Trade in secured debt, adjustment in haircuts and international portfolios[1]

Tommaso Trani[2]
The Graduate Institute | Geneva

First version: May 2011
This version: October 2011

Abstract

I study the composition of international portfolios under collateral constraints and the implied cross-border transmission of shocks. I develop an international portfolio model with these features, in which leveraged investors seek diversification in both assets and secured liabilities and in which the pledgeable portion of assets adjusts to the state of the economy, reflecting borrowers' credit risk. The new analytical results are as follows. First, agents choose endogenously how much to borrow from each country. Second, the collateral constraint, being a contractual link between secured and unsecured financial instruments, permits to compute portfolios without an arbitrage condition between those classes of assets. Finally, haircuts adjust endogenously through the change in the collateral values. After estimating the parameters governing this adjustment, I find that both portfolios and international transmission mechanism are quite sensitive to leveraged investors' funding. As for portfolios, secured bonds have particularly effective hedging properties in managing the terms of trade risk. As for the international transmission, tightening haircuts affect the economic slowdown: initially severe contractions are followed by quick reversions to the long-term equilibrium. On a cumulative basis, these two effects compensate if haircuts adjust precisely to the economic state. But in case of uncertainty about this adjustment, collateral constraints are a source of risk which cannot be internationally diversified.

JEL classification: F32, F34, F41, G15.

Keywords: financial flows, borrowing limits, creditworthiness, risk premia, international business cycle, macroeconomic interdependence.

[1]I am profoundly grateful to Cedric Tille for providing careful guidance throughout the entire development of this project. I thank Rahul Mukerjee for his helpful advices on the implementation and interpretation of the model. Finally, I want to thank Julia Schmidt and Sergio Sola for their comments. Clearly, all remaining errors are exclusively mine.

[2]Contact: tommaso.trani@graduateinstitute.ch.

1 Introduction

Especially over the last decade, financial integration has been increasingly characterized by the international role of financial intermediaries. At the same time, intermediaries have pursued a transformation of their trading model, which started at least in the nineties. One evident outcome of the combination between these two processes is that the actual banking system relies heavily on secured interbank transactions and is globally interconnected.

In this paper, I analyze the impact of these *privately* guaranteed transactions on the portfolio strategies of internationally active financial intermediaries and their relevance in the size and directions of capital flows. What we currently know is that the globalization in banking has progressively modified the international transmission mechanism through both cross-country transactions and foreign offices and subsidiaries (Goldberg, 2009; Goldberg and Cetorelli, 2010). Leaving the case of multinational banks out of the analysis, I focus on cross-border international interbank transactions, which are introduced in an international portfolio framework. In this way, international traders face a broad portfolio choice which involves not only the asset side of their balance-sheets, but also the liability side, which is made of collateralized bonds. In practice, the trade in such types of bonds is a simplified and synthetic way to capture such real-world wholesale funds as those involving repurchase agreements (repos) and asset-backed commercial paper (ABCPs).

The use of collateral constraints in international portfolio models has been already explored by Devereux and Yetman (2010) to formalize Krugman's (2008) idea of an "international financial multiplier", a label meant to capture the phase of global financial transmission that the world economy experienced between the first and the second phase of the recent financial crisis. Observing generalized deleveraging, Devereux and Yetman (2010) convincingly show that one mechanism which can generate such a multiplier works through the collateral constraints faced by leverage investors on their internationally diversified asset holdings. It follows that borrowing at home and in the foreign country is set to react only in case of valuation effects on these assets.

While valuation effects on diversified collateral assets are surely central types of (transmission) linkages, they cannot probably account for the entire mechanism at work. Although he was inspired by the similar experiences of previous crises (e.g., LTCM, Russian Crisis, etc.), at the end of his note Krugman (2008) made a strong call for authorities to *recapitalize* banks worldwide. The emphasis on capital suggests two things: the international transmission linkages involve the entire bank balance-sheet, and there was something new about the recent crisis. With a focus on the liability side of international traders' portfolio choice, here I find that the financial linkages involve not only traded assets but also cross-border liabilities. More precisely, the *size*

of the international transmission of shocks depends on both the international diversification of collateral assets and the composition of the secured bond portfolio. I obtain this result considering the mechanism proposed by Devereux and Yetman (2010) as the core modeling structure and expanding the analysis in two fundamental directions: allowing active investors to choose endogenously where to sell bonds (i.e., where to borrow); considering haircuts time-varying, in accordance with the margin setting rules described by the financial literature.

Indeed, the use of wholesale funding has become pervasive among banks, and data suggest that this practice is not confined within the national borders but has an international dimension. In this regard, the ideal would be to have a model where international bankers and brokers choose endogenously not only their long positions but also their funding partners. Focusing on funds that are granted against collateral, this type of model is a good candidate for providing new insights on the role of interconnected banks in an integrated economy, where the possibility to diversify idiosyncratic shocks may have *knife hedge* properties. On one side, there is the well-known forced deleveraging of assets, which has in many historical events affected more than one country. On the other, there is the innovation of financial intermediation, which spurs financial flows across countries. But this is a mixed blessing in that these flows may bring about heightened international synchronization and, thus, more complex dynamics, for example, reinforcing deleveraging should a shock affect the world economy.

I make a step toward this kind of model, but I define the interbank market in the simplest possible way, maintaining the assumption originally made by Devereux and Yetman (2010) in their framework. Specifically, I only consider the funds supplied by saving institutions to leveraged institutions, neglecting the fact that many financial intermediary can be at the same time borrowers as well as lenders[1]. Characterizing the interbank (i.e., *intra-agents*) relationships this way and assuming that financiers in both countries are willing to lend cross-border, the contributions of my approach are as follows. First, I endogenize the allocation of secured bonds across countries, where the bonds are specifically used as debt instruments. Second, I show analytically (and confirm numerically) that the presence of collateral constraints insulates the portfolio choice of unsecured assets from that involving secured ones (debt in this case), which thus means that the existing portfolio solution methods[2] do apply. Third, rewriting the collateral constraints in terms of value-at-risk (VaR) limits, I can specify the dynamics of borrowers' debt-to-asset ratios as functions of state variables, through observed asset prices across borders. Finally, I estimate the parameters governing these dynamics in a structural way, matching the empirical moments

[1] It follows that my model cannot capture the "gridlock risk" as defined by Brunnermeier (2009).

[2] See Devereux and Sutherland (2011) and Tille and Van Wincoop (2010).

with those generated by the model. Considering haircuts as unobservable, I use a simulated method of moments (SMM) procedure.

The model reproduces both equity home bias and home *funding* bias (i.e., the tendency to have liabilities tilted to the local economy). An investment shock breaks the perfect correlation between agents' capital income and their non-capital income (Coeudarcier et al., 2010). This is the origin of the equity home bias. As for funding, the analysis of the portfolio choice shows that funding depends on arbitraging the lending rates across countries. Therefore, short positions with home bias tend to arise because of the hedging properties of bonds (as insurance against terms of trade risk), even though these are secured by collateral.

Clearly, the fact that haircuts are adjusted in accordance with the prevailing economic state does not affect the equilibrium portfolios. Indeed, what matters in the steady state is whether the constraints are binding, and one can compute portfolios simply by adjusting the standard portfolio choice in line with the collateral constraints. As far as the dynamics are concerned, the adjustment in haircuts becomes crucial. Being a guarantee on loans, the pledge must be adapted to the state-dependent counterparty risk, which is here limited to the sole borrower-specific credit risk component[3]. It is this adjustment in the pledge that drives the time variation in haircuts. I find that when haircuts *tighten* in response to a drop in productivity, the variables display a characteristic dynamics which is absent when the mechanism is not at work. Initially, the contraction of model variables is more severe. Yet, afterwards the tightening in haircuts brings about a correction which is due to the marked reduction in leveraged investors' borrowing capacity in the first periods after the shock. Basically, lenders start again to consider traders as creditworthy and to lend to them only when they start to repay their debt.

The fluctuations in haircuts can contribute to risk sharing, in the sense that if margins are set accounting for the fact that borrowers hold a diversified portfolio of assets, then home and foreign borrowers' holdings of financial instruments show a tendency to converge. Unsurpraisingly, this is especially true for debt-holdings. Yet, the model features the amplification typical of credit constraints, no matter whether haircuts are constant or time-varying. Nevertheless, this is true only if there is no uncertainty surrounding the revision of haircuts. If instead this revision is subject to some sorts of shocks, the adjustment in haircuts can compensate some of the gains of risk diversification. These shocks to haircuts are comparable to the financial shocks introduced

[3] At first sight this choice may sound unattractive, but in fact this is the most consistent assumption with the problem I address in this paper: an analysis on cross-border funding, involving the liability side of balance sheets. The alternative analysis concerns the other side of balance sheets and causes technical issues that represent a topic in themselves. I discuss one possible way to deal with these alternative questions in another work (Trani, 2011).

by Jermann and Quadrini (2011) while analyzing the causes of macroeconomic volatility. Here, the shocks to haircuts can be interpreted as unexpected changes in credit risk, which cannot be easily hedged through portfolio diversification.

In terms of the overall goal, these results can be summarized by saying that traders' funding strategies affects the financial linkages between integrated economies for two reasons. The first concerns the fact that the country where to borrow short-term, wholesale resources is chosen endogenously. The second reason is about the interaction between assets and liabilities because, for one thing, all portfolios are solved under binding constraints, and for another, valuation effects on assets spur the haircuts to react. Note that here I do not derive haircuts optimally, and in general I do not want to provide a new theory for their behaviour. I just draw from established theories to suggest one possible framework through which they change endogenously, consistently with portfolio models where collateral is internationally diversified.

The structure of this paper is the following. In the first two sections, I present some evidence on international banking (section 2) and describe how this paper relates with previous studies (section 3). Section 4 is devoted to the model, and after I analyze the portfolio choice problem (section 5 and appendix 9.1). In section 6 (and appendix 9.2), I describe my calibration and estimation strategies. Numerical results on portfolios, economic dynamics and amplification are in section 7. Section 8 is the concluding section.

2 Evidence: a brief look

The liability structure of the balance sheets of global banks is a crucial source of information for understanding private capital flows and interconnectedness between countries: for example, the currency composition and the maturity structure of funds affect the stability of both cross-border claims and cross-border liabilities. In the BIS Quarterly Review released in March, McGuire and Von Peter (2009) try to extract this type of information from the BIS Consolidated and Locational Banking Statistics, breaking these data down by countries, currencies and counterparties (as a proxy for maturities). Apart from their specific focus on currency mismatches, they show that the integration among markets for bonds and other debt securities has made a substantial step forward. Yet, regions tend to take heterogeneous positions on the various segments of these integrated markets. While major European banks are net borrowers with other institutions in the interbank market and with the Central Bank, Japanese banks have been net borrowers on the domestic retail market.

In principle, interbank loans and securities are more exposed to the issues of asymmetric information than households' deposits. However, these issues are often overcome with a pledge, which renders these wholesale deposits a cheap and quick source of funds, which have gained popularity not only within the domestic borders, but also in the international markets. Using BIS Locational Statistics, one can separate the amount of deposits that international banks have vis-à-vis the foreign banking sectors from the part owed to non-banks. The resulting dataset cannot be broken down further by currencies, but it includes all interbank transactions made "on a trust basis"[4]. That is, these data cature secured transactions such as ABCPs and repos. Scaling by World GDP, I report these data in Figure 1, together with the total amount of foreign claims held by global banks, which are considered as term of comparison. The sample is made of OECD countries, which I broadly separate according to economic and financial similarities. Both foreign interbank deposits and foreign claims have followed similar patterns, and the former are quite as large as the latter. Since 2000, there has been a clear increase in cross-border claims and interbank liabilities, confirming that globalization in financial intermediation has deepened in the last decade (Goldberg, 2009). All amounts outstanding more than doubled in size, with the only exception of foreign deposits held by European banks.

In terms of the model, I attempt to capture the close relationship between claims and interbank deposits solving simultaneously the endogenous portfolio selection between assets and that between secured liabilities. Furthermore, key structural features of these OECD countries shall be used to parametrize the model for the quantitative analysis.

3 Literature

This paper is related with four strands of literature: 1) that on international transmission in presence of constraints on portfolio choice; 2) that on the effects of the limits to borrowing on asset prices and economic fluctuations; 3) that on the type of (cross-border) hedging guaranteed by different asset classes; 4) that on financial intermediation, liquidity and related asset pricing. In this section, I briefly review some of this literature, without aiming at being comprehensive.

This paper is closest to the first strand of literature above, as I build a two-country portfolio model with collateral constraints. A pioneering article on the role of portfolio constraints in the international transmission of shocks is the one proposed by Pavlova and Rigobon (2008). However, they work with constraints of a general form, and their specific examples do not concern the subject studied here. In fact, my model features a financial accelerator mechanism as it is

[4]BIS (2008), p. 5.

the case of Dedola and Lombardo (2009) and Devereux and Yetman (2010). I actually build on the latter, since they study the decisions taken by leveraged investors and I, similarly, focus on loans secured by collateral.

Due to this focus on collateralized borrowing, my model shares some characteristics with the studies on the macroeconomic effects of this type of borrowing. Aiyagari and Gertler (1999) study how they affect asset prices, and Mendoza and Smith (2006) and Mendoza (2008, 2010) use margin requirements to examine the effects of Sudden Stops on emerging open economies. Iacoviello (2005) use a monetary model where entrepreneurs and households can pledge real estate as collateral.

I take advantage of recent findings on the hedging properties of financial assets. Motivated by the empirical relevance of the home equity bias puzzle (Sercu and Vanpée, 2007), Nicolas Coeudarcier and his co-authors have recently searched for shocks that can reproduce this stylized fact in a quantitative model. For this purpose, Coeudarcier et al. (2007) show what is the necessary condition that the model economy needs to satisfy. In a successive paper, Coeudarcier et al. (2010) show that one of such models is a framework with capital accumulation and trade in bonds. However, the deepest analysis on the role of bonds in country portfolios is by Gourinchas and Coeudarcier (2009).

Besides the portfolio models with credit constraints, my analysis is substantially influenced by some works in the financial literature. Brunnermeier (2009) and Gorton (2009) discuss the economic instability that can originate from secured interbank loans. In these transactions, collateral assets can be seen as risk-sensitive private guarantees needed to render marketable otherwise non-marketable assets (Gorton and Pennacchi, 1995). The risk-sensitivity of assets means that haircuts are time-varying. Brunnermeier and Pedersen (2009) offer an explanatory theory of fluctuating margins. A part of their argument is incorporated in the model below, because collateral constraints amount to VaR limits (Adran and Shin, 2008) and haircuts can be estimated by SMM - drawing from Duffie and Singleton (1993) and Michaelides and Ng (2000).

4 The model

Building on Devereux and Yetman (2010) - DY henceforth, I develop an open economy model where leveraged agents diversify their secured liabilities as an endogenous solution of optimal portfolio choice. The basic framework features two countries, two goods, two agents. The countries are symmetric and populated by two groups of households. Active investors belong to the first group and have dimension n; passive investors belong to the second group and have

dimesion $1 - n$. The total size of the population is thus normalized to 1.

The heterogeneity between the two groups of agents is justified by their different role in the economy and is obtained through heterogeneous rates of time preference (Calstrom and Fuerst, 1997; Iacoviello, 2005). Active investors finance final good firms, buying their stocks with internal resources and debt. Loans are granted by passive investors, whose role in the economy is that of patient consumers and "residual" producers. However, due to an imperfect commitment to repay, passive investors are willing to lend only against collateral. An integration between home and foreign markets is possible because active investors engage in international financial trade; they represent the unique group of households that has direct access to international markets as well as domestic ones.

Within this framework, DY show that binding collateral constraints cause financial accelarator dynamics, which propagates though balance sheet transmission. A scheme of the resulting model is represented in Figure 2. The model below borrows this structure as the main building block. The new features are meant to characterize the terms of collateralized borrowing. The corresponding diagram is in Figure 3. DY follow Krugman (2008) closely and reproduce his international financial multiplier hypothesis, emphasizing the international diversification of assets in which agents are *long*, while borrowing creates the basis for leverage. But, as Figure 2 shows, the structure of loan covenants is not analyzed further, and the degree of bond market integration is imposed, distinguishing between perfect bond market segmentation and perfect bond market integration. In any case, the traded bond is homogeneous, as homogeneous are the production technologies used in the two countries. On the other hand, loan covenants are of primary importance here. As Figure 3 shows, the structure of the collateral limits can affect the integration between financial markets, which is an endogenous outcome of the cross-border trade in bonds. International diversification in secured bonds is a bit unusual for the international portfolio literature, in that bond holdings are generally fully endogenous to portfolio choice, while here there is a contractual limit to satisfy[5]. The tightness of collateral constraints reflects the international financial trade and can be linked *ex post* to portfolio choice. This sort of endogeneity of the collateral constraint is not optimal but simply a consequence of the implicit value-at-risk (VaR) rule, which governs the fluctuations in borrowers' creditworthiness.

The terminology used to identify the two groups of agents is largely borrowed from Adrian and Shin (2009). Passive investors are non-leveraged institutional investors: pension funds, mutual funds, insurance companies, investment trusts, etc. Active investors are leveraged institutional investors (hedge funds and investment banks) and large commercial banks. Thus, in the model

[5] A discussion on how to solve for portfolios in this case is deferred to the next section.

below, active investors supplement internal resources with wholesale funds only. In this case, it is appropriate to talk about private loan guarantees (as opposed to public guarantees) and an international *intra-agents funding market* (a modelling counterpart of a portion of the international interbank transactions). In terms of Figure 3, this market involves both local bond trade between heterogeneous agents and international bond trade between (homogeneous) active investors.

4.1 Firms

Each country produces a traded good; traded goods are differentiated across countries. The firms producing these goods are perfectly competitive public companies, and their objective is to maximize the present value of future profits:

$$E_t \sum_{\tau=0}^{\infty} \Lambda^A_{t,t+\tau} \left(Y_{it} - P^I_t I_{t-1} - w_t l \right) \tag{1}$$

where $i = H, F$ is a country-specific subscript, P^I_t is the price of investment goods, $\Lambda^A_{t,t+\tau}$ is shareholders' discount factor and l is a fixed amount of labour hours, under the assumption that all agents in the economy supply the same equilibrium quantity of labour. When $i = F$, price variables, P^I_t, w_t, agents' discount factor and investment expenditures, I_{t-1}, carry a star "*". Similar notation shall be adopted throughtout all the paper.

Production and capital accumulation in the two countries are as follows

$$\begin{array}{ll} Y_{Ht} = A_t \left(K_{Ht-1}\right)^{\alpha} 1^{1-\alpha} & ; Y_{Ft} = A^*_t \left(K_{Ft-1}\right)^{\alpha} 1^{1-\alpha} \\ K_{Ht} = (1-\delta) K_{Ht-1} + \Xi_t I_{t-1} & ; K_{Ft} = (1-\delta) K_{Ft-1} + \Xi^*_t I^*_{t-1} \end{array} \tag{2}$$

where A_t, A^*_t are productivity processes, K_{it} denotes the stock of capital available in country i, α is the capital share, l is normalized to 1, δ is the constant rate of depreciation and Ξ_t, Ξ^*_t are investment shocks. These shocks are introduced following Greenwood et al. (1997), Fisher (2006) and, for portfolio modeling, Coeudarcier et al. (2010)[6].

Since goods are differentiated across countries, behind capital accumulation there is an international allocation of investment expenditures. Using a standard CES aggregator featuring

[6]Note that here there is no need to specify the nature of the investment shocks. Specifically, Ξ_t, Ξ^*_t do not necessarily represent shocks to "investment-specific" technologies, as the most of the literature - included the papers I refer to - generally assumes. Justiniano et al. (2009) show that there is a distinction between the "marginal efficiency" effects of investment and its "investment-specific" component. But this debate is outside the scope of the present paper.

home bias, I_t, I_t^* are

$$\begin{aligned} I_t &\equiv \left[\gamma_I^{\frac{1}{\theta_I}} \left(I_{Ht}\right)^{\frac{\theta_I-1}{\theta_I}} + \left(1-\gamma_I\right)^{\frac{1}{\theta_I}} \left(I_{Ft}\right)^{\frac{\theta_I-1}{\theta_I}}\right]^{\frac{\theta_I}{\theta_I-1}} \quad ; P_t^I = \left[\gamma_I + \left(1-\gamma_I\right) p_{Ft}^{1-\theta_I}\right]^{\frac{1}{1-\theta_I}} \\ I_t^* &\equiv \left[\left(1-\gamma_I\right)^{\frac{1}{\theta_I}} \left(I_{Ht}^*\right)^{\frac{\theta_I-1}{\theta_I}} + \gamma_I^{\frac{1}{\theta_I}} \left(I_{Ft}^*\right)^{\frac{\theta_I-1}{\theta_I}}\right]^{\frac{\theta_I}{\theta_I-1}} \quad ; P_t^{*I} = \left[\left(1-\gamma_I\right) + \gamma_I p_{Ft}^{1-\theta_I}\right]^{\frac{1}{1-\theta_I}} \end{aligned} \tag{3}$$

where P_t^I and P_t^{*I} are the corresponding investment deflators, $\gamma_I > 0.5$ is the share of domestic goods in total expenditures, and θ_I is the elasticity of substitution between home and foreign goods. The assumption underlying the form of the investment deflators is that the home good is the numeraire and all the other prices are expressed in terms of it. In this sense, the relative price of the foreign good, p_{Ft}, plays the role of the terms of trade. The law of one price (LOP) holds for each individual good, but purchasing power parity (PPP) fails to be satisfied due to home bias.

Let us consider the home country. Given (2), discounted profits in (1) are maximized when

$$\frac{P_t^I}{\Xi_t} = E_t \Lambda_{t,t+1}^A \left[\alpha A_{t+1} \left(K_{Ht}\right)^{\alpha-1} + \left(1-\delta\right) \frac{P_{t+1}^I}{\Xi_{t+1}}\right]$$

In equilibrium, this condition is satisfied because shareholders choose their optimal portfolio taking the following dividend as given (see below):

$$d_{Ht} = \alpha \frac{Y_{Ht}}{K_{Ht-1}} - P_t^I \frac{I_{t-1}}{K_{Ht-1}} \tag{4}$$

The wage rate follows as a residual

$$w_t = \left(1-\alpha\right) Y_{Ht} \tag{5}$$

According to (4), investment is made out of retained earnings. On each date, this portion of retained earnings is optimally allocated between traded goods as follows:

$$I_{Ht} = \gamma_I \left(\frac{1}{P_t^I}\right)^{-\theta_I} I_t \quad ; I_{Ft} = \left(1-\gamma_I\right) \left(\frac{p_{Ft}}{P_t^I}\right)^{-\theta_I} I_t \tag{6}$$

The efficiency conditions for the foreign economy are analoguous to equations (4)-(6).

