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# International Financial Market Integration, Asset Compositions and the Falling Exchange Rate Pass-Through\*

—Preliminary—

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## Abstract

This paper provides an explanation for the observed decline of exchange rate pass-through into import prices by modeling the effects of financial market integration on the optimal choice of the pricing currency in the context of rigid nominal goods prices. Contrary to previous literature, the interdependence of this choice with an optimal portfolio choice of internationally traded financial assets is explicitly taken into account. In particular, price setters move towards more local-currency pricing while the debt portfolio includes more foreign assets following increased financial integration. Both predictions are in line with novel empirical evidence.

*Keywords:* Exchange rate pass-through, financial integration,  
portfolio home bias, international price setting

*JEL-Codes:* F41, F36, F31

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# 1 Introduction

What drives the observed decline in exchange rate pass-through over time?<sup>1</sup> This paper aims to reassess this question. We show that international financial integration, measured by the number and nature of available assets, affects the international portfolio compositions of domestic relative to foreign bonds and equities, and thereby the exchange rate pass-through. We present novel empirical observations over the time period 1990 to 2010 showing that an increase in equity trade is positively associated with a decline in the holding of domestic relative to foreign debt positions (which we call a fall in debt home bias), lower exchange-rate volatility, and a smaller degree of exchange rate pass-through.

Trade in equity has increased considerably over the recent decades. The left panel of figure 1 shows the sum of portfolio equity assets and liabilities plus the sum of foreign direct investment assets and liabilities over GDP (blue solid line), as reported in the updated and extended version of the data set constructed by Lane and Milesi-Ferretti (2007), over the time period 1990 to 2010 for a broad set of countries.<sup>2</sup> As visible, trade of equity has grown impressively relative to GDP post 1987, the start of the "financial globalization period" (see Kose et al., 2006), as well as relative to total debt assets and liabilities pictured by the black dashed line in the same panel.<sup>3</sup> The empirical evidence thus shows a trend towards holding foreign equity, such that domestic agents benefit from an improvement of economic conditions abroad.

At the same time, relative holdings of debt positions in domestic relative to foreign currencies have declined internationally. In the right panel of figure 1, we plot the net debt in domestic currency less net debt in foreign currency over GDP (blue solid line) and over total debt assets and liabilities (black dashed line), for the same country group as above. Hence, the empirical evidence shows a trend towards holding debt in foreign currency, such that domestic agents benefit from an appreciation of their own currency. Similarly, Bertaut and Grier (2004) document an increase in the portfolio weights of *foreign* long-term debt between 1997 until 2001 for Australia, Denmark, the Euro Area, the United Kingdom, and Sweden.

Based on these observations, we develop a two-country stochastic general equilibrium model of optimal portfolio choice and endogenous pricing currencies in which we analyze the relationship between the exchange rate pass-through and international financial integration in detail. In particular, starting from a world with trade in nominal bonds only, we add the possibility of trade in equity. The possibility for households to trade not only in nominal bonds but also in equities is interpreted as increased international financial market integration.<sup>4</sup> The expanded set of tradeable financial assets by equity

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<sup>1</sup>For example, Ihrig et al. (2006) report a statistically significant decline in the average exchange rate pass-through between 1975-1989 and 1990-2004 in the G-7 countries. Marazzi et al. (2005) and Otani et al. (2003) have established similar results concentrating on the U.S. and Japan, respectively. Campa et al. (2005)'s study of cross-country trade between EMU and non-EMU countries suggests also a decline in the exchange rate pass-through in a majority of countries. Also International Monetary Fund (2006b) shows a considerable fall of pass-through to import prices for Canada, France, Germany, Italy, Japan, the UK, and the US from 1975-89 to 1990-2002. Frankel et al. (2005) and International Monetary Fund (2006a) document a particular strong decline for emerging economies. HM Customs and Excise (2001) reports a reduction of the share of UK imports priced in pound sterling between 1999 and 2002 by 18 per cent. See also Taylor (2000) and Campa and Goldberg (2002).

<sup>2</sup>We use this time period throughout the paper due to the availability of data on currencies of foreign debt holdings. Appendix C provides a detailed description of the data.

<sup>3</sup>Arguably, falling transaction costs and reduced informational frictions have triggered this development and have increased the possibilities of countries to hedge against idiosyncratic risk by changing relative portfolio weights of domestic to foreign equity. This is particularly relevant for countries that started with less developed financial markets.

<sup>4</sup>Thus, the degree of international financial integration is measured by the amount of financial instruments available to insure against different types of risk. Kose et al. (2006) argue that this quantity-based measure is best suited to capture

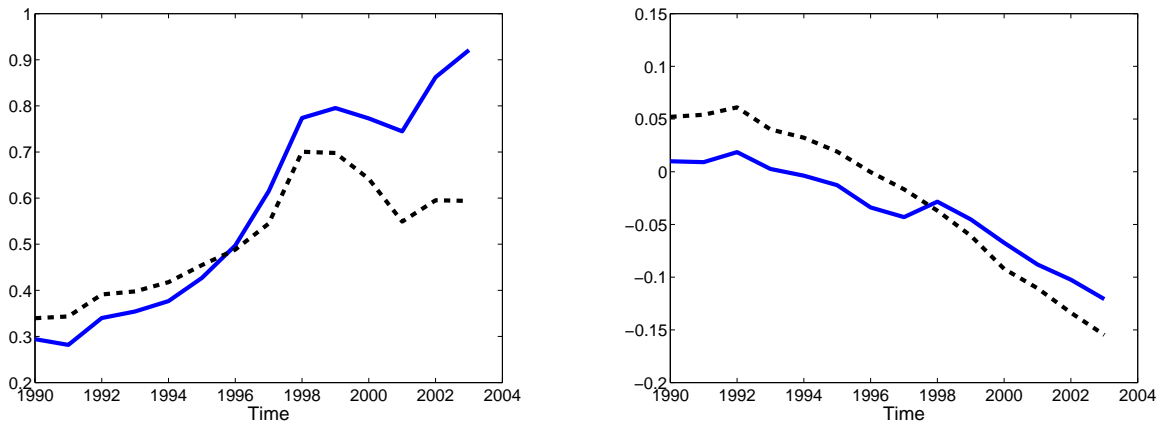


Figure 1: Sum of portfolio equity and FDI assets and liabilities over GDP (left, blue solid line) and divided by sum of debt assets and liabilities (left, black dashed line); average debt home bias over total debt (right, blue solid line) and divided by sum of debt assets and liabilities (right, black dashed line). Sources: Lane and Milesi-Ferretti (2007) and Lane and Shambaugh (2010).

allows agents in both countries to hedge more effectively, resulting in an increase of international trade in equity. Using both assets, in turn, frees debt from some of its burden to hedge against all shocks present in the economy. A fall in the home bias of international debt holdings obtains.

The re-balancing of optimal international cross-country asset holdings does not come without an effect on other variables in our general equilibrium model, especially the nominal exchange rate. Since the nominal exchange rate is the key variable when firms decide to pre-set their export price in their own currency (full exchange rate pass-through) or in the local currency (incomplete exchange rate pass-through), financial market deepening will also affect the firms export pricing decision. When deciding to sell the export good in their own or local currency firms compare their expected profits. As prices are pre-set the expected domestic revenues and, hence, profits increase one-to-one with a nominal exchange rate depreciation when selling in the local currency while exchange rate movements would not induce any changes in the cost of producing the export good. In contrast, when selling in their own currency, domestic revenues increase over proportionally with a depreciation of the nominal exchange rate due to the expenditure switching effect, which prevails in the case of full exchange rate pass-through. However, firms would have to meet the higher demand at the given price and have to adjust their labor inputs. This requires adjustments in marginal costs which increases expected total costs of firms. Exporting firms take this into account when deciding to set their export prices in their own or in local currency. Better hedging possibilities via deeper international financial markets stabilize countries' nominal spending and lead to less pronounced swings in the nominal exchange rate. Consequently, the positive effect exchange rate movements have on the firms expected revenue is mitigated. At the same time the deepening of international financial markets leads to a stronger correlation between exchange rate movements and expected costs. Both aspects induce firms to switch to local-currency pricing, as discussed in Devereux et al. (2004).<sup>5</sup> Consequently, when international financial integration internationally.

<sup>5</sup>In a previous version, Devereux and Engel (2004) find that switching from a bond-only international financial market to a complete set of state-contingent assets increases the importance of relative instead of absolute monetary stability for price setting. As their model features only monetary disturbances as a source of fluctuations and does not endogenize optimal portfolio decisions, we see our paper as complementary. Similarly, our analysis adds to the insights of Engel and Matsumoto

financial markets are more integrated the exchange rate pass-through declines.

Despite the importance of the exchange rate pass-through on welfare and optimal monetary policy, as well as the creation of a monetary union there have been relatively few explanations put forward in explaining the decline of the exchange rate pass-through.<sup>6</sup> For example, Taylor (2000) argues that in (increasingly prevailing) low-inflation environments the persistence of inflation is lower, which also reduces the persistence of cost changes and the incentives to change prices after exchange-rate movements. Campa and Goldberg (2005) confirm the negative correlation between lower inflation rates and lower pass-through, but attribute this to the shift of imports towards goods that exhibit a lower degree of pass-through. Our explanation that the falling exchange rate-pass-through is affected by the increased international financial integration does not contradict the above hypotheses and can indeed be one of several important factors explaining the decline in the exchange rate pass-through. By modeling this link, we combine two separate strands of literature. On the one hand, the above mentioned theoretical papers deal with the determinants and effects of local-currency pricing vs. producer-currency pricing, while the optimal international portfolio choice is subject of a distinct body of literature. Most importantly, we use the method developed by Devereux and Sutherland (2011) to solve for the optimal composition of each country's debt and equity portfolio in terms of currency denomination. The insights obtained within this paper might be particularly important for groups of countries that move towards a currency union. The preceding financial market integration can reduce exchange rate pass-through, lowering the costs of giving up the nominal exchange rate as a channel of adjustment after idiosyncratic shocks, see also Engel (2000) and Devereux and Engel (2003). To the best of our knowledge, this aspect of the endogeneity of optimum-currency-area criteria has not been explored so far.

The remainder of this paper is organized as follows. Section 2 describes our theoretical framework. Section A lays out the optimal portfolio choice under alternative assumption regarding financial markets, while section 3 describes the results regarding the interaction between international financial markets and the pricing currency choice. In section 4 we provide empirical evidence on the link between international financial integration and the increase in debt home bias, falling exchange-rate volatility, and the decline in the exchange rate pass-through. Section 5 concludes. In appendix A we solve the model for unrestricted parameter values, while appendix C lists the sources for all data used throughout the paper.

## 2 The Model

Having obtained some empirical indications for the importance of international equity trade in relation to debt holdings for explaining the decline in the exchange rate pass-through, we now present a formal analysis of the effects of international asset trade on the exchange rate pass-through. The analysis builds on Devereux and Engel (2003) and similar models. Our model will be able to confirm the

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(2009), who show that an explicit exchange-rate insurance can induce the same allocation as trade in a complete-markets setup. In our model with more shocks, bond and equity holdings serve as imperfect substitutes for such a insurance.

<sup>6</sup>Obstfeld and Rogoff (2000) have shown that with full exchange rate pass-through it is not desirable for countries to target the nominal exchange rate in terms of welfare. A floating exchange rate allows for the adjustment of relative prices and helps to stabilize output and other macroeconomic variables in response of an external shock. However, if exchange rate pass-through is incomplete the exchange rate becomes powerless to alter relative prices and, hence, the shock absorbing mechanism of a floating exchange rate evaporates (Devereux and Engel, 2003). An important consequence is that under these assumptions countries should adopt a monetary policy oriented at minimizing exchange rate fluctuations to improve welfare. Other studies showing the importance of pass-through include Betts and Devereux (1996, 2000), Engel (2000), and Obstfeld and Rogoff (2002).

empirical findings by allowing for both, an endogenous portfolio choice by households and optimal price-setting behavior by firms.

In a stochastic two-country world, agents of the home,  $H$ , and foreign,  $F$ , country produce traded goods. Both countries are of the same size and its inhabitants are indexed by numbers in the interval  $[0, 1]$ . Home agents consume a continuum of  $z$  differentiated home and foreign goods. Each household provides labor supply to the domestic monopolistic firms. Monopolistic firms set their prices prior to the realization of aggregate technology disturbances, monetary policy shocks and demand disturbances, induced by the fiscal authority in each country. They meet the demand at the pre-set price. Foreign country conditions, indicated by an asterisk, are defined analogously.

There are two periods. In period  $t = 0$  no output is produced and no consumption takes place but households trade assets in international financial markets *before* any shocks occur in the economies. Two different international financial asset markets are assessed. Households can either endogenously choose the amount of wealth they like to invest in home and foreign nominal bonds, or in either home and foreign nominal bonds as well as equities (i.e., claims on the future profits of foreign firms). Moving from an asset market where only nominal bonds are traded towards financial markets where both nominal bonds and equities are held is interpreted as international financial market integration. After asset trade has taken place firms decide whether to set their pre-set price of export goods either in their own currency (i.e., producer-currency pricing, PCP) or in the currency of the importing country (i.e., local-currency pricing, LCP). In period  $t = 1$  households decide about money balances, consumption, and labor supply, while firms produce and sell goods that consumers demand, once uncertainty is resolved.

**Preferences** Expected utility of the representative household is increasing in the aggregate consumption index  $C(i)$ , real balances  $M(i)/P$  and decreasing in the disutility of work effort  $L(i)$  in period 1:

$$U(i) = E_0 \left[ \frac{C(i)^{1-\rho} - 1}{1-\rho} + \chi \ln \frac{M(i)}{P} - K \frac{L(i)^v}{v} \right]. \quad (1)$$

The expectation operator across states of nature in period  $t = 1$  given date  $t = 0$  information is denoted by  $E_0$ . The parameter  $\rho > 0$  is the degree of relative risk aversion,  $v \geq 1$  is the inverse of the elasticity of labor supply while  $\chi$  and  $K$  are strictly positive parameters. Total labor supply  $L(i)$  of household  $i$  is distributed across  $z$  monopolistic firms in the traded goods sector,  $L(i) = \int_0^1 L(z) dz$ . The consumption index is a composite of domestic goods and goods produced abroad,

$$C(i) = \left( a^{\frac{1}{\eta}} C_H(i)^{\frac{\eta-1}{\eta}} + (1-a)^{\frac{1}{\eta}} C_F(i)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \quad \text{with } P = \left( a P_H^{1-\eta} + (1-a) P_F^{1-\eta} \right)^{\frac{1}{1-\eta}}, \quad (2)$$

reflecting the home consumer price index. The elasticity of substitution between home and foreign goods  $\eta > 0$  captures the sensitivity of the allocation between home and foreign goods with respect to relative price changes. For  $\eta > 1$ , home and foreign goods are substitutes. The parameter  $a = 1 - n/2$  measures the overall share of home goods in the home consumption basket (see Sutherland, 2005). Trade openness is measured by the parameter  $0 \leq n \leq 1$ . This formulation accounts for the empirical consumption bias towards tradable goods produced locally. Households give a higher weight to local than to foreign goods. In case of complete trade openness ( $n = 1$ ), there is no home bias in consumption and domestic as well as foreign households consume equal shares of home and foreign goods. In case of  $n = 0$ , both countries are completely closed. Consumption of home and foreign goods are each a constant-elasticity-of-substitution bundle of differentiated products, with  $\sigma > 1$  reflecting the elasticity of substitution between differentiated goods.

