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Monetary Policy Rules and Foreign Currency Positions

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Abstract
Using an endogenous portfolio choice model, this paper examines how different monetary policy regimes can lead to different foreign currency positions by changing the cyclical properties of the nominal exchange rate. We find that strict inflation targeting regimes are associated with a short position in foreign currency, while the opposite is true for noninflation targeting regimes. We also explore how these different external positions affect the international transmission of monetary shocks through the valuation channel. When central banks follow inflation targeting Taylor-type rules, valuation effects of monetary expansions are beggar-thy-self, but they are beggar-thy-neighbour in a money growth targeting regime (or when monetary policy puts weight on output stabilization).

Keywords: Portfolio choice, international transmission of shocks, monetary policy
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1 Introduction

Over the past decade, international financial markets have become increasingly integrated. This process of financial globalisation is reflected in the rapid expansion of the external balance sheets of countries which records cross-border ownership of assets and liabilities (see Lane and Milesi-Ferretti (2006) and Lane and Shambough (2009)). In this world of interlinked balance sheets, exchange rate movements can give rise to large valuation effects. In fact, recent shifts in US and UK external positions have been attributed to currency movements (see Higgins *et al* (2007) and Astley *et al* (2009)). This paper looks at the interplay between monetary policy rules and foreign asset positions in two ways. First, it examines how different monetary policy regimes can lead to different foreign currency positions in external balance sheets. Second, it explores how these different foreign currency positions affect the valuation effect of monetary shocks.

Lane and Shambough (2010) present evidence that the covariance between nominal exchange rates and output fluctuations is an important determinant of foreign currency exposure. In particular, they find that countries where domestic currency tends to depreciate in bad times are associated with longer foreign currency positions in their external balance sheets. At the same time, Clarida and Waldman (2007) show how monetary policy regimes affect the covariance between exchange rates and inflation and hence the comovements between inflation and output. They find evidence that in response to bad news about inflation, domestic currency tends to appreciate in inflation-targeting countries, but depreciate in non inflation targeters. Arguably, these two pieces of evidence would suggest an indirect link between monetary policy regimes and external positions. In particular, together these facts would indicate that non inflation targeting countries are inclined to have longer positions in foreign currency than inflation-targeting countries.

The main contribution of this paper is to formalise this link between monetary policy and foreign asset holdings, emphasising the role of monetary policy regimes in determining the cyclical properties of nominal exchange rates. Consistent with the conjecture above, in our framework countries in which monetary policy does not focus solely on inflation stabilisation will tend to hold a portfolio weighted towards foreign currency denominated bonds. For example, if the central bank is assumed to target money growth, agents would choose a portfolio that is short in domestic bonds and long in foreign bonds. This is because, with a money-growth rule, any adverse real country-specific shocks will be associated with a nominal depreciation of the domestic currency. Holding domestic currency denominated assets is therefore a bad hedge. On the other hand, when the central bank conducts policy through a Taylor-type rule that responds only to inflation, the same adverse shock will trigger a nominal domestic currency appreciation. So holding domestic currency denominated assets is a good hedge and agents will choose to hold an optimal portfolio that is overweight in home bonds.

These results are shown analytically in a two-country flexible price model with incomplete markets, where there is international asset trade in nominal bonds. We also consider an extension where we allow for international trade in equities as well as bonds. We show numerically that the model's link between monetary policy and foreign currency positions is robust provided that we add an extra source of risk to keep the financial markets incomplete. In addition, we demonstrate that the results also hold in a model where prices are sticky - irrespective of whether exports are invoiced in local currency or in the currency of the producer. Moreover, the portfolio shares in the sticky price set-up are quantitatively similar to that in the flexible price model. Finally, we show that the results obtained under a money-growth rule also hold under a Taylor rule that puts weight on stabilising output growth. So the crucial determinant of portfolios in our analysis is whether policy is sufficiently focused on inflation stabilisation.

Nominal bond portfolios have been analysed before by, among others, Devereux and Sutherland (2008b) and Engel and Matsumoto (2009).[1] In a model where monetary policy is specified as a Taylor rule that reacts to PPI inflation, Devereux and Sutherland (2008b) finds a negative position in foreign bonds under incomplete markets.[2] Our results show that this finding is overturned if the central bank follows a money-growth rule, or a 'passive' monetary policy. On the other hand, Engel and Matsumoto (2009), under a similar money-growth rule find that the negative foreign currency position would still be optimal when asset markets are complete. So overall, our results highlight the importance of both the asset market structure and the policy rule specification as determinants of foreign currency positions.

Our paper also examines how foreign currency positions affect the valuation effect of monetary shocks. In our model, a domestic monetary loosening which depreciates the domestic currency will have positive or negative valuation effects depending on the country's position in the foreign currency market. Under an inflation-targeting Taylor-type rule, it is optimal to be short in foreign currency so a domestic currency depreciation generates a decrease in net external wealth of domestic agents. Hence, valuation effects of monetary policy shocks are beggar-thy-self. Conversely, if the domestic portfolio is long in foreign bonds, as under a money-growth rule, then a domestic monetary policy loosening would trigger an increase in net external wealth and international valuations effects are beggar-thy-neighbour.

The valuation channel of monetary policy has been explored in earlier literature. For instance, Dornbusch and Fischer (1980) and Svensson (1989) and later Kim (2002) examine the implications of net foreign asset positions for the transmission mechanism of monetary policy in a setting in

[1] Devereux and Sutherland (2008a), Benigno and Nistico (2009), Benigno and Kucuk-Tuger (2010) and Coeurdacier and Gourinchas (2009) are other examples of open economy DSGE models with endogenous nominal bond portfolios.

[2] This is true under the regularity condition which ensures that a positive technology shock at home deteriorates the home terms of trade.

which portfolio positions are exogenous.[3] Until recently, the analysis of optimal portfolio choice was mostly restricted to partial equilibrium models. But new methodological contributions (Devereux and Sutherland (2008a), Tille and van Wincoop (2007) and Evans and Hnatkovska (2007)) have now allowed us to analyse optimal portfolio choice in general equilibrium models. Therefore, in this paper we revisit the old insights from Dornbusch and Fischer (1980) and Svensson (1989) in a two-country general equilibrium model where agents can choose optimally among home and foreign nominal bonds.

In our analysis, as in Devereux and Sutherland (2008b), monetary policy shocks can have real effects even when all prices are fully flexible as long as financial markets are incomplete. In a set-up where agents optimally choose to hold a portfolio of nominal bonds that are either denominated in domestic or foreign currency, monetary shocks will generate endogenous currency movements that trigger international valuation effects.[4] These valuation effects on international bond portfolios that work through unanticipated nominal exchange rate depreciation would still be present when trade in real assets (equities) is also allowed, provided that there is an extra source of risk in the model such that trade in equities and bonds cannot complete the markets.

Quantitatively, our results points to small valuation effects in that, changes in net external wealth due to the valuation channel have a small effect on consumption and other real variables. This result is consistent with both empirical and earlier theoretical literature. Labhard *et al* (2005) and Fair (2004) find that a 1% change in aggregate wealth has less than 0.03% effect on steady-state consumption in the United Kingdom and United States. In addition, Chari *et al* (2002), Baxter and Crucini (1995) and Betts and Devereux (2001) show that international wealth transfers also tend to be small in theoretical models. But we also find that the valuation channel becomes more important in an economy that is subject to more persistent shocks. Increasing the persistence of shocks means that agents are exposed to more country-specific risks which they want to hedge against by holding a larger gross portfolio position. Then monetary shocks become more potent and can trigger larger valuation effects when gross positions are very large - perhaps even unrealistically large. We do not think it is necessarily desirable to have a set-up which implies very strong wealth effects given the aforementioned empirical literature. Thus, what we aim to achieve in this paper is a good understanding of the valuation channel, acknowledging (and demonstrating) that its quantitative importance is small relative to other channels such as the one coming from sticky prices.[5]

[3] Neumeyer (1998) analyses how a monetary union affects welfare by changing the hedging properties of currencies in an incomplete market setting with nominal securities and mean-variance preferences. Doepke and Schneider (2006) look at the effects of inflation on the redistribution of wealth between old and young generations in a closed economy model with trade in nominal assets.

[4] We focus on valuation effects caused by *unanticipated* movements in the nominal exchange rate. Devereux and Sutherland (2010) show that anticipated valuation effects (risk premia) are small.

[5] The cross-border implication of monetary policy has already been thoroughly examined in the New Open Economy Macro literature. Corsetti and Pesenti (2001), Corsetti *et al* (2000) showed that monetary expansions can be beggar-

The remainder of the paper is structured as follows. Section 2 presents the flexible price model with trade in nominal bonds. Section 3 focuses on the derivation of the optimal foreign currency position under different monetary policy regimes, and in Subsection 3.3 we analyse valuation effects of monetary policy shocks implied by these positions. Section 4 is devoted to our quantitative analysis and model extensions. We start by illustrating our results under flexible prices numerically (Subsection 4.1). The model is then extended to allow for trade in equities (Subsection 4.2). Finally, in Subsection 4.3, we consider the case in which prices are sticky. Section 5 concludes.

2 The Model

We develop a basic two-country open economy model with tradable endowments. There is a home and a foreign country, each endowed with its own tradable good. Households maximise utility over infinite horizon and they can trade in home and foreign nominal bonds; one-period risk-free bonds that pay one unit of the currency they are issued in.[6]

2.1 Consumers

The representative agent in the home economy maximises the expected present discounted value of the utility:

$$U_t = E_t \sum_{s=t}^{\infty} \delta_s u\left(C_s, \frac{M_s}{P_s}\right) \tag{1}$$

with

$$u\left(C_s, \frac{M_s}{P_s}\right) = \frac{C_s^{1-\rho}}{1-\rho} + \chi \log\left(\frac{M_s}{P_s}\right) \tag{2}$$

where C is consumption, $\frac{M}{P}$ is real money holdings.[7] δ_s is the discount factor, which is determined as follows:

thy-self in a micro-founded version of the Mundell-Fleming model. When prices are sticky, currency depreciations coming from such shocks lead to a deterioration in the country's purchasing power. So this literature focuses on the cross-border implications of policy shocks coming from expenditure-switching effects that would only be present under sticky prices. Our work, on the other hand, concentrates on the wealth effects which are present even under flexible prices.

[6] See Section 4.2 for a brief account of the case where equities are traded alongside bonds.

[7] While agents' preferences towards different bonds are determined through an endogenous portfolio choice problem, preferences toward currency (or cash) are exogenously imposed in the utility function. Our specification is equivalent to the one in which agents can only do transactions with (domestic) currency – that is, they face cash-in advance constraint. And these constraints directly determine the demand for money. Although this is out of the scope of this paper, one could think of an alternative specification in which the choice of money holdings is also an outcome of a portfolio decision.

$$\delta_{s+1} = \delta_s \beta(C_{As}),\ \ \delta_0 = 1 \tag{3}$$

where C_A is aggregate home consumption and $0 < \beta(C_A) < 1$. To achieve stationarity under incomplete market specification, we assume $\beta_C(C_A) \leq 0$, which implies that agents discount the future more as aggregate consumption increases, ie agents bring consumption forward when aggregate consumption is high.[8] We assume that the individual takes C_A as given when optimising and follow Devereux and Sutherland (2008a) in assuming:

$$\beta(C_A) = \omega C_A^{-\eta} \tag{4}$$

with $0 \leq \eta < \rho$ and $0 < \omega \bar{C}_A^{-\eta} < 1$ (as in the constant discount factor).

C represents a consumption index defined over C_H and C_F, home and foreign produced goods, respectively.

$$C_t = \left[\nu^{\frac{1}{\theta}} C_{H,t}^{\frac{\theta-1}{\theta}} + (1-\nu)^{\frac{1}{\theta}} C_{F,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{5}$$

where θ is the elasticity of intratemporal substitution between C_H and C_F and ν is the weight that the household assigns to home consumption. The consumption price index, defined as the minimum expenditure required to purchase one unit of aggregate consumption for the home agent is given by:

$$P_t = \left[\nu P_{H,t}^{1-\theta} + (1-\nu) P_{F,t}^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{6}$$

We adopt a similar preference specification for the foreign country except that variables are denoted with an asterisk.

In each country agents can invest in two nominal bonds denominated in the home and foreign currency. The budget constraint of the home agent in real terms is given by:

$$\alpha_{H,t} + \alpha_{F,t} + \frac{M_t}{P_t} = \alpha_{H,t-1} r_{H,t} + \alpha_{F,t-1} r_{F,t} + \frac{M_{t-1}}{P_{t-1}} \frac{P_{t-1}}{P_t} + \frac{P_{H,t} Y_t}{P_t} - C_t - T_t \tag{7}$$

where Y is the endowment received by home agents, C is consumption of home agents, T represents real taxes minus transfers. The role of T_t will be to allow for variations in the nominal supply of money, with $-T_t = \frac{M_t}{P_t} - \frac{M_{t-1}}{P_{t-1}} \frac{P_{t-1}}{P_t}$. $\alpha_{H,t-1}$ and $\alpha_{F,t-1}$ are the real holdings of home and foreign bonds expressed in units of home consumption good, purchased at the end of period $t-1$ for holding

[8] Another way of ensuring stationarity is to assume, following Turnovsky (1985), that the international trade of foreign currency denominated bonds is subject to intermediation costs.

into period t.[9] $r_{H,t}$ and $r_{F,t}$ are gross real returns in home units:

$$\begin{aligned} r_{H,t+1} &= \frac{1/P_{t+1}}{Z_{H,t}} \\ r_{F,t+1} &= r^*_{F,t+1}\frac{Q_{t+1}}{Q_t} = \frac{1/P^*_{t+1}}{Z^*_{F,t}}\frac{Q_{t+1}}{Q_t} \end{aligned} \tag{8}$$

where Z_H and Z^*_F are bond prices in terms of home and foreign consumption baskets, respectively. Q_t is the real exchange rate defined as $\frac{P^*_t S_t}{P_t}$. Nominal returns (in home currency) for each of these assets will be given by $R_{i,t} = r_{i,t}\frac{P_t}{P_{t-1}}$ for $i = H, F$.