4.2 Menu of financial instruments

In addition to the two equities used to finance the productive sector of the two countries, there are two bonds used by agents for financial transactions between them. Specifically, the asset

structure consists of four instruments, as a bond and an equity claim are the basis of the financial transactions taking place in each country and both instruments are internationally traded.

Equities in each country are claims on the stock of capital demanded by local firms. The aggregate stock is defined as

$$K_{Ht} = n\chi^A_{Ht} \quad ; K_{Ft} = n\chi^A_{Ft} \tag{8}$$

where n is the total number of shareholders and $\chi^A_{Ht} = k^A_{Ht} + k^{*A}_{Ht}, \chi^A_{Ft} = k^A_{Ft} + k^{*A}_{Ft}$ is the *per-capita* total amount of traded shares. I interpret shareholding in a loose way involving not only pure portfolio flows, but also the loans that productive firms may receive from international investors. The superscript A in (8), which has already appeared in (1), refers to active investors: due to the assumed structure of financial intermediaries, active investors are the only household category that owns productive firms. However, even if passive investors do not have a direct role in economic activity, they finance active investors' portfolio allocations. This intra-agents funding link takes the form of bond-holdings, as passive investors purchase the debt securities issued by the other group of households. Bonds are expressed in units of the local consumption good, so there are an home good bond and a foreign good bond.

For convinience, I express all asset prices and payoffs in terms of the numeraire, the home good. So in terms of the home good, equities are marketed at prices q^e_{Ht} and q^e_{Ft}, and their dividend payments are, correspondingly, d_{Ht} and d_{Ft}. Then, by definition, the rates of return on home and foreign equities are

$$r_{Ht} = \frac{q^e_{Ht} + d_{Ht}}{q^e_{Ht-1}} \quad ; r_{Ft} = \frac{q^e_{Ft} + d_{Ft}}{q^e_{Ft-1}} \tag{9}$$

The gross rates of interest paid by active investors are similarly defined in terms of the home good. Bonds are short-term contracts, according to which one unit of the local good purchased at time t at the prevailing market prices, q^b_{Ht}, q^b_{Ft}, yields one unit of the same good at time $t+1$. Hence

$$R_{Ht} = \frac{1}{q^b_{Ht-1}} \quad ; R_{Ft} = \frac{p_{Ft}}{q^b_{Ft-1}} \tag{10}$$

According to this definition, the rate of interest prevailing in each country is riskless from the viewpoint of the residents of that country.

4.3 Households

Each economy is populated by two groups of households, the active investors and the passive investors. Both groups seek to maximize lifetime utility, which is simply a function of consump-

tion:

$$E_0 \sum_{t=0}^{\infty} \eta_t^h \frac{\left(c_t^h\right)^{1-\sigma}}{1-\sigma} \quad ; E_0 \sum_{t=0}^{\infty} \eta_t^{*h} \frac{\left(c_t^{*h}\right)^{1-\sigma}}{1-\sigma}$$

where the index $h = A, P$ individuates the household reference group, $1/\sigma$ is the intertemporal elasticity of substitution in consumption and η_t^h is an endogenous discount factor without internalization. As usual, the endogeneous discount factor removes the unit root typical of open economy models[7], and its evolution is governed only by the consumption of the average agent in the household reference group: $\eta_{t+1}^h = \zeta^h \left(1 + C_t^h\right)^{-\phi} \eta_t^h$, where ζ^h is just a preference parameter.

In spite of the common objective, the two groups have different economic roles. Only active investors finance production and investment, but for this to be possible they need financial support from passive investors. Hence, let passive investors be more patient consumers than active investors:

$$\frac{\eta_{t+1}^P}{\eta_t^P} > \frac{\eta_{t+1}^A}{\eta_t^A} \tag{11}$$

4.3.1 Homogeneous intratemporal preferences

The heterogeneity between groups of agents concerns their rate of time preference but not preference for varieties. In this respect, all agents are alike and consume a given bundle of goods similar to that in (3):

$$\begin{aligned} c_t^h &\equiv \left[\gamma^{\frac{1}{\theta}} \left(c_{Ht}^h\right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(c_{Ft}^h\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \quad ; P_t = \left[\gamma + (1-\gamma)\, p_{Ft}^{1-\theta}\right]^{\frac{1}{1-\theta}} \\ c_t^{*h} &\equiv \left[(1-\gamma)^{\frac{1}{\theta}} \left(c_{Ht}^{*h}\right)^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}} \left(c_{Ft}^{*h}\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \quad ; P_t^* = \left[(1-\gamma) + \gamma p_{Ft}^{1-\theta}\right]^{\frac{1}{1-\theta}} \end{aligned} \tag{12}$$

where $\gamma > 0.5$ is the share of domestic goods in total consumption expenditures featuring home bias, and θ is the elasticity of substitution between the two goods. Note that, although consumption and investment bundles are similar, γ, θ do not have to be necessarily equal to γ_I, θ_I. As a consequence, the consumer price indexes, P_t, P_t^*, might differ from the investment deflators.

Subject to (12), home households' optimal consumption demand functions are

$$c_{Ht}^h = \gamma \left(\frac{1}{P_t}\right)^{-\theta} c_t^h \quad ; c_{Ft}^h = (1-\gamma) \left(\frac{p_{Ft}}{P_t}\right)^{-\theta} c_t^h \tag{13}$$

A similar result is derived for foreign households as well.

[7] See Schmitt-Grohé and Uribe (2003).

4.3.2 Consumption smoothing: active investors

By assumption, active investors have some specific capabilities as direct international traders. They operate in all financial markets, in order to channel funds to profitable investments everywhere. In addition, I follow Kiyotaki and Moore (1997) closely and make a second assumption: I assume that active investors' ability to diversify savings across countries is inalienable (Hart and Moore, 1995). This means that no one could replace active investors in supporting the final goods sectors should they deny their role as international direct investors. It follows that they cannot precommit to pay back to their creditors, the group of passive investors. Concerned by this, lenders are willing to lend only in presence of some sort of guarantee on the future repayment. In absence of any *explicit* public guarantees, debt guarantees are supplied by the borrowers themselves, securing (short-term) loans with collateral.

The first assumption implies that active investors take positions in both bonds and equities across borders. So the budget constraint of the representative household in this group is

$$\begin{bmatrix} P_t c_t^A - q_{Ht}^b b_{Ht}^A - q_{Ft}^b b_{Ft}^A \\ +q_{Ht}^e k_{Ht}^A + q_{Ft}^e k_{Ft}^A \end{bmatrix} = \begin{bmatrix} w_t - b_{Ht-1}^A - p_{Ft} b_{Ft-1}^A \\ + \left(q_{Ht}^e + d_{Ht}\right) k_{Ht-1}^A + \left(q_{Ft}^e + d_{Ft}\right) k_{Ft-1}^A \end{bmatrix} \tag{14}$$

where b_{Ht}^A and b_{Ft}^A denote bond holdings and k_{Ht}^A and k_{Ft}^A are equity holdings. Foreign household's budget constraint is analoguous to (14). Following DY, I have attached opposite signs to bonds and equities as if investors distinguish between assets according to whether their position in these assets is long or short. I keep this distinction for convenience: it allows me refer to bonds as either liabilities or debt instruments, whenever the word "asset" can render their role obscure.

The second assumption introduces a second constraint, a collateral requirement with an ex-ante-like form[8]. As in DY, the collateral consists of the mark-to-market value of borrowers' equity holdings, given the specific debt-to-asset ratios κ_t, κ_t^* of home and foreign agents, respectively. Expanding the resulting collateral constraint just to allow for the possibility of diversified short positions, it turns out that active investors are also subject to the following constraint:

$$q_{Ht}^b b_{Ht}^A + q_{Ft}^b b_{Ft}^A \leq \kappa_t \left(q_{Ht}^e k_{Ht}^A + q_{Ft}^e k_{Ft}^A\right) \quad ; \; q_{Ht}^b b_{Ht}^{*A} + q_{Ft}^b b_{Ft}^{*A} \leq \kappa_t^* \left(q_{Ht}^e k_{Ht}^{*A} + q_{Ft}^e k_{Ft}^{*A}\right) \tag{15}$$

Due to assumption (11) on time preferences, the constraints in (15) will be binding for sure even in the steady state of the model, and borrowers will never accumulate so much as to invalidate their debt limits (Iacoviello, 2005).

The collateral constraints in (15) presents two new features. The first innovation is that the value of the collateral constrains borrowing regardless of the origin of the funds. Active investors

[8] See Mendoza and Smith (2006) and Mendoza (2010).

can diversify not only their assets but also their liabilities. Yet, their total borrowing (on the LHS) cannot be greater than a share of all their *gross* assets, which are given by the value of all their equity portfolio. The second innovation concerns the debt-to-asset ratios themselves: κ_t and κ_t^* are assumed to be both borrower-specific and time-varying.

Each of these two extensions has important implications. The first extension introduces an endogenous portfolio choice in line with the literature on international portfolios. Active investors can choose how much to borrow locally and how much to borrow in the foreign country. This diversification of debt translates into bond shares sold in the home and in the foreign country. Technically, these shares are pinned down by the structure of the model because the two bonds are linearly related under the same pledge[9].

The second extension amounts to an interpretation of κ_t and κ_t^* in terms of time-varying credit risk. Being borrower-specific, a debt-to.asset ratio measures the creditworthiness of the borrowers it refers to. Here, creditworthiness has a *restrictive* meaning: it is all the counterparty risk which remains after stripping out the riskiness of the assets pledged as collateral (commodity risk). Credit risk fluctuates through time in accordance with a standard risk management rule, which can be easily recovered from (15). Adding the total value of equity holdings on both sides of (15), I obtain the following value-at-risk (VaR) limits:

$$m_t \left(q_{Ht}^e k_{Ht}^A + q_{Ft}^e k_{Ft}^A\right) \leq W_t^A \quad ; m_t^* \left(q_{Ht}^e k_{Ht}^{*A} + q_{Ft}^e k_{Ft}^{*A}\right) \leq W_t^{*A} \tag{15'}$$

where W_t^A, W_t^{*A} are home and foreign agents' net financial wealth[10] and m_t, m_t^* are time-varying haircuts, whose definition is $m_t = 1 - \kappa_t$, for home borrowers, and $m_t^* = 1 - \kappa_t^*$, for foreign borrowers. This definition reminds of the very clear one stated by Gorton (2009, p. 31): "the haircut is the percentage difference between the market value of the pledged collateral and the amount of funds lent".

The time-variation in the margins is a consequence of the private guarantees. The only reason why active investors are charged a risk-free rate on each type of bond they issue (equations (10) and (14)) is that they secure the transaction pledging their net asset portfolio as in (15'). As

[9] Iacoviello and Minetti (2006) adopt an alternative approach, in which home and foreign borrowing depend on the share of collateral pledged to, respectively, home and foreign agents, under the assumption that the latter pay higher liquidation costs than the former.

[10] For example, given the buget constraint in (14), home country traders' net worth can be written as follows:

$$P_t c_t^A + W_t^A = w_t + W_{t-1}^A + \sum_{i=H}^{F} \left(q_{it}^e + d_{it} - q_{it-1}^e\right) k_{it-1}^A - \left(1 - q_{Ht-1}^b\right) b_{Ht-1}^A - \left(p_{Ft} - q_{Ft-1}^b\right) b_{Ft-1}^A$$

Gorton and Pennacchi (1990, 1995) suggest, active investors are international financial traders because of their ability to produce some new assets, the secured bonds. However, these assets may have some unpleasant properties if the seller uses them to discharge part of the risk it faces. Note that the implicit assumption in (15) is that the collateral is not constituted by *formely* owned assets but by the same equities international traders buy *today*. Put it differently, the flow of capital income feeding W_t^A, W_t^{*A} is exposed to productivity and investment shocks - and active investors' wage income follows the cycles of aggregate production. It follows that b_{Ht}, b_{Ft} can be sold as risk-free bonds in terms of the good produced in the corresponding market only if the private guarantee is made risk-sensitive. In this way, the haircuts can adjust in accordance with the changes in borrowers' creditworthiness, which is state-dependent. Formally, the model can capture a variation in m_t, m_t^* only through a variation in κ_t, κ_t^*, which determine the size of the pledge through the size of the loan granted by lenders. m_t, m_t^*, on one side, and κ_t, κ_t^*, on the other, are perfectly negatively correlated. As the latter increase, haircuts can correspondingly decrease, the reason being that financiers become less concerned about credit risk and reduce their request for guarantees against unexpected losses. This type of mechanism is implicit in (15') and restricts the possibility of unexpected shocks to future financial wealth. Adapting the margin setting behaviour formalized by Brunnermeier and Pedersen (2009) to equation (15'), I obtain the following condition:

$$\varsigma \approx \Pr\left(-E_t \Delta V_{kt+1}^A > m_t\right) = \Pr\left(-E_t \Delta V_{kt+1}^{*A} > m_t^*\right) \tag{16}$$

where ς is a given confidence level and $V_{kt+1}^A, V_{kt+1}^{*A}$ denote the unitary market value of active investors' equity portfolio (capital holdings). Once financiers have accounted for this risk properly, the probability that borrowers suffer from an unpredicted negative valuation effect on their overall equity portfolio must be very small: equal to ς. The negative sign is used to characterize the unfavourable state of the world.

Note, however, that there is a slight contrast between this result and what is usually done in practice. While usually the constraint on borrowers' net worth arises from all their long and short financial positions, in (15')-(16) these positions are somewhat aggregated in a unique measure. More precisely, there is no specific margin on either home shares or foreign shares but an overall haircut m_t or m_t^*. It follows that m_t and m_t^* are set on a *purely relational basis*, which means that haircuts represent agent-specific characteristics, depending on the country of origin. In contrast, the riskiness of collateral does not show up explicitly.

Although this is a quite strong feature of this model, there are two reasons for maintaining it. The first is that the prevailing approach in macroeconomics is to consider just one collateral instrument, most likely assuming that this is a synthetic measure for the entire collateral pledged.

This is the same approach chosen by DY, who clearly could not use a synthetic collateral asset in a portfolio paper where collateral comes from internationally diversified assets. From this viewpoint, I follow them and apply the same logic. Second, it is rightly this approach that gives the possibility to focus on creditworthiness alone, as I can easily isolate its determinants and effects[11].

As far as the determinants of credit risk are concerned, the risk-profile of borrowers reflect their portfolio choice: keeping everything else equal, one would expect that borrowers with more diversified portfolios are also less exposed to a given idiosyncratic shock. The guarantees on private debt on the intra-agents market embed this angle of financial integration in the following way:

$$\kappa_t = \frac{q_{Ht}k^A_{Ht}}{q_{Ht}k^A_{Ht}+q_{Ft}k^A_{Ft}}\kappa_{Ht} + \frac{q_{Ft}k^A_{Ft}}{q_{Ht}k^A_{Ht}+q_{Ft}k^A_{Ft}}\kappa_{Ft} \quad ; \kappa^*_t = \frac{q_{Ht}k^{*A}_{Ht}}{q_{Ht}k^{*A}_{Ht}+q_{Ft}k^{*A}_{Ft}}\kappa_{Ht} + \frac{q_{Ft}k^{*A}_{Ft}}{q_{Ht}k^{*A}_{Ht}+q_{Ft}k^{*A}_{Ft}}\kappa_{Ft} \tag{17}$$

where κ_{Ht}, κ_{Ft} measure the size of the loans granted against each unit of home and foreign equities, respectively. The weights in (17) are, first, the portfolio share of home country equities and, second, the share of foreign country equity. Other real-world determinants which do not fit the definition of borrower's creditworthiness used in the present model, so I shall neglect them.

As usual, the optimality conditions for active investors' choice of bond and equity holdings are obtained maximizing their objective function under the constraints in (14) and (15):

$$\begin{aligned}
\lambda^A_t &= \frac{\left(c^A_t\right)^{-\sigma}}{P_t} \\
\left(\lambda^A_t - \mu_t\right) q^b_{Ht} &= \zeta^A \left(1+c^A_t\right)^{-\phi} E_t \lambda^A_{t+1} && (18)\\
\left(\lambda^A_t - \mu_t\right) q^b_{Ft} &= \zeta^A \left(1+c^A_t\right)^{-\phi} E_t \lambda^A_{t+1} p_{Ft+1} && (19)\\
\left(\lambda^A_t - \mu_t\kappa_t\right) q^e_{Ht} &= \zeta^A \left(1+c^A_t\right)^{-\phi} E_t \lambda^A_{t+1} \left(q^e_{Ht+1} + d_{Ht+1}\right) && (20)\\
\left(\lambda^A_t - \mu_t\kappa_t\right) q^e_{Ft} &= \zeta^A \left(1+c^A_t\right)^{-\phi} E_t \lambda^A_{t+1} \left(q^e_{Ft+1} + d_{Ft+1}\right) && (21)
\end{aligned}$$

where μ_t is the lagrange multiplier attached to the collateral constraint. The consumption Euler equations of the foreign active investor are alike.

4.3.3 Consumption smoothing: passive investors

Passive investors are not leveraged and actually supply accumulated savings to active investors. In my interpretation, "passive" means that these investors do not take direct positions in productive firms, yet they do it funding active investors' portfolio strategies. In this sense, it is the

[11] For an alternative approach, see Trani (2011).

functioning of the intra-investors market that generates the necessary resources needed for production and investment by final good firms. To accomodate this interpretation in the framework developed by DY, I allow passive investors in any country to buy the bonds issued by both local and foreign international traders. For the rest, I follow DY in assuming that, in terms of the aggregate economy, passive investors conduct some residual activity.

I model passive investors' cross-border loans in a very simple way, which is however consistent with margin constraints, in general, and with the state-dependency of margins assumed above, in particular. I assume that passive investors fund both local and foreign traders, but they lend *only* in terms of the domestic good. In other words, lenders aim is to remain safe at each point in time, so they lend at the local interest rate given by (10) and adjust the haircuts in line with borrowers' credit risk, as in (16).

The implication is that there are two separate bond markets for active investors' liabilities: an home market and a foreign market. However, the two markets are financially integrated because active investors meet on international markets to transact not only equities, but also secured bonds. In this sense, the portfolio choice problem is limited to one group of agents, and it is this group of agents that decide whether to borrow at home or abroad. Financiers in each market are passive with respect to the portfolio choice, and the security that they receive as a result of this allocation is just equal to total borrowing denominated in terms of the domestic group:

$$B_{Ht}^{P} \equiv b_{Ht}^{P} + b_{Ht}^{*P} \quad ; B_{Ft}^{P} \equiv b_{Ft}^{P} + b_{Ft}^{*P}$$

where the star indicate that the claim is owned against foreign active investors.

The residual activity of passive investors is to produce output in the backyard sector, absorbing a small portion of the total stock of capital available in the economy. The production function in this case is $z\left(k_{Ht-1}^{P}\right)^{\nu}$, in the home economy, and $z\left(k_{Ft-1}^{*P}\right)^{\nu}$, in the foreign economy. These technologies are characterized by fixed productivity z and decreasing returns to scale, $\nu < 1$. Passive investors are the unique owners of the stock of capital used in the backyard sector, which does not contribute to production and investment in the final good sector. Finally, the backyard sector is a rather peculiar non-traded good sector: its output is completely consumed inside the sector. That is, final and backyard good are perfect substitute in passive investors' consumption.

Summing up, passive investors' budget constraints are

$$P_t c_t^{P} + q_{Ht}^{e}\left(k_{Ht}^{P} - k_{Ht-1}^{P}\right) - q_{Ht}^{b} B_{Ht}^{P} = w_t + z\left(k_{Ht-1}^{P}\right)^{\nu} - B_{Ht-1}^{P} \tag{22}$$

$$P_t^{*} c_t^{*P} + q_{Ft}^{e}\left(k_{Ft}^{*P} - k_{Ft-1}^{*P}\right) - q_{Ft}^{b} B_{Ft}^{P} = w_t^{*} + p_{Ft} z\left(k_{Ft-1}^{*P}\right)^{\nu} - p_{Ft} B_{Ft-1}^{P} \tag{23}$$

Home agents maximize under (22), so that their bond and equity holdings must satisfy, respectively, the following conditions:

$$\begin{aligned}
\lambda_t^P &= \frac{\left(c_t^P\right)^{-\sigma}}{P_t} \\
\lambda_t^P q_{Ht}^b &= \zeta^P \left(1+c_t^P\right)^{-\phi} E_t \lambda_{t+1}^P \qquad (24) \\
\lambda_t^P q_{Ht}^e &= \zeta^P \left(1+c_t^P\right)^{-\phi} E_t \lambda_{t+1}^P \left[q_{Ht+1}^e + \nu z \left(k_{Ht}^P\right)^{\nu-1}\right] \qquad (25)
\end{aligned}$$

Foreign passive investors' consumption Euler equations are analogous.

4.3.4 Funding, risk premia and margins

The first order conditions (18)-(21) express active investors' supply of bonds and demand for equities. The first order conditions (24)-(25) express passive investors' demand for bonds and for (residual) capital. The optimality conditions of foreign agents have analogous implications. Taken together, all these equations determine the equilibrium asset prices. Since active investors borrow at a margin, equilibrium prices embed two characteristic types of risk premia.

