q}, \tag{4}$$

$$c_2=e_{2L}+\mathbf{w}'\mathbf{d}, \tag{5}$$

where real consumption in period i is c_i and $\tilde{e}_1$ is the sum of the first-period labor endowment and earnings from claims on the first period capital endowment. We will assume that asset payoffs and labor income are both normally distributed, so that second period consumption has a normal distribution as well.

We adopt a specific form of Selden (1978, 1979) preferences, also used by Persson and Svensson (1989). This approach has the advantage of mathematical tractability and a separation of the intertemporal elasticity of substitution of consumption from the rate of risk aversion. Preferences are given by

$$U(c_1)+\beta U(\hat{c}_2), \tag{6}$$

where

$$U(c)=c^{1-1/\rho}/(1-1/\rho). \tag{7}$$

Here β is the discount factor, ρ the intertemporal elasticity of substitution of consumption, and $\hat{c}_2$ the certainty equivalent of c_2. The latter is derived from a constant absolute risk aversion atemporal utility function V:$V(\hat{c}_2)=EV(c_2)$, where $V(c)=-e^{-\gamma c}$, and γ is the degree of absolute risk-aversion. Consequently, using the fact that consumption is normally distributed,

$$\hat{c}_2=\bar{c}_2-\frac{\gamma}{2}var(c_2). \tag{8}$$

Denote by $\bar{\mathbf{d}}$ the vector of expected payoffs ($\bar{\mathbf{d}}'=(1,1,\bar{e}_{2K},\bar{e}_{2K})$) and by $\mathbf{\Sigma}=var(\mathbf{d})$ the 4×4 variance-covariance matrix of asset payoffs. Then

$$\bar{c}_2=E(c_2)=\bar{e}_{2L}+\mathbf{w}'\bar{\mathbf{d}}, \tag{9}$$

$$var(c_2)=var(e_{2L})+\mathbf{w}'\mathbf{\Sigma}\mathbf{w}+2\mathbf{w}'cov(e_{2L},\mathbf{d}). \tag{10}$$

The variance of consumption is the sum of three terms: the variance of labor income, the variance of asset payoffs, and the covariance between labor income and asset payoffs.

It is convenient to denote by r the marginal rate of substitution between risk-adjusted consumption levels:

$$r \equiv \frac{U'(c_1)}{\beta U'(\hat{c}_2)} \tag{11}$$

r is the risk-adjusted return on assets held by domestic residents. We will also refer to it as the real interest rate. In the absence of trade in indexed bonds, and with nominal risk, there is no risk-free asset, so r is not the return on an existing asset. It is the return that investors would be willing to accept on a risk-free asset if it were traded, in the sense that marginal holdings of the risk-free asset makes investors equally well of, ex-ante, as marginal holdings of risky assets.

Maximization of Eq. (6) over $\mathbf{w}$ leads to the following first-order condition:

$$r\mathbf{q} = \bar{\mathbf{d}} - \gamma \mathbf{\Sigma} \mathbf{w} - \gamma cov(e_{2L}, \mathbf{d}). \tag{12}$$

The price on an asset depends positively on its expected payoff, negatively on the covariance with the overall asset portfolio and negatively on its covariance with labor income. A similar first-order condition applies to the foreign country:

$$r^* \mathbf{q} = \bar{\mathbf{d}} - \gamma \mathbf{\Sigma} \mathbf{w}^* - \gamma cov(e_{2L}^*, \mathbf{d}). \tag{13}$$

2.3. Equilibrium

The model is summarized by five equations: Eq. (11), its foreign counterpart, first-order conditions Eqs. (12) and (13), and market equilibrium condition Eq. (1). The first two equations represent the intertemporal decisions, while the third and the fourth describe portfolio allocation decisions. These equations can be used to solve for $\mathbf{w}$, $\mathbf{w}^*$, r, r^* and $\mathbf{q}$. In a symmetric equilibrium $r=r^*$, $q=q^*$, and $q_K=q_K^*$. The vector of asset holdings in the symmetric equilibrium is

$$\mathbf{w} = \frac{1}{2}\bar{\mathbf{w}} + \frac{1}{2}\mathbf{\Sigma}^{-1} cov(e_{2L}^* - e_{2L}, \mathbf{d}). \tag{14}$$

