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

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Abstract

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

Foreign exposure in interconnected balance sheets of levered investors can act as a powerful propagation mechanism across countries. However, in the model financial and real interdependence can be very strong even with minimal balance sheet exposure to foreign risky assets, if asset markets are integrated across the board, reflecting a strong pressure towards the cross-border equalization of external finance premia faced by levered investors. In turn, the resulting global "flight to quality" may bring about tight international linkages in (de-)leveraging, financial and macroeconomic dynamics.

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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 the balance sheets of cross-border levered investors, as postulated in the literature on international transmission through financial channels (e.g. Calvo (1998) and Krugman (2008)), and study its effects for shocks propagation, as empirically documented e.g. by Kaminsky and Reinhart (2000) in the context of fundamentals-based "contagion" of financial shocks and crises.

This literature argue that the need to rebalance the overall risk of an investor's cross-border asset portfolio and to deleverage following the losses after an initial shock can lead to a marked reversal in investment and asset prices across markets where the investor has substantial exposure. For instance, Kaminsky and Reinhart (2000) find that in the case of banks this helps explain cross-border spillovers of shocks, 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 net worth.

While this literature has emphasized the degree of the exposure to foreign assets, several episodes of rapid international propagation of asymmetric (financial) shocks are difficult to reconcile with this view of an exclusive role of foreign exposure as a transmission channel. For instance, Rose and Spiegel (2009) argue that exposure to the US cannot account for the cross-country heterogeneity in the effects of the recent US financial shocks. In Figures 7 and 7 we reproduce their scatter plots showing, for a large set of countries, various measures of exposure to the US vs. GDP-growth and change of stock-market prices, respectively. For each country, there are four measures of exposure: i) US assets held as a share of total foreign assets; ii) claims of US-based banks as a share of total claims by foreign banks; iii) liabilities towards the US as a share of total foreign liabilities; and, finally iv) the share of trade with the US over total exports and imports. These scatter plots show that exposure to the US is uncorrelated with GDP growth or shock-market prices across a large set of countries, lending (informal but intriguing) support to the idea that not only trade linkages, but also exposure to US assets cannot be main determinant of comovements between the US and other countries during the recent financial crisis, and thus that there may be other relevant channels of international propagation.

In this paper, in addition to modeling cross-border exposure, we introduce a new source of international propagation. In our model economy "investors" in each country buy claims to capital stocks installed both domestically and abroad, to be rented out for production of a local, country-specific good which is then traded internationally for consumption and investment demand. Broadly motivated with financial frictions in the spirit of Bernanke et al. (1999), these investors face an external finance premium, which is an inverse function of their net worth, when borrowing to finance their domestic and foreign capital investment. 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, making these assets effectively illiquid.

This way we broadly capture the idea that the international financial multiplier works through the cross-border exposure of assets in the balance sheet of leveraged agents. When asset prices (Tobin's Q price of capital) fall heavily in one country, investors find themselves undercapitalized, and have to restore their net worth by decreasing borrowing and thus investment across-the-board, effectively selling off both domestic and foreign risky assets. This in turn puts pressure on the balance sheet of investors abroad, and so on, potentially enhancing cross-border spillovers.

For a variety of shocks, including technology and financial (to the external 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 levered investors. Specifically, starting from the case of complete financial autarky, we study the implications of gradually expanding international trade in assets to bonds and capital claims, 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 (2008).

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 constitutes a further powerful source of shock propagation. By leading to tight linkages in the premia paid by financially constrained investors, through the imposition of no arbitrage conditions across different asset classes, financial integration could result in cross-border"flight to quality" away from illiquid assets, and strong cross-country comovements in the process of deleveraging by these agents, irrespective of the actual incidence of foreign assets in their portfolios.

These additional market-based transmission channels in our model are notable in light of the debate on the international propagation of financial shocks. In addition to the evidence presented in Figure 1 and 2 above concernign the effects of the recent US financial shocks, another case in point was raised by Calvo (1998) in the aftermath of the 1998 Russian default and the ensuing widespread financial turmoil. In the words of Calvo (1998, 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." 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 instances of rapid shock transmission without strong trade and financial linkages. On the contrary, our paper shows that explicitly taking account portfolio choices, and the ensuing no-arbitrage conditions, can generate strong propagation of shocks through strong correlation in"flight to quality" and deleveraging, even when balance sheets of leveraged investors are only marginally exposed to foreign assets.

Similarly to our paper, a recent and growing literature has analyzed financial frictions á la la Bernanke et al. (1999) in an open economy context, including Gilchrist (2003), Gilchrist et al. (2002), Gertler et al. (2007) and Faia (2007a,b). The paper by Gilchrist et al. (2002) is close to our work in that it considers financially constrained entrepreneurs undertaking cross-border capital investement. These entrepreneurs, however, are modeled as multi-nationals producing goods in different countries under a consolidated balance sheet, while our investors are assumed to face pure financial portfolio decisions.[1] Faia (2009) uses a two-country model with a financial accelerator to assess quantitatively the implications of financial frictions in the presence

[1] Faia (2007b) studies the business-cycle properties of a two-country model with financial accelerator with particular focus on a currency area, while Faia (2007a) extends the focus by comparing the model with data from a larger set of OECD countries. Neither contribution, however, considers the effects of foreign exposure of financially constrained agents.

of different exchange rate regimes, finding that the introduction of foreign exposure in the form of foreign currency denomination of entrepreneurs' debt does not alter significantly the international propagation of shocks. Larger effects of the foreign denomination of debt is shown by Gertler et al. (2007), however. It is important to notice that the type of exposure discussed in this earlier literature (namely currency mismatch between the assets and liabilities of financially constrained agents) is radically different from the one that we study in this paper. First, the balance-sheet effect of pure asset-price movements (as opposed to exchange rate movements) is absent in models that focus only on the currency composition of debt. Second, and most importantly, the key driver of our results is the endogeneity of the portfolio decision: ad-hoc assumptions regarding the degree of exposure (either to the exchange rate through debt in foreign currency or to the domestic value of foreign asset through asset composition) would neglect the effects of fundamental no-arbitrage conditions on returns and prices.

Finally, most similarly to this paper, although assuming collateral constraints in the fashion of Kiyotaki and Moore (1997) and Iacoviello (2005), Devereux and Yetman (2009) have introduced capital portfolio choice in two-country model, finding that high foreign exposure results in powerful propagation mechanism of asymmetric technology shocks. They do not study the implications of full asset market integration for the propagation of shocks, however.

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 et al. (2002), and in particular Gilchrist (2003), who shows how to incorporate financial frictions in a simple yet tractable way in such an environment.[2] 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 a set of differentiated goods, but consumers in any country consume both sets of 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 in the goods 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:

$$C_t \equiv \left[n^{\frac{1}{\theta}} {C_{\mathrm{H},t}}^{1-\frac{1}{\theta}} + (1-n)^{\frac{1}{\theta}} {C_{\mathrm{F},t}}^{1-\frac{1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

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

$$\mathbb{P}_t = \left[n P_{\mathrm{H},t}^{1-\theta} + (1-n)\, P_{\mathrm{F},t}^{1-\theta} \right]^{\frac{1}{1-\theta}}.$$

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 an imperfect substitute for all other goods' varieties, with constant elasticity of substitution $\eta > 1$:

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

[2] Faia (2007a,b) also uses a two-country model with "financial accelerator".

the price index of the Home goods is given by:

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

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 $\mathcal{E}_t P^*_{\mathrm{H},t} = P_{\mathrm{H},t}$ and $\mathcal{E}_t P^*_{\mathrm{F},t} = P_{\mathrm{F},t}$. Notice however that $\mathcal{E}_t \mathbb{P}^*_t$ will generally be different from $\mathbb{P}_t$ 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 $RER = \dfrac{\mathcal{E}_t \mathbb{P}^*_t}{\mathbb{P}_t}$.

Budget constraint and asset markets Households solve the following standard intertemporal problem

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

(where, following Schmitt-Grohé and Uribe (2003), 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:

$$C_t + B_t + \sum \alpha_{s,t} = w_t H_t + r_t B_{t-1} + \sum \alpha_{s,t-1} r_{s,t} + \Pi_t + T^e_t. \tag{2}$$

Households receive income in the form of wage w_t, profits in the form of lump-sum transfers from all domestic firms (Π_t, to be fully specified below), and returns $(r_t, r_{s,t})$ from asset holdings $(B_t, \alpha_{s,t})$. 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 $r_{d^*,t} = \dfrac{RER_t}{RER_{t-1}} r^*_t$. We can also extend the model allowing households to trade in claims to aggregate profits Π_t. The variable T^e_t denotes a net lump-sum transfer from households to investors. This net-transfer consists of "intermediation costs" generated in the investment sector minus resources transferred from households to new entrepreneurs. Further below we discuss this term in more detail.

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

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

where $\alpha^*_{j,t}$ denotes bond holdings abroad in consumption units.

