Financial frictions, financial integration and the international propagation of shocks*

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Abstract

This paper develops a quantitative two-country model with a financial accelerator and endogenous portfolio choice to study how the international transmission of asymmetric shocks is affected in the presence of levered cross-border investors.

Foreign exposure in interconnected balance sheets of financially constrained investors can indeed act as a powerful propagation mechanism of asymmetric shocks across countries. However, in the model financial and real interdependence can be very strong even with minimal balance sheet exposure, if financial markets are integrated, reflecting a strong pressure towards the cross-border equalization of external finance premia faced by levered investors. In turn, this may result in tight linkages in leverage and macroeconomic dynamics across countries.

*The views expressed here are those of the authors and do not necessarily reflect those of the European Central Bank.
1 Introduction

This paper develops a two-country model featuring financial frictions on capital investment and nontrivial portfolio choices by agents under incomplete markets. This framework allows us to analyze the concept of international financial multiplier working through balance sheet effects on cross-border leveraged investors postulated in the literature on financial crises (e.g. Calvo (2000) and Krugman (2008)), and study its effects for fundamentals-based "contagion", as empirically documented e.g. by Kaminsky and Reinhart (2000). The latter authors argue that the need to rebalance the overall risk of an investor’s cross-border asset portfolio and to deleverage following the initial losses can lead to a marked reversal in investment and asset prices across markets where the investor has substantial exposure. For instance, they find that in the case of banks this helps explain cross-border spillovers, since if a bank is confronted with a marked rise in nonperforming loans in one country it is likely to be called upon to reduce the overall risk of its assets by pulling out of other high risk projects elsewhere. Furthermore, it will lend less (if at all), as it is forced to recapitalize and adjust to its lower level of wealth.

In our model economy "entrepreneurs/investors" in each country buy claims to capital stocks installed both domestically and abroad, to be used for production of a local, country-specific good which is then traded internationally for consumption and investment. Broadly motivated with financial frictions in the spirit of Bernanke et al. (1999), these entrepreneurs are subject to a collateral constraint. Specifically, they finance their demand for capital investment by issuing debt in domestic currency, facing an external finance premium which is an inverse function of their net worth. Effectively, financial frictions thus impinge on the amount of savings that can be invested by a given economy into productive but risky activities, domestically and abroad.

This way we broadly capture the idea that the international financial multiplier works through the balance sheet of leveraged agents engaged in cross-border asset investment. When asset prices (Tobin’s $Q$ price of capital) fall heavily in one country, entrepreneurs find themselves undercapitalized, and have to decrease investment across-the-board, effectively selling off domestic and foreign assets. This puts pressure on the balance sheet of entrepreneurs abroad, and so on, potentially enhancing cross-border spillovers.

We close the model allowing domestic and foreign households to also hold a nontrivial portfolio, as they invest in domestic and foreign bonds, thus departing from the assumption of perfect international risk sharing among households usually entertained in the literature studying financial frictions in the open economy.

For a variety of shocks, including technology (neutral and investment-specific) and financial (to the premium) shocks, we then study how the international transmission mechanism is shaped by the degree of financial integration across countries, captured by the set of assets that can be traded internationally, in the presence of leveraged investors. Specifically, starting from the case of complete financial autarky, we study the implications of gradually expanding interna-
tional trade in assets to bonds and capital shares, drawing from the recent literature solving for optimal portfolio allocations in DSGE models with perturbation methods, pioneered by Van Wincoop and Tille (2007) and Devereux and Sutherland (2007).

Our main results are as follows. We find that a large degree of exposure to foreign assets in the balance sheets of financially constrained investors leads to a heightened international propagation of asymmetric shocks, consistent with the hypothesis e.g. by Krugman (2008), formulated in a partial equilibrium setting. However, we also find that international financial integration, by imposing no-arbitrage conditions on prices of risky assets across borders, constitutes a further powerful source of shock propagation. By leading to tight linkages in the premia paid by financially constrained investors, financial integration could result in strong cross-country comovements in the process of deleveraging by these agents, irrespective of the actual share of cross-border assets in their portfolios.

These additional market-based transmission channels in our model are notable in light of the evidence on the international propagation of financial crises. A case in point is the widespread financial turmoil in the aftermath of the 1998 Russian default. According to Calvo (2000, p. 3) "deleveraging associated with the collapse of a very small share of world’s financial portfolio (as Russian debt is), should not result in an across-the-board implosion of EM markets," in contrast with what occurred in reality. While a propagation mechanism based only on foreign exposure of balance sheets, as the one stressed by Krugman (2008), would not be able to account for the above episode and other similar ones, our model can rationalize a strong propagation even when balance sheets of leveraged investors are only marginally exposed to foreign assets through simple arbitraging in integrated financial markets, as the strong correlation in deleveraging is ensured simply because of the endogenization of portfolios decisions.

The structure of the paper is as follows. The next section presents in detail the structure of our two-country model, while Section 3 discusses the concept of the financial multiplier in the literature in light of our setting. After reporting our benchmark model parameterization in Section 4, Section 5 illustrates our main results in terms of impulse responses to asymmetric shocks. Finally, Section 6 concludes.

2 A two-country model with financial frictions and endogenous portfolio choice

This section develops a general equilibrium framework that incorporates capital market imperfections into an international environment, following Gilchrist (2003), who shows how to incorporate financial frictions in a simple yet tractable way in such an environment. The building block of the model corresponds to a two-country monetary economy under a flexible exchange rate regime. Both countries are similar in size and structure and are characterized by a continuum of agents of equal measure. Consequently, there is trade across countries. While
labor is internationally immobile, we allow capital in each country to be owned by domestic and foreign investors, which may or may not be subject to financial frictions. Each country is specialized in the production of one good, but consumers in any country consume both goods. We assume incomplete international financial markets: households in each country have access to nominal bonds denominated in domestic and foreign currency (and potentially to domestic and foreign equities, defined as claims to aggregate profits), but do not have access to a complete set of contingent assets. There is imperfect competition on the good markets, allowing the introduction of nominal rigidities due to price contracts à la Calvo (1983).

2.1 Households

The representative infinitely lived household in each country chooses consumption, $C$, and hours, $H$. Consumption, $C$, is a composite of the two goods indexed by $H$ for the good produced in the domestic country and $F$ for the good produced in the foreign country, according to the following CES aggregator:

$$C_t \equiv \left[ n \bar{P}_{H,t}^{1-\beta} \left( 1 - n \right) \frac{1}{\beta} \bar{P}_{F,t}^{1-\beta} \right]^{\frac{\theta}{\beta - 1}},$$

where $n$ is the weight on the consumption of Home traded goods, $\theta$ is the constant (trade) elasticity of substitution between $C_{H,t}$ and $C_{F,t}$. The associated utility based price index is

$$P_t = \left[ n \bar{P}_{H,t}^{1-\theta} + \left( 1 - n \right) \bar{P}_{F,t}^{1-\theta} \right]^{\frac{1}{1-\theta}}.$$

We define $C_t(h)$ as the Home agent’s consumption as of time $t$ of the Home good $h$; similarly, $C_t(f)$ is the Home agent’s consumption of the imported good $f$. We assume that each good $h$ (or $f$) is an imperfect substitute for all other goods’ varieties, with constant elasticity of substitution $\eta > 1$:

$$C_{H,t} \equiv \left[ \int_0^1 C_t(h)^{\frac{\eta-1}{\eta}} dh \right]^{\frac{\eta}{\eta-1}}, \quad C_{F,t} \equiv \left[ \int_0^1 C_t(f)^{\frac{\eta-1}{\eta}} df \right]^{\frac{\eta}{\eta-1}};$$

the price index of the Home goods is given by:

$$P_{H,t} = \left[ \int_0^1 P_t(h)^{1-\eta} dh \right]^{\frac{1}{1-\eta}}.$$

Throughout the paper we assume that the law of one price holds, so that prices of trade goods in the foreign country, denoted with an asterisk, will obey $\mathbb{E}_t \bar{P}_{H,t}^* = \bar{P}_{H,t}$ and $\mathbb{E}_t \bar{P}_{F,t}^* = \bar{P}_{F,t}$. Notice however that $\mathbb{E}_t \bar{P}_{H,t}^*$ will generally be different from $\bar{P}_t$, because of the different weights attached to goods in the foreign consumption basket, giving rise to deviations from PPP and fluctuations in the real exchange rate $RER = \frac{\bar{P}_{H,t}^*}{\bar{P}_t}$.
**Budget constraint and asset markets**  
Households solve the following standard intertemporal problem

$$
\max_{C_t, H_t, B_t, \alpha_j} E_t \sum \beta(\tau) \left[ U(C_{\tau}, \overline{C}_{\tau-1}) - \phi(H_t) \right]
$$

