Financial Globalization and Monetary Policy*

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First Draft: September 17, 2006
Revised: August, 2007

Abstract

This paper is concerned with the effects of monetary policy when international portfolio choice is endogenous. We analyze the link between monetary policy and gross national bond and equity portfolios. With endogenous portfolio structure and incomplete markets, monetary policy takes on new importance due to its impact on the distribution of returns on nominal assets. Despite this, we find that the case for price stability as an optimal monetary rule still remains. In fact, it is reinforced. Even without nominal price rigidities, price stability has a welfare benefit through its enhancement of the risk sharing properties of nominal bond returns.

Keywords: Portfolio Choice, International Risk Sharing, Exchange Rate
JEL: E52, E58, F41

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*We thank Philippe Bacchetta, Ali Dib, Dale Henderson, and numerous seminar participants for comments. This research is supported by the ESRC World Economy and Finance Programme, award number 156-25-0027. Devereux also thanks SSHRC, the Bank of Canada, and the Royal Bank of Canada for financial support.

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1 Introduction

The growth in the size and complexity of international financial markets has been one of the most striking aspects of the world economy over the last decade. Lane and Milesi-Ferretti (2001,2006) document the increase in gross holdings of cross-country bond and equities for a large group of countries. They describe this as a process of *financial globalization*. Economists and policy makers have speculated on the implications of financial globalization for the design of monetary policy[1]. There are many aspects to this question. Most central banks now either explicitly or implicitly follow a policy of inflation targeting. Under this policy, price stability, appropriately defined, is the principal goal of monetary policy. Is this conclusion altered by the presence of large cross country gross holdings of financial assets, where movements in asset prices and exchange rates may have significant wealth redistribution effects? In addition, should policy-makers be concerned about asset prices directly, rather than focusing on inflation in goods prices?

This paper constructs a two-country open economy model with endogenous portfolio choice. We can address the questions raised above, because our model determines the structure of gross holdings of cross-country financial assets. Our principal finding is that endogenous portfolio structure does not alter the case for price stability as an optimal monetary policy. In fact, it may even reinforce this case. In an environment where financial markets are incomplete, price stability is desirable because it enhances the international risk-sharing properties of nominal assets, even without nominal goods price rigidities.

An intellectual foundation for price stability in monetary policy has been given by King and Wolman (1989), Woodford (2003), and others. They have sticky-price dynamic general equilibrium models where a monetary rule devoted to stabilizing prices eliminates the inefficiency of costly price adjustment. In an open economy, the optimality of price stability as the sole goal of monetary policy depends on the structure of international financial markets. Benigno (2001) and Obstfeld and Rogoff (2002) show that the absence of full international risk-sharing may interact with the inefficiency arising from sticky prices, so that price stability may not constitute the unique optimal goal of monetary

[1] See, for instance, Fergusen, (2005), Fisher (2006), and Rogoff (2006).

policy[2].

A drawback of many of these papers is that international financial markets are modeled in a very rudimentary way. Financial markets are typically represented either by the absence of any type of international risk-sharing (e.g. trade in non-contingent bonds) or by full risk-sharing (complete markets). In reality, international financial markets are likely to be somewhere in the middle. In addition, previous literature has not distinguished gross from net cross-country asset holdings. Once we allow for endogenous portfolio choice, it is possible that monetary policy impacts on the structure or efficiency of international financial markets. And as mentioned, the presence of large gross holdings of different financial assets may in turn have repercussions for the choice of optimal monetary policy. Thus, the analysis of monetary policy with endogenous international portfolio structure is an important direction for this literature.

Until recently however, the analysis of portfolio structure in dynamic general equilibrium macro models was impeded by the difficulty in solving the higher order aspects of these models that are required to determine optimal portfolios, while retaining enough tractability to analyze the general equilibrium impact of shocks and monetary policy. This paper resolves this difficulty by making use of some recent results on the approximation of optimal portfolio choice in general equilibrium. We apply a methodology developed in Devereux and Sutherland (2006a), which shows how to incorporate optimal portfolio choice in a standard dynamic general equilibrium macro model in a tractable way. This is combined with an otherwise standard two-country model of an open economy with staggered price-setting, stochastic productivity and interest rate shocks, and monetary policy governed by an interest rate. The model is then solved under a number of financial market configurations, differing in the range of assets that are traded across countries. In the least complex of these, the only financial asset is a non-contingent real bond, and there is essentially no portfolio choice at all. In the most complex, there is trade in nominal bonds and equities, and given our stochastic environment, markets are complete. In an intermediate case, nominal bonds denominated in each country's currency can be traded. In this intermediate case, portfolio choice is endogenous, but asset markets are

[2] Nevertheless, both papers conclude that, for reasonable quantitative estimates over parameters and volatilities, price stability represents a close approximation to an optimal policy. See also Devereux (2004).

incomplete.

The model is simple enough to produce analytical solutions for gross asset holdings under each financial market configuration, and show how these depend on the stance of monetary policy, the relative importance of shocks, and the degree of price stickiness[3]. We can then use these results to ask how monetary policy interacts with portfolio choice in affecting macro-economic outcomes, to investigate how monetary policy influences the degree of international risk-sharing, and to characterize an optimal monetary. Since the stance of monetary policy determines the stochastic properties of inflation and the nominal exchange rate, it affects the properties of returns on both nominal bonds and equities, which in turn govern both the endogenous portfolio choices of agents as well as the equilibrium degree of international risk-sharing.

With trade in both bonds and equities, there are complete markets, and all possible international risk-sharing is exploited, for any monetary policy. Then we find that the portfolio composition of bonds and equities is independent of the monetary policy rule. Thus, under complete markets, there is no interaction between country portfolios and monetary policy. Then price stability is an optimal policy for conventional reasons, since it eliminates the welfare losses coming from slow price adjustment.[4]

On the other hand, when assets markets are restricted to trade only a real non-contingent bond, the results of Benigno (2001) and Obstfeld and Rogoff (2002) apply. A monetary policy that deviates from price stability would in general be desirable, so as to alleviate risk-sharing inefficiencies.

But in the intermediate case, with international trade in nominal bonds, the implications for monetary policy are substantially different. In this case, asset markets are incomplete, and the monetary policy rule does affect the composition of countries portfolios. Monetary policy actually plays a dual role. First, it can be used so as to support the

[3]The method of Devereux and Sutherland (2006a) is fully general, however, and is not restricted to models simple enough to be characterized analytically.

[4]Throughout this paper the focus is on optimal monetary policy from a global perspective, i.e. where monetary policy in all countries is chosen *cooperatively* to maximise world aggregate welfare. In our model price stability is the optimal cooperative policy for all parameter combinations as long as financial markets are complete. Benigno and Benigno (2003), who analyse a framework which is similar to the complete-markets version of our model, show that price stability is only a *non-cooperative* equilibrium for certain parameter combinations.

flexible price equilibrium of the economy, as in the standard model. In general, we would expect such a policy not to be fully optimal, due to market incompleteness. But this does not take account of the secondary role of monetary policy. Monetary policy can enhance the degree of international risk-sharing itself, by improving the risk-hedging properties of nominal bonds in optimal portfolios. This second property of policy is conceptually independent of the first. In fact, it remains useful even in a flexible price economy. Our results show that in an environment where nominal bonds are traded, a policy of strict price stability will endogenously generate full international risk-sharing. Strict price stability is therefore desirable on both counts. It supports the flexible price outcome, and it also allows nominal bond returns to offer full risk-sharing against country specific productivity shocks. Moreover, even if prices are fully flexible, with incomplete asset markets there is still a non-trivial welfare case for price stability.

Although our model produces a international financial structure where countries are holding large offsetting gross nominal asset positions, so that exchange rate movements can generate substantial 'valuation effects', the presence of these effects does not directly change the optimal monetary rule. Because portfolios are chosen optimally, the wealth redistribution arising from exchange-rate-induced valuation effects represent the workings of an efficient international financial structure. Moreover, monetary authorities do not have to be concerned with these redistributions. It is still the case that monetary authorities are best to use the exchange rate in the traditional Friedman (1953) manner - to generate efficient terms-of-trade adjustment. The new insight from this paper is that it may be desirable to have the nominal exchange rate play the same role as in Friedman's analysis, *even without* his underlying assumption of sluggish nominal goods price adjustment. That is, when risk sharing is pursued via trade in nominal bonds, the Friedman argument - that it is better to use the exchange rate to facilitate terms of trade adjustment rather than price levels - is supported, *even in a fully flexible price economy.*

Our results do show however that the effects of monetary policy on other variables may be very different in a model with endogenous portfolio choice than in the standard analysis. Because the monetary rule leads to changes in the structure of international portfolios, the effects of monetary policy may be the opposite of what traditional reasoning would imply. For instance, a policy putting more weight on price stability may increase rather than reduce exchange rate volatility and the volatility of international capital flows. Because the exchange rate represents the excess return on nominal bonds, this means that an optimal monetary policy may increase rather than reduce asset price volatility.

This paper is related to a growing literature on the analysis of portfolio composition and financial markets in dynamic general equilibrium models. As mentioned, the method we use is developed in Devereux and Sutherland (2006a). Related papers are Engel and Matsumoto (2006), Evans and Hnatkovska (2006), and Kollmann (2006). Engel and Matsumoto (2006) incorporate endogenous portfolio choice into a complete markets version of a sticky-price open economy macro model, focusing on the 'home equity bias' puzzle. They do not directly analyze the role of monetary policy. Kollmann (2006) and Evans and Hnatkovska (2005) construct non-monetary dynamic general equilibrium environments with endogenous portfolio choice. Kollmann's (2006) analysis is based on complete markets, also examining the determinants of home equity bias. Evans and Hnatkovska (2005) employ a numerical approximation method to solve for portfolio choice[5].

A slightly older literature has examined the determinants of trade in nominal bonds. Svensson (1989) develops a stochastic, two country, two period cash in advance model to analyze the determinants of nominal bond trading and the welfare gains to asset trade, but does not characterize the specific gross portfolio positions or the determination of optimal monetary policy. Bacchetta and Van Wincoop (2000) also develop a two period endowment economy model, and obtain optimal portfolios in a model where equity and nominal bonds are traded. They focus on the impact of nominal bonds on capital flows. An early fundamental contribution is Helpman and Razin (1978).

The next section develops the open economy model. Section 3 discusses the approach to solving for optimal portfolios. Section 4 solves for the optimal portfolios and discusses the effects of monetary policy on portfolios. Some conclusions follow.

[5]See also related papers by Devereux and Saito (2006), Ghironi et al. (2005), and Tille (2004). In addition, Tille and Van Wincoop (2007) present a method similar to that used in this paper.