All home goods sold domestically by local firms are priced in domestic currency, resulting in the bundle  $C_H(i) = \left( \int_0^1 C_H(i, z)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}}$ , with the corresponding price index  $P_H = \left( \int_0^1 P_H(z)^{1-\sigma} dz \right)^{\frac{1}{1-\sigma}}$ . Imports can be priced either in the consumer's (LCP) or exporting firm's (PCP) currency. It is assumed that the fraction  $z$  ( $z^*$ ) of firms in home (foreign) country exhibits LCP, and the remaining fraction  $1 - z$  ( $1 - z^*$ ) is engaged in PCP, so that

$$C_F(i) = \left( \int_0^1 C_F(i, z)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}} \quad \text{and} \quad P_F = \left( \int_0^{z^*} P_F(z)^{1-\sigma} dz + \int_{z^*}^1 (SP_F^*(z))^{1-\sigma} dz \right)^{\frac{1}{1-\sigma}}. \quad (3)$$

The nominal exchange rate  $S$  reflects the home currency price of the foreign currency. Analogous conditions hold for the foreign country.

**International financial markets and budget constraints** We assume different international financial market structures reflecting an ongoing process of the international financial market integration and financial market deepening. In period  $t = 0$  international asset trade may take place in nominal bonds (NB) or in nominal bonds and equity shares (NBE). Moving from a financial market where only nominal bonds are traded towards financial markets where both bond and equity trade takes place is interpreted as increasing international financial integration. Thus, the degree of international financial integration is measured by the amount of financial instruments available to insure against different types of risk.

#### *Trade in bonds only*

When international financial markets are less integrated it is assumed that there is only trade in home and foreign nominal bonds in period  $t = 0$ . Bonds are in zero net supply in each period such that

$$B_H + B_H^* = 0 \quad \text{and} \quad B_F + B_F^* = 0, \quad (4)$$

where  $B_H$  ( $B_F$ ) are domestic (foreign) nominal bonds held by domestic households and  $B_H^*$  ( $B_F^*$ ) are domestic bonds held by foreign consumers. Home bonds are denominated in home currency and foreign bonds in foreign currency. Furthermore, we assume that the initial and final net foreign asset positions in both countries are zero so that

$$B_H = -S_0 B_F \quad \text{and} \quad B_H^* = -S_0 B_F^*,$$

when expressed in country  $H$  currency units. If a country goes short in its own bonds,  $B_H < 0$  ( $B_F^* < 0$ ), this implies that this country,  $H$  ( $F$ ), holds a positive position of foreign bonds,  $B_F$  ( $B_H^*$ ). Using (4) this can be written as

$$B_H^* = S_0 B_F \quad \text{and} \quad B_H = S_0 B_F^*.$$

We can thus express both bonds as  $B = B_H = S_0 B_F^*$ .  $B < 0$  then implies that country  $H$  borrows in domestic currency and lends in foreign currency.  $H$  would in this case benefit from a depreciation of its currency. At time  $t = 0$  the home household  $i$  faces the following budget constraint

$$p_B B_H - p_B^* S_0 B_F^* = 0. \quad (5)$$

Due to the initial symmetry, the foreign budget constraint at  $t = 0$  can be written as:  $p_B S_0 B_H^* + p_B^* S_0 B_F^* = -p_B B_H + p_B^* S_0 B_F^* = 0$ . Furthermore, the price for bonds is initially identical and

$S_0 = 1$ . Consequently,  $p_B = p_B^*$  holds. In period  $t = 1$  the representative household derives its income by supplying labor at the nominal wage rate, receiving nominal profits from domestic firms and returns from bond holdings determined in the previous period. Turning to the expenditure side, the household consumes, holds money  $M$ , and pays lump-sum taxes  $T$ . The budget constraints of the representative households in countries  $H$  and  $F$  in period  $t=1$  are then given by

$$\begin{aligned}\Pi + B_H - SB_F^* + WL &= PC + M - M_0 + T, \\ S\Pi^* - B_H + SB_F^* + SW^*L^* &= SP^*C^* + S(M^* - M_0^* + T^*),\end{aligned}\tag{6}$$

respectively. Total nominal profits from home and foreign sales of the domestic and foreign firms are  $\Pi$  and  $\Pi^*$ .  $W$  and  $W^*$  reflect the nominal wage rate at home and abroad. In case of only nominal bonds trade, the Euler equations that characterize the domestic household's optimal portfolio choice decision are given by

$$\lambda_0 p_B = E_0(\lambda), \quad \lambda_0 p_B^* = E_0(\lambda S),$$

where  $\lambda = \frac{C^{-\rho}}{P}$  is the Lagrange multiplier associated with the period  $t = 1$  budget constraint. Due to the initial symmetry  $p_B = p_B^*$ . The marginal benefits of both types of assets have to be equal in expected terms, if expressed in the same currency. Hence, the following equation defines the asset market equilibrium conditions at home and abroad,

$$E_0\left(\frac{C^{-\rho}}{P}\right) = E_0\left(\frac{C^{-\rho}}{P}S\right) \text{ and } E_0\left(\frac{C^{*-\rho}}{SP^*}\right) = E_0\left(\frac{C^{*-\rho}}{SP^*}S\right),\tag{8}$$

expressed in  $H$  currency units. Note that due to the zero net foreign asset positions, either no or both bonds will be held, such that the Euler equations have to hold for both bonds.

#### *Trade in bonds and equity*

If financial markets are integrated, two types of financial assets are traded, bonds and equities. The home agent then faces the following additional budget constraint at time  $t=0$ :

$$\phi p_E + (1 - \phi) S p_E^* = p_E,\tag{9}$$

where  $p_E$  ( $p_E^*$ ) is the price for a home (foreign) equity share and  $\phi$  ( $1 - \phi$ ) is the optimal amount of home (foreign) shares purchased by domestic consumers. The supply of each share is normalized to unity. Due to the initial symmetry, the foreign budget constraint at  $t = 0$  can be written as:  $(1 - \phi)p_E + \phi S p_E^* = S p_E^*$ . Consequently,  $p_E = S p_E^*$  holds. Initially, households fully own their local firms and the net foreign asset position is zero. Combining the budget constraints for trade in bonds (5) and in equities (9), we derive the relevant budget constraint in the NBE economy at time  $t=0$ :

$$p_B B_H - S_0 p_B^* B_F^* + \phi p_E + (1 - \phi) S_0 p_E^* = p_E.\tag{10}$$

In period  $t = 1$  the budget constraints of the representative consumers in countries  $H$  and  $F$  are then given by

$$\begin{aligned}\phi\Pi + (1 - \phi) S\Pi^* + B_H - SB_F^* + WL &= PC + M - M_{-1} + T, \\ \phi S\Pi^* + (1 - \phi) \Pi - B_H + SB_F^* + SW^*L^* &= SP^*C^* + S(M^* - M_{-1}^* + T^*),\end{aligned}\tag{11}$$

where the households derive their financial income from holding nominal bonds and receiving nominal profits from domestic and foreign firms according to the amounts of shares determined in the previous



period. For  $\phi > 0.5$  we have a home bias in equity holdings. For trade in equities, the Euler equations with respect to equity shares equalize the marginal costs of buying an additional unit of firms profits in period  $t=0$  to the marginal gains in period  $t=1$ . They are given by

$$\lambda_0 p_E = E_0(\lambda \Pi), \quad \lambda_0 p_E = E_0(\lambda S \Pi^*).$$

Plugging the Lagrange multiplier of the period  $t = 1$  budget constraint into the above equation, the Euler equations can be written as

$$E_0\left(\frac{C^{-\rho}}{P}\Pi\right) = E_0\left(\frac{C^{-\rho}}{P}S\Pi^*\right) \text{ and } E_0\left(\frac{C^{*-\rho}}{SP^*}\Pi\right) = E_0\left(\frac{C^{*-\rho}}{SP^*}S\Pi^*\right), \quad (12)$$

which define the asset market equilibrium condition at home and abroad.

**Fiscal and monetary authorities** The home government finances its consumption spending by means of taxes and seigniorage. Its budget constraint equals  $PG = T + M - M_{-1}$ , where  $T$  denotes lump-sum taxes. It is assumed that total government expenditure  $G$  is a random demand shift with a mean value of  $E_{-1}(G) = 0$  and a finite variance  $Var(G)$ . A similar expression holds for the foreign country. We assume that home and foreign government spending shocks are uncorrelated. Furthermore, the money supply in each country has a mean value of zero, i.e.,  $E_{-1}(M) = E_{-1}(M^*) = 0$  and a finite variance  $Var(M)$  and  $Var(M^*)$ , where the home and foreign monetary disturbances are uncorrelated.

## 2.1 First-order conditions

The above described setup gives rise to a number of first-order conditions. In particular the consumption Euler equations will depend on the assumed asset market structure, i.e., the number of internationally traded financial assets.

**Money demand and labor supply** In period  $t = 1$  the representative consumer maximizes her utility (1) with respect to consumption, money balances, and work effort subject to the budget constraint (6) or (11). The first-order conditions associated with money holdings and the labor supply decision imply

$$\frac{M}{P} = \chi C^\rho \text{ and } \frac{W}{P} = \frac{KL^{v-1}}{C^{-\rho}}, \quad (13)$$

respectively. The first-order condition associated with the labor supply decision implies that the marginal rate of substitution between consumption and leisure is equal to their relative price. As in Devereux and Engel (2004) we assume in the following that  $v = 1$ , which implies an infinite wage elasticity of labor supply. The foreign country has similar first-order conditions.

**Money market and the nominal exchange rate** The first order conditions associated with money holdings allow to express the money market conditions as functions of the nominal spending at home and abroad

$$PC = \frac{1}{\chi} \frac{M}{C^{\rho-1}} \text{ and } P^*C^* = \frac{1}{\chi} \frac{M^*}{C^{*\rho-1}}. \quad (14)$$

Expressing the two conditions in domestic currency units and solving for the nominal exchange rate yields

$$S = \frac{M}{M^*} \left( \frac{PC}{SP^*C^*} \right)^{-\rho} \left( \frac{SP^*}{P} \right)^{1-\rho} \quad (15)$$

The nominal exchange rate will be affected by the underlying international financial market integration since differences in nominal spending,  $\frac{PC}{SP^*C^*}$ , depend on the amount of assets to be traded, as shown by equations (6) and (11).

**Demand for goods** Domestic demand for home and foreign goods depends on the intra-temporal budget constraint

$$PC(i) = P_H C_H(i) + P_F C_F(i).$$

Maximizing (2) subject to the intra-temporal budget constraint leads to the following demand functions for home and foreign goods

$$C_H(i) = a \left( \frac{P_H}{P} \right)^{-\eta} C(i) \quad \text{and} \quad C_F(i) = (1-a) \left( \frac{P_F}{P} \right)^{-\eta} C(i), \quad (16)$$

with the following demand functions for individual home,  $C_H(z) = (P_H(z)/P_H)^{-\sigma} C_H$ , and foreign goods

$$\begin{aligned} C_F(i, z) &= \left( \frac{P_F^{LCP}(z)}{P_F} \right)^{-\sigma} C_F(i) && \text{for } z = 0, \dots, z^*, \\ C_F(i, z) &= \left( \frac{SP_F^{PCP}(z)}{P_F} \right)^{-\sigma} C_F(i) && \text{for } z = z^*, \dots, 1. \end{aligned} \quad (17)$$

Analogous demand functions apply for the foreign country. The government in each country consumes constant shares of local and foreign products, such that the home government demand for differentiated goods takes the same form as for the private demand functions (16) and (17),  $G_H = a (P_H/P)^{-\eta} G$  and  $G_F = (1-a) (P_F/P)^{-\eta} G$ . Consequently, the individual government demand function are the same as in (17) and also hold for the foreign country.

**Profits and Firms' price setting decision** Firms produce differentiated goods under monopolistic competition and hire labor  $L$  at the nominal wage rate  $W$ . In  $t=0$  firms set their prices by maximizing expected profits from sales in  $t=1$  and decide in which currency the prices of the export goods have to be set. The production function is given by

$$Y(z) = AL(z) = C_H(z) + G_H(z) + C_H^*(z) + G_H^*(z),$$

where  $A$  is the productivity parameter that can be seen as a random shift in productivity with a mean value of  $E_{-1}(\ln A) = 0$  and a finite variance  $Var(\hat{A})$ . A similar expression holds for the foreign country. We assume that both shocks are not correlated. The associated profits for domestic sales are

$$E_0(\pi) = E_0 \left[ d (P_H(z) - mc) \left( \frac{P_H(z)}{P_H} \right)^{-\sigma} \left( \frac{P_H}{P} \right)^{-\eta} D \right].$$

Profits are discounted with the discount factor  $d$  since firms are owned by domestic households and future profits from production will be evaluated according to the household's marginal utility of consumption  $d = C^{-\rho}/P$ .  $D$  denotes a home demand variable which consists of private  $((1-a)C)$  and

state  $((1 - a)G)$  consumption and is independent of prices.<sup>7</sup> Marginal costs are equal to

$$mc = \frac{W}{A}. \quad (18)$$

The profit-maximizing price for domestic sales of an individual home firm equals

$$P_H(z) = \frac{\sigma}{\sigma - 1} E_0 \frac{mc C_H d}{E_0(C_H d)},$$

given the respective individual demand functions. When firms decide whether to set the export price in their own currency (PCP) or in the local currency (LCP), they compare their expected profits from selling in PCP or LCP. The expected profit function of a home firm from sales to the foreign country in local currency can be written as

$$E_0(\pi^{LCP}) = E_0 d (SP_H^{*LCP}(z) - mc) \left( \frac{P_H^{*LCP}(z)}{P_H^*} \right)^{-\sigma} \left( \frac{P_H^*}{P^*} \right)^{-\eta} D^*. \quad (19)$$

The profit-maximizing price for local-currency pricing firms is  $P_H^{*LCP}(z) = \frac{\sigma}{\sigma - 1} E_0 mc Z^* / E_0(SZ^*)$ , for  $z = 0, \dots, z$ , with  $Z^* = dP_H^{*\sigma - \eta} P^{*\eta} D^*$ . Using this solution, the expected discounted profits from export sales in the local currency are

$$E_0(\pi^{LCP}) = \tilde{\sigma} (E_0 S Z^*)^\sigma (E_0 mc Z^*)^{1 - \sigma}, \quad (20)$$

where  $\tilde{\sigma} = 1/(\sigma - 1)(\sigma/(\sigma - 1))^{-\sigma}$ . The first term of the right-hand side of equation (20) reflects the expected revenues from sales while the second term shows the cost component of expected profits. Thus, revenues and therefore profits under LCP are linear in the nominal exchange rate. This means that under LCP domestic currency revenues increase one-to-one with a nominal exchange rate depreciation. Costs are unaffected by changes in the nominal exchange rate since exchange-rate movements do not induce any demand changes. This can be seen more clearly when taking a second-order approximation of expected profits under LCP

$$E_0(\hat{\pi}^{LCP}) \propto \sigma \frac{Var(\hat{S})}{2} - (\sigma - 1) \left[ \frac{Var(\hat{mc})}{2} + \frac{Var(\hat{Z}^*)}{2} + Cov(\hat{mc}, \hat{Z}^*) \right], \quad (21)$$

where  $\hat{X} = \ln X - \ln \bar{X}$  denotes the percentage deviation of the variable  $X$  from its steady state  $\bar{X}$ ,  $Var(\hat{X}) = E_0((\hat{X})^2)$  its variance and  $Cov(\hat{X}, \hat{Y}) = E_0(\hat{X} \cdot \hat{Y})$  its covariance with variable  $Y$ . Equation (21) shows that expected profits under LCP are increasing in nominal exchange rate changes via expected revenues. Furthermore, changes in the nominal exchange rate do not affect expected costs. The expected profit function of a home firm from sales to the foreign country in producer currency can be written as

$$E_0(\pi^{PCP}) = E_0 d (P_H^{PCP}(z) - mc) \left( \frac{P_H^{PCP}(z)}{SP_H^*} \right)^{-\sigma} \left( \frac{P_H^*}{P^*} \right)^{-\eta} D^*. \quad (22)$$

The corresponding profit-maximizing price for firms that employ producer-currency pricing is then given by  $P_H^{PCP}(z) = \frac{\sigma}{\sigma - 1} E_0 mc S^\sigma Z^* / E_0(S^\sigma Z^*)$ , for  $z = z, \dots, 1$ . Using this solution, the expected discounted profits from export sales in the producer currency are given as

$$E_0(\pi^{PCP}) = \tilde{\sigma} (E_0 S^\sigma Z^*)^\sigma (E_0 mc S^\sigma Z^*)^{1 - \sigma}. \quad (23)$$

<sup>7</sup>Given that each firm is a monopolistic producer, profits will be positive for a finite  $\sigma > 1$ .