The first characteristic premium is the cost of the debt guarantee, the *guarantee premium* (GP). Since the purpose of intra-investors loans is to provide short-term, cheap funds to international traders, the fundamental price of bonds is determined by passive investors' Euler equations - specifically, (24) and its foreign counterpart:

$$E_t R_{Ht+1} = \frac{1}{E_t \Lambda_{t,t+1}^P} \quad ; E_t R_{Ft+1} = \frac{1}{E_t \Lambda_{t,t+1}^{*P}} - \frac{cov_t\left(\Lambda_{t,t+1}^{*P}, p_{Ft+1}\right)/q_{Ft}^b}{E_t \Lambda_{t,t+1}^{*P}}$$

where $\Lambda_{t,t+1}^h = \zeta^h \left(1+c_t^h\right)^{-\phi} \lambda_{t+1}^h / \lambda_t^h$, for $h = A, P$. On the other hand, active investors use these riskless liabilities to invest in risky assets. To bridge this mismatch, they pledge collateral, whose cost affect the (unit) cost of borrowing. From (18)-(19), I obtain

$$\begin{aligned}
\frac{E_t\left(\Lambda_{t,t+1}^P - \Lambda_{t,t+1}^A\right)}{E_t \Lambda_{t,t+1}^A E_t \Lambda_{t,t+1}^P} &= \frac{\mu_t/\lambda_t^A}{E_t \Lambda_{t,t+1}^A} \\
\frac{E_t\left(\Lambda_{t,t+1}^{*P} - \Lambda_{t,t+1}^A\right)}{E_t \Lambda_{t,t+1}^A E_t \Lambda_{t,t+1}^{*P}} &= \frac{\mu_t/\lambda_t^A}{E_t \Lambda_{t,t+1}^A} + \frac{cov_t\left(\Lambda_{t,t+1}^A, p_{Ft+1}\right)/q_{Ft}^b}{E_t \Lambda_{t,t+1}^A} - \frac{cov_t\left(\Lambda_{t,t+1}^{*P}, p_{Ft+1}\right)/q_{Ft}^b}{E_t \Lambda_{t,t+1}^{*P}}
\end{aligned} \qquad (26)$$

where the GP is given by $\mu_t/\zeta^A \left(1+c_t^A\right)^{-\phi} E_t \lambda_{t+1}^A$. This term has been called in various ways[12]; I use the new label GP for it seems to fit well the economic context I refer to. The GP is a sort of insurance premium that international traders must pay on each unit of borrowed good, so what they eventually receive from lenders is less than one unit of a loan. Being a ratio between two lagrange multipliers, the GP implies that active investors who issue secured debt internalize the

[12] For alternative definitions, see Aiyagari and Gertler (1999) and Mendoza (2010).

shadow cost of the guarantee in terms of consumption. Clearly, when borrowing from foreign lenders, home investors take into account the exhange rate risk, given by the comovements between the pricing kernel and the terms of trade (second and third terms in the bottom equation in (26)).

The second premium does not characterize intra-investors transactions but the use of the resources generated by these transactions to finance final good firms. This risk premium is the *equity* premium (EP). Combining (20)-(21) with (18)-(19) and writing in compact form, I obtain the following EP:

$$E_t\left(r_{it+1} - R_{jt+1}\right) = \frac{\mu_t m_t/\zeta^A \left(1 + c_t^A\right)^{-\phi} - cov_t\left(\lambda_{t+1}^A, r_{it+1} - R_{jt+1}\right)}{E_t \lambda_{t+1}^A} \tag{27}$$

with $i, j = H, F$. When $i = j$, equities issued in one country pay a premium over secured liabilities sold in the same country; otherwise, the premium links borrowing in one country to investment in another country. Given (27), the EP is split into two components (Mendoza and Smith, 2006). In line with the definition of the funding premium as GP, the first component is the "insurance" part of the EP. This is the extra-yield generated by collateralized funds and is denoted by $\mu_t m_t/\zeta^A \left(1 + c_t^A\right)^{-\phi}$: the marginal value of an additional unit of borrowing, μ_t, is limited by the size of the haircut. The novelty here is that, given (16), m_t is state-dependent, introducing considerations on the perception of active investors' creditworthiness. The second component is the traditional comovement between pricing kernel and the return differential between yields on assets and rates on liabilities.

The two types of risk premia defined in (26)-(27) can be analogously derived from foreign active investors' efficiency conditions, considering that in the latter case case the movements in the terms of trade have an opposite effect to the one above. More important is to note that the risk-sensitivity of the haircut does have not only a quantity effect (the tightness of (15) and (15')), but also a price effect through the insurance component of the equity premium. As (27) shows, the pricing effect is directly consequential to the quantity effect: the insurance component of the EP gets smaller, the tighter the collateral constraint. Yet, (16) implies that the tightness of the constraint is not due to the quantity of assets but to their market valuation. The underlying mechanism is in fact the margin setting rule followed by financiers.

My approach to model margin setting is the following. I do not attempt to derive optimal margins, but I consider them as implied by the VaR constraint (15'). This is the same perspective used to write down (16), but this equation cannot work as a margin setting rule. Without knowing active investors' portfolio shares, it is not possible to unambigously determine κ_t, κ_t^*. In fact, the precise argument made by Brunnermeier and Pedersen (2009) is that haircuts are computed

by financiers on individual positions. I simplify their argument, which accounts for the role of financiers' information about shocks and fundamentals. In fact, Brunnermeier and Pedersen show that, conditional on their information set and on the chosen quantile of the distribution of future payoffs, financiers set the margin in such a way that it can reflect either the fundamental volatility or the volatility of observed prices. Since the implications of such a result are outside the scope of the current model, I simply assume that m_{it}, with $i = H, F$, must satisfy the following condition:

$$\varsigma = \Pr\left(-\Delta q^e_{it+1} > m_{it}\right) \tag{28}$$

Here, passive investors' information does not have any role, although at the end I shall allow for an exogenous shock in the determination of the haircuts.

In general, rules like this one can be solved standardizing the random variable m_{it} and inverting the relevant distribution function. With a general equilibrium perspective, here this distribution results from the combination between the exogenous states and the structure of the economy. Moreover, since (28) is forward-looking but not optimally derived, it cannot be imposed straightaway without problems in the eigenvalue-eigenvector decomposition needed to find the reduced form of the model. To take these two considerations into account, I exploit the inverse relation between m_{it} and κ_{it} and incorporate (28) in my model using a close substitute:

$$\kappa_{it} = f\left(\frac{q^e_{it}}{q^e_{it-1}}\right) \text{ with } f'(\cdot) > 0 \tag{28'}$$

The functional relation $f(\cdot)$ depends on un-modelled aspects like, for instance, the relevant quantile of the distribution of prices. An interpretation for (28') is as follows: if the market value of asset i grows over time, borrowers can obtain more debt against each unit of i. Its haircut turns out to be correspondingly lower.

Expectations play a role in (28') because time t equilibrium price q^e_{it} must satisfy agents' Euler equations. From this viewpoint, the heterogeneity between the borrowers and lenders means that the margin setting rule must account for distorted (equity) prices as well as for the different pricing kernels between household-types. Taking a simple weighted average of (20) and (25), where the weights reflect the size of each group of agents, I get

$$q^e_{Ht} = \left[n\underline{\Lambda}^A_{t,t+1} + (1-n)\,E_t\Lambda^P_{t,t+1}\right] q^e_{Ht+1} + n\underline{\Lambda}^A_{t,t+1} d_{Ht+1} + (1-n)\,E_t\Lambda^P_{t,t+1}\nu z\left(k^P_{Ht}\right)^{\nu-1} \tag{29}$$

with

$$\underline{\Lambda}^A_{t,t+1} = \frac{\zeta^A\left(1+c^A_t\right)^{-\phi} E_t\lambda^A_{t+1}}{\lambda^A_t - \mu_t\kappa_t} < \Lambda^A_{t,t+1}$$

The equilibrium price is biased downward (Aiyagari and Gertler, 1999) because active investors' discount factor internalizes the shadow cost of secured debt, $\underline{\Lambda}^A_{t,t+1}$, and because the backyard sector is less productive than the final good sector, $\nu < 1$. More importantly, (29) shows that the equilibrium asset price must be coherent with the expectations (the horizon) of each group of agents as well as with the dicounted return from future economic activity in both productive sectors. Conceptually, this result resembles the one obtained by Geanakoplos (2009), although (29) is in no way comparable with his extensive analysis on the determination of haircuts in general equilibrium. According to him, secured borrowing can be characterized ex ante as an indexed stream of contracts, as in an Arrow-Debreu setup. However, in equilibrium only one contract is observable, the one aligning the views of borrowers and lenders, who have heterogeneous preferences (optimistic versus pessimistic beliefs) regarding the traded assets. One of the main elements of his analysis that are missing here is the fact that I assume that active and passive investors are both equal to a given fraction of total population, while the distinction between natural buyers and sellers is endogenous in his case.

Finally, (28') can be plugged back into (17) in order to derive a simple but endogenous rule for κ_t, κ^*_t. Considering the home country, I have

$$\kappa_t = \frac{q_{Ht}k^A_{Ht}}{q_{Ht}k^A_{Ht} + q_{Ft}k^A_{Ft}} f\left(\frac{q^e_{Ht}}{q^e_{Ht-1}}\right) + \frac{q_{Ft}k^A_{Ft}}{q_{Ht}k^A_{Ht} + q_{Ft}k^A_{Ft}} f\left(\frac{q^e_{Ft}}{q^e_{Ft-1}}\right)$$

and a similar relation can be written for the foreign country. In order to reconcile this result with the portfolio choice problem, I take an empirical approach, as the model is a candidate framework to estimate haircuts in a structural manner, under the solution for endogenous portfolios. Hence, invoking symmetry, I approximate the last equation and its foreign counterpart with a simple linear specification:

$$\kappa_t = \psi \frac{q^e_{Ht}}{q^e_{Ht-1}} + \psi^* \frac{q^e_{Ft}}{q^e_{Ft-1}} + \frac{\bar{m}}{\bar{\kappa}}\epsilon_{\kappa t} \quad ; \kappa^*_t = \psi^* \frac{q^e_{Ht}}{q^e_{Ht-1}} + \psi \frac{q^e_{Ft}}{q^e_{Ft-1}} + \frac{\bar{m}}{\bar{\kappa}}\epsilon_{\kappa^* t} \tag{30}$$

where $\epsilon_{\kappa t}, \epsilon_{\kappa^* t}$ are exogenous innovations. These innovations can be alternatively interpreted as pure shocks or as approximation errors, and $\bar{m}/\bar{\kappa}$ is a scaling factor. ψ, ψ^* reflect the symmetry between the two economies and are affected by the cross-border ownership of productive capital. The effect of symmetry cannot be easily removed, as it has been initially imposed by construction. The effect of diversified equity portfolios can instead be purged out as soon as optimal portfolios are recovered from the model solution.

As a final remark, the scaling factor $\bar{m}/\bar{\kappa}$ represents the inverse of active investors' debt-to-capital ratio in the steady state. Technically, this scaling is needed to transform a given shock to κ_t or κ^*_t into a unit impulse in the corresponding haircut (m_t or m^*_t). Haircuts are the

variables of interest as it is the ultimate adjustment in haircuts that satisfies (15'). It is thus important that a unit impulse in κ_t or κ_t^* leads to a unit impulse in haircuts, rendering a shock to haircuts comparable to all the other (more standard) shocks. Intuitively, this technical point can be explained as follows. The debt-to-asset ratio κ_t (κ_t^*) arises from stock variables expressed in *gross* terms, but the VaR restricts agents' capital, that is, their *net* financial assets. Due to the practice of borrowing against the same equities for which the loan is demanded (equations (15)), collateralization drives an important wedge between gross and net figures. This wedge is leverage (Adrian and Shin, 2008), which is captured by $\bar{m}/\bar{\kappa}$. In any case, this scaling factor will not affect the analysis until the very last section of the paper (section 8), where I shall come back to it.

4.4 Competitive equilibrium

For $t = 0, ..., \infty$, the competitive equilibrium consists of a vector of allocations ($c_{H,t}^A$, $c_{F,t}^A$, $c_{H,t}^{*A}$, $c_{F,t}^{*A}$, $c_{H,t}^P$, $c_{F,t}^P$, $c_{H,t}^{*P}$, $c_{F,t}^P$, I_{Ht}, I_{Ft}, I_{Ht}^*, I_{Ft}^*, b_{Ht}^A, b_{Ht}^{*A}, b_{Ft}^A, b_{Ft}^{*A}, B_{Ht}^P, B_{Ft}^P, k_{Ht}^A,k_{Ht}^{*A}, k_{Ht}^P, k_{Ft}^A, k_{Ft}^{*A}, k_{Ft}^P) and of a vector of prices (P_t, P_t^*, P_t^I, P_t^{I*}, p_{Ft}, q_{Ht}^e, q_{Ft}^e, q_{Ht}^b, q_{Ft}^b, w_t^A, w_t^P, w_t^{*A}, w_t^{*P}, d_{Ht}, d_{Ft}) such that: a) firms in both countries maximize profits; b) active investors in both countries maximize lifetime utility subject to their budget and collateral constraints; c) passive investors in both countries maximize lifetime utility subject to their budget constraints; d) the clearing conditions on the markets for goods, bonds and equities are satisfied. In this order, the market clearing conditions are:

$$n\left(c_{Ht}^A + c_{Ht}^{*A}\right) + I_{Ht} + I_{Ht}^* + (1-n)\left(c_{Ht}^P + c_{Ht}^{*P}\right) = Y_{Ht} + (1-n)\, z\left(k_{Ht-1}^P\right)^\nu \quad (31)$$

$$n\left(c_{Ft}^A + c_{Ft}^{*A}\right) + I_{Ft} + I_{Ft}^* + (1-n)\left(c_{Ft}^P + c_{Ft}^{*P}\right) = p_{Ft}\left[Y_{Ft} + (1-n)\, z\left(k_{Ft-1}^{*P}\right)^\nu\right] \quad (32)$$

$$n\left(b_{Ht}^A + b_{Ht}^{*A}\right) + (1-n)\, B_{Ht}^P = 0 \quad ; n\left(b_{Ft}^A + b_{Ft}^{*A}\right) + (1-n)\, B_{Ft}^P = 0 \quad (33)$$

$$n\chi_{Ht}^A + (1-n)\, k_{Ht}^P = 1 \quad ; n\chi_{Ft}^A + (1-n)\, k_{Ft}^P = 1 \quad (34)$$

5 Portfolio choice: the case of secured liabilities

In the model, the solution for international portfolios depends on the endogenous choice of active investors. Passive investors invest only in domestic capital and issue loans expressed in terms of the local good. In this way, the terms of trade risk is entirely borne by borrowers, who are as well concerned about the variation in their credit risk because margins are adjusted accordingly. Active investors' cross border holdings involve both equities and secured bonds.

However, since collateral constraints generate risk premia such as those defined in (26) and (27), setting up the asset allocation problem on the basis of the usual arbitrage conditions presents some difficulties. The usual approach to constructing portfolio Euler equations is to take one asset as the reference and to compare it with all the other assets. In this model, there are four financial instruments: two standard assets (equities) and two constrained assets (secured bonds). Considering the foreign equity as the reference asset, the standard approach suggests to combine (18)-(20) with (21) so as to obtain the three portfolio Euler equations that follow:

$$\zeta^A \left(1 + c_t^A\right)^{-\phi} E_t \lambda_{t+1}^A \left(R_{Ht+1} - r_{Ft+1}\right) + \mu_t m_t = 0 \quad (35)$$

$$\zeta^A \left(1 + c_t^A\right)^{-\phi} E_t \lambda_{t+1}^A \left(R_{Ft+1} - r_{Ft+1}\right) + \mu_t m_t = 0 \quad (36)$$

$$E_t \lambda_{t+1}^A \left(r_{Ht+1} - r_{Ft+1}\right) = 0 \quad (37)$$

Apart from (37), the first two portfolio selection conditions are more complex than those allowed by the existing portfolio solution methods. These techniques solve for the endogenous portfolio shares evaluating the return differential, which is discounted at agents' pricing kernel. Hence, the complexity of (35)-(36) does not have to do with the return differentials $\left(R_{Ht+1} - r_{Ft+1}\right), \left(R_{Ft+1} - r_{Ft+1}\right)$ but with the second terms, the insurance component of the EP. This is the way in which the private guarantee affects the choice between assets belonging to different classes.

In principle, this drawback of binding collateral constraints should also affect the comparison between assets of the same class, the equities. However, in (37) there is no other term than the excess return between home and foreign equities. According to DY, the explanation for this is that each active investor internalizes the collateral constraint symmetrically across home and foreign equities[13]. But in light of the analysis on counterparty risk carried out in the previous section, the symmetric collateralization is itself an outcome, whose source is subtly hidden. The following claim makes this point clear.

Claim. Assume that intra-agent loans are uniquely influenced by leveraged investors' creditworthiness (in its strict sense). It follows then that leveraged investors cannot benefit at all from considering the shadow value of borrowing against different collaterals as a part of the arbitrage condition between home and foreign assets.

Reasoning by absurd, I make even a further step, in order to show what dynamics one would obtain for the net foreign assets by applying the existing portfolio solution faithfully. To this end,

[13] See equations (20)-(21).

I neglect the fact that (35)-(36) are difficult to evaluate and aim at computing three portfolio shares. Following Devereux and Sutherland (2011), this can be done defining active investors' net foreign assets as $NFA_t^A = q_{Ft}^e k_{Ft} - q_{Ft}^b b_{Ft}^A - q_{Ht}^e \left(\chi_{Ht}^A - k_{Ht}^A\right) + q_{Ht}^b \left(B_{Ht}^A - b_{Ht}^A\right)$ and rewriting their budget constraint (14), in order to recover the effect of the three shares:

$$P_t c_t^A + NFA_t^A = \begin{bmatrix} w_t - q_{Ht}^e \left(\chi_{Ht}^A - \chi_{Ht-1}^A\right) + d_{Ht}\chi_{Ht-1}^A \\ +q_{Ht}^b B_{Ht}^A - B_{Ht-1}^A - \left(R_{Ht} - r_{Ft}\right)\omega_{Ht-1}^b \\ -\left(R_{Ft} - r_{Ft}\right)\omega_{Ft-1}^b + \left(r_{Ht} - r_{Ft}\right)\omega_{t-1}^e + r_{Ft} NFA_{t-1}^A \end{bmatrix} \tag{14'}$$

where

$$\omega_{Ht-1}^b = q_{Ht-1}^b \left(b_{Ht-1}^A - B_{Ht-1}^A\right) \quad ; \omega_{Ft-1}^b = q_{Ft-1}^b b_{Ft-1}^A \quad ; \omega_{t-1}^e = q_{Ht-1}^e \left(k_{Ht-1}^A - \chi_{Ht-1}^A\right) \tag{38}$$

are the portfolio shares of home good bonds, foreign good bonds and home equities, respectively.

Postponing an interpretation of the transformed budget constraint and the related portfolio shares, I now pass to show one possible approach to circumvent the problems posed by (35) and (36), as a straightfoward application of the conventional approach is not strictly needed to obtain the equilibrium portfolios. Due to the properties of secured bonds in the model, the system of portfolio Eulers (35)-(37) contain one redundant equation and the dynamics of active investors' NFA can be adapted accordingly.

Remark 1. The collateral constraint is a strong tie not only for asset and liability sides of balance sheets, but also for the liabilities among themselves: ω_{Ht-1}^b and ω_{Ft-1}^b in (38) are interdependent.

In general, given (15), the overall per-capita value of local borrowing is at most equal to the total size of the collateral. Portfolio choice solves then for the optimal level of cross-country diversification. Concerning the zero-order component of portfolios, appendix (A) shows that this procedure allows me to write (15) as

$$\bar{q}^b \bar{B}^A = \bar{\kappa} \bar{q}^e \bar{\chi}^A$$

where the RHS is the market value of the pledge. Due to the symmetry between the two countries, this constraint can be equivalently written as

$$\bar{\kappa} \bar{q}^e \bar{\chi}^A = \bar{q}^b \left(\bar{b}_H^A + \bar{b}_F^A\right)$$

which implies that bond shares are closely linked in the long-run equilibrium:

$$\bar{\omega}_F^b = -\bar{\omega}_H^b \equiv \bar{q}^b \bar{b}_H^{*A}$$

Remark 2. The transmission of shocks is not entirely governed by the active agents' NFA because not all assets are collateralizable.

A major point made by DY is that the NFA dynamics create a transmission channel for countrywide shocks because the balances of payments - which affect the tightness of collateral constraints - are intertwined across countries. In fact, introducing trade in secured bonds this remains true just for a part of international payment transactions, and the NFA can be technically separated in two predetermined states. Plugging the above definition of NFA in (15), I get

$$m_t \left(q^b_{Ht} b^A_{Ht} + q^b_{Ft} b^A_{Ft}\right) - \kappa_t q^b_{Ht} B^A_{Ht} \leq \kappa_t \left(NFA^A_t + q^e_{Ht} \chi^A_{Ht}\right) \tag{39}$$

which is formally correct but intrinsically flawed because of double-counting. In the model, there is no margin on short positions, but in (39) home secured bonds carry the same margin m_t that is required on active investors' long positions. But this is just a first impression, as the effect of the haircut on the LHS of (39) can be compensated with its effect on bonds on the RHS, for bonds are by definition included in active investors' NFA. So netting out the two effects, the collateral constraints show clearly that only equities can be pledged as collateral:

$$NFB^A_t + q^b_{Ht} B^A_{Ht} \leq \kappa_t \left(NFE^A_t + q^e_{Ht} \chi^A_{Ht}\right) \quad ; -NFB^A_t + q^b_{Ft} B^A_{Ft} \leq \kappa^*_t \left(-NFE^A_t + q^e_{Ft} \chi^A_{Ft}\right) \tag{15"}$$

where $NFE^A_t = q^e_{Ft} k^A_{Ft} - q^e_{Ht}\left(\chi^A_{Ht} - k^A_{Ht}\right)$ is the net foreign long (i.e., equity) position and $NFB^A_t = q^b_{Ft} b^A_{Ft} - q^b_{Ht}\left(B^A_{Ht} - b^A_{Ht}\right)$ is the net foreign short (i.e., bond) position. NFE^A_t and NFB^A_t are the new state variables describing the dynamics of international traders' balance-sheet, with $NFA^A_t = NFE^A_t - NFB^A_t$. Of course, the global equilibrium in international payments must be satisfied for both the newly defined states: $NFB^A_t + NFB^{*A}_t = 0$ and $NFE^A_t + NFE^{*A}_t = 0$.

The implication of the previous two remarks is that one of the two portfolio shares is redundant. Let $\bar{\omega}^b_H = \bar{\omega}^b$, with $\omega^b_{t-1} = q^b_{Ht-1}\left(b^A_{Ht-1} - B^A_{Ht-1}\right)$, while ω^e_{t-1} is still defined as in (38). Using ω^b_{t-1}, equation (14') can be rewritten in an equivalent way:

$$P_t c^A_t + NFE^A_t - NFB^A_t = \begin{bmatrix} w_t - q^e_{Ht}\left(\chi^A_{Ht} - \chi^A_{Ht-1}\right) + d_{Ht}\chi^A_{Ht-1} \\ +q^b_{Ht} B^A_{Ht} - B^A_{Ht-1} + r_{xt}\omega^e_{t-1} \\ -R_{xt}\omega^b_{t-1} + r_{Ft} NFE^A_{t-1} - R_F NFB^A_{t-1} \end{bmatrix} \tag{14"}$$

As in (14'), ω^e_{t-1} depends on the excess returns between equities, $r_{xt} = r_{Ht} - r_{Ft}$, but ω^b_{t-1} is now related only to a version of the uncovered interest parity condition (UIP), $R_{xt} = R_{Ht} - R_{Ft}$. As in Devereux and Yetman (2010), obtaining $\omega^j_{t-1} < 0$ means that home active investors hold

less than 100 percent of the domestic per-capita stock of instrument j, with $j = e, b$. Clearly, home investors holdings' of foreign equities and bonds are, respectively, equal to $NFE^A - \omega^e$ and $NFB^A - \omega^b$.