2 An Open Economy Macro Model

We develop a basic two-country open economy model. There is a 'home' and 'foreign' country, with each country being specialized in a particular range of products. Households maximize utility over an infinite horizon. It is assumed that consumers in each country can trade in a range of financial assets. We vary the menu of available assets, but at its most extensive there are four assets, consisting of home and foreign equity shares, and home and foreign nominal bonds. The payoffs to each of these assets are defined below. We also allow for two types of shocks; interest rate (or financial market) shocks, and shocks to productivity, in each country.

2.1 Consumers

All agents in the home country have utility functions of the form:

$$U = E_0 \sum_{t=0}^{\infty} \left[\frac{C_t^{1-\rho}}{1-\rho} - KL_t \right] \tag{1}$$

where $\rho > 0$, C is a consumption index defined across all home and foreign goods, L is labor supply and E is the expectations operator. The consumption index C for home agents is given by:

$$C = \left[\mu^{\frac{1}{\theta}} C_H^{\frac{\theta-1}{\theta}} + (1-\mu)^{\frac{1}{\theta}} C_F^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{2}$$

where C_H and C_F are indices of individual home and foreign produced goods with an elasticity of substitution between individual goods denoted ϕ, where $\phi > 1$. The parameter θ in (2) is the Armington elasticity of substitution between home and foreign goods. The parameter μ measures the importance of consumption of the home good in preferences.

The aggregate consumer price index for home agents is therefore:

$$P = \left[\mu P_H^{1-\theta} + (1-\mu) P_F^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{3}$$

where P_H and P_F are the aggregate price indices for home and foreign goods.

The budget constraint of the home country agent is:

$$P_t C_t + W_{t+1} = w_t L_t + P_t \Pi_t + P_t \sum_{k=1}^{N} \alpha_{k,t-1} r_{kt} \tag{4}$$

where W_t denotes the net value of nominal wealth for the home agent, w_t is the nominal wage, and Π_t is the real profit stream of the home firm that accrues to the home country agent. The final term represents the total return on the home country portfolio, which is comprised of N assets, where in our case $N \leq 4$. The term $\alpha_{k,t-1}$ represents the real holdings of asset k, brought into period t from the end of period $t-1$, and $r_{k,t}$ is the period t real return on this asset. It is assumed that the home consumer is the default owner of home firms and receives all profits from home firms. In cases where an international equity market exists however, claims to home profits may be transferred to foreign consumers via trade in equity shares[6]. From the definition of wealth, it must be the case that:

$$W_t = P_t \sum_k^N \alpha_{k,t-1}$$

That is, the total period $t-1$ investment in assets must add up to beginning of period t wealth.

The conditions for consumers' utility maximization are standard. The home consumer's demand for home and foreign goods may be written as:

$$C_H = \mu \left(\frac{P_H}{P}\right)^{-\theta} C, \qquad C_F = (1-\mu)\left(\frac{P_F}{P}\right)^{-\theta} C.$$

The optimal consumption-leisure tradeoff implies:

$$\frac{w_t}{P_t} C_t^{-\rho} = K. \tag{5}$$

Optimal consumption and portfolio choices are characterised by the conditions:

$$C_t^{-\rho} = \beta E_t C_{t+1}^{-\rho} r_{N,t+1}, \tag{6}$$

$$E_t C_{t+1}^{-\rho}(r_{k,t+1} - r_{N,t+1}) = 0, \qquad k = 1..N-1. \tag{7}$$

[6]Firms earn monopoly profits because each firm is the monopoly supplier of a differentiated good. Note also that, because the home agent receives all home profits, in a symmetric equilibrium with zero net foreign assets ($W_t = 0$), gross portfolio holdings exactly offset each other in value terms. This is simply an accounting convention which simplifies the development of the model, but it is not at all critical. It is easy to treat all profit income as traded on a stock market (so that wage earnings represent the home residents' only non-portfolio income). In this case, even in a symmetric equilibrium with zero net foreign assets, agents in each economy would have non-zero *net* portfolio positions. The solution method for optimal portfolios applies equally to this environment.

2.2 Firms

Firms produce differentiated products. The production function for a good produced by firm i is

$$Y(i) = AL(i),$$

where A is a common stochastic productivity shock. We assume that:

$$\log A_t = \zeta \log A_{t-1} + u_t, \tag{8}$$

where $0 \leq \zeta \leq 1$ and u_t is an i.i.d. shock with $E_{t-1}[u_t] = 0$ and $Var[u_t] = \sigma_u^2$.

Firms maximize profits. Sticky prices are modelled in the form of Calvo-style contracts with a probability of re-setting price given by $1-\kappa$. To keep the model as close as possible to the benchmark open economy formulation, we assume that all prices are pre-set in terms of producer's currency. If firms use the discount factor Ω_{t+i} to evaluate future profits, then we may write out the dynamics of the newly-set price $\widetilde{P}_H$ and the home price index P_H as:

$$\widetilde{P}_{H,t} = \frac{\phi}{\phi-1}\frac{E_t \sum\limits_{i=0}^{\infty} \Omega_{t+i}\frac{w_{t+i}}{A_{t+i}} X_{H,t+i}}{E_t \sum\limits_{i=0}^{\infty} \Omega_{t+i} X_{H,t+i}}, \qquad P_{H,t} = \left[(1-\kappa)\widetilde{P}_{H,t}^{1-\phi} + \kappa P_{H,t-1}^{1-\phi}\right]^{\frac{1}{1-\phi}}, \tag{9}$$

where $X_{H,t+i}$ represents demand for the home firm's output[7].

2.3 Monetary Authorities

Monetary policy is represented as an interest rate schedule which is subject to stochastic financial shocks. Monetary authorities follow a policy that adjusts the path of the rate of

[7] In an incomplete markets environment, there is an open question as to what determines the discount factor Ω_{t+i}. If firms are to discount future profits at the same discount rate as their shareholders, then both home and foreign intertemporal rates of substitution would need to enter into the firm's evaluation of future profits. Fortunately, at the level of approximation in which the portfolio solution is obtained, any time variation in the firm's discount factors drops out. Since all the non-portfolio equations in the model are evaluated by linear approximation around a steady state without growth, the discount factor at this level of approximation will simply be β, the common subjective time discount factor of consumers. As a result, the price dynamics of the model are identical to those of the standard producer currency pricing model of Benigno and Benigno (2005), for instance.

return on the nominal bonds of their respective currencies. But in addition, we assume that there are financial market shocks which affect equilibrium nominal interest rates, outside the direct control of the monetary authorities. This leads to an interest rate rule described by:

$$R_{t+1} = \beta^{-1} \left(\frac{P_{H,t}}{P_{H,t-1}} \right)^{\gamma} \exp(m_t) \tag{10}$$

where m_t is an *i.i.d.* stochastic shock such that, $E_{t-1}[m_t] = 0$, $Var[m_t] = \sigma_m^2 > 0$. The role of m_t shocks in the model is to allow a shorthand way of introducing non-productivity related disturbances to domestic inflation rates. It is easy to develop a structural interpretation of these shocks. We could introduce a more explicit model of money demand and money supply in which m_t shocks entered into the equilibrium nominal interest rate schedule in the form of (10). For instance, a money in the utility function specification would give a demand for money being negatively related to the nominal interest rate, and if the supply of money, coming from the Central Bank's open market operations, was positively related to the nominal interest rate, but negatively related to the domestic PPI inflation rate, then in an equilibrium with random shocks to the demand for funds (e.g. velocity shocks altering the demand for money as for instance, in Devereux and Engel (2003)), we would arrive at a reduced-form expression in the form of (10)[8].

Empirically, even for Central Banks that conduct explicit inflation targeting, there are volatile and perisistent differences between the target interest rate and other short terms interest rates (such as the T-bill rate), which are more likely to govern consumer choice. Also, the VAR literature on the identification of monetary policy shocks incorporates i.i.d. shocks such as m_t into the monetary policy rule. In their study of optimal monetary policy, Rotemberg and Woodford (1998) also introduce interest rate rules which are subject to stochastic shocks[9].

Note that the rule (10) determines the nominal interest rate as a function of historic domestic PPI inflation rates. We choose PPI rather than CPI inflation rates because it

[8] In this sense, (10) can be thought of as representing a hybrid form of monetary policy rule somewhere between an interest rate rule and a money targeting rule.

[9] Even without m_t shocks, the central results of the paper; the desirability of price stability as a risk sharing monetary policy rule, still holds. These shocks however introduce a role for the monetary policy stance in an economy with sticky prices. Without m_t shocks, then the interest rate rule (10) would lead to a zero inflation equilibrium, and sticky prices would play no role in the analysis.

is well known that in a benchmark complete markets open economy (without 'cost-push' or government spending shocks), it is optimal (from a global welfare point of view) to stabilize PPI inflation rates. The main analysis of the paper will focus on the relationship between the stance of monetary policy, captured by the parameter γ, and the equilibrium portfolio holdings among countries.

2.4 The Menu of Assets

Asset trade may take place in nominal bonds of each currency, and in the equities of each country. Home nominal bonds represent a claim on a unit of home currency. The real payoff to a home nominal bond purchased at time t is therefore $1/P_{t+1}$. The real price of the bond is denoted $Z_{B,t}$. The gross real rate of return on a home nominal bond is thus $r_{B,t+1} = 1/(P_{t+1}Z_{B,t})$. From the definition of the monetary policy rule, we note that it must be the case that $R_{t+1} = r_{B,t+1}P_{t+1}/P_t = 1/(P_tZ_{B,t})$.

Home equities represent a claim on home aggregate profits. The real payoff to a unit of the home equity purchased in period t is defined to be $\Pi_{t+1} + Z_{E,t+1}$, where Π_{t+1} is the real value of home country profits, and $Z_{E,t}$ is the real price of home equity. Thus the gross real rate of return on the home equity is $r_{E,t+1} = (\Pi_{t+1} + Z_{E,t+1})/Z_{E,t}$.

2.5 Goods Market Clearing

Domestic GDP is determined by demand from home and foreign consumers:

$$Y_t = \mu \left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t + (1-\mu)\left(\frac{P_{H,t}}{S_tP_t^*}\right)^{-\theta} C_t^* \tag{11}$$

2.6 Foreign Economy

The foreign economy has an analogous representation. Thus, foreign consumers choose labor supply and portfolio holdings in the same manner, subject to a budget constraint defined as:

$$P_t^*C_t^* + \frac{1}{S_t}W_{t+1}^* = w_t^*L_t^* + \Pi_t^* + \frac{P_t^*}{Q_t}\sum_{k=1}^{N}\alpha_{k,t-1}^*r_{kt} \tag{12}$$

where Q_t is defined as the real exchange rate; $Q_t = \frac{S_tP_t^*}{P_t}$, (with S_t the nominal exchange rate). The real exchange rate enters (12) because wealth, portfolio holdings, and returns are defined in terms of the home good. Foreign firms adjust prices in the same way as (9), foreign equities and bonds are defined analogously, and the foreign monetary authority follows a rule defined as in (10), except where it targets the foreign rate of PPI inflation.