Endowments in each country follow an AR(1) process:

$$\begin{aligned} \log Y_t &= \zeta_Y \log Y_{t-1} + \varepsilon_{Y,t},\ E_{t-1}[\varepsilon_{Y,t}] = 0,\ Var[\varepsilon_{Y,t}] = \sigma^2_Y \\ \log Y^*_t &= \zeta_Y \log Y^*_{t-1} + \varepsilon_{Y^*,t},\ E_{t-1}[\varepsilon_{Y^*,t}] = 0,\ Var[\varepsilon_{Y^*,t}] = \sigma^{*2}_Y \end{aligned}$$

Defining $NFA_t = \alpha_{H,t} + \alpha_{F,t}$ as the total net claims of home agents on the foreign country at the end of period t (ie the net foreign assets of home agents) and $r_{x,t} = r_{F,t} - r_{H,t}$ as the excess return of foreign bond on home bond, we write the home budget constraint as follows:[10]

$$NFA_t = NFA_{t-1}r_{H,t} + \alpha_{F,t-1}r_{x,t} + \frac{P_{H,t}Y_t}{P_t} - C_t + \frac{M_{t-1}}{P_{t-1}}\frac{P_{t-1}}{P_t} - \frac{M_t}{P_t} - T_t \tag{9}$$

Note that once α_F is determined, α_H, α^*_H and α^*_F will also be determined as $\alpha_H = NFA - \alpha_F$ by definition and $\alpha^*_H = -\alpha_H$, $\alpha^*_F = -\alpha_F$ from market clearing conditions. Thus, we let $\alpha_F \equiv \alpha$ and only focus on α in what follows.

2.2 Policy rules

To examine how the choice of monetary policy regime affects foreign currency positions and valuation effects, we consider two extreme policy specifications: a Taylor rule that only responds to inflation and a money-growth rule with no feedback to another variable. The former represents an 'active' central bank, which sets interest rates to offset the effects of shocks on inflation. The latter, on the other hand, represents a 'passive' central bank, which does not respond to inflation or any

[9] A similar budget constraint holds for the foreign agent, where foreign variables are denoted with an asterisk, *. Thus, $\alpha^*_{H,t-1}$ and $\alpha^*_{F,t-1}$ denote the foreign country's real holdings of home and foreign bonds, expressed in units of home consumption good. Bonds are assumed to be in net zero supply in each country. Thus, equilibrium in asset market requires that total bond holdings of home and foreign agents should equal zero, ie $\alpha_{H,t} + \alpha^*_{H,t} = 0$ and $\alpha_{F,t} + \alpha^*_{F,t} = 0$.

[10] Net foreign assets of home agent is defined as net claims of home country on foreign country assets, ie $NFA_t = \alpha_{F,t} - \alpha^*_{H,t}$. Since bonds are assumed to be in net zero supply $\alpha_{H,t} = -\alpha^*_{H,t}$. It follows that $NFA_t = \alpha_{H,t} + \alpha_{F,t}$.

other variable at all. We also consider Taylor rules which feedback to domestic output as well as inflation and show in Section 5 that a Taylor rule which puts sufficient weight on output stabilisation has similar implications for foreign currency positions and valuation effects as a 'passive' money-growth rule.

Under the inflation-targeting Taylor rule, the central bank sets the nominal interest rate on domestic bonds in response to CPI inflation (inflation target assumed to be zero):

$$\begin{aligned} R_{H,t+1} &= \bar{\beta}^{-1}\left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi} \exp(\varepsilon_{R,t}),\ E_{t-1}[\varepsilon_{R,t}] = 0,\ Var[\varepsilon_{R,t}] = \sigma_R^2 \\ R^*_{F,t+1} &= \bar{\beta}^{-1}\left(\frac{P^*_t}{P^*_{t-1}}\right)^{\phi_\pi} \exp(\varepsilon^*_{R,t}), E_{t-1}[\varepsilon_{R^*,t}] = 0,\ Var[\varepsilon_{R^*,t}] = \sigma_R^{*2} \end{aligned}$$

Under the money-growth rule, the central bank sets the rate of growth of the money supply. [11]

$$\begin{aligned} \mu_t &= \zeta_M \mu_{t-1} + \varepsilon_{M,t},\ E_{t-1}[\varepsilon_{M,t}] = 0,\ Var[\varepsilon_{M,t}] = \sigma_m^2 \\ \mu^*_t &= \zeta^*_M \mu^*_{t-1} + \varepsilon_{M^*,t},\ E_{t-1}[\varepsilon_{M^*,t}] = 0,\ Var[\varepsilon_{M^*,t}] = \sigma_m^2 \end{aligned}$$

where $\mu_t = \log\left(\frac{M_t}{M_{t-1}}\right)$ and $\mu^*_t = \log\left(\frac{M^*_t}{M^*_{t-1}}\right)$. Monetary shocks differ with respect to the monetary policy specification we are considering.

2.3 Equilibrium

Given our assumption on preferences in 2, the Euler equations are given by:

$$C_t^{-\rho} = \beta(C_t) E_t C_{t+1}^{-\rho} r_{i,t+1},\ i = H, F \tag{10}$$

where $\beta(C_t) = \omega C_t^{-\eta}$ from (4) since in equilibrium aggregate consumption, $C_{A,t}$, is equal to individual consumption, C_t. Money demand depends negatively on the opportunity cost of holding money, which is equal to $\frac{R_{i,t+1}-1}{R_{i,t+1}}$ in terms of gross returns.

$$\frac{M_t}{P_t} = \chi C_t^{\rho}\left(1 - R_{i,t+1}^{-1}\right)^{-1} \tag{11}$$

Equilibrium bond prices, Z_H and Z^*_F, are obtained by substituting $r_{H,t+1}$ and $r^*_{F,t+1}$ from (8)

[11] Under both rules, steady-state inflation is zero. But our results would go through with non-zero steady-state inflation.

into home and foreign Euler equations:

$$Z_{H,t} = \beta(C_t)E_t \frac{C_{t+1}^{-\rho}}{C_t^{-\rho}} \frac{1}{P_{t+1}}$$
$$Z_{F,t}^* = \beta(C_t^*)E_t \frac{C_{t+1}^{*-\rho}}{C_t^{*-\rho}} \frac{1}{P_{t+1}^*} \quad (12)$$

Goods market clearing implies:

$$Y_t = \nu \left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t + (1-\nu) \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\theta} C_t^*$$
$$Y_t^* = \nu \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\theta} C_t^* + (1-\nu) \left(\frac{P_{F,t}}{P_t}\right)^{-\theta} C_t$$

We assume that law of one price holds, ie $P_{H,t}^* = \frac{P_{H,t}}{S_t}$ and $P_{F,t} = P_{F,t}^* S_t$.

2.4 Approximated solution

To solve the model we use the approximation techniques proposed in Devereux and Sutherland (2008a) and Tille and van Wincoop (2007). We approximate our model around the symmetric steady state in which steady-state inflation rates are assumed to be zero.

To determine the portfolio allocation, it is useful to rewrite the home portfolio choice equation given in (10) and its foreign counterpart as follows:

$$E_t \left[\psi_{t+1} r_{x,t+1}\right] = 0$$
$$E_t \left[\psi_{t+1}^* r_{x,t+1} \frac{Q_t}{Q_{t+1}}\right] = 0$$

where home and foreign stochastic discount factors are given by $\psi_{t+1} = \beta(C_t)\frac{C_{t+1}^{-\rho}}{C_t^{-\rho}}$ and $\psi_{t+1}^* = \beta(C_t^*)\frac{C_{t+1}^{*-\rho}}{C_t^{*-\rho}}$, respectively, and $r_{x,t+1}$ is the excess return on foreign nominal bond, taking home bond as a reference.

These two sets of conditions imply the following equation that characterises optimal portfolio choice up to a second order:

$$E_t \left[(\hat{\psi}_{t+1} - \hat{\psi}_{t+1}^* + \Delta\hat{Q}_{t+1})\hat{r}_{x,t+1}\right] = 0 + O(\varepsilon^2)$$

This is an orthogonality condition between excess returns in domestic currency and the difference in the stochastic discount factors evaluated in the same currency. Since expected excess returns are zero up to a first-order approximation, ie $E_t\left[\hat{r}_{x,t+1}\right] = 0 + O(\varepsilon^2)$, this condition can be expressed as:

$$Cov_t(\hat{\psi}_{t+1} - \hat{\psi}^*_{t+1} + \Delta\hat{Q}_{t+1}, \hat{r}_{x,t+1}) = 0 + O(\varepsilon^2) \tag{13}$$

As shown by Devereux and Sutherland (2008a), to evaluate (13) and determine the portfolio shares, it is sufficient to take a first-order approximation of the remaining equilibrium conditions for which the only aspect of portfolio behaviour that matter is the steady-state foreign bond portfolio, $\bar{\alpha}$.

3 Optimal Foreign Currency Position and Valuation Effects

In this section we derive the optimal foreign currency portfolio position and valuation effects of a monetary expansion under different assumptions as to how monetary policy is conducted. To understand the hedging motives of investors in our economy we first derive a partial equilibrium expression for their foreign bond position. We then analyse the determinants of the portfolio orthogonality condition under the different policy regimes. This allows us to understand the investors' optimal portfolio allocation. Finally, a full general equilibrium solution to these portfolios is derived.[12]

3.1 Partial equilibrium analysis of foreign currency position

Investors in our model can choose to hold both domestic as well as foreign currency denominated nominal bonds. In what follows, we will show that this portfolio choice depends on the hedging characteristics of both types of bonds. Following Benigno and Nistico (2009), we derive a partial equilibrium solution for foreign bond holdings. Specifically, we use the first-order approximation to the model equations to evaluate the portfolio orthogonality condition coming from the second-order approximation to the portfolio choice equations.

Using the definition of stochastic discount factors, equation (13) can be written in terms of relative consumption growth adjusted for the change in the real exchange rate:

$$Cov_t\left(\Delta\hat{C}^R_{t+1} - \Delta\frac{\hat{Q}_{t+1}}{\rho}, \hat{r}_{x,t+1}\right) = 0 + O(\varepsilon^2) \tag{14}$$

Thus to get a partial equilibrium solution for portfolios, we need to express $\Delta\hat{C}^R_{t+j+1} - \Delta\frac{\hat{Q}_{t+1}}{\rho}$ as a function of prices, relative endowments and excess returns on the steady-state foreign bond

[12] Throughout this section we set $\eta = 0$, and use the standard constant discount factor rather than Uzawa preferences to characterise analytical solutions.

portfolio using the equations for the accumulation of net foreign assets and the combined Euler equations.

As shown in the appendix, we can write the relative net foreign asset ($\widehat{NFA}_t^R \equiv \widehat{NFA}_t - \widehat{NFA}_t^*$) accumulation as:

$$\widehat{NFA}_t^R = \frac{1}{\beta}\widehat{NFA}_{t-1}^R + 2\tilde{\alpha}\hat{r}_{x,t} + \hat{Y}_t^R - \hat{C}_t^R + \hat{Q}_t \tag{15}$$

where $\tilde{\alpha} = \frac{\bar{\alpha}}{\beta\bar{Y}}$ is the steady-state foreign bond portfolio of home agents normalised by income, $\hat{r}_{x,t} \equiv \hat{r}_{F,t} - \hat{r}_{H,t}$ is the excess return on foreign bonds expressed in home currency, $\hat{Y}_t^R \equiv \hat{P}_{H,t} + \hat{Y}_{H,t} - (\hat{P}_{F,t}^* + \hat{S}_t + \hat{Y}_{F,t}^*)$ is the relative non-financial income measured in domestic currency.