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

$$W_t = B_t + \sum \alpha_{st}, \tag{3}$$

$$C_t + W_t = w_t H_t + r_t W_{t-1} + \alpha_{d^*,t-1}\left(\frac{RER_t}{RER_{t-1}} r^*_t - r_t\right) + \Pi_t + T^e_t; \tag{4}$$

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:

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

Finally, we assume standard functional forms for preferences $U\left(\cdot\right) = \frac{\left(C - \overline{C}\right)^{1-\sigma}}{1-\sigma}$, $\phi\left(H\right) = \frac{H^{1+\eta}}{1+\eta}$; however, we also assume that the discount factor $\beta\left(\tau\right)$ 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 $\lambda^*_{t+1}\frac{RER_t}{RER_{t+1}}$ replaces λ_{t+1}). Therefore, up to first order, i.e. under certainty equivalence, the portfolio choice is indeterminate. However, following the perturbation approach of Devereux and Sutherland (2008) and Judd and Guu (2001), we can take a second order approximation of the difference of the two nonlinear first order conditions,

$$E_t\left[\left(\lambda_{t+1}-\lambda^*_{t+1}\frac{RER_t}{RER_{t+1}}\right)\left(\frac{RER_{t+1}}{RER_t}r^*_{t+1}-r_{t+1}\right)\right]=0 \tag{5}$$

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

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

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

so that, under flexible prices,

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

and

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

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

Price setting When retail firms are subject to nominal rigidities à la Calvo, at any time t, they keep their price fixed with probability ζ. 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:

$$Max_{\mathcal{P}(h),\mathcal{P}^*(h)} \ E_t \left\{ \sum_{k=0}^{\infty} \Lambda_{t+k} \zeta^k \left(\begin{array}{c} \left[\mathcal{P}_t(h) D_{t+k}(h) + \mathcal{E}_t \mathcal{P}_t^*(h) D_{t+k}^*(h)\right] - \\ MC_{t+k}(h) \left[D_{t+k}(h) + D_{t+k}^*(h)\right] \end{array} \right) \right\} \tag{6}$$

where Λ_{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:

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

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

In these expressions, $P_{\mathrm{H},t}$ and $P_{\mathrm{H},t}^*$ 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

$\mathcal{P}_t(h)$ in domestic currency charged to domestic customers is:

$$\mathcal{P}_t(h) = \frac{\eta}{\eta - 1} \frac{E_t \sum_{k=0}^{\infty} \zeta^k \Lambda_{t+k} D_{t+k}(h) MC_{t+k}(h)}{E_t \sum_{k=0}^{\infty} \zeta^k \Lambda_{t+k} D_{t+k}(h)}; \tag{7}$$

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: $\mathcal{P}_t^*(h) = \frac{\mathcal{P}_t(h)}{\mathcal{E}_t}$.

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

$$P_{\mathrm{H},t}^{1-\eta} = \zeta P_{\mathrm{H},t-1}^{1-\eta} + (1-\zeta) \mathcal{P}_t(h)^{1-\eta}.$$

The representative retailer pricing decision implies (to first order of approximation) the standard new Keynesian Phillips curve, where current inflation is a function of expected inflation and marginal costs μ_t:

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

where ξ is a function of the probability of adjustment ζ.

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:

$$\begin{aligned}
&\max_{L_t, K_{t+1}} E_t \sum_{i=0}^{\infty} \beta^i \lambda_{t+i} \left[Q_{K,t+i} K_{H,t+1+i}^s - I_{t+i} - Q_{K,t+i} K_{H,t+i}^P \right] \\
&\quad \text{s.t.} K_{H,t+1}^s = K_{H,t}^P + \varepsilon_{I,t} F(I_t, I_{t-1}) \\
&\quad K_{H,t}^P = (1-\delta) K_{H,t}
\end{aligned}$$

where

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

and

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

where $\gamma_I \geq 0$, and where λ_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 $\varepsilon_{I,t}$.

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 Investors 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 at the rate of interest R_t^D, potentially at a premium over the local domestic nominal risk free rate. Contrary to Gilchrist (2003), but consistently with Bernanke et al. (1999), we assume that the financial intermediation generates a resource cost. In Bernanke et al. (1999) this is a function of the monitoring costs and is, therefore, related to the default rate. In the reduced-form implementation of the financial accelerator used here, the monitoring cost is simply reflected in the external-finance premium: the difference between the households' deposit rate and the lending rate paid by entrepreneurs (times the amount of the loans). Denoting this value by Ω_t we set up the model so that we can either assume that this cost absorbs domestic resources (as in Bernanke et al. (1999)) or that it is transferred lump-sum to household. The latter is our benchmark assumption as it avoids that hikes in the finance premium translate, other things equal, into increases in aggregate demand.

The problem of the representative capitalist firm is thus to maximize discounted profits

$$\max_{K_{t+1},K^*_{t+1}} \sum_{i=0}^{\infty} E_t R^e_{t|t+i} \left[r_{K,t+i} K_{t+i} + RER_t r_{*,K,t+i} K^*_{t+i} - Q_{K,t+i} \left(K_{t+1+i} - (1-\delta) K_{t+i} \right) \right.$$
$$\left. - RER_{t+i} Q^*_{K,t+i} \left(K^*_{t+1+i} - 1 - \delta K^*_{t+i} \right) - R^D_{t-1+i} \frac{D_{t-1+i}}{\pi_{t+i}} + D_{t+i} \right]$$
$$\text{s.t. } Q_{K,t} K_{t+1} + RER_t Q^*_{K,t} K^*_{t+1} = D_t + N_t,$$

where D_t is the real value of the debt, N_t is the real value of the net-worth of the firm (equities) and $R^e_{t|t+i}$ is the discount rate of the investors (discussed later).

The first order condition for the investor's problem are

$$K_{t+1} : \; E_t R^e_{t|t+1} \left(r_{K,t+1} + (1-\delta) Q_{K,t+1} - \frac{R^D_t}{\pi_{t+1}} Q_{K,t} \right) = 0 \tag{8}$$

$$K^*_{t+1} : \; E_t R^e_{t|t+1} \left(RER_{t+1} r_{*,K,t} + RER_{t+1} (1-\delta) Q^*_{K,t+1} - RER_t \frac{R^D_t}{\pi_{t+1}} Q^*_{K,t} \right) = 0 \tag{9}$$

we can rewrite

$$E_t \left[R^e_{t|t+1} R^K_{t+1} \right] \equiv E_t \left[R^e_{t|t+1} \frac{r_{K,t+1} + Q_{K,t+1} (1-\delta)}{Q_{K,t}} \right] = E_t \left[R^e_{t|t+1} \frac{R^D_t}{\pi_{t+1}} \right]$$

and

$$E_t \left[R^e_{t|t+1} \frac{RER_{t+1}}{RER_t} R^{K*}_{t+1} \right] \equiv E_t \left[R^e_{t|t+1} \frac{RER_{t+1}}{RER_t} \frac{r_{K*,t+1} + Q^*_{K,t+1} (1-\delta)}{Q^*_{K,t}} \right] = E_t \left[R^e_{t|t+1} \frac{R^D_t}{\pi_{t+1}} \right]$$

and for the foreign entrepreneur

$$E_t \left[R^{*e}_{t|t+1} \frac{RER_t}{RER_{t+1}} R^K_{t+1} \right] \equiv E_t \left[R^{*e}_{t|t+1} \frac{RER_t}{RER_{t+1}} \frac{r_{K,t+1} + Q_{K,t+1} (1-\delta)}{Q_{K,t}} \right] = E_t \left[R^{*e}_{t|t+1} \frac{R^{*D}_t}{\pi^*_{t+1}} \right]$$

and

$$E_t\left[R^{*e}_{t|t+1}R^{K*}_{t+1}\right] \equiv E_t\left[R^{*e}_{t|t+1}\frac{r^*_{K*,t+1}+Q^*_{K,t+1}(1-\delta)}{Q^*_{K,t}}\right] = E_t\left[R^{*e}_{t|t+1}\frac{R^{*D}_t}{\pi_{t+1}}\right].$$

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

$$E_t\left[R^e_{t|t+1}\left(R^K_{t+1}-\frac{RER_{t+1}}{RER_t}R^{K*}_{t+1}\right)\right]=0 \tag{10}$$

and

$$E_t\left[R^{*e}_{t|t+1}\left(\frac{RER_t}{RER_{t+1}}R^K_{t+1}-R^{K*}_{t+1}\right)\right]=0. \tag{11}$$

$$E_t\left[R^e_{t|t+1}\frac{RER_{t+1}}{RER_t}\left(\frac{RER_t}{RER_{t+1}}R^K_{t+1}-R^{K*}_{t+1}\right)\right]=0 \tag{12}$$

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

However, as in the case of households, we know that the optimal portfolio must satisfy the following equation to order of approximation higher than one[3]

$$E_t\left[\left(R^{*e}_{t|t+1}\frac{RER_t}{RER_{t+1}}-R^e_{t|t+1}\right)\left(R^K_{t+1}-\frac{RER_{t+1}}{RER_t}R^{K*}_{t+1}\right)\right]=0, \tag{13}$$

so that we can use the same approach as before to solve for the optimal long run portfolio composition for Home and Foreign investors. Specifically, observe that if, following Gilchrist (2003), we assume that $R^e_{t|t+1}=\frac{\lambda_{t+1}}{\lambda_t}$, 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:

$$E_t\left[\frac{\lambda_{t+1}}{\lambda_t}R^K_{t+1}\right]=E_t\left[\frac{\lambda_{t+1}}{\lambda_t}r_{t+1}\right]=1.$$

[3]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.