3 Solving the model

The full solution to the model is described by the sequence $\Big\{C_t, C_t^*, \widetilde{P}_{H,t}, \widetilde{P}_{F,t}, P_{H,t}, P_{Ft}, S_t,$ $Y_t, Y_t^*, R_t, R_t^*\}$, $\{r_{1,t}..r_{N,t}\}$, and the vector $\alpha_t = \{\alpha_{1,t}..\alpha_{N,t}\}$ which solves equations (5)-(7), (9)-(11) and the equivalent equations for the foreign economy. It is well known that, except in very special cases, it is not possible to obtain analytical solutions to dynamic general equilibrium models of this type, even without endogenous portfolio choice. This difficulty becomes more extreme when we allow for a menu of independent assets and endogenous portfolio choice, particularly when markets are incomplete.

The open economy macro literature typically analyzes this model by the method of first-order approximation of all the necessary conditions of the model around a non-stochastic steady state. But, up to a first order approximation, the value of α_t is indeterminate, because at this level of approximation all assets are perfect substitutes. The existing literature therefore tends to confine attention to asset market structures where the portfolio allocation problem is not relevant. In this section, we describe our method for obtaining optimal portfolio shares by means of a particular second-order approximation approach. In particular, we show that it is necessary to increase the order of approximation, so as to incorporate terms involving risk, but one only needs to do this for the portfolio selection equation, (7). The rest of the model conditions can be approximated only up to the first order. This solution method makes it possible to analyse the above model with any asset market structure.

3.1 Asset Market Solution

The non-portfolio aspects of the model are entirely standard. They describe a two-country dynamic open economy model with Calvo price adjustment and producer currency pricing, as in Benigno and Benigno (2006). The innovation in our analysis is the focus on the determination of the equilibrium portfolio holdings, α_t. A full description of the method of solution for portfolio variables is contained in Devereux and Sutherland (2006a). Here we present just a brief account of the approach. The method is based on approximating the model using first and second-order Taylor series expansions of the equilibrium conditions. The approximation is based on an approximation point where all variables, except portfolio holdings, are set at their values in a symmetric non-stochastic steady state with zero net foreign assets. As is well-known, portfolio holdings are indeterminate in a non-stochastic steady state, so portfolio holdings at the approximation point, denoted $\bar{\alpha}$, are treated as unknowns, and the method yields a solution for $\bar{\alpha}$[10].

First, re-write the portfolio selection equations for the home country in the following vector form:

$$E_t C_{t+1}^{-\rho} r_{x,t+1} = 0, \tag{13}$$

where $r'_{x,t+1} = [r_{1,t+1} - r_{N,t+1}, r_{2,t+1} - r_{N,t+1} ... r_{N-1,t+1} - r_{N,t+1}]$ is the vector of excess returns, using the Nth asset as a reference. Taking a second order approximation of (13), we get:[11]

$$E_t \left[\widehat{r}_{x,t+1} + \frac{1}{2} \widehat{r}^2_{x,t+1} - \rho \widehat{C}_{t+1} \widehat{r}_{x,t+1} \right] = 0 + O\left(\epsilon^3\right), \tag{14}$$

where a hat is used to indicate a log-deviation from a non-stochastic steady state.[12] Now write the equivalent expression for the foreign country as follows:

$$E_t \left[\widehat{r}_{x,t+1} + \frac{1}{2} \widehat{r}^2_{x,t+1} - \rho \widehat{C}^*_{t+1} \widehat{r}_{x,t+1} - \widehat{Q}_{t+1} \widehat{r}_{x,t+1} \right] = 0 + O\left(\epsilon^3\right), \tag{15}$$

where the real exchange rate enters because asset returns are defined in terms of the home consumption basket. Subtracting (15) from (14) yields:

$$E_t \left[\left(\widehat{C}_{t+1} - \widehat{C}^*_{t+1} + \widehat{Q}_{t+1}/\rho \right) \widehat{r}_{xt+1} \right] = 0 + O\left(\epsilon^3\right) \tag{16}$$

[10] In effect, our solution for $\bar{\alpha}$ represents asset holdings in a near-non-stochastic steady state.

[11] For the purposes of taking approximations, we assume that the innovations are symmetrically distributed in the interval $[-\epsilon, \epsilon]$. This ensures that any residual in an equation approximated up to order n can be captured by a term denoted $O\left(\epsilon^{n+1}\right)$

[12] The notation for returns is slightly different. We define $\hat{r}'_{x,t+1} = [\hat{r}_{1,t+1} - \hat{r}_{N,t+1}, \hat{r}_{2,t+1} - \hat{r}_{N,t+1}, ... \hat{r}_{N-1,t+1} - \hat{r}_{N,t+1}]$ where $\hat{r}_{k,t+1}$ $(k = 1...N)$ is the log-deviation of $r_{k,t+1}$ from its value in the non-stochastic steady state. The term $\widehat{r}^2_{x,t+1}$ is defined as the vector $[\hat{r}^2_{1,t+1} - \hat{r}^2_{N,t+1}, \hat{r}^2_{2,t+1} - \hat{r}^2_{N,t+1}, ... \hat{r}^2_{N-1,t+1} - \hat{r}^2_{N,t+1}]$.

This equation can now be used to derive a solution for $\bar{\alpha}$ by making use of the following three powerful properties of the approximated model. First, (16) is a second-order accurate approximation so the individual components $\widehat{C}_{t+1} - \widehat{C}^*_{t+1}$, $\widehat{r}_{x,t+1}$, and $\widehat{Q}_{t+1}$, need only be approximated up to first order. Second, all assets are perfect substitutes in expectation up to first order, so $\widehat{r}_{x,t+1}$ is a mean-zero i.i.d. process up to first order. And third, in a first-order approximation of the other equilibrium conditions of the model, the only aspect of portfolio behaviour that matters is $\bar{\alpha}$.

To see this last point more clearly, take a linear approximation of the home budget constraint (4). This gives:

$$\widehat{W}_{t+1} = \frac{1}{\beta}\widehat{W}_t + \widehat{Y}_t - \widehat{C}_t + \hat{P}_{H,t} - \hat{P}_t + \widetilde{\alpha}'\widehat{r}_{x,t} + O\left(\epsilon^2\right) \tag{17}$$

where $\widetilde{\alpha} = \overline{\alpha}/\beta\overline{Y}$ is the vector of asset holdings at the approximation point expressed (approximately) as ratios to steady state GDP, $\overline{Y}$, and $\widehat{W}_t$ is defined as a difference (relative to steady state GDP) rather than a log deviation[13]. This expression shows that, because excess returns are zero in a non-stochastic steady state, deviations of portfolio holdings from the value at the approximation point do not play any part in the first-order accurate evolution of net foreign assets. Furthermore, since α only appears in the budget constraint, it must follow that deviations of α from $\overline{\alpha}$ play no part in the first-order dynamics of any other aspect of the model.

Since $\widetilde{\alpha}$ is time invariant and $\widehat{r}_{x,t}$ is mean zero i.i.d. process, it must be true that $\widetilde{\alpha}'\widehat{r}_{x,t}$ is also a mean zero i.i.d. process. The solution method exploits this fact by temporarily replacing $\widetilde{\alpha}'\widehat{r}_{x,t}$ in (17) with an exogenous i.i.d. process denoted ξ_t. We then solve the linear approximation of the non-portfolio parts of the macro model, using standard methods, taking as given the exogenous i.i.d. shocks $\varepsilon_t' = [u_t, m_t]$ and the i.i.d. shock ξ_t. The

[13] The wealth dynamics of the model have a unit root for the same reason as in many open economy models. It would be possible to eliminate the unit root by assuming endogenous time preference or imposing a portfolio adjustment penalty (see for instance, Schmitt Grohe and Uribe 2004). But this would have minimal consequences for our results. What matters for the equilibrium portfolio is the conditional one-step ahead moments of consumption and returns. These conditional statistics are always well defined in our model. Imposing an added structure on the model to eliminate the unit root would not affect the method of construction of $\widetilde{\alpha}$ at all (the same method applies equally in this case), but we would forfeit the cleanly interpretable analytical solutions for $\widetilde{\alpha}$. For this reason, we choose to proceed with the present model.

solutions for the components of (16) may thus be written as

$$\widehat{C}_{t+1} - \widehat{C}^*_{t+1} + \widehat{Q}_{t+1}/\rho = D_1\xi_{t+1} + D_2\varepsilon_{t+1} + E_t\left(\widehat{C}_{t+1} - \widehat{C}^*_{t+1} + \widehat{Q}_{t+1}/\rho\right) + O\left(\epsilon^2\right) \quad (18)$$

$$\widehat{r}_{x,t+1} = R_1\xi_{t+1} + R_2\varepsilon_{t+1} + O\left(\epsilon^2\right) \quad (19)$$

where the D_1, D_2, R_1, and R_2 matrices are obtained by choosing the appropriate elements of the general linear solution to the non-portfolio parts of the macro model. Then, combining (18) and (19) with (16), and substituting for ξ_{t+1} using $\xi_{t+1} = \widetilde{\alpha}'\widehat{r}_{x,t+1}$, it is shown in Devereux and Sutherland (2006a) that the solution for $\widetilde{\alpha}$ may be written as

$$\tilde{\alpha} = \left[R_2\Sigma D_2' R_1' - D_1 R_2 \Sigma R_2'\right]^{-1} R_2\Sigma D_2' + O\left(\epsilon\right) \quad (20)$$

where $\Sigma = E_{t-1}(\varepsilon_t\varepsilon_t')$ is the covariance matrix of the exogenous i.i.d. innovations.

The solution for $\tilde{\alpha}$ derived by this method is sufficient to allow us to solve for the first-order accurate behaviour of all the other variables of the model[14].

3.2 Linear approximation to the rest of the model

In order to obtain the solution given in (20), we need to construct the linear approximation for the non-portfolio equations in the model. The linear approximation of the home country budget constraint is given by (17). Taking a linear approximation of the Euler equations implies that

$$E_t\widehat{C}_{t+1} - \widehat{C}_t = E_t\widehat{r}_{N,t+1} \quad (21)$$

The equivalent condition for the foreign economy is

$$E_t\widehat{C}^*_{t+1} - \widehat{C}^*_t = E_t\widehat{r}_{N,t+1} + E_t\widehat{Q}_{t+1} - \widehat{Q}_t \quad (22)$$

Note that, in these expressions, and all those that follow, we omit the residual term, $O\left(\epsilon^2\right)$

[14] Devereux and Sutherland, (2006a) provide a complete development of this solution method and discuss more fully the reasons why time variation in portfolios plays no part in the solution process. If it is desired to analyse time-variation in portfolios, it is necessary to approximate the portfolio selection equation up to a 3rd order, and the rest of the model's equilibrium conditions up to a 2nd order. This would capture the way in which conditional moments evolve over time depending on persistent movements in the state variables of the economy. For a complete analysis, see Devereux and Sutherland (2006b). See also Tille and Van Wincoop (2007).