We combine the domestic and foreign Euler equations to get:

$$E_t\hat{C}_{t+1}^R - \hat{C}_t^R = \frac{1}{\rho}\left(E_t\hat{Q}_{t+1} - \hat{Q}_t\right) \tag{16}$$

The appendix shows that solving equations (15) and (16) forward for $NF\hat{A}_t^R$ and $\hat{C}_t^R$, we can express the first component of the covariance in (14) as:

$$\begin{aligned} \Delta\hat{C}_{t+1}^R - \Delta\frac{\hat{Q}_{t+1}}{\rho} &= 2(1-\beta)\tilde{\alpha}\hat{r}_{x,t+1} \\ &\quad + E_{t+1}\sum_{j=0}^{\infty}\beta^j\Delta\hat{Y}_{t+1+j}^R - E_t\sum_{j=0}^{\infty}\beta^j\Delta\hat{Y}_{t+1+j}^R \\ &\quad + \left(1-\frac{1}{\rho}\right)\left(E_{t+1}\sum_{j=0}^{\infty}\beta^j\Delta\hat{Q}_{t+1+j}^R - E_t\sum_{j=0}^{\infty}\beta^j\Delta\hat{Q}_{t+1+j}^R\right) \end{aligned} \tag{17}$$

Now define $\Lambda_{Y,t+1}$ as the 'news at time $t+1$' about relative non-financial income. That is, $\Lambda_{Y,t+1}$ is the net present value of the relative non-financial income (expressed in the same currency), ie $\Lambda_{Y,t+1} \equiv E_{t+1}\sum_{j=0}^{\infty}\beta^j\Delta\hat{Y}_{t+1+j}^R - E_t\sum_{j=0}^{\infty}\beta^j\Delta\hat{Y}_{t+1+j}^R$. Similarly, we define $\Lambda_{Q,t+1}$ as 'news at time $t+1$' about the future value of real exchange rates, ie $\Lambda_{Q,t+1} \equiv E_{t+1}\sum_{j=0}^{\infty}\beta^j\Delta\hat{Q}_{t+1+j} - E_t\sum_{j=0}^{\infty}\beta^j\Delta\hat{Q}_{t+1+j}$. Using equations (17) and (14) we can derive an expression for the foreign currency portfolio, $\tilde{\alpha}$:

$$\tilde{\alpha} = -\frac{1}{2(1-\beta)}\left(\frac{Cov_t(\Lambda_{Y,t+1}, \hat{r}_{x,t+1})}{Var_t(\hat{r}_{x,t+1})} + \left(1-\frac{1}{\rho}\right)\frac{Cov_t(\Lambda_{Q,t+1}, \hat{r}_{x,t+1})}{Var_t(\hat{r}_{x,t+1})}\right) \tag{18}$$

Equation (18) shows that the foreign currency portfolio, $\tilde{\alpha}$, depends on two covariance-variance ratios, which represent the two risks that agents want to hedge against irrespective of the special characteristics of the model: the relative non-financial income risk given by $\Lambda_{Y,t+1}$ and the real exchange rate risk given by $\Lambda_{Q,t+1}$. As put forth by Coeurdacier and Gourinchas (2009) and Benigno and Nistico (2009), these covariance-variance ratios can be interpreted as asset return loadings on risk - the regression coefficient when you regress risk on excess return.

The excess return on foreign bonds relative to home bonds is given by surprises in home currency depreciation as the UIP holds in a first-order approximation to the model:

$$\hat{r}_{x,t+1} = \hat{S}_{t+1} - E_t\hat{S}_{t+1} \tag{19}$$

Then, according to (18) and (19), it is optimal to take a long position in foreign currency (ie $\tilde{\alpha} > 0$) if the home currency depreciates in periods when non-financial income is lower at home than abroad, ie $Cov_t(\Lambda_{Y,t+1}, r_{x,t+1}) < 0$ and/or when home consumption basket is more expensive, ie $Cov_t(\Lambda_{Q,t+1}, r_{x,t+1}) < 0$. In other words, domestic investors would prefer to hold foreign over domestic bonds if foreign bonds yield an excess return (foreign currency appreciates) in periods when domestic income is relatively low or when the domestic consumption basket rises in price relative to the foreign (a domestic real appreciation).[13] This in turn, would depend crucially on the monetary policy regime as we illustrate in the general equilibrium solution below.

3.2 General equilibrium solution for optimal foreign currency position

It is possible to characterise closed-form solutions for optimal foreign bond portfolios given the relatively simple structure of our model.[14] Since optimal portfolios are pinned down by the portfolio orthogonality condition given in equation (14), it is useful to analyse the components of this covariance, $\hat{C}^R_{t+1} - \frac{\hat{Q}_{t+1}}{\rho}$ and $\hat{r}_{x,t+1}$ (or $\hat{S}_{t+1}$) to understand the equilibrium foreign currency position.

First, we consider the solution for the real exchange rate adjusted consumption differential. We rewrite equation (17) as a function of the structural shocks and the excess return on foreign bond holdings in the following way:[15]

$$\begin{aligned} \hat{C}^R_{t+1} - \frac{\hat{Q}_{t+1}}{\rho} &= \frac{2\nu(\theta\rho - 1) - (\rho - 1)}{\rho(1 + 2\nu(\theta - 1))}(\varepsilon_{Y,t+1} - \varepsilon_{Y^*,t+1}) \\ &\quad + \frac{(1-\beta)(1 + 4\nu(1-\nu)(\theta\rho - 1))}{(1-\nu)\rho(1 + 2\nu(\theta - 1))}\tilde{\alpha}\hat{r}_{x,t+1} \end{aligned} \tag{20}$$

[13] Note that under log utility ($\rho = 1$) there is no real exchange rate hedging motive but investors are still facing relative non-financial income risk. This is also true if real exchange rate is constant, which corresponds to $\nu = 0.5$ in our model.

[14] Even in this simple endowment economy the expressions are quite complicated. Thus, for ease of exposition, we set the persistence of endowment shocks to 1 in this section.

[15] Note that we ignore other state variables in the solution as they do not matter when evaluating the conditional covariance given in equation 14.

Equation (20) shows that if agents did not have any foreign currency position, that is $\tilde{\alpha} = 0$, the real exchange rate adjusted relative consumption would depend only on the relative supply shock. This is because, without valuation effects coming from movements in the exchange rate, monetary policy has no effect on real variables under flexible prices. So, if agents were only faced with monetary policy shocks, the optimal portfolio would imply having no foreign currency position, as this ensures perfect smoothing in the adjusted relative consumption. But equation (20) also shows that the zero-portfolio position, ie $\tilde{\alpha} = 0$, would not insure agents against endowment shocks. So the relative importance of the different shocks will pin down how far from the zero portfolio agents will choose to be.

3.2.1 Money-growth rule

Consider now that the central bank follows a money-growth rule, as specified in Section 2.2. Taking the difference of money demand equations in each country yields:

$$\hat{M}_t^R = \rho \hat{C}_t^R - \frac{\bar{\beta}}{1-\bar{\beta}}(\hat{R}_{H,t+1} - \hat{R}^*_{F,t+1}) + \hat{P}_t - \hat{P}_t^* \tag{21}$$

where $\hat{M}_t^R = \hat{M}_t - \hat{M}_t^*$. Substituting (19) into (21) it is possible to express the nominal exchange rate as a function of relative money supplies and consumption differential adjusted by the real exchange rate:

$$\frac{1}{1-\bar{\beta}}(\hat{S}_t - \bar{\beta} E_t \hat{S}_{t+1}) = \hat{M}_t^R - \rho(\hat{C}_t^R - \frac{\hat{Q}_t}{\rho}) \tag{22}$$

Note that under complete markets where $\hat{C}_t - \hat{C}_t^* = \frac{\hat{Q}_t}{\rho}$, the nominal exchange rate only depends on relative money supplies. But in our incomplete markets setting, solving equation (22) forward for the nominal exchange rate, and assuming a no-bubbles solution, gives:

$$\hat{S}_t = E_t \sum_{j=0}^{\infty} \beta^j \left(\Delta \hat{M}_{t+j}^R - \rho \left(\Delta \hat{C}_{t+j}^R - \frac{\Delta \hat{Q}_{t+j}}{\rho} \right) \right) \tag{23}$$

Equation (23) shows that for a given level of relative money supply growth, the domestic currency depreciates when the economy is hit by adverse real shocks that decrease relative consumption (adjusted by the real exchange rate). The intuition is that an adverse domestic real shock implies a decline in the demand for money. Given a fixed supply of money, domestic interest rates fall relative to foreign which - via the UIP condition - would entail a domestic currency depreciation. Hence, this partial equilibrium equation already illustrates how assuming a money-growth rule implies that the domestic currency will be negatively correlated with relative consumption in the face of real shocks. It, thus, suggests that a long position in foreign currency would help investors hedge against such shocks.

In fact, the general equilibrium solution for excess returns in terms of the shocks and steady-state portfolio is given by the following expression:

$$\begin{aligned}\hat{r}_{x,t+1} &= \hat{S}_{t+1} - E_t\hat{S}_{t+1} \\ &= \varkappa_{mg}\left[-\frac{(2\nu(\theta\rho-1)-(\rho-1))}{1+2\nu(\theta-1)}(\varepsilon_{Y,t+1}-\varepsilon_{Y^*,t+1})+(\varepsilon_{M,t+1}-\varepsilon_{M^*,t+1})\right]\end{aligned} \tag{24}$$

where

$$\varkappa_{mg} = \left[1+\frac{\tilde{\alpha}_{mg}(1-\beta)(1+4\nu(1-\nu)(\theta\rho-1))}{(1-\nu)(1+2\nu(\theta-1))}\right]^{-1}$$

If agents did not have any foreign bond holdings, ie $\tilde{\alpha}_{mg} = 0$, a fall in relative home endowment would lead to a nominal exchange rate depreciation. At the same time, equation (20) demonstrates that, in the presence of home bias and when goods are substitutes in the utility (ie $v > 1/2$ and $\theta\rho > 1$),[16] a fall in relative home endowment decreases relative home consumption. This suggests that agents would want to have a long position in foreign bonds, ie have $\tilde{\alpha}_{mg} > 0$, to hedge against relative endowment shocks.

But if $\tilde{\alpha}_{mg} \neq 0$, relative consumption is also subject to relative money supply shocks. However, regardless of the sign of the foreign currency position, relative consumption and excess returns will be positively correlated ($\hat{C}^R_{t+1} - \frac{\hat{Q}_{t+1}}{\rho}$ depends positively on $\tilde{\alpha}_{mg}\hat{r}_{x,t+1}$ as shown in equation (20)). Hence, the presence of monetary shocks limits the size of the bond portfolio, but it does not influence the sign.

Using equations (20) and (24) in the second-order portfolio orthogonality condition (14), we get the following analytical expression for steady-state foreign bond holdings under the money-growth rule:

$$\tilde{\alpha}_{mg} = \frac{(1-\nu)(2\nu(\theta\rho-1)-(\rho-1))^2}{(1-\beta)(1+2\nu(\theta-1))(1+4\nu(1-\nu)(\theta\rho-1))}\frac{\sigma_Y^2}{\sigma_M^2} \tag{25}$$

Equation (25) confirms that, under the money-growth rule, it is optimal to have a long position in foreign bonds (regardless of the value of structural parameters). The expression above also confirms that the size of the bond position decreases as the relative variance of monetary shocks increases.

3.2.2 Inflation-targeting Taylor rule

Consider next the case where monetary policy is characterised by a Taylor rule that only responds to movements in inflation. We can derive the relative stance of monetary policies in the two countries

[16] The presence of home bias and substitute goods is a sufficient condition. The necessary condition is $2\nu(\theta\rho-1) > (\rho-1)$.

by taking the difference of the linearised Taylor rules:

$$\hat{R}_{H,t+1} - \hat{R}^*_{F,t+1} = \phi_\pi(\hat{P}_t - \hat{P}_{t-1}) - \phi_\pi(\hat{P}^*_t - \hat{P}^*_{t-1}) + \varepsilon_{R,t} - \varepsilon_{R^*,t}$$

Substituting the condition for excess returns (19) we get:

$$-(\hat{S}_t - E_t\hat{S}_{t+1}) = \phi_\pi(\hat{\pi}_t - \hat{\pi}^*_t) + \varepsilon_{R,t} - \varepsilon_{R^*,t} \tag{26}$$

Equation (26) shows that the domestic currency appreciates when domestic inflation increases relative to foreign. The intuition is that higher inflation at home requires the domestic central bank to raise interest rates which would trigger a domestic nominal appreciation. In the words of Clarida and Waldman (2007), any bad news about inflation is 'good news for the exchange rate'. Note that, in our model, for most parameter values, a decline in relative domestic endowment is associated with an increase in domestic inflation. Hence, assuming a Taylor rule implies that adverse endowment shocks are associated with both a nominal appreciation of the domestic currency and a decline in the excess return on foreign bonds ($\hat{r}_{x,t+1}$). This suggests that foreign currency denominated bonds are a poor hedge in the face of endowment shocks.

To demonstrate this point formally, and derive an analytical expression for the optimal portfolio, we obtain a general equilibrium solution for excess returns:

$$\begin{aligned} \hat{r}_{x,t+1} &= \hat{S}_{t+1} - E_t\hat{S}_{t+1} \\ &= \varkappa_{tr}\left[\frac{2\nu-1}{1+2\nu(\theta-1)}(\varepsilon_{Y,t+1} - \varepsilon_{Y^*,t+1}) - \frac{1}{\phi_\pi}(\varepsilon_{R,t+1} - \varepsilon_{R^*,t+1})\right] \end{aligned} \tag{27}$$

where

$$\varkappa_{tr} = \left[1 + \frac{\tilde{\alpha}_{tr}(1-\beta)(2\nu-1)^2)}{(1-\nu)(1+2\nu(\theta-1))}\right]^{-1}$$

Let us consider the zero-portfolio solution (ie $\tilde{\alpha}_{tr} = 0$) in a specification of the model that features consumption home bias and assumes that domestic and foreign goods are substitutes in the utility. In this case, a negative relative endowment shock at home leads to a unexpected appreciation in the home currency. And, as shown in equation (20), this shock also decreases relative consumption. So, in the face of such shocks, agents would want to hold a short position in foreign bonds, ie $\tilde{\alpha}_{tr} < 0$.