Under PCP, expected profits are convex in the nominal exchange rate since  $\sigma > 1$ . Then, due to the expenditure-switching effect a nominal exchange rate depreciation increases foreign demand for domestic goods by more than one since  $\sigma > 1$ . This means that ceteris paribus, with a rise in nominal exchange rate expected, revenues from sales under PCP increase relatively to LCP. However, in contrast to LCP a change in the nominal exchange rate directly impacts expected costs and hence expected profits negatively. Both points can be illustrated by taking a second-order approximation of expected profits under PCP:

$$E_0(\widehat{\pi}^{PCP}) \propto \sigma^2 \frac{Var(\widehat{S})}{2} - (\sigma - 1) \left[ \frac{Var(\widehat{mc})}{2} + \frac{Var(\widehat{Z}^*)}{2} + Cov(\widehat{mc}, \widehat{Z}^*) + \sigma Cov(\widehat{mc}, \widehat{S}) \right], \quad (24)$$

Under PCP, nominal exchange rate variability increases revenues by more than one, as  $\sigma > 1$ , due to the expenditure-switching effect. However, changes in the nominal exchange rate induce demand changes under PCP. As the firm has to meet the demand the given price it has to adjust its labor inputs. A higher variability in production inputs requires adjustments in firms marginal costs which affects expected costs negatively, so that  $Cov(\widehat{mc}, \widehat{S}) > 0$ . Thus, a positive covariance between the nominal exchange rate and marginal costs leads to an increase in expected total costs under PCP relatively to total costs under LCP. This fact will be of importance when assessing the role of international financial market integration on the export price setting behavior of firms. As financial integration affects the behavior of the nominal exchange rate it will influence the price setting decision of firms. Following Devereux et al. (2004) and subtracting (21) from (24), we obtain the decision rule of the home firm whether to set its export price in its own or the local currency. The firm will set its price in PCP (LCP) as long as expected profits under PCP (LCP) are higher than under LCP (PCP), such that a firm's decision rule becomes

$$\frac{Var(\widehat{S})}{2} - Cov(\widehat{mc}, \widehat{S}) > 0, \quad (< 0). \quad (25)$$

The optimal pricing currency condition (25) holds under the assumption that the discount factor, prices of other firms, foreign total demand and foreign prices are initially exogenous to an individual firm and its pricing currency decision. Analogously, we can think about a foreign firm exporting to the domestic economy and its optimal pricing currency decision. The foreign firm has similar profit structures and will decide to price its exports in the foreign (home) currency if

$$\frac{Var(\widehat{S})}{2} + Cov(\widehat{mc}^*, \widehat{S}) > 0, \quad (< 0). \quad (26)$$

## 2.2 Equilibrium and steady state

The above described optimality and market clearing conditions are used to determine the endogenous variables in equilibrium – in particular, the bond,  $b$ , and equity portfolios,  $\phi$ , as well as the equilibrium exchange rate pass-through,  $1 - z(1 - z^*)$ . The rational expectations equilibrium is a set of values for consumption, output, labor, real wages, prices and the optimal portfolio shares, given the distribution of shocks to technology, government spending and money supplies at home and abroad,  $(A, A^*, G, G^*, M, M^*)$ . The model is solved by log-linearizing around the symmetric steady state where the economic disturbances equal unity.

Within the steady state a country's revenue is given by  $\overline{REV} = \overline{Y} \overline{P}_H = \overline{PC}$ . Then it follows that profits and labor income are shares of a country's income, given by  $\overline{\Pi} = (1/\sigma)\overline{REV}$  and  $\overline{WL} = ((\sigma - 1)/\sigma)\overline{REV}$ , respectively. Given the symmetry across countries, purchasing power parity holds within the steady state, so that  $\overline{SP}^* = \overline{P}$ . Furthermore, individual prices are given by  $\overline{P}_H = ((\sigma -$

1)/ $\sigma$ ) $\overline{W}/\overline{A}$ . As the two countries are identical in the steady state it follows that the law of one price holds within and across goods,  $\overline{P}_H = \overline{SP}_H^* = P_F = \overline{SP}_F^*$ . Having described the optimal pricing conditions, the equilibrium and steady state we will now show how the integration of international asset markets affect the exchange rate pass-through via the composition of asset traded within financial markets.

### 3 Financial Markets and the falling exchange rate pass-through

Having described the optimal pricing conditions we will show how the integration of international asset markets affect in equilibrium the nominal exchange rate behavior, which is the main variable in the exporting firms' choice to set their price in their own or local currency, and the exchange rate pass-through. To analytically illustrate the mechanisms at work we first make a set of simplifying assumptions. Section 3.2 reports results of numerical simulations of the unrestricted model, whose solution together with additional intuition is presented in appendix A. In the following we draw on this solution for deriving the simplified version.

#### 3.1 Analytical solution for the simple model structure

As a first step, we assume that there is no home bias in household and government consumption, such that  $a = 0.5$ . Furthermore, we assume log-utility, i.e.,  $\rho = 1$  and that the elasticity of substitution between home and foreign traded goods,  $\eta$ , equals unity.<sup>8</sup> This allows us to derive a closed-form solution. With the solution at hand we first discuss the portfolio allocation outcome and then show how it relates to the price-setting behavior of firms.

##### 3.1.1 The nominal exchange rate

The money market equilibrium allows to solve for the nominal exchange rate. Expressing (15) in log-linear terms yields

$$\widehat{S} = (\widehat{M} - \widehat{M}^*) + (\widehat{PC} - \widehat{SP}^*C^*). \quad (27)$$

In equilibrium the nominal exchange rate will not only be affected by the relative money supplies but also via the differences in nominal spending,  $\widehat{PC} - \widehat{SP}^*C^*$ , by the amount of assets traded. To see this consider in turn the households budget constraint at home and abroad when only bonds are traded or with trade in both bonds and equity.

##### 3.1.2 Trade in bonds only

Consider first equations (6) and (7), which show that relative nominal spending in the case of trade in bonds equates to

$$\widehat{PC} - \widehat{SP}^*C^* = -2b\widehat{S} + (\widehat{REV} - \widehat{SREV}^*) - (\widehat{G} - \widehat{G}^*). \quad (28)$$

The financial return to the bond holdings  $b$  is given by nominal exchange rate deviations,  $-\widehat{S}$  while relative sales revenues are the non-financial income. We define  $b \equiv \overline{B}/(\overline{PC})$ ,  $\widehat{G} = G/\overline{C}$ ,  $\widehat{REV} =$

<sup>8</sup>The assumption of  $\eta = 1$  implies Cobb-Douglas preferences. In this case, the terms of trade provide a risk-sharing role, as shown by Cole and Obstfeld (1991), and the asset market structure might not be relevant. However, this is only true when there are only productivity shocks and international asset positions are zero. In the case of demand shocks, such as government spending shocks, risk sharing requires relative income to move asymmetrically, which might also cause non-zero asset positions.

$\widehat{\Pi} - \widehat{WL}$  and we have used the fact that  $B_H = B_F^*$  for  $S_0 = 1$ .  $\bar{B}$  is the equilibrium amount of bonds we are looking for. Given equations (28), we can express the nominal exchange rate (27) in the economy with trade in bonds only as

$$\widehat{S} = \left( \frac{1}{1-2b} \right) (\widehat{M} - \widehat{M}^*) + \left( \frac{1}{1-2b} \right) (\widehat{G} - \widehat{G}^*), \quad (29)$$

given that  $\widehat{REV} - \widehat{SREV}^* = 0$  in our simple model structure. Given the insurance properties in the economies with nominal bonds only, the exchange rate only transmits two of the three possible economic disturbances across countries. The impact effect of the shocks is affected by the size of the equilibrium portfolio holding of  $b$ . The fact that not all disturbances are transmitted via the nominal exchange rate has direct implications for the price setting decision of the firm. To see this more clearly, consider the log-linearized version of the home marginal costs, equation (18), and its foreign counterpart

$$\widehat{mc} = \widehat{M} - \widehat{A} \text{ and } \widehat{mc}^* = \widehat{M}^* - \widehat{A}^*, \quad (30)$$

respectively, given equation (13). It follows that the covariance between marginal costs and the nominal exchange rate can be written as

$$Cov(\widehat{mc}, \widehat{S}) = \frac{Var(\widehat{M})}{1-2b} \text{ and } Cov(\widehat{mc}^*, \widehat{S}) = -\frac{Var(\widehat{M}^*)}{1-2b}, \quad (31)$$

respectively. Note that when nominal bonds are traded only monetary disturbances affect the covariance relationship between marginal costs and the nominal exchange rate. Since all shocks are uncorrelated, the variance of the nominal exchange rate equals

$$Var(\widehat{S}) = \frac{Var(\widehat{M} + \widehat{M}^*)}{(1-2b)^2} + \frac{Var(\widehat{G} + \widehat{G}^*)}{(1-2b)^2}, \quad (32)$$

with  $Var(\widehat{G} + \widehat{G}^*)$  and  $Var(\widehat{M} + \widehat{M}^*)$  reflecting the sum of variances of the government spending and monetary policy shocks. The magnitude of the covariance relationship and the variability of the nominal exchange rate, however, will depend on the equilibrium bond holding  $b$ .

What will be the amount of equilibrium bonds  $b$  hold within this financial market structure? Consider the equilibrium evolution of the nominal exchange rate (29) together with the equilibrium consumption, equation (13), which can be stated as

$$\widehat{C} = \widehat{M} - \frac{(1-z^*)}{2} \widehat{S}. \quad (33)$$

It then follows that a positive monetary policy shock, i.e.,  $\widehat{M} > 0$ , will increase consumption, despite the depreciation, i.e. increase of the nominal exchange rate.<sup>9</sup> In contrast, a positive disturbance to government spending, i.e.,  $\widehat{G} > 0$ , will also cause a depreciation of the nominal exchange rate but this in turn will cause a decline in consumption. The latter effect dominates, as a relatively higher domestic government shock also causes a decline in relative nominal spending, which is determined by (28),  $\widehat{PC} - \widehat{SP}^*C^* = -2b\widehat{S} - (\widehat{G} - \widehat{G}^*)$ . Households can hedge against the risk of a decline in consumption and nominal spending by choosing the appropriate equilibrium bond portfolio such that  $-2b\widehat{S} > 0$ . Foreign bonds, i.e.,  $b < 0$ , are a good hedge against income risk if a higher domestic government spending causes a depreciation of the nominal exchange rate and, hence, a higher return on

<sup>9</sup>To ensure that a depreciation occurs it needs to be the case that  $b < 0.5$ , a condition shown to be satisfied.

foreign bonds. Thus, given that the relative financial return of nominal bonds holding is  $-\widehat{S}$ , holding foreign currency bonds would allow households to hedge against unexpected nominal exchange rate depreciations due to domestic government disturbances. In such a case the country will receive net financial payments from abroad when its currency is unexpectedly weak. To obtain the equilibrium portfolio choice of  $b$  we follow an approximation method for computing the equilibrium portfolio positions developed by Devereux and Sutherland (2011) and take a second-order approximation of the asset market equilibrium condition for the home country (8) and its foreign counterpart. The full details of the derivations are found in the appendix. From (A-8) the solution to the equilibrium bond portfolio is then given by

$$b = -\frac{Var(\widehat{G} + \widehat{G}^*)}{2Var(\widehat{M} + \widehat{M}^*)}. \quad (34)$$

The equilibrium bond position implies that the home country lends in the foreign currency and borrows in its own since  $b < 0$ . Thus, in states when the domestic currency is weak the equilibrium bond positions ensure that the home country will receive net payments from abroad to insure against country specific shocks. This effect is more pronounced the larger are the variances of government spending relative to money supply shocks.

Since the home country decides to hold a larger amount of foreign assets, i.e.,  $b < 0$ , the covariance between marginal costs and the nominal exchange rate (31) will be low in absolute value. From (32) it follows that the variance of the nominal exchange rate is decreasing in the home country's foreign asset position, i.e., the smaller is  $b$ . This has direct implications for the home firm's pricing decision. For illustrative purposes we consider a symmetrical equilibrium where all home and foreign shock variances are identical. The firm's decision rule to either price its exports in its own or local currency can be written as (see equations 25 and 26)

$$\mathcal{R}^{NB} \equiv \frac{Var(\widehat{S})}{2} - Cov(\widehat{mc}, \widehat{S}) = \frac{1 + 2b}{(1 - 2b)^2}. \quad (35)$$

Equation (35) shows that the decision of firms to set their export prices either in their own currency (PCP) or in the currency of consumers (LCP) depends on the equilibrium allocation of  $b$ . For example, if the equilibrium bond position is  $b > -1/2$ , it follows from (35) that  $\mathcal{R}^{NB} > 0$  and firms will decide to price their export goods in the domestic currency. However, if the asset position  $b$  is  $b < -1/2$ , firms will decide to price exports in the foreign currency, as  $\mathcal{R}^{NB} < 0$ . Given the symmetric equilibrium with home and foreign shock variances being identical, the equilibrium bond position equals  $b = -1/2$ . This implies that  $\mathcal{R}^{NB} = 0$ . Consequently, in the NB economy home firms will be indifferent between setting their export prices in PCP or LCP. The same argument applies to the foreign country. As  $\mathcal{R}^{NB} = 0$ , the price setting incentives will depend on what other exporting firms do. If all exporting firms follow PCP, then any single firm would have an incentive to deviate and choose LCP. But if all firms follow LCP, then any single firm would have an incentive to deviate and choose PCP. Thus, there is no equilibrium where all firms follow the same pricing policy. By continuity, an intermediate equilibrium exists in which some firms choose PCP and some firms decide on LCP (see Devereux et al. 2004). Consequently, there is neither full nor zero exchange rate pass-through, i.e.,  $0 < z = z^* < 1$ .