When asset returns are uncorrelated with labor endowments, agents hold no nominal bonds and invest in half the equity supplies of each country. More generally, $b_H+b_F=0$ and $k_H+k_F=1$, with the distribution between domestic and foreign assets dependent on the correlation between asset returns and labor endowments. The net capital outflow or, equivalently, the current account, is given by $CA=\mathbf{q}'(\mathbf{w}-\mathbf{w_0})$, which is zero in the symmetric equilibrium.

3. Net capital flows

3.1. Nominal risk and net capital flows

In Section 2 there were no net capital flows since we analyzed a symmetric equilibrium. In this section we examine the impact of nominal uncertainty on net flows. To introduce net flows we allow for endowment and preference parameter asymmetries. No analytic closed-form solution exists in the asymmetric case. Consequently, we consider the effect on the current account of marginal asymmetries, starting from the symmetric equilibrium described above. This is done by fully differentiating the entire system of equations around the symmetric equilibrium. We consider marginal changes in the home country of e_{1L}, $\overline{e}_{2L}$, the preference parameters β and ρ, and the variance of second period labor income $var(e_{2L})$.[6] We denote this set of parameters by the vector $\mathbf{x}'=(e_{1L},\overline{e}_{2L},\beta,\rho,var(e_{2L}))$.

By using symmetry assumptions, the Appendix A shows that differentiation of the portfolio allocation Eqs. (12) and (13) leads to

$$dr-dr^{*}=-2\gamma dCA/\mathbf{q}'\mathbf{\Sigma}^{-1}\mathbf{q}. \tag{15}$$

The risk-adjusted returns r and r* are equal to expected returns minus risk premia. An increase in holdings of risky assets implies that investors demand a higher risk premium. Since expected asset returns are the same from the point of view of home residents as from the point of view of foreign residents, the difference in the risk-adjusted return in the two countries only depends on the difference in the risk premium that investors demand. In response to a net capital outflow, holdings of risky assets by home country residents rise relative to that of foreign country residents. This leads to a drop in the risk-adjusted return in the home country relative to that in the foreign country, hence the negative sign in Eq. (15). The effect is stronger the larger the rate of absolute risk aversion γ, and the higher the degree of riskiness ($\mathbf{q}'\mathbf{\Sigma}^{-1}\mathbf{q}$ *small*).

We obtain another relationship between dCA and $dr-dr^*$ by differentiating the intertemporal allocation Eq. (11), its foreign counterpart, and the budget constraints. As shown in the Appendix A, these equations lead to

$$2r(\theta+\beta)dCA=\mathbf{a}'d\mathbf{x}+\rho\beta c_1(dr-dr^{*}), \tag{16}$$

where $\theta=U'(c_1)c_1/U'(\hat{c}_2)\hat{c}_2$,$\mathbf{a}'=(\beta r,-\theta,\rho c_1 r,\dfrac{\beta c_1 r}{\rho}(\ln\hat{c}_2-\ln c_1),\theta\gamma/2)$. In contrast to Eqs.

[6] We do not include the analysis of asymmetries with regards to the degree of nominal risk or capital endowment risk. It can be shown that these asymmetries do not lead to net capital flows when asset prices are uncorrelated with the labor endowment (or more generally when $cov(e_{2L},d)=cov(e^{*}_{2L},d)$). In that case investors in each country hold the same quantities of each asset ($w=w^{*}=\frac{1}{2}\overline{w}$). When asset prices are correlated with the labor endowment, the sign of the current account in response to asymmetries in nominal risk or capital endowment risk depends on the difference in asset positions.

(15), (16) describes a positive relationship between dCA and $dr-dr^*$. This reflects the intertemporal substitution effect. A higher risk-adjusted return leads to higher saving and therefore a current account improvement.