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^D and R_t^{*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, in the vein of Bernanke et al. (1999). The key mechanism involves an inverse relation between the external finance premium, χ (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 rate R_t^D in the above equations would reflect a premium on external finance, arising from monitoring costs:

$$E_t\left[R^e_{t|t+1}\left(\frac{R^D_{t+1}}{\pi_{t+1}} - \chi\left(\frac{D_t}{N_t}, \varepsilon_{e,t}\right) r_{t+1}\right)\right] = 0,$$

where $\chi(\cdot)$ is the external finance premium. Notice that the latter equation and the following one, reproducing the above condition for the optimal choice of domestic capital investment,

$$E_t\left[R^e_{t|t+1}\left(\frac{r_{K,t+1} + Q_{K,t+1}(1-\delta)}{Q_{K,t}} - \frac{R^D_t}{\pi_{t+1}}\right)\right] = 0,$$

up to first order 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. (2007) can be interpreted as a shock affecting 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:[4]

$$N_t = \gamma \left[R_t^K Q_{t-1} K_t + \frac{RER_t}{RER_{t-1}} R_t^{K*} Q_{t-1}^* RER_{t-1} K_t^* - R_{t-1}^D \frac{D_{t-1}}{\pi_t} \right] + (1-\gamma) T_t$$

or

$$N_t = \gamma \left[R_t^K We_{t-1} + \left(RER_t R_t^{K*} - RER_{t-1} R_t^K \right) \alpha_{K^*t} - R_{t-1}^D \frac{D_{t-1}}{\pi_t} \right] + (1-\gamma) T_t, \tag{14}$$

where $\alpha_{K^*t} \equiv Q_{t-1}^* K_t^*$, and

$$We_t = Q_{K,t} K_{t+1} + RER_t Q_{K,t}^* K_{t+1}^*$$

is the total holdings of capital by the entrepreneur, which has to be equal to $D_t + N_t$. The coefficient γ can be interpreted as the share of entrepreneurs that exit the market, while $T_t = T_t^e - \Omega_t$ is the real value of a transfer to entrepreneurial start-ups.[5]

[4] The financial-accelerator mechanism that we assume in this paper captures the salient feature of the financial accelerator described in Bernanke et al. (1999). In particular while the external financial premium can be forced to be identical to that implied by Bernanke et al. (1999), the net-worth dynamics would be slightly different: the two definitions of net-worth are generally very highly correlated. To first order the function $\chi(\cdot)$ is chosen to reproduce the average premium paid by non-financial corporations to monetary and financial institutions as well as the elasticity of the premium to the leverage used in Bernanke et al. (1999).

[5] The original setting in BGG requires that entrepreneurs be risk neutral, whereas we are assuming that they have the same discount factor as households and are thus risk averse. However, since we solve the model up to first order, in equilibrium this assumption only helps in pinning down the portfolio allocation of investors, while the dynamics of all aggregate variables will be the same as in the standard BGG setting, for a given portfolio composition. In turn, the latter, as we will show below, will be immaterial for the properties of the model under cross-border integration of bond and capital markets.

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

$$R_t = \lambda_R R_{t-1} + (1 - \lambda_R)\, \lambda_\pi \pi_t + \varepsilon_{Rt}, \tag{15}$$

where interest rates respond only to inflation with a smoothing coefficient, and ε_{Rt} 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 α_k and α_{k^*}, 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 we have seen that

$$N_t \propto R^K_t Q_{t-1} K_t + \frac{RER_t}{RER_{t-1}} R^{K*}_t Q^*_{t-1} K^*_t - R^D_{t-1} \frac{D_{t-1}}{\pi_t}$$

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 $[Q_{K,t}]$, by increasing [the leveraged investor's] capital, increases the demand for Foreign assets, a rise in $[RER_t Q^*_{K,t}]$ similarly increases the demand for Home assets."[6] 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 important 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, after some manipulation of the first order conditions of the home and foreign entrepreneurs we get

$$\frac{\chi_t}{\chi_t^*} = \frac{E_t\left(R^{e*}_{t|t+1} r^*_{t+1}\right)}{E_t\left(R^{*e}_{t|t+1} R^{K*}_{t+1}\right)} \frac{E_t\left(R^{e}_{t|t+1} R^{K}_{t+1}\right)}{E_t\left(R^{e}_{t|t+1} r_{t+1}\right)} \tag{16}$$

Up to first order this relationship implies that

$$\hat{\chi}_t - \hat{\chi}_t^* = E_t \hat{r}^*_{t+1} + E_t \hat{S}_{t+1} - E_t \hat{r}_{t+1}$$

where hats denote log deviations. The right-hand-side of this expression coincide, to first order, to the UIP emerging from the first order conditions of the households' portfolio problem. Our model, therefore, predicts that, up to first order, if there is international trade in nominal assets in the two currencies, the home and foreign external finance premia are equalized. Importantly, this result is independent of the discount factor, and hence of the degree of risk aversion of the entrepreneurs.

A further interesting case is when we consider equation (16) under the assumption that the entrepreneur is risk neutral so that $R^e_{t|t+1} = 1$. In

[6] 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,

$$\frac{\partial K_{t+1}}{\partial Q_{K,t}} = \alpha_k \left(1 + \chi^{-1}(\cdot)\right) \frac{(1-\delta)\, Q_{K,t} - N_t}{Q^2_{K,t}} > 0;$$

precisely this would be the case when net worth is relatively low and leverage high.

this case the gap between the two external finance premia is determined by the ratio of the equity premia in the two economies. To higher orders of approximation the gap between the two external finance premia would fluctuate only to the extent that the gap between the two equity premia fluctuates.[7]

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.

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 shocks. 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

[7] Ehrmann et al. (2009) find that the transmission of the sub-prime financial crisis from the US to other countries has been stronger the more correlated the excess equity return of those countries with that of the US.

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 (illiquid) 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 this instance of "flight to quality" no arbitrage effects — without resorting to any informational friction, as postulated by Calvo (1998).

Furthermore, and as commented in the introduction, more recent evidence by Rose and Spiegel (2009) suggest that also the international propagation of the current financial crisis can be hardly understood by simply looking at the balance-sheet exposure.

Before turning to a quantitative analysis of the different propagation channels that 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:

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

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:

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

The term $\widehat{\varkappa}_t$ 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:

$$E_t\left[\widehat{r}^*_{t+1}+\frac{\widehat{RER_{t+1}}}{RER_t}\right]+\widehat{\varkappa}^*_t=E_t\left[\widehat{r}_{t+1}\right]+\widehat{\varkappa}_t,$$

implying that the premia differential across countries, up to first order, should be equal to the expected real interest differential.[8] Thus, if trade in short term bonds were also allowed, a case not entertained in DY, the premia $\widehat{\varkappa}_t$ and $\widehat{\varkappa}^*_t$ 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 $\varkappa_t$, $\varkappa^*_t$ in the DY framework à la la Kyiotaki and Moore, and the risk premia χ_t, χ^*_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 $\widehat{\frac{D_t}{N_t}}=\widehat{\frac{D^*_t}{N^*_t}}$, also up to first order. Conversely, one can show that equalization of $\widehat{\varkappa}_t$ and $\widehat{\varkappa}^*_t$ implies that the expected investors' discount factors ($R^e_{t|t+1}$ and $R^{*e}_{t|t+1}$, in our notation) should be equalized across borders, as it can be shown that:

$$\widehat{\varkappa}_t=-E_t\left[\widehat{r}_{t+1}+\widehat{R}^e_{t|t+1}\right].$$

Discount factors in DY reflect the investors's growth rate of the marginal utility of consumption, obviously a function of current leverage, but not

[8]Actually, DY study a one-good economy, implying that their analysis abstracts from real exchange rate fluctuations so that $\frac{\widehat{RER_{t+1}}}{RER_t}=0$.

only. Specifically, from the budget constraint and borrowing constraint of investors,

$$C_t = R^K_t Q_{K,t-1} K_t + RER_t R^{K*}_t Q^*_{K,t-1} K^*_t - r_t D_{t-1} + D_t - \left(Q_{K,t} K_{t+1} + RER_t Q^*_{K,t} K^*_{t+1} \right)$$
$$D_t = \kappa \left(Q_{K,t} K_{t+1} + RER_t Q^*_{K,t} K^*_{t+1} \right),$$

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

$$\Delta \widehat{C}_t = \frac{D}{\kappa C} \left(R^K \Delta \widehat{R}^K_t - \kappa r \Delta \widehat{r}_t \right) + \left(R^K - \kappa r \right) \frac{D}{\kappa C} \Delta \widehat{D}_{t-1} + \frac{\kappa - 1}{\kappa} \frac{D}{C} \widehat{D}_t + \frac{R^K}{C} \alpha_{k^*} \left(\Delta \widehat{RER}_t - \Delta \widehat{RER}_{t-1} + \Delta \widehat{R}^{K*}_t - \Delta \widehat{R}^K_t \right),$$

where in the steady state

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

and α_{k^*} 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 à la Kiyotaki and Moore, relative to an economy à 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 standard values for preferences and technologies – see Table 1 for a synopsis. The purpose of this calibration is only illustrative. We don't aim at reproducing particular stylized facts. With simply aim at showing the extent to which no-arbitrage conditions in the bond and capital market can make portfolio compositions virtually irrelevant for the international transmission of shocks. Focusing first on the benchmark parameterization of financial frictions, we set the steady state ratio $\frac{D+N}{N}$ to 2 as in BGG, and the steady state premium to 1.0164;[9] finally the elasticity of premium to leverage $\frac{D}{N}$ is set to 0.05 as in Bernanke et al. (1999), 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 wit 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 0.24% and 0.8%, respectively (persistence 0.8 and 0.6); an autoregressive markup shock to final goods producers with standard deviation 0.14% (persistence 0.6); an iid monetary policy shock ε_{Rt} with standard deviation 0.16% ; and an autoregressive shock $\varepsilon_{e,t}$ to the external financial premium with standard deviation 0.2% (persistence 0.4). 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 about 11% 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 (short) 37% of GDP, implying an offsetting long position in domestic currency bonds.