A simple interpretation for (14") is as follows. The dynamics of NFA depend on capital and non-capital income, net of consumption expenditures. Capital income has various components. One is equal to the interest payments on the inherited stock of foreign equity, net of the interests paid on foreign liabilities. Capital income is increasing in dividend payments, $d_{Ht}\chi^A_{Ht-1}$, and in the excess returns of home versus foreign equities, $r_{xt}\omega^e_{t-1}$, while the same income decreases with interest payments, B^A_{Ht-1}, and with the excess cost of home versus foreign funds, $R_{xt}\omega^b_{t-1}$. To this net payoff of foreign assets, active investors add the resources received selling new bonds, $q^b_{Ht}B^A_{Ht}$, and subtract the cost of increasing the economy-wide capital stock, $q^e_{Ht}\left(\chi^A_{Ht} - \chi^A_{Ht-1}\right)$.

The ultimate version of active investors' budget constraint in (14") supports two arbitrage conditions in two different reference assets, the foreign bond and the foreign equity. So the three portfolio Eulers in (35)-(37) can be simplified, combining the first two. In compact form, the resulting portfolio Eulers are

$$E_t\left(c^A_{t+1}\right)^{-\sigma}\frac{1}{\pi_{t+1}}\begin{bmatrix} r_{xt+1} \\ R_{xt+1} \end{bmatrix} = \underset{2\times 1}{0} \tag{40}$$

where $\pi_t = P_t/P_{t-1}$. The solution for the zero order component of international portfolios then satisfies the second-order approximation of the following condition:

$$\left[E_t\left(c^A_{t+1}\right)^{-\sigma}\frac{1}{\pi_{t+1}} - E_t\left(c^{*A}_{t+1}\right)^{-\sigma}\frac{1}{\pi^*_{t+1}}\right]\begin{bmatrix} r_{xt+1} \\ R_{xt+1} \end{bmatrix} = 0 \tag{41}$$

The simplification of the portfolio problem achieved in this section supports the following conclusion. When agents seek to diversify their international positions in assets that are subject to some constraints (here, the size of the pledge), they act as if these constrained assets were detached from the other instruments in the portfolio. Hence, the constrained assets are compared only between themselves, and the NFA position can be distinguished in the component made of constrained assets and the component containing all other financial instruments (here, only equities). In this sense, the collateral constraint replaces the arbitrage condition between the constrained and the unconstrained assets.

6 Calibration

I devote a distinct section to the calibration of the model because here I also describe my structural approach to estimate the margin setting rules in (30) using aggregate data. I calibrate all the model parameters with conventional methods, with the only exception of the haircut. In this case, I combine standard strategies with a simulated method of moments (SMM) estimation procedure.

6.1 Parameters excluding haircuts

As far as the parameters other than the haircut are concerned, I either draw from values used in previous studies or perform computation on OECD data and financial time series. Table 1 reports all the parameters chosen in either one of these ways. In general, OECD data are used to calibrate the forcing variables, and two financial time-series are useful to determine the steady state values of the rate of interest and the risk premium (specifically, the GP as defined in (26)). The OECD sample contains the G10 countries with the addition of Australia and Switzerland[14], the interest rate is from the UK and the US markets, and the overnight interest swap (OIS) rate is from the US. Finally, one model period corresponds to one year.

Starting with the parameters that I borrow from previous studies, I follow DY for those parameters that are present also in their model. This is the case of n, ϕ, σ, z and ν. In contrast, parameters such as γ, θ, γ_I, θ_I are specifc to the present model because DY do not consider differentiated goods nor capital accumulation. As for γ and θ, I follow the recent results obtained by Corsetti, Dedola and Leduc (2008). Using OECD data, they find that the elasticity of substitution between traded goods is below 1 (i.e., 0.85), so I calibrate γ and θ accordingly. I use similar values also for capital accumulation, under the assumption that the investment goods bundles in (3) and the consumption goods bundles in (12) have similar properties. However, I set γ_I, θ_I slightly above γ, θ, in order to allow for a steady state difference between CPI, P_t, and the investment deflator, P_t^I.

The values attributed to all the remaining parameters are from real data. Coherently with the model, I use financial time series that are relevant for interbank (i.e., intra-agents) transactions: the interest rate is the 3-month LIBOR and, on the basis of the strong case made by Gorton and Metrick (2009 b), the GP is proxied with the LIB-OIS spread. As far as the interest rate is concerned, I consider the daily LIBOR prevailing in the U.K. and in the U.S. over December 31,

[14] The sample of countries is: Australia, Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, the U.K. and the U.S.

1998 to September 16, 2009. Converting these data on a yearly basis and computing averages across both dates and markets, I obtain $\bar{R} = 1.0418$. Turning to the GP, the 3-month LIB-OIS spread is a good metric for the state of the U.S. interbank market. In an attempt to avoid the effect of the recent financial crisis, I restrict my computation to the period between January 2004 and August 2007. The average spread over this period is equal to 11.34 basis points. Though tiny[15], this spread introduces an heterogeneity between discount factors which is sufficient to generate a steady state difference between $\bar{R}$ and $\bar{r}$ (i.e., $\bar{r} > \bar{R}$).

The last set of parameters that I compute is the one specifying the exogenous states. There are three exogenous variables, and one of them is the shock to the margin setting rule. Leaving this for the next section, the other two exogenous shocks are the productivity shock and the investment shock. Their dynamics is described by standard log-linear, autoregressive specifications:

$$\begin{aligned} \ln A_t &= \rho_A \ln A_{t-1} + \varepsilon_{At} \text{ with } \varepsilon_{At} \sim N\left(0, \sigma_A^2\right) \\ \ln \Xi_t &= \rho_\Xi \ln \Xi_{t-1} + \varepsilon_{\Xi t} \text{ with } \varepsilon_{\Xi t} \sim N\left(0, \sigma_\Xi^2\right) \end{aligned}$$

In general, I assume that shocks of different types are independent yet shocks of the same type can be correlated across countries. For instance, it can be that $corr\left(\varepsilon_{At}, \varepsilon_{\Xi t}\right) = 0$ but $corr\left(\varepsilon_{At}, \varepsilon_{A^* t}\right) \neq 0$.

For productivity shocks, I take OECD data on GDP, employment and capital, in order to construct Solow Residuals. For the investment shock, I follow Fisher (2006) and use OECD statistics on CPI and investment deflator to construct the ratios P/P^I[16]. To have a balanced panel and maximize data availability, I consider yearly observations between 1970 and 2010. For the same reason, I also have to omit Germany because of the effect of reunification on its time series, and, when computing Solow Residuals, Switzerland. I perform the same computation for both Solow Residuals and price ratios: for each country, I take the log-transformation of the two variables, I linearly detrend them and, finally, I fit the resulting time series as AR(1) processes. Averaging the persistence parameters and the second moments across countries, I obtain the values in the last rows of Table 1[17].

[15] Consider that, during the crisis, the same spread reached levels even higher than 1 to 2 percentage points.

[16] The investment deflator is the gross total fixed capital formation deflator.

[17] The cross-country correlation between Solow residuals might seem very high, yet it is what I obtain when I extend my sample. Early results based only on Canada, Japan, the U.K. and the U.S. showed a much smaller correlation. I can thus conclude that the high value obtained with the second sample is due to the inclusion of the European countries.

6.2 Margin setting

Margins reflecting borrowers' creditworthiness are captured by the debt-to-value ratios in (30), so the parameters that are still to be chosen are: $\bar{\kappa}$, ψ, ψ^* and those describing the shock variables $\epsilon_{\kappa t}, \epsilon_{\kappa^* t}$. While an assumption is needed for these innovations, the first three parameters are obviously related with each other. Given (30), the long-run value of the debt-to-asset ratio is $\bar{\kappa} = \psi + \psi^*$. Thus, I can combine straightforward calibration with structural estimation, proceeding in three steps: computation of $\bar{\kappa}$ from observed statistics, specification of $\epsilon_{\kappa t}$ and, finally, estimation of ψ (and ψ^*).

To start with, I compute the steady state debt-to-asset ratio from real data on financial institutions, the reason being that $\bar{\kappa}$ should be consistent with some time series which describe the positions that financial intermediaries has taken in the recent past. In particular, $\bar{\kappa}$ should be in line with the composition of their balance sheets, depending on what role they play in interbank transactions. In this regard, an important information is available for the countries in my sample: the OECD collects statistics on the institutional investors operating in each member country. Since these statistics break the total assets of institutional investors in sub-categories, in principle one can compute ratios that describe key features of investors' balance sheets and try to match them within the model. This is the route that I follow because the type of institutional investors covered in the OECD database coincide with the notion of passive investor used here: specifically, I consider the categories "investment funds, consolidated" (i.e., mutual funds) and "insurance corporations and pension funds, consolidated". For these two categories, I compute the empirical shares-to-asset ratio prevailing over 1999-2006[18], and I match it with its theoretical counterpart, $\bar{q}^e \bar{k}^P / \left(\bar{q}^e \bar{k}^P - \bar{q}^b \bar{B}^P \right)$. The results are shown in Table 2. For that period, the cross-country, cross-time average ratio is 0.49 for investment funds and 0.42 for insurance companies and pension funds. So I choose to calibrate $\bar{\kappa}$ in such a way that $\bar{q}^e \bar{k}^P / \left(\bar{q}^e \bar{k}^P - \bar{q}^b \bar{B}^P \right) = 0.45$. As a result, I get $\bar{\kappa} = 0.31$, which implies an haircut of 0.69 and a leverage of 1.45.

Although $0\bar{\kappa} = 0.31$ might seem to imply a fairly high haircut - and the leverage might seem correspondingly low, note that the frequency of my sample is quite high. When the time unit is one year, the short-term debt is, by aggregation, a loan of duration no longer than 12 months. Clearly, such a loan has a bigger haircut than a typical interbank transaction, which takes place at much lower frequencies - the extreme example being the overnight deposit. Moreover, a caveat of my computation is that I am implicitly assuming that whatever non-leveraged institutional

[18] Including the observations for 2007 might affect the computation of a steady state parameter through the effects of the crisis (i.e., financiers hoarding behaviour), so I remove that observation. However, the averages over the period 1999-2007 are almost identical to those reported in Table 2.

investors hold in other forms than shares is lent to active investors. However, this assumption is not a bad approximation. At an early stage, I used to calibrate $\bar{\kappa}$ as the debt-to-assets ratio of the U.S. shadow banking sector, which is the real-world representative of the sector of active investors. I consider as shadow banks classified in this way by Adrian and Shin[19] (2009), and I take data from the Federal Flow of Funds. To remove the effect of the crisis-driven deleveraging, I restrict my attention to the years between 1997 and 2006 and find the results in Table 2, which refer to the average shadow bank type. As shown, the computation retrieves values close to 0.31, with some variation around this value depending on whether I keep or remove assets vis-à-vis household and public sectors (i.e., types of bank credit which are not considered in the model). Therefore, my preference for OECD data can be justified on two grounds. One is the consistency with the overall calibration; the other is the aim to avoid the steady state of a two-country model to be that of a single country such as the U.S.

Next, I estimate ψ, ψ^*, conditionally on the calibrated value for $\bar{\kappa}$. More precisely, what I do is to estimate ψ, given all the calibrated parameters, and then compute ψ^* as a residual. My empirical strategy is based on the following consideration: data on haircuts are not at all overwhelming, but a structural framework may help pin down their determinants as haircuts must be consistent with the structure of the model itself. Again, this is an indirect - or implicit - computation as the one for the steady state value $\bar{\kappa}$. The literature contains some direct attempts. Brunnermeier and Pedersen (2009) plot the margins on S&P 500 futures for members of the CME (Chicago Mercantile Exchange) and find that margins are not constant over time. Gorton and Metrick (2009 a,b) construct an index for repo haircuts from the period preceding the recent financial meltdown onwards. Their index goes from zero before the crisis to about 0.5 during it. However, CME data on S&P 500 futures are just a proxy for the haircuts on interbank loans, and the message they deliver is in contrast with the findings on repo transactions. At odds with Gorton and Metrick's results, CME haircuts were never zero from 1982 to 2008.

My point is just that, in spite of some preceding empirical attempts, the estimation or statistical measurement of haircuts is still a largely unexplored domain. So praising the previous approaches for their pioneering effort and getting inspiration from them, I try to follow an alternative route. Let the debt-to-asset ratios, the LHS variables of equations (30), be unobservable variables, a case which can be handled with a matching-moment procedure, the SMM. This SMM estimator is used with the objective of *identifying*, at least, one of ψ and ψ^*. Specifically, since $\bar{\kappa} = \psi + \psi^*$, the natural expectation is that one can only indentify one parameter and compute the other as a residual; however, I do not impose it a priori. If the identification is possible, then

[19] See at the bottom of Table 2 for a definition.

I can conclude that the data validate the margin setting behaviour derived above as a possible interpretation of time-varying haircuts. As there is still no consensus on their determinants, haircuts are assimilated to the taste shocks in Duffie and Singleton (1993), with a slightly different estimation approach than the one used today to parametrize DSGE models[20].

According to (30), κ_t, κ_t^* could be simply regressed on the log-return generated by home and foreign equities. The OECD database contains the time series of the stock market indexes of the countries in my sample. To estimate ψ and ψ^*, I thus combine these time series with those of purely macroeconomic variables such as output, consumption, investment, etc. The goal is to find out whether there is a set of empirical moments that provides empirical support to the adjustment in haircuts as in (30).

The way I estimate κ_t, κ_t^* has some similarities with the (G)ARCH approach to VaR limits, because of the set of moments that I choose and of the way I specify the shocks $\epsilon_{\kappa t}, \epsilon_{\kappa^* t}$.

Remanding to appendix 9.2 for more details on the intuition, the data used and computational algorithm, consider first the problem of estimating or proxying the shock to debt-to-asset ratios. I use OECD data on private consumption, output, stock market indices, fixed capital formation (i.e., investment), fixed capital stock, and so on. In general, I have data from 1975 to 2010, which amounts to $T = 35$[21]. In theory, one wants to study the behaviour of variables that, given the model equations, are expected to be strongly affected by κ_t, κ_t^*. On empirical grounds, the model does a better job in reproducing the behaviour of consumption and output than, for instance, fixed capital formation (i.e., investment) and fixed capital stock; also, the correlations of the first two variables with stock market indices are better evaluated than those of the latter two variables with the same indices. Nevertheless, the model tends to overestimate the (average) volatility of equity prices, which is most probably due to the strength of binding collateral constraints. Therefore, being more interested in the explanatory part of equations in (30) than to its shock component, I simplify the problem and proxy $\epsilon_{\kappa t}$ with (the mean equation for) $\ln r_t$, where r_t represents the return on the local stock market index. Though very approximative, this assumption allows me to control for all of the features of log equity returns which are not captured by the explanatory part of (30): namely persistence, volatility and cross-correlation. Coherently, I specify $\epsilon_{\kappa t}$ as an autoregressive process, whose form is akin to that of productivity

[20] SMM estimators are increasingly used for attributing a value to the of DSGE models, leaving to pure calibration only those that are impossible to identify or standard to use. In this way, are implicitly treated as unobservable even variables for which the dataset contains an implicit or explicit proxy based on some theory (e.g., productivity shocks can be proxied with the Solow Residual). However, this does not create any problem because the final objective is to validate the models using an easier alternative to, say, the GMM estimator.

[21] One lag is needed to compute the log returns on stock indices as differences in log price data.

and investment shocks:

$$\epsilon_{\kappa t} = \rho_{\varkappa}\epsilon_{\kappa t-1} + \varepsilon_{\kappa t} \text{ with } \varepsilon_{\kappa t} \sim N\left(0, \sigma_{\kappa}^2\right)$$

The cross-country average of the empirical log returns on OECD fits an AR(1) process reasonably well. That is, although I neglect possible (G)ARCH effects, the autocorrelation and partial-correlation functions of the *average* time series show that residuals are well behaved (i.e. not serially correlated). Hence, I compute ρ_r, σ_r^2 using the residuals on the average time series, and I obtain $corr\left(r_t, r_t^*\right)$ averaging across pairwise correlations between country-specific time series, whose behaviour is largely AR(1) as well. Recall that I impose shocks of different types not to be cross-correlated, but I allow each shock to be correlated across countries.

Adding $\rho_{\varkappa}, \sigma_{\kappa}^2$ and $corr\left(\varepsilon_{\kappa t}, \varepsilon_{\kappa^* t}\right)$ to the above parametrization, I estimate ψ by SMM and compute ψ^* residually (i.e., $\psi^* = \kappa - \psi$). In the ultimate refinements, I attempt to match the following set of moments: 1) the home consumption-output correlation; 2) the home stock price-output correlation; 3) the skewness of equity returns; 4) the kurtosis of equity returns. The last two moments allow me control for the (G)ARCH-like effects neglected so far; more specifically, I can check how far the model goes from observed data when (G)ARCH-like effects are not directly imposed - as it is instead usually done in empirical finance. As reported in the appendix, I use usual estimating formulas and test statistics in a specific minimization and simulation algorithm, which adapts the SMM to the specific features of this paper. Since I match three moments for estimating just one parameter, there are three possible degrees of overidentification; consequently, I test for overidentification restrictions (OIR test).

The results are in Table 3, where I report not only the estimation of (30), but also that of the AR(1) for the forcing process. As far as this shock is concerned, its persistence is much lower than in the case of pruductivity shocks. Nevertheless, its variance is almost always twice as big as that of productivity and investment shocks, and it tends to be more correlated across countries. Turning the attention to the SMM estimate, I present results for different T_s, which is the length of a time-series of simulated data. As usual $T_s = \tau T$, where τ is equal to 10, 20 and 30, meaning that simulated data are as long as 350, 700 and 1050 points. In order to control for small sample bias, I consider τ as the number of repetitions needed to construct a sample of simulated data rather than the length a simulated sample obtained in one shot. For every τ, I find that the the minimum distance between empirical and simulated moments is achieved when ψ is between 0.12 and 0.13. Since the asymptotic properties of the estimator improve as $\tau \to \infty$, I choose the case of $\tau = 30$ as my benchmark estimation.

For this case, the shape of the criterion function (i.e., the squared distance between empirical and theoretical data) is as shown in Figure 4, which confirms that only one parameter can be

identified. The criterion function is well-behaved along one dimension and basically flat on the other, which is partly due to the fact that, as shall be clear below, equity prices are strongly correlated across countries in presence of binding collateral constraints. The identified parameter is ψ, which I eventually choose to be 0.126, implying $\psi^* = 0.185$. The last four columns of Table 3 show how the model performs at the optimum in terms of matching the empirical moments. Given the fact that the model does not contain many of the features of RBC models, some predictive weakness of the model has to be expected. For instance, $\rho\left(c_t Y_{Ht}\right)$ is roughtly 0.2 higher in the data than in the model, but the model does not allow for habits in consumption, labor in output and utility, and so on. Not surprisingly, the model does a bit better in reproducing the moments of financial variables. The match of $\rho\left(q^e_{Ht}, Y_t\right)$ is almost perfect, and so is remarkably that of the empirical kurtosis. Here, data turn out to be slightly - and probably insignificantly - platykurtic, which I deem to be a feature of their low frequency; fatter tails show up at higher frequencies. Where the model fails the most is in reproducing real-world skewness. In aggregate data, stock returns are negatively skewed, meaning that the bulk of the concentration of return data is on the right of the mean. With $\tau = 30$, the model is capable to predict the negative sign, but in absolute terms, it fails to reproduce a skewness of about $|0.7|$. One explanation for this weakness of the model might be related to the solution method for dynamic macro-models. If the mean corresponds to stock returns in the steady state, then simulating the model through a series of shocks can skew the distribution around the mean, but the allowed distance from the mean should be small. If it was not so, the linearization around the steady state would break down. In any case, the weaknesses of the theoretical model are not so large that the four moments used represent a bad choice. At 5 percent significance, the test for OIR cannot reject the hypothesis that the three extra-moments are valid to identify ψ.

7 Numerical solution

7.1 Portfolios

I solve the model numerically, writing it as in Devereux and Sutherland (2011)[22]. Through their formula, the second order approximation of (41) yields the zero-order portfolio holdings displayed in Table 4. In this table, positions are reported for two levels of aggregation. The first level is

[22] I use standard Matlab functions for the analysis of linear systems. However, the implementation of the Devereux-Sutherland method requires caution with some control and state variables (their 2007 working paper is more specific on this aspect). I gratefully acknowledge the help received by Alan Sutherland, whose reply allowed me to double-check my files.

the most disaggregated one, being targeted at the two groups of households in each country. The corresponding portfolio holdings are a measure of international diversification. The second level of aggregation refers to the two groups of households across countries. This amounts to determine the overall availability of a certain asset for a given sector in each country. Finally, to clarify what portion of each asset is internationally traded, the bottom two lines distinguish international financial transactions according to the country where assets originate. Each quantity is valued at market prices and scaled by total ouput[23].

Passive investors invest in home capital and buy domestic good bonds issued by cross-border investors but do not hold foreign capital. Indeed, they finance final goods production only indirectly, in their role of bond investors. It follows that even their holdings of home capital are not employed by local firms. Thus, this is capital that passive investors subtract from that backed by internationally traded claims. It can be termed as *non-tradable capital*, given by the variables k_H^P, k_F^{*P} in (22)-(25) and (34). The table shows that, in the symmetric equilibrium, the value of both of these stocks is 0.8. Passive investors put their remaining wealth in local good bonds. Both home and foreign financiers show a tendency to purchase more bonds from domestic issuers (0.78) than from foreign issuers (0.21).

Active investors take positions in all the segments of financial markets, diversifying their assets and liabilities across countries. On the liability side, they start with a debtor position of 0.99 vis-à-vis local passive investors, but as soon as international financial transactions are concluded some of this debt is exchanged for foreign debt. The pattern of diversification shapes the above passive investors' bond portfolios and, thus, shows a greater exposure to local financiers than to foreign ones. On the asset side, since $\bar{\kappa} = 0.31$ and active investors' total debt sums to 0.99, their overal capital ownership turns out to be 3.18. Out of this total amount, local firms receive 1.88, and foreign firms 1.3. Once again, this means that active agents prefer to take positions within the national borders.