Combining Eqs. (15) and (16) gives our basic equation describing net capital flows:

$$dCA=\frac{\mathbf{a}'d\mathbf{x}}{2r(\theta+\beta)+2\gamma\rho\beta c_1\hat{\sigma}}, \tag{17}$$

where $\hat{\sigma}=1/\mathbf{q}'\mathbf{\Sigma}^{-1}\mathbf{q}$. $\hat{\sigma}$ plays an important role in the analysis as it depends on nominal risk. In the Appendix A we show, after inverting the matrix $\mathbf{\Sigma}$, that $\hat{\sigma}$ can be written as

$$\hat{\sigma}=\frac{1}{4}\frac{var(P^w)var(e^W_{2K})-cov(P^W,e^W_{2K})^2}{q^2var(e^W_{2K})+q^2_Kvar(P^W)-2qq_Kcov(P^W,e^W_{2K})}, \tag{18}$$

where $P^W=\frac{1}{P}+\frac{1}{P^*}$ and $e^W_{2K}=e_{2K}+e^*_{2K}$ (W stands for "world"). It depends on both "nominal risk", captured by P^W, and "real risk", captured by e^w_{2K}.

As a preliminary step towards evaluating the impact of nominal risk on net capital flows, it is important to notice that the parameters r, θ, c_1, and $\mathbf{a}$ in the expression Eq. (17) for net capital flows are the same for different levels of nominal risk. These parameters depend on first period consumption and the certainty equivalent of second period consumption. First period consumption is always equal to $\tilde{e}_1$ in the symmetric equilibrium. Expected second period consumption is equal to $\bar{e}_{2L}+\bar{e}_{2K}$. The variance of second period consumption is also unaffected by nominal risk. This is immediately clear when asset returns are uncorrelated with the labor endowment. It follows from Eq. (14) that in that case $\mathbf{w}=\frac{1}{2}\bar{\mathbf{w}}$, so that nominal bond holdings are zero in the symmetric equilibrium. In the Appendix A we show that $var(c_2)$ is also independent of nominal risk when asset returns are correlated with labor income, as long as we keep the correlations between asset returns, and between asset returns and labor income, constant when changing the degree of nominal risk.

When nominal risk tends to zero, it follows from Eq. (18) that $\hat{\sigma}$ is infinitesimally close to zero, so that net capital flows become

$$dCA=\frac{\mathbf{a}'d\mathbf{x}}{2r(\theta+\beta)}. \tag{19}$$

This equation is familiar from the standard two-period endowment economy model without uncertainty, such as Frenkel and Razin (1992). Since $\hat{\sigma}>0$, a comparison to Eq. (17) shows that reducing nominal risk to approximately zero enhances the size of net capital flows. This leads to an important conclusion: *net capital flows are dampened by nominal risk*. This result is quite intuitive. The increased risk exposure associated with a net capital outflow under significant nominal risk reduces the risk-adjusted return from the point of view of home country residents. This reduces their saving and dampens the net capital outflow.

The extent to which nominal risk dampens net capital flows depends on a trade-off between consumption smoothing and avoiding risk. In the denominator of Eq. (17), $\hat{\sigma}$ is multiplied by $\gamma\rho$. Consider for example a rise in the first-period labor endowment. For intertemporal consumption smoothing reasons, this leads to a net capital outflow. However, risk exposure increases, captured by $\hat{\sigma}$. The larger the willingness to substitute consumption intertemporally, and the larger the rate of risk aversion, the greater the extent to which net capital flows are dampened by nominal risk.

So far we have only compared infinitesimal with non-infinitesimal levels of nominal risk. In order to see whether the relationship between nominal risk and the level of net capital flows is monotonic, we differentiate the expression Eq. (18) of $\hat{\sigma}$ with respect to $var(P^W)$, holding constant the correlation $corr(P^W,e^W_{2K})$. The resulting expression is positive, except when $corr(P^W,e^W_{2K})>0$ and nominal risk is sufficiently large such that

$$corr(P^W,e^W_{2K})>\frac{\sqrt{var(e^W_{2K}/2q_K)}}{\sqrt{var(P^W/2q)}}. \tag{20}$$

Here $e^W_{2K}/2q_K$ and $P^W/2q$ are respectively the return on "world" equity and nominal bonds portfolios, assuming equal weights to domestic and foreign equity and bonds.[7] Since equity returns are more volatile than prices, this condition is unlikely to be satisfied in practice. For a realistic parameterization therefore, the model implies a monotonous positive relationship between nominal risk and the size of net capital flows.