However, for $\tilde{\alpha}_{tr} \neq 0$, monetary shocks affect consumption through the valuation channel. But again, as illustrated by (20) and (27), this relative consumption risk cannot be diversified away (that is, relative consumption and excess returns move in the same direction in response to relative monetary shocks for any value of $\widetilde{\alpha}_{tr} \neq 0$).

Evaluating equations (14), (20) and (27) we can obtain an analytical expression for steady-state foreign bond holdings under the Taylor rule:

$$\tilde{\alpha}_{tr} = -\frac{(1-\nu)(2\nu-1)(2\nu(\theta\rho-1)-(\rho-1))}{(1-\beta)(1+2\nu(\theta-1))\left[(1+4\nu(1-\nu)(\theta\rho-1))\frac{\sigma_R^2/\phi_\pi^2}{\sigma_Y^2}+(2\nu-1)^2\rho\right]} \tag{28}$$

This shows that for $\nu > \frac{1}{2}$ and $\theta\rho > 1$, it is optimal to have a short position in foreign bonds under the Taylor rule. As with a money-growth rule, the size of the bond portfolio decreases as the relative variance of monetary shocks increases. Also, the bigger the response to inflation in the Taylor rule, the bigger the size of the bond portfolio. This is because with a stronger response to inflation the monetary authority offsets the effect of monetary shocks on excess returns (as shown in equation (27) and pointed out by Devereux and Sutherland (2008b)).

As illustrated above and emphasised by Benigno and Benigno (2008) and Clarida and Waldman (2007), different monetary regimes change the cyclical properties of the exchange rate. Moreover, these different cyclical properties of the exchange rate will determine the hedging characteristic of domestic over foreign bonds - that is, whether the domestic currency depreciates or appreciates in periods of low domestic income determines whether investors take a long or a short position in the foreign currency. Therefore, the agents' optimal portfolio position crucially depends on the choice of policy rule.

3.3 Valuation effects of monetary policy

Having demonstrated how different monetary policy rules affect the optimal currency positions, we now turn to the international transmission of monetary shocks. In our set-up, monetary policy shocks generate endogenous currency movements. Since agents hold a portfolio of both foreign and domestic-currency denominated bonds, any shifts in the nominal exchange rate will trigger international valuation effects. As defined below, these valuation effects depend on the excess return $\hat{r}_{x,t}$ as well as the foreign bond position $\tilde{\alpha}$.

$$\underbrace{\widehat{NFA}_t - \frac{1}{\beta}\widehat{NFA}_{t-1}}_{\Delta NFA_t} = \underbrace{\hat{P}_{H,t} + \hat{Y}_{H,t} - \left(\hat{P}_t + \hat{C}_t\right)}_{CA_t} + \underbrace{\tilde{\alpha}(\hat{r}_{x,t})}_{VAL_t} \tag{29}$$

To see how the valuation effect changes across monetary policy regimes, we use the expressions for excess returns (24) and (27) to obtain:

$$VAL_t^{mg} = \tilde{\alpha}_{mg}\varkappa_{mg}\left[-\frac{(2\nu(\theta\rho-1)-(\rho-1))}{1+2\nu(\theta-1)}(\varepsilon_{Y,t+1}-\varepsilon_{Y^*,t+1})+(\varepsilon_{M,t+1}-\varepsilon_{M^*,t+1})\right] \tag{30}$$

$$VAL_t^{tr} = \tilde{\alpha}_{tr}\varkappa_{tr}\left[\frac{2\nu-1}{1+2\nu(\theta-1)}(\varepsilon_{Y,t+1}-\varepsilon_{Y^*,t+1}) - \frac{1}{\phi_\pi}(\varepsilon_{R,t+1}-\varepsilon_{R^*,t+1})\right] \quad (31)$$

where $\tilde{\alpha}_{mg}$ and $\tilde{\alpha}_{tr}$ are given by (25) and (28), respectively.

In our model, an exogenous domestic monetary expansion always depreciates the domestic currency.[17] Given that $\hat{r}_{x,t} = \hat{S}_t - E_{t-1}\hat{S}_t$, this shock increases the excess return on the foreign bond. If domestic investors are long in foreign currency, as is the case under the money-growth rule (ie $\tilde{\alpha}_{mg} > 0$), then this domestic monetary expansion will give rise to a positive valuation effect in the domestic economy as shown by equation (30). Therefore, monetary policy will be *beggar-thy-neighbour*. In contrast, if the same investors are short in foreign currency, as is the case under the Taylor rule (ie $\tilde{\alpha}_{tr} < 0$), monetary policy will be *beggar-thy-self.*[18]

Although in this paper we are mainly interested in the valuation effects implied by monetary policy shocks, it is worth noting that supply shocks also create portfolio valuation effects through their effect on the nominal exchange rate as shown in (30) and (31). Whether a positive supply shock at home implies positive or negative valuation effect would also depend on monetary policy regime.

4 Numerical Results and Robustness Checks

The previous section provided some analytical results for the foreign currency portfolios and the valuation effects of monetary policy. In this section, we present numerical results for our model, and discuss how the valuation channel of monetary policy works under flexible prices using impulse response functions. We look at the sensitivity of these results to different values of shock persistence, relative variance and monetary policy stance. We then provide more robustness checks by allowing for trade in equities in addition to bonds in the flexible price model and by considering a sticky price model with trade in nominal bonds. When prices are sticky we also allow for a more general specification of the Taylor rule.

4.1 Numerical solution of the flexible price model

In this section, we calculate the optimal steady-state portfolio holdings numerically and analyse the model up to a first-order approximation around that particular steady-state. We compare the

[17] Note that a relative monetary expansion is an increase in relative money supplies ($\varepsilon_{M,t+1} - \varepsilon_{M^*,t+1} > 0$) under the money-growth rule, and a fall in relative nominal interest rates ($\varepsilon_{R,t+1} - \varepsilon_{R^*,t+1} < 0$) under the Taylor rule.

[18] Under the conditions for which $\tilde{\alpha}_{tr} < 0$, namely for $v > \frac{1}{2}$ and $\theta\rho > 1$, $VAL_t^{tr} < 0$ in a home monetary expansion ($\varepsilon_R - \varepsilon_{R^*} < 0$). This becomes clear when we substitute the expression for $\tilde{\alpha}_{tr}$ from equation 28 into equation 31, which yields:

$$VAL_t^{tr} = -\Omega[(2\nu-1)\phi_\pi(\varepsilon_{Y,t+1}-\varepsilon_{Y^*,t+1}) - (1+2\nu(\theta-1))(\varepsilon_{R,t+1}-\varepsilon_{R^*,t+1})]$$

where $\Omega = \frac{(1-\nu)(2\nu(\theta\rho-1)-(\rho-1))(2\nu-1)\phi_\pi V_Y}{(1-\beta)(1+4\nu(1-\nu)(\theta\rho-1))(1+2\nu(\theta-1))^2 V_M + (2\nu-1)^2\phi_\pi^2 V_Y}$.

simulations from the case of a money-growth rule with that for the Taylor rule. While the analytical results in the previous section explained how portfolio choice affects the international transmission of monetary shocks, the aim of the simulation results in this section is to quantify the importance of the international valuation effects.

The calibration parameters are summarised in the top panel in Table 1 while the bottom panel contains the steady-state portfolio shares and percentage change in net foreign asset position implied by a 1% exchange rate depreciation for the case of a money-growth rule as well as for the Taylor-rule case.

Table 1: Baseline calibration and steady-state foreign bond position

Parameter	Description	Money-Growth Rule	Taylor Rule
$\bar{\beta} = \omega \bar{C}^{-\eta}$	Steady-state discount factor	0.99	0.99
η	Uzawa convergence parameter	0.01	0.01
ρ	CRRA	2	2
θ	Elas. of subs. across dom. and foreign goods	2.5	2.5
ν	Preference for domestic goods in consumption	0.72	0.72
ζ_Y	Persistence of endowment shocks	0.96	0.96
ζ_M	Persistence of monetary shocks	0	0
ϕ_π	Reaction to inflation	-	1.2
σ_y^2/σ_m^2	Relative size of endow. shocks wrt mon. shocks	1	1
$\bar{\alpha}/\bar{\beta}\bar{Y}$	Steady-state foreign bond position rel. to GDP	2.0297	-1.4103
$\frac{\bar{\alpha}}{\bar{\beta}\bar{Y}}\hat{r}_{x,t}$	Valuation effect of 1% nominal exch. rate dep.	2% of GDP	-1.4% of GDP

The calibration parameters are fairly standard. The steady-state discount factor, $\overline{\beta}$, equals 0.99 while the Uzawa convergence parameter equals 0.01 which is similar to Devereux and Yetman (2009). The coefficient of relative risk aversion (CRRA), ρ, equals 2 and the elasticity of substitution across domestic and foreign goods, θ, equals 2.5. This is slightly higher than the values chosen by Heathcote and Perri (2002) but below that typically chosen in the New Open Economy Macroeconomics literature (see for instance de Paoli (2009)). The home bias in consumption parameter, ν, is equal to 0.74 which implies an import share of 26%. The persistence of endowment process, ζ_Y, is set equal to 0.96 while monetary shocks are assumed to be i.i.d. Our benchmark calibration presumes that the volatility of monetary shocks is similar to that of real shocks but our sensitivity analysis considers the case where real shocks are more volatile than monetary shocks.

4.1.1 Monetary shocks and a money-growth rule

Under a money-growth rule, we calculate that the steady-state foreign bond position relative to GDP is 203%. Hence, agents find it optimal to go short in their home currency (and long in the foreign currency). This is consistent with the analytical results in Section 3.2.1. With a money-growth rule, agents realise that adverse real shocks (which lower their income and consumption) are associated with a foreign currency appreciation and hence a positive excess return from holding foreign currency denominated bonds.

Figure 1 illustrates the effects of a positive domestic monetary shock when monetary policy is conducted via a money-growth rule. On impact, the domestic currency depreciates in nominal terms. Given that domestic investors are long in foreign currency denominated bonds, the endogenous currency movement generates an increase in the domestic currency value of the country's net foreign asset (NFA) position (shown as a 1.7% jump in the NFA position in Figure 1). This valuation effect allows domestic consumers to increase their consumption. Since part of the domestic consumption is imported, the domestic currency has to appreciate in real terms to satisfy the higher demand for imported consumption. This adjustment in real exchange rates comes about via higher domestic prices.

Thus, because agents are long in foreign bonds, monetary policy shocks trigger international valuation effects that are *beggar-thy-neighbour*. While the effects are quantitatively fairly small (a 1.7% rise in net external wealth is associated with a 0.03% increase in consumption), the size of these are roughly in line with the estimates of wealth effects on consumption found in the empirical literature (see Labhard *et al* (2005) and Fair (2004)).

4.1.2 Monetary shocks and an inflation-targeting Taylor rule

We now turn to the case when monetary policy is assumed to follow a Taylor rule. Here the steady-state foreign bond position to GDP is calculated to be -141% which implies that agents want to go short in foreign currency (and long in domestic currency). This is because adverse real shocks which lower consumption are now associated with a foreign currency depreciation and hence a negative excess return from holding foreign currency denominated bonds. So agents prefer to hold domestic bonds over foreign bonds. Figure 2 illustrates the valuation effects from a positive domestic monetary policy shock when the central bank follows a Taylor rule. We assume this is an exogenous shock to the domestic Taylor rule function (ie a rise in $\varepsilon_{R,t}$) where the size of the shock is standardised to give a one standard deviation increase in domestic money growth. This shock implies a jump in the nominal exchange rate. Since agents hold a portfolio that is short in foreign currency denominated bonds, this nominal appreciation of the foreign currency causes a decline in the domestic net foreign wealth (measured in domestic currency). The loss in wealth triggers a decline in domestic consumption and as a result an excess supply of domestic goods. The domestic currency has to depreciate in real terms to ensure that this excess supply is eliminated.

In contrast to our previous experiment, monetary policy shocks with a Taylor rule cause international valuation effects that are *beggar-thy-self*. Agents have chosen a portfolio position to optimally hedge themselves against the consumption risks caused by real shocks. So in the case of the Taylor rule, agents prefer to hold a positive position in domestic bonds and a negative position in foreign bonds. The side-effect of having these optimally chosen portfolios is that monetary shocks can cause negative valuation effects. As in the case with money-growth rules, the size of these wealth effects are quantitatively small (a 1.46% fall in wealth is associated with a 0.02% decline in consumption).

4.1.3 Sensitivity analysis

This section first examines the sensitivity of our results using the model where monetary policy is conducted via a Taylor rule where the central bank targets inflation. As previously shown, with an inflation-targeting Taylor rule investors will choose an optimal portfolio that is overweight in home bonds.

Varying the shock persistence

Baxter and Crucini (1995) have shown how more persistent shocks in an incomplete markets model imply greater changes in relative wealth across countries. The first panel in Figure 3 shows the effects of a 1% domestic monetary expansion (1% fall in home policy rates) on the steady-state foreign bond position, the impact response on the nominal exchange rate as well as on domestic consumption for different degrees of shock persistence. The figures show that making the endowment shocks more persistent exposes agents to larger exchange rate movements and thus more risk - which they want to hedge against by holding a larger gross portfolio position. A higher gross portfolio position amplifies the valuation effects of monetary policy shocks. As illustrated in Figure 3, domestic consumption declines by more (on impact) following a domestic monetary expansion, the more persistent the endowment process.