The same situation can be read under another perspective, that is, at the level of productive sectors. The backyard sector is owned (and run) by passive investors, and has a creditor position with respect to the final goods sector. Since both its factor and its product remain within the sector, it is termed NT (non-tradable) sector just for clarity (not accuracy). On the other hand, the final goods sector uses T (tradable) goods when investing in capital and selling its output. Owners of this sector are the active investors, who have a debtor position vis-à-vis the saving

[23] "Total output" in the steady state is the sum of final goods production and economy-wide backyard production: $\overline{Y} + (1-n)\, z \left(\overline{k}^P\right)^{\nu}$. I consider total ouput because I show results for both agents' portfolios. Otherwise, I generally refer to GPD as the lone production of final goods.

sector. The interesting thing here is that we can easily capture the *power of leverage*: this is the extent to which leveraged owners (who proxy for leveraged intermediaries) lead firms to boost their investment beyond what the internal resources would allow. Table 4 shows that the availability of external funds (0.99) allow firms to use as much capital as 3.18, although their net worth is just 2.19.

The above tendency of active investors to attract a large share of 0.99 from local financiers and to invest more in local than foreign capital can be assessed more precisely as the ratio of local holdings (or positions) to the total position in each asset class. As for equities, this is a proxy of the so-called home equity bias; concerning secured bond, the ratio can be termed as local *funding* bias whenever it exceeds 0.5. Table 5 reports the results I obtain for both the case analyzed so far (baseline calibration) and a series of sensitivity excercises aimed at a deeper analysis. The precise formulas that I use are at the bottom of the table.

The above figures for international diversification and sectoral allocation give rise to both home equity bias and home funding bias: the first equals 60 percent of the local stock, and the second 78.8 percent of total debt. In other words, there is always local bias, and the largest one is that restraining the diversification of the (secured) liability portfolio. The presence of local equity bias is not entirely surprising as the model embeds investment expenditures as in Coeudarcier et al. (2010). So, in spite of the fact that here international investors are subject to collateral constraints, capital accumulation is strong enough to break the perfect correlation between capital income and non-capital income, as it was in their model[24]. Indeed, the analytical findings of section 5 suggest that binding collateral constraints should not be expected to affect the equity portfolio so much. Formally, the effect of the pledge is that of replacing the arbitrage conditions between secured financial instruments (bonds) and non-secured instruments (equities). It follows that arbitrage cannot bridge changes in collateral to changes in equity portfolio shares.

These shares matter instead from another viewpoint. Binding constraints imply that the debt-to-asset ratios behave as in (30), and an estimate for ψ is available through the empirical strategy discussed in the previous section. Given these results and the link between (13) and (30), I can purge ψ, ψ^* from the effect of equity portfolio shares. The computation is of interest as it measures the pure sensitivity of κ_t, κ_t^* (measures of borrowers' creditworthiness) to local and foreign collateral:

$$\frac{\psi}{\text{local equity bias}} = 0.213 \quad ; \frac{\psi^*}{\text{1 - local equity bias}} = 0.450$$

[24] When capital income is perfectly correlated with non-capital income, the prediction of international portfolio models goes back to Baxter and Jermann (1997): investors tend to use foreign equities as a protection against their labour income risk.

Focusing more on the qualitative implications than on the quantitative accuracy, the above result means that borrowers' creditworthiness is more "threatened"[25] by changes in the value of foreign collateral than by changes in the value of local assets. An explanation for this is that diversifying short (guaranteed) positions across countries is always subject to a mismatch. Home financiers can receive foreign collateral, but the promise made by borrowers is to repay at the rate of interest prevailing in the local economy. Seemingly, foreign financiers accept home equity as collateral, but they expect to be eventually repaid at the rate of interest prevailing in the foreign economy.

More insights on the link between equilibrium portfolios and collateral are offered by the sensitivity of endogenous equity and bond shares to model parameters. I focus on the following parameters: γ, θ, γ_I, θ_I, $\bar{\kappa}$ and its split between ψ and ψ^*. The first four parameters, γ, θ, γ_I, θ_I, have to do with the revealed preferences for consumption and investment goods across countries. Interested mainly in the sign of the change than its absolute value, I study what happens when γ, γ_I increase by 0.10 and θ, θ_I increase by 0.20. This last test is especially important as it allows me to determine what happens when the elasticity of substitution between goods raises above 1: apart from Corsetti et al. (2008), many studies assume that θ, θ_I take on values larger than 1. My findings are in line with the previous literature. The most sensitive portfolio share is the bond portfolio, which renders the equity share as stable as empirical observations suggest (Coeudarcier and Gourinchas, 2009). Bond shares increase univocally in all four cases, and especially so for higher values of θ, γ_I: this provides evidence on the hedging properties of bonds. Bonds are used as a protection against shocks to the terms of trade (Coeudarcier et al., 2007).

While the sensitivity tests discussed so far do not add any new findings to previous knowledge, some new inference can be drawn from the sensitivity to changes in $\bar{\kappa}, \psi, \psi^*$. Specifically, I consider two alternative scenarios: 1) a steady state where $\bar{\kappa}$ is greater than in the baseline case by 0.1, while keeping $\psi/\bar{\kappa}$ constant; 2) a steady state where the role of ψ and ψ^* on $\bar{\kappa}$ is inverted ($\psi = 0.185$, $\psi^* = 0.126$), for the same $\bar{\kappa}$ as in the baseline scenario. The latter exercise is actually a simple double-check for the consistency between analytical and numerical results. In principle, the relation between ψ and ψ^* should not affect the steady state, which only depend on their sum. Indeed, the last row in Table 5 shows that portfolio shares are completely invariant with respect to a switch between ψ and ψ^*. What changes is only the effect of home and foreign collateral on credit risk (in the last two columns of the table). More intersting is instead the first exercise, which amounts to questioning what is the effect of higher leverage on diversification. Note that an increase of 0.1 in the debt-to-asset ratio increases leverage from 1.45 to 1.69; this

[25] Recall that, though not microfounded, the behaviour of κ_t, κ_t^* depend on financiers' reaction to (perceived) borrowers' creditworthiness.

means that the relative increase in leverage is almost twice as large as the initial increase in $\bar{\kappa}$. In response to such a change, active investors would increasingly tilt their bond portfolio to the home market, while equity home bias would stay the same.

In combination with the analytics of the model, I interpret the results of this sensitivity analysis as follows. Secured bonds combine the features of unsecured portfolios with the *specificity* of the pledge. As any other bond for which the model does not involve constraints, a secured bond insure against the risk in the terms of trade. However, its reactiveness to this risk is hightened in comparison with that of an unsecured bond: now fluctuations in the terms of trade do not only depend on preference parameters, but also on $\bar{\kappa}$. Strikingly, the effect of leverage is completely absorbed by bonds, supporting the theoretical observation that the collateral constraint replaces arbitrage conditions. In turn, this result supports the derivation of equations (14") and (40), that show indeed that leveraged investors' unique benchmark is the UIP condition when choosing between home and foreign financiers.

Clearly, the model overestimate the sensitivity of secured bonds to model parameters due to the absence of unsecured bonds. Introducing such financial instruments would improve the quantitative predictions of the model, but the qualitative gain would almost surely be outpaced by the increase in the required technical analysis.

7.2 Business-cycle shocks: *loss spirals* and adjusting haircuts

Although the dynamics of the two-country framework depend on the state of six exogenous variables, economic fluctuations are mainly caused by country-specific productivity shocks. Contrary to what some closed economy studies suggest, here investment shocks do not cause large business cycles. One reason for this may be seen in the home equity bias reproduced by the model: leading to local bias, the effects of investment shocks are (partly) neutralized by optimally diversified equity portfolios. Shocks to haircuts are instead more meaningful, but the mechanism that they put into motion is the same as the one activated by productivity shocks - together with the analysis that shall be conducted in the next section. Thus, I limit the analysis contained in this section to the effects of an unexpected fall of 1 percent in home country productivity.

Figure 5 shows the impulse responses of key variables: prices of assets, terms of trade, outstanding debt expressed in a given country good, investors' capital holdings, and so on. Under binding collateral constraints and financial integration, these variables show a strong tendency to comove, evidence that the international transmission mechanism formalized by DY is at work. In terms of (15"), current account balances link collateral values across countries by determining traders' NFE positions.

Accounting for this angle of collateral constraints, Figure 5 shows a case of the well-known contraction set off by margin requirements. A perverse cycle involving real and financial variables follows, the origin of it being the immediate reaction of prices. At home, the shock to productivity traduces directly in a reduction in the market value of shares. In the foreign economy, the adjustment is a bit more complex. For one thing, trade in goods implies that p_{Ft} must follow the dynamics of home country productivity. For another, the initial portfolio diversification guarantees that not only home active investors but also foreign traders (who hold *ex ante* 40 percent of the total capital stock) would be negatively hit by the negative valuation effect on home equity holdings. Hence, foreign equity prices drop as well.

Thus, the initial fall in home equity prices leads to a first decrease in the worth of international investors worlwide. A margin call follows for all of them, reducing their capability to borrow, so that also their financial support to final goods firms must correspondingly decrease. Finally, these firms are forced to use less capital, so that both output and investment plunge, in line with decreased consumption expenditures. As one would expect in a contraction, the fall in investment spending is more severe than that in consumption.

The problem posed by binding collateral constraints is that a macroeconomic adjustment to equilibrium is not readily possible. The drop in output and investment can be seen as the last stage of the *first round*. Coupled with the consequences it leads to, the first margin call is enhanced by the fall in the value of foreign equities and eventually translates into another fall in prices, a new margin call and further rounds. However, this perverse cycle displays an interesting pattern here. Between the third and fourth steps ahead, the system starts to benefit from a correcting mechanism that accelerates the convergence of variables from date 5 onwards. This correction matches the behaviour of haircuts and of guarantee premia at the bottom of the figure, but in fact the process begins with the *adjustment in haircuts*. This conclusion is drawn from an analogous exercise, which I conduct shutting down the rules in (30). The results for this alternative case are in Figure 6, whose first message is that, absent any adjustment in margins, the home country productivity shock has very persistent effects. The slowdown in the capability to borrow, equity ownership and consumption of final goods at step 5 is (in absolute terms) almost as large as the impact multiplier. Not surpraisingly, in this case the GPs goes back slowly after an initial jump.

Before pursuing a deeper analysis of the differences between the two cases, I briefly attempt a first interpretation of the results so far, getting inspiration from Brunnermeier (2009). The last exercise corresponds to a margin call where, for *given* leverage, the market value of collateral plunges by a given amount (about $|1.6|$ at home and $|1.2|$ in the foreign economy; Figure 6) leading

to a quantitatively *equivalent* decrase in short positions (at market prices). Using Brunnermeier's terminology, this perverse cycle is a cycle where only "loss-spirals" take place. The first exercise shows, however, that this is not necessarily the complete picture of the overall effects of binding collateral constraints; a loss-spiral does not capture the reaction of players in the market for funds. Starting from an already binding state, these constraints must adjust to the post-shock scenario, the difference being that it is now more likely that borrowers (leveraged investors) will face further losses in the future. In few words, borrowers' creditworthiness falls everywhere, and so does their ability to leverage, which is the flipping side of *tightening* haircuts on intra-agents loans. This is a cycle that combines loss-spirals with what I termed above as adjustment in margins. In quantitative terms, the credit crunch is *larger in size* than the initial fall in agents' shareholdings, both on impact and at the nadir of the slowdown (Figure 5).

Clearly, the question is now to understand how the adjustment in margins interact with the loss-spirals, extracting information from the observed response functions. To this end, I perform three experiments, reporting the results in Figures 7, 8-9 and 10, respectively.

First, I take the difference betwen the dynamics caused by loss-spirals with adjusting margins and those caused by loss-spirals-only contractions; see Figure 7. Reading it intuitively, the graph shows that the first effect of the adjustment is to highten the contraction, suggesting that lenders get more concerned about counterparty risk, in the restrictive sense considered here. This can occur on impact and/or up to the third period after the initial productivity shock. At this point, the situation reverts and a correction can start. This is guaranteed by the fact that haircuts go back to normal because active investors have had time to start repaying their debts in a credible way. Indeed, just after the shock, the relative change in haircuts is almost 0.3. And it stays there also for the next period, a sign that passive investors are very unwilling to lend further resources. A remarkable evidence of this unwillingness is given by the differential effect of the shock on the volume of bonds issued in either goods on dates 2 to 3 ahead: basically, -1. Yet, this severe reaction gives active investors the opportunity to deleverage, repay some debt and, consequently, regain credibility. All in all, adjustment in margins have both an impact effect and a subsequent effect, with contrasting signs.

Second, I study how these two effects originate and which of them tend to prevail over a longer horizon. I focus on impact multipliers (Figure 8) as well as cumulative multipliers (Figure 9), computing the latter over the first 5 steps after the shock, deemed to be the bulk of the dynamic reaction. Let then introduce the possibility of an adjustment in margins in a progressive way, for ψ, ψ^* that are raised from zero to their estimated or implied value. To start with, it is easy to see that there is a univocal pattern for each of the two types of multipliers on a set of key

macroeconomic variables: the stocks of debt and capital, bond prices and the flow of investment (i.e., the top four diagrams). As haircuts increase, the impact effects of the shock on the stock of debt, that of capital and investment is negative and gets larger in absolute value. On a cumulative basis instead, debt (with its own price) proves almost insensitive, while capital and investment show even a progressive improvement. The gain is the *market discipline* provided by the guarantee when margins can adjust to changes in counterparty risk, as reflected in the dynamics of the risk premium paid by borrowers.

The same experiment is informative about what happens to agents' specific positions (not aggregate variables) as margins are allowed to react. Quite evident is the fact that active investors' effective borrowing (outstanding debt in value terms) worsens both on impact and cumulatively. This is not surprising: if there is one variable that should pay for the cumulative improvement in debt, capital and investment, this is borrowing. It matters that the reaction of passive investors is to stop completely trusting in borrowers. But perhaps more important is the cross-country effect of the adjustment. International investors' financial assets and liabilities tend to converge under the effect exerted by time-varying haircuts. Insofar as financial instruments are used by the two economies to insure against each other. This result can be read as an improvement in risk sharing.

Finally and consequentially, I use a simple counterfactual simulation to check this first impression of a link between the movement in margins and financial integration. The logic is simple: consider two extreme cases, financial integration as implied in the model and autarky, and wonder what would happen to active investors' balance sheets were diversification less important for the assessment of counterparty risk. Let thus the case in which $\psi = \psi^* = \bar{\kappa}/2$ be defined as "complete integration in setting haircuts" and the case $\psi = \bar{\kappa}, \psi^* = 0$ denote full autarky. As Figure 10 shows, if haircuts were imposed neglecting financial integration, impact multipliers would once again remain unaffected but cumulative multipliers would lead to a divergence between agents' asset holding. Due to the adjustment in haircuts, this divergence is more evident for active investors' ability to borrow than for their long positions. Together with the previous experiments, I interpret this result simply as follow. Leading all the other factors aside, international traders' with diversified portfolios are more likely to have an equivalent credit risk across (symmetric) countries. Note that this is not driven by changes in optimal portfolio shares: as the previous section shows, portfolio shares are insensitive to the ψ-to-ψ^* ratio (Table 5, last row). So, even if there was full local bias in the demand for intra-agents funds, passive investors would still be concerned about the world economy as long as their borrowers continue to pledge a *diversified collateral portfolio* of assets.

7.3 Amplification and *margin spirals*?

Given the previous results, the model with loss spirals and time-varying margins suggest that, after an initial worsening of the contraction, the adjustment in the haircuts has stabilizing properties. Interestingly, Genakoplos (2009) concludes that endogenous changes in leverage have these types of properties for the most of the possible economic shocks. From another viewpoint, Brunnermeier and Pedersen (2009) find that stabilizing margins are prevailing when financiers have enough information about the fundamentals of the economy. However, both studies point out that alternative conditions bring to even more cyclical, if not diverging, dynamics: in the first case, these dynamics are caused by shocks to the tail distribution of asset returns; in the second, they are due to lack of information.

Various questions can then arise. One may wonder whether the adjustment in margins add anything to the traditional properties of credit constraints, which are asymmetry and amplification of business cycles (Kocherlakota, 2000). Pushing the analysis a bit further, one can thus search for cases in which the stabilizing property of haircuts shows a tendency to break down even in the model at hand. These are the two questions that I address in this last section, focusing only on amplification and risk. I disregard any consideration on the possibility that binding collateral constraints cause asymmetries between negative and positive phases of the business cycle.

To start with, I examine the amplification effects of binding collateral constraints. Given the international transmission, evidence of amplification does not only show how quantitatively important are the collateral constraints for the size of the business cycles of each single economy, but also how they lead to hightened comovement between two given countries. Again, I consider a subset of key macroeconomic variables. As in the literature on Sudden Stops (Mendoza and Smith, 2006; Mendoza, 2010), the term amplification refers to the differential behaviour of macroeconomic variables when collateral constraints are binding as compared to the unconstrained scenario. The information is extracted from the responses to shocks over a given time horizon and not from the impact multipliers, the latter being the approach originally suggested by Kocherlakota (2000). I then construct a Monte-Carlo experiment[26], where the *unconstrained* model (i.e., the model where collateral constraints do not bind) is built as in DY: by construction, the fact that constraints are non-binding means that agents have homogeneous time preferences,

[26] The Monte Carlo experiment is setup as follows. I simulate time-series of 70 datapoints (as the model is calibrated in years), which are then filtered and subject to a burn-in of the first 50 observations. I repeat this simulation for $N = 600$ times.

yet passive investors lend in the steady state in the same way as they do when collateral is binding. Note that, in the non-binding case, the analytical results on portfolio choice described in section 5 do not apply: to solve for portfolios I have to use the three standard arbitrage conditions, together with the NFA dynamics in (14'). I compute the amplification coefficients with a simplified version of the formula proposed by Mendoza (2010)[27]:

$$ac\left(x\right)=\frac{1}{N}\sum_{r=1}^{N}\hat{x}_{r}^{c}-\hat{x}_{r}^{u}$$

where $\hat{x}_i$ denotes a variable in deviation from its steady state at repetition r and the superscripts "c" and "u" denote the constrained or unconstrained by collateral, respectively. Under this definition, there is evidence of amplification only if $ac\left(x\right)>0$.

One caveat of my analysis is that these amplification coefficients have been developed with models of occasionally binding credit constraints (global optimum). The drawback is that, since the collateral constraints are always binding or non-binding, it is impossible for me to capture any endogenous non-linear effects given by the structural break between one state and the next one. However, the analysis can be justified on two grounds. First, this is an international portfolio model, which follows the recent advancements on the subject; all of these are based on local solutions[28]. Second, even in the occasionally binding tradition, the debt-to-asset ratios would be zero in the unconstrained states and equal to some calibrated positive value in the constrained states.

That said, results are reported in Table 6 for different specifications and various combinations of states. The first column reports the results for the model suggested by DY, the others refer to the model developed here. Being a building structure for my framework, I solve and simulate the model of DY under my calibration, with the aim of finding out whether the collateral limits are

[27] Specifically, Mendoza (2010) computes an amplification coefficient like the following

$$ac\left(x\right)=\sum_{s_1}\sum_{s_2}...\sum_{s_n}\Pr\left(constraint|s_1,s_2,...,s_n\right)\frac{x^{c}\left(s_1,s_2,...,s_n\right)-x^{u}\left(s_1,s_2,...,s_n\right)}{x^{u}\left(s_1,s_2,...,s_n\right)}$$

where $s_1,s_2,...,s_n$ are state variables and $\Pr\left(constraint|s_1,s_2,...,s_n\right)$ is the conditional probability of the *constraint* being binnding/non-binding. In my setup, I cannot account for this probability, but I look at volatility. In addition, the approximation method allows me to simplify the computation of relative changes.

I benefited from a message by Enrique Mendoza on the properties of this coefficient and its superiority to previous attempts (Smith and Mendoza, 2006); I am very graful to him for these advices.

[28] For a general study on portfolios in presence of heterogeneous agents which uses a global solution, see Judd, Kubler and Schmedders (2002). Their method is based on approximating the equilibrium equations using collocation splines.

not only able to generate international transmission, but also the amplification often attributed to them by another strand of the literature. Consequently, the systems faces shocks to home and foreign productivity only. As shown in the table, I obtain a couple of interesting findings. One is that their model reproduces a great deal of symmetry across countries, which is probably justified by the fact that it is a one good model without capital accumulation. The other finding is that their model shows very little amplification, with the exception of two variables: home and foreign borrowing. These two exceptions show heterogenous amplification coefficients, but this difference might be explained by some of the results obtained by the authors themselves[29].

The model developed in this paper yields different results. Some variables behave basically in the same way, no matter whether collateral limits bind or not. These are variables such as home equity price, home (per capita) capital, etc. for which $ac(x)$ is even slightly negative. These variables produce little amplification also in DY. In all the other cases amplification is quantitatively relevant, emphasizing the asymmetry between home and foreign variables. Only the reaction of home and foreign investment is amplified equally by the collateral constraints, probably due to the fact that these variables are modelled as symmetric CES bundles of goods differentiated across countries. As for the asymmetry between the amplification of home and foreign comparable variables, the natural candidates to which this asymmetry can be imputed are the terms of trade (as captured by p_{Ft}, in the last row of the table). The reaction of the relative price of foreign goods to the introduction of collateral limits is to have more amplified swings around the steady state: these are increased by more than 7 percent in comparison to the unconstrained model. The sensitivity analysis on computed portfolios performed above shows in fact that the collateral constraint interacts with the fluctuations in the terms of trade, so that secured bonds can be used as a protection against these fluctuations.

Remarkably, the model produces basically the same results, no matter what types of specifications and shocks one takes into account. In other words, what I have just obtained is valid for the model with only loss spirals (column 2) as well as for the model with adjustment in margins (subsequent columns). The most striking result is that even the shock to the debt-to-asset ratios, $\varepsilon_{\kappa t}, \varepsilon_{\kappa^* t}$, does not lead to (economically and quantitatively) different amplification coefficients. The same is true for a double-check that I do replacing the shocks to debt-to-assets ratios with the investment shocks, $\varepsilon_{\Xi t}, \varepsilon_{\Xi^* t}$. The message coming from this puzzling results is twofold. First, the result confirms that in a two-country portfolio model the main drivers of business cycles are

[29]DY found that, when no further restrictions are imposed on the endogenous determination of portfolios, the impulse response functions of foreign borrowing is wider in absolute value than that of domestic borrowing. Indeed, in their case home equity bias is generated by an "iceberg cost" (Tille and Van Wincoop, 2010). In absence of such a cost - the case here - agents tend to show foreign bias.

the productivity shocks, while the investment shocks are neutralized through diversification in equity holdings. Second, abstracting from its effects on the dynamics of the system, the fact that collateral constraints *tighten* do not create any additional amplification with respect to the one already generated by their *bindness*.