3.2. The role of the asset market structure

The above analysis is derived for a situation in which trade is allowed both in nominal bonds and in equities. It is interesting to examine how the results are affected under different asset market structures.[8]

First consider trade in an indexed bond, with a payoff of one good in period 2. The presence of a risk-free real asset implies that real interest rates must be equal across countries, so $r=r^*$.[9] Therefore the expression for the equilibrium current account is the same as that with infinitesimal nominal risk, so that nominal risk no longer dampens net capital flows (see Eq. (19)). The presence of a risk-free vehicle

[7] The intuition for such a negative relationship is as follows. It can be shown that when Eq. (20) is satisfied, a net capital outflow is associated with increased equity holdings, but also a decrease in nominal bond holdings. That is because for sufficiently large values of corr(P^W, e^W_{2K}) nominal bond holdings become a very useful hedge against capital return uncertainty. In that case additional nominal risk makes nominal bonds an even better hedge, reducing the overall risk measure $\hat{\sigma}$.

[8] In this section we continue to assume that there is always trade in nominal bonds. Otherwise the term "nominal risk" has little meaning.

[9] The other condition that needs to be added to the previous equations is the indexed bond market equilibrium $b_I+b^*_I=0$, where b_I and b^*_I are indexed bond holdings by domestic and foreign residents, respectively. The current account is now $CA=\mathbf{q}'(\mathbf{w}-\mathbf{w_0})+(1/r)b_I$.

for intertemporal asset trade allows agents to smooth consumption over time without a change in nominal risk exposure.

In order to understand the role of equity trade, we can consider a setup where asset trade is limited to nominal bonds only. In that case Eq. (17) still represents the correct current account response. The difference is that in the definition for the risk factor $\hat{\sigma}=1/\mathbf{q}'\mathbf{\Sigma}^{-1}\mathbf{q}$, the vector $\mathbf{q}$ is replaced by (q, q') and $\mathbf{\Sigma}$ is replaced by the variance-covariance matrix of nominal bond payoffs, Then $\hat{\sigma}=var(P^W)/4q^2$, so that only nominal risk matters. The value of $\hat{\sigma}$ is larger than in Eq. (18). Therefore nominal risk matters more than in the absence of trade in equity. In general the conclusion is that additional tradable assets allow investors to diversify, which reduces the effect of nominal risk on net capital flows. Indexed bonds allow investors to circumvent nominal risk altogether.

4. Asymmetric information sets and exchange rate uncertainty

In an open-economy framework nominal risk is associated with both price level and nominal exchange rate risk. However, with PPP exchange rate changes are equal to inflation differentials. This strong assumption prevents a separate analysis of the impact of exchange rate uncertainty.[10] In this section, we present an extension of the benchmark model that allows us to distinguish perceived exchange rate risk from inflation risk within the limitations imposed by PPP. We show that exchange rate risk can have a strong dampening effect on net capital flows separate from inflation risk.[11]

We assume that agents in the two countries have different information sets. Domestic residents are better informed about domestic monetary policy, while foreign residents are better informed about foreign monetary policy. As a result, the variance of $\frac{1}{P}$ is lower for H-country than for F-country residents, while the opposite is the case for the variance of $\frac{1}{P^*}$. Viewed in another way, the variance of nominal asset returns is perceived by domestic residents as higher on foreign assets than on domestic ones, i.e., $var(\frac{S}{P})>var(\frac{1}{P})$. It is even possible that there is no domestic inflation risk from the point of view of residents of both countries, but there is significant exchange rate risk because of uncertainty about foreign monetary policy. In this case, the risk on foreign bonds is measured by $var(S)$ for domestic residents in each country. We assume that there is no asymmetric information with respect to capital claims.