Up to a first order approximation, it must be the case that $E_t\widehat{r}_{k,t+1} = E_t\widehat{r}_{N,t+1}$, for all $k = 1..N-1$. Therefore, using the policy rule (10) and the definition of the real return on home country nominal bonds, we have:

$$\gamma(\widehat{P}_{H,t} - \widehat{P}_{H,t-1}) - E_t(\widehat{P}_{t+1} - \widehat{P}_t) = \rho(E_t\widehat{C}_{t+1} - \widehat{C}_t) \tag{23}$$

Likewise for the foreign country, we must have:

$$\gamma(\widehat{P}^*_{Ft} - \widehat{P}^*_{F,t-1}) - E_t(\widehat{P}^*_{t+1} - \widehat{P}^*_t) = \rho(E_t\widehat{C}^*_{t+1} - \widehat{C}^*_t) \tag{24}$$

From the usual linearization of the Calvo pricing equation and the home goods price index (9) around a path of zero inflation, in combination with the marginal cost definition (5) we have the forward-looking inflation equation given by:

$$\widehat{P}_{H,t} - \widehat{P}_{H,t-1} = 1/\lambda(\rho\widehat{C}_t + \widehat{P}_t - \widehat{P}_{H,t} - \widehat{A}_t) + \beta E_t(\widehat{P}_{H,t+1} - \widehat{P}_{H,t}) \tag{25}$$

where $\lambda = \kappa/\left[(1-\kappa)(1-\beta\kappa)\right]$ is a measure of the degree of price stickiness arising from the Calvo price-adjustment restriction. Likewise for the foreign country, we have

$$\widehat{P}^*_{F,t} - \widehat{P}^*_{F,t-1} = 1/\lambda(\rho\widehat{C}^*_t + \widehat{P}^*_t - \widehat{P}^*_{F,t} - \widehat{A}^*_t) + \beta E_t(\widehat{P}^*_{F,t+1} - \widehat{P}^*_{F,t}) \tag{26}$$

Finally, a linear approximation of the home country goods market clearing condition (11) implies

$$\widehat{Y}_t = \mu\widehat{C}_t + (1-\mu)\widehat{C}^*_t - \theta\mu(\widehat{P}_{H,t} - \widehat{P}_t) - \theta(1-\mu)(\widehat{P}_{H,t} - \widehat{S}_t - \widehat{P}^*_t) \tag{27}$$

We may re-write this system in terms of inflation and the terms of trade, using the definition $\pi_{H,t} = \widehat{P}_{H,t} - \widehat{P}_{H,t-1}$ and $\pi_{F,t} = \widehat{P}^*_{F,t} - \widehat{P}^*_{F,t-1}$for domestic and foreign PPI inflation, respectively, and $\tau_t = \widehat{P}^*_{F,t} + \widehat{S}_t - \widehat{P}_{H,t}$ for the home country terms of trade. Then we can use conditions (21)-(22) to reduce the model to a system of 6 equations in net foreign assets, consumption, inflation, home country output, and the terms of trade. The full system is described in Table 1.

This system contains the term $\widetilde{\alpha}'\widehat{r}_{x,t}$, which represents the wealth effects for the home country given an ex-post realization of excess returns, for an arbitrary portfolio holding. As noted before, up to a linear approximation, $\widehat{r}_{x,t}$ is a mean zero, i.i.d. variable. We may use this condition, and the definition of each asset in section 2 above, to compute

Table 1 Linear approximation of the model for given $\widetilde{\alpha}$

Capital markets	$E_t(\widehat{C}_{t+1}-\widehat{C}_t)= E_t(\widehat{C}^*_{t+1}-\widehat{C}^*_t)+(2\mu-1)E_t(\widehat{\tau}_{t+1}-\widehat{\tau}_t)$
Budget constraint	$\widehat{W}_{t+1}=\frac{1}{\beta}\widehat{W}_t+\widehat{Y}_t-\widehat{C}_t-(1-\mu)\widehat{\tau}_t+\widetilde{\alpha}'\widehat{r}_{x,t}$
Home output	$\widehat{Y}_t= \mu\widehat{C}_t+(1-\mu)\widehat{C}^*_t-\theta\mu(\widehat{P}_{H,t}-\widehat{P}_t)-\theta(1-\mu)(\widehat{P}_{H,t}-\widehat{S}_t-\widehat{P}^*_t)$
Home inflation	$\pi_{H,t}= \lambda^{-1}[\rho\widehat{C}_t+(1-\mu)\widehat{\tau}_t-u_t]+\beta E_t\pi_{H,t+1}$
Foreign inflation	$\pi^*_{F,t}= \lambda^{-1}[\rho\widehat{C}^*_t-(1-\mu)\widehat{\tau}_t-u^*_t]+\beta E_t\pi^*_{F,t+1}$
Home monetary rule	$\gamma\pi_{H,t}+m_t= E_t\widehat{C}_{t+1}-\widehat{C}_t+E_t[\pi_{H,t+1}+(1-\mu)\widehat{\tau}_{t+1}]$
Foreign monetary rule	$\gamma\pi^*_{F,t}+m^*_t= E_t\widehat{C}^*_{t+1}-\widehat{C}^*_t+E_t[\pi^*_{F,t+1}-(1-\mu)\widehat{\tau}_{t+1}]$

the realization of $\widehat{r}_{x,t}$ for a given $\widetilde{\alpha}$, using the solution to the system in Table 1. Without loss of generality, let the foreign nominal bond represent the residual asset N. Then the linearized vector of excess returns on home equity, foreign equity, and home nominal bonds is written as:

$$\begin{aligned}\widehat{r}_{x,1,t+1} &= \beta\widehat{\Pi}_{t+1}+(1-\beta)\widehat{Z}_{E,t+1}-E_t\left(\beta\widehat{\Pi}_{t+1}+(1-\beta)\widehat{Z}_{E,t+1}\right)\\ &\quad -(\widehat{Q}_{t+1}-E_t\widehat{Q}_{t+1})+\widehat{P}^*_{t+1}-\widehat{P}^*_t-E_t\left(\widehat{P}^*_{t+1}-\widehat{P}^*_t\right)\end{aligned} \tag{28}$$

$$\begin{aligned}\widehat{r}_{x,2,t+1} &= \beta\widehat{\Pi}^*_{t+1}+(1-\beta)\widehat{Z}^*_{E,t+1}-E_t\left(\beta\widehat{\Pi}^*_{t+1}+(1-\beta)\widehat{Z}^*_{E,t+1}\right)\\ &\quad +\widehat{P}^*_{t+1}-\widehat{P}^*_t-E_t\left(\widehat{P}^*_{t+1}-\widehat{P}^*_t\right)\end{aligned} \tag{29}$$

$$\widehat{r}_{x,3,t+1}=-\left(\widehat{S}_{t+1}-E_t\widehat{S}_{t+1}\right) \tag{30}$$

To compute $\widehat{Z}_{E,t}$, we use (6) and (7) applied to the pricing of home equity. This gives the change in the real price of equity as a function of the expected changes in the discounted sum of future real profits. In a similar way, we may compute $\widehat{Z}^*_{E,t}$.

3.3 Construction of the Equilibrium Portfolios

In the next section, we adapt the solution formula (20) to compute equilibrium bond and equity holdings under a number of different assumptions concerning the existence of asset markets. The key focus of interest is the influence of the monetary policy stance on equilibrium portfolio holdings, and indirectly, the effect of monetary policy on the degree of risk-sharing across countries.

4 Equilibrium Portfolios under alternative Asset Market Configurations

Using Table 1, the excess returns definitions (28)-(30), along with assumptions on Σ we may employ (20) to construct $\widetilde{\alpha}$. The Appendix reports the solutions for D_1, D_2, R_1, R_2 and Σ in all cases.

We will examine three different asset market configurations. First, assume that only a non-contingent risk-free real bond (denominated in the home good) is traded across countries. In this case, there is no portfolio selection problem at all, and the solution is equivalent to the standard incomplete markets open economy model in which only a non-contingent bond allows for intertemporal trade. The solution to this configuration is obtained from Table 1 by simply imposing $\widehat{r}_{x,t} = 0$. A second asset market structure allows nominal bonds in either currency to be traded across countries. This environment allows for more international risk-sharing so long as the ex-post returns on nominal bonds differ across currencies. But markets are still incomplete, since there are four independent shocks (interest rate and productivity shocks in each country) but only two assets. Finally, the asset menu is extended to allow for trade in both nominal bonds and the equity of each country. This situation is one of complete markets, since there are four assets with independent returns.

These three environments are denoted respectively as the 'non-contingent bond economy' (NC), the 'nominal bonds economy' (NB), and the 'nominal bonds and equity' economy (NBE). In fact, the key contribution of the paper is the detailed analysis of the NB economy, since many previous papers have explored various versions of the NC and

NBE economies, where there is either no risk-sharing at all (NC), or complete markets (NBE).

Our main focus is on the question of how monetary policy affects portfolio holdings and risk-sharing under each asset market setup. In general the solutions for asset holdings are highly complicated expressions that can only be described numerically. Because of this, we focus on a special case of the model which admits easily interpretable algebraic expressions. This special case assumes a) $\rho = 1$, or log utility, b) $\mu = \frac{1}{2}$, so that there is no home bias in preferences over domestic vs. foreign goods (and so PPP holds at all times) and c) $\zeta = 1$, so that technology shocks are random walks. In fact the qualitative results of the paper are more general, as we discuss below.

4.1 Optimal Portfolios

In the NC economy, there is no portfolio problem at all, since there is only a single non-contingent asset traded across countries. In the NB economy, agents choose a portfolio of home and foreign currency bonds, and in the NBE economy, they choose home and foreign equity as well as home and foreign currency bonds. The model is entirely symmetric, and we approximate around an initial steady state where $W = 0$. This implies that in the NB economy, agents in both countries will have bond holdings that sum to zero, and in the NBE economy, their equity holdings and bond holdings will separately sum to zero. Thus, for the home country, we have $\widetilde{\alpha}_{B,NB} + \widetilde{\alpha}^*_{B,NB} = 0$ in the NB economy, and separately, $\widetilde{\alpha}_{B,NE} + \widetilde{\alpha}^*_{B,NE} = 0$, $\widetilde{\alpha}_{E,NE} + \widetilde{\alpha}^*_{E,NE} = 0$ in the NBE economy, where an asterisk denotes the investment in the foreign asset, and the other notation is self-explanatory.