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

[9] Approximately corresponding to the mean value of the premium on the treasury-bill rate paid by non-financial corporations to monetary and financial institutions on loans with maturity of up to one year in the euro area.

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 foreign exposure of the balance sheet 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: namely, the fact that leveraged investors equate the returns that they can obtain from different assets in different countries, quite distinctly from 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 real synchronization in aggregate variables like output and investment. Specifically, in what follows we will focus on two types of asymmetric shocks: a (negative) Foreign neutral technology shock, as studied in Devereux and Yetman (2009), and a (positive) shock to the Foreign external finance premium. We can expect that the repercussions of shocks on the external finance premium in the Home country will be crucial in shaping the international transmission to investment and output, namely that an increase in the Home premium will be a key factor in the propagation of recessions from the Foreign to the Home country.

In order to better 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 markets; iii) the case of no trade in bonds but integration in the capital market; 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, while under cases i) and ii) investors optimally decide their level of borrowing according to the following, purely domestic, first order condition (and its Foreign counterpart)

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

we nevertheless will assume that net worth evolves according to

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

and its Foreign counterpart, where $\alpha_{k^*} = 0$ under full home bias (the true equilibrium outcome) and, admittedly in ad-hoc way $\alpha_{k^*} = \alpha_k$ under full diversification.

Conversely, the full home bias and full diversification portfolios, under cases iii) and iv) when we allow for capital trade and the no-arbitrage conditions also hold

$$E_t R_{t+1}^K = E_t \frac{RER_{t+1} R_{t+1}^{K*}}{RER_{t1}} = \chi \left(\frac{D_t}{N_t}, \varepsilon_{e,t} \right) E_t r_{t+1},$$

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 — notice that the optimal choice would also fall between these two extremes.

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), consumption (C), real exchange rate (RER) 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 7 to 7 report impulse responses to a 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; in contrast, 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 included 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. Specifically, the Home external premium falls reflecting the expected increase in domestic asset prices and the fall in investment and thus in borrowing.

The introduction of full diversification in capital holdings, though in an admittedly crude and partial equilibrium way, affects the responses of the Home premium, GDP, and especially asset prices and investment. Specifically, the direction of the international propagation for asset prices and investment flips. While home asset prices now fall only on impact, and subsequently increase, the response of investment is persistently positive, reflecting a larger reduction in the external finance premium; moreover the temporary contraction in GDP, after the initial rise, is followed by above-trend growth. The reason for the positive spillovers on the Home economy is clear when the response of the real exchange rate is taken into account: the Home real depreciation more than offsets the fall in Foreign asset prices, generating a *positive* valuation effect on Home net worth under full diversification. In this case, more exposure to foreign capital actually shields the Home economy from the negative shock from abroad.

In order to study the effects of increasing international financial integration, in 7 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 — again in this case the first order conditions for endogenous cross-border capital choices are not included in the model solution, so that the no-arbitrage effect on returns on capital is ruled out. This setting under full home bias 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 at least trade in one bond (e.g. Gilchrist (2003) Faia (2007b,a)).

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 7, 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 under our calibration. As before, the comparison of the black and the red line shows that introducing (ad-hoc) 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 7, 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 7. 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 7, displaying negative comovements with their Foreign counterparts. Again, the reduction in the Home premium, resulting from the positive valuation effects stemming from real currency depreciation, mostly accounts for the expansionary effects on the Home variables.

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 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 7, 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, again reflecting the opposite valuation effects on net worth brought about by the real exchange rate response to the shock. 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 7, the no-arbitrage effect on capital returns arising from the endogenous choice of cross-border capital investment is not enough to increase synchronization in asset prices and external premia. In addition, more exposure to assets abroad in investors' portfolio overall results in less rather than more across-the-board synchronization.

Finally, a different story emerges from Figure 7, 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 to financial variables, 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 global fall in the external premium.

The sign of the transmission to real variables however 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 7 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.[10].

To summarize our results so far, we have shown that once financial markets are integrated, including risky illiquid assets, the size of home bias in portfolios of leveraged investors 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 under integration of capital trade only, similar to those in our Figure 7, finds that increased diversification results in a heightened international transmission of technology shocks, reflecting the greater sensitivity of domestic leverage constraints to developments in 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 is 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,

[10]In this case the optimal portfolio holdings are about (short) 65% of GDP in foreign bonds and about 13% of foreign capital.

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 an increase in 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 7 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 only international bond trade displayed in Figure 7, the climb in the Foreign premium clearly 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 on capital returns 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.

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. Because of the Home real appreciation, the adverse effect of falling Foreign asset prices on domestic net worth is now magnified. 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 the responses of all variables to the asymmetric financial shock.

To summarize, our results point to the fact that when financial markets are integrated, including those of risky illiquid 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 Robustness check: Higher order implications of financial integration

So far we have seen that to first order of approximaition external finance premia are equalized across countries when financial markets are fully integrated. In particular we have shown the strong result that conditional on financial shocks the two economies co-move almost perfectly.[11] In this section we extend this analysis to the second order of approximation to show that: *i*) the response of the premia is still identical across countries; *ii*) portfolio composition still plays a minor role in the response of the economy to shocks and in the propagation of shocks across countries and *iii*) the co-movement of the two economies is less than perfect even under financial shocks.

At this point is important to notice that we assume a power function for the premium. The coefficient on the second order term of the premium does not necessarily coincide with the coefficient on the second order term of an expansion of the fully fledged BGG model. The results should therefore be interpreted as suggestive of the implications of including second order terms in the solution of the model, rather than exact quantitative implications of the BGG-type financial frictions.

Here we show only the response of the economy to financial shocks, as these are the shocks that imply stronger co-movements up to first order. Figure 7 shows the response of the home and foreign country to a foreign-country financial shock under three shenarios: *a*) first order approximation; *b*) second order approximation and full home-bias in capital and *c*) second order approximaiton and full diversification in captial.[12]. A first thing to notice about these impulse response functions is that the second order response differs markedly from the first order response.[13]. In particular home output and investment fall more than the foreign coutnerpart, although the shock originated in the foreign country. Nevertheless, the premium is still equalized across coutnries indicating that the country-specific premia associated to the no-arbitrage conditions don't generate wedges between the external finance premia.[14] Finally Figure 7 shows that the portfolio composition matters slightly more than up to first order. Nevertheless it plays a marginal role in the response of the economies to the shock and in the propagation of the

[11] Obviously not all variables co-move perfectly in this case either. Since the premia are equalized and they reflect the combined effect of the exogenous shock and the endogenous leverage ratio, the latter must increase by more in the country not subject to the shock. As the figures have shown, though, the asymmetric response of the leverage has no sizable consequences for the dynamics of the main macroeconomic variables.

[12] Notice again that the optimal portfolio composition lies within this range. Notice also that including a variable portfolio did not affect the results

[13] Second order responses are produced using the solution suggested by Lombardo and Sutherland (2007) and Kim et al. (2008) and implemented for Dynare by Stephan Fahr

[14] Notice that premia are constant up to second order.

shock across countries.

7 Concluding remarks

In this paper we have developed a quantitative two-country model with financial frictions à la 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 leveraged 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 to foreign illiquid assets, 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, triggering cross-border "flight to quality" and thus imparting tight linkages in leverage and macroeconomic dynamics across countries.

Under a high degree of financial integration, our model implies that external premia and thus leverage ratios 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 a global"flight to quality" due to pricing effects in integrated asset markets has the potential to account for fundamentals-based financial and real propagation even in cases where the foreign exposure of levered investors is not substantial, similarly to the recent evidence documented by Rose and Spiegel (2009). While noting that this mechanism has found some supporting evidence in cases of "fundamentals-based contagion" among integrated financial markets (e.g. Kaminsky & Reinhart (2000), who proxy integration with return correlations), we believe this is an important feature given the rather pervasive degree of home bias in cross-border holdings of (illiquid) assets still prevalent even among advanced countries.