(where we have allowed for external habit in consumption as a function of aggregate domestic consumption $\overline{C}_{\tau-1}$ in preferences) subject to the following budget constraint in real terms:

$$
C_t + B_t + \sum \alpha_{st} = w_t H_t + r_t B_{t-1} + \sum \alpha_{st-1} r_{st} + \Pi_t.
$$

(2)

Households receive income in the form of wage $w_t$, profits in the form of lump-sum transfers from all domestic firms ($\Pi_t$, to be fully specified below), and returns $(r_t, r_{st})$ from asset holdings $(B_t, \alpha_{st})$. We first assume that households, through financial intermediaries, provide loans to the domestic capital investors ($B_t$, in consumption units), earning an ex-post rate real $r_t$. Depending on the degree of integration of international financial markets, households can also hold different types of financial assets; in the benchmark case we assume they can trade in short-term foreign and domestic nominal bonds, whose holdings in consumption units we denote with $\alpha_{d,t}$ and $\alpha_{d^*},t$, respectively, yielding ex-post returns $r_{d,t} = r_t$ and $r_{d^*,t} = \frac{RER_t}{RER_{t-1}} r_{d^*}^*$. We can also extend the model allowing households to trade in claims to aggregate profits $\Pi_t$.

A similar problem applies to households abroad; notice that because of market clearing in financial markets,

$$
\alpha_{d,t} + \alpha_{d^*}^* = 0
$$

$$
\alpha_{d^*,t} + \alpha_{d}^* = 0,
$$

where $\alpha_{d^*}^*$ denotes bond holdings abroad in consumption units.

It is useful to rearrange the budget constraint defining households net wealth $W_t$ as follows:

$$
W_t = B_t + \sum \alpha_{st},
$$

(3)

$$
C_t + W_t = w_t H_t + r_t W_{t-1} + \alpha_{d^*,t-1} \left( \frac{RER_t}{RER_{t-1}} r_{d^*}^* - r_t \right) + \Pi_t;
$$

(4)

this rearrangement underlines that households are not at all constrained by the amount of loans $B_t$ and can choose any position in domestic bonds they want in equilibrium.

The representative household optimization yields the following standard first
order conditions:

\[ C_t : \lambda_t = U_C (C_t) \]
\[ H_t : w_t = \frac{\phi_H (H_t)}{\lambda_t} \]
\[ W_t : \lambda_t = \beta (t) E_t r_{t+1} \lambda_{t+1} \]
\[ \alpha_{d*,t} : E_t \lambda_{t+1} \left( \frac{RER_{t+1}}{RER_t} r_{t+1}^* - r_{t+1} \right) = 0. \]

Finally, we assume standard functional forms for preferences \( U (\cdot) = \frac{(C - \bar{C})^{1-\sigma}}{1-\sigma} \), \( \phi (H) = \frac{H^{1+\eta}}{1+\eta} \); however, we also assume that the discount factor \( \beta (\tau) \) is endogenous to ensure stationarity of the steady state.

Similar equations holds for the foreign representative households; notice however that the last equation implies that up to first order, \( E_t \left( \frac{RER_{t+1}}{RER_t} r_{t+1}^* - r_{t+1} \right) = 0 \), the same implication of its foreign counterpart (where \( \lambda_{t+1}^* RER_t \) replaces \( \lambda_{t+1} \)). Therefore, up to first order, i.e. under certainty equivalence, the portfolio choice is indeterminate. However, following the perturbation approach of Devreux and Sutherland (2007) and Judd and Guu (2001), we can take a second order approximation of the difference of the two nonlinear first order conditions,

\[ E_t \left[ \left( \lambda_{t+1} - \lambda_{t+1}^* \frac{RER_t}{RER_{t+1}} \right) \left( \frac{RER_{t+1}}{RER_t} r_{t+1}^* - r_{t+1} \right) \right] = 0 \]  

and use it to solve for the steady state portfolio allocation. This is enough to characterize the first order equilibrium system dynamics, including the evolution of the wealth distribution, since up to first order \( E_t \left( \frac{RER_{t+1}}{RER_t} r_{t+1}^* - r_{t+1} \right) \alpha_{d*,t-1} = 0 \), implying that we only need to determine the steady state portfolio allocation.

### 2.2 Production

The production sector in each country is divided into a monopolistically competitive retail sector, a competitive wholesale sector which produces capital goods and a competitive sector of "entrepreneurs". These final goods producers in both countries specialize in an array of imperfectly substitutable goods sold to households and capital goods producers. Final goods are produced with labor, hired from households, and capital, hired from entrepreneurs. These competitive entrepreneurs in turn purchase capital from capital goods producers in both countries at the beginning of each period, and rent it to final goods producers; they resell capital to capital goods producers at the end of next period. Given that the retailers are price setters, this structure allows the introduction of nominal rigidities while maintaining a constant-returns-to-scale assumption.
in the wholesale sector, which is necessary for aggregation when financial market imperfections are introduced.

2.2.1 Final goods producers

In each country a large number of monopolistically competitive producers use the intermediate capital input together with labor to produce a final good sold domestically and abroad.

The problem of the firm is

$$\min_{L,K} w_t L_t + r_{K,t} K_t$$

s.t. \( Y_t = \varepsilon_{Y,t} L_t^{1-\alpha} K_t^\alpha \)

so that, under flexible prices,

$$P_{H,t} = \frac{1}{\varepsilon_{Y,t}} \frac{w_t^{1-\alpha} \Omega_{K,t}}{\alpha^\alpha (1-\alpha)^{1-\alpha}}$$

and

$$L_t = (1-\alpha) \frac{P_{H,t} Y_t}{\mu_C w_t}$$

$$K_t = \alpha \frac{P_{H,t} Y_t}{\mu_C r_{K,t}}$$

Price setting  When retail firms are subject to nominal rigidities à la Calvo, at any time \( t \), they keep their price fixed with probability \( \zeta \). We assume that when firms update their prices, they do so simultaneously in the Home and in the Foreign market, in the respective currencies. The maximization problem is then as follows:

$$\max_{P(h), P^*(h)} E_t \left\{ \sum_{k=0}^{\infty} \Lambda_{t+k} \zeta^k \left( \frac{[P_t(h)D_{t+k}(h) + \varepsilon_1 P^*_t(h) D^*_{t+k}(h)] - MC_{t+k}(h) [D_{t+k}(h) + D^*_{t+k}(h)]}{MC_{t+k}(h) [D_{t+k}(h) + D^*_{t+k}(h)]} \right) \right\}$$

(6)

where \( \Lambda_{t+k} \) is the firm’s stochastic discount factor between \( t \) and \( t+k \), which we assume is the same as that of the household, and the firm’s demand at Home and abroad is given by:

$$D_t(h) = \int \left( \frac{P_t(h)}{P_{H,t}} \right)^{-\eta} (C_{H,t} + I_{H,t}) dh$$

$$D^*_t(h) = \int \left( \frac{P^*_t(h)}{P^*_{H,t}} \right)^{-\eta} (C^*_{H,t} + I^*_{H,t}) dh$$

In these expressions, \( P_{H,t} \) and \( P^*_{H,t} \) denote the price index of industry \( h \) and of Home goods, respectively, in the Foreign country, expressed in Foreign currency.
By the first order condition of the producer’s problem, the optimal price $P_t(h)$ in domestic currency charged to domestic customers is:

$$P_t(h) = \frac{\eta}{\eta - 1} \frac{E_t \sum_{k=0}^{\infty} \zeta^k \Lambda_{t+k}D_{t+k}(h)MC_{t+k}(h)}{E_t \sum_{k=0}^{\infty} \zeta^k \Lambda_{t+k}D_{t+k}(h)};$$  \hspace{1cm} (7)$$

as we posit that firms set prices in producer currency, the price charged to foreign consumers is a function of the optimal Home price and the exchange rate via the law of one price: $P^*_t(h) = \frac{P_t(h)}{E_t}$.