Table 2 describes the optimal portfolio holdings in the NB and NBE economies. The first thing to note is that when $\theta = 1$ (unit elasticity of substitution across home and foreign goods), the optimal bond and equity holdings in all cases are zero. This reflects the well-known Cole and Obstfeld (1990) result that trade in goods alone will ensure full risk-sharing across countries under a unit elasticity of substitution across home and foreign goods.

Table 2: Optimal Portfolio Holdings

NB	$\widetilde{\alpha}_{B,NB} = \frac{1}{2}\frac{(\theta-1)}{(1-\beta)}\frac{(\gamma+\lambda)^2\sigma_A^2+[\lambda+\theta-\beta\lambda(1-\theta)]\lambda(1-\beta)\sigma_m^2}{(\gamma+\lambda)^2\sigma_A^2+[\lambda+\theta-\beta\lambda(1-\theta)](1+\lambda)\sigma_m^2}$
NBE (Bonds)	$\widetilde{\alpha}_{B,NE} = \frac{1}{2}\frac{\lambda(\theta-1)(\phi-1)}{(\theta-1)(1+\lambda\beta)+\lambda(\phi-1)(1-\beta)}$
NBE (Equity)	$\widetilde{\alpha}_{E,NE} = -\frac{1}{2}\frac{1}{1-\beta}\frac{(\theta-1)(1+\lambda\beta)}{(\theta-1)(1+\lambda\beta)+\lambda(\phi-1)(1-\beta)}$

4.1.1 The NB Economy

First focus on the solutions for the NB economy. Optimal holdings of home currency bonds are positive (negative) when $\theta > 1$ ($\theta < 1$). But the size of $\widetilde{\alpha}_{B,NB}$ depends on the importance of technology shocks relative to monetary policy shocks. When technology shocks are predominant, so that $\sigma_A^2/\sigma_m^2 \longrightarrow \infty$, bond holdings tend to $\frac{1}{2}\frac{(\theta-1)}{(1-\beta)}$, while as $\sigma_A^2/\sigma_m^2 \longrightarrow 0$, bond holdings tend to $\frac{1}{2}\frac{\lambda(\theta-1)}{(1+\lambda)}$.

To explain these portfolio shares, first imagine that each country had a zero portfolio share of all assets. Then we can solve the model from Table 1 by setting $\widetilde{\alpha} = 0$. The solution for relative consumption, $\widehat{C}_t - \widehat{C}_t^*$ may be written as[15]:

$$\widehat{C}_t - \widehat{C}_t^* = \frac{(\theta-1)}{\theta}\left[(u_t - u_t^*) - \frac{\lambda(1-\beta)}{(\gamma+\lambda)}(m_t - m_t^*)\right]. \tag{31}$$

At the same time, if each country were holding a zero portfolio, the excess return on foreign bonds (which equals the unanticipated depreciation in the exchange rate) would equal:

$$\widehat{r}_{x,t} = \frac{1}{\theta}\left[(u_t - u_t^*) - \frac{(\theta+\lambda(1+\beta(\theta-1)))}{(\gamma+\lambda)}(m_t - m_t^*)\right]. \tag{32}$$

Without any portfolio diversification, (31) shows that in response to a positive home country productivity shock, home relative consumption rises, when $\theta > 1$. To hedge this consumption risk, home consumers would like to hold an asset that has a negative correlation with home productivity. Since from (32) the exchange rate depreciates when home productivity is positive, then it is best to have a long position in home currency bonds, matched by a short position in foreign currency bonds. The scale of bond holdings to

[15] To simplify the notation, we also assume that $\widehat{W}_t = 0$ in these expressions. Since total wealth is predicable one-period ahead, it has no implications for portfolio solutions.

GDP must be proportional to $1/(1-\beta)$ since the payoff on a one period bond represents a one-time, transitory return, while the productivity shock is a permanent income increment. Thus, in order to adequately hedge the consumption risk from productivity shocks, bond holdings must be large relative to GDP.

In response to a home country interest rate shock, from (31) relative home consumption falls by $\frac{\lambda(\theta-1)(1-\beta)}{(1+\lambda)\theta}$, when $\theta > 1$. At the same time, (32) indicates that domestic inflation falls relative to foreign inflation, and the exchange rate appreciates. Hence, home currency nominal bonds are a better hedge against monetary-shock-related consumption risk than are foreign currency bonds. Thus, in the NB economy, for both types of shocks, consumers would like to hold a positive position in domestic currency bonds, and a negative position in foreign currency bonds, when $\theta > 1$[16].

On the other hand, in the case $\theta < 1$, the opposite reasoning applies. In this case, relative home consumption falls in response to a home productivity shock,[17] and rises in response to a home country interest rate shock. Then foreign currency bonds represent a good hedge against consumption risk on both counts.

The extent of nominal bond holdings will depend on the degree of price stickiness. As λ falls, there is less price stickiness, so that consumers can ignore the direct consumption fluctuations due to interest rate shocks, and bond holdings will be lower. Note also that $\left|\frac{\lambda(\theta-1)}{(1+\lambda)}\right| < \left|\frac{(\theta-1)}{(1-\beta)}\right|$. Since interest rate shocks are transitory, households need to hold a smaller bond position to hedge money shocks than productivity shocks. Thus, as σ_A^2/σ_m^2 rises, gross bond portfolios will rise in both countries.

The solution for $\widetilde{\alpha}_{B,NB}$ in the special case where $\lambda = 0$ (fully flexible prices) is $\frac{1}{2}\frac{(\theta-1)}{(1-\beta)}\frac{\gamma^2\sigma_A^2}{\gamma^2\sigma_A^2+\theta\sigma_m^2}$. The greater are interest rate shocks, the smaller is the country's bond portfolio. This points to a key qualitative feature of the model with endogenous portfolio choice. In the benchmark open economy macro model of Table 1, money is completely neutral if prices are flexible, since the model is based on a 'cashless' economy as described by Woodford (2003). The NC economy reflects this property (see below). But in the NB

[16] This result does depend on the configuration of shocks, the structure of the model, and the monetary policy specification. Under a monetary targeting rule for monetary policy, an optimal bond portfolio may involve a long (short) position in foreign currency (home currency) bonds, even when $\theta > 1$.

[17] In this case the negative welfare impact of a terms-of-trade decline following an increase in u is greater that the positive welfare effect of higher home GDP.

economy, where agents must use nominal bonds to engage in international risk-sharing, the excess return on nominal bonds (i.e. the exchange rate) is affected by interest rate shocks, *even in a flexible price economy*, as shown in (32). Hence, interest rate shocks reduce the effectiveness of nominal bonds as a hedging device against consumption risk due to productivity shocks.

4.1.2 The NBE economy

Now assume that households can trade in both nominal bonds and equities. In the NBE economy, households will also hold a positive nominal bond position in home currency bonds (negative in foreign currency bonds) when $\theta > 1$, but will also now hold a positive share of foreign equity. Unlike the NB economy, under NBE portfolio shares are independent of the relative size of productivity shocks to interest rate shocks. The explanation is easy to see. Since in the NBE economy, markets are complete, the NBE portfolio of Table 2 ensures that $\widehat{C}_t - \widehat{C}_t^* = 0$ for every possible realization of shocks. This implies that the relative volatilities of the shocks are irrelevant for the portfolio solutions which achieve this - agents are not trading off consumption risk sharing with respect to one shock against another shock.

Holdings of foreign equity are given by $\frac{1}{2}\frac{1}{1-\beta}\frac{(\theta-1)(1+\lambda\beta)}{(\theta-1)(1+\lambda\beta)+\lambda(\phi-1)(1-\beta)}$. If prices were fully flexible, i.e. $\lambda = 0$, then no nominal bonds would be held at all, and the optimal equity portfolio would to hold a share $\frac{1}{2}\frac{1}{1-\beta}$ in foreign equity, matched by the negative of this in home equity. This is a 'full diversification' outcome. Agents in each country hold equity shares such that, in equilibrium, they have a claim to half of the GDP of their own country, and half that of the other country. When $\lambda = 0$, the real return on equity is independent of monetary shocks. In this case, agents hold no nominal bonds. In contrast to the NB case, money is fully neutral in the NBE economy, under flexible prices.

More generally, with sticky prices, the real return on equity and bonds depends on both productivity shocks and money shocks, so the optimal portfolio weights must reflect this. As λ rises, portfolio shares held in equity fall, while the portfolio share in bonds rises. In fact there is an interesting discontinuity in the determination of equity holdings at $\lambda = 0$. With fully flexible prices, the elasticity θ has no implications for equity holdings at all,[18] and there is complete portfolio diversification. But for *any* positive λ there is a value of θ close enough to unity such that $\widetilde{\alpha}_{E,NE} \approx 0$. Thus, there can be complete equity *home bias* even for very small degrees of price rigidity, if θ is relatively close to unity[19].

4.1.3 Portfolio holdings and Monetary Policy

How does the stance of monetary policy affect portfolio holdings? We use the parameter γ as a measure of the tightness of monetary policy. As γ rises, the variance of PPI inflation falls. Thus, a higher γ can be interpreted as a policy placing more emphasis on price stability. From Table 1 we can establish:

Proposition 1. In the NB economy, a rise in γ increases the gross holdings of home and foreign currency bonds. In the NBE economy, the portfolio shares in bonds and equities are independent of γ.

Proof: From Table 1.

In the NB economy, markets are incomplete, and gross bond holdings have to act as a hedge against a combination of productivity shocks and interest rate shocks. The higher is γ, the less impact will interest rate shocks have on the variance of consumption in each country. As γ rises, bonds holdings are dedicated more and more to the hedging of productivity shocks, which require higher gross holdings. On the other hand, in the NBE economy, the portfolio which achieves full risk-sharing is independent of the relative importance of each shock, as we have shown above. But the effect of changes in the monetary policy parameter γ in the model is only to scale up or down the relative importance of the interest rate shocks in overall volatility. As a result, changes in the monetary policy stance which alter the share of total volatility due to the different shocks have no impact on the portfolio shares in the NBE economy.

[18] This is because both relative consumption (as in (31)) and relative equity returns respond to productivity shocks in proportion to $(1-\theta)$.

[19] Home bias is equivalent to a value of $\widetilde{\alpha}_{E,NE}$ close to zero, since the zero-portfolio status quo implies that the home agent owns 100 percent of the home equity. The potential for sticky prices to generate home equity bias in portfolio is highlighted in Engel and Matsumoto (2006). These results are different principally due to the different monetary rule employed in this paper.