FIGURES AND TABLES

Figure 1: Rose and Spiegel (2009))

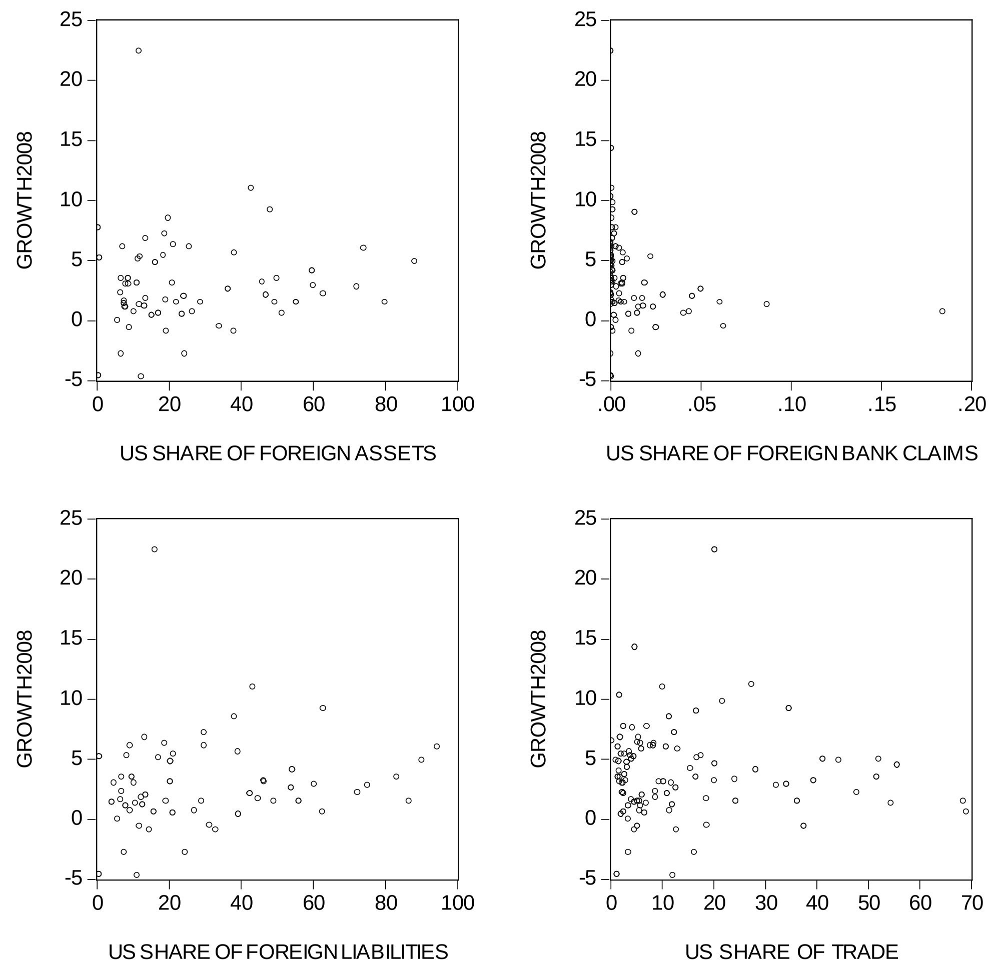

Figure 2: Rose and Spiegel (2009))

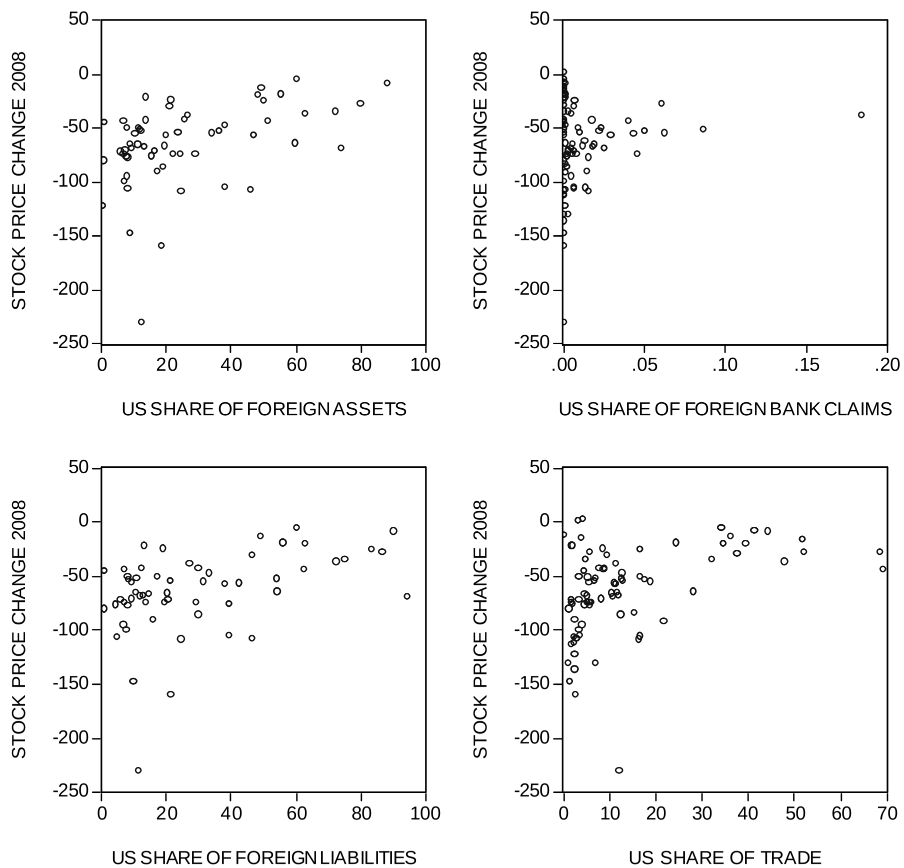

Figure 3: Full autarky: Foreign productivity shock.

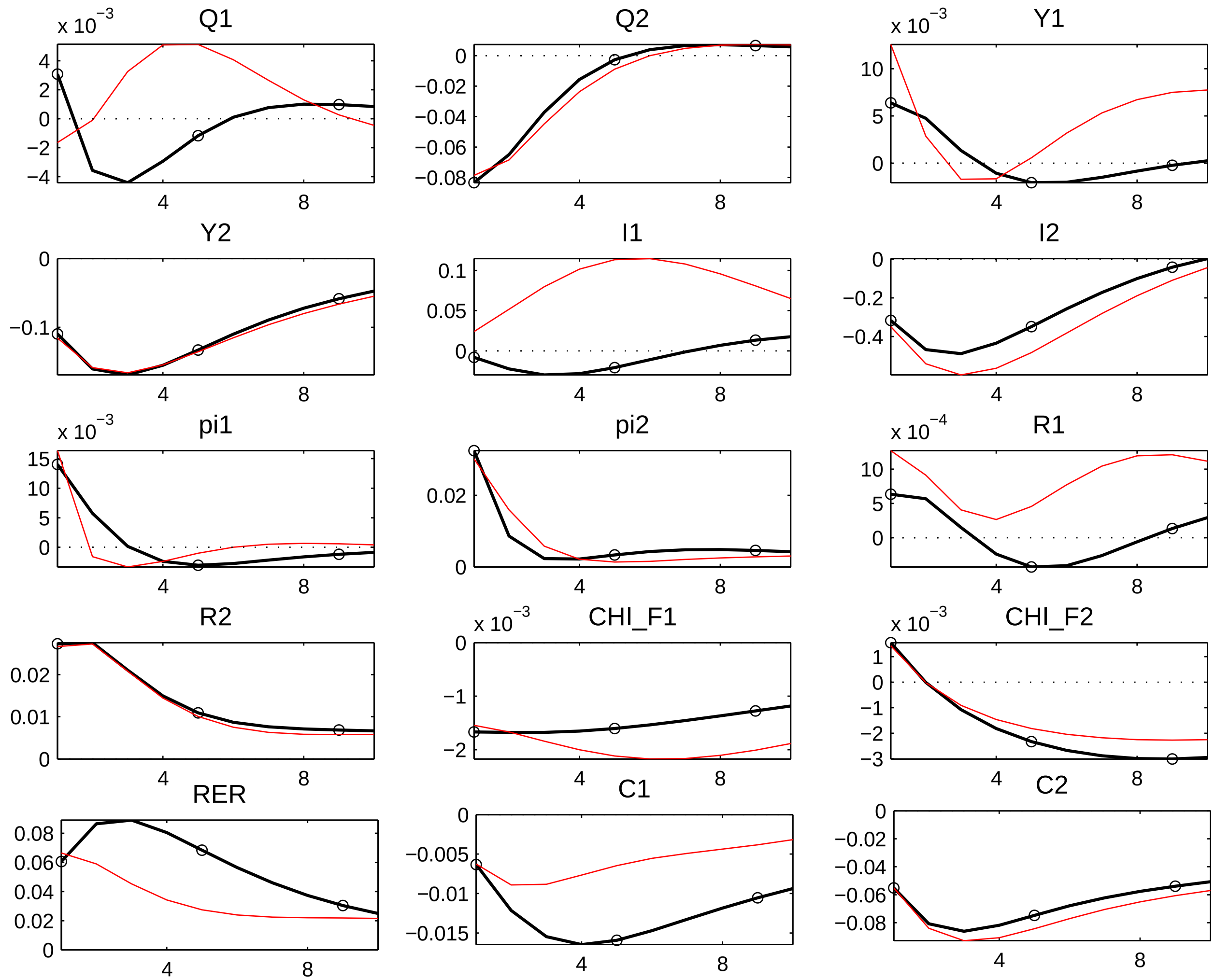

Figure 4: Capital autarky: Foreign productivity shock.