### 3.1.3 Trade in bonds and equities

When financial markets become more integrated, households have the possibility to trade not only nominal bonds internationally but also equities,  $\phi$ . Since those assets have a different risk profile,

the two countries exchange assets to smooth fluctuations in consumption (spending) across different states of nature.

When both nominal bonds and equities are traded we linearize the period  $t = 1$  budget constraint for the home country and its foreign counterpart, (11). Taking country differences yields

$$\widehat{PC} - \widehat{SP^*C^*} = \frac{(2\phi - 1)}{\sigma}(\widehat{\Pi} - \widehat{S\Pi^*}) - 2b\widehat{S} - (\widehat{G} - \widehat{G^*}) + \frac{\sigma - 1}{\sigma}(\widehat{WL} - \widehat{S\widehat{W^*L^*}}). \quad (36)$$

In equilibrium the return on equities,  $\widehat{\Pi} - \widehat{S\Pi^*}$ , and labour income,  $\widehat{WL} - \widehat{S\widehat{W^*L^*}}$ , is given by

$$\widehat{\Pi} - \widehat{S\Pi^*} = \frac{(\sigma - 1)}{\sigma} \left[ (\widehat{A} - \widehat{A^*}) - (\widehat{M} - \widehat{M^*}) + \frac{z + z^*}{2}\widehat{S} \right], \quad (37)$$

and

$$\widehat{WL} - \widehat{S\widehat{W^*L^*}} = \frac{\frac{(z+z^*)}{2}}{1 - \zeta} \left[ \frac{(2\phi - 1)}{\sigma}(\widehat{\Pi} - \widehat{S\Pi^*}) - 2b\widehat{S} + (\widehat{M} - \widehat{M^*}) - (\widehat{G} - \widehat{G^*}) - \frac{(\widehat{A} - \widehat{A^*})}{\frac{z+z^*}{2}} \right],$$

with  $\zeta = \frac{\sigma - 1}{\sigma} \frac{(z + z^*)}{2}$ . Given equation (36) we can express the nominal exchange rate (28) in the economy as

$$\widehat{S} = \frac{-(2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1)(\widehat{M} + \widehat{M^*}) + (\widehat{G} + \widehat{G^*}) + (2(1 - \phi)\frac{\sigma - 1}{\sigma})(\widehat{A} + \widehat{A^*})}{(2b - 2(\phi - 1)\zeta - 1)}. \quad (38)$$

Again, the equilibrium outcome of the nominal exchange rate depends on the equilibrium portfolio allocation, here bonds,  $b$ , and equities,  $\phi$ . Furthermore, in contrast to the economy where only nominal bonds can be traded, the holding of both, bonds and equities allows the exchange rate to transmit all three economic disturbances across countries. From (30) and (38) it follows that the covariance between marginal costs and the nominal exchange rate can now be written as

$$\begin{aligned} Cov(\widehat{mc}, \widehat{S}) &= -\frac{2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1}{2b - 2(\phi - 1)\zeta - 1}Var(\widehat{M}) - \frac{2(\phi - 1)\frac{\sigma - 1}{\sigma}}{2b - 2(\phi - 1)\zeta - 1}Var(\widehat{A}), \quad (39) \\ Cov(\widehat{mc^*}, \widehat{S}) &= \frac{2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1}{2b - 2(\phi - 1)\zeta - 1}Var(\widehat{M^*}) + \frac{2(\phi - 1)\frac{\sigma - 1}{\sigma}}{2b - 2(\phi - 1)\zeta - 1}Var(\widehat{A^*}), \end{aligned}$$

Now, all shocks that affect marginal costs will also be reflected in the covariance relationship with the nominal exchange rate. Thus, the covariance relationship between marginal costs and the nominal exchange rate is not only affected by monetary disturbances, as in economy where only nominal bonds are traded internationally, but also by productivity disturbances. The variance of the nominal exchange rate equals

$$\begin{aligned} Var(\widehat{S}) &= \frac{(2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1)^2Var(\widehat{M} + \widehat{M^*}) + Var(\widehat{G} + \widehat{G^*})}{(2b - 2(\phi - 1)\zeta - 1)^2} \\ &\quad + \frac{(2(\phi - 1)\frac{\sigma - 1}{\sigma})^2Var(\widehat{A} + \widehat{A^*})}{(2b - 2(\phi - 1)\zeta - 1)^2}. \quad (40) \end{aligned}$$

For a given monopolistic markup,  $\sigma/(\sigma - 1)$ , the sign and magnitude of the variance of the nominal exchange rate and its covariance with marginal costs will depend on both the equilibrium amount of bonds and equities held as well as the global incomplete exchange rate pass-through  $(z + z^*)/2$ .



The higher is this expression, the lower will be the exchange rate pass-through. What determines the equilibrium portfolio within this economy? From equilibrium consumption, equation (13), and

$$\widehat{C} = \widehat{M} - \frac{(1 - z^*)}{2} \widehat{S}, \quad (41)$$

it follows that in states of nature when the domestic currency is unexpectedly weak, consumption would be low. Households can hedge by choosing a combination of nominal bond and equity holdings that stabilizes relative nominal consumption. For example, a depreciated currency would cause a decline in consumption but would have a favorable impact on the returns of equities, (37), since  $\widehat{\Pi} - \widehat{S}\Pi^*$  rises as the nominal exchange rate increases. Thus, if households hold mainly domestic equities and at the same time choose a bond allocation that provides net payments in states when the domestic currency is unexpectedly weak (i.e.,  $b < 0$ ) a higher nominal income is ensured, given (36). Again, following an approximation method for computing the equilibrium portfolio positions developed by Devereux and Sutherland (2011) the solution to the equilibrium bond position is

$$b = -\frac{Var(\widehat{G} + \widehat{G}^*)[Var(\widehat{A} + \widehat{A}^*) + \frac{2-z-z^*}{2}Var(\widehat{M} + \widehat{M}^*)]}{2Var(\widehat{A} + \widehat{A}^*)Var(\widehat{M} + \widehat{M}^*)}, \quad (42)$$

while the equilibrium equity position turns into

$$\phi = \frac{2Var(\widehat{A} + \widehat{A}^*) + \frac{\sigma}{\sigma-1}Var(\widehat{G} + \widehat{G}^*)}{2Var(\widehat{A} + \widehat{A}^*)}. \quad (43)$$

Equations (42) and (43) illustrate that expanding the set of tradeable financial assets by equity allows agents in both countries to hedge more effectively since now households can hedge against productivity disturbances, which is not possible in the NB economies. Households decide to hold a higher amount of foreign bond assets, i.e.,  $b < 0$ , and a larger amount of domestic equity,  $\phi > 1$ . This ensures them an optimal hedge against fluctuations in spending due to disturbances in government, monetary policy and productivity.

In contrast to the NB economy, the equilibrium bond position is affected by the exchange rate pass-through  $z$  and  $z^*$ . Hence, to specify the equilibrium outcome in the NBE economies it is necessary to have a closer look at the firms' price setting decision rules. Using (39) and (40), in the symmetric equilibrium the home firms' pricing decision rule (25) can be expressed as

$$\mathcal{R}^{NBE} = \frac{2(\phi - 1) \left[ 4\frac{\sigma-1}{\sigma}(\phi - 1) \left( \frac{\sigma-1}{\sigma} - \zeta \right) - \zeta \right] + 1 + 2b \left[ 1 + 4(\phi - 1)\frac{\sigma-1}{\sigma} \right]}{[2b - 2(\phi - 1)\zeta - 1]^2},$$

Since we are assuming a symmetric equilibrium. We assess the decision rule  $\mathcal{R}^{NBE}$  between  $z = z^* = 0$  and  $z = z^* = 1$ , changing the value of  $\zeta$ . Then

a) PCP is a unique equilibrium if

$$b > -\frac{1}{2} \frac{1 + \left[ 4(\phi - 1)\frac{\sigma-1}{\sigma} \right]^2}{1 + 4(\phi - 1)\frac{\sigma-1}{\sigma}} \text{ and } b > -\frac{1}{2} \frac{1 - 2(\phi - 1)\frac{\sigma-1}{\sigma}}{1 + 4(\phi - 1)\frac{\sigma-1}{\sigma}},$$

which ensures that  $\mathcal{R}^{NBE} > 0$  for all  $z$ .

b) LCP is the unique equilibrium if

$$b < -\frac{1}{2} \frac{1 + [4(\phi - 1) \frac{\sigma-1}{\sigma}]^2}{1 + 4(\phi - 1) \frac{\sigma-1}{\sigma}} \text{ and } b < -\frac{1}{2} \frac{1 - 2(\phi - 1) \frac{\sigma-1}{\sigma}}{1 + 4(\phi - 1) \frac{\sigma-1}{\sigma}},$$

which ensures that  $\mathcal{R}^{NBE} < 0$  for all  $z$ .

c) a mixture between PCP and LCP is a unique equilibrium for  $0 < \tilde{z} < 1$  if

$$b < -\frac{1}{2} \frac{1 + [4(\phi - 1) \frac{\sigma-1}{\sigma}]^2}{1 + 4(\phi - 1) \frac{\sigma-1}{\sigma}} \text{ and } b > -\frac{1}{2} \frac{1 - 2(\phi - 1) \frac{\sigma-1}{\sigma}}{1 + 4(\phi - 1) \frac{\sigma-1}{\sigma}},$$

which ensures that  $\mathcal{R}^{NBE} = 0$  for  $\tilde{z}$ .

As we have assumed a symmetric equilibrium, the markup  $\sigma/(\sigma - 1)$  is the driving coefficient that decides about the equilibrium outcome. Martins et al. (1996) find markups ranging between 10 and 35 percent, which implies a  $\sigma$  in the range of around 4 to 10. For markups in this range, it holds that the pricing decision rule  $\mathcal{R}^{NBE} < 0$  for all  $z$ . Consequently, the equilibrium value of  $z$  equals 1 and the global incomplete exchange rate pass-through for  $z = z^*$  equals 0. Thus, there is no global short-run exchange rate pass-through. Consequently, when moving towards internationally more integrated financial markets, i.e., moving from the nominal bond economy to an economy where both bonds and equities are traded internationally, the global exchange rate pass-through declines. The solution for  $z$  implies that the equilibrium bond position will be equal to  $-1/2$ .

What explains the decline in exchange rate pass-through? It is the possibility to hedge more effectively against country-specific shocks by balancing the optimal international cross-country asset holdings between equity and bond holdings. By trading equities additional to bonds, the agents stabilize their consumption fluctuations and, consequently, relative nominal spending is less volatile under more integrated international financial markets. To see this more clearly, consider nominal spending in the NB and NBE economies. Using (29) as well as (34) and taking expectations, the variance of relative nominal spending, equation (28), can be written as

$$Var(\widehat{PC} - \widehat{SP^*C^*})^{NB} = \frac{(2b)^2 Var(\widehat{M} + \widehat{M}^*) + Var(\widehat{G} + \widehat{G}^*)}{(1 - 2b)^2},$$

while in the NBE economy, given (40), (42) and (43), the variance of relative nominal spending equals

$$Var(\widehat{PC} - \widehat{SP^*C^*})^{NBE} = \frac{Var(\widehat{M} + \widehat{M}^*) + Var(\widehat{A} + \widehat{A}^*) + Var(\widehat{G} + \widehat{G}^*)}{[2(b + (1 - \phi)\zeta) - 1]^2}.$$

It follows that the impact effect of any economic disturbance on nominal spending will be smaller in the NBE economies since for a given symmetric shock it holds that  $1/(1 - 2b)^2 > 1/[2(b + (1 - \phi)\zeta) - 1]^2$ . Thus, the more integrated financial markets are the better can households hedge against fluctuation in nominal spending. The lower volatility of nominal spending has a stabilizing effect on the nominal exchange rate, which is the main variable in the firm's pricing decision rule (25). Furthermore, the covariance of the exchange rate with marginal costs increases if not only bonds but also equities are traded across countries due to the transmission of productivity shocks by the nominal exchange rate in the NBE economies. Given (31) and (39), it therefore holds that  $Cov(\widehat{mc}, \widehat{S})^{NBE} > Cov(\widehat{mc}, \widehat{S})^{NB} > 0$  for  $[4(\phi - 1) \frac{\sigma-1}{\sigma} + 1] / (1 + 2((\phi - 1)\zeta - b)) > 1/(1 - 2b)$ . Those aspects will induce firms to switch to local-currency pricing. This then causes a decline in exchange rate pass-through when international financial markets become more integrated.

### 3.2 A more general model structure

In the previous section we concentrated on the model’s main implication within a simplified framework. The results obtained in this setting are, however, conditional on the simplifying assumption we have made with respect to the preference parameters and the shocks that can hit the two economies. In this section we relax the above made assumptions about the model’s structural parameter values of  $a$ ,  $\rho$  and  $\eta$  and are more general regarding the volatility of shocks. By numerically simulating the model for a variety of parameter values it will be shown that the result of a decline in the exchange rate pass-through remains valid within this more realistic setting. Furthermore, under the more general parameterization we establish a fall in the home bias of bond portfolio holdings. The simulations use the solution of the full model in appendix A.

We use parameter values, where applicable, from Devereux et al. (2004). In particular, we set the trade price elasticity between domestically produced and imported goods to  $\eta = 1.5$ . The coefficient of relative risk aversion is set to  $\rho = 1.25$ . Trade openness is calibrated to  $a = 0.88$ , the empirical average for the US over recent decades (see Enders and Müller 2009.) The elasticity of substitution between varieties is set to  $\sigma = 6$ , corresponding to a steady-state markup of 20%. To obtain values for the variances of the shocks, we estimate AR(1)-processes for the HP-filtered logs of M2, Government consumption, and Solow residuals for the US. The resulting variances of the error terms result in  $\sigma_M^2 = 0.43\%$ ,  $\sigma_G^2 = \sigma_{G^*}^2 = 0.45$ , and  $\sigma_A^2 = \sigma_{A^*}^2 = 0.41$ . The foreign volatility of the money supply is set 10% higher,  $\sigma_{M^*}^2 = 0.47$ , such that firms are not indifferent regarding the pricing currency decision in the bonds-only case. For all these parameters, as well as for  $\rho$  and  $\eta$ , we conduct robustness checks further below.