Since all the producers that can choose their price set it to the same value, we obtain the following equations for $P_{H,t}$:

$$P_{H,t}^{1-\eta} = \alpha P_{H,t-1}^{1-\eta} + (1 - \zeta) P_t(h)^{1-\eta}.$$

The representative retailer pricing decision implies the standard new Keynesian Phillips curve, where current inflation is a function of expected inflation and marginal costs $\mu_t$:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \xi \mu_t,$$

where $\xi$ is a function of the probability of adjustment $\zeta$.

Similar relations hold for the Foreign firms.

### 2.2.2 Capital goods producers

In each country there is a representative competitive capital goods producer that uses final goods to produce physical capital. The latter is sold at the beginning of the period to entrepreneurs and re-purchased (net of depreciation) at the end of next period. Investments generates adjustment costs as in Christiano et al. (2005). The problem of this firm is thus:

$$\max_{L_t, K_{t+1}} E_t \sum_{i=0}^{\infty} \beta^i [Q_{K,t+i}K_{H,t+i+1} - I_{t+i} - Q_{K,t+i}K_{P,t+i}]$$

s.t. $K_{H,t+1} = K_{H,t} + \varepsilon_t F(I_t, I_{t-1})$

$$K_{P} = (1 - \delta) K_{H,t}$$

where

$$F(I_t, I_{t-1}) = \left[ 1 - S \left( \frac{I_t}{I_{t-1}} \right) \right] I_t$$

and

$$S \left( \frac{I_t}{I_{t-1}} \right) = \exp \left( \gamma_t \left( \frac{I_t}{I_{t-1}} \right) \right) + \exp \left( -\gamma_t \left( \frac{I_t}{I_{t-1}} \right) \right) - 2$$

where $\gamma_t \geq 0$, and where $\lambda_t$ is the household marginal utility, and $I_t$ is a composite of domestic and foreign goods obtained with the same CES aggregator.
as domestic consumption. Notice that the assumed form of capital accumulation introduces embodied technological change in the form of the shock $\varepsilon_{t,t}$.

After substituting the constraints into the objective function we can derive the FOC, that is

$$I_t : -1 + Q_{K,t} \varepsilon_{I,t} F_{1,t} + \beta \frac{\lambda_{t+1}}{\lambda_t} Q_{K,t+1} F_{2,t+1} = 0$$

where

$$F_{1,t} = -S' \left( \frac{I_t}{I_{t-1}} \right) \left( \frac{I_t}{I_{t-1}} \right) + 1 - S \left( \frac{I_t}{I_{t-1}} \right) ,$$

$$F_{2,t} = S' \left( \frac{I_t}{I_{t-1}} \right) \left( \frac{I_t}{I_{t-1}} \right)^2$$

and where $Q_{K,t}$ is the Lagrange multiplier on the capital accumulation constraint, relative to household’s marginal utility, (Tobin’s Q).

### 2.3 Investor sector

We introduce financial frictions in capital accumulation in the spirit of Gilchrist (2003). In order to combine them with the choice of capital investment in each country as a standard portfolio problem, we assume a large number of identical capitalist firms (entrepreneurs or investors) which in each period rent out domestic and foreign capital purchased in period $t-1$ from capital producers. In order to finance capital purchases, we assume that these firms have to borrow short term, potentially at a premium over the local domestic nominal risk free rate.

The problem of the representative capitalist firm is thus

$$\max_{K_{t+1},K_{t+1}} \sum_{i=0}^{\infty} E_t R_{K,t+i}^e \left[ r_{K,t+i} K_{t+i} + RER_t R_{K,t+i} K_{t+i}^* - Q_{K,t+i} (K_{t+1+i} - (1 - \delta) K_{t+i}) ight. \\
- RER_t Q_{K,t+i} (K_{t+1+i}^* - 1 - \delta K_{t+i}^*) - R_{D,t+1} D_{t+1} \left. \right]$$

s.t. $Q_{K,t} K_{t+1} + RER_t Q_{K,t} K_{t+1}^* =Dt + N_t$

$D_t$ is the real value of the debt, $N_t$ is the real value of the net-worth of the firm (equities) and $R_{D,t+1}^e$ is the discount rate of the investors (discussed later).

The first order condition for the investor’s problem are

$$K_{t+1}^* : E_t R_{K,t+1}^e \left( R_{K,t+1} + (1 - \delta) Q_{K,t+1} - \frac{R_{D,t+1}^e}{\pi_{t+1}} Q_{K,t} \right) = 0$$

(8)

$$K_{t+1}^* : E_t R_{K,t+1}^e \left( RER_{t+1} R_{K,t} + RER_{t+1} (1 - \delta) Q_{K,t+1} - RER_{t+1} \frac{R_{D,t+1}^e}{\pi_{t+1}} Q_{K,t} \right) = 0$$

(9)
we can rewrite

\[ E_t \left[ R_{t+1}^e R_{t+1}^K \right] = E_t \left[ R_{t+1}^e \left( \frac{r_{K,t+1} + Q_{K,t+1} (1 - \delta)}{Q_{K,t}} \right) \right] = E_t \left[ R_{t+1}^e \frac{R_t^D}{\pi_{t+1}} \right] \]

and

\[ E_t \left[ R_{t+1}^e \frac{R_{t+1}^* R_{t+1}^K}{R_{t+1}^* \pi_{t+1}} \right] = E_t \left[ R_{t+1}^e \frac{R_{t+1}^*}{R_{t+1}^* \pi_{t+1}} \right] \]

and for the foreign entrepreneur

\[ E_t \left[ R_{t+1}^e \left( \frac{R_{t+1}^e R_{t+1}^K}{R_{t+1}^e \pi_{t+1}} \right) \right] = E_t \left[ R_{t+1}^e \left( \frac{R_{t+1}^e}{R_{t+1}^e \pi_{t+1}} \right) \right] \]

and

\[ E_t \left[ R_{t+1}^e \left( \frac{r_{K,t+1} + Q_{K,t+1} (1 - \delta)}{Q_{K,t}} \right) \right] = E_t \left[ R_{t+1}^e \frac{R_t^D}{\pi_{t+1}} \right] . \]

We can write these FOCs in differences, i.e.

\[ E_t \left[ R_{t+1}^e \left( \frac{r_{t+1} + Q_{t+1} (1 - \delta)}{Q_{t}} \right) \right] = 0 \] (10)

and

\[ E_t \left[ R_{t+1}^e \left( \frac{R_{t+1}^e}{R_{t+1}^e \pi_{t+1}} \right) \right] = 0. \] (11)

\[ E_t \left[ R_{t+1}^e \left( \frac{R_{t+1}^e}{R_{t+1}^e \pi_{t+1}} \right) \right] = 0 \] (12)

These two conditions, to first order, give exactly the same information, so that in order to solve the model up to first order, we could keep only one of these equations. Notice also that, to first order, these conditions simply equate the gross return on the two types of capital.