Varying the relative variance of real shocks

Agents in our model choose a portfolio to hedge themselves against the consumption risk caused by real shocks. As equation 28 shows, the size of the bond portfolio increases as the relative variance of real shocks increases. This analytical result is confirmed by the second panel in Figure 3. When real shocks are assumed to be ten times more volatile than monetary shocks, agents will choose a steady-state foreign bond position relative to GDP equal to minus 10! In other words, investors will *significantly* short foreign bonds and go long in domestic bonds. Again, a higher gross portfolio position increases the potency of monetary shocks. This implies a greater nominal depreciation in the domestic currency (on impact), triggering greater valuation effects and a larger decline (on impact) in domestic consumption (as shown in the second panel in Figure 3).

Varying the weight of inflation in the Taylor rule

The implication of a larger Taylor rule response to inflation (ie a larger ϕ_π) for the valuation effect of monetary shocks is twofold: First, the higher ϕ_π the smaller is the effect of the money shock on inflation and the exchange rate. But this increases the importance of real shocks relative to monetary shocks. So this increases the investors' hedging motives and thus the size of their portfolio positions. The first effect - the smaller exchange rate response - would diminish the valuation effect of monetary shocks. But the second effect - the increase in portfolio position - would amplify it. As shown in the bottom panel of Figure 3 for values of ϕ_π between 0 and 20, the second effect dominates. But for larger values of ϕ_π the endogenous monetary policy response completely offsets the effects of monetary shocks. This is consistent with Devereux and Sutherland (2008b), who show that the central bank can complete the markets and ensure full risk-sharing by pursuing a price stability objective.

4.2 Trade in equities in the flexible price model

In this part, we allow for international trade in equities as well as bonds and show that the main implication of our model about the link between monetary policy and foreign currency positions is robust provided that we continue to have incomplete markets. As shown by Engel and Matsumoto (2009) and Devereux and Sutherland (2008b), monetary policy does not have a significant effect on equilibrium portfolios under complete markets. If there are only supply shocks and monetary shocks in each country, allowing for trade in equities in addition to bonds will complete the markets. In this case, the optimal bond position becomes zero irrespective of the monetary policy regime. This is because real shocks will be hedged by equities whose returns are not affected by nominal shocks under flexible prices, unlike nominal bonds. Then, having a zero bond portfolio will insulate the economy from monetary shocks. However, the optimal equity portfolio in this case will exhibit a foreign bias: when output is higher at home, the home consumption basket becomes cheaper (real exchange rate depreciates), while the returns on home equity relative to foreign goes up because of the increase in output (dividend).

We know from the existing literature on general equilibrium portfolio models that one possible way to derive home bias in equity is to have a negative correlation between relative non-financial income and relative home equity returns.[19] Thus, when we allow for trade in equities, we assume that only a part of total endowment in each country can be diversified away by holding equities. This part of the income is generally referred to as financial income (or capital income) in the literature. The rest of the income, which is not subject to equity returns, is the non-financial income, which can be thought of as labour income in a production economy. We allow for both capital income and non-financial income to be stochastic as in Devereux and Sutherland (2010). These shocks work as the redistributive shocks introduced by Coeurdacier *et al* (2007).

[19] See Heathcote and Perri (2007), Coeurdacier *et al* (2007), Engel and Matsumoto (2009), Coeurdacier *et al* (2010) and the references in these papers.

The linearised net foreign asset accumulation equation with equities can be written as follows:

$$\widehat{NFA}_t = \frac{1}{\beta}\widehat{NFA}_{t-1} + \frac{\bar{\alpha}_F}{\beta\bar{Y}}(\hat{r}_{F,t} - \hat{r}_{H,t}) + \frac{\bar{\alpha}_F^E}{\beta\bar{Y}}(\hat{r}_{F,t}^E - \hat{r}_{H,t}^E) + \hat{P}_{H,t} - \hat{P}_t + \hat{Y}_t - \hat{C}_t \tag{32}$$

where $\bar{\alpha}_F$ is the steady-state foreign currency (bond) portfolio as before and $\bar{\alpha}_F^E$ is the steady-state foreign equity holdings.[20] $\hat{r}_{F,t} - \hat{r}_{H,t}$ is the excess return on foreign bonds relative to home bonds as before while $\hat{r}_{F,t}^E - \hat{r}_{H,t}^E$ gives the excess return on foreign equities relative to home equities expressed in terms of home good. Another key difference here relative to the model with only bonds is that $Y_t = Y_{K,t} + Y_{L,t}$ and $Y_t^* = Y_{K,t}^* + Y_{L,t}^*$, where Y_K and Y_L represent financial and non-financial incomes as explained above.[21] The stochastic processes for Y_K and Y_L are specified as in Devereux and Sutherland (2010). A similar structure exists for the foreign country with symmetric parameters.

$$\begin{aligned}
\log Y_{K,t} &= (1-\zeta_K)\log \bar{Y}_K + \zeta_K Y_{K,t-1} + \varepsilon_{K,t},\ E_{t-1}[\varepsilon_{K,t}] = 0, Var[\varepsilon_{K,t}] = \sigma_K^2,\ Cov[\varepsilon_K, \varepsilon_L] = \sigma_{KL} \\
\log Y_{L,t} &= (1-\zeta_L)\log \bar{Y}_L + \zeta_L Y_{L,t-1} + \varepsilon_{L,t},\ E_{t-1}[\varepsilon_{L,t}] = 0,\ Var[\varepsilon_{L,t}] = \sigma_L^2
\end{aligned}$$

How does international trade in equities affect optimal bond positions within this framework? When equity trade is allowed, nominal bonds hedge the part of the risk that is not hedged by equities. Thus, what matters for the bond portfolio in this case is the conditional covariance-variance ratios. The partial equilibrium solution for foreign bond position presented earlier in the paper, in equation (18), changes in the following way:

$$\tilde{\alpha}_F = -\frac{1}{2(1-\beta)}\left(\frac{Cov_t(\Lambda_{Y_L,t+1}, \hat{r}_{x,t+1}|\hat{r}_{x,t+1}^E)}{Var_t(\hat{r}_{x,t+1}|\hat{r}_{x,t+1}^E)} + \left(1-\frac{1}{\rho}\right)\frac{Cov_t(\Lambda_{Q,t+1}, \hat{r}_{x,t+1}|\hat{r}_{x,t+1}^E)}{Var_t(\hat{r}_{x,t+1}|\hat{r}_{x,t+1}^E)}\right) \tag{33}$$

where $\Lambda_{Y_L,t+1}$ is the news at time $t+1$ about the net present value of the relative non-financial income and $\Lambda_{Q,t+1}$ is the news at time $t+1$ about the net present value of real exchange rates as before. As shown in Coeurdacier and Gourinchas (2009), non-financial income risk will be mainly hedged by equities, while nominal bonds will be used to hedge against the real exchange rate risk since real exchange rates are correlated more with relative bond returns than with relative equity returns. Thus, there will still be a role for nominal assets in providing consumption risk-sharing across countries in the presence of equities provided that equities do not complete the markets. What is more, the sign of the conditional covariance-variance ratios given in equation (33) will still be determined by the monetary policy regime in the same way as in the bonds only case. On the

[20] Here, equity holdings are defined as gross real holdings, not as shares of total equity stock but it is possible to express these gross positions as shares of stock as we do later when reporting numerical results. We use the assumption that all assets are in net zero supply when writing equation 32.

[21] Note that Y_K is what is paid out every period by domestic equity (dividend). In the model without equities, all endowment is non-financial income because bonds do not represent any claims on income, ie $Y_{K,t} = 0$ and $Y_t = Y_{L,t}$.

other hand, equity portfolios will not be affected by monetary policy much. The important factors in determining optimal equity portfolio are the share of capital income and the correlation between financial and non-financial incomes. In Table 2, we give some numerical results regarding the model with equities. We only report the calibration for the new parameters, the calibration for the rest of model parameters is the same as in Table 1.

Table 2: Steady-state foreign bond position and domestic equity shares when there is trade in bonds and equities

Parameter	Description	Money-Growth Rule	Taylor Rule
ζ_K	Persistence of financial income shocks	0.96	0.96
ζ_L	Persistence of non-financial income shocks	0.96	0.96
$\bar{Y}_K/\bar{Y}_L$	Steady-state financial income share	0.36	0.36
σ_K^2/σ_M^2	Rel. size of financial income wrt mon. shocks	2	2
σ_L^2/σ_K^2	Rel. size of fin. income wrt non-fin. income shocks	1	1
$Corr(\varepsilon_K, \varepsilon_L)$	Correlation of fin. and non-fin. income shocks	-0.2	-0.2
$\bar{x}_H$	Steady-state share of dom. stock held by home agents	0.9056	0.9091
$\bar{\alpha}_F/\bar{\beta}\bar{Y}$	Steady-state foreign bond position rel. to GDP	1.8067	-1.2611
$\frac{\bar{\alpha}_F}{\bar{\beta}\bar{Y}}\hat{r}_{x,t}$	Valuation effect of 1% unexpected nom. exch. rate dep.	1.8% of GDP	-1.3% of GDP

Our calibration for the parameters that determine the stochastic properties of capital and labour income shocks follow closely that of Devereux and Sutherland (2010). Accordingly, we set the steady-state financial income share equal to 0.36 and the correlation between financial and non-financial income shocks to -0.2, which is a less negative number than is required to derive equity home bias in a one-good model without bonds. We take the relative variance of financial and non-financial income shocks to be equal, while we lower the size of monetary policy shocks relative to income shocks to get bond positions closer in size to the bond positions we obtain under the bonds only case.[22]

With the calibration in Table 2, we get that 90% of domestic equity is held by home agents, which is in line with the observed home equity bias. Note that the equity portfolio is independent of the monetary policy rule as expected. On the other hand, the sign of bond portfolios continue to depend crucially on the policy rule, even when relative bond returns are conditioned on relative equity returns. When bond portfolios are mainly hedging against real exchange rate appreciations, a negative relative non-financial income shock that appreciates the real exchange rate will require a long position in foreign bonds if the home currency depreciates in response to the negative non-financial income shock as is the case under a passive monetary policy regime. *Vice versa* is true for the inflation-targeting Taylor rule. These results justify analysing only bonds to study international

[22] When monetary shocks are the same size as (capital) income shocks, steady–state foreign bond positions are -0.6411 under Taylor rule and 0.9016 under money-growth rule.

valuation effects created by monetary policy.

With trade in equities, there will also be valuation effects coming from the capital gains and losses on equity positions. Taking the difference in net foreign assets using equation (32) and decomposing it into current account and valuation terms as we did before in equation (29), we can define the valuation effect with trade in equities as follows:

$$VAL_t = \frac{\bar{\alpha}_F}{\bar{\beta}\bar{Y}} \underbrace{(\hat{r}_{F,t} - \hat{r}_{H,t})}_{r_{x,t}} + \frac{\bar{\alpha}_F^E}{\bar{\beta}\bar{Y}} \underbrace{(\hat{r}^E_{F,t} - \hat{r}^E_{H,t})}_{r^E_{x,t}}$$

where the first term is what we analyse as valuation effects throughout the paper. Using the definitions of bond and equity returns and the property that expected excess returns are zero in a first order approximation, we can further write this as follows:

$$\begin{aligned} VAL_t &= \tilde{\alpha}_F(\hat{S}_t - E_{t-1}\hat{S}_t) \\ &+\tilde{\alpha}_F^E \left[\begin{array}{c} TO\hat{T}_t - E_{t-1}TO\hat{T}_t - (1-\bar{\beta})(\hat{Y}^R_{K,t} - E_{t-1}\hat{Y}^R_{K,t}) \\ +\bar{\beta}(\hat{Z}^*_{F,t} - E_{t-1}\hat{Z}^*_{F,t}) - \bar{\beta}(\hat{Z}_{H,t} - E_{t-1}\hat{Z}_{H,t}) \end{array} \right] \end{aligned} \tag{34}$$

where TOT is the terms of trade defined as the price of imports relative to exports, $Y^R_{K,t}$ is the difference between home and foreign capital incomes and Z_H and Z^*_F are the real prices of home and foreign equity defined in terms of home and foreign goods, respectively.

The first important point is that relative equity returns only depend on real variables like the terms of trade, relative income and relative equity prices as shown in (34). Thus, even though we are operating under incomplete markets and monetary policy shocks have real effects through home bond portfolios, the effect of monetary policy shocks on $\hat{r}^E_{F,t} - \hat{r}^E_{H,t}$ is negligible. Thus, in our flexible price set-up, a currency depreciation caused by a monetary policy expansion affects VAL_t mainly through relative bond returns, which is what we have analysed so far in the paper.

4.3 Sticky prices

Our analysis so far only considers fully flexible prices. A natural question that comes to mind is whether our results on the link between policy regimes and foreign bond positions, and consequently on the valuation channel of monetary policy, would go through in a sticky price environment. To answer this question, we introduce price rigidities in the model with only bonds and show that the sign of the foreign currency portfolio continues to be affected in a similar way as in the flexible price model for reasonable calibrations of the model.