#### 3.2.1 Interaction between portfolio home bias and pass-through

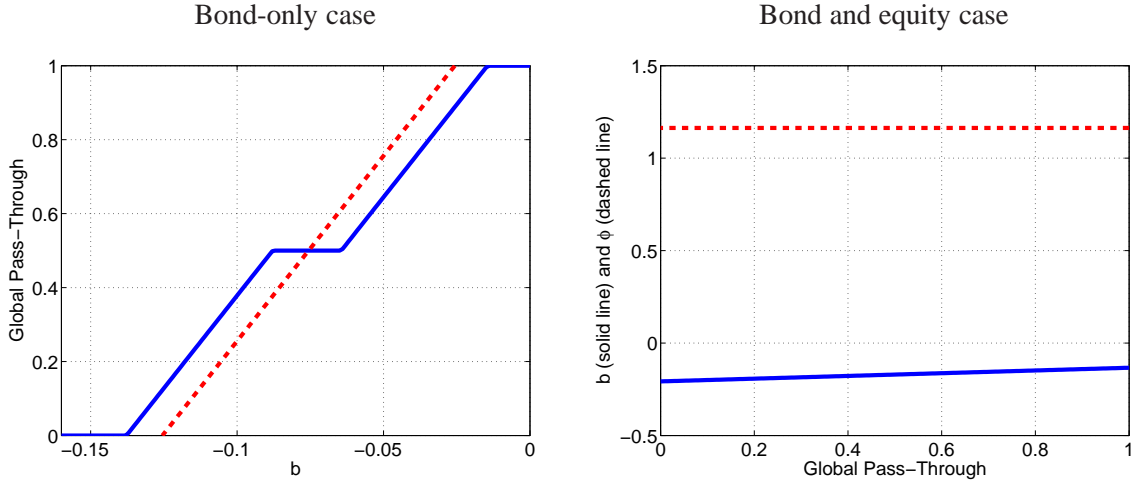


Figure 2: Left: dependence of global pass-through on debt home bias (blue solid line) and vice versa (red dashed line) in bond-only case. Right: dependence of debt home bias (blue solid line) and equity home bias (red dashed line) on global pass-through in bond and equity case.

Before investigating the effects of shifting from bond-only economies to a world with bond and equity trade, we first analyze the interaction between global pass-through (the global percentage of firms choosing LCP, i.e.,  $1 - (z + z^*)/2$ ) and bond and equity holdings graphically for the general case.

The left panel of figure 2 shows this interaction for the bond-only case. The red dashed line depicts the dependence of  $b$  on the value of the—counterfactually treated as exogenously—global pass-through, while the blue solid line plots the resulting pass-through if we assume that the home bias is exogenous. Technically, we replace equations (25) and (26) with exogenous values for  $z$  and  $z^*$  in the first case, and equation (A-8) by exogenous values of  $b$  in the second case. When varying global pass-through, we start at  $z = z^* = 0$  and let first  $z$  increase to unity, after which  $z^*$  rises from 0 to one. In the case of an exogenously set  $b$ , we observe that  $z = z^* = 1$  for the low starting value of  $b$ . An increasing  $b$  lets  $z$  fall to zero, i.e., home switches from LCP to PCP. For intermediate values of  $b$ , this remains an equilibrium. Further raising  $b$  leads to a falling  $z^*$ , until the foreign country has switched to PCP too. As visible, both lines are increasing functions of their respective arguments. We obtain a unique solution at their intersection (in this case at a pass-through of 0.5). Also visible is a stronger dependency of the pass-through on the home bias of bond holdings, while the reverse dependence is fairly limited. We conclude that financial markets matter quantitatively and qualitatively more for pass-through than vice versa. In particular, the home bias does not reverse sign, independently of the level of pass-through.

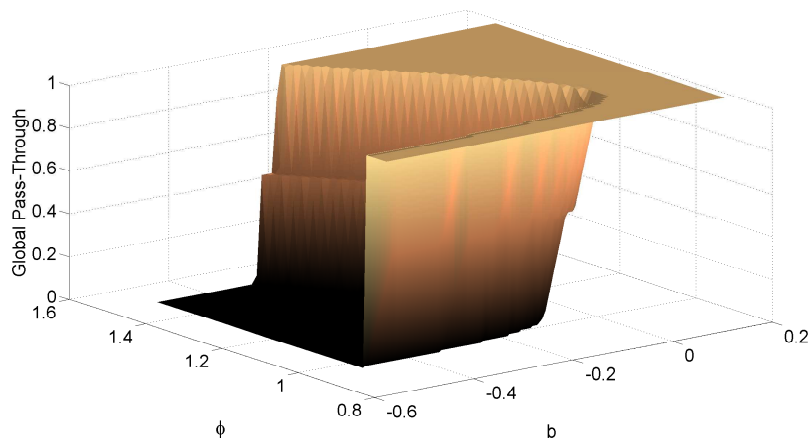


Figure 3: Bonds and equity case: dependence of global pass-through (vertical axis) on home bias in equity (left axis) and debt (right axis).

Figures 2 (right panel) and figure 3 depict the same interdependencies for the case of financial integration, i.e., trade in bonds and equities. For these plots, equations (25) and (26) or (A-20) were replaced by exogenous settings of the parameters. As the global pass-through now depends on the home bias in bonds and in equities, figure 3 is three-dimensional. Because there are unique mappings from pass-through to optimal asset home biases in bonds (blue solid line in the right panel of figure 2) and equities (red dashed line), and a unique mapping from each combination of these parameter to pass-through (figure 3), we again obtain a unique solution at their mutual intersection.

Regarding the pricing-decisions of firms, the same pattern as above is visible. Increasing the value of  $b$  induces first the home country to switch from LCP to PCP, followed by a small region of constant  $z$  and  $z^*$ . Finally, the foreign country also charges according to PCP if  $b$  rises further. Regarding the reaction to a changing  $\phi$ , the pattern is quite different. For a given intermediate value of  $b$ , a low level of  $\phi$  lets both producers follow PCP rules. For increasing values of  $\phi$ , the optimal  $z^*$  rises first. However, some domestic firms switch to LCP already before all foreign firms have done so. It is also

Table 1: Changes in debt home bias for varying  $\eta$  and  $\rho$  (upper left),  $\sigma_M^2$  and  $\sigma_{M^*}^2$  (upper right),  $\sigma_A^2$  and  $\sigma_{A^*}^2$  (lower left) or  $\sigma_G^2$  and  $\sigma_{G^*}^2$  (lower right) due to financial integration.

$\eta \backslash \rho$	1.00	1.55	2.10	2.65	3.20	3.75	$\sigma_M^2 \backslash \sigma_{M^*}^2$	0.24	0.33	0.43	0.52	0.61	0.71
1.00	-0.03	-0.04	-0.05	-0.04	-0.03	-0.02	0.22	-0.11	-0.11	-0.12	-0.13	-0.13	-0.13
1.70	-0.11	-0.12	-0.12	-0.12	-0.11	-0.10	0.32	-0.12	-0.12	-0.13	-0.13	-0.13	-0.14
2.40	-0.18	-0.19	-0.19	-0.19	-0.18	-0.17	0.43	-0.12	-0.13	-0.13	-0.13	-0.14	-0.14
3.10	-0.26	-0.26	-0.27	-0.26	-0.26	-0.24	0.54	-0.13	-0.13	-0.13	-0.14	-0.14	-0.14
3.80	-0.33	-0.34	-0.34	-0.34	-0.33	-0.32	0.64	-0.13	-0.13	-0.14	-0.14	-0.14	-0.14
4.50	-0.40	-0.41	-0.41	-0.41	-0.40	-0.39	0.75	-0.13	-0.14	-0.14	-0.14	-0.14	-0.14
$\sigma_A^2 \backslash \sigma_{A^*}^2$	0.21	0.33	0.45	0.57	0.70	0.82	$\sigma_G^2 \backslash \sigma_{G^*}^2$	0.22	0.36	0.49	0.63	0.76	0.90
0.21	-0.21	-0.18	-0.16	-0.15	-0.13	-0.13	0.22	-0.08	-0.09	-0.09	-0.10	-0.10	-0.11
0.33	-0.18	-0.16	-0.15	-0.13	-0.13	-0.12	0.36	-0.09	-0.09	-0.10	-0.10	-0.11	-0.11
0.45	-0.16	-0.15	-0.13	-0.13	-0.12	-0.11	0.49	-0.09	-0.10	-0.10	-0.11	-0.11	-0.12
0.57	-0.15	-0.13	-0.13	-0.12	-0.11	-0.11	0.63	-0.10	-0.10	-0.11	-0.11	-0.12	-0.12
0.70	-0.13	-0.13	-0.12	-0.11	-0.11	-0.10	0.76	-0.10	-0.11	-0.11	-0.12	-0.12	-0.12
0.82	-0.13	-0.12	-0.11	-0.11	-0.10	-0.10	0.90	-0.11	-0.11	-0.12	-0.12	-0.12	-0.13

domestic firms that are first to go back to PCP for even higher values of  $\phi$ , followed by their foreign counterparts once all home firms use LCP. Furthermore, we can draw similar conclusions as in the bonds-only case. Financial markets, both in terms of home bias in bonds as well as in equity, matter highly for pass-through. The reverse is not true, according to figure 2 (right panel). While the home bias in bonds varies but stays negative if global pass-through changes from zero to one, the home bias in equity is independent of the level of pass-through. Hence, pass-through has only a limited feedback to financial markets. To conclude, when investigating determinants of pass-through, financial markets are crucial.

### 3.2.2 Effects of financial integration

Table 1 displays the change in the home bias of debt holdings when switching from a bonds-only economy to international financial markets with bonds and equity, for different values of the key parameters of the model. As visible, for reasonable ranges of parameter values, the home bias of debt holdings declines after an increase in financial market integration, as empirically found and explained in the introduction. Trading equity across countries frees debt from some of its burden to hedge against all shocks present in the economy, and reduces therefore its share in the optimal country portfolio. Similarly, the global exchange rate pass-through for all shown combinations falls by 0.5. This results from the fact that one country always switches from PCP to LCP. The more stable international relative demand stemming from the enhanced risk-sharing possibilities stabilizes the exchange rate. Trade in equities link developments in total-factor productivity to the exchange rate via financial payments that depend on technology, increasing the correlation between marginal costs and the exchange rate. Because of these two factors, firms are induced to switch to local-currency pricing (see also Devereux et al., 2004).

Table 2: Changes in debt home bias for varying  $\sigma_M^2 = \sigma_{M^*}^2$  and  $\sigma_A^2 = \sigma_{A^*}^2$  due to financial integration.

$\sigma_M^2 \& \sigma_{M^*}^2$ \backslash $\sigma_A^2 \& \sigma_{A^*}^2$	0.21	0.33	0.45	0.57	0.70	0.82
0.22	-0.19	-0.15	-0.13	-0.11	-0.10	-0.09
0.34	-0.19	-0.15	-0.13	-0.11	-0.10	-0.09
0.47	-0.19	-0.15	-0.13	-0.11	-0.10	-0.09
0.60	-0.19	-0.15	-0.13	-0.11	-0.10	-0.09
0.73	-0.19	-0.15	-0.13	-0.11	-0.10	-0.09
0.86	-0.19	-0.15	-0.13	-0.11	-0.10	-0.09

The upper-left panel of table 1 reports the change in the debt home bias for different values for  $\rho$  and  $\eta$ . The upper-right panel shows the same statistic for different values of the volatilities of the shocks to the money supply, while in the lower-left panel the variances of technology shocks are altered. The lower-right panel of table 1 displays the statistics of interest for different volatilities of the shocks to government expenditure in both countries. Finally, in table 2 we change the volatility of money shocks, set to the same value in both countries, and technology shocks, also equal across countries. Summarizing the information of the tables, increased financial integration leads to a reduction in pass-through and debt home bias, independently of parameter constellations (where for some parameter values, no change occurs). We see this in line with empirical evidence, and therefore as an important explanation for the falling exchange rate pass-through.

## 4 Empirical evidence

In this section, we try to empirically identify the importance of international equity trade (relative to trade in debt) for explaining the decline in the exchange rate pass-through over time. To this end, we review related literature and present novel estimates regarding the explanatory power of equity trade for the debt home bias, exchange-rate volatility, and the exchange rate pass-through. Our empirical analysis shows for 109 countries over the time period 1990 to 2004 that higher levels of equity trade lead to a decline in the relative holdings of domestic-currency relative to foreign-currency debt positions, which we call a fall in debt home bias (i.e. dhb). Furthermore, we also demonstrate that higher equity trade is associated with lower exchange-rate volatility. Furthermore, within a sub sample of our countries for which data on exchange rate pass-through are available, we give some indication that the more equity is traded internationally, the smaller is the degree of exchange rate pass-through. We thereby confirm the key predictions of our theoretical model. Our results are meant as first steps towards a verification of our model predictions. A full characterization of the data, however, is beyond the scope of this paper.

To analyze the connection between increased trade in equity and a falling debt home bias we conduct a panel regression analysis of 109 countries covering the time period 1990-2004.<sup>10</sup> Table 3 shows a significant negative impact of (the log of) the sum of portfolio equity and FDI assets and liabilities on debt home bias over GDP, as defined above. We control for time and country fixed effects and a set of other variables that might impact on the debt home bias. These are log GDP, log Population,

<sup>10</sup>For this pooled OLS regression, we discard outliers, use robust regressions, and cluster standard errors at the country level. See appendix C for a description of all data sources and handling as well as summary statistics and correlations.