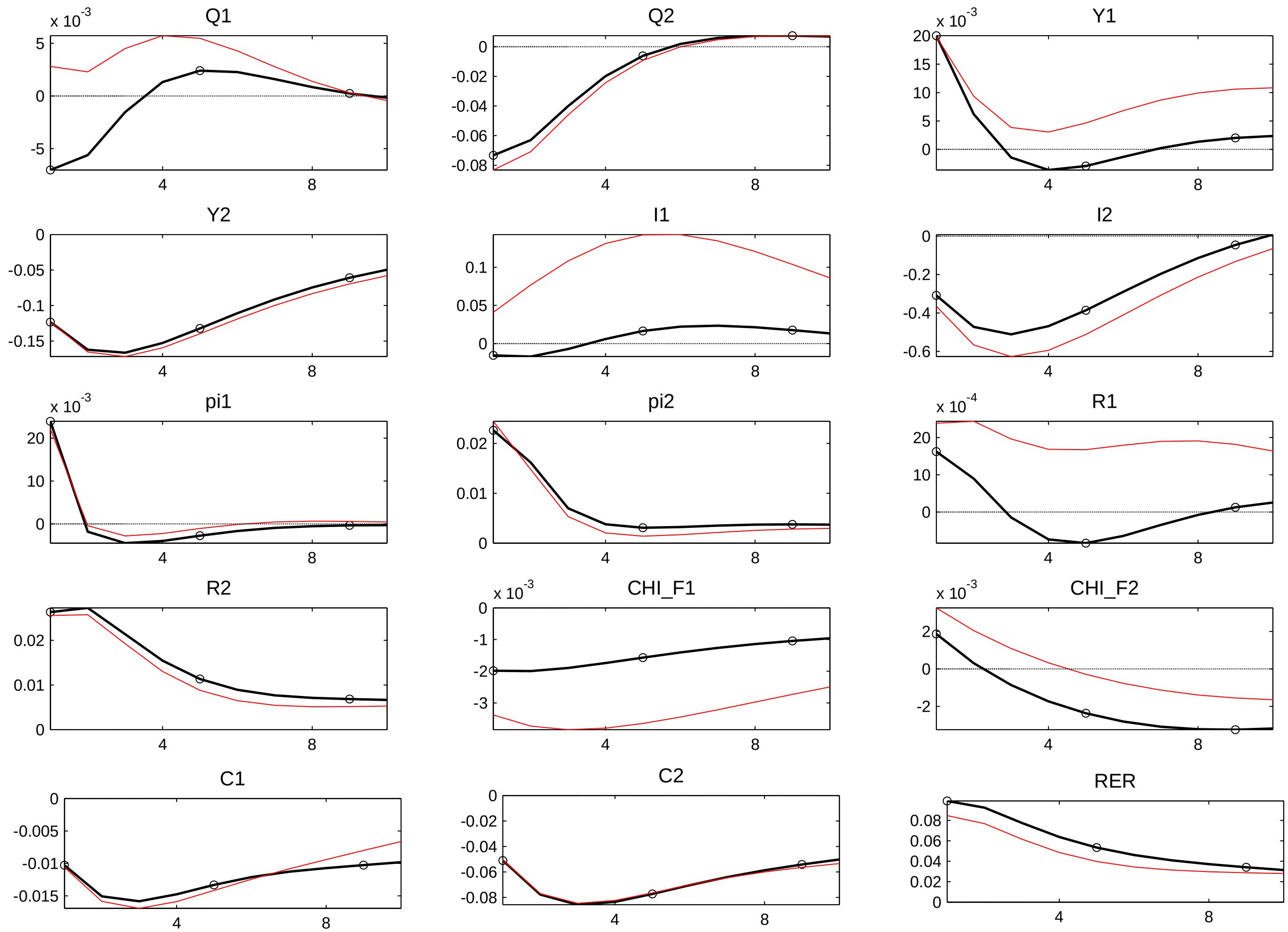

Figure 5: Bond autarky: Foreign productivity shock.

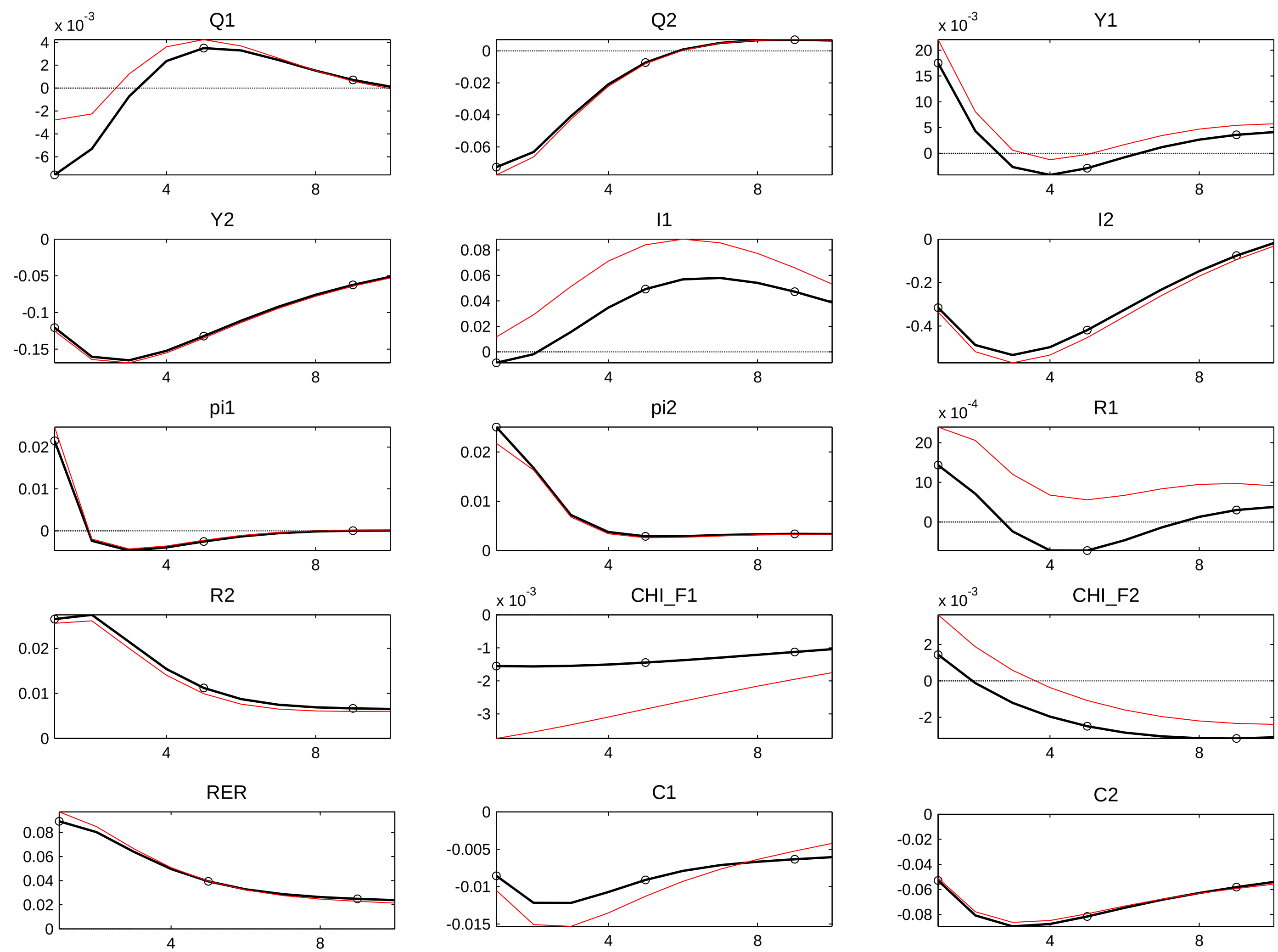

Figure 6: Full integration: Foreign productivity shock.