I now pass to the second question: are there cases in which the correcting properties of the adjustment in haircuts break down? Amplification coefficients are not so informative for this question because, in the model, haircuts m_t, m_t^* change with κ_t, κ_t^*, which are the first variables to capture changes in borrowers' creditworthiness. In this sense, depending on their properties, time-varying haircuts may leave amplification on average unaffected ($ac(x)$ does not change for any x), but they may still increment the swings around this average (creating additional risk). My approach to disentangle these effects is the following: I compute a new measure, which has nevertheless the same flavour as $ac(x)$, to study the volatility of model variables; I check whether the adjustment in margins affects it, stressing the difference between normal adjustments and those characterized by the uncertainty that may occasionally wreck the borrowing relationships between debtors and creditors. In line with (30), a simple way to capture this type of uncertainty is a shock to haircuts; here this shock can be triggered by a shock to debt-to-asset ratios. Let then

$$vr(x) = \frac{1}{N}\sum_{r=1}^{N}\frac{\sigma_r^c(x)}{\sigma_r^u(x)}$$

be the volatility ratio as the average ratio between the standard deviations computed, for each variable of interest, under binding constraints and non-binding constraints. $vr(x) = 1$ only if the variable x is as volatile in the first case as in the second case.

The results for this exercise are in Table 7. The table shows that, in the model of this paper (columns different from the first one), $vr(x)$ is below 1 for the most of the variables, generally for the foreign country variables. Again, risk sharing is beneficial when international traders can diversify their secured liabilities across countries, as the bonds they sale have strong hedging properties against terms of trade shocks. In contrast, at home the strength of collateral constraints produces similar effects as in closed economy. It follows that, while variables not affected by the terms of trade are not subject to amplification effects[30], they cannot seemingly benefit from international diversifications (i.e., home country variables tend to have $vr(x) = 1$). This is true for the loss-spiral-only version of the model (column 2), the model with adjusting haircuts (column 3) and the model in which the covariance matrix is expanded with either shocks to the debt-to-asset ratios or with investment shocks (columns 4-5).

[30] See again Table 6.

Yet, from another viewpoint, the addition of $\varepsilon_{\kappa t}, \varepsilon_{\kappa^* t}$ to the standard productivity shocks is a somewhat more singular case. As column 4 indicates, $vr\,(x)$ is higher than in other versions of the model (columns 2, 3 and 5) for almost all the variables. The only exceptions are the equity prices, q^e_{Ht}, q^e_{Ft}, and the terms of trade, p_{Ft}. The first two prices benefit from the cross-country positions in equity holdings; the third price creates amplification but its riskiness is neutralized for by the debt portfolio. But apart from these hedging properties of optimal portfolio positions, all the other variables turn out to incorporate the additional risk generated by the shocks to the debt-to-asset ratios. In spite of the fact that through financial integration binding collateral constraints do not amplify economic cycles at home, home country borrowing (B^A_{Ht}, R_{Ht}) and capital (χ^A_{Ht}) tend now to be more volatile under binding constraints than under non-binding constraints. Interest rates (R_{Ht}, R_{Ft}) have higher volatility ratios than in other versions of the model, pointing out that the adjustment in haircuts renders debt costs more sensitive to innovations. The shocks to the haircuts affect the volatility of these two variables so much that their volatility ratios are more than twice as large as in the case of other model specifications. The previous section shows in fact that the risk premia paid on debt (the GPs) are very sensitive to the haircut adjustment.

These results show that the time-variation in haircuts does not have quantitative implications under normal business cycle fluctuations. Under these conditions, there is amplification in the two-country economy if collateral constraints bind, for borrowing from foreigners means facing the additional real exchange rate risk, as one would intuitively expect. Seemingly, the market value of collateral is affected by valuation effects on foreign assets. However, provided that traders can borrow from foreign lenders, this amplification is counterbalanced by the international diversification of risk. Domestically, the economy faces the opposite situation: domestic variables are not affected by the amplification typical of collateral constraints in closed economy, but they can neither show volatility gains that can be produced only by the international diversification of the risk of margin calls. All in all, the effects of risk sharing can be both positive and negative: non-amplified fluctuations with risk, for home country variables; amplification but reduced risk, for the foreign country variables. In this regard, time-varying margins do not have any negative effects: it is even the case that its spur in favour of market discipline results in a slightly positive outcome: for instance, that of reducing the volatility ratio of χ^A_{Ht} from 1.23 (loss-spiral-only case in column 2, Table7) to 1.03 (full model in column 3, same table).

Fluctuating margins can show signs of dynamics similar to the *margin spirals* discussed by Brunnermeier (2009) only in one case: when the normal economic fluctuations are accompanied by shocks to debt-to-asset ratios. This is proper of these shocks. As column 5 of Table 7 shows,

investment shocks can only increase the volatility of investment spending, leaving borrowing largely unchanged. In contrast, shocks to the debt-to-asset ratios have a much more generalized and pronounced effect on model variables. This complies with recent findings that attribute an important role to financial shocks in explaining the observed macroeconomic volatility (Jermann and Qadrini, 2011): in this model, financial shocks can create additional risk through the adjustment in the size of the collateral (and, thus, of the loan) in line with changes in the borrower-specific credit risk. This type of explanation seems close to Geanakoplos' perspective, recalled at the beginning of this section. Note however that it depends on my choice for modelling the shocks to κ_t, κ_t^*. I scale these shocks so that they can retrieve shocks to the haircuts, which are the variables of interest for the satisfaction of (15'). The simple modelling device I use for this purpose is the (inverse of) the stady state debt-to-capital ratio of borrowers, $\bar{m}/\bar{\kappa}$[31]. Without this measure for initial leverage, shocks to κ_t, κ_t^* cannot be interpreted as haircut shocks and tend to have quantitatively smaller effects on the volatility of borrowing and interest rates (column 6, Table 7).

8 Conclusions

I develop a two-country portfolio model with binding collateral constraints, which is suitable to study the effects of both the cross-border diversification of secured debt and the adjustment of haircuts to country-specific shocks. The parameters governing the reaction of haircuts are estimated via SMM, using financial and macroeconomic data of major OECD countries.

The model is capable to reproduce the empirical tendency of countries to display home equity bias and a short position in bonds. Yet, bonds here are not generic but specific, in the sense that they are constrained by collateral. Although collateral represent a limit to borrowing, the diversification of secured short position across countries has nice hedging properties against fluctuations in the terms of trade. Consequently, the terms of trade risk is more easily shared when collateral limits bind than when not. On the other hand, binding constraints generate the usual amplification issues, rightly through the terms of trade. It seems in fact that, in an integrated world, amplification and volatility are connected to changes in the real exchange rate.

In this type of environment, the transmission mechanism discovered by Devereux and Yetman (2010) works in a complex way. Originally thought to be the reaction of borrowing limits to the diversification of collateral assets, here this transmission mechanism works through the asset side as well as through the liability side of investors' balance-sheets. In the first periods after a shock,

[31] See also Adrian and Shin (2008) and various of their other works.

both home and foreign economies react by more, while there is a correction in the longer horizon. These dynamics are proper of loss spirals with adjustment in haircuts, implying the transmission mechanism incorporates the typical features that have characterized the evolution of the banking sectors around the world. Generally, this combination leads to stabilizing haircuts, but there is a case in which shocks to haircuts may add to the risk of the normal business cycle, generating a sort of margin spiral. This happens when, accounting for the initial leverage of the representative investor, the dynamics of the system are driven by both productivity and haircut shocks.

References

[1] Adrian, T. and H. S. Shin (2008) "Procyclical leverage and Value-at-Risk", *Federal Reserve of New York*, Staff Report n.338.

[2] Adrian, T. and H. S. Shin (2009) "Financial Intermediaries and Monetary Economics", *Federal Reserve of New York*, Staff Report n.398.

[3] Aiyagari, S. R. and M. Gertler (1999) "Overreaction of asset prices in general equilibrium", *Review of Economic Dynamics*, 2, 3-35.

[4] Baxter, M. and U. J. Jermann (1997) "The international diversification puzzle is worse than you think", *American Economic Review*, 87(1), 170-80.

[5] BIS (2008) "Guidelines to international locational banking statistics"; Monetary and Economic Department, *Bank for International Settlments*.

[6] Brunnermeier, M. (2009) "Deciphering the liquidity and credit crunch 2007-2008", *Journal of Economic Perspectives*, 23(1), 77-100.

[7] Brunnermeier, M. and L. H. Pedersen (2009) "Market liquidity and funding liquidity", *Review of Financial Studies*, 22(6), 2201-2238.

[8] Carlstrom, C. T. and T. S. Fuerst (1997) "Agency costs, net worth and business fluctuations: a computable general equilibrium analysis", American Economic Review, 87(5), 893-910.

[9] Cetorelli, N. and L. S. Goldberg (2010) "Global banks and international shock transmission: evidence from the crisis", *NBER Working Paper*, 15974.

[10] Coeudarcier, N. and P.-O. Gourinchas (2009) "When bonds matter: home bias in goods and assets", *mimeo.*

[11] Coeudarcier, N., R. Kollmann and P. Martin (2007) "International portfolios with supply, demand and redistributive shocks", in Clarida and Giavazzi (2009) *NBER International Seminar on Macroeconomics 2007*, NBER Books.

[12] Coeudarcier, N., R. Kollmann and P. Martin (2010) "International portfolios, capital accumulation and foreign asset dynamics", *Journal of International Economics*, 80, 100-112.

[13] Corsetti, G., L. Dedola and S. Leduc (2008) "International Risk Sharing and the Transmission of Productivity Socks", *Review of Economic Studies*, 75(2).

[14] Dedola, L. and G. Lombardo (2009) "Financial frictions, financial integration and the international propagation of shocks", *mimeo.*

[15] Devereux, M. B. and J. Yetman (2010) "Leverage constraints and the international transmission of shocks", *Journal of Money, Credit and Banking*, 42(6).

[16] Devereux, M. B. and A. Sutherland (2007) "Solving for Country Portfolios in Open Economy Macro Models", *HKIMR Working Paper* No.16.

[17] Devereux, M. B. and A. Sutherland (2011) "Country Portfolios in Open Economy macro models", *Journal of European Economic Association*, 9(2), 337-369.

[18] Duffie, D. and K. J. Singleton (1993) "Simulated moments estimation of Markov models of asset prices", *Econometrica* 61(4), 929-952.

[19] Fisher, J. D. M. (2006) "The dynamic effects of neutral and investment-specific technology shocks", *Journal of Political Economy*, 114, 413-452.

[20] Geanakoplos, J. (2009) "The Leverage Cycle", in D. Acemoglu, K. Rogoff and M. Woodford, eds., *NBER Macroeconomic Annual 2009*, vol. 24, 1-65, University of Chicago Press.

[21] Gorton, G. B. (2009) "Slapped in the face by the invisible hand: banking and the panic of 2007", *Federal Reserve Bank of Atlanta*, Conference Paper.

[22] Gorton, G. B. and G. G. Pennacchi (1990) "Financial intermediaries and liquidity creation", *The Journal of Finance*, 45(1), 49-71.

[23] Gorton, G. B. and G. G. Pennacchi (1995) "Banks and loan sales. Marketing non-marketable assets", *Journal of Monetary Economics*, 35, 389-411.

[24] Goldberg, L. S. (2009) "Understanding banking sector globalization", *IMF Staff Papers*, 56(1), 171-197.

[25] Gorton, G. B. and A. Metrick (2009a) "Haircuts", *NBER Working Paper* 15273.

[26] Gorton, G. B. and A. Metrick (2009b) "Securitized banking and the run on repo", *NBER Working Paper* 15223.

[27] Greenwood, J., Z. Hercowitz and P. Krusell (1997) "Long run implications of investment-specific technology shocks", *American Economic Review*, 87(3), 342-362.

[28] Hart, O. D. and J. Moore (1995) "Debt ad seniority: an analysis of the role of hard claims in constraining management", *American Economic Review*, 87(3), 567-585.

[29] Iacoviello, M. (2005) "House prices, borrowing constraints and monetary policy in the business cycle", *American Economic Review*, 95(3), 739-764.

[30] Iacoviello, M. and R. Minetti (2006) "International business cycle with domestic and foreign lenders", *Journal of Monetary Economics*, 53(8), 2267-2282.

[31] Kiyotaki, N and J. Moore (1997) "Credit cycles", *The Journal of Political Economy*, 105(2), 211-248.

[32] Krugman, P. R. (2008) "The international financial multiplier", *mimeo*, www.princeton.edu/~pkrugman/finmult.pdf.

[33] Jermann, U. J. and V. Quadrini (2011) "Macroeconomic effects of financial shocks", *American Economics Review*, forthcoming.

[34] Judd, K. L., F. Kubler and K. Schmedders (2002) "A solution method for incomplete markets with heterogeneous agents", *mimeo*.

[35] Justiniano, A., G. E. Primiceri and A. Tambalotti (2009) "Investment shocks and the relative price of investment", *Federal Reserve Bank of New York,* Staff Report no. 411.

[36] Kocherlakota, N. (2000) "Creating Business Cycle through Credit Constraints", *Federal Reserve Bank of Minneapolis Quarterly Review*, 24(3), 2-10.

[37] Michaelides, A. and S. Ng (2000) "Estimating the rational expectation model of speculative storage: a Monte Carlo comparison of three simulation estimators", *Journal of Econometrics*, 96, 231-266.

[38] McGuire, P. M. and G. Von Peter (2009) "The US dollar shortage in global banking", *BIS Quarterly Review*, March, 47-63.

[39] Mendoza, E. (2008) "Sudden Stops, Financial Crises and Leverage: a Fisherian Deflation of Tobin's Q", *Board of Governors of the Federal Reserve System*, International Finance Discussion Paper 960.

[40] Mendoza, E. G. (2010) "Sudden Stops, Financial Crises and Leverage", *American Economic Review*, 100(5), 1941-66.

[41] Mendoza, E. G. and K. A. Smith (2006) "Quantitative implications of a debt-deflation theory of Sudden Stops and asset prices", *Journal of International Economics*, 70, 82-114.

[42] Pavlova, A. and R. Rigobon (2008) "The role of portfolio constraints in the international propagation of shocks", *Review of Economic Studies*, 75(4), 1215-1256.

[43] Ruge-Murcia, F. (2007) "Methods to estimate dynamic stochastic general equilirbium models", *Journal of Economic Dynamics and Control*, 31, 2599-2636.

[44] Sercu, P. and R. Vanpée (2007) "Home bias in international equity portfolios: a review", *Catholic University of Leuven working paper*, AFI 0710.

[45] Tille, C. and E. Van Wincoop (2010) "International Capital Flows", *Journal of International Economics*, 80(2), 157-175.

[46] Trani, T. (2011) "Heterogeneous pledgeability: implications for premia and international portfolios", *working paper*.

A Appendix

A.1 Conditions for zero-order portfolios

The solution for the equity portfolio developed by DY is based on the allocation of capital across sectors. Since my model embeds the framework proposed by DY, the steady state allocation of capital is an important condition also here. Moreover, the portfolio diversification between home and foreign liabilities is, by construction, based on the collateral constraint. Through this channel, the allocation of capital leads to another steady state condition. In this appendix, I briefly derive both conditions.

Let the steady state level of the endogenous discount factors be denoted in the traditional way: $\beta^A = \zeta^A \left(1+\bar{c}^A\right)^{-\phi}$ and $\beta^P = \zeta^P \left(1+\bar{c}^P\right)^{-\phi}$. Then, from (24), the gross rate of interest is

$$\bar{R}_H = \bar{R}_F = \bar{R} \equiv \frac{1}{\beta^P}$$

which, combined with (18), yields the GP on funding:

$$\frac{\bar{\mu}}{\beta^A \left(\bar{c}^A\right)^{-\sigma}} = \frac{\beta^P - \beta^A}{\beta^A \beta^P} > 0$$

Plugging the GP into (20)-(21), I find the return on equity:

$$\bar{r}_H = \bar{r}_F \equiv \bar{r} = \frac{1}{\beta^A} - \bar{\kappa} \frac{\bar{\mu}}{\beta^A \left(\bar{c}^A\right)^{-\sigma}} > \bar{R}$$

Being it the active investors' pricing of capital, this equation can be combined with passive investors' pricing of capital (25) as well as with the clearing condition (34). Given the distortion in pricing caused by collateral constraints (Aiyagari and Gertler, 1999), this step allows DY obtain a necessary condition for the diversification between home and foreign equities.

CONDITION 1. By definition, equities are in positive net-supply. So the cross-country diversification of the capital used to produce final goods, $n\bar{\chi}^A$, is conditional on the allocation of domestic capital across sectors. The following system pins down $\bar{\chi}^A$ and $\bar{k}^P$:

$$\begin{aligned} \frac{1}{1-\beta^P} \nu z \left(\bar{k}^P\right)^{\nu-1} &= \frac{\beta^A}{1-\beta^A - \bar{\kappa} \frac{\bar{\mu}}{\left(\bar{c}^A\right)^{-\sigma}}} \bar{d} \\ n\bar{\chi}^A + (1-n)\,\bar{k}^P &= 1 \end{aligned}$$

with

$$\bar{\chi}^A = \bar{k}^A + \bar{k}^{*A}$$

Under binding constraints, I can combine this result with (15) in order to obtain the total size of the collateral pledged by active investors to passive investors. This identifies the necessary condition to determine the diversification between home and foreign liabilities.

CONDITION 2. From active investors' viewpoint, secured bonds behave like assets that are in positive net supply. The per-capita amount of secured bonds depends on the volume of collateral and the steady state value of all asset prices:

$$\bar{B}^A = \frac{\bar{\kappa}\bar{q}^e\bar{\chi}^A}{\bar{q}^b}$$

with

$$\bar{B}^A = \bar{b}^A + \bar{b}^{*A}$$

A.2 The SMM estimation

I consider my OECD sample of 12 countries. My target is to estimate on the basis of cross-country averages, given an unbalanced panel and the longest possible time series, I have to make the following two choices: 1) I set $T = 35$ and consider the period 1975-2010; 2) I drop Belgium and Germany.

My approach is based on a logic which combines various existing studies. Iacoviello (2005) obtains an empirical measure of the effects of loan-to-value ratios by matching impulse response functions. Michaelides and Ng (2000) applying simulation estimators to the speculative storage model, find that a set of moments which includes the skewness and the kurtosis of commodity prices performs better than a set of moments that does not. In empirical finance, the use of GARCH models for the conditional variance of log-returns on assets is the standard way to go. Brunnermeier and Pedersen (2009) adopt a similar approach assuming that the dynamics of economic fundamentals follow an ARCH process, which thus influence the margin set by lenders.

On the basis of these types of studies and various attempts, I choose to proxy $\epsilon_{\kappa t}, \epsilon_{\kappa^* t}$ with an AR(1) process for the log-return on local stock market indices and to match the following four moments: 1) the home consumption-output correlation; 2) the home stock price-output correlation; 3) the skewness of equity returns; 4) the kurtosis of equity returns. In this way, I do not impose GARCH effects from the very beginning yet I control, simultaneously, for their presence as well as for the suitability of the model to reproduce them. Indeed, there is no suitable a priori assumption on the possibility to find the notorious volatility clustering in aggregate data and on whether the theoretical model can capture it.

Then, the variables involved in the estimation and corresponding data series are reported below:

Var.	Definition in model	Data
Y_H	H country output of final goods	GDP at current market prices
c	aggregate consumption of final goods at H	Private final consumption expenditures
q_H^e	H country equity price	Share prices, Index

where the data are taken from the OECD Stat Extracts database, as in other instances of the calibration.

Let $M_t(\psi)$ be the vector of moments computed on the simulated time-series and M_t^d that of empirical moments. Then, given the results in Duffie and Singleton (1993), my estimation problem can be described as follows:

$$\begin{aligned} G_T(\psi) &= \frac{1}{T}\sum_{t=1}^{T} M_t^d - \frac{1}{\tau}\sum_{t=1}^{\tau T} M_t(\psi) \\ \hat{\psi} &= \arg\min_{\psi\in\Psi} G_T(\psi)' W_T G_T(\psi) \\ W_T &= \left(1+\frac{1}{\tau}\right)\sum_{j=-\infty}^{\infty} E\left[\left(M_t^d - EM_t^d\right)\left(M_{t-j}^d - EM_{t-j}^d\right)'\right] \\ \sigma_{\hat{\psi}}^2 &= \left(1+\frac{1}{\tau}\right)\left(D' W_T^{-1} D\right)^{-1} \\ OIR &= \left(1+\frac{1}{\tau}\right) T G_T\left(\hat{\psi}\right)' W_T G_T\left(\hat{\psi}\right) \to \chi^2(3) \end{aligned}$$

Note that the optimal weighting matrix, W_T, coincides with the empirical covariance matrix, Σ_0^{-1}, where the approximation is largely satisfied for $\tau \to \infty$. Σ_0^{-1} is computed with the Newey-West estimator. The derivatives $D = E\partial M_t(\psi)/\partial\psi$ are computed computed numerically as the time-mean of two-sided differences. The only caveat of this numerical approximation is that I minimize with a grid search, a "derivative-free" method. As a result, for sure I cannot evaluate differences between points that exceed the grid, and the shape of the criterion function, $G_T(\psi)' W_T G_T(\psi)$, should be replicated at best. To take this into account, I expand my grid as much as possible (unfortunately, losing in terms of computational speed), and I account for the direction of the grid along which I compute the derivative.

Grid search: a justification. The model at hand does not only involve solving for the first-order behavior of model variables, but also for an endogenous portfolio allocation. In this sense, it is not obvious to cast the model into a unique function to supply to pre-existing optimization procedures. I thus refrain from influencing the core part of the paper, the computation of equilibrium portfolios, and rely more heavily on optimization procedures which can be rather easily programmed, namely, grid

search and ascent gradient. But since the latter was not performing better than the former and entailed more "baby-sitting", I have eventually opted for the grid search.