The perceived variance-covariance matrix of asset payoffs is now different for domestic than for foreign residents. Denote by $\mathbf{\Sigma}_H$ and $\mathbf{\Sigma}_F$ the matrices for H-country and F-country residents respectively. While $\mathbf{\Sigma}_H \neq \mathbf{\Sigma}_F$, we impose symmetry by

[10] This also implies that the analysis of the exchange rate regime is not very interesting.

[11] This result is consistent with a recent extension to deviations from PPP in Bacchetta and van Wincoop (1998).

assuming that the variance of $\mathbf{d}'=(\frac{1}{P},\frac{1}{P^*},e_{2K},e^*_{2K})$ perceived by H-country residents is the same as the variance of $(\frac{1}{P^*},\frac{1}{P},e^*_{2K},e_{2K})$ perceived by F-country residents. The Appendix A shows the general form of the matrices $\mathbf{\Sigma}_H$ and $\mathbf{\Sigma}_F$ after imposing the symmetry condition.

The consumer's problem is similar to the one in Section 2, but $\mathbf{\Sigma}$ should be substituted by $\mathbf{\Sigma}_H$ in Eq. (12) and by $\mathbf{\Sigma}_F$ in Eq. (13). The current account is $dCA=\mathbf{q}'d\mathbf{w}+(\mathbf{w}-\mathbf{w_0})'d\mathbf{q}$. The second component is equal to capital gains or losses on the current net international asset position $\mathbf{w}-\mathbf{w_0}=(b_H,-b_H,k_H-\bar{k}_H,-(k_H-\bar{k}_H))$. In the bench mark model $dq=dq^*$ and $dq_K=dq^*_K$ (see Appendix A), so that net capital gains are zero. In the extension considered here the change in the price of domestic bonds and equity is generally not equal to that of foreign bonds and equity, so that the net capital gains term is not zero. However, since in this paper we are interested in net capital flows, we abstract from net capital gains effects on the current account by assuming that asset return properties are such that the net asset position $\mathbf{w}-\mathbf{w_0}$ is zero.

In that case, Eqs. (15)–(19) still hold, with $\mathbf{\Sigma}$ replaced by $\frac{\mathbf{\Sigma}_H+\mathbf{\Sigma}_F}{2}$. The risk measure $\hat{\sigma}$ is still given by Eq. (18). Because P^W and e^W_{2K} are world variables, the moments in Eq. (18) are the same from the point of view of both countries (given our symmetry assumption). But we are now able to separate price and exchange rate uncertainty because $P^W=\frac{1}{P}+\frac{S}{P}$, while $var\left(\frac{1}{P}\right)$ and $var\left(\frac{S}{P}\right)$ are separate parameters. We have assumed that from the perspective of domestic agents $var\left(\frac{1}{P}\right)<var\left(\frac{S}{P}\right)$. If there is no domestic price uncertainty, and domestic prices are expected to be one, we have $var(P^W)=var(S)$. In that case, only nominal exchange rate uncertainty dampens net capital flows.

Interestingly, in equilibrium $db_H=db_F$. Even though domestic residents prefer to hold domestic bonds, in equilibrium the change in domestic and foreign bond holdings is identical. This means that domestic and foreign residents equally share exchange rate risk in equilibrium. The mechanism through which this occurs is the interest rate. The initial excess demand for domestic bonds leads to a lower interest rate on domestic bonds, which makes domestic residents willing to increase their holdings of foreign bonds. The interest differential reflects the exchange rate risk premium.

5. Conclusion

The determination of net international capital flows has traditionally been addressed in the context of models that allow for a risk-free vehicle to intertemporal asset trade. But in reality most international asset trade takes place through nominal assets, so that agents are exposed to both price and exchange rate risk. In order to understand the macroeconomic implications of this nominal uncertainty we have developed a two-country general equilibrium model with incomplete markets, where trade is limited to nominal bonds and real assets (equities). We find that nominal risk reduces the size of net international capital flows.