The optimal portfolio must satisfy\(^1\)

\[ E_t \left[ \left( R_{t+1}^e \frac{R_{t+1}^e}{R_{t+1}^e \pi_{t+1}} \right) \left( r_{t+1} + Q_{t+1} (1 - \delta) \right) \right] = 0 \] (13)

Moreover, we would have one of the FOC per country (agent) i.e., say

\[ E_t \left[ R_{t+1}^e \frac{R_{t+1}^e}{R_{t+1}^e \pi_{t+1}} \right] = E_t \left[ R_{t+1}^e \frac{R_t^D}{\pi_{t+1}} \right] \]

\(^1\)Satisfying these conditions yields the optimal portfolio. either of the previous three equations will be used in solving the model, hence ensuring that all of them are simultaneously satisfied. Notice that the equation used in the solution of the model will impose constraint on the premium when solved at higher orders of approximation only.
Observe that if, following Gilchrist (2003), we assume that \( R_{t+1}^K = \lambda_{t+1} \lambda_t \), in the absence of capital market imperfections, the return on capital is equated to the risk-free return and hence satisfies the household Euler equation:

\[
E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} R_{t+1}^K \right] = E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} r_{t+1} \right] = 1.
\]

Therefore, our specification encompasses standard models of the optimal choice of foreign and domestic capital investment, such as Coeurdacier et al. (2008). However, when \( R_{t+1}^D \) and \( R_{t+1}^D \) coincide with the nominal risk-free rate paid on bonds traded by households, these conditions together reproduce the UIP condition above up to first order, and are therefore jointly collinear with it. In this case we should only retain one of these conditions, as it would impose a restriction on the gross return on capital being equal to the gross return on bonds.

### 2.3.1 Financial frictions and the evolution of net worth

A convenient way to formalize financial frictions is by introducing a financial accelerator, as in Bernanke, Gertler, and Gilchrist (1999). The key mechanism involves a negative link between the external finance premium, \( \chi \) (the difference between the cost of funds raised externally and the opportunity cost of funds internal to the firm), and the net worth of borrowers, \( N \) (defined as the liquid assets plus collateral value of illiquid assets less outstanding obligations).

The inverse relationship between external finance premiums and the strength of the balance sheet arises because when borrowers have little wealth to contribute to project financing, the potential divergence of interests between the borrowers and the lenders is greater, implying increased agency costs. In equilibrium, lenders must be compensated for higher agency costs by a large premium. Because borrower net worth is procyclical through the behavior of profits and asset prices, the financial accelerator enhances swings in borrowing and thus in investment, spending, and production.

Following the formulation in Gilchrist (2003), in the presence of the financial accelerator, the above equations are modified to allow for a premium on external finance, arising from monitoring costs:

\[
E_t \left[ R_{t+1}^E \left( \frac{R_{t+1}^D}{\pi_{t+1}} - \chi \left( \frac{D_t}{N_t}, \xi_{e,t}, \epsilon_{e,t} \right) r_{t+1} \right) \right] = 0,
\]

where \( \chi(\cdot) \) is the external finance premium. Notice that up to first order the latter equation and the following one, modifying the above condition for the optimal choice of capital investment,

\[
E_t \left[ R_{t+1}^E \left( \frac{R_{t+1}^D}{\pi_{t+1}} + \frac{Q_{K,t+1} (1 - \delta)}{Q_{K,t}} - \frac{R_{t+1}^D}{\pi_{t+1}} \right) \right] = 0,
\]
are the same as in a setting in which the financial accelerator could be motivated from microfoundations (see e.g. Bernanke, Gertler, and Gilchrist, (1999)). It can be shown that in a such a setting the function $\chi(\cdot)$ is strictly increasing and convex over the relevant range, so that the external finance premium is negatively related to the share of the capital investment that is financed by entrepreneurs’ own net worth. We also include a shock $\varepsilon_{e,t}$ to the external finance premium, which following Christiano et al. (2006) can be interpreted as a shock originating in the financial sector.

By analogy with the BGG model we assume that the evolution of entrepreneurial net worth, $N_t$, reflects the equity stake that entrepreneurs have in their firms, specifically:

\[
N_t = \gamma \left[ R^K_t Q_{t-1} K_{ht} + \frac{RER_t}{RER_{t-1}} R^K_t K_{ht} - R^K_{t-1} K_{ht} - R^K_{t-1} K_{ht} D_{t-1} \right] + (1 - \gamma) T_t
\]

or

\[
N_t = \gamma \left[ R^K_t W_{e,t-1} + (RER_t R^K_t - RER_{t-1} R^K_t) K_{f1,t} - R^K_{t-1} K_{ht} D_{t-1} \right] + (1 - \gamma) T_t,
\]

where $K_{f1,t} = Q^*_t K_{ht}^*$ and

\[
W_{e,t} = Q_{K,t} K_{ht+1} + RER_t Q^*_{K,t} K^*_{ht+1}
\]

is the total holdings of capital by the entrepreneur, which has to be equal to $D_t + N_t$. The coefficient $\gamma$ can be interpreted as the share of entrepreneurs that exit the market, while $T_t$ is the real value of a transfer to entrepreneurial start-ups.

### 2.4 Monetary policy

In order to close the model, we need to assume a behavioral rule for monetary policy. We assume that each central bank follows the following standard Taylor-type rule

\[
R_t = \lambda_r R_{t-1} + (1 - \lambda_r) \lambda_\pi \pi_t + \varepsilon_{R_t},
\]

where interest rates respond only to inflation with a smoothing coefficient, and $\varepsilon_{R_t}$ represents a monetary policy shock.

### 3 On modeling the international financial multiplier: Balance-sheet and no-arbitrage effects

In this section we discuss how the propagation mechanism in our model economy compares with the idea of an international financial multiplier recently formulated by Krugman (2008), in a partial equilibrium framework, and formalized by Devereux and Yetman (2009) in a dynamic general equilibrium context, though in an alternative way relative to ours.
Krugman (2008) dubs international financial multiplier the channel of cross-border transmission of changes in asset prices through balance sheets effects of leveraged agents, crediting Calvo (2000) for the original insight, against the backdrop of the contagion of financial turmoil to other emerging markets after the 1998 Russian default. In our setting, the main gist of Krugman’s argument can be rendered by postulating that entrepreneurs have a preferred, exogenously given composition of their holdings of domestic and foreign risky assets $\kappa$ and $1 - \kappa$, implying that:

$$K_{t+1} = \alpha_k \left(1 + \frac{D_t}{N_t} \right) \frac{N_t}{Q_{K,t}} = \alpha_k \left(1 + \chi^{-1} (\cdot) \right) \frac{N_t}{Q_{K,t}}$$

$$K_{t+1}^* = \alpha_k^* \left(1 + \chi^{-1} (\cdot) \right) \frac{N_t}{RER_t Q_{K,t}^*}$$

where net worth is given by

$$N_t = \frac{r_{K,t} + Q_{K,t} (1 - \delta)}{Q_{K,t-1}} \alpha_k + \frac{RER_t \left( r_{K,t} + Q_{K,t} (1 - \delta) \right)}{RER_{t-1} Q_{K,t-1}^*} \alpha_k^* - \frac{D_{t-1}}{\epsilon_{t-1}}$$

and $1 + \chi^{-1} (\cdot) > 1$ is leverage over the net worth of the investor, which is also assumed exogenous in Krugman (2008).

The implications for the comovements of the price of domestic and foreign risky assets through their effects on investors’ net worth are apparent. In the words of Krugman (2008, page 5), “Home and Foreign risky assets become complements: a rise in $\left[ Q_{K,t} \right]$, by increasing [the leveraged investor’s] capital, increases the demand for Foreign assets, a rise in $\left[ RER_t Q_{K,t}^* \right]$ similarly increases the demand for Home assets.”\(^2\) It is clear that, as argued by Krugman (2008), this propagation channel via balance sheet effects will be stronger the larger the international cross-holdings of assets, other things equal.