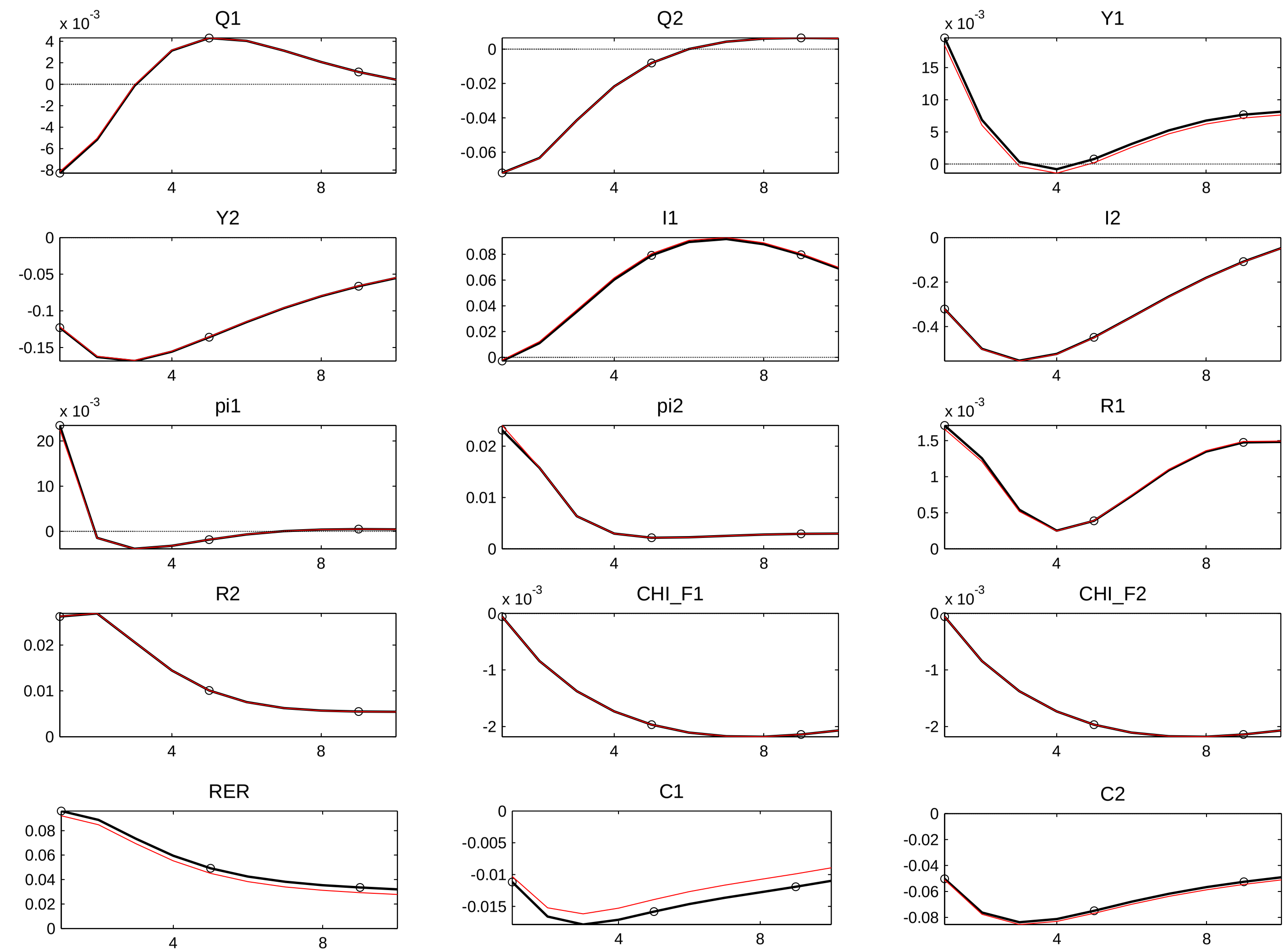

Figure 7:
Full integration and large leverage: Foreign productivity
shock.

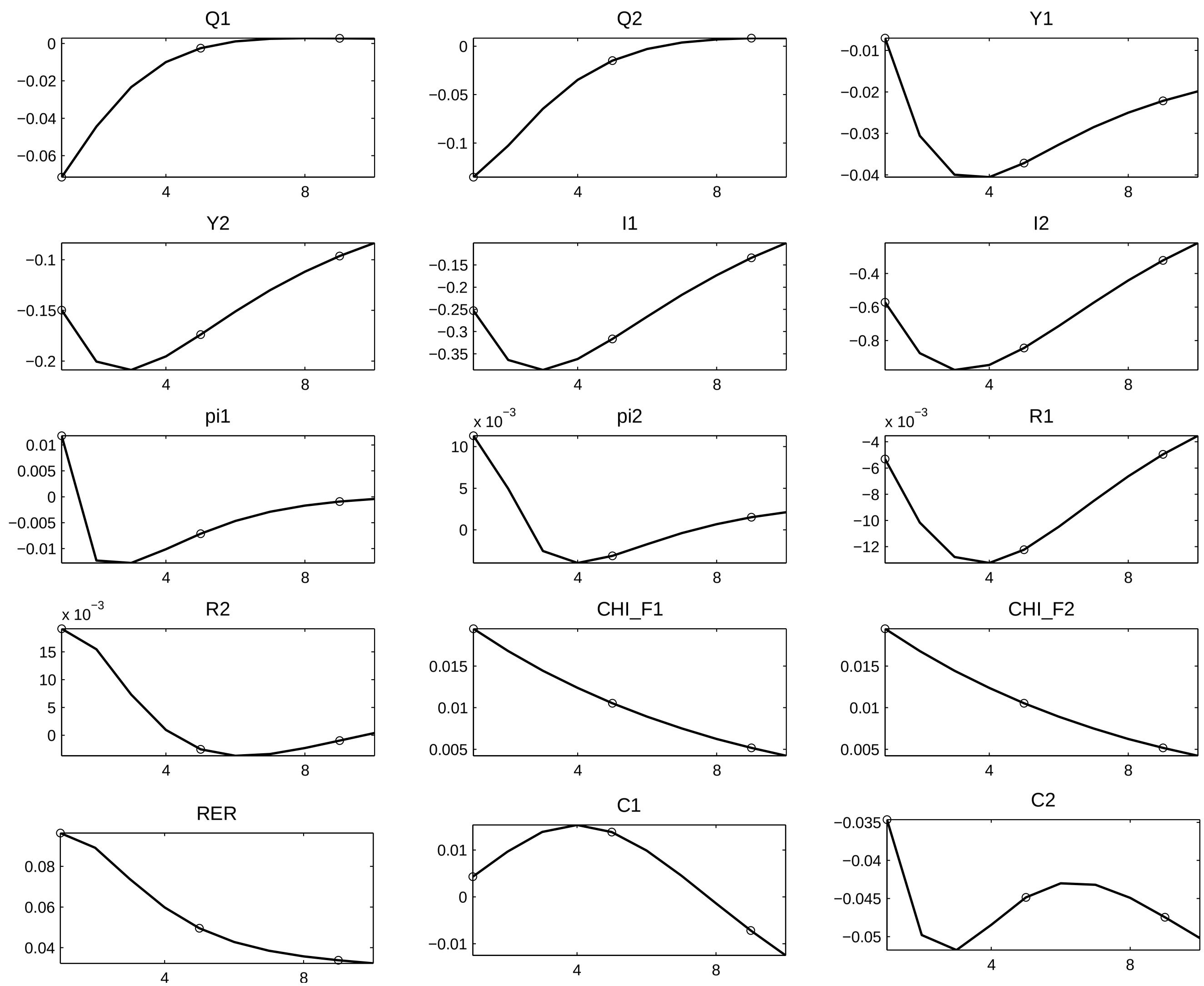

Figure 8: Capital autarky: Foreign financial shock.

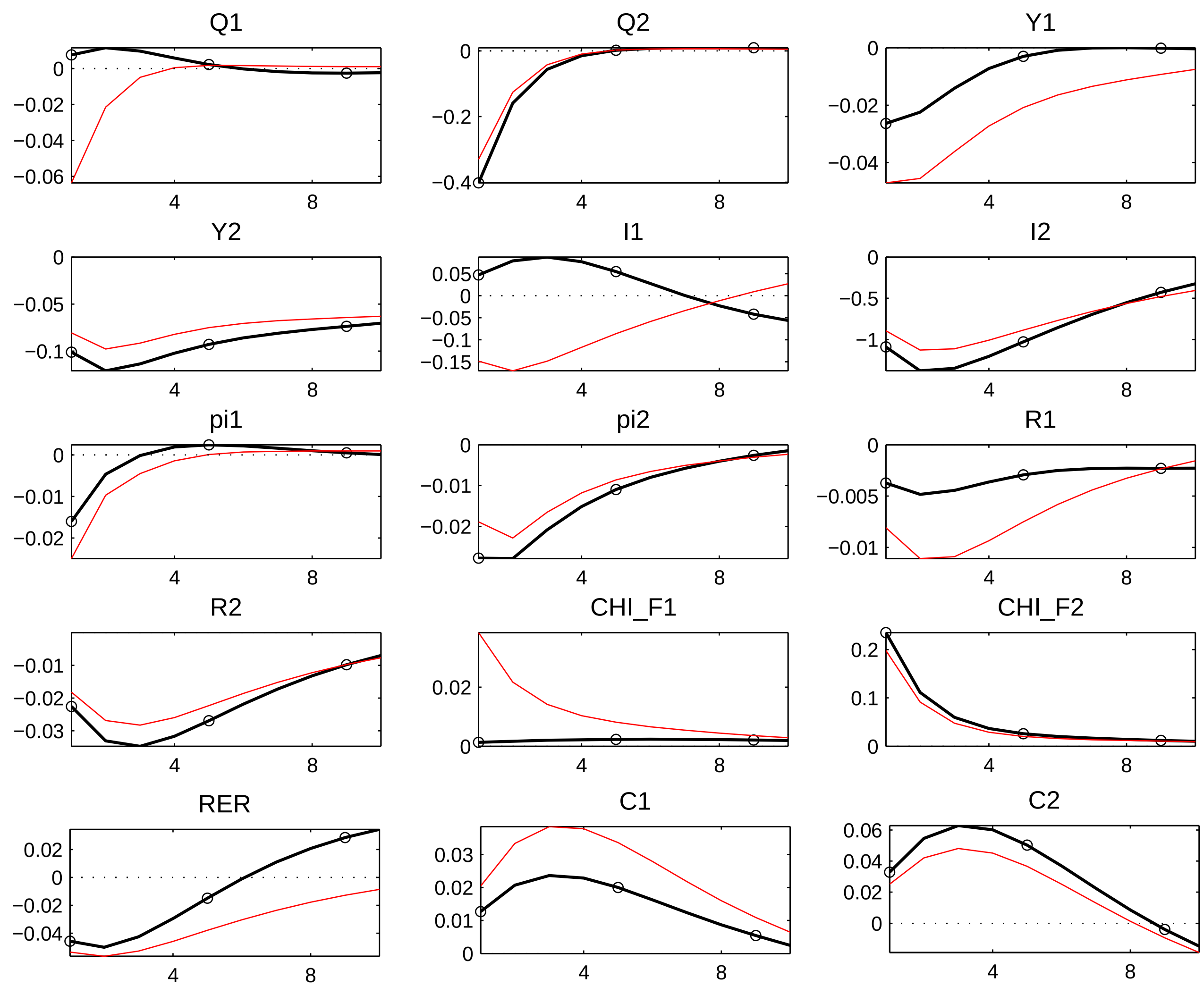

Figure 9: Full financial integration: Foreign financial shock.