Table 3: Impact of equity trade on debt home bias over GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	dhb/gdp	dhb/gdp	dhb/gdp	dhb/gdp	dhb/gdp	dhb/gdp	dhb/gdp	dhb/gdp
log(Eq. & FDI)	0.110 (0.123)	-0.386*** (0.106)	-0.370*** (0.107)	-0.339*** (0.101)	-0.339*** (0.0786)	-0.322*** (0.0795)	-0.324*** (0.0776)	-0.611*** (0.0867)
NFA		-0.803*** (0.0554)	-0.786*** (0.0552)	-0.785*** (0.0514)	-0.557*** (0.0548)	-0.558*** (0.0547)	-0.558*** (0.0549)	-0.819*** (0.0716)
Net Exp.			-0.0756 (0.0944)	-0.0805 (0.0832)	-0.115* (0.0677)	-0.111 (0.0693)	-0.115 (0.0756)	-0.0155 (0.0669)
Openness				-0.108** (0.0451)	-0.105*** (0.0338)	-0.113*** (0.0340)	-0.121*** (0.0325)	-0.0415 (0.0411)
log(Gross Debt)					0.277*** (0.0422)	0.258*** (0.0472)	0.225*** (0.0524)	0.0332 (0.0435)
log(GDP/Pop.)						-0.0386 (0.0270)	-0.0617 (0.0375)	-0.0833** (0.0340)
Chinn-Ito							-0.0152* (0.00857)	0.00280 (0.00321)
log(Pop.)							-0.322** (0.154)	0.0548 (0.103)
Constant	0.365*** (0.0322)	0.0622*** (0.0213)	0.0634*** (0.0211)	0.124*** (0.0307)	0.0142 (0.0301)	0.316 (0.216)	1.336** (0.612)	0.657* (0.393)
T & C FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Observations	1363	1363	1324	1324	1324	1324	1302	1033
Adjusted $R^2$	0.168	0.697	0.698	0.705	0.767	0.769	0.775	
F	8.043	48.09	45.72	48.15	69.22	86.04	98.23	

Robust standard errors (clustered at the country level) in parentheses.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

the updated Chinn and Ito (2006) index for the capital account openness, net exports over GDP, net foreign assets over GDP, and total debt (log of debt assets plus liabilities). We include the index of Chinn and Ito as restriction on debt and equity trade could have an impact on the relative size of these two variables. Furthermore, table 4 shows that the negative effect of total equity trade is also present if debt home bias over total debt (sum of debt assets and liabilities) is used as the dependent variable. Regarding the size of the effect, a 1% increase in the sum of equity and FDI assets and liabilities decreases debt home bias over GDP around .10%, and debt home bias over total debt by .07%. Importantly, this effect is also present if we control for total debt in both sets of regressions. If we replace the log of gross equity and FDI holdings with gross equity and FDI holdings over GDP (and similarly for gross debt assets), the results indicate that an increase of this variable by one percentage point decreases debt home bias over GDP by .32%, significant at a 1% level. Likewise, debt home bias over total debt falls by 0.22%, significant at a 5% level. We can therefore conclude that the more equity is traded internationally, the lower is the debt home bias. This implies that agents choose a debt

Table 4: Impact of equity trade on debt home bias over total debt

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	dhb/debt	dhb/debt	dhb/debt	dhb/debt	dhb/debt	dhb/debt	dhb/debt	dhb/debt
log(Eq. & FDI)	-0.00247 (0.0892)	-0.282*** (0.0920)	-0.266*** (0.0922)	-0.234** (0.0916)	-0.234** (0.0934)	-0.241** (0.0958)	-0.219** (0.0951)	-0.913*** (0.175)
NFA		-0.453*** (0.0642)	-0.435*** (0.0636)	-0.434*** (0.0642)	-0.483*** (0.0887)	-0.483*** (0.0881)	-0.454*** (0.0912)	-1.001*** (0.117)
Net Exp.			-0.102 (0.0798)	-0.107 (0.0759)	-0.0995 (0.0754)	-0.101 (0.0761)	-0.0809 (0.0798)	-0.0283 (0.118)
Openness				-0.108** (0.0536)	-0.109** (0.0518)	-0.105** (0.0523)	-0.102* (0.0514)	-0.0982 (0.0759)
log(Gross Debt)					-0.0604 (0.0585)	-0.0525 (0.0642)	-0.0851 (0.0759)	-0.440*** (0.102)
log(GDP/Pop.)						0.0160 (0.0481)	-0.0418 (0.0590)	-0.157*** (0.0499)
Chinn-Ito							-0.0111 (0.0124)	0.00193 (0.00492)
log(Pop.)							-0.171 (0.242)	-0.0486 (0.227)
Constant	0.453*** (0.0220)	0.282*** (0.0278)	0.280*** (0.0277)	0.341*** (0.0354)	0.364*** (0.0419)	0.239 (0.389)	1.137 (0.992)	2.154*** (0.741)
T & C FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Observations	1363	1363	1324	1324	1324	1324	1302	1033
Adjusted $R^2$	0.246	0.408	0.412	0.419	0.421	0.421	0.428	
F	6.789	8.229	7.730	7.865	7.724	7.470	8.514	

Robust standard errors (clustered at the country level) in parentheses.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

portfolio from which they benefit more in case of a depreciation of their own currency.

Next, we investigate the impact of increased equity trade on exchange-rate volatility. Our model predicts a negative relationship, as relative incomes of two countries can be stabilized by engaging in higher equity trade. Once cross-country equity trade becomes easier to conduct, may it be because of reduced informational asymmetries or the like, exchange-rate volatility should therefore fall. The left side of table 5 displays the results from a corresponding regression. Exchange-rate volatility is constructed using quarterly data on nominal effective exchange rates. Inflation volatility is calculated correspondingly. Since nominal effective exchange rates and inflation rates are available for a smaller set of countries, we are left with observations on 67 countries. Specifically, we use a rolling eight-quarter window to calculate volatilities.<sup>11</sup> Since our annual measure of exchange-rate volatility

<sup>11</sup>Eight quarters strikes us as a good compromise between having enough observations to calculate meaningful volatilities and reducing the constructed autocorrelation of the resulting variable to one annual lag.



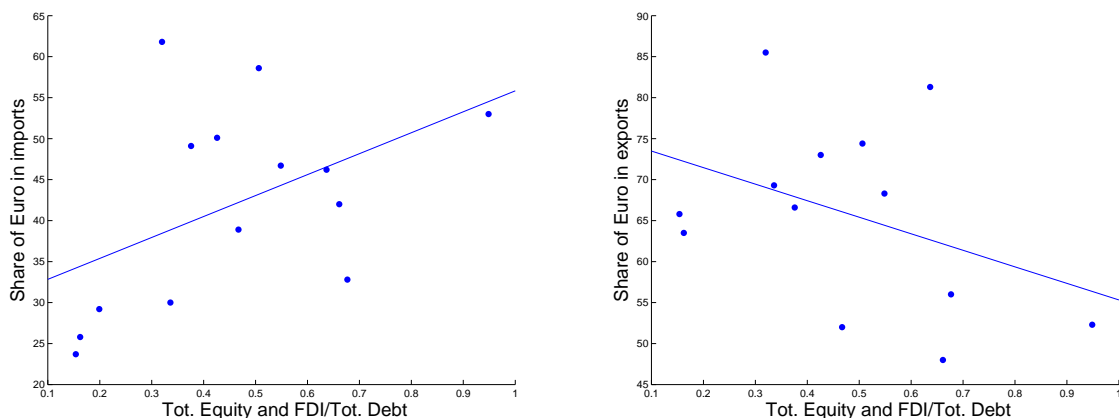


Figure 4: Relation between share of imports (left) and exports (right) priced in euro vs. equity and FDI (assets plus liabilities) over debt (assets plus liabilities) for euro-area countries. Sources: Lane and Milesi-Ferretti (2007) and Eurostat (2012).

is therefore autocorrelated by construction, we include its lagged value on the right-hand side and employ the estimator proposed by Arellano and Bond (1991).<sup>12</sup> The control variables are listed in the table and are included in levels (the  $\Delta$  in parentheses refers to the right side of the table). Additional to previously used variables we include inflation volatility, as it is expected to have a strong impact on exchange rate volatility. We find a significant negative impact of equity trade and FDI on exchange-rate volatility, as predicted by the model.

Unfortunately, we lack a similar comprehensive data set on exchange rate pass-through. Our analysis is therefore restricted to very small samples, which can give us only indications for the relationship between pass-through and equity trade. As a first approach, figure 4 uses data from Eurostat for the invoicing currency of euro countries for extra-EU imports (left panel) and exports (right panel).<sup>13</sup> This variable is plotted on the y-axis against the sum of portfolio equity and FDI assets and liabilities over the sum of debt assets and liabilities. We find that a increase of equity and FDI relative to debt is positively correlated with the share of imports priced in euro, and negatively with the corresponding share of exports. Both facts hint at more local currency pricing, and therefore lower exchange rate pass-through for higher equity trade relative to debt trade.<sup>14</sup> These conclusions, however, rest on a sample of only 13 countries. A slightly larger sample is provided by Campa and Goldberg (2002), who report estimates of pass-through changes for roughly the same time period for which we have data on equity trade. Specifically, they estimate levels of the pass-through for the years 1989 and 1999. As the data on our financial control variables starts only in 1990, we regress the change of the short-run pass-through in percentage points between 1989 and 1999 on percentage changes of the control variables between the 1990 and 1999. Because of the very small sample size, we do not include all control variables at the same time (results, however, do not change). Table 5 reports, acknowledging the mentioned constraints, a clearly negative relationship between exchange rate pass-through and

<sup>12</sup>The Arellano-Bond test for zero autocorrelation in first-differenced errors shows that the used moment conditions are valid.

<sup>13</sup>The data is available only for 2010. Luxemburg and Ireland have been excluded as they are clear outliers regarding the equity and FDI variable. Including them, however, does not change the conclusion. The same applies for the consideration of portfolio equity assets and liabilities only.

<sup>14</sup>Gopinath et al. (2010) show that goods priced in dollar indeed exhibit a much lower degree of pass-through (25%) into US import prices than goods priced in nondollars (95%).

Table 5: Impact of equity trade on exchange-rate volatility and Pass-Through

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ex. Vol.	Ex. Vol.	Ex. Vol.	Ex. Vol.	$\Delta$ PT	$\Delta$ PT	$\Delta$ PT
( $\Delta$ ) Eq. & FDI	-0.0234*** (0.00629)	-0.0241*** (0.00768)	-0.0245** (0.00955)	-0.0246** (0.0108)	-0.226** (0.0849)	-0.838*** (0.187)	-0.210*** (0.0213)
( $\Delta$ ) NFA		-0.00773 (0.0122)	0.00600 (0.00883)	0.00560 (0.00845)		0.400*** (0.0988)	
( $\Delta$ ) Tot. Debt			0.00801 (0.00712)	0.00813 (0.00717)		-0.0989 (0.114)	-0.0350 (0.0239)
( $\Delta$ ) Openness			0.00556 (0.0103)	0.00557 (0.0105)		-1.314* (0.626)	1.513*** (0.0895)
( $\Delta$ ) Net Exp.			-0.142*** (0.0304)	-0.141*** (0.0305)			0.00727*** (0.00116)
( $\Delta$ ) log GDP/Pop.			0.0118 (0.00733)	0.0118* (0.00685)		-9.177 (6.051)	8.926*** (0.943)
( $\Delta$ ) Chinn-Ito				0.000328 (0.00194)			-0.00980*** (0.00135)
$\Delta$ Ex. Rate Vol.						5.423** (1.568)	-0.294* (0.153)
( $\Delta$ ) Infl. Vol.	8.920*** (2.755)	9.069*** (2.784)	8.982*** (2.734)	9.024*** (2.728)		0.00343*** (0.000867)	0.000568*** (0.000115)
L.Ex. Vol.	0.0543 (0.0434)	0.0440 (0.0465)	0.0825* (0.0485)	0.0834* (0.0483)			
Constant	0.0121*** (0.00241)	0.00919** (0.00420)	-0.0953 (0.0611)	-0.0963* (0.0565)	0.194 (0.196)	2.708*** (0.738)	-0.403*** (0.0772)
Observations	615	615	615	615	16	15	16
Adjusted $R^2$					0.288	0.622	0.986
F					7.057	4.295	132.2

Robust standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ 

total equity and FDI.

For the table, we regressed the change in the pass-through in percentage points on the changes of the independent variables in percent. According to these estimations, a 1% increase in the sum of equity and FDI assets and liabilities decreases the exchange rate pass-through around 12 percentage points.

## 5 Conclusion

In this paper we have put forward a new explanation for the decline in exchange rate pass-through into import prices. Crucial for our theoretical model is the impact of financial globalization, modeled as an

increase in the number and nature of tradable financial assets, on the pricing decision of firms. In the model, we take the mutual interaction between the optimal portfolio and the choice of the invoicing currency into account. The main impact of financial globalization on pass-through works via the reaction of the optimal portfolio, which features more foreign debt assets following the increased availability of international equity. This represents the hedging possibilities that equity takes over from debt. As a reaction to the better hedging opportunities, the exchange rate stabilizes and optimal pass-through falls. We also present some empirical evidence supporting the negative effect of gross equity holdings on the home bias of international debt assets and on pass-through. An obvious policy implication concerns the design of monetary unions: if preceded by financial integration, volatility of the nominal exchange rate and its effect on relative prices is reduced. Moving towards abolishing the nominal exchange rate altogether is therefore likely to have smaller real consequences.

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## Appendix

### A Equilibrium of the full model

In this section we derive the optimal portfolio solutions under the different degrees of international financial market integration for unrestricted parameter values and show how they influence the equilibrium behavior of the nominal exchange rate and the marginal costs.

**Money market equilibrium and the nominal exchange rate** First, we use the money market equilibrium to solve for the nominal exchange rate. The money market equilibrium allows to solve for the equilibrium exchange rate. Expressing (15) in log-linear terms yields

$$\widehat{S} = \frac{(\widehat{M} - \widehat{M}^*)}{\rho + (1 - \rho)(1 - a)(2 - z - z^*)} - \frac{\rho(\widehat{PC} - \widehat{SP}^*C^*)}{\rho + (1 - \rho)(1 - a)(2 - z - z^*)}. \quad (\text{A-1})$$

The equilibrium nominal exchange rate will not only be affected by the relative money supplies but also via the differences in nominal spending,  $\widehat{PC} - \widehat{SP}^*C^*$ , by the amount of assets traded as will be now shown.

#### A.1 Trade in bonds only

We follow an approximation method for computing equilibrium portfolio positions developed by Devereux and Sutherland (2011) and take a second-order approximation of the asset market equilibrium condition for the home country (8) and its foreign counterpart. The differences of these two equations lead to the following arbitrage condition

$$Cov(-\widehat{S}, \widehat{PC} - \widehat{SP}^*C^*) = \frac{1 - \rho}{\rho} Cov(-\widehat{S}, \widehat{Q}), \quad (\text{A-2})$$

which relates the covariance between excess returns on nominal bonds—given by nominal exchange rate deviations,  $\hat{R}_{Fin}^B = -\hat{S}$ —and relative nominal consumption expenditures,  $\widehat{PC} - \widehat{SP^*C^*}$ , to the covariance between excess returns on nominal bonds and the real exchange rate,  $\hat{Q} = \widehat{SP^*} - \hat{P}$ . Linearizing the period  $t = 1$  budget constraints for the home (6) and foreign country (7) and taking country differences, we get an expression for linearized relative nominal consumption expenditures. In doing so we take the government budget constraints into consideration and assume that government expenditures are equal to zero in the deterministic steady state. Then for  $\hat{X} \equiv \frac{X - \bar{X}}{\bar{X}}$  the budget constraints equal

$$\widehat{PC} - \widehat{SP^*C^*} = 2b\hat{R}_{Fin}^B + (\widehat{REV} - \widehat{SREV^*}) - (\hat{G} - \hat{G}^*), \quad (\text{A-3})$$

where  $b \equiv \bar{B}/(\bar{PC})$ ,  $\hat{G} = G/\bar{C}$ ,  $\widehat{REV} = \hat{\Pi} - \widehat{WL}$  and we have used the fact that  $B_H = B_F^*$  for  $S_0 = 1$ .  $\bar{B}$  is the equilibrium amount of bonds we are looking for. Relative sales revenues will be defined as the non-financial return,  $\hat{R}_{Fin}^{Non} = \widehat{REV} - \widehat{SREV^*}$ .

**Optimal nominal bond portfolio** Plugging (A-3) into the asset market arbitrage condition (A-2) and rearranging terms we get

$$b = \frac{1}{2} \left( \frac{1 - \rho}{\rho} \frac{Cov(\hat{R}_{Fin}^B, \hat{Q})}{Var(\hat{S})} - \frac{Cov(\hat{R}_{Fin}^B, \hat{R}_{Fin}^{Non})}{Var(\hat{S})} + \frac{Cov(\hat{R}_{Fin}^B, \hat{G} - \hat{G}^*)}{Var(\hat{S})} \right).$$

This expression states that the optimal equilibrium bond holdings  $b$  depend on three components: the covariance between relative nominal bond returns, i.e., the nominal exchange rate, and the real exchange rate, the covariance between the nominal exchange rate and relative sale revenues as well as the covariance between the nominal exchange rate and relative government expenditures, all weighted by the variance of relative nominal bond returns, i.e., the nominal exchange rate.