4.2 Risk-Sharing and Portfolio Holdings

We now examine in more detail the risk-sharing implications of the portfolio positions just described. There is a natural contrast between the risk-sharing inherent in the NC, NB and NBE economies. We can also describe the optimal monetary policy rules under each environment. To avoid issues of non-cooperative behavior, define an optimal monetary rule as one which maximizes the sum of expected utility across home and foreign households. Since the model is fully symmetric, in equilibrium expected utility will be equalized across countries. Moreover, because we can isolate the market distortions that are due to both price stickiness and incomplete assets markets, we may describe an optimal monetary policy rule without explicitly solving a policy welfare-maximization problem.

As a measure of risk-sharing, we use the conditional variance of relative consumption movements; $var_{t-1}(\widehat{C}_t - \widehat{C}_t^*)$[20]. We also describe the implication of each case for consumption variance $var_{t-1}(\widehat{C}_t)$. Table 3 describes these statistics for each asset market configuration.

It is easiest to begin the description of Table 3 from the NBE case, in which markets are complete. In this case, there is full risk-sharing. Since there is no home bias in preferences or real exchange rate variability, consumption is equalized across countries. Monetary policy has no role to play in international risk-sharing. Due to price stickiness however, monetary policy does affect the variability of consumption. A policy of strict price stability will eliminate the effect of interest rate shocks on consumption. This captures the traditional role for monetary policy. By eliminating the effect of the constraint inherent in costly price adjustment, monetary policy replicates the flexible price equilibrium with complete markets.

Since markets are complete, and assuming that any distortions associated with monopoly pricing are eliminated by optimal subsidies, then it must also be the case that full price stability is an optimal *cooperative* monetary policy in the NBE environment.

In the NC economy there is a failure of international risk-sharing, except in the special case where $\theta = 1$. Moreover, consumption volatility is higher than under incomplete mar-

[20] As noted above, all conditional variances are well defined, even though there is a unit root in the wealth distribution.

Table 3 risk-sharing across alternative asset market configurations

NC	$var_{t-1}(\widehat{C}_t)$	$= \frac{1}{2}\left[(1+\frac{(1-\theta)^2}{\theta^2})\sigma_A^2 + \frac{\lambda^2}{(\lambda+\gamma)^2}(1+(1-\beta)^2\frac{(1-\theta)^2}{\theta^2})\sigma_m^2\right]$
	$var_{t-1}(\widehat{C}_t - \widehat{C}_t^*)$	$= 2\left[\frac{(1-\theta)^2}{\theta^2}\sigma_A^2 + \frac{\lambda^2}{(\lambda+\gamma)^2}(1-\beta)^2\frac{(1-\theta)^2}{\theta^2}\sigma_m^2\right]$
NB	$var_{t-1}(\widehat{C}_t)$	$= \frac{1}{2}\left[\frac{(\lambda+\gamma)^4\left(\sigma_A^2\right)^2 + \Omega\sigma_A^2\sigma_m^2 + \lambda^2(\lambda+\theta-\lambda\beta(1-\theta))^2\left(\sigma_m^2\right)^2}{(\lambda+\gamma)^4\sigma_A^2 + (\lambda+\gamma)^2(\lambda+\theta-\lambda\beta(1-\theta))^2\sigma_m^2}\right]$
	$var_{t-1}(\widehat{C}_t - \widehat{C}_t^*)$	$= 2\left[\frac{(1+\lambda\beta)^2(1-\theta)^2\sigma_A^2\sigma_m^2}{(\lambda+\gamma)^2\sigma_A^2 + \Phi\sigma_m^2}\right]$
NBE	$var_{t-1}(\widehat{C}_t)$	$= \frac{1}{2}\left[\sigma_A^2 + \frac{\lambda^2}{(\lambda+\gamma)^2}\sigma_m^2\right]$
	$var_{t-1}(\widehat{C}_t - \widehat{C}_t^*)$	$= 0$

$$\Omega = (\lambda+\gamma)^2\left[(1+\lambda)^2 + \lambda^2 - 2(1-\theta)(1+\lambda\beta)(\lambda+\theta-\beta\lambda(1-\theta))\right]$$

$$\Phi = \left[(1+\lambda)^2 - (1+\lambda\beta)((1+\lambda\beta)(1-\theta^2) + 2\lambda(1-\beta)(1-\theta))\right]$$

kets. In this case, monetary policy can enhance risk-sharing by eliminating the impact of interest rate shocks on consumption. Conceptually however, this operates in the same way as with complete markets. That is, monetary policy enhances international risk-sharing only by supporting the full flexible price equilibrium of the *NC* economy. What is more, monetary policy cannot attain full international risk-sharing. Even in the flexible price equilibrium households cannot use non-contingent bond trade to offset the consumption risks of productivity disturbances, which are permanent[21]. Within this restricted class of monetary rule, a policy of price stability is still optimal in the *NC* economy. But we may infer from the results of Benigno (2001), Obstfeld and Rogoff (2002), and Devereux (2004) that an alternative monetary rule (for instance, a rule which responds to both the interest

[21] If productivity disturbances were temporary, then non-contingent bond trade would offer some risk sharing benefits. In this case also, monetary policy can enhance the sharing of consumption risk due to productivity shocks, but it still cannot achieve fully efficient risk sharing.

rate and the exchange rate), which leads allocations to deviate from their flexible price equilibrium, would do better. An alternative rule would act so as to eliminate interest rate shocks, but also lead consumption and employment in each economy to respond more closely to that of the equilibrium with complete markets[22]. Hence, price stability is not efficient within a wider class of monetary rules.

Now focus on the NB economy. In this case, the stance of monetary policy has a more complex effect. This is because, as we have seen above, monetary policy influences the gross holdings of nominal bonds in each currency. Monetary policy has a two-fold effect on risk-sharing. First, as in the NC economy, by setting $\gamma \to \infty$, monetary policy can (in the traditional manner) support the flexible price equilibrium and eliminate the influence of interest rate shocks on consumption volatility. But the monetary stance also *endogenously* enhances the ability of households to achieve international risk-sharing. A policy of strict price stability leads agents to concentrate their gross nominal portfolio holdings towards eliminating country specific productivity shocks, and allowing them to ignore the presence of interest rate shocks. In doing so, increasing γ generates effectively complete international assets markets. Table 3 indicates that as $\gamma \to \infty$, $var_{t-1}(\widehat{C}_t - \widehat{C}_t^*)$ goes to zero, and $var_{t-1}(\widehat{C}_t)$ approaches $\frac{1}{2}\sigma_A^2$. Thus, price stability leads to the *equivalence* of the NB and the NBE economies.

It is important to see that the enhanced role of monetary policy in the NB economy is distinct from the traditional function of monetary policy in eliminating the effects of sticky prices. This point is clarified by focusing on the special case of fully flexible prices; i.e. $\lambda = 0$. Then there is no role for monetary policy at all in the NC or the NBE economies. But in the NB economy, monetary policy still plays a role. When $\lambda = 0$, in the NB economy, Table 3 implies that:

$$var_{t-1}(\widehat{C}_t) = \frac{1}{2}\left[\frac{\gamma^2(\sigma_A^2)^2 + (1-2\theta(1-\theta))\sigma_A^2\sigma_m^2}{\gamma^2\sigma_A^2 + \theta^2\sigma_m^2}\right] \tag{33}$$

$$var_{t-1}(\widehat{C}_t - \widehat{C}_t^*) = 2\left[\frac{(1-\theta)^2\sigma_A^2\sigma_m^2}{\gamma^2\sigma_A^2 + \theta^2\sigma_m^2}\right] \tag{34}$$

The monetary stance parameter γ still appears in (33) and (34), even though $\lambda = 0$. Moreover both consumption variance and the degree of risk-sharing are affected by

[22] We do not explore in detail the nature of these alternative rules. See Benigno (2001) for an elaboration, within a model almost identical to our NC economy.

the variability of interest rate shocks. By setting $\gamma \to \infty$ monetary policy eliminates the influence of interest rate shocks, ensuring that $var_{t-1}(\widehat{C}_t)$ in (33) approaches the consumption variance of the NBE economy, and that $var_{t-1}(\widehat{C}_t - \widehat{C}_t^*)$ in (34) approaches zero. The influence of monetary policy in this case operates purely through its ability to enhance the effectiveness of nominal bonds in hedging country specific productivity disturbances.

Monetary policy also has implications for asset returns. For the NB economy, the excess return on foreign nominal bonds is equal to the unexpected movement in the exchange rate. In the case $\lambda = 0$, this is:

$$var_{t-1}(\widehat{r}_{x,t}) = \frac{2}{\gamma^2} \frac{\left(\gamma^2\sigma_A^2 + \theta\sigma_m^2\right)^2}{\left(\gamma^2\sigma_A^2 + \theta^2\sigma_m^2\right)} \tag{35}$$

Thus, exchange rate variance will reflect shocks both to interest rates and to productivity, even in a flexible price economy. The higher is the variance of interest rate shocks, the less efficient are nominal bond returns in reflecting country specific productivity shocks, and hence less effective in supporting international risk-sharing. A policy of strict price stability eliminates the influence of interest rate shocks on bond returns. In doing so, price stability naturally reduces exchange rate volatility the NB economy.

The welfare implications for the NB economy follow immediately from these observations. Price stability is an optimal policy in the NB economy, even though markets are incomplete. Price stability is optimal for two reasons. First, it eliminates the effect of sticky nominal prices. Secondly, even if all prices were flexible, price stability is still optimal because it ensures that the real return on nominal bonds reflect only the efficient fundamental shocks to productivity, and are independent of interest rate shocks. This ensures that households may use nominal bonds to achieve full cross-country risk-sharing. Therefore, price stability supports the first-best allocation[23].

More generally, this points to the fact that there is an independent role for monetary policy in targeting asset returns in this economy. If there are interest rate shocks (or

[23] It is important to see that this result does not depend on our restricted class of monetary rules. Any monetary policy rule that generates full risk sharing can be fully optimal only if it also supports price stability. Even in the case $\lambda = 0$, an optimal monetary policy using a wider class of monetary rule than (10) will ensure that the nominal exchange rate responds efficiently to productivity shocks, and domestic PPI inflation is zero.

other financial-market shocks which reduce the effectiveness of nominal bonds in hedging productivity risk), then monetary policy can be used to ensure that nominal bond returns do not reflect these shocks. Does this mean that monetary policy should stabilize the volatility of asset returns? In fact, the answer is not necessarily. We examine this question more carefully in the next section.

We may summarise the discussion of this sub-section as follows:

Proposition 2.

a) In the NC economy, international risk sharing is limited, and an optimal monetary rule would in general deviate from price stability.

b) In the NBE economy, there is full risk international sharing, and price stability is optimal because it replicates the flexible price equilibrium.

c) In the NB economy, price stability is optimal, because it replicates the flexible price equilibrium, and at the same time generates full international risk-sharing.