Optimal portfolios under sticky prices have been analysed before in Devereux and Sutherland (2008b) and Engel and Matsumoto (2009). In a model where monetary policy is specified as a

Taylor rule that reacts to PPI inflation, Devereux and Sutherland (2008b) find a negative position in foreign bonds under incomplete markets. The main difference of our model with Devereux and Sutherland (2008b) is that we analyse portfolios under 'passive' monetary policy regimes as well as inflation targeting regimes and show how the optimal foreign bond portfolio might switch sign depending on this classification in an incomplete market setting. Engel and Matsumoto (2009), on the other hand, assume a money-growth rule for monetary policy and show that the optimal foreign curreny position will be negative whether or not money supplies are allowed to respond to productivity shocks under a complete market setting where there is also trade in equities.[23] Therefore, market incompleteness is crucial for our result on the link between policy and portfolio currency shares under sticky prices.

The basic features of the model are as follows: Price stickiness is modelled à la Calvo. In each period, a fraction $\kappa \in [0, 1)$ of randomly selected firms in each country cannot change their prices. The remaining $1 - \kappa$ fraction of firms chooses prices optimally to maximise the expected discounted value of future profits. Each firm produces a single variety of the domestic consumption good according to a production function that is linear in labour, ie $Y_t = A_t L_t$ for the home country, where A_t is an AR(1) productivity shock common across all home firms. A similar production function and productivity shock exist for the foreign country. The representative agent in each country now also gets disutility from work as well as utility from consumption and real money holdings. The model is otherwise similar to the model presented in Section 2. We present the important equations of the sticky price model in the appendix.

We know from the literature that the currency in which export prices are set is crucial for the international tranmission of monetary shocks under sticky prices.[24] Therefore, we consider two different price-setting assumptions for exports: producer currency pricing (PCP) and local currency pricing (LCP). Under PCP, producers in each country set export prices in their own currency, whereas under LCP, export prices are set in the currency of the buyer.[25] When prices are set according to LCP, the law of one price no longer holds. In this case, real exchange rate fluctuations reflect both the presence of home bias in consumption and deviations from the law of one price.

We solve the model numerically to analyse the interaction between policy regimes and bond portfolios under sticky prices. We use the same parameter values as in the flexible price model given in Table 1, where applicable. The rest of the model parameters are calibrated as follows. The

[23] The intuition in Engel and Matsumoto is as follows: due to price stickiness, home labour income and relative returns on home equity are negatively correlated for a given exchange rate. Thus, it is optimal to have home bias in equity. When exchange rate depreciates, home revenues increase in home currency terms. Given that equity portfolios are home biased, this leads to an increase in relative consumption which can be hedged by having a short position in foreign currency.

[24] See for example Betts and Devereux (2000, 2001), Devereux and Engel (2003), Corsetti and Pesenti (2005).

[25] Optimal price for each case is given in the appendix.

elasticity of substitution across varieties in each country, ϕ, is set to 10, which is consistent with a price mark-up of 11%. The price stickiness parameter κ equals 0.75, so that prices are set for a year at a time. The inverse of the Frisch elasticity of labour supply, ϖ, is set to 2−the same value as the coefficient of relative risk aversion. The persistence of the productivity shock in each country, ζ_A, equals 0.96, the same value as the persistence of the endowment process in the flexible price model. Monetary shocks are assumed to be i.i.d as before. Our benchmark calibration presumes that the volatility of monetary shocks is equal to that of real shocks but we also report the results for different values of relative variance.

Table 3: Steady-state foreign bond position and implied valuation effects under the baseline calibration

	Money-Growth Rule			Taylor Rule		
$\bar{\alpha}/\bar{\beta}\bar{Y}$	Flex	PCP	LCP	Flex	PCP	LCP
$\sigma_A/\sigma_M = 1$	1.9821	1.0327	2.0037	-1.9014	-2.0975	-1.3250
$\sigma_A/\sigma_M = 0.5$	0.9890	0.1317	1.1104	-0.9743	-1.3870	-0.6490
$\sigma_A/\sigma_M = 0.1$	0.1975	-0.5867	0.3982	-0.1988	-0.8003	-0.0885
$\frac{\bar{\alpha}}{\bar{\beta}\bar{Y}}\hat{r}_{x,t}$						
$\sigma_A/\sigma_M = 1$	2% of GDP	1% of GDP	2% of GDP	-1.9% of GDP	-2.1% of GDP	-1.3% of GDP

$\bar{\alpha}/\bar{\beta}\bar{Y}$ is steady-state foreign bond position rel. to GDP and $\frac{\bar{\alpha}}{\bar{\beta}\bar{Y}}\hat{r}_{x,t}$ gives the valuation effect of 1% nominal exch. rate dep.

Table 3 gives home country's optimal steady-state foreign bond holdings in proportion to GDP for two different policy regimes and three different price-setting assumptions under the benchmark calibration described above.[26] We see that the link between monetary policy regimes and foreign bond portfolios under sticky prices is similar to that under flexible prices. That is, money-growth targeting is associated with a long position in foreign bonds, while the opposite is true for strict inflation targeting irrespective of the currency in which export prices are set. To understand the portfolio positions given in Table 3 and explain the differences across different policy regimes and price-setting assumptions, we look at the covariance of real exchange rate adjusted relative consumption and excess returns conditional on relative supply shocks and monetary shocks under the zero-portfolio solution (ignoring the valuation effects). Table 4 shows how each component of the portfolio orthogonality condition given in equation (13) responds to these shocks under the benchmark calibration.

First of all, just as in the case of flexible prices, the covariance of real exchange rate adjusted relative consumption, $\hat{C}_t^R - \hat{Q}_t/\rho$, and excess returns, $\hat{r}_{x,t} = \hat{S}_t - E_{t-1}\hat{S}_t$, conditional on relative productivity shock is negative under money-growth rule and positive under inflation-targeting Tay-

[26]We obtain the flexible price solution by letting $\kappa \to 0$. Note that the flexible price solution for this model is different than the one for the endowment model, because here labour supply is elastic. As $\varpi \to \infty$, labour supply becomes infinitely inelastic and the model collapses to the endowment economy case.

Table 4: Conditional covariance of real exchange rate adjusted relative consumption and excess returns under zero-portfolio solution

Zero-portfolio solution	Money-Growth Rule		Taylor Rule	
	$\varepsilon^R_{A,t}$	$\varepsilon^R_{M,t}$	$\varepsilon^R_{A,t}$	$-\varepsilon^R_{R,t}$
Flexible Price				
$\hat{C}^R_t - \frac{\hat{Q}_t}{\rho}$	$+$	0	$+$	0
$\hat{r}_{x,t}$	$-$	$+$	$+$	$+$
Sticky price with PCP				
$\hat{C}^R_t - \frac{\hat{Q}_t}{\rho}$	$+$	$+$	$+$	$+$
$\hat{r}_{x,t}$	$-$	$+$	$+$	$+$
Sticky price with LCP				
$\hat{C}^R_t - \frac{\hat{Q}_t}{\rho}$	$+$	$-$	$+$	$-$
$\hat{r}_{x,t}$	$-$	$+$	$+$	$+$

lor rule - irrespective of the price-setting assumption. Indeed, whether export prices are set in producer's or buyer's currency does not affect relative consumption and excess returns significantly in the face of productivity shocks.[27] Thus, hedging against the relative consumption risk coming from productivity shocks requires a long position in foreign currency under money-growth rule and a short position under strict inflation targeting just as in the case of flexible prices. The difference in the sign of the covariance across policy regimes comes from the different response of nominal exchange rates. The intuition for this result is as described in Section 2.

The most important implication of sticky prices for bond positions is that now agents use bonds *also* to hedge against the relative consumption risk coming from monetary shocks. Table 4 shows that the covariance of relative consumption and nominal exchange rate, conditional on monetary shocks, does not change sign across different policy regimes, but across different price-setting assumptions for a given a policy regime. That is, a monetary expansion leads to a rise in adjusted relative consumption, as well as a depreciation in home currency, ie $\hat{C}^R_t - \hat{Q}_t/\rho \uparrow$ and $\hat{r}_{x,t} \uparrow$, under both policy regimes if prices are set in producer's currency. However, if prices are set in buyer's currency, a monetary expansion at home actually depresses relative consumption, while depreciating domestic currency, ie $\hat{C}^R_t - \hat{Q}_t/\rho \downarrow$ and $\hat{r}_{x,t} \uparrow$.

What explains this difference in the response of adjusted relative consumption, $\hat{C}^R_t - \hat{Q}/\rho$, to a home monetary expansion across PCP and LCP? Under PCP, a domestic monetary expansion that depreciates the nominal exchange rate also worsens the terms of trade given that import and export prices are sticky in the currency of the producer.[28] Depreciation in the terms of trade shifts

[27]See Benigno and Benigno (2008) and Clarida and Waldman (2007) for the analysis of nominal exchange rate dynamics under different policy rules in a sticky price model with PCP, and Benigno (2004) for an LCP model.

[28]Under PCP, $TOT_t = \hat{P}^*_{F,t} + \hat{S}_t - \hat{P}_{H,t}$. Since $\hat{P}_{H,t}$ and $\hat{P}^*_{F,t}$ are sticky in home and foreign currencies, respectively,

the world demand towards the cheaper home good. Consumption increases in both countries, but by more in the home country. Real exchange rate depreciates due to home bias in consumption. Overall, given the strong expenditure-switching effects created by a home currency depreciation, consumption of home agents increase by more compared to foreign agents in purchasing power terms under PCP.

Under LCP, on the other hand, a domestic monetary expansion that depreciates the nominal exchange rate does not generate expenditure-switching effects like it does under PCP, because foreign currency price of home good does not fall. Revenues of home exporters increase, which improves the home terms of trade and raises the value of home output.[29] Thus, home consumption increases by much more than in the PCP case and foreign consumption falls due to the worsening in foreign terms of trade. So, under LCP relative consumption, $\hat{C}_t^R = \hat{C}_t - \hat{C}_t^*$, increases by much more in response to a domestic monetary expansion than under PCP. But, the real exchange rate also depreciates by much more under LCP compared to the PCP case - so much that relative consumption adjusted for purchasing power, $\hat{C}_t^R - \hat{Q}/\rho$, slightly falls in the face of a positive monetary shock.[30] This result is in line with the literature which shows that the presence of pricing to market increases exchange rate volatility relative to the case in which law of one price holds.[31]

Given the discussion on the comovement of relative consumption and excess returns under different price-setting assumptions, the optimal hedge against monetary shocks under LCP is to go long in the foreign bond irrespective of the policy regime, while the opposite is true for PCP.[32] Consequently, for a money-growth rule, it is optimal to have a *bigger* long position in foreign bonds under LCP compared to flexible prices or PCP, because in this case hedging against monetary shocks also requires a long position in foreign currency, reinforcing the effect coming from productivity shocks. However, under PCP, monetary shocks affect the covariance between relative consumption and excess returns in the opposite way as productivity shocks and therefore a *smaller* long position in FX is optimal. A similar reasoning applies to an inflation-targeting Taylor rule. For this regime, the short position in FX is magnified under PCP and reduced under LCP (Tables 3 and 4).

The result presented above implies that, for a sufficiently large relative variance of monetary

home terms of trade depreciates following a monetary expansion that depreciates the nominal exchange rate.

[29] Under LCP, $TOT_t = \hat{P}_{F,t} - \hat{P}^*_{H,t} - \hat{S}_t$. Since $\hat{P}_{F,t}$ and $\hat{P}^*_{H,t}$ are sticky in home and foreign currencies, respectively, home terms of trade appreciates following a monetary expansion that depreciates the nominal exchange rate.

[30] To understand the real exchange rate response under LCP, it is useful to decompose it in terms of the deviation from the law of one price in each country and home terms of trade:

$$\hat{Q}_t = \nu(\hat{P}^*_{H,t} + \hat{S}_t - \hat{P}_{H,t}) + \nu(\hat{P}^*_{F,t} + \hat{S}_t - \hat{P}_{F,t}) + (2\nu - 1)(\hat{P}_{F,t} - \hat{P}^*_{H,t} - \hat{S}_t)$$

Despite the fact that the home terms of trade improves following an expansionary monetary shock, real exchange rate depreciates because of the deviation from the law of one price in each country, which are equal because of symmetry.

[31] For example, see Betts and Devereux (2000).

[32] Note that in the flexible price case, the optimal hedge against monetary shocks is to have zero portfolio as discussed in Section 2.

shocks, optimal foreign bond position might be negative under a passive policy when prices are sticky in the producer's currency and positive under an inflation-targeting policy when prices are sticky in the buyer's currency. Table 3 shows how portfolios change when monetary shocks are twice and ten times more volatile than productivity shocks, ie $\sigma_A^2/\sigma_M^2 = 0.5$, and $\sigma_A^2/\sigma_M^2 = 0.1$. First of all, bond portfolios shrink in size as monetary shocks become more important. Secondly, increasing the size of monetary shocks affects portfolios less under a Taylor rule compared to a money-growth rule because the reaction to inflation in the Taylor rule partially offsets the increase in the variance.[33] Therefore, foreign bond position does not switch sign under Taylor rule with LCP even when monetary shocks are ten times more volatile than productivity shocks. All in all, for reasonable calibrations of the relative variance, the link between policy regimes and foreign bond positions is robust to the introduction of sticky prices in the model.