Our aim was to develop a general equilibrium model that can be solved analytically, but that is rich enough to address the question we had in mind. Future work should extend the model along three important dimensions. First, the two-period setup does not allow us to study more interesting dynamics. There is no distinction between net capital flows and the net international investment position. Allowing for dynamics would allow us, for example, to ask the question: does nominal uncertainty have more significant implications for persistent than temporary current account imbalances?[12]

A final major shortcoming of the model is that it is based on the assumption of purchasing power parity. Although this keeps with the tradition of Lucas (1982) type stochastic general equilibrium models of exchange rate determination, it is in stark contrast with the evidence. In the short to medium run, there is a close relationship between the nominal and real exchange rate and the law of one price does not hold even for tradables. The nominal exchange rate is much more variable than relative price levels. Developing a tractable general equilibrium model that captures these features may be central to our understanding of the role of nominal risk. In such a framework it becomes interesting to compare fixed and floating exchange rate regimes. In Bacchetta and van Wincoop (1998) we make a first step in this direction.

Evidence on the relationship between nominal risk and net capital flows is scarce. There is no evidence on price uncertainty. With regards to exchange rate uncertainty there is some suggestive evidence that is consistent with our findings. First, as documented by Bayoumi (1990), net capital flows as a fraction of GDP were substantially larger during the 1880–1913 gold standard period than during 1965–86. Second, as documented by Iwamoto and van Wincoop (1999), net capital flows as a share of GDP tend to be substantially larger across regions within a country, which share a common currency, than across countries. Finally, for a set of 47 countries we have computed an average exchange rate system index over the period 1982–94 based on the IMF classification, with a larger number referring to more flexibility.[13] We also computed for each country the average over the sample of absolute net capital flows as a share of GDP and find a cross-country correlation with the exchange rate system flexibility index of -0.32, with a standard error of 0.12. Consistent with the theory,

[12] Bacchetta and van Wincoop (1994) consider an extension of this model to a production economy and find that the nominal uncertainty leads to a closer relationship between saving and investment. However, with a production economy the model is only analytically solvable under more restrictive assumptions.

[13] To construct the index, we attibuted 3 to pure float, 2 to managed float, and 1 to countries whose currency is pegged to another currency or composite, as well as countries with a cooperative arrangement. For each country we use the average of the annual index values over the sample. The countries selected, as well as the sample period, were dictated by data availability. A list of countries is available upon request.

more exchange rate flexibility corresponds to a smaller size of absolute net capital flows.

The evidence is only suggestive and does not control for a wide range of other differences between regions and countries, the gold standard and the post war period, and between countries over the recent period. A similar problem arises when comparing the Bretton Woods system to the subsequent period, because we know that the change in exchange rate regime was accompanied by a liberalization of capital controls. It is important that better evidence be developed on this question, both for exchange rate and price level uncertainty.

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Appendix A

A.1. Derivation of Eq. (15)

Differentiating Eqs. (12) and (13) gives:

$$rd\mathbf{q}+\mathbf{q}dr=-\gamma\boldsymbol{\Sigma}d\mathbf{w}, \tag{21}$$

$$rd\mathbf{q}+\mathbf{q}dr^{*}=-\gamma\boldsymbol{\Sigma}d\mathbf{w}^{*}. \tag{22}$$

Given the symmetry assumptions, it is useful to consider the matrix $\mathbf{M}=\begin{pmatrix}1 & -1 & 0 & 0\\ 0 & 0 & 1 & -1\end{pmatrix}$. With symmetry, $\mathbf{Mq}=0$. Pre-multiplying Eqs. (21) and (22) by $\mathbf{M}$ and using the fact that $d\mathbf{w}=-d\mathbf{w}^*$ (from Eq. (1)), it can be seen that $db_H=db_F$, $dk_H=dk_F$, $dq=dq^*$ and $dq_K=dq_k^*$.

The equalities in asset price changes also imply that $(\mathbf{w}-\mathbf{w_0})'d\mathbf{q}=0$, so that $dCA=\mathbf{q}'d\mathbf{w}$ in the absence of an indexed bond. This means that current account changes are not affected by revaluation effects (capital gains and losses). We obtain an expression for $\mathbf{q}'d\mathbf{w}$ by subtracting Eq. (22) from Eq. (21), again using $d\mathbf{w}=-d\mathbf{w}^*$. This gives Eq. (15).