Intuitively, the grid search is good enough for my purpose, because the estimation of ψ or ψ^* is simplified by the fact that $\psi + \psi^* \in [0, \bar{\kappa}]$. The only difficulty is that making just one parameter vary (or the two varying simultaneously in opposite directions) does not allow to find an optimum. So the strategy I follow is to start with an equal range for both parameters which implies $\psi + \psi^* < \bar{\kappa}$, to increase this range progressively until $\psi + \psi^* = \bar{\kappa}$, estimating at each iteration. In such a way, I find an interior and significant optimum (Figure 4), using a large grid for both ψ and ψ^*. The drawack of such large grids is that the required computational time increases substantially.

TABLE 1. Calibrated coefficients, except margin setting

Parameter	Description	Value
from previous studies		
n	number of constrained investors	0.5
ϕ	discount factor parameter	0.022
γ	share of home goods in consumption	0.72
θ	elasticity of substitution in consumption	0.85
γ_I	share of home goods in investment	0.75
θ_I	elasticity of substitution in investment	0.9
σ	CRRA	2
α	capital share in income	0.4
z	fixed productivity in backyard production	1
ν	degree of homogeneity in backyard sector	0.1
from UK, US (rates) and OECD (shocks) data		
$\overline{R}$	gross rate of interest	1.0418
$\bar{\mu}/\beta^A \left(\bar{c}^A\right)^{-\sigma}$	guarantee premium	0.001134
σ_A^2	TFP shock: volatility	0.015^2
σ_Ξ^2	investment shock: volatility	0.017^2
ρ_A	TFP shock: persistence	0.81
ρ_Ξ	investment shock: persistence	0.85
$\rho\left(\varepsilon_{At}, \varepsilon_{A^*t}\right)$	TFP shocks: cross-country correlation	0.45
$\rho\left(\varepsilon_{\Xi t}, \varepsilon_{\Xi^*t}\right)$	investment shocks: cross-country correlation	0.26

TABLE 2. Calibrating the steady state κ

chosen strategy: OECD data on lenders		
Passive investors	Shares-to-Assets Ratio $\frac{\bar{q}^e \bar{k}^P}{\left(\bar{q}^e \bar{k}^P - \bar{q}^b \bar{B}^P\right)}$	Model implied $\bar{\kappa}$
Investment funds	0.49	-
Insurance corporations and pension funds	0.42	-
Model	0.45	0.31
alternative strategy: US data on borrowers		
	Debt-to-Assets Ratio: $\bar{\kappa}$	
Active investors	Total assets	Assets (No household/public)
Shadow banks[1]	0.351	0.293
Commercial banks	-	0.224
Commercial banks (no mutual funds shares)	-	0.221

Source: Institutional Investor Statistics, OECD database; Flow of Funds Accounts of the U.S., Federal Reserve Statistics.

[1] Shadow banks are finance companies, funding corporations, issuers of ABCP and security broker-dealers.

TABLE 3. Estimating the haircut through the debt-to-asset ratio

	Estimate[1] s.e.	Criterion function	p-value OIR test	Moments to match			
				$\rho\left(c_t, Y_t\right)$ [3]	$\rho\left(q^e_{Ht}, Y_t\right)$	$Skew\left(r_{Ht}\right)$	$Kurt\left(r_{Ht}\right)$
data: $T = 35$	-	-	-	0.9241	0.7152	-0.7260	2.6880
SMM: $\tau = 10$	$0.1233^{\dagger\dagger\dagger}$ 0.0020	0.1513	0.1204	0.6792	0.6236	0.0050	2.7683
SMM: $\tau = 20$	$0.1215^{\dagger\dagger\dagger}$ 0.0049	0.1499	0.1381	0.7229	0.6783	-0.0556	2.7433
SMM: $\tau = 30$	$0.1260^{\dagger\dagger\dagger}$ 0.0034	0.1488	0.1458	0.7021	0.6676	-0.0733	2.5614
			chosen parametrization				
	ψ	Implied ψ^*		ρ_κ	σ^2_κ	$\rho\left(\varepsilon_{\kappa t}, \varepsilon^*_{\kappa t}\right)$	$\rho\left(\varepsilon_{\kappa t}, \varepsilon_{it}\right)$ [2]
drivers	0.126	0.185	shock	0.37	0.03^2	0.64	0

[1] $\dagger\dagger\dagger$ means that the confidence level is $p < 0.001$.

[2] $i = A, \Xi$, meaning that the shock to κ is uncorrelated with other types of shocks.

[3] In the model, c_t is (country H) consumption of final goods only, as backyard production is a substitute for them in lenders' preferences: $c_t = n\left(c^A_{Ht} + c^A_{Ft}\right) + (1-n)\left[c^P_{Ht} + c^P_{Ft} - z\left(k^P_{Ht-1}\right)^\nu\right]$.

TABLE 4. Portfolios at market prices and in terms of total output

	Home		Foreign		Fin. wealth
	Equity	Bond	Equity	Bond	
investors					
Home passive	0.80	0.78	-	0.21	1.79
Home active	1.88	-0.78	1.30	-0.21	2.19
Foreign passive	-	0.21	0.80	0.78	1.79
Foreign active	1.30	-0.21	1.88	-0.78	2.19
Market clearing	3.98	0	3.98	0	7.96
sectors					
Home backyard: NT	0.80	0.99	-	-	1.79
Home final goods: T	3.18	-0.99	-	-	2.19
Foreign backyard: NT	-	-	0.80	0.99	1.79
Foreign final goods: T	-	-	3.18	-0.99	2.19
cross-border trading					
Home assets	1.30	0.21	-	-	1.51
Foreign assets	-	-	1.30	0.21	1.51

TABLE 5. Sensitivity: home bias and *implied* effect of collateral on credit risk

		Fin. home bias %		Credit risk	
	Value used	Equity	Secured debt	Local c.	Foreign c.
Baseline calibration	-	59.1	78.8	0.213	0.450
sensitivity analysis					
Greater home bias in consumption	$\gamma = 0.82$	59.8	79.8	0.211	0.457
Greater substitutability in consumption	$\theta = 1.05$	56.9	94.9	0.221	0.427
Greater home bias in investment	$\gamma_I = 0.85$	69.0	88.9	0.183	0.593
Greater substitutability in investment	$\theta_I = 1.1$	58.9	79.8	0.214	0.448
Greater leverage	$\bar{\kappa} = 0.41$	59.1	92.4	0.282	0.595
Inverted role of prices in credit risk	$\psi = 0.181$	59.1	78.8	0.311	0.301

Note: In terms of the results in Table 4, the definitions in the table at hand are as follows:

a) local bias in asset $i = \frac{\text{H (F) active investors' ownership of H (F) asset } i}{\text{stock of asset } i \text{ used by H (F) final goods sector}}$, where i = equity, bond

b) effect of local collateral on domestic investors' creditworthiness = $\frac{\psi}{\text{local equity bias}}$

c) effect of foreign collateral on domestic investors' creditworthiness = $\frac{\psi^*}{\text{1 - local equity bias}}$

TABLE 6. Binding costraints: deleveraging and amplification

Shocks per country		ε_{At}		$\varepsilon_{At}, \varepsilon_{\kappa t}$	$\varepsilon_{At}, \varepsilon_{\Xi t}$
Model	DY (2010)	Model herewith			
Version	(1)	loss spiral only (2)	baseline (3)	baseline (4)	baseline (5)
	coefficient % num. s.e.	coefficient % num. s.e.	coefficient % num. s.e.	coefficient % num. s.e.	coefficient % num. s.e.
q^e_{Ht}	0.0339 0.0002	−0.0875 0.0008	−0.0925 0.0009	−0.1085 0.0008	−0.0783 0.0008
q^e_{Ft}	0.0305 0.0002	10.1115 0.0791	10.1065 0.0791	10.0906 0.0791	10.1226 0.0791
χ^A_{Ht}	0.0570 0.0004	−0.1084 0.0011	−0.1179 0.0011	−0.1457 0.0011	−0.1095 0.0011
χ^A_{Ft}	0.0753 0.0004	1.0639 0.0082	1.0544 0.0082	1.0266 0.0082	1.0671 0.0082
I_t	−	1.2398 0.0086	1.2363 0.0085	1.2100 0.0086	1.1387 0.0086
I^*_t	−	1.2398 0.0086	1.2363 0.0085	1.2100 0.0086	1.1387 0.0086
B^A_{Ht}	0.4731 0.0085	−0.0347 0.0030	−0.0464 0.0030	0.0172 0.0030	−0.0259 0.0030
B^A_{Ft}	1.3246 0.0085	5.7969 0.0473	5.7852 0.0473	5.8489 0.0473	5.8183 0.0473
R_{Ht}	0.0077 0.0001	−0.0076 0.0001	−0.0054 0.0001	0.0068 0.0001	−0.0054 0.0001
R_{Ft}	0.0121 0.0001	0.1722 0.0010	0.1744 0.0010	0.1866 0.0010	0.1742 0.0010
p_{Ft}	−	7.3262 0.0574	7.3262 0.0574	7.3263 0.0574	7.3237 0.0574

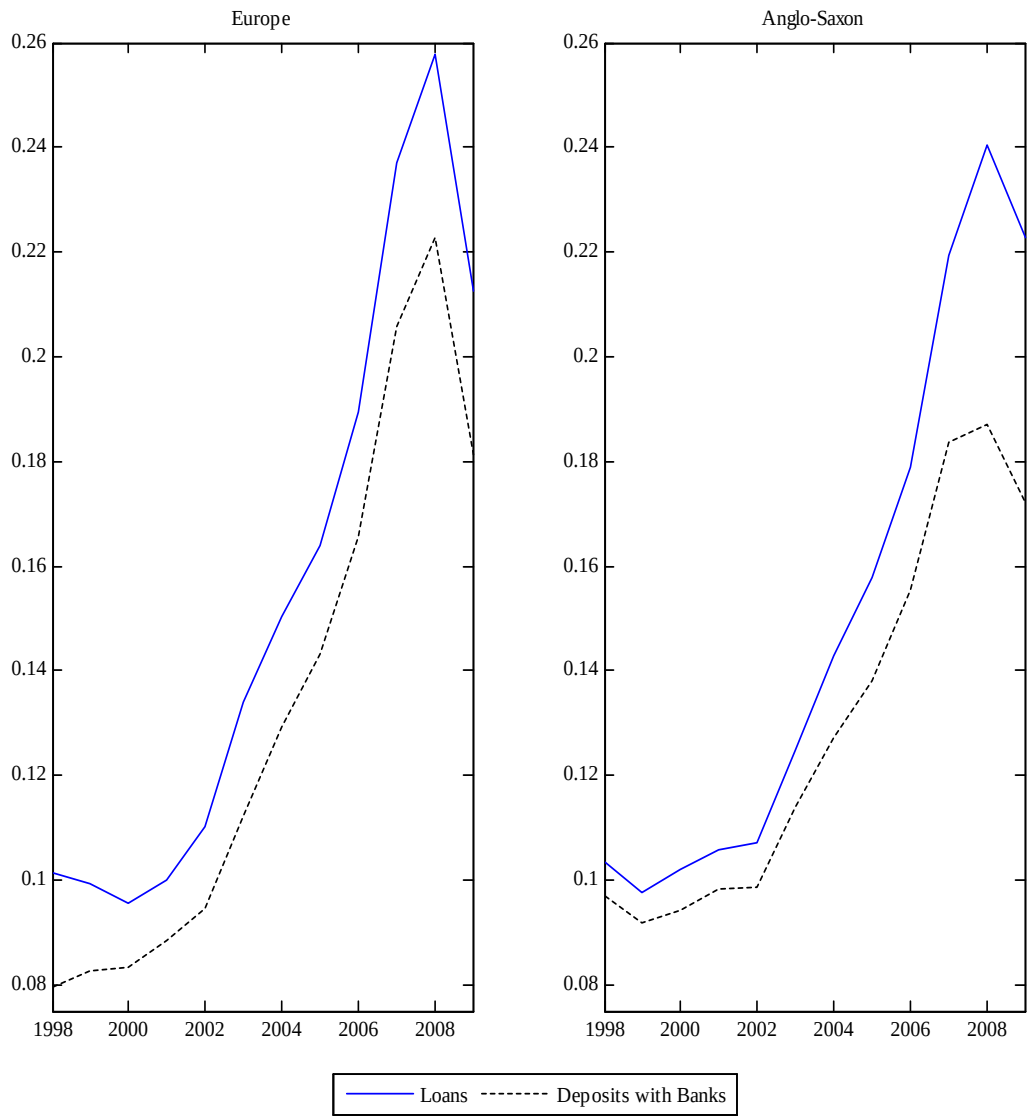
q^e_i	price of equity i
χ^A_i	per-capita stock of capital in country i
I, I^*	investment bundles
B^A_i	per-capita debt stock, expressed in terms of good i
R_i	rate of interest on debt issued in terms of country i good
p_F	foreign good price

TABLE 7. Unexpected tightening: margin spirals and risk

Shocks per country		ε_{At}		$\varepsilon_{At}, \varepsilon_{\kappa t}$	$\varepsilon_{At}, \varepsilon_{\Xi t}$	$\varepsilon_{At}, \varepsilon_{\kappa t}$
Model	DY (2010)	Model herewith				
Version	(1)	loss spiral only (2)	baseline (3)	baseline (4)	baseline (5)	no $\bar{m}/\bar{\kappa}$ in eq. 30 (6)
	vol. ratio num. s.e.	vol. ratio num. s.e.	vol. ratio num. s.e.	vol. ratio num. s.e.	vol. ratio num. s.e.	vol. ratio num. s.e.
q^e_{Ht}	1.2799 0.0010	1.0647 0.0043	1.0484 0.0042	1.0704 0.0054	1.0600 0.0054	1.0537 0.0045
q^e_{Ft}	1.2793 0.0010	0.0492 0.0008	0.0485 0.0008	0.0495 0.0007	0.0490 0.0007	0.0487 0.0008
χ^A_{Ht}	4.6477 0.0310	1.2333 0.0154	1.0305 0.0129	1.4819 0.0262	1.0466 0.0137	1.1413 0.0163
χ^A_{Ft}	4.7102 0.0321	0.2389 0.0036	0.1993 0.0030	0.2878 0.0056	0.2020 0.0031	0.2213 0.0036
I_t	–	0.2913 0.0037	0.2491 0.0034	0.4559 0.0091	0.3654 0.0066	0.3032 0.0050
I^*_t	–	0.2913 0.0037	0.2491 0.0034	0.4559 0.0091	0.3654 0.0066	0.3032 0.0050
B^A_{Ht}	0.8865 0.0155	1.1035 0.0211	1.0625 0.0205	1.6791 0.0366	1.0723 0.0205	1.2084 0.0237
B^A_{Ft}	0.8983 0.0149	0.1429 0.0025	0.1371 0.0024	0.2215 0.0051	0.1386 0.0025	0.1578 0.0031
R_{Ht}	0.5853 0.0032	0.5441 0.0037	0.6998 0.0080	1.8914 0.0333	0.7044 0.0081	1.0599 0.0165
R_{Ft}	0.5778 0.0035	0.0510 0.0004	0.0657 0.0008	0.1710 0.0030	0.0660 0.0008	0.0970 0.0015
p_{Ft}	–	0.0794 0.0004	0.0794 0.0008	0.0794 0.0030	0.0806 0.0008	0.0794 0.0015

q^e_i	price of equity i
χ^A_i	per-capita stock of capital in country i
I, I^*	investment bundles
B^A_i	per-capita debt stock, expressed in terms of good i
R_i	rate of interest on debt issued in terms of country i good
p_F	foreign good price

FIGURE 1. External positions in all currencies (share of world GDP)



Source: BIS Locational banking statistics; The World Bank WDI

Note: The group of European countries is formed by Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland. The group of Anglo-Saxon countries is made by Australia, Canada, Japan, U.K., U.S.

FIGURE 2. Financial transactions in Devereux and Yetman (2010)

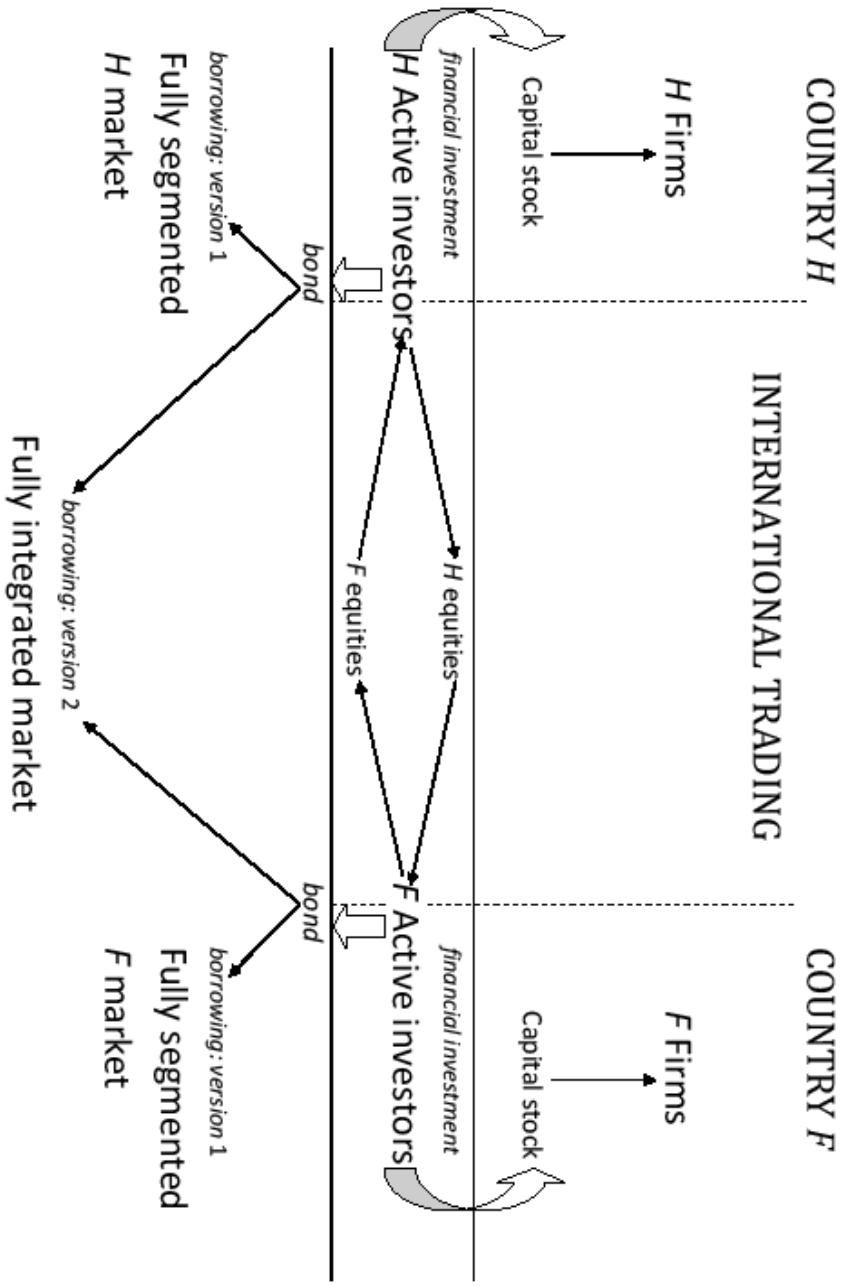


FIGURE 3. Financial transactions in the model herewith

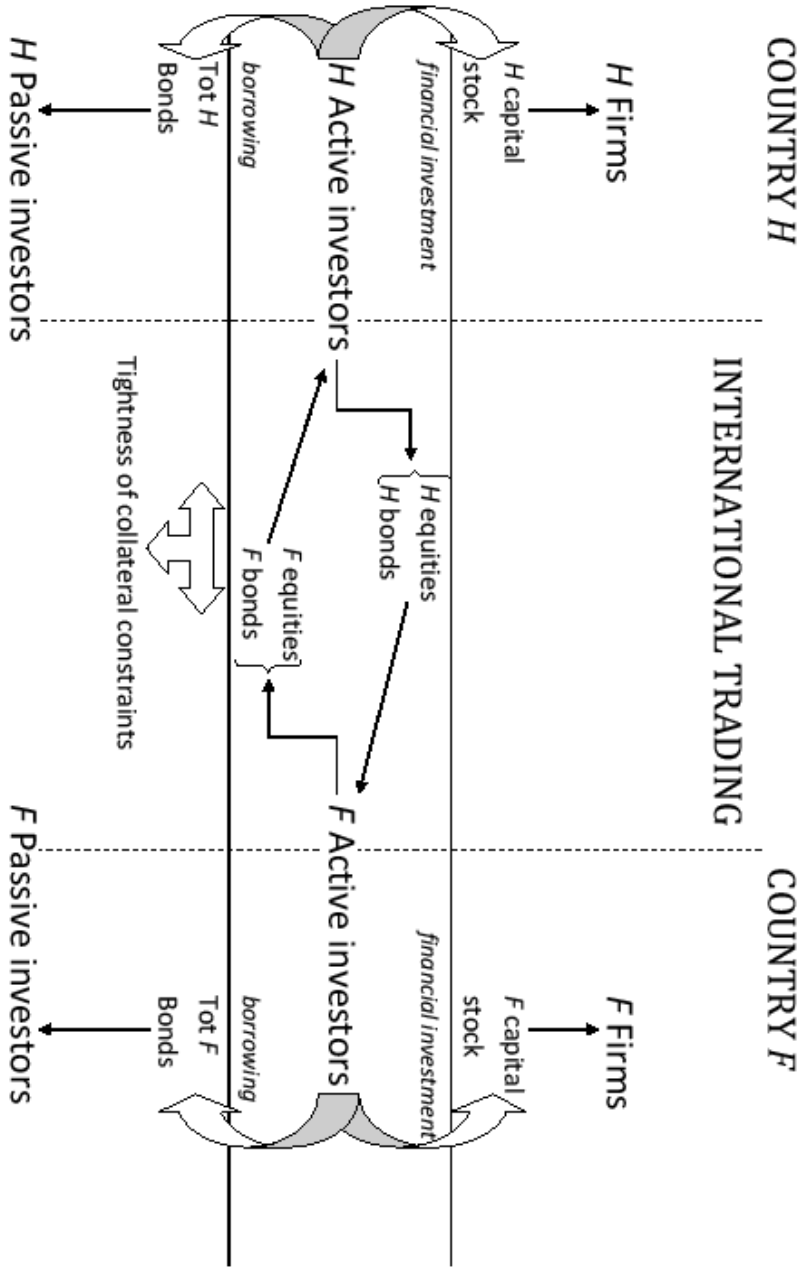


FIGURE 4. Determination of coefficient(s) with the SMM algorithm (case with $\tau = 30$)