Valuation effects of monetary policy shocks under sticky prices

Under the benchmark calibration, a monetary expansion that generates 1% depreciation in domestic currency creates a positive valuation effect up to 2% of GDP under a money-growth rule and a negative valuation effect up to -2% of GDP under a Taylor rule depending on the price-setting assumption (Table 3). However, this valuation effect on international bond positions created by monetary policy shocks is small when compared with the conventional effect coming from the slow adjustment of prices. For example, the negative valuation effect that follows a monetary expansion under a Taylor rule is not enough to make monetary policy beggar-thy-self as in the case of flexible prices (where there is no other channel for the transmission of monetary shocks except the valuation channel). Figure 4 shows how the valuation channel works in the case of a Taylor rule with PCP by comparing the impulse responses from a non-contingent bond economy (zero-portfolio solution) with those from the model with trade in two nominal bonds. The difference between the dashed line and the solid line is due to the valuation channel.

As can be seen from the impulse response of NFA in Figure 4, the valuation effect of a monetary expansion is negative, but the response of home and foreign consumption, real exchange rate and other variables are not much affected by the fall in NFA, because this channel is dominated by the conventional sticky-price channel. The only variable that is affected most significantly by the valuation channel is relative home consumption adjusted for the real exchange rate, which shows deviations from perfect risk-sharing.

4.3.1 A more general specification of the Taylor rule

A standard Taylor rule (Taylor (1993)) specifies that interest rates respond to divergences of inflation from target and output from trend. Here we consider a set-up where the central bank

[33] See equation 28 and the related discussion in Section 2 for the flexible price argument.

responds to inflation and output growth. Arguably, a rule that responds to output growth rather than the output gap (defined as the deviation of actual output from its efficient level) might not be consistent with a central bank that cares about social welfare. We allow for such specification in order to consider the case that the monetary policy has some preference for stabilising output itself. The analysis of this rule will be an alternative way of assessing the implications of having a more accommodative policy.[34]

Figure 5 examines the effects of increasing the weight on output stabilisation in the Taylor rule ϕ_y. The case of $\phi_y = 0$ corresponds to the set-up where the central bank only targets inflation and is analysed above. In this special case, the domestic currency depreciates in response to a positive endowment shock and agents would want to hold a portfolio that is short in foreign bonds (ie the steady share foreign bond position is negative). Expansionary domestic monetary policy shocks cause a domestic nominal depreciation which triggers negative valuation effects at home.

However, as Figure 5 illustrates, this result is overturned as ϕ_y increases. Then positive endowment shocks that raise output would require the central bank to raise interest rates, appreciating the domestic currency in nominal terms. This different exchange rate dynamic has been emphasised by Clarida and Waldman (2007) and Benigno and Benigno (2008). In response to this new exchange rate dynamic, agents would now choose to hold less domestic and more foreign bonds. As a consequence of this change in the international portfolio position, domestic monetary shocks can trigger positive valuation effects.

Note that in our set-up, the weight on output stabilisation, ϕ_y, only needs to be slightly positive to overturn the results obtained under a pure inflation-targeting Taylor rule. So the case of a Taylor rule with a small weight on output stabilisation has similar implications for the international transmission of monetary policy as the results obtained under money-growth rule. Therefore our results suggests that the relevant classification of policy rules distinguishes between those that focus solely on inflation stabilisation and those that do not.

5 Conclusion

Over recent decades, the external balance sheets of countries have grown in size. At the same time, the currency denomination of those balance sheets has changed. While some countries have most of their foreign debt liabilities denominated in domestic currency, in others most debt liabilities are in foreign currency (Lane and Shambough (2009)). In our model, the optimal portfolio currency

[34] Note that a specification of the Taylor rule that responds to output gap - defined as deviations of actual output from its flexible price allocation - would not change our results (at least in qualitative terms). This is because the objective of targeting the flexible price allocation is no different than the objective of targeting stable inflation. We actually run this sensitivity analysis and find that the presence of an output gap in the Taylor rule would make the FX position even more negative.

shares are directly linked to exchange rate dynamics. Whether the domestic currency depreciates or appreciates in periods of low domestic income determines whether investors take a long or a short position in the foreign currency. The key insight of our analysis is that different monetary regimes change the cyclical properties of the exchange rate which then affects the hedging characteristic of domestic over foreign bonds. Specifically, if the central bank is assumed to target money growth, or follows a Taylor rule which puts weight on output stabilisation, agents would choose a portfolio that is short in domestic bonds and long in foreign bonds. This is because, with such rules, any adverse real country-specific shocks will be associated with a nominal depreciation of the domestic currency. Holding domestic currency denominated assets is therefore a bad hedge. On the other hand, when the central bank conducts policy through an inflation-targeting Taylor-type rule, the same adverse shock will trigger a nominal domestic currency appreciation. So holding domestic currency denominated assets is a good hedge and agents will choose an optimal portfolio that is overweight in home bonds.

We also show how the endogenous portfolio choice determines the cross-border transmission of monetary policy shocks via a valuation channel. In the case of money-growth rules, agents are long in foreign bonds and monetary policy shocks then trigger international valuation effects that are *beggar-thy-neighbour*. In contrast, monetary policy shocks with a Taylor rule cause international valuation effects that are *beggar-thy-self* since agents are holding a portfolio that is short in foreign bonds.

Our results on the optimal portfolio under different monetary policy regimes appear in line with the findings of Clarida and Waldman (2007) and Lane and Shambough (2010). When put together, the empirical evidences from these papers tend to suggest that inflation-targeting countries are inclined to hold relatively more foreign debt liabilities denominated in foreign currency than non inflation targeting countries. But we believe that a clear look at the data on the link between policy regimes, hedging motives and portfolio positions would be an interesting avenue for future research.

Figures

Figure 1: Impulse responses following a monetary shock under a money-growth regime (X-axis: periods measured in quarters; Y-axis: percentage deviations from steady state)

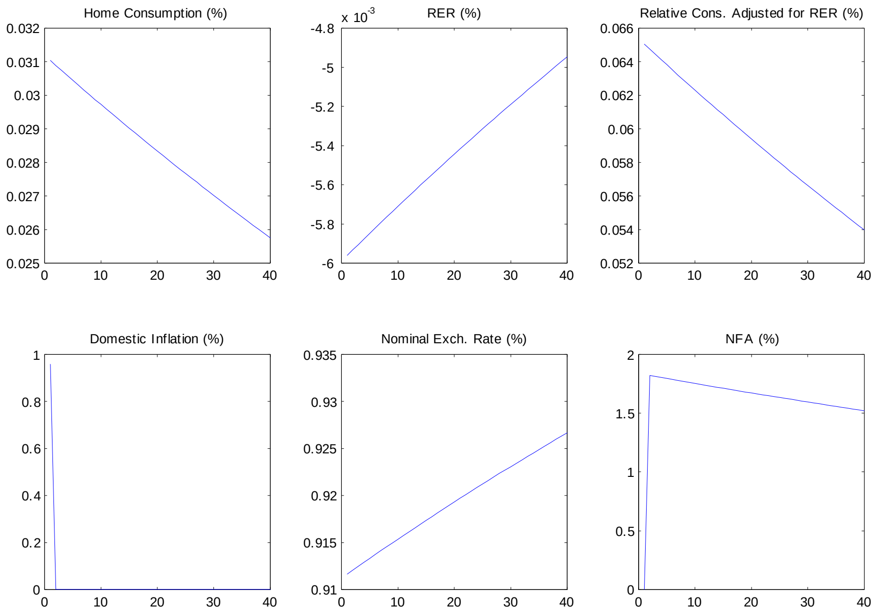


Figure 2: Impulse responses following a monetary shock (standardised to give one standard deviation increase in money growth) under a Taylor rule (X-axis: periods measured in quarters; Y-axis: percentage deviations from steady state)

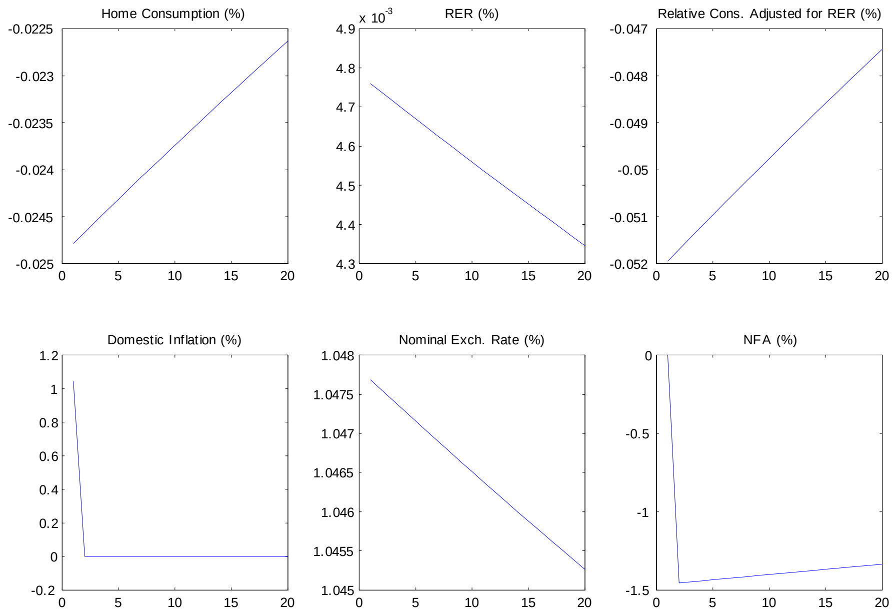


Figure 3: Steady-state foreign bond position, initial response of nominal exchange rate and consumption to an expansionary home monetary shock with respect to persistence, relative variance and inflation response under Taylor rule

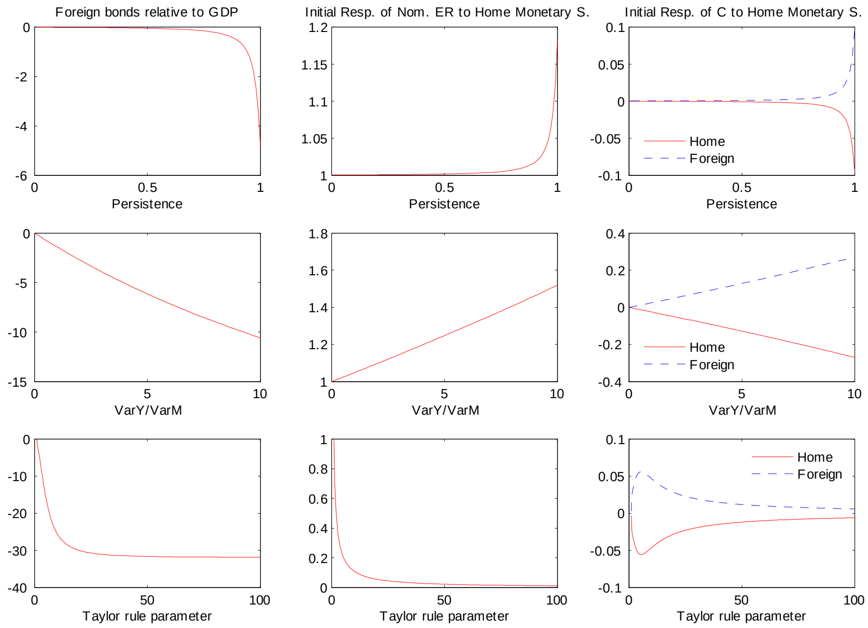


Figure 4: Impulse responses following an expansionary monetary shock under Taylor rule with sticky prices and PCP (X-axis: periods measured in quarters; Y-axis: percentage deviations from steady state)