A.2. Derivation of Eq. (16)

Differentiating Eq. (11), its foreign counterpart, and first and second period budget constraints of both countries, we find

$$\theta d\hat{c}_2 = \beta r dc_1 + \rho c_1(\beta dr + r d\beta) + \frac{\beta r c_1}{\rho}(\ln\hat{c}_2 - \ln c_1)d\rho, \tag{23}$$

$$\theta d\hat{c}_2^* = \beta r dc_1^* + \rho c_1 \beta dr^*, \tag{24}$$

$$dc_1 = de_{1L} - dCA, \tag{25}$$

$$d\hat{c}_2 = d\bar{e}_{2L} - (\gamma/2)dvar(e_{2L}) + rdCA, \tag{26}$$

$$dc_1^* = dCA, \tag{27}$$

$$d\hat{c}_2^* = -rdCA. \tag{28}$$

In deriving Eq. (26), we used that $d\hat{c}_2 = d\bar{e}_{2L} + (\partial\hat{c}_2/\partial\mathbf{w})'d\mathbf{w}$, $\partial\hat{c}_2/\partial\mathbf{w} = r\mathbf{q}$ (Eq. (12)), and $dCA = \mathbf{q}'d\mathbf{w}$. Eq. (16) follows by subtracting Eq. (24) from Eq. (23) and substituting Eqs. (25)–(28).

A.3. Proof of Eq. (18)

Define $\boldsymbol{\Sigma}_{\mathbf{p}}$ as the variance of the vector $\left(\frac{1}{\mathbf{P}}, \frac{1}{\mathbf{P}^*}\right)'$, $\boldsymbol{\Sigma}_{\mathbf{k}}$ as the variance of the vector $(e_{2K}, e_{2K}^*)'$, and $\boldsymbol{\Sigma}_{pk}$ as the covarience between these two vectors. It is easily verified that

$$\boldsymbol{\Sigma}^{-1} = \begin{pmatrix} \mathbf{A}\boldsymbol{\Sigma}_k & -\mathbf{A}\boldsymbol{\Sigma}_{kp} \\ -A\Sigma_{kp} & \mathbf{A}\boldsymbol{\Sigma}_p \end{pmatrix},$$

where $A = (\boldsymbol{\Sigma}_p\boldsymbol{\Sigma}_k - \boldsymbol{\Sigma}_{kp}^2)^{-1}$. Therefore

$$\mathbf{q}'\boldsymbol{\Sigma}^{-1}\mathbf{q} = (\iota'\mathbf{A}\boldsymbol{\Sigma}_k)q^2 + (\iota'\mathbf{A}\boldsymbol{\Sigma}_p)q_k^2 - 2(\boldsymbol{\iota}'\mathbf{A}\boldsymbol{\Sigma}_{kp})qq_k,$$

where $\boldsymbol{\iota} = (1,1)'$. After writing out the expressions in brackets, $\boldsymbol{\iota}'\mathbf{A}\boldsymbol{\Sigma}_k = var(e_{2K}^w)/B$, $\boldsymbol{\iota}'\mathbf{A}\boldsymbol{\Sigma}_p = var(P^W)/B$, and $\boldsymbol{\iota}'\mathbf{A}\boldsymbol{\Sigma}_{kp} = cov(P^W, e_{2K}^W)/B$, where $B = (var(P^W)var(e_{2K}^W) - \mathrm{cov}(P^W, e_{2K}^W)^2)/4$. Since $\hat{\sigma} = 1/\mathbf{q}'\boldsymbol{\Sigma}^{-1}\mathbf{q}$, Eq. (18) follows.