In our model, however, other propagation mechanisms are at work. As noted above, a first notable mechanism is that desired leverage is endogenously determined by investors taking into account the cost of external debt and the return on capital investment. Specifically, taking again as given portfolio choices, leverage would be determined according to the following equation (abstracting from the discount factors, which is correct under risk neutral entrepreneurs or up to first order):

$$E_t \left( \left[ R_{t+1}^K + \alpha_{k,t} \left( \frac{RER_{t+1}}{RER_t} \frac{R^K_{t+1}}{R_{t+1}^K} \right) \right] \right) = \chi \left( \frac{D_t}{N_t} \epsilon_{t-1} \right) E_t r_{t+1}, \quad (16)$$

\(^2\)Krugman (2008) also argues that the demand for risky assets by leveraged investors may be upward sloping in its own prices. It can be shown that in our framework this could occur as well, if, taking the leverage ratio as exogenous,

$$\frac{\partial K_{t+1}}{\partial Q_{K,t}} = \alpha_k \left(1 + \chi^{-1} (\cdot) \right) \frac{(1 - \delta) \alpha_k Q_{K,t} (1 - \delta) - N_t}{Q_{K,t}} > 0;$$

precisely this would be the case when net worth is relatively low and leverage high.
and its counterpart for the foreign investor:

$$E_t \left[ \left( R^K_{t+1} + \alpha^*_k, t \left( \frac{R^D_{t+1} RER_{t+1}}{RER_t} - R^K_{t+1} \right) \right) \right] = \chi \left( \frac{D^*_t}{N^*_t} \right) E_t \left[ \frac{RER_{t+1}}{RER_t} r^*_t \right],$$

(17)

where now $\alpha^*_k$ and $\alpha^*_k$ are the shares of investors funds invested in capital abroad, rather than the holdings. Thus, in our setting portfolio choices of levered investors will also affect the leverage ratio across countries, implying that the more similar the former, the more similar the latter, and thus the effects of a given shock on asset prices and aggregate variables like investment and output. Specifically, consider the case in which the shares are equal across countries, $\alpha^*_k = \alpha^*_k$, and households trade in bonds across countries; then $\chi_t = \chi^*_t \frac{E_t RER_{t+1}}{E_t r^*_t} = \chi^*_t \frac{Cov_t \lambda_{t+1} RER_{t+1}}{Cov_t \lambda_{t+1} r^*_t}$ implying that cross-country premia will be equalized up to a proportionality factor reflecting forward exchange risk — if UIP holds so that $E_t r^*_t = E_t \frac{RER_{t+1}}{RER_t} r^*_t$, which is true in our setting up to first order, then premia will be equalized across countries. In turn, this will impart further cross-border comovements between asset prices to bring about the equalization of premia and thus leverage ratios. Therefore, in our setting exposure of leveraged investors to foreign assets not only will affect the cross-border demand of assets, as e.g. highlighted by Krugman (2008), but it may also make broad financial conditions and thus leverage dynamics more similar across countries.

Nevertheless, this tendency to equalization of premia will be ensured in our setting when we consider endogenous portfolio decisions, quite independently of the amount of balance sheet exposure to foreign assets. Indeed, it is clear that, abstracting again from the investors’ discount factor, Home and Foreign investor’s first order conditions for optimal portfolio choice impose the following no-arbitrage relation:

$$E_t \left[ \frac{R^D_{t+1}}{\pi_{t+1}^*} \right] = E_t \left[ \frac{R^K_{t+1}}{\pi_{t+1}^*} \right] = E_t \left[ \frac{R^D_{t+1}}{\pi_{t+1}^*} \right],$$

which, combined again with UIP, implies that $\chi_t = \chi^*_t$ up to first order at any point in time, regardless of the portfolio composition of entrepreneurs capital investment. Intuitively, if the financially constrained agents have access to the same investment opportunities at the margin, the premia in excess of the risk free rate they pay on their debt will have to be equalized because of arbitrage. In turn, this means that integration in financial markets, irrespective of portfolio composition, could be a powerful source of propagation of shocks in equilibrium, particularly reflecting strong comovements in leverage ratios across countries, above and beyond the cross-border portfolio exposure of leveraged investors. The portfolio composition, however, will still be crucial in the determination of the general equilibrium wealth effects on aggregate demand stemming from the risk sharing channel of portfolio diversification.
These additional market-based transmission channels in our model are notable in light of the evidence on the international propagation of financial crises. A case in point is again the turmoil in the aftermath of the 1998 Russian default. According to Calvo (1998, p. 3) “an exogenous and unexpected negative shock, like Russia’s debt repudiation, will lower [...] investors’ portfolio values and, in turn, trigger margin calls, i.e., instant debt repayment obligations on leveraged positions. In an ideal perfect-information world, deleveraging associated with the collapse of a very small share of world’s financial portfolio (as Russian debt is), should not result in an across-the-board implosion of EM markets. This implication, however, is not valid if informed investors were liquidity-constrained. Under those circumstances, new EM debt instruments, for example, would have to be acquired by non-informed investors. This may bring about a major disturbance in the capital market” — our emphasis added.

The following two things are important to stress. First, a propagation based only on balance sheets exposure, as the one stressed by Krugman (2008), would not be able to account for the above and other similar episodes. Second, our model can rationalize a strong propagation to asset prices even when the balance sheets of leveraged investors are only marginally exposed to foreign assets, reflecting simple pricing in integrated financial markets — let us dub them no arbitrage effects — without resorting to any informational friction, as postulated by Calvo (1998).

Before turning to a quantitative analysis of the different propagation channels we have discussed only qualitatively so far, namely the balance sheet and the no-arbitrage effects, it is useful to consider alternative ways of modeling the international financial multiplier, particularly as implied by the recent paper by Devereux and Yetman (2009) — henceforth DY.

Following the collateral borrowing constraints introduced by Kiyotaki and Moore (1997), DY assume that capital investors can borrow only in proportion to the value of their holdings of domestic and foreign equities. Namely, these investors face the following borrowing constraint:

$$D_t \leq \kappa (Q_{K,t}K_{ht} + RER_t Q^*_{K,t}K^*_{ht})$$

which is assumed to be always binding with equality as in Iacoviello (2005). This implies that the first order conditions of the investors’ utility maximization problem yield that, up to first order, there is a wedge between the risk free rate they pay on their debt $D_t$ and the expected return on their capital investment:

$$E_t \left[ \tilde{R}^{K}_{t+1} \right] = E_t \left[ \tilde{R}^{K^*}_{t+1} \right] = E_t \left[ \tilde{r}_{t+1} \right] + \tilde{\kappa}_t.$$

The term $\tilde{\kappa}_t$ is the (first order approximation of the) Lagrange multiplier on the investors’ borrowing constraint above and can effectively be interpreted as a first order premium that borrowers have to pay on the risk free rate to invest in risky assets.

As DY assume that only capital is traded across borders by investors, the following relation, similar to the one derived above for our model, holds up to
first order:

\[ E_t \left[ \hat{r}_{t+1} + \frac{\hat{R}ER_{t+1}}{RER_t} \right] + \hat{\kappa}_t^* = E_t [\hat{r}_{t+1}] + \hat{\kappa}_t, \]

implying that the premia differential across countries, up to first order, should be equal to the expected real interest differential.\(^3\) Thus, if trade in short term bonds were also allowed, a case not entertained in DY, the premia \( \hat{\kappa}_t \) and \( \hat{\kappa}_t^* \) would be equalized across countries, as in our model, leading to further propagation across countries.

However, even in the case DY study under cross-border integration in capital trade only, the strength of propagation of asymmetric technology shocks seems to be directly related to the share of foreign capital owned by investors. This seems at odds with the intuition built above for our model and also the quantitative results we will present in the next section, namely that integration in capital trade, because of no-arbitrage effects, is powerful enough to internationally propagate asymmetric shocks, pretty much irrespective of balance sheet exposure to cross-border assets.