Proof: From Table 3 and above discussion.

Finally, it is important to point out that the key result in Proposition 2c is robust to different versions of the model. For instance, even without financial market (m_t) shocks, it would still be desirable to set monetary policy so that the domestic PPI was stabilized, for risk-sharing purposes. This is because the relative return on nominal bonds is equal to the nominal exchange rate, and in order to sustain full risk sharing in the NB economy, this must also be governed by movements in the terms of trade. Thus, an efficient monetary policy must insure that the nominal exchange rate moves so as to replicate the efficient terms of trade. But this means that inflation movements must be eliminated.

4.3 Capital Flows and Exchange Rate Volatility

The previous section showed that a policy of price stability can act so as to enhance international risk-sharing as well as sustain a flexible price equilibrium. What implications does this have for exchange rates and capital flows? Since exchange rates affect the returns on nominal bonds and equity, this question also relates to the issue of how monetary policy should affect the distribution of asset returns.

Table 4 illustrates the implications of each asset market environment for the behaviour of the current account (locally equivalent to the trade balance) and the exchange rate. The table shows the variance of the current account and the exchange rate as a function variance of the underlying interest rate and productivity.

Table 4 Capital Flows and Exchange Rate variability

NC	$var_{t-1}(CA_t)^{NC} = \frac{1}{2}(1-\theta)^2 \frac{\lambda^2\beta^2}{(\lambda+\gamma)^2}\sigma_m^2$
	$var_{t-1}(\Delta S_t)^{NC} = \frac{2}{\theta^2}\left[\sigma_A^2 + \frac{(\lambda+\theta-\lambda\beta(1-\theta))^2}{(\lambda+\gamma)^2}\sigma_m^2\right]$
NB	$var_{t-1}(CA_t)^{NB} = \frac{1}{2}(1-\theta)^2\left[\frac{(\lambda+\gamma)^4\left(\sigma_A^2\right)^2+\Psi\sigma_A^2\sigma_m^2+\lambda^2(\lambda+\theta-\lambda\beta(1-\theta))^2\left(\sigma_m^2\right)^2}{(\lambda+\gamma)^4\sigma_A^2+(\lambda+\gamma)^2(\lambda+\theta-\lambda\beta(1-\theta))^2\sigma_m^2}\right]$
	$var_{t-1}(\Delta S_t)^{NB} = 2\left[\frac{(\lambda+\gamma)^4\left(\sigma_A^2\right)^2+\Upsilon\sigma_A^2\sigma_m^2+(1+\lambda)^2(\lambda+\theta-\lambda\beta(1-\theta))^2\left(\sigma_m^2\right)^2}{(\lambda+\gamma)^4\sigma_A^2+(\lambda+\gamma)^2(\lambda+\theta-\lambda\beta(1-\theta))^2\sigma_m^2}\right]$
NBE	$var_{t-1}(CA_t)^{NBE} = \frac{1}{2}(1-\theta)^2\left[\sigma_A^2 + \frac{\lambda^2}{(\lambda+\gamma)^2}\sigma_m^2\right]$
	$var_{t-1}(\Delta S_t)^{NBE} = 2\left[\gamma_A^2 + \frac{(1+\lambda)^2}{(\lambda+\gamma)^2}\gamma_m^2\right]$

$$\Psi = \lambda(\lambda+\gamma)^2\left[2(\lambda+\theta-\beta\lambda(1-\theta))+\lambda\beta^2\right]$$

$$\Upsilon = 2(1+\lambda)(\lambda+\gamma)^2(\lambda+\theta-\beta\lambda(1-\theta))$$

4.3.1 Exchange Rate Volatility

From Table 4 we see that in the NC economy, for both interest rate and productivity shocks, exchange rate variability is lower, the higher is θ, while the same mechanism does not operate in the NBE economy. This is due to the income effects of shocks, causing labor supply to move in the opposite direction to consumption and output, acting so as to stabilize the terms of trade. This channel does not operate in the economy with full risk-sharing across countries. But these effects will partially operate in the NB economy, since risk-sharing is not perfect in that case.

How does exchange rate variability differ across the three different asset market configurations? First, we focus on a comparison of exchange rate variability for a given value of γ and σ_m^2. Using the relevant rows of Table 4, we may establish the following proposition:

Proposition 3 For given values of γ and σ_m^2 exchange rate volatility across regimes satisfies the following inequalities:

$$var_{t-1}(\Delta S_t)^{NBE} \geq var_{t-1}(\Delta S_t)^{NB} \geq var_{t-1}(S_t)^{NC}.$$

Proof: From Table 4 we may establish that:

$$\begin{aligned} & var_{t-1}(\Delta S_t)^{NBE} - var_{t-1}(\Delta S_t)^{NB} \\ = \; & \frac{(1+\lambda\beta)^2(1-\theta)^2\sigma_m^2\sigma_A^2}{(\lambda+\theta-\beta\lambda(1-\theta))^2\sigma_m^2+(\gamma+\lambda)^2\sigma_A^2} \end{aligned} \tag{36}$$

and

$$\begin{aligned} & var_{t-1}(\Delta S_t)^{NB} - var_{t-1}(\Delta S_t)^{NC} \\ = \; & \frac{(\lambda+\gamma)^2(\theta^2-1)\sigma_A^2+(\theta-1)\Xi\sigma_m^2\sigma_A^2+(\theta-1)\Lambda\sigma_m^2}{(\lambda+\gamma)^2\theta^2\left[(\lambda+\theta-\beta\lambda(1-\theta))^2\sigma_m^2+(\gamma+\lambda)^2\sigma_A^2\right]} \end{aligned} \tag{37}$$

where $\Xi > 0$, and $\Lambda > 0$ are composite functions of parameters.

Thus, exchange rate volatility is greatest under the complete markets regime, and lowest in the regime with no risk-sharing at all, with the nominal bond economy lying somewhere in between. Notice that from (36), if either type of shock is absent, then exchange rate volatility is equal in the NBE and the NB economy. This follows from the results of the previous section, since with only one type of shock, nominal bonds can achieve full risk-sharing.

Proposition 3 indicates that increasing the number of assets traded will lead to an increase in exchange rate volatility, for a given monetary rule. But in the previous section we saw that the monetary rule itself could alter the effective degree of completeness of assets markets. This raises the question of how the stance of monetary policy influences exchange rate volatility.

From inspection of Table 4, we see that under both the NC and NBE economies, a policy of price stability unambiguously reduces exchange rate volatility, since it eliminates the direct component of exchange rate volatility coming from interest rate shocks. Under the NB economy however, the monetary stance affects exchange rate variability both directly through the affect of interest rate shocks and indirectly through altering the composition of the portfolio. The first effect will clearly reduce exchange rate volatility, but from Proposition 3 the second effect may increase exchange rate volatility, since it moves the NB economy closer to the NBE economy. Again using Table 4, we may establish

Proposition 4 An increase in γ may either increase or reduce exchange rate volatility. In addition, the relationship may not be monotonic.

Proof: The proposition can be established by looking at a special case of $var_{t-1}(S_t)^{NB}$ where prices are flexible ($\lambda = 0$). We can show then that:

$$\left.\frac{\partial var_{t-1}(S_t)^{NB}}{\partial \gamma}\right|_{\lambda=0} \propto -\sigma_m^2(\sigma_A^2\gamma^2(2-\theta)+\sigma_m^2\theta^2) \tag{38}$$

If $\theta > 2$, this expression may be positive. The more important are productivity shocks relative to interest rate shocks, the more likely it is that the expression is positive. Moreover, we see that the relationship may be non-monotonic, since when $\theta > 2$, (38) is more likely to be positive, the higher is γ itself.

In the more general case however, with some price stickiness, the direct channel of monetary policy on exchange rate volatility becomes more important. In fact, calibration of the general value for $\frac{\partial var_{t-1}(S_t)^{NB}}{\partial \gamma}$ suggests that it is likely to be negative in the range of empirically relevant parameter values.

This discussion relates to the question about the role of monetary policy in affecting asset returns. As we show in the previous section, a policy of price stability eliminates the influence of non-productivity shocks on the excess returns on foreign-currency bonds. This represents an optimal policy in the NB economy. But this may involve either increasing or reducing the volatility of returns. Thus, our results suggest that monetary authorities should be concerned about the volatility of asset returns, at least as described by the exchange rate. But they don't necessarily tell us that it is desirable to reduce this volatility.

4.3.2 Capital Flows

From the results so far, we see that monetary policy affects the gross portfolio position in the NB economy. But the monetary rule also impacts on net capital flows. This is described in Table 4. Recall our assumption that productivity shocks are permanent. This means that in the economy without risk-sharing, a productivity shock has no impact on the current account, since there are no gains from intertemporal consumption smoothing following a productivity shock. Table 4 indeed indicates that under the NC economy, the current account is affected only by interest rate shocks. In comparing the NBE and NC economies for a given monetary policy rule, we see that the volatility of the current account is unambiguously higher in the complete markets case. It is also possible to show that the current account is more volatile in the NB economy than the NC economy, although the comparison between the NB economy and the NBE economy is theoretically ambiguous[24].

How does monetary policy affect the volatility of the current account? Again, the answer is qualitatively different between the NC and NBE economies on the one hand, where monetary policy works only through the traditional channel, and the NB economy, where monetary policy affects the structure of portfolios. In the first two cases, Table 4 indicates that a rise in γ always reduces the volatility of the current account, since it tends to eliminate the component of the current account that is due to interest rate shocks. But in the NB economy, a rise in γ also increases the weight put on hedging against productivity shocks in the optimal portfolio. This tends to increase the volatility of the current account, since the more that productivity shocks are hedged, the more the country will engage in trade imbalances as a result of the risk-sharing of these shocks. To illustrate this mechanism, again let us focus on the special case where $\lambda = 0$. In that case, we establish:

Proposition 5 In the NB economy with $\lambda = 0$, current account volatility is increasing in γ.

Proof: Table 4 illustrates the volatility of the current account is independent of σ_m^2 in both the NC and NBE economies. But in the NB economy, the current account may

[24] For $\lambda = 0$, the volatility of the trade balance is always higher in the NBE economy. But for a high degree of price stickiness, this conclusion may be reversed.

be then written as:

$$var_{t-1}(CA_t)|_{\lambda=0} = \frac{1}{2}(1-\theta)^2 \left[\frac{(\lambda+\gamma)^2 \left(\sigma_A^2\right)^2}{(\lambda+\gamma)^2\sigma_A^2 + \left(\lambda+\theta-\lambda\beta(1-\theta)\right)^2 \sigma_m^2} \right]. \tag{39}$$

Expression (39) implies that interest rate shocks reduce the volatility of the current account, since consistent with the previous results, they reduce the usefulness of nominal bonds in supporting risk-sharing. But (39) also shows that in this case, current account volatility is unambiguously increasing in γ. An increase in γ eliminates the effect of nominal shocks on bond returns and enhances the effectiveness of nominal bonds in risk-sharing. Hence it increases the variability of capital flows.