A.4. The symmetric equilibrium and nominal risk

We show that the extent of nominal risk does not affect the variance of second period consumption. As argued in the text, in that case the parameters r, θ, c_1, and $\mathbf{a}$ that enter the net capital flows equation are all independent of the extent of nominal risk. We have already explained in the text why the variance of second period consumption does not depend on nominal risk when asset returns are uncorrelated with labor endowments. We now allow for non-zero correlations between asset returns and labor endowments. When changing the degree of nominal risk, we keep constant the correlations between asset returns, and between asset returns and the labor endowment. Define $\mathbf{\Omega}$ as the correlation matrix for the asset payoff vector $\mathbf{d}$, and $\mathbf{S}$ a matrix with zeros off-diagonal and standard deviations of the asset payoffs on the diagonal. Therefore $\mathbf{\Sigma}=\mathbf{S\Omega S}$. Also define $\mathbf{l}$ as the vector of correlations between the asset payoff vector and $e^*_{2L}-e_{2L}$, so that $cov(e^*_{2L}-e_{2L},\mathbf{d})=\mathbf{Sl}\sigma_L$. Here σ_L is the standard deviation of $e^*_{2L}-e_{2L}$. Eq. (14) can then be written as

$$\mathbf{w}=\frac{1}{2}\bar{\mathbf{w}}+\frac{1}{2}\mathbf{S}^{-1}\mathbf{\Omega}^{-1}\mathbf{l}\sigma_L.$$

Substitution into Eq. (10) yields (using the symmetry of S^{-1} and Ω^{-1}):

$$var(c_2)=var(e_{2L})+\frac{1}{4}\bar{\mathbf{w}}^1\mathbf{\Sigma}\bar{\mathbf{w}}+\frac{\sigma_L}{4}(\bar{\mathbf{w}}'\mathbf{Sl}+\mathbf{l}'\mathbf{S}\bar{\mathbf{w}})+\frac{\sigma_L^2}{4}\mathbf{l}'\mathbf{\Omega}^{-1}\mathbf{l}+\bar{\mathbf{w}}'\mathbf{Se}\sigma_e+\sigma_L\sigma_e\mathbf{l}'\mathbf{\Omega}^{-1}\mathbf{e},$$

where $\mathbf{e}$ is the correlation between e_{2L} and the asset payoff vector $\mathbf{d}$ and σ_e is the standard deviation of e_{2L}. Given the symmetry assumptions and the definition of $\bar{\mathbf{w}}$, this expression becomes:

$$var(c_2)=var(e_{2L})+\frac{1}{4}var(e^W_{2K})+\frac{\sigma_L^2}{4}\mathbf{l}'\mathbf{\Omega}^{-1}\mathbf{1}+cov(e_{2L},e^W_{2K})+\sigma_L\sigma_e\mathbf{l}'\mathbf{\Omega}^{-1}\mathbf{e}.$$

It is clear that the matrix $\mathbf{S}$ does not enter in the latter expression, so that the variance of nominal risk does not affect the variance of second period consumption in the symmetric equilibrium.

A.5. Definitions of $\mathbf{\Sigma}_H$ and $\mathbf{\Sigma}_F$

These matrices take the following general form:

$$\mathbf{\Sigma}_H=\begin{pmatrix}\sigma_p^2 & \sigma_{pf} & \sigma_{kp} & \sigma_{k*p}\\ \sigma_{pf} & \sigma_f^2 & \sigma_{kf} & \sigma_{k*f}\\ \sigma_{kp} & \sigma_{kf} & \sigma_k^2 & \sigma_{kk*}\\ \sigma_{k*p} & \sigma_{k*f} & \sigma_{kk*} & \sigma_k^2\end{pmatrix}\ \mathbf{\Sigma}_F=\begin{pmatrix}\sigma_f^2 & \sigma_{pf} & \sigma_{k*f} & \sigma_{kf}\\ \sigma_{pf} & \sigma_p^2 & \sigma_{k*p} & \sigma_{kp}\\ \sigma_{k*f} & \sigma_{k*p} & \sigma_k^2 & \sigma_{kk*}\\ \sigma_{kf} & \sigma_{kp} & \sigma_{kk*} & \sigma_k^2\end{pmatrix}$$

where σ_i^2 is the variance of i and σ_{ij} is the covariance between i and j. We also define: $p=1/P$, $f=1/P^*$, $k=e_{2K}$, $k^*=e^*_{2K}$.

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