The reason for these differences is that quite different forces affect the risk premia \( \hat{\kappa}_t \), \( \hat{\kappa}_t^* \) in the DY framework à la Kyiotaki and Moore, and the risk premia \( \chi_t \), \( \chi_t^* \) in our framework à la BGG. Consider for the sake of simplicity the case in which the premia need to be equalized across countries up to first order as also trade in bond is allowed. As argued above, in our model, this implies that leverage ratios have to be also equalized across border, namely

\[ \frac{\hat{D}_t}{N_t} = \frac{\hat{D}_t^*}{N_t^*}, \]

also up to first order. Conversely, one can show that equalization of \( \hat{\kappa}_t \) and \( \hat{\kappa}_t^* \) implies that the expected investors’ discount factors (\( \hat{R}_{t+1}^\kappa \) and \( \hat{R}_{t+1}^{\kappa*} \), in our notation) should be equalized across borders, as it can be shown that:

\[ \hat{\kappa}_t = -E_t \left[ \hat{r}_{t+1} + \hat{R}_{t+1}^\kappa \right]. \]

Discount factors in DY reflect the investors’ growth rate of the marginal utility of consumption, obviously a function of current leverage, but not only. Specifically, from the budget constraint and borrowing constraint of investors,

\[ C_t = R_t^K Q_{K,t-1} K_t + RER_t R_t^K Q_{K,t-1}^* K_t - r_t D_{t-1} + D_t - (Q_{K,t} K_t + RER_t Q_{K,t}^* K_t^*) \]
\[ D_t = \kappa \left( Q_{K,t} K_t + RER_t Q_{K,t}^* K_t^* \right), \]

it is possible to show that up to first order investors’ consumption growth should obey:

\[ \Delta C_t = \frac{D}{\kappa C} \left( R^K \Delta \hat{R}_{t}^{K} - \kappa r \Delta \hat{r}_{t} \right) + \left( R^K - \kappa r \right) \frac{D}{\kappa C} \Delta \hat{D}_{t-1} + \frac{\kappa - 1}{\kappa} \frac{D}{C} \hat{D}_{t} + \]
\[ \frac{R^K}{C} \alpha_{k^*} \left( \Delta \hat{R}_{t}^{K} - \Delta \hat{R}_{t-1}^{K^*} + \Delta \hat{R}_{t}^{K^*} \right), \]

\(^3\)Actually, DY study a one-good economy, implying that their analysis abstracts from real exchange rate fluctuations so that \( \frac{RER_t}{RER_t + 1} = 0. \)
where in the steady state

$$C = (R^K - 1 - \kappa (r - 1)) \frac{D}{\kappa} \geq 0 \iff \frac{R^K - 1}{r - 1} \geq \kappa$$

and $\alpha_k^\ast$ is the steady state holdings of foreign capital in investors’ portfolios. In turn, this means that the expected change in marginal utility will be a function of the expected change in debt and net worth, implying thus a less tight relation between leverage ratios across countries in an economy á la Kyotaki and Moore, relative to an economy á la BGG, per se. As we argued before, this feature of the BGG environment is attractive because of the kind of evidence that originally motivated Calvo (1998), namely shock propagation across financial markets with quite limited cross-border asset holdings.

4 Calibration and steady state portfolio composition

We parameterize our model picking rather standard values for preferences and technologies — see Table 1 for a synopsis. Focusing first on the benchmark parameterization of financial frictions, we set the steady state ratio $\frac{D}{N}$ to 2 as in BGG, and the steady state premium to 1.0164; finally the elasticity of premium to leverage $\frac{D}{N}$ is set to 0.05, implying that a 1% climb in leverage would lead to a 5 basis points increase in the premium. Concerning trade parameters, we set the trade elasticity to 1.2 and the import shares in consumption and investment to 15%, in line with relatively large and closed economies like the US, Japan and the euro area. Finally, the probability of not adjusting prices is set to 0.65.

Concerning the stochastic structure of the model, we consider the following 5 shocks in each country: two autoregressive technology shocks, $\varepsilon_{Y,t}$ and $\varepsilon_{I,t}$, to the production function of final goods producers and the production function of capital goods producers, with standard deviation 0.9% and 0.3%, respectively; an autoregressive markup shock to final goods producers with standard deviation 0.12%; an iid monetary policy shock $\varepsilon_R$ with standard deviation 0.12%; and an autoregressive shock $\varepsilon_{e,t}$ to the external financial premium with standard deviation 0.15%. For simplicity we assume that these shocks are orthogonal across countries.

On the basis of these parameter values we obtain that the (near-stochastic) steady state portfolio composition under integration in both bonds and capital markets implies that each country holds 13.24% of the capital abroad, thus matching the substantial home equity bias in the data, while the value of the position in foreign currency bonds is -.698721, implying an offsetting long position in domestic currency bonds.

An important implication of the model concerns the cyclical behavior of the external premium. In the data the premium is negatively correlated with
output, investment and consumption (these HP-filtered). In the model under
the benchmark calibration the premium is negatively correlated with output
and investment (about -0.54 in the data vs -0.39 and -0.46 respectively in the
model). In the model the premium is positively or negatively correlated with
consumption depending on the assumption concerning the nature of default
costs. If it is assumed that the bankruptcy costs are transferred lump sum
to the households, the correlation between consumption and the premium is
positive. If, instead, it is assumed that the costs are used to purchase final
goods (as often done in this literature, e.g. BGG), the correlation between
consumption and the premium becomes negative (and the negative correlation
between output and the premium is reduced by half). 4

5 Balance sheet and no-arbitrage effects in the
international propagation of shocks

In this section we analyze quantitatively the implications of financial frictions
and international financial integration for the cross-country transmission of
shocks. As discussed above, since the Asian financial crisis in the 1990s, the
literature on fundamentals-based contagion in financial markets has highlighted
international cross-holdings of assets as a crucial determinant of exposure to
foreign financial turbulence, particularly because of the workings of a financial
multiplier. According to this view, the larger is the share of foreign assets held
by domestic agents, the stronger is the transmission of shocks, as recently put
forward by Krugman (2008) to account for the cross-country diffusion of the
recent financial crisis. As discussed above, we have referred to this channel as
the balance sheet effect.

In Section 3, however, we have argued that the strength of the international
transmission of shocks may or may not be related to the exact portfolio com-
position of leveraged agents, depending on the degree of international financial
markets integration. One key factor governing the international transmission is
arbitrage in international financial markets: i.e. the fact that levered investors
equate the returns that they can obtain from the different assets in different
countries, quite distinctly of the exact amount of foreign assets that they will
end up holding — we have referred to this channel as the no-arbitrage effect.

Here, we provide a quantitative assessment of both the balance sheet and
the no-arbitrage effects in our calibrated two-country economy, by looking at
the international ramifications of a variety of asymmetric shocks. A key aspect
we want to investigate is how and to what extent propagation across asset prices
and financial market conditions will entail synchronization in real quantities like
output and aggregate demand. Specifically, in what follows we will focus on two
types of asymmetric shocks: a (negative) Foreign neutral technology shock, as

4While the empirical correlation is most likely also driven by the fact that the premium
paid by firms is positively correlated to the premium paid by households, we have abstracted
from this aspect in our model
studied in Devereux and Yetman (2009), and a (positive) shock to the Foreign external finance premium. We can expect that the shocks repercussions on the external finance premium in the Home country will be crucial in shaping the international transmission to investment and output, namely that a increase in the Home premium will be a key factor in propagation recessions from the Foreign to the Home country.

In order to isolate the balance-sheet effect from the no-arbitrage effect, we will consider four different scenarios concerning international financial integration: i) the case of complete financial autarky; ii) the case of no trade in capital but integration in bond trade; iii) the case of no trade in bonds but integration in capital trade; iv) the case of full financial integration in bond and capital trade. For each of these scenarios we will display the response of the model economy for the following two cases: a) full home bias, when the actual amount of foreign capital holding is set to zero; and b) full diversification, when the capital investors’ portfolio comprises equal shares of domestic and foreign capital. Specifically, under cases i) and ii) we will assume that investors decide their level of borrowing according to the following first order condition and its Foreign counterparts,

$$E_t R_{t+1}^K = \chi \left( \frac{D_t}{N_t}, \varepsilon_{e,t} \right) E_t r_{t+1},$$

but net worth evolves following

$$N_t = R_t^K \alpha_k + \frac{RER_t R_t^K}{RER_{t+1}} \alpha_{k^*} - R_t^D \frac{D_t}{\pi_t},$$

and its Foreign counterpart, where $\alpha_{k^*} = 0$ under full home bias and $\alpha_{k^*} = \alpha_k$ under full diversification. Notice that the full home bias and full diversification cases, when capital trade is allowed and the following no-arbitrage conditions will also hold

$$E_t R_{t+1}^K = E_t \frac{RER_{t+1}^K}{RER_{t+1}} = \chi \left( \frac{D_t}{N_t}, \varepsilon_{e,t} \right) E_t r_{t+1},$$

could be interpreted as two possible equilibrium portfolio allocations under the assumption of risk-neutral capital investors, as their portfolio choice would be indeterminate at any order of approximation.