More generally, when $\lambda > 0$, the more conventional channel of monetary policy is operative. In that case, a policy of price stability may either increase or reduce the total volatility of capital flows.

4.4 More general parameter values

Our solution has been restricted to a special case of the model, with log utility, no home bias in preferences, and permanent productivity shocks. This is necessary only so as to obtain manageable algebraic expressions for optimal portfolio holdings. The portfolio solution method also gives solutions for the more general case, but they can be usefully interpreted only through calibration and numerical comparisons. But even so, the qualitative results of the paper are unchanged in the more general case. Conceptually, it is straightforward to see why this is so. Even under more general conditions, but remaining within a framework where there exist just productivity and interest rate shocks, a monetary policy which supports the flexible price equilibrium in the NB economy will lead to an endogenous movement towards completeness in financial markets. Therefore, because it eliminates all welfare distortions, this policy must be fully optimal.

With a more general extension of the model, the results would have to be qualified somewhat. For instance, if we introduced more shocks (e.g. fiscal policy shocks), then it is no longer true that a price stability rule facilitates full risk sharing, since eliminating interest rate shocks as a source of variability in bond returns would not establish complete markets. In that case, an explicit welfare comparison across alternative rules would be necessary. This would require higher order solutions to the model. Nevertheless, the principle that monetary policy has a role to play in enhancing the efficiency of nominal asset returns would still remain.

5 Conclusion

This paper shows how a simple benchmark two-country sticky-price open-economy macro model can be amended so as to incorporate endogenous portfolio choice. We solve for the optimal portfolio holdings of national equities and nominal bonds, and show how these depend on the magnitude of stochastic shocks, the degree of price stickiness, and the stance of monetary policy. A key result is that a monetary policy of strict price stability is desirable, not just because it sustains the flexible price equilibrium outcome of the real economy, but also because it endogenously generates full international risk-sharing. Monetary policy is useful not just in influencing aggregate demand in desirable ways, but also in ensuring that assets returns reflect underlying productivity shocks in the right ways. This argument for price stability holds even in a fully flexible price economy, and arises due to the fact that such a policy maximizes the risk-hedging properties of nominal bond returns.

More generally, our results suggest that while financial globalization alters the environment within which monetary policy operates, it may not alter the fundamental objectives of optimal monetary policy.

Appendix

The solution of the dynamic model of Table 1, for a given η, may be written in terms of the linear system of undetermined coefficients:

$$\widehat{C} = c_1\widehat{W} + c_2 u + c_3 u^* + c_4 m + c_5 m^* + c_6 \xi \tag{40}$$

$$\widehat{C}^* = c_1^*\widehat{W} + c_2^* u + c_3^* u^* + c_4^* m + c_5^* m^* + c_6^* \xi \tag{41}$$

$$\widehat{\tau} = t_1\widehat{W} + t_2 u + t_3 u^* + t_4 m + t_5 m^* + t_6 \xi \tag{42}$$

$$\widehat{W'} = w_1\widehat{W} + w_2 u + w_3 u^* + w_4 m + w_5 m^* + w_6 \xi \tag{43}$$

$$\widehat{\pi} = p_1\widehat{W} + p_2 u + p_3 u^* + p_4 m + p_5 m^* + p_6 \xi \tag{44}$$

The solutions for the coefficients $c_i, c_i^*, t_i, w_i, y_i, p_i$, $i = 1..6$, are given by:

$$\begin{aligned} c_1 &= \frac{(1-\beta)}{\beta\theta}, \quad c_2 = 1 - \frac{0.5}{\theta}, \quad c_3 = \frac{0.5}{\theta}, \quad c_4 = .5\frac{\lambda(1-2\theta-\beta(1-\theta))}{\theta(\gamma+\lambda)}, \\ c_5 &= .5\frac{\lambda(1-\beta(1-\theta))}{\theta(\gamma+\lambda)}, \quad c_6 = \frac{1-\beta}{\theta} \end{aligned}$$

$$\begin{aligned} c_1^* &= -\frac{(1-\beta)}{\beta\theta}, \quad c_2^* = \frac{0.5}{\theta}, \quad c_3^* = 1 - \frac{0.5}{\theta}, \quad c_4^* = .5\frac{\lambda(1-\beta(1-\theta))}{\theta(\gamma+\lambda)}, \\ c_5^* &= .5\frac{\lambda(1-2\theta-\beta(1-\theta))}{\theta(\gamma+\lambda)}, \quad c_6^* = -\frac{1-\beta}{\theta} \end{aligned}$$

$$\begin{aligned} t_1 &= \frac{-2(1-\beta)}{\beta\theta}, \quad t_2 = \frac{1}{\theta}, \quad t_3 = -\frac{1}{\theta}, \quad t_4 = -\frac{\lambda(1-\beta(1-\theta))}{\theta(\gamma+\lambda)}, \\ t_5 &= \frac{\lambda(1-\beta(1-\theta))}{\theta(\gamma+\lambda)}, \quad t_6 = -2\frac{1-\beta}{\theta} \end{aligned}$$

$$y_1 = \frac{1-\beta}{\beta}, \ y_2 = 1, \ y_3 = 0, \ y_4 = -.5\frac{\lambda(2-\beta(1-\theta))}{(\gamma+\lambda)}, \ y_5 = -.5\frac{\lambda\beta(1-\theta)}{(\gamma+\lambda)}, \ y_6 = -(1-\beta)$$

$$w_1 = 1, \quad w_2 = 0, \quad w_3 = 0, \quad w_4 = .5\frac{\lambda\beta(1-\theta)}{(\gamma+\lambda)}, \quad w_5 = -.5\frac{\lambda\beta(1-\theta)}{(\gamma+\lambda)}, \quad w_6 = \beta$$

$$p_1 = 0, \quad p_2 = 0, \quad p_3 = 0, \quad p_4 = -\frac{1}{(\gamma+\lambda)}, \quad p_5 = 0, \quad p_6 = 0$$

The excess return equations (28)-(30) may be written as:

$$\widehat{r}_{x,1} = r_{11}\widehat{W} + r_{12}u + r_{13}u^* + r_{14}m + r_{15}m^* + r_{16}\xi \tag{45}$$

$$\widehat{r}_{x,2} = r_{21}\widehat{W} + r_{22}u + r_{23}u^* + r_{24}m + r_{25}m^* + r_{26}\xi \tag{46}$$

$$\widehat{r}_{x,3} = r_{31}\widehat{W} + r_{32}u + r_{33}u^* + r_{34}m + r_{35}m^* + r_{36}\xi \tag{47}$$

The solutions for the coefficients r_{ij}, $i = 1..3$, $j = 1..6$, are given by:

$$\begin{aligned} r_{11} &= \frac{(2-\theta)(1-\beta)}{\beta\theta} \quad r_{12} = \frac{\theta-1}{\theta} \quad r_{13} = \frac{1}{\theta} \quad r_{14} = -0.5\frac{\lambda[(4\theta - 2(1+\phi\theta))(1-\beta) - \theta\beta]}{\theta(\lambda+\gamma)} \\ r_{15} &= -0.5\frac{[\lambda(2(1-\beta)+\beta\theta)+2\theta]}{\theta(\lambda+\gamma)} \quad r_{16} = \frac{(2-\theta)(1-\beta)}{\beta} \end{aligned}$$

$$\begin{aligned} r_{21} &= \frac{(1-\beta)}{\beta} \quad r_{22} = 0 \quad r_{23} = 1 \quad r_{24} = 0.5\frac{\lambda\beta}{(\lambda+\gamma)} \\ r_{25} &= -0.5\frac{[\lambda(4-3\beta-2\phi(1-\beta))+2]}{(\lambda+\gamma)} \quad r_{26} = (1-\beta) \end{aligned}$$

$$\begin{aligned} r_{31} &= \frac{2(1-\beta)}{\beta\theta} \quad r_{32} = -\frac{1}{\theta} \quad r_{33} = \frac{1}{\theta} \quad r_{34} = \frac{(\theta+\lambda(1+\beta(\theta-1)))}{\theta(\lambda+\gamma)} \\ r_{35} &= -\frac{(\theta+\lambda(1+\beta(\theta-1)))}{\theta(\lambda+\gamma)} \quad r_{36} = \frac{2(1-\beta)}{\theta} \end{aligned}$$

The matrices used to compute the portfolio rules from (20) are given as follows. For the NB economy:

$$D1 = \frac{2(1-\beta)}{\theta}$$

$$D2 = \left[\frac{(\theta-1)}{\theta}, -\frac{(\theta-1)}{\theta}, \frac{\lambda(1-\beta)(\theta-1)}{\theta(\lambda+\theta)}, \frac{-\lambda(1-\beta)(\theta-1)}{\theta(\lambda+\theta)}\right]$$

$$R2 = \left[\frac{1}{\theta}, -\frac{1}{\theta}, -\frac{[\lambda+\theta+\beta\lambda(1-\theta))]}{\theta(\lambda+\gamma)}, \frac{[\lambda+\theta+\beta\lambda(1-\theta)]}{\theta(\lambda+\gamma)}\right]$$

For the NBE economy, the $D1$ and $D2$ matrices are the same, and the $R1$ and $R2$ matrices are:

$$R1' = \left[-\frac{2(1-\theta)(1-\beta)}{\theta}, (1-\beta), -\frac{(\theta-2)(1-\beta)}{\theta}\right]$$

$$R2 = \begin{bmatrix} \frac{(1-\theta)}{\theta}, & -\frac{(1-\theta)}{\theta}, & \frac{\lambda(2\theta-\phi\theta-1)(1-\beta)}{\theta(\lambda+\gamma)}, & -\frac{\lambda(2\theta-\phi\theta-1)(1-\beta)}{\theta(\lambda+\gamma)} \\ -1, & 0, & 0.5\frac{(2-3\lambda\beta+4\lambda-2\lambda\phi(1-\beta))}{(\lambda+\gamma)}, & -0.5\frac{\beta\lambda}{(\lambda+\gamma)} \\ \frac{(1-\theta)}{\theta}, & -\frac{1}{\theta}, & -0.5\frac{\lambda[(2-4\theta+2\phi\theta)(1-\beta)+\beta\theta]}{\theta(\lambda+\gamma)}, & 0.5\frac{[2\theta+\lambda(2(1-\beta)+\beta\theta)]}{\theta(\lambda+\gamma)} \end{bmatrix}.$$

For the value of Σ, we assume that all shocks are independent of one another.

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