By making an optimal portfolio choice the representative household wants to hedge her marginal utility of consumption. A risk averse investor ( $\rho > 1$ ) hedges consumption risks stemming from variations in her purchasing power, reflected by movements in the real exchange rate. Domestic bonds are a good hedge against this risk if domestic bond returns are high whenever the domestic price level is high. In the case of  $\rho = 1$ , a unit increase in real returns of bond assets (domestic or foreign) decreases marginal utility of consumption by a unit, such that bond asset gains evaluated at the marginal utility of consumption vanish and the covariance between relative nominal returns and the real exchange rate becomes irrelevant for the portfolio choice decision.

Furthermore, the representative household wishes to hedge nominal income risks associated with variations in nominal revenues from domestic firms and government expenditures. Domestic bonds are a good hedge against if relative domestic bond returns are high whenever domestic revenues are low. For example, an appreciation of the nominal exchange rate causes both, a fall in domestic revenues from foreign sales and a higher relative domestic bond return. Consequently, holding a higher amount of domestic bonds allows to hedge the nominal revenue risk.

Government expenditures are fully paid by the seignorage and lump-sum taxes which reduce nominal disposable income. Domestic bonds are a good hedge against taxation risk if domestic bond returns are high whenever the income risk associated with government expenditure is high.

To solve for the optimal portfolio bond holdings we write the nominal exchange rate, nominal consumption spending, and sale revenues as functions of the underlying shocks. We first treat portfolio-based nominal income as exogenous,  $\widehat{Ex}_{Fin} = 2b\hat{R}_{Fin}^B$ , such that relative domestic bond returns are

$$\hat{R}_{Fin}^B = -\Theta_M^S(\widehat{M} - \widehat{M}^*) + \Theta_{PC}^S(\widehat{Ex}_{Fin} + \hat{R}_{Fin}^{Non}) - \Theta_{PC}^S(\hat{G} - \hat{G}^*), \quad (\text{A-4})$$

where the coefficients  $\Theta_{PC}^S$  and  $\Theta_M^S$  are illustrated in the appendix, table B-1. Furthermore, non financial income can be written as

$$\hat{R}_{Fin}^{Non} = \Theta_{ExFin}^{R_{Fin}^{Non}} \widehat{Ex}_{Fin} + \Theta_M^{R_{Fin}^{Non}} (\widehat{M} - \widehat{M}^*) + \Theta_G^{R_{Fin}^{Non}} (\widehat{G} - \widehat{G}^*), \quad (\text{A-5})$$

where the structural parameters  $\Theta_{ExFin}^{R_{Fin}^{Non}}$ ,  $\Theta_M^{R_{Fin}^{Non}}$  and  $\Theta_G^{R_{Fin}^{Non}}$  are provided in table B-1. Combining (A-4) and (A-5) we get

$$\hat{R}_{Fin}^B = \mathbf{R}_1 \widehat{Ex}_{Fin} + \mathbf{R}_2 [(\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \quad (\text{A-6})$$

where  $\mathbf{R}_1 = \Theta_{PC}^S (1 + \Theta_{ExFin}^{R_{Fin}^{Non}})$  is a scalar and  $\mathbf{R}_2 = [-(\Theta_M^S - \Theta_{PC}^S \Theta_M^{R_{Fin}^{Non}}), -\Theta_{PC}^S (1 - \Theta_G^{R_{Fin}^{Non}})]$  is a  $1 \times 2$  vector. Now we can write the relative discount factor as

$$-\rho(\widehat{PC} - \widehat{SP}^* C^*) + (1 - \rho) \widehat{Q} = \mathbf{D}_1 \widehat{Ex}_{Fin} + \mathbf{D}_2 [(\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \quad (\text{A-7})$$

with  $\mathbf{D}_1 = -\Theta_{PC}^D (1 + \Theta_{ExFin}^{R_{Fin}^{Non}})$  being a scalar and  $\mathbf{D}_2 = [\Theta_M^D - \Theta_{PC}^D \Theta_M^{R_{Fin}^{Non}}, \Theta_{PC}^D (1 - \Theta_G^{R_{Fin}^{Non}})]$  a  $1 \times 2$  vector of combinations of structural parameters  $\Theta_M^D$  and  $\Theta_{PC}^D$ , shown in appendix B, table B-1. Given (A-6) and (A-7), the arbitrage condition (A-2) can be written as  $\mathbf{R} \Sigma \mathbf{D}' = 0$ , where  $\mathbf{R} = \mathbf{R}_1 \mathbf{H} + \mathbf{R}_2$ ,  $\mathbf{H} = 2b(1 - 2b\mathbf{R}_1)^{-1} \mathbf{R}_2$ , and  $\mathbf{D} = \mathbf{D}_1 \mathbf{H} + \mathbf{D}_2$  are  $1 \times 2$  vectors.  $\Sigma$  is the  $2 \times 2$  covariance matrix of the exogenous disturbances. Even so the economies are hit by monetary policy, demand and productivity shocks, only the first two are insured via bond holding in the NB economies. Thus households cannot insure themselves against relative productivity movements across countries. Solving for  $b$  yields

$$b = \frac{1}{2} \left\{ [\mathbf{R}_2 \Sigma \mathbf{D}'_2 \mathbf{R}'_1 - \mathbf{D}_1 \mathbf{R}_2 \Sigma \mathbf{R}'_2]^{-1} \mathbf{R}_2 \Sigma \mathbf{D}'_2 \right\}. \quad (\text{A-8})$$

**Nominal exchange rate in NB economies** Given the solution to nominal bonds holdings we can express the nominal exchange rate in equation (A-1) as

$$\widehat{S} = \frac{(1 - \rho \Theta_M^{PC}) (\widehat{M} - \widehat{M}^*) + \rho \Theta_G^{PC} (\widehat{G} - \widehat{G}^*)}{\rho + (1 - \rho) (1 - a) (2 - z - z^*)}, \quad (\text{A-9})$$

with  $\Theta_M^{PC}$  and  $\Theta_G^{PC}$  provided in table B-1. Given the insurance properties in the NB economies, the exchange rate only transmits two of the three possible economic disturbances across countries. The impact effect of the shocks is affected by the size of the equilibrium portfolio holding of  $b$  since  $\Theta_M^{PC}$  and  $\Theta_G^{PC}$  depend on the size of  $b$ . The fact that not all disturbances are transmitted via the nominal exchange rate has direct implications for the price setting decision of the firms since it directly affects the covariance relationship between the nominal exchange rate and marginal costs of the firm. To see this more clearly, consider the log-linearized version of the home marginal costs, equation (18), and its foreign counterpart

$$\widehat{m}c = \widehat{M} - \widehat{A} \text{ and } \widehat{m}c^* = \widehat{M}^* - \widehat{A}^*, \quad (\text{A-10})$$

respectively, given equation (13). From (A-9) and (A-10) it follows that the covariance between marginal costs and the nominal exchange rate can be written as

$$Cov(\widehat{m}c, \widehat{S}) = \frac{(1 - \rho \Theta_M^{PC})}{\rho + (1 - \rho) (1 - a) (2 - z - z^*)} Var(\widehat{M}), \quad (\text{A-11})$$

$$Cov(\widehat{m}c^*, \widehat{S}) = -\frac{(1 - \rho \Theta_M^{PC})}{\rho + (1 - \rho) (1 - a) (2 - z - z^*)} Var(\widehat{M}^*), \quad (\text{A-12})$$

respectively. Note that in the NB economies only monetary disturbances affect the covariance relationship between marginal costs and the nominal exchange rate. The magnitude of this covariance relationship, however, will depend on the equilibrium bond holding  $b$ . Since all shocks are uncorrelated, the variance of the nominal exchange rate equals

$$Var(\widehat{S}) = \frac{(1 - \rho\Theta_M^{PC})^2 Var(\widehat{M} + \widehat{M}^*) + (\rho\Theta_G^{PC})^2 Var(\widehat{G} + \widehat{G}^*)}{(\rho + (1 - \rho)(1 - a)(2 - z - z^*))^2}, \quad (\text{A-13})$$

with  $Var(\widehat{G} + \widehat{G}^*)$  and  $Var(\widehat{M} + \widehat{M}^*)$  reflecting the sum of variances of the government spending and monetary policy shocks.

## A.2 Trade in bonds and equities

Additional to the asset market equilibrium condition for bonds, equation (A-2), we also take a second-order approximation of the home Euler equity equation (12) and its foreign counterpart to obtain

$$Cov(\widehat{\Pi} - \widehat{S\Pi}^*, \widehat{PC} - \widehat{S P^* C^*}) = \frac{1 - \rho}{\rho} Cov(\widehat{\Pi} - \widehat{S\Pi}^*, \widehat{Q}). \quad (\text{A-14})$$

As for bonds, we linearize the period  $t = 1$  budget constraint for the home country and its foreign counterpart, (11). Taking country differences yields

$$\widehat{PC} - \widehat{S P^* C^*} = \frac{(2\phi - 1)}{\sigma} (\widehat{\Pi} - \widehat{S\Pi}^*) + 2b\widehat{R}_{Fin}^B - (\widehat{G} - \widehat{G}^*) + \frac{\sigma - 1}{\sigma} (\widehat{WL} - \widehat{S W^* L^*}). \quad (\text{A-15})$$

Taking into account that  $\widehat{R}_{Fin}^E = \frac{1}{\sigma} (\widehat{\Pi} - \widehat{S\Pi}^*)$  and  $\widehat{R}_{Fin}^{Non} = \frac{\sigma - 1}{\sigma} (\widehat{WL} - \widehat{S W^* L^*})$ , we rewrite (A-15) as

$$\widehat{PC} - \widehat{S P^* C^*} = (2\phi - 1)\widehat{R}_{Fin}^E + 2b\widehat{R}_{Fin}^B - (\widehat{G} - \widehat{G}^*) + \widehat{R}_{Fin}^{Non}. \quad (\text{A-16})$$

**Optimal bond and equity portfolio** From the expressions above it follows that non financial returns  $\widehat{R}_{Fin}^{Non}$  are now determined by the relative labor income of households. Given that both bonds and equity are traded, the equilibrium bond position will depend now also on the covariance between the relative returns from equity and bond holdings as well as the equilibrium equity holdings. Following the solution approach from above, non financial income equals

$$\widehat{R}_{Fin}^{Non} = \Theta_{ExFin}^{RFinNon} \widehat{\mathbf{Ex}}_{Fin} - \Theta_A^{RFinNon} (\widehat{A} - \widehat{A}^*) + \Theta_M^{RFinNon} (\widehat{M} - \widehat{M}^*) - \Theta_G^{RFinNon} (\widehat{G} - \widehat{G}^*), \quad (\text{A-17})$$

with  $\widehat{\mathbf{Ex}}_{Fin} = [2b, (2\phi - 1)] [\widehat{R}_{Fin}^B, \widehat{R}_{Fin}^E]'$  and  $\Theta_{ExFin}^{RFinNon}$ ,  $\Theta_A^{RFinNon}$ ,  $\Theta_M^{RFinNon}$  and  $\Theta_G^{RFinNon}$  defined in the appendix, table B-2. The structural parameters  $\Theta_{PC}^S$  and  $\Theta_M^S$  are also shown in appendix B, table B-2. Financial returns can be written as

$$[\widehat{R}_{Fin}^B, \widehat{R}_{Fin}^E]' = \mathbf{R}_1 \widehat{\mathbf{Ex}}_{Fin} + \mathbf{R}_2 [(\widehat{A} - \widehat{A}^*), (\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \quad (\text{A-18})$$

with  $\mathbf{R}_1 = [\Theta_{PC}^S (1 + \Theta_{ExFin}^{RFinNon}), -(\Theta_{PC}^{RFin} + \Theta_S^{RFin} \Theta_{PC}^S) (1 + \Theta_{ExFin}^{RFinNon})]'$  and  $\mathbf{R}_2$  being a 3x2 matrix, containing additional structural parameters  $\Theta_{PC}^{RFin}$  and  $\Theta_S^{RFin}$  defined in table B-2 of appendix B. Finally, the relative discount factor equals

$$-\rho(\widehat{PC} - \widehat{S P^* C^*}) + (1 - \rho)\widehat{Q} = \mathbf{D}_1 \widehat{\mathbf{Ex}}_{Fin} + \mathbf{D}_2 [(\widehat{A} - \widehat{A}^*), (\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \quad (\text{A-19})$$



with  $\mathbf{D}_1 = -\Theta_{PC}^D(1 + \Theta_{EXFin}^{RNon})$  being a scalar and  $\mathbf{D}_2 = [\Theta_{PC}^D\Theta_A^{RNon}, \Theta_M^D - \Theta_{PC}^D\Theta_M^{RNon}, \Theta_{PC}^D(1 + \Theta_G^{RNon})]$  a  $1 \times 3$  vector of combinations of the structural parameters, where  $\Theta_M^D$  and  $\Theta_{PC}^D$  are defined in table B-2. Equations (A-17)-(A-19) allow to write the solution to the bond and equity holding in the NBE economy as

$$[2b \quad (2\phi - 1)]' = [\mathbf{R}_2 \Sigma \mathbf{D}_2' \mathbf{R}_1' - \mathbf{D}_1 \mathbf{R}_2 \Sigma \mathbf{R}_2']^{-1} \mathbf{R}_2 \Sigma \mathbf{D}_2'. \quad (\text{A-20})$$

**Nominal exchange rate in NBE economies** Given the solution to nominal bonds and equity holdings, the nominal exchange rate in equation (A-1) equals

$$\widehat{S} = \frac{\rho \Theta_A^{PC} (\widehat{A} - \widehat{A}^*) + (1 - \rho \Theta_M^{PC}) (\widehat{M} - \widehat{M}^*) + \rho \Theta_G^{PC} (\widehat{G} - \widehat{G}^*)}{\rho + (1 - \rho)(1 - a)(2 - z - z^*)}, \quad (\text{A-21})$$

with  $\Theta_A^{PC}$ ,  $\Theta_M^{PC}$  and  $\Theta_G^{PC}$  defined in table B-2. In contrast to the NB economy, the NBE economy allows the exchange rate to transmit all three economic disturbances across countries. Again, the equilibrium outcome of the nominal exchange rate depends on the equilibrium portfolio allocation of bonds,  $b$ , and equities,  $\phi$ . From (A-10) and (A-21) it follows that the covariance between marginal costs and the nominal exchange rate in the NBE economies can be written as

$$Cov(\widehat{mc}, \widehat{S}) = \frac{(1 - \rho \Theta_M^{PC}) Var(\widehat{M}) + \rho \Theta_A^{PC} Var(\widehat{A})}{\rho + (1 - \rho)(1 - a)(2 - z - z^*)}, \quad (\text{A-22})$$

$$Cov(\widehat{mc}^*, \widehat{S}) = -\frac{(1 - \rho \Theta_M^{PC}) Var(\widehat{M}^*) + \rho \Theta_A^{PC} Var(\widehat{A}^*)}{\rho + (1 - \rho)(1 - a)(2 - z - z^*)}. \quad (\text{A-23})$$

Now, all shocks that affect marginal costs will also impact the nominal exchange rate. Thus, the covariance relationship between marginal costs and the nominal exchange rate is not only affected by monetary disturbances, as in the NB economy, but also by productivity disturbances. The sign of this covariance relationship, however, will depend on the equilibrium bond holding  $b$  as well as the equilibrium equity position  $\phi$ . Since all shocks are uncorrelated, the variance of the nominal exchange rate in the NBE economy equals

$$Var(\widehat{S}) = \frac{(1 - \rho \Theta_M^{PC})^2 Var(\widehat{M} + \widehat{M}^*) + (\rho \Theta_G^{PC})^2 Var(\widehat{G} + \widehat{G}^*)}{(\rho + (1 - \rho)(1 - a)(2 - z - z^*))^2} + \frac{(\rho \Theta_A^{PC})^2 Var(\widehat{A} + \widehat{A}^*)}{(\rho + (1 - \rho)(1 - a)(2 - z - z^*))^2}. \quad (\text{A-24})$$

## B Coefficients of the full model

### B.1 Trade in bonds only

Table B-1 provides the coefficients used when assessing the nominal bond economies.