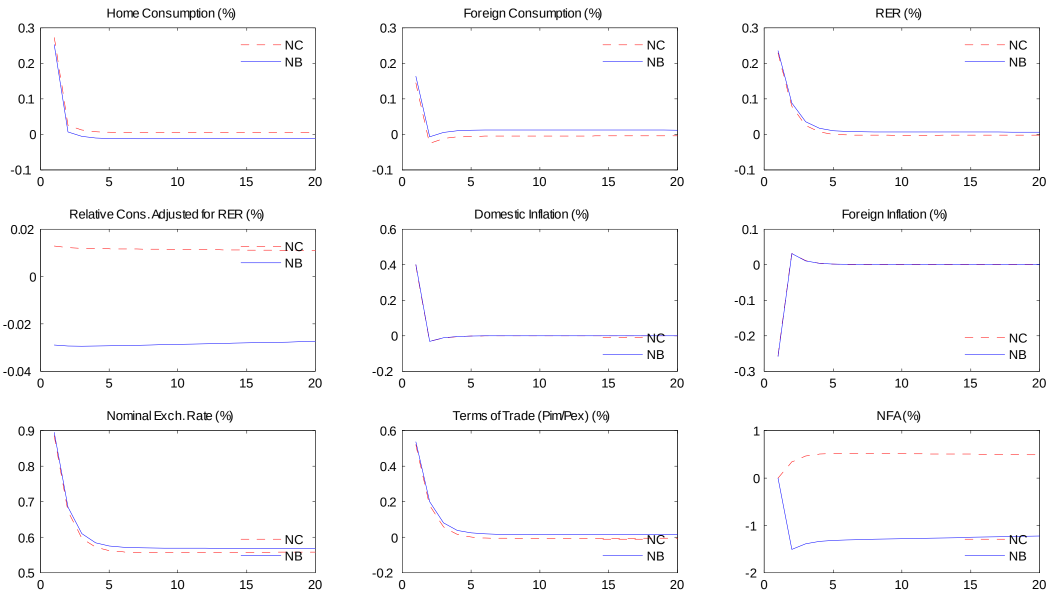
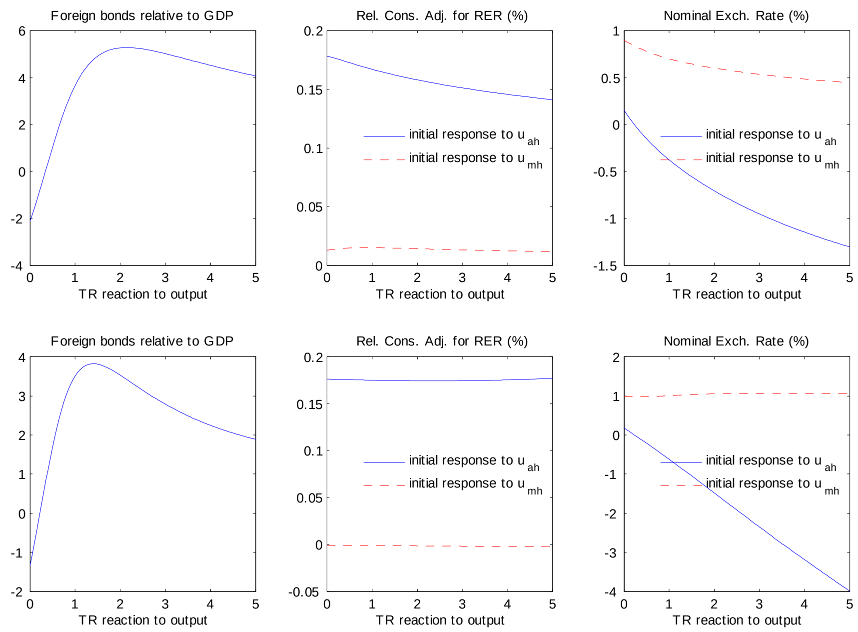


Figure 5: Steady-state foreign bond position and initial response of real exchange rate adjusted relative consumption and nominal exchange rate under zero-portfolio to a 1% productivity and (expansionary) monetary shock under PCP (top row) and LCP (bottom row) for different values of Taylor rule reaction to output



Appendix A: Deriving conditions determining optimal shares

We use the first-order approximation to the model equations to evaluate the portfolio orthogonality condition coming from the second-order approximation to the portfolio choice equations.

The first-order approximation to the accumulation of net foreign assets given by equation (9) in the text and its foreign counterpart can be written as follows:[35]

$$\widehat{NFA}_t = \frac{1}{\beta}\widehat{NFA}_{t-1} + \tilde{\alpha}(\hat{r}_{F,t} - \hat{r}_{H,t}) + \hat{P}_{H,t} - \hat{P}_t + \hat{Y}_{H,t} - \hat{C}_t \tag{35}$$

$$\widehat{NFA}^*_t = \frac{1}{\beta}\widehat{NFA}^*_{t-1} - \tilde{\alpha}(\hat{r}_{F,t} - \hat{r}_{H,t}) + \hat{P}^*_{F,t} - \hat{P}^*_t + \hat{Y}^*_{F,t} - \hat{C}^*_t \tag{36}$$

Taking the difference of two asset accumulation equations we get equation (15) in the text:

$$\widehat{NFA}^R_t = \frac{1}{\beta}\widehat{NFA}^R_{t-1} + 2\tilde{\alpha}\hat{r}_{x,t} + \hat{Y}^R_t - \hat{C}^R_t + \hat{Q}_t$$

where $\widehat{NFA}^R_t = \widehat{NFA}_t - \widehat{NFA}^*_t$, $r_{x,t} = r_{F,t} - r_{H,t}$ (excess return on foreign bonds expressed in home currency), $\hat{Y}^R_t = \hat{P}_{H,t} + \hat{Y}_{H,t} - (\hat{P}^*_{F,t} + \hat{S}_t + \hat{Y}^*_{F,t})$ (relative non-financial income adjusted for the terms of trade), $\hat{C}^R_t = \hat{C}_t - \hat{C}^*_t$ and $\hat{Q}_t = \hat{P}^*_t + \hat{S}_t - \hat{P}_t$.

The second dynamic equation we have is the combined Euler equations, ie equation (16) in the text:

$$E_t\hat{C}^R_{t+1} - \hat{C}^R_t = \frac{1}{\rho}\left(E_t\hat{Q}_{t+1} - \hat{Q}_t\right)$$

We can solve equations (15) and (16) forward for NFA^R_t and C^R_t as a function of NFA_{t-1}, $\tilde{\alpha}\hat{r}_{x,t}$, $\hat{Y}^R_t$ and $\hat{Q}_t$:

$$\widehat{NFA}^R_t = \widehat{NFA}^R_{t-1} - E_t\sum_{j=0}^{\infty}\beta^{j+1}\Delta\hat{Y}^R_{t+1+j} - \left(1 - \frac{1}{\rho}\right)E_t\sum_{j=0}^{\infty}\beta^{j+1}\Delta\hat{Q}^R_{t+1+j} + 2\beta\tilde{\alpha}\hat{r}_{x,t} \tag{37}$$

$$\hat{C}^R_t = \frac{1-\beta}{\beta}\widehat{NFA}^R_{t-1} + E_t\sum_{j=0}^{\infty}\beta^{j+1}\Delta\hat{Y}^R_{t+1+j} + \left(1 - \frac{1}{\rho}\right)E_t\sum_{j=0}^{\infty}\beta^{j+1}\Delta\hat{Q}^R_{t+1+j} + 2(1-\beta)\tilde{\alpha}\hat{r}_{x,t} + \hat{Y}^R_t + \hat{Q}_t \tag{38}$$

We get the equation for $\Delta\hat{C}^R_{t+1} - \Delta\frac{\hat{Q}_{t+1}}{\rho}$ given in equation (17) in the text by using (37) and (38):

[35] Note that in Section 2 of the text we defined $\alpha = \alpha_F$ and mentioned that we can define all other portfolio shares in terms of α using the definition of NFA and the asset market clearing conditions.

$$\Delta\hat{C}^R_{t+1} - \Delta\frac{\hat{Q}_{t+1}}{\rho} = 2(1-\beta)\tilde{\alpha}\hat{r}_{x,t+1}$$
$$+E_{t+1}\sum_{j=0}^{\infty}\beta^j\Delta\hat{Y}^R_{t+1+j} - E_t\sum_{j=0}^{\infty}\beta^j\Delta\hat{Y}^R_{t+1+j}$$
$$+\left(1-\frac{1}{\rho}\right)\left(E_{t+1}\sum_{j=0}^{\infty}\beta^j\Delta\hat{Q}^R_{t+1+j} - E_t\sum_{j=0}^{\infty}\beta^j\Delta\hat{Q}^R_{t+1+j}\right)$$

Appendix B: Equations of the sticky price model

Here, we present the important equations of the sticky price model discussed in Section 4.3 in the main text.

Consumers

The representative agent in the home economy now also gets disutility from work as well as utility from consumption and real money holdings. So the expected present discounted value of utility given in equations (1) and (2) changes as follows:

$$U_t = E_t\sum_{s=t}^{\infty}\delta_s u\left(C_s, \frac{M_s}{P_s}, L_s\right) \tag{39}$$

with

$$u\left(C_s, \frac{M_s}{P_s}, L_s\right) = \frac{C_s^{1-\rho}}{1-\rho} + \chi\log\left(\frac{M_s}{P_s}\right) - K\frac{L_s^{1+\varpi}}{1+\varpi} \tag{40}$$

where $\varpi > 0$, $K > 0$ and L_s is the hours worked.

The consumption index and the associated price index are given in equations (5) and (6) with the elasticity of substitution between home and foreign goods denoted by θ. C_H and C_F are now composite indices of domestic and foreign varieties. The elasticity of substitution between varieties produced within a country is $\phi > 1$.

The budget constraint and the definition of asset returns are as before. Note that total income that accrues to the home agent, $P_{H,t}Y_t$ in equation (7), is now the sum of profits and wage income, ie $P_{H,t}Y_t = P_t\Pi_t + W_tL_t$, where Π denotes real profits of home firms and W_t is nominal wage.

Firms

Firms have market power over the supply of their products. Each firm produces a single variety of the home consumption good according to the production technology:

$$Y_t = A_tL_t$$

where A_t is a common stochastic productivity shock that follows an AR(1) process.

$$\log A_t = \zeta \log A_{t-1} + u_t,\ 0 \leq \zeta \leq 1,\ u_t \text{ is } i.i.d \text{ with } E_{t-1}[u_t] = 0, Var_{t-1}[u_t] = \sigma_u^2$$

Prices change at random intervals à la Calvo. At each period a fraction $\kappa \in [0, 1)$ of randomly selected firms cannot change their prices. The remaining $1 - \kappa$ fraction of firms chooses prices optimally to maximise expected discounted value of future profits.

Each firm in home country chooses the optimal home and foreign market price, $\tilde{P}_{H,t}$ and $\tilde{P}^*_{H,t}$, respectively to maximise expected value of discounted future profits from selling at home and abroad:

$$E_t \sum_{j=0}^{\infty} \kappa^j \Psi_{t+j} \left[\tilde{P}_{H,t} \tilde{Y}_{H,t+j} + S_{t+j} \tilde{P}^*_{H,t} \tilde{Y}^*_{H,t+j} - \frac{W_{t+j}}{A_{t+j}} (\tilde{Y}_{H,t+j} + \tilde{Y}^*_{H,t+j}) \right] \tag{41}$$

where Ψ is the stochastic discount factor and $\tilde{Y}_{H,t}$ and $\tilde{Y}^*_{H,t}$ are the demand for home good from the home market and the demand for home good from the foreign market, respectively and are given by the following expressions:

$$\tilde{Y}_{H,t+j} = \left(\frac{\tilde{P}_{H,t}}{P_{H,t+j}} \right)^{-\phi} \nu \left(\frac{P_{H,t+j}}{P_{t+j}} \right)^{-\theta} C_{t+j} \tag{42}$$

$$\tilde{Y}^*_{H,t+j} = \left(\frac{\tilde{P}^*_{H,t}}{P^*_{H,t+j}} \right)^{-\phi} (1 - \nu) \left(\frac{P^*_{H,t+j}}{P^*_{t+j}} \right)^{-\theta} C^*_{t+j} \tag{43}$$

The optimal price for the home good sold in the home market is given by:

$$\tilde{P}_{H,t} = \frac{\phi}{\phi - 1} \frac{E_t \sum_{j=0}^{\infty} \kappa^j \Psi_{t+j} \frac{W_{t+j}}{A_{t+j}} \tilde{Y}_{H,t+j}}{E_t \sum_{j=0}^{\infty} \kappa^j \Psi_{t+j} \tilde{Y}_{H,t+j}} \tag{44}$$

The foreign currency price can be set in two ways depending on the currency in which home exports are invoiced. Under producer currency pricing (PCP), exporters in both countries set export prices in their own currency. Home firms maximise equation (41) with respect to $S_{t+j}\tilde{P}^*_{H,t}$ and the optimal export price is given by:

$$\tilde{P}^*_{H,\,t} \underset{pcp}{|} = \frac{\tilde{P}_{H,t}}{S_t} \tag{45}$$

On the other hand, under local currency pricing (LCP), export prices are set in the destination market's currency. Maximising equation (41) with respect to $\tilde{P}^*_{H,t}$ gives the following equation for optimal export price under LCP:

$$\tilde{P}^*_{H,t}\underset{lcp}{|} = \frac{\phi}{\phi-1}\frac{E_t\sum_{j=0}^{\infty}\kappa^j\Psi_{t+j}\frac{W_{t+j}}{A_{t+j}}\tilde{Y}^*_{H,t+j}}{E_t\sum_{j=0}^{\infty}\kappa^j\Psi_{t+j}S_{t+j}\tilde{Y}^*_{H,t+j}} \tag{46}$$

Under Calvo price-setting, the price indices $P_{H,t}$ and $P^*_{H,t}$ can be written as follows:

$$\begin{aligned} P_{H,t} &= \left[(1-\kappa)\tilde{P}^{1-\phi}_{H,t} + \kappa P^{1-\phi}_{H,t-1}\right]^{\frac{1}{1-\phi}} \\ P^*_{H,t} &= \left[(1-\kappa)\tilde{P}^{*1-\phi}_{H,t} + \kappa P^{*1-\phi}_{H,t-1}\right]^{\frac{1}{1-\phi}} \end{aligned}$$

Optimal prices for the foreign goods sold in the domestic market and abroad, $\tilde{P}^*_{F,t}$ and $\tilde{P}_{F,t}$ as well as $P^*_{F,t}$ and $P_{F,t}$ are derived in a similar way.

Policy rules are as described in Section 2.2 and equilibrium conditions are as in Section (2.3). In addition to the Euler equations and the money demand equation given by (10) and (11), there is a new household first-order condition that determines optimal labour supply:

$$KL^{\varpi}_t = C^{-\rho}_t\frac{W_t}{P_t} \tag{47}$$

The law of one price no longer holds in the sticky price model with LCP, but it continues to hold if exports are priced according to PCP.

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