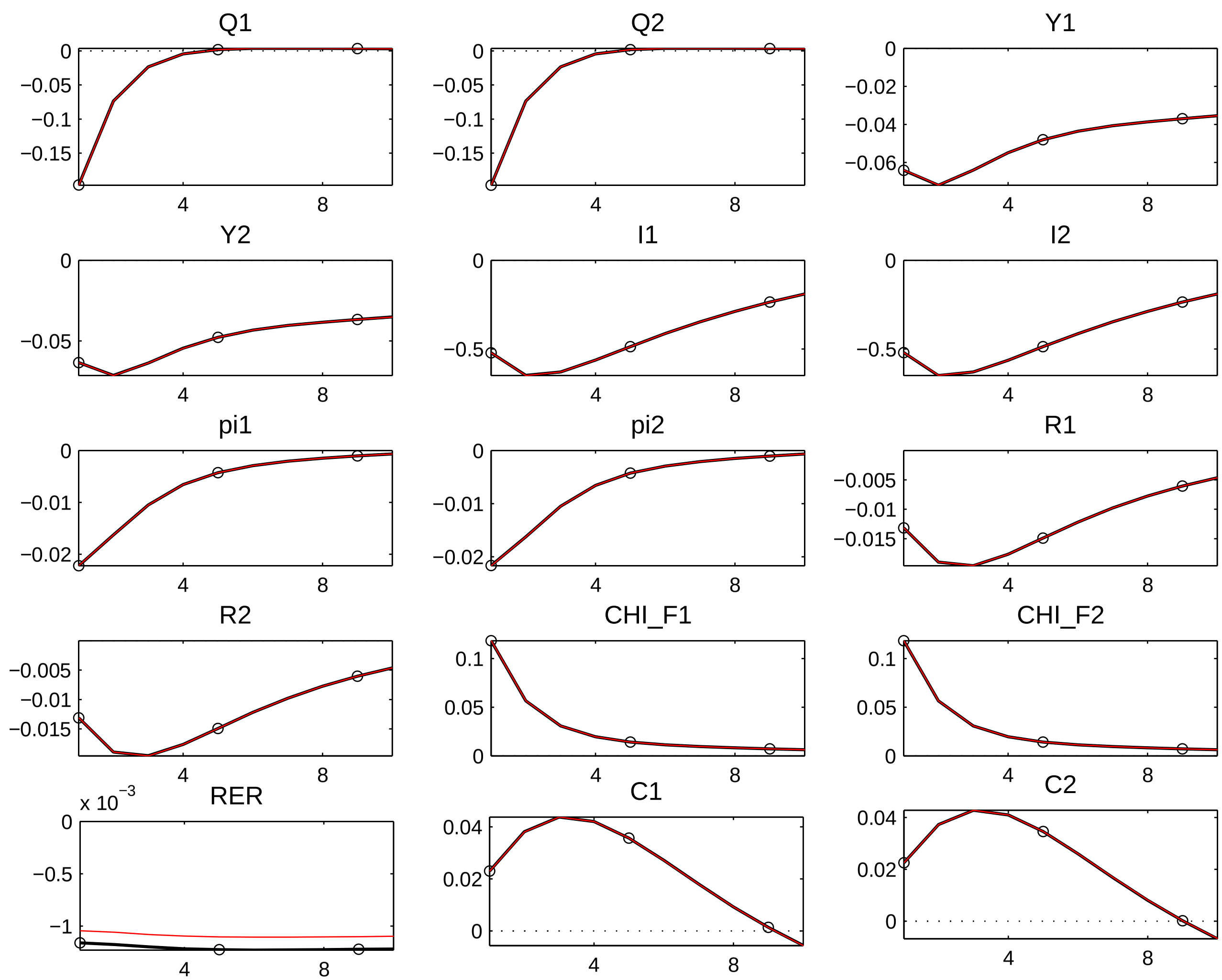

Figure 10: Financial shock: second- vs. first-order approximation (black circled=full home bias; red=full diversification; blue=firs-order)

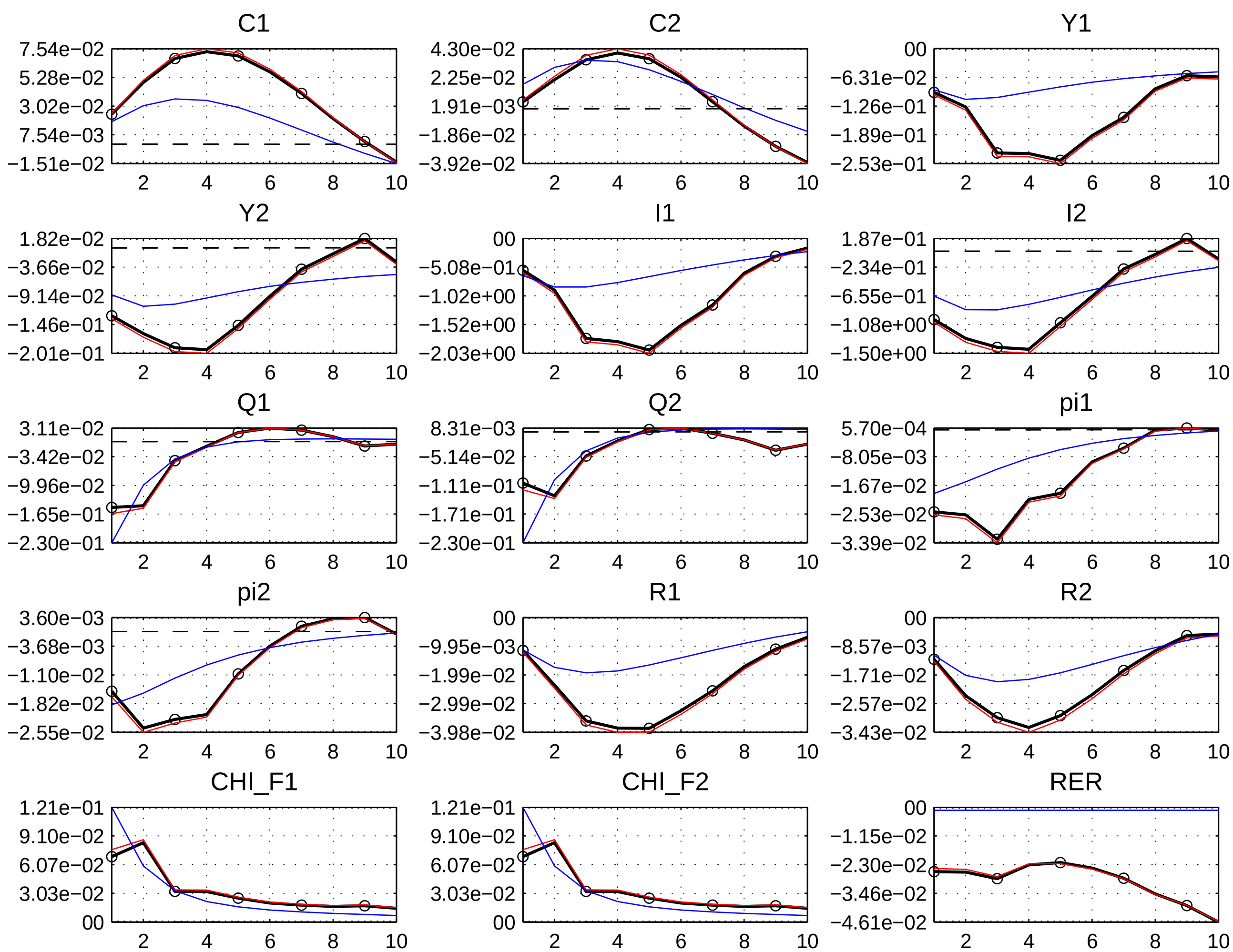

Table 1: Calibrated parameters

Parameters		
Description	Symbol	Value
Home bias in consumption and investment	$n\,(n^*)$	0.85
Calvo probability of not-adjusting prices	$\xi\,(\xi^*)$	0.65
Steady-state depreciation of capital	$\bar{\delta}$	0.025
Investment adjustment cost parameter	γ_I	0.5
Elasticity of Labor supply	η	1
Intratemporal elasticity of substitution	θ	1.2
Intertemporal elasticity of substitution	ρ^{-1}	1.01^{-1}
Final-goods producers' mark-up	μ_f	1.2
Habit formation in consumtpion	$\kappa\,(\kappa^*)$	0.6
Interest rule response to inflation	$\lambda_\pi\,(\lambda_\pi^*)$	2
Interest rule inertia	$\lambda_R\,(\lambda_R^*)$	0.7
Households discount factor	β	0.99
Leverage ratio	$\frac{B}{N}$	1
Steady-state premium (p.a.)	$\bar{\chi}$	1.0164
Elasticity of premium to leverage	χ	0.05

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