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$$\Theta_{PC}^S = \rho \Theta_M^S$$

$$\Theta_M^S = [\rho + (1 - \rho)(1 - a)(2 - z - z^*)]^{-1}$$

$$\Theta_{ExFin}^{RFin} = -\frac{1 - 2a - 2(1 - \eta)(1 - a)a(2 - z - z^*)\Theta_{PC}^S}{2(1 - a) - 2(1 - \eta)(1 - a)a(2 - z - z^*)\Theta_{PC}^S}$$

$$\Theta_M^{RFin} = -\frac{2(1 - \eta)(1 - a)a(2 - z - z^*)\Theta_M^S}{2(1 - a) - 2(1 - \eta)(1 - a)a(2 - z - z^*)\Theta_{PC}^S}$$

$$\Theta_G^{RFin} = \frac{1 - 2a - 2(1 - \eta)(1 - a)a(2 - z - z^*)\Theta_{PC}^S - 1 + 2a}{2(1 - a) - 2(1 - \eta)(1 - a)a(2 - z - z^*)\Theta_{PC}^S}$$

$$\Theta_M^D = (1 - \rho)[1 - (1 - a)(2 - z - z^*)]\Theta_M^S$$

$$\Theta_{PC}^D = \rho + (1 - \rho)[1 - (1 - a)(2 - z - z^*)]\Theta_{PC}^S$$

$$\Theta_M^{PC} = -\frac{\Theta_M^S[2b + (1 - \eta)(1 - a)a(2 - z - z^*)]}{2(1 - a) - [2b + (1 - \eta)(1 - a)a(2 - z - z^*)]\Theta_{PC}^S}$$

$$\Theta_G^{PC} = \frac{2(1 - a)}{2(1 - a) - [2b + (1 - \eta)(1 - a)a(2 - z - z^*)]\Theta_{PC}^S}$$


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Table B-1: Structural coefficients of the NB economies.

### B.2 Trade in bonds and equities

The matrix  $\mathbf{R}_2$  is given by

$$\mathbf{R}_2 = \begin{bmatrix} -\Theta_{PC}^S \Theta_A^{RFin}, & (\Theta_{PC}^{RFin} + \Theta_S^{RFin} \Theta_{PC}^S) \Theta_A^{RFin} + \frac{\sigma - 1}{\sigma} \\ -\Theta_M^S + \Theta_{PC}^S \Theta_M^{RFin}, & \Theta_S^{RFin} \Theta_M^S - (\Theta_{PC}^{RFin} + \Theta_S^{RFin} \Theta_{PC}^S) \Theta_M^{RFin} \\ -\Theta_{PC}^S (1 + \Theta_G^{RFin}), & (\Theta_{PC}^{RFin} + \Theta_S^{RFin} \Theta_{PC}^S) (1 + \Theta_G^{RFin}) - \frac{1 - 2a}{\sigma} \end{bmatrix}'.$$

Table B-2 provides the coefficients used when assessing the nominal bond and equity economies.

$$\begin{aligned}
\Theta_{ExFin}^{RFin} &= \frac{\frac{\sigma-1}{\sigma} \{2a-1+\rho-\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\} \Theta_{PC}^S\}}{1-\frac{\sigma-1}{\sigma} \{2a-1+\rho-\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\} \Theta_{PC}^S\}} \\
\Theta_A^{RFin} &= \left[ \frac{\sigma}{\sigma-1} - \{2a-1+\rho-\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\} \Theta_{PC}^S\} \right]^{-1} \\
\Theta_M^{RFin} &= \frac{\frac{\sigma-1}{\sigma} \{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-(1-\rho))]\} \Theta_M^S}{1-\frac{\sigma-1}{\sigma} \{2a-(1-\rho)-\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\} \Theta_{PC}^S\}} \\
\Theta_G^{RFin} &= \frac{\frac{\sigma-1}{\sigma} \{\rho-\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\} \Theta_{PC}^S\}}{1-\frac{\sigma-1}{\sigma} \{2a-(1-\rho)-\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\} \Theta_{PC}^S\}} \\
\Theta_{PC}^{RFin} &= [1-2a+(\sigma-1)\rho] \sigma^{-1} \\
\Theta_S^{RFin} &= [(\sigma-1)\{(1-a)[z+z^*-(2-z-z^*)(1-\rho-2a(1-\eta))]-\rho\}-2\sigma a(1-a)(1-\eta)(2-z-z^*)] \sigma^{-1} \\
\Theta_A^{PC} &= \frac{2(1-\phi)\frac{\sigma-1}{\sigma}}{\left\{1+(2\phi-1)\left(\Theta_{PC}^{RFin}+\Theta_S^{RFin}\Theta_{PC}^S\right)-2b\Theta_{PC}^S-\frac{\sigma-1}{\sigma}(2a-(1-\rho))+\frac{\sigma-1}{\sigma}\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\}\Theta_{PC}^S\right\}} \\
\Theta_M^{PC} &= \frac{\left\{\frac{\sigma-1}{\sigma}\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-(1-\rho))]\}-(1-2\phi)\Theta_S^{RFin}-2b\right\}\Theta_M^S}{\left\{1+(2\phi-1)\left(\Theta_{PC}^{RFin}+\Theta_S^{RFin}\Theta_{PC}^S\right)-2b\Theta_{PC}^S-\frac{\sigma-1}{\sigma}(2a-1+\rho)+\frac{\sigma-1}{\sigma}\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\}\Theta_{PC}^S\right\}} \\
\Theta_G^{PC} &= \frac{(1-2\phi)\frac{1-2a}{\sigma}-\frac{\sigma-1}{\sigma}(1-2a)-1}{\left\{1+(2\phi-1)\left(\Theta_{PC}^{RFin}+\Theta_S^{RFin}\Theta_{PC}^S\right)-2b\Theta_{PC}^S-\frac{\sigma-1}{\sigma}(2a-1+\rho)+\frac{\sigma-1}{\sigma}\{\rho-(1-a)[z+z^*+(2-z-z^*)(2a(1-\eta)-1+\rho)]\}\Theta_{PC}^S\right\}}
\end{aligned}$$

Table B-2: Structural coefficients of the NBE economies.

## C Data appendix

Table B-3: Summary statistics of variables used in Tables 3 and 4.

	count	mean	Var	min	max
dhb/gdp	1302	.2990385	.124145	-.4762988	1.719974
log(Eq. & FDI)	1302	.2990971	.0674573	.0049113	1.606499
NFA	1302	-.4805071	.1582936	-2.372993	4.253488
log(Gross Debt)	1302	.7918523	.1506004	.1549832	2.377564
Chinn-Ito	1302	.1391335	2.147392	-1.85564	2.45573
Openness	1302	.6854251	.1447153	.1389551	2.850813
Net Exp.	1302	-.0372739	.0117157	-.7324887	4.743858
log(GDP/Pop.)	1302	7.567197	2.372067	4.606878	10.65228
log(Pop.)	1302	2.697694	2.096801	-1.367304	7.15924

### C.1 Data sources

We use the following variables from the following, freely accessible, data sets:

- Lane and Shambaugh (2010): debt assets in domestic currency % of GDP, debt assets in foreign currency % of GDP, debt liabilities in domestic currency % of GDP, and debt liabilities in foreign currency % of GDP for 109 countries (after eliminating outliers, see section C.2).
- The updated and extended version of the data set constructed by Lane and Milesi-Ferretti (2007): GDP (US\$), Portfolio equity assets (stock), Portfolio equity liabilities (stock), FDI assets (stock), FDI liabilities (stock), Debt assets (stock), Debt liabilities (stock), Portfolio debt assets, Portfolio debt liabilities, and net foreign assets (NFA) for the same countries as in Lane and Shambaugh (2010).
- International Financial Statistics from the IMF: exports of goods and services, imports of goods and services (both in national currencies), official or market exchange rates (to convert into US\$), and population.
- Campa and Goldberg (2002): change in short-run pass-through elasticities 1999 vs. 1989 in their table 1 (expressed in percentage points). After eliminating outliers (see section C.2), we use Austria, Germany, Greece, USA, Canada, New Zealand, Netherlands, Japan, Australia, France, Denmark, Italy, Norway, Spain, Portugal, Sweden, UK.
- Eurostat: invoicing currency of all export and import goods (extra-EU trade) of the individual euro countries for the year 2010.
- Chinn and Ito (2006): updated Financial Openness Index.
- OECD Main Economic Indicators: M2. OECD Economic Outlook 92: Government final consumption expenditure, volume; GDPV: Gross domestic product, volume, market prices; ET: Total employment from 1970Q1 until 2012Q4, all for the calculation of the shock variances.

The time period for our regression data, 1990-2004, is dictated by the length of the series in Lane and Shambaugh (2010).

Table B-4: Summary statistics of variables used in Tables 5.

	count	mean	Var	min	max
Ex. Vol.	754	.0075362	.0006026	3.98e-06	.3054336
( $\Delta$ ) Eq. & FDI	754	.4063114	.1122991	.0102665	1.786552
Tot. Debt	754	.8488083	.1969875	.1549832	2.880083
NFA	754	-.4133297	.156323	-2.026217	.6376782
Chinn-Ito	754	.4421156	2.396458	-1.85564	2.45573
Openness	754	.7176627	.1546269	.1492615	2.915713
Net Exp.	754	-.0091765	.0100844	-.6649232	.4743858
GDP/Pop.	754	8.321264	2.279793	4.606878	10.93966
Infl. Vol.	754	.0005317	2.67e-06	5.37e-07	.0183961

## C.2 Data selection

Table B-5: Correlation of variables used in Tables 3 and 4.

	dhb/gdp	log(Eq. & FDI)	NFA	log(Gross Debt)	Chinn-Ito	Openness	Net Exp.	log(GDP/Pop.)
dhb/gdp	1							
log(Eq. & FDI)	-0.177	1						
NFA	-0.843	-0.166	1					
log(Gross Debt)	0.607	0.104	-0.542	1				
Chinn-Ito	-0.307	0.328	0.246	0.103	1			
Openness	0.00603	0.294	-0.223	0.168	-0.0486	1		
Net Exp.	-0.231	0.215	0.211	-0.0947	0.0610	0.0720	1	
log(GDP/Pop.)	-0.498	0.381	0.471	-0.0720	0.562	0.0258	0.388	1
log(Pop.)	-0.182	-0.146	0.266	-0.186	-0.110	-0.371	0.141	-0.0865

The financial variables (debt home bias over GDP or total debt, sum of portfolio equity and FDI assets plus liabilities over GDP, net foreign assets over GDP, total debt over GDP) feature some outliers. These are mainly financial centers such as Luxembourg, Hong Kong etc. As large parts of their assets do most likely not represent asset holdings of their own inhabitants (as assumed in our model), they are not subject of our analysis. Using different ways to remove outliers gives similar results. We use the multivariate technique to detect outliers proposed in Hadi (1992, 1994) with a significance level of 0.01 (the results are robust to changes in this value, where higher values tend to strengthen the results). Defining observations that are outside of three standard deviations of the final sample as outliers for each of the variables separately gives very similar results.

Table B-3 summarizes the variables used in the regressions of Tables 3 and 4, while table B-5 shows their correlations. Analogously, table B-4 summarizes the variables used in the regressions of Tables 5 and table B-5 displays their correlations. Table B-7 displays the countries which were used in the regressions of Tables 3 and 4

Table B-6: Correlation of variables used in Table 5

	Ex. Vol.	( $\Delta$ ) Eq. & FDI	Tot. Debt	NFA	Chinn-Ito	Openness	Net Exp.	GDP/Pop.
Ex. Vol.	1							
( $\Delta$ ) Eq. & FDI	-0.187	1						
Tot. Debt	-0.0363	0.364	1					
NFA	-0.0348	0.0114	-0.146	1				
Chinn-Ito	-0.191	0.475	0.407	0.254	1			
Openness	-0.0565	0.382	0.0790	-0.107	-0.0646	1		
Net Exp.	-0.0802	0.168	0.00127	0.202	0.0113	0.0255	1	
GDP/Pop.	-0.214	0.422	0.194	0.538	0.660	-0.0909	0.266	1
Infl. Vol.	0.642	-0.206	0.00457	-0.135	-0.250	-0.0353	-0.115	-0.311

Table B-7: Countries used in the regressions of Tables 3 and 4.

United States	Pakistan	El Salvador	Tunisia
Austria	Philippines	Guatemala	Uganda
Denmark	Thailand	Haiti	Burkina Faso
France	Vietnam	Honduras	Fiji
Germany	Algeria	Mexico	Papua New Guinea
Italy	Cameroon	Nicaragua	Armenia
Netherlands	Chad	Paraguay	Azerbaijan
Norway	Congo, Republic of	Peru	Belarus
Sweden	Benin	Uruguay	Albania
Canada	Equatorial Guinea	Venezuela, Rep. Bol.	Georgia
Japan	Ethiopia	Jamaica	Kazakhstan
Finland	Gabon	Trinidad and Tobago	Kyrgyz Republic
Greece	Ghana	Iran, Islamic Republic of	Moldova
Iceland	Guinea	Israel	Russia
Ireland	Côte d'Ivoire	Jordan	China, P.R.: Mainland
Portugal	Kenya	Oman	Ukraine
Spain	Madagascar	Syrian Arab Republic	Czech Republic
Turkey	Malawi	Egypt	Slovak Republic
Australia	Mali	Yemen, Republic of	Estonia
New Zealand	Morocco	Bangladesh	Latvia
South Africa	Mozambique	Cambodia	Hungary
Argentina	Niger	Sri Lanka	Lithuania
Bolivia	Nigeria	India	Croatia
Brazil	Rwanda	Indonesia	Slovenia
Chile	Senegal	Korea	Macedonia
Colombia	Tanzania	Malaysia	Bosnia and Herzegovina
Dominican Republic	Togo	Nepal	Poland
	Romania		