For all experiments, the figures below display the following variables for each country: price of capital ($Q$), GDP ($Y$), investment ($I$), CPI inflation ($\pi$), nominal (policy) interest rate ($R$) and external finance premium ($CHI_F$) — the Home country will be denoted with 1, while 2 will denote the Foreign country. The black (circled) line denotes variables’ responses in the case of full home bias in capital holdings, while the red line denotes variables’ responses in the case of full diversification.
5.1 The cross-border propagation of asymmetric technology shocks

Figures 1 to 4 report impulse responses to a one standard deviation (1%) neutral technology shock to the Foreign country for the scenarios i) to iv) with varying degrees of international financial integration. Starting from Figure 1, in which complete financial autarky is assumed, the Foreign negative technology shock brings about a persistent fall in Foreign GDP, investment and asset prices; the external finance premium, after an initial climb, becomes procyclical and also decreases, reflecting the decline in investment and thus borrowing by entrepreneurs. The increase in marginal costs due to lower productivity entails a rise in Foreign inflation, and, given the assumed monetary reaction function, in the nominal interest rate.

Comparing the black and the red line, it is clear that there are no qualitative differences in the response of Foreign variables between the case of full home bias and full diversification in capital holdings. The main quantitative differences concern a more pronounced fall in Foreign investment, and to a much lesser extent in Foreign asset prices and GDP, in the case of full diversification; instead, the finance premium reduces by less.

Conversely, as expected, the propagation of the Foreign shock to the Home country is greatly affected by the amount of cross-border asset holdings under complete financial autarky — recall that in this case the first order conditions for endogenous cross-border asset choices are not considered in the model solution, so that effectively the no-arbitrage effect is totally ruled out. Under full home bias the only cross-country channel of transmission is through goods trade, implying that the Foreign technology shock brings about a decline in the Home external premium, investment and, after an initial increase, asset prices, but a rise in GDP, followed by a short-lived contraction after a few quarters; inflation and the nominal rate both increase in the Home country.

The introduction of full diversification in capital holdings, though in an admittedly partial equilibrium way, affects the responses of the Home premium, GDP, and especially asset prices and investment. While the external finance premia behave more similarly across countries, the sign of the international propagation for asset prices and investment changes. Home asset prices now fall only on impact, and subsequently increase, while the response of investment is persistently positive, reflecting also the larger reduction in the external finance premium; also the temporary contraction in GDP, after the initial rise, is followed by above-trend growth.

In order to study the effects of increasing international financial integration, in Figure 2 we report the responses for the case in which nominal short term bonds denominated in both currencies are freely traded by households and their portfolio composition is optimally chosen, but capital trade is not allowed — recall that in this case the first order conditions for endogenous cross-border capital choices are not considered in the model solution, so that the no-arbitrage effect on returns on capital is ruled out. This setting is similar to the one adopted in the open economy literature studying financial frictions, usually assuming
complete markets among households (see e.g. Gilchrist et al. (2002) or Faia (2002)) or at least trade in one bond (e.g. Gilchrist (2003)).

The responses of all Foreign variables under full home bias in capital holdings — again displayed with the black circled line — are quite similar to their counterparts under financial autarky in Figure 1, implying that allowing for some intertemporal trade by households does not significantly change the effects of an asymmetric technology shock on investment and GDP in the country where the shock originates, as only the Foreign premium seems to be somehow less affected — although also Foreign consumption is slightly less depressed by the shock as households borrow from abroad (not shown).

Again, the comparison of the black and the red line shows that introducing full diversification in capital holdings does not result in any significant qualitative differences in the response of Foreign variables to the negative technology shock; however the finance premium rises by more, leading to a sharper contraction in investment and GDP.

Similarly to Figure 1, the transmission of the Foreign shock to the Home country depends a great deal on the share of cross-border asset holdings. Starting with the case of full home bias, international transmission, in addition to the goods trade channel, takes place through intertemporal trade and some risk sharing by households, but the effects on Home variables are again quite similar to those displayed in Figure 1 — although because of higher risk sharing Home consumption falls by more (not shown).

With the introduction of full diversification in capital holdings the responses of the Home premium, asset prices, investment and GDP are also akin to those in Figure 1, displaying negative comovements with their Foreign counterparts. Again, the reduction in the Home premium mostly accounts for the expansionary effects on the Home variables, along with the increase in Home labor supply induced by higher risk sharing.

These results seem at odds with the partial equilibrium conjecture discussed in Section 3 and entertained by some of the literature on the international financial multiplier, namely, that more exposure to foreign risky assets in the portfolio of leveraged investors should per se entail a stronger propagation of shocks, particularly to domestic asset prices. Conversely, mere balance sheet effects in an otherwise fully specified and worked out model with levered investors seem to make asset prices across countries more substitutes rather than more complement, in contrast with to the hypothesis by Krugman (2008), at least in response to standard technology shocks. Moreover, the divergence in the response of external finance premia also leads to negative comovements between investment and GDP across the two countries.

We now turn to the examination of the no-arbitrage effects, reporting in the next two Figures impulse responses when allowing for endogenous cross-border capital choice, with and without international trade in bonds between households — here we do not report results under the optimal capital portfolio composition, obtained under the assumption that capital investors share the same discount factor as households, as it is obvious they would represent just an intermediate case, adding little to our results.
Starting first with the case of no cross-border bond trade depicted in Figure 3, it is clear that the differences between the cases of full home bias and full diversification are rather minimal — we do not report results under the optimal portfolio composition, when capital investors are assumed to share the same discount factor as households, as it is obvious they would add little.

Starting first with the case of no cross-border bond trade depicted in Figure 3, it is clear that the differences between the cases of full home bias and full diversification are not very consequential. Asset prices in the short run respond similarly across countries, both falling, while premia decline together only after a few quarters; strikingly, under full diversification the response of both variables become less synchronized. Concerning the other, non-financial variables, we also see little cross-country synchronization. Against the backdrop of the sustained contraction in Foreign investment and GDP, Home investment slightly declines only initially under full home bias, and actually always rises under full diversification, while GDP, after an initial positive response, contracts only for a few quarters irrespective of the capital portfolio composition.

Therefore, relative to the cases of full financial autarky in Figure 1 and bond trade in Figure 2, the no-arbitrage effect on capital returns arising from the endogenous choice of cross-border capital investment increases synchronization in asset prices and, to a lesser extent, external premia. However, similarly to the balance sheet effect, it turns the transmission to Home GDP and especially investment from negative to positive, acting as to reduce international comovements in real variables. In addition, more exposure to assets abroad in investors' portfolio overall results in less rather than more across-the-board synchronization.

Finally, a similar story emerges from Figure 4, in which full integration in bonds and capital trade is allowed. With full financial integration, changing cross-border holdings of capital has basically no impact on the international transmission, featuring perfect correlation between asset prices and premia. However, full integration induces negative comovements in real variables in response to asymmetric technology shocks, reflecting the equilibrium response of labor supply in the Home country to make up for lower output in the less productive Foreign country. The short term increase in the external premium is not enough to overturn this mechanism, typical of the international business cycle literature.

However, this result can be overturned by ensuring that the external finance premium increases persistently in the Foreign country in the aftermath of a negative productivity shock, becoming decisively countercyclical. This could be obtained by assuming a higher leverage ratio in the steady state. Figure 5 reports responses when we set this ratio to 4, showing that financial frictions can lead to close interdependence not only in asset prices but also in investment and output across countries, as financial conditions deteriorate enough in the country hit by the shock and quickly spill over abroad because of financial integration.5

To summarize our results so far, we have shown that once financial markets

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5 In this case the portfolio share are Bonds = -1.22544 and capital = 14.6%
are integrated, especially those of risky assets, the size of home bias in equity portfolios is largely inconsequential for the sign and strength of the international propagation of technology shocks in economies with financial frictions. Similar results are obtained when we consider investment-specific technology shocks, that we do not report here to save on space.

These results are also notable in light of the recent paper by DY, which in experiments similar to those in our Figure 3 under integration of capital trade only finds that increased diversification results in a heightened international transmission of technology shocks, reflecting the greater sensitivity of domestic leverage constraints to asset prices abroad. In DY setting à la Iacoviello (2005), the greater is the exposure of the Home portfolio to the foreign asset price, the greater is the negative transmission on leverage constraints following a negative shock to Foreign productivity. As we have argued in Section 3, the difference between DY results and ours can be explained by the different models of leverage constraints and financial frictions adopted, implying a different evolution of net worth and leverage across border in the presence of no-arbitrage conditions.

A further difference in the effects on investment and GDP, which in DY decline in both countries in response to an asymmetric negative technology shock, just reflects the lack of endogenous labor supply in the DY model, which is so crucial in generating the negative comovements in production inputs highlighted by the international business cycle literature.

5.2 The cross-border propagation of asymmetric financial shocks

We now turn to the analysis of the consequences of a shock to the external finance premium, which can be interpreted, in line with Christiano et al. (2007), as a negative shock to the financial sector — effectively in the original BGG framework this would represent a shock to the probability of default of individual borrowers. Considering the patterns of international propagation of such a shock could be particularly interesting in the context of the current juncture, characterized by large and synchronized declines in asset prices and macroeconomic variables, driven by negative developments in financial markets.

Figures 6 and 7 report impulse responses to an unexpected, one standard deviation increase in the Foreign external finance premium for the cases iii) and iv) with varying degrees of financial integration, using the same format as before — in all figures the black (circled) line shows the response under full home bias in capital holdings, while the red line shows the response of the variables under full diversification.

Starting with the case of international bond trade only displayed in Figure 6, the climb in the Foreign premium brings about a persistent decline in Foreign GDP, investment and asset prices; in turn the output reduction entails a fall in prices of adjusting firms and thus inflation, and, given the assumed monetary reaction function, in the Foreign nominal interest rate. The comparison of the black and the red line shows that introducing full diversification in capital
Holdings helps in slightly cushioning the negative repercussions of the domestic shock on foreign variables.

Conversely, the transmission of the foreign shock to the home country significantly depends on the share of cross-border capital holdings — again, it is important to remember that in this case no-arbitrage effects are ruled out by assumption even under full diversification. Under full home bias, cross-country transmission occurs through intertemporal trade linkages, implying that the foreign shock represents a negative demand shock for the home country, leading to a persistent decline in home GDP; asset prices and investment marginally rise, while the premium is basically unaffected; inflation and the nominal rate also decline in the home country.

Conversely, with the introduction of full diversification in capital holdings, the responses of the home premium, GDP, asset prices and investment display strong positive comovements with their foreign counterparts. The rise in the home premium, mirroring on a smaller scale that abroad, results in a sharp decline of domestic asset prices, investment and GDP.

These results seem more in agreement with the conjecture that a higher exposure to foreign risky assets in the portfolio of leveraged investors would per se entail a stronger propagation of shocks, particularly to domestic asset prices, to the extent that they lead to cross-border spillovers of the changes in the external finance premium.

Turning to the comparison of balance sheet and no-arbitrage effects, Figure 7 displays impulse responses when we introduce an endogenous cross-border capital choice, along with international trade in bonds between households. It is immediately apparent that the differences between the cases of full home bias and full diversification are quite negligible — again, we do not report results under the optimal capital portfolio composition, as it is obvious they would add little. However, full integration, leading to equalization of the premia across countries, now brings about perfect synchronization of all variables’ response to the asymmetric financial shock.

To summarize, our results point to the fact that when financial markets are integrated, especially those of risky assets, no-arbitrage effects can act as powerful complement to balance sheet effects, to the extent that the size of home bias in equity portfolios could be largely inconsequential for the sign and strength of the international propagation of shocks in economies with financial frictions. As discussed in Section 3, this is particularly important in light of the (otherwise puzzling) rapid propagation of shocks across asset markets even when exposure to those very assets in cross-border portfolios is limited.

6 Concluding remarks

In this paper we have developed a quantitative two-country model with financial frictions à la BGG and endogenous portfolio choice to study how the international transmission of asymmetric shocks is affected in the presence of levered cross-border investors.
In line with the hypothesis formulated e.g. by Calvo (2000) and recently Krugman (2008), we have found that foreign exposure in interconnected balance sheets of financially constrained investors can indeed act as a powerful propagation mechanism of asymmetric shocks across countries. However, in our setting financial and real interdependence can be very strong even with minimal balance sheet exposure, if financial markets are integrated. Because of the no-arbitrage conditions it imposes, a high degree of financial integration exerts a strong pressure towards the cross-border equalization of external finance premia faced by levered investors, in turn imparting tight linkages in leverage and macroeconomic dynamics across countries.

Under a high degree of financial integration, our model implies that premia have to be literally equalized across countries, not only a very strong empirical implication, but also a theoretical prediction which may not be shared by different models of financial frictions, such as that recently studied by Devereux and Yetman (2009). Nevertheless, our mechanism based on pricing in integrated markets has the potential to account for fundamentals-based financial and real contagion even in cases where the foreign exposure of levered investors is not large, an important feature given the rather pervasive degree of home bias in cross-border holdings of assets still prevalent even among advanced countries.

References


<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Home bias in consumption and investment</td>
<td>( n (n^*) )</td>
<td>0.85</td>
</tr>
<tr>
<td>Calvo probability of not-adjusting prices</td>
<td>( \xi (\xi^*) )</td>
<td>0.65</td>
</tr>
<tr>
<td>Steady-state depreciation of capital</td>
<td>( \delta )</td>
<td>0.025</td>
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<tr>
<td>Investment adjustment cost parameter</td>
<td>( \gamma_I )</td>
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</tr>
<tr>
<td>Intratemporal elasticity of substitution</td>
<td>( \theta )</td>
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<tr>
<td>Intertemporal elasticity of substitution</td>
<td>( \rho^{-1} )</td>
<td>1.01^{-1}</td>
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<tr>
<td>Final-goods producers’ mark-up</td>
<td>( \mu_f )</td>
<td>1.2</td>
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<tr>
<td>Habit formation in consumption</td>
<td>( \kappa (\kappa^*) )</td>
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<tr>
<td>Interest rule response to inflation</td>
<td>( \lambda_\pi (\lambda_\pi^*) )</td>
<td>2</td>
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<td>Interest rule inertia</td>
<td>( \lambda_R (\lambda_R^*) )</td>
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<td>Households discount factor</td>
<td>( \beta )</td>
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<td>Leverage ratio</td>
<td>( \frac{B}{N} )</td>
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<tr>
<td>Steady-state premium</td>
<td>( \chi )</td>
<td>1.0164</td>
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<tr>
<td>Elasticity of premium to leverage</td>
<td>( \chi )</td>
<td>0.05</td>
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Figure 1: Foreign negative technology shock under complete financial autarky
Figure 2: Foreign negative technology shock under capital trade autarky
Figure 3: Foreign negative technology shock under bond trade autarky
Figure 4: Foreign negative technology shock under full financial integration
Figure 5: Foreign negative technology shock under full financial integration

High leverage ratio
Figure 6: Foreign financial shock under capital trade autarky
Figure 7: Foreign financial shock under full financial integration