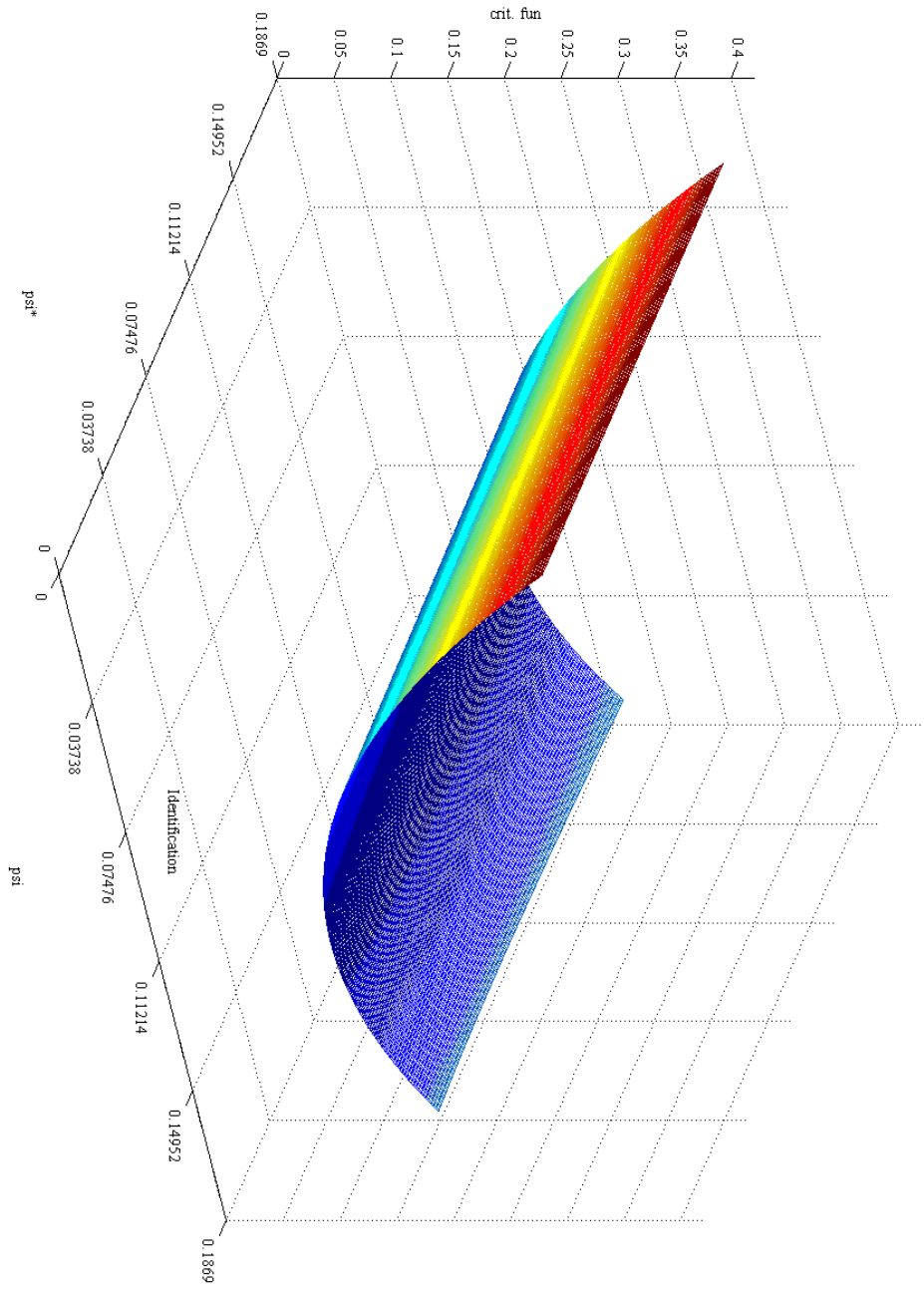


FIGURE 5. Responses to home productivity shocks: loss spirals with adjusting haircuts

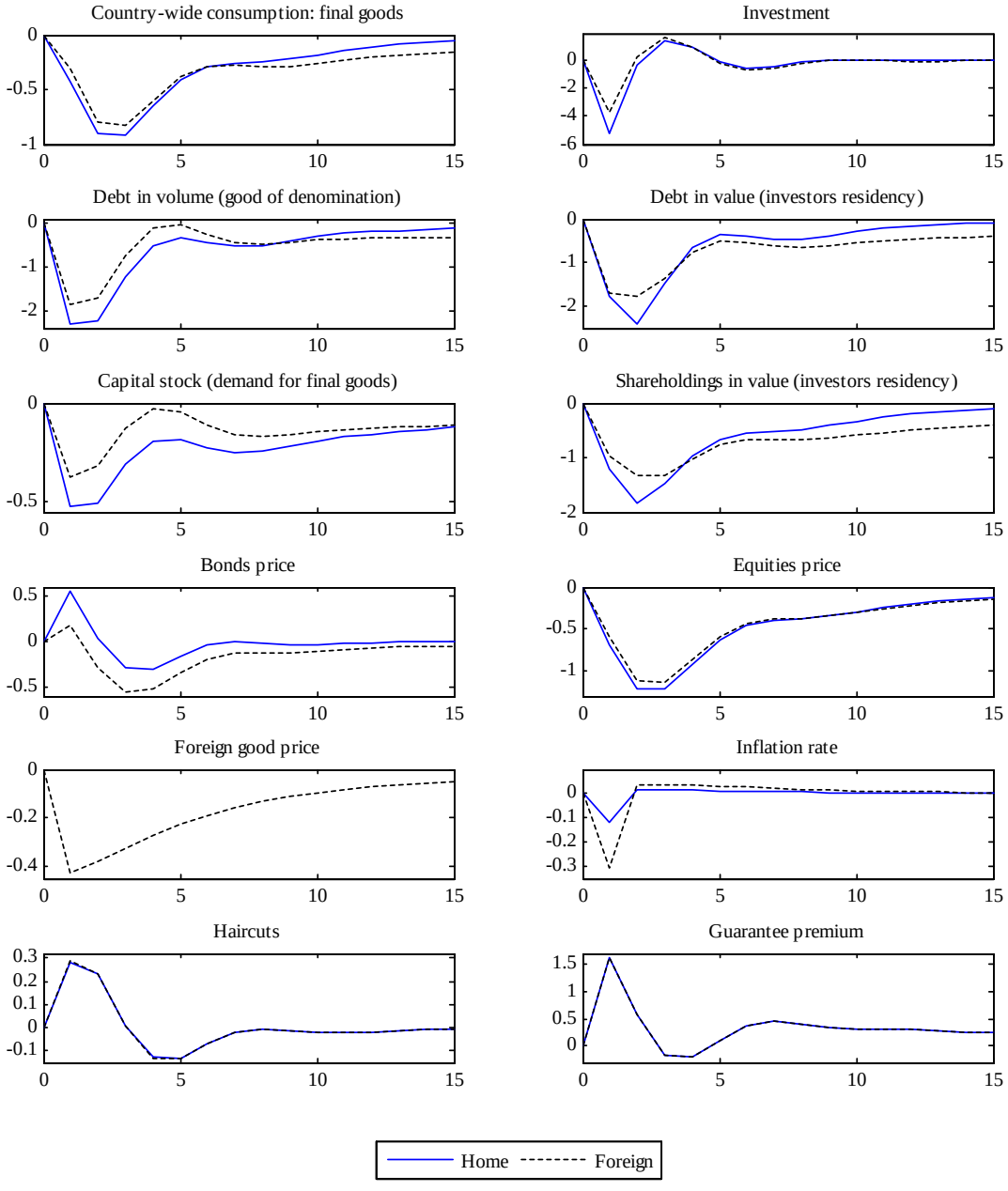


FIGURE 6. Responses to home productivity shocks: loss spirals without adjusting haircuts

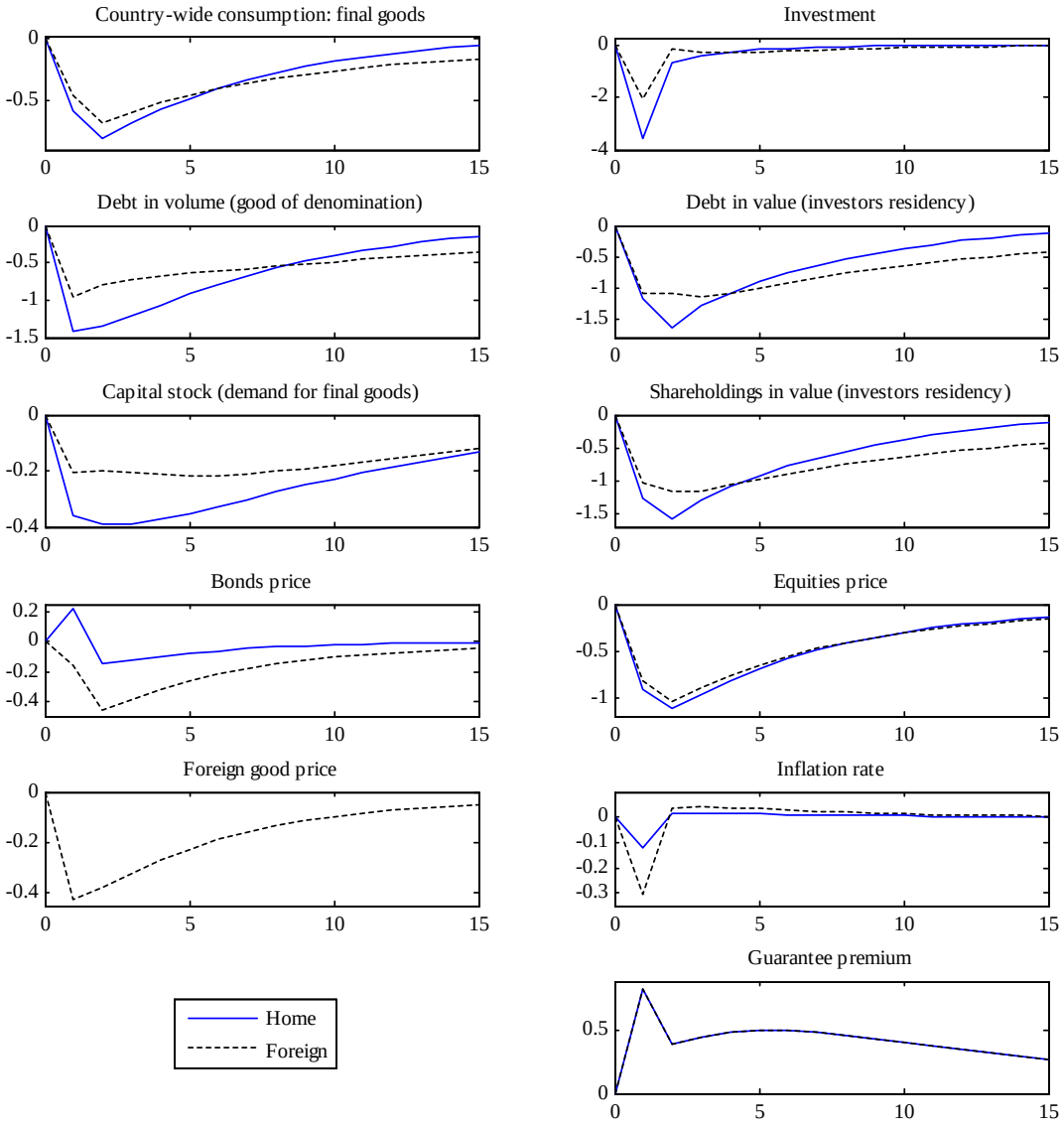


FIGURE 7. Home productivity shocks: the differential effect of adjusting haircuts

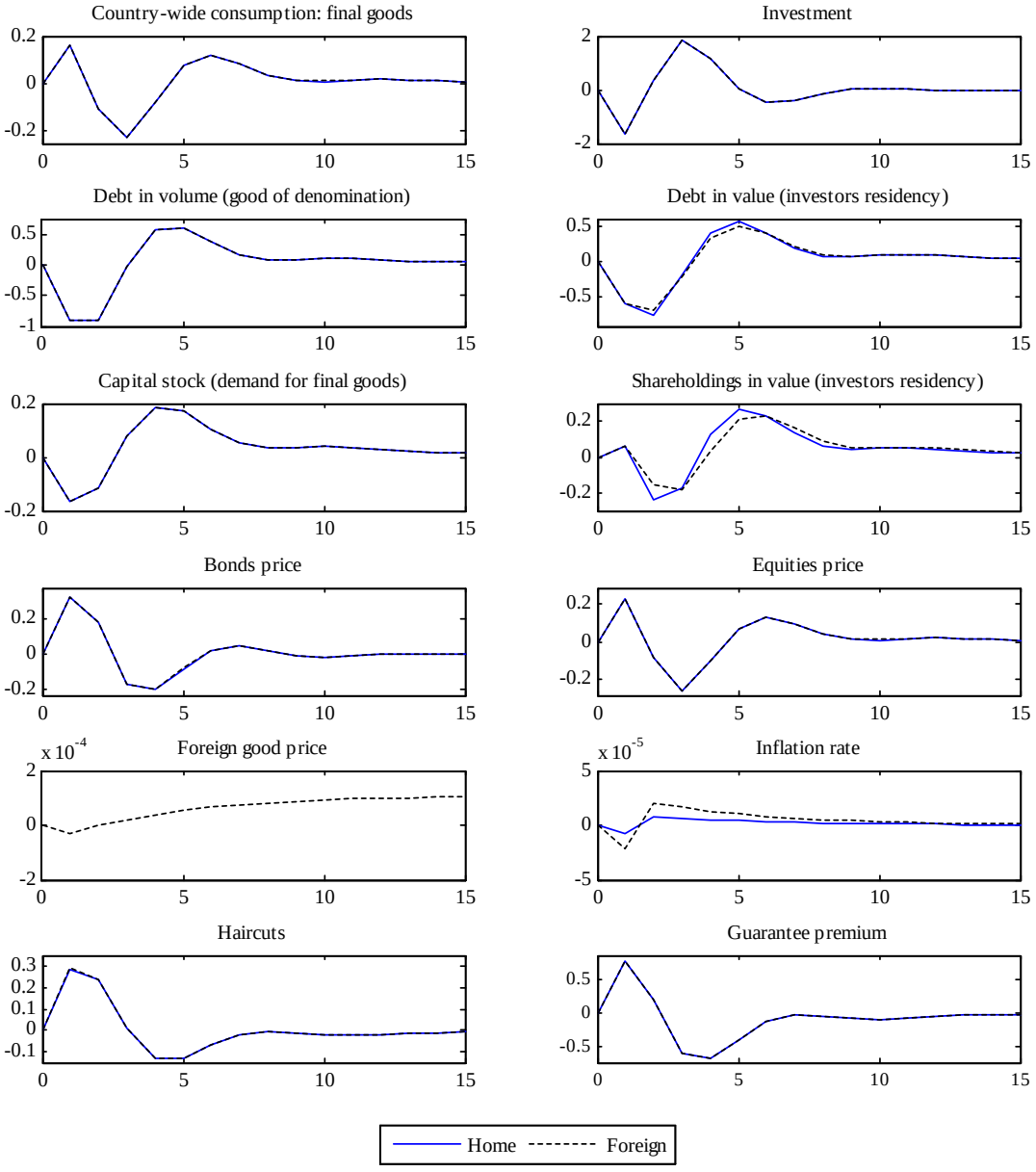
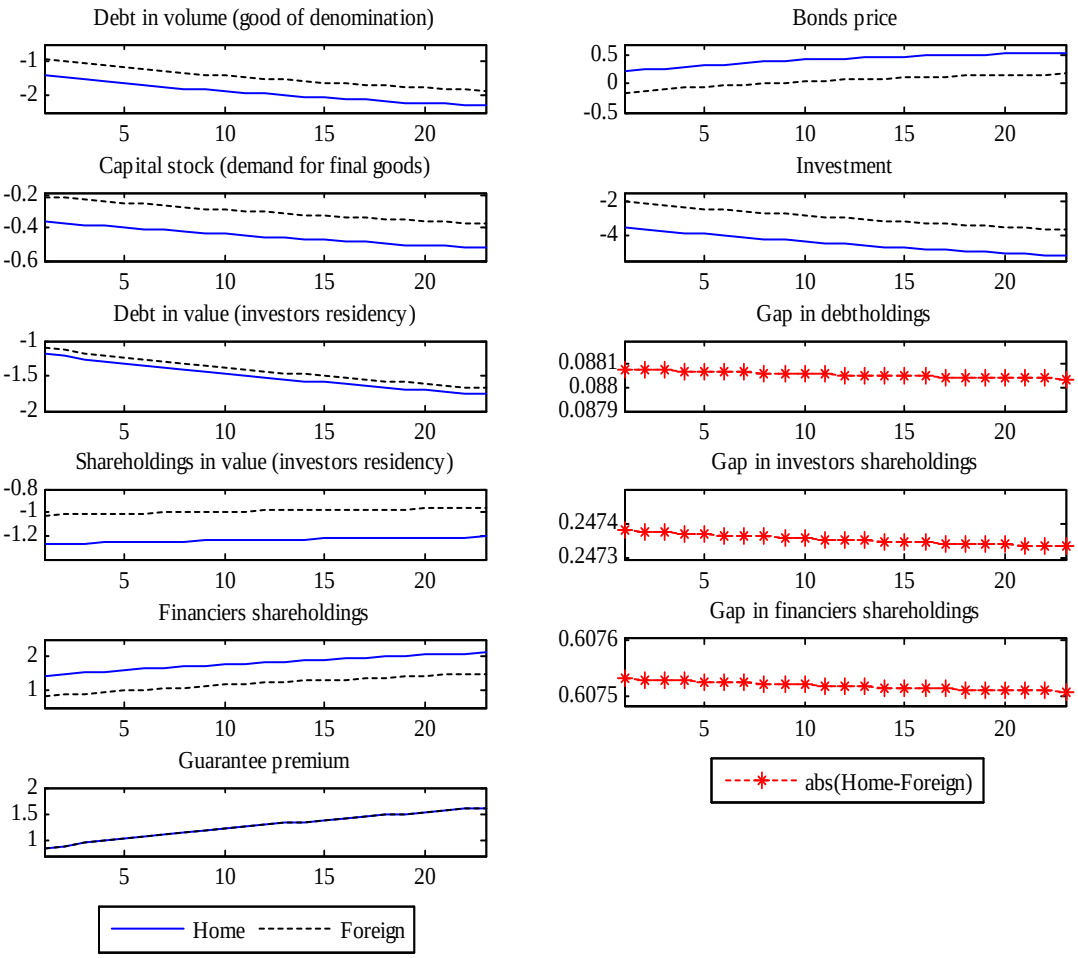
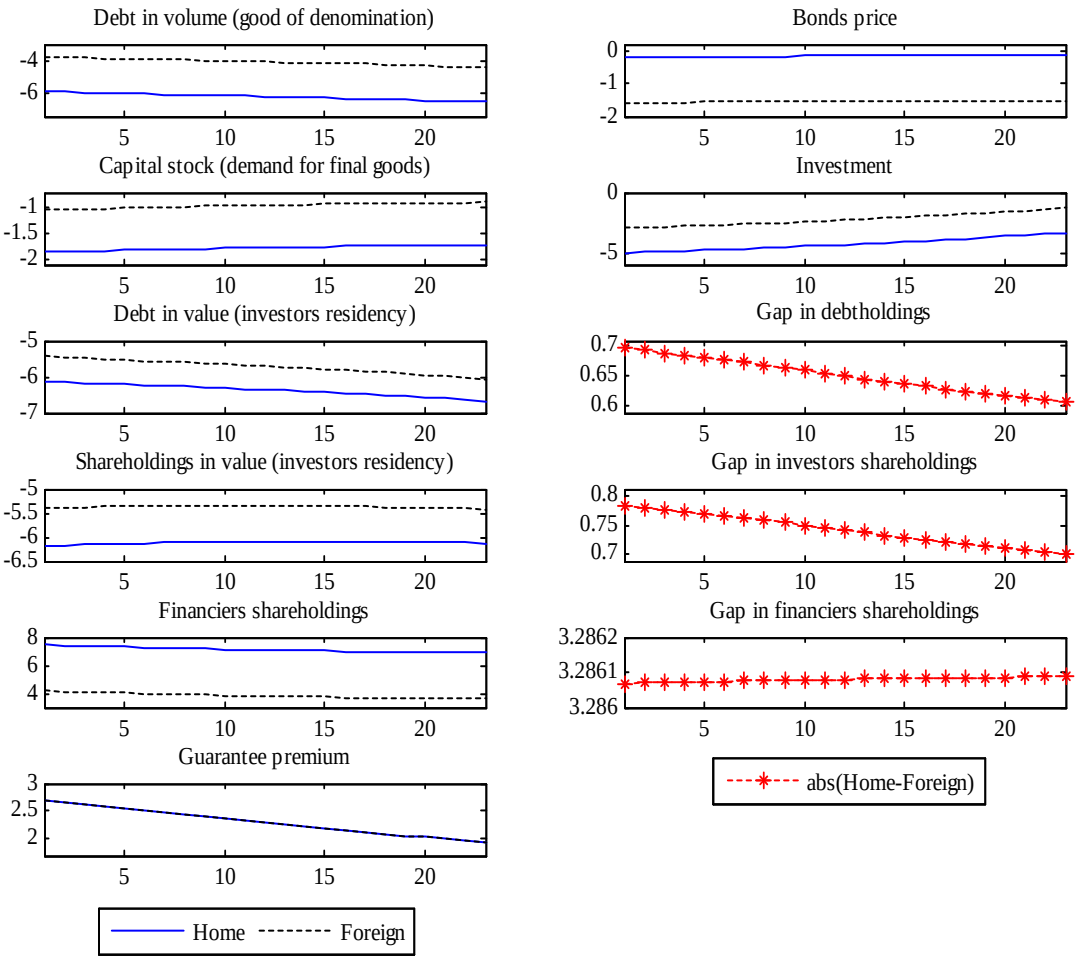


FIGURE 8. Decomposing the contribution of haircuts: Impact multipliers



Note: ψ, ψ^* simultaneously increase in their respective ranges, with 23 steps each: $\psi \in [0, 0.126]$, $\psi^* \in [0, 0.185]$. The number of steps is on the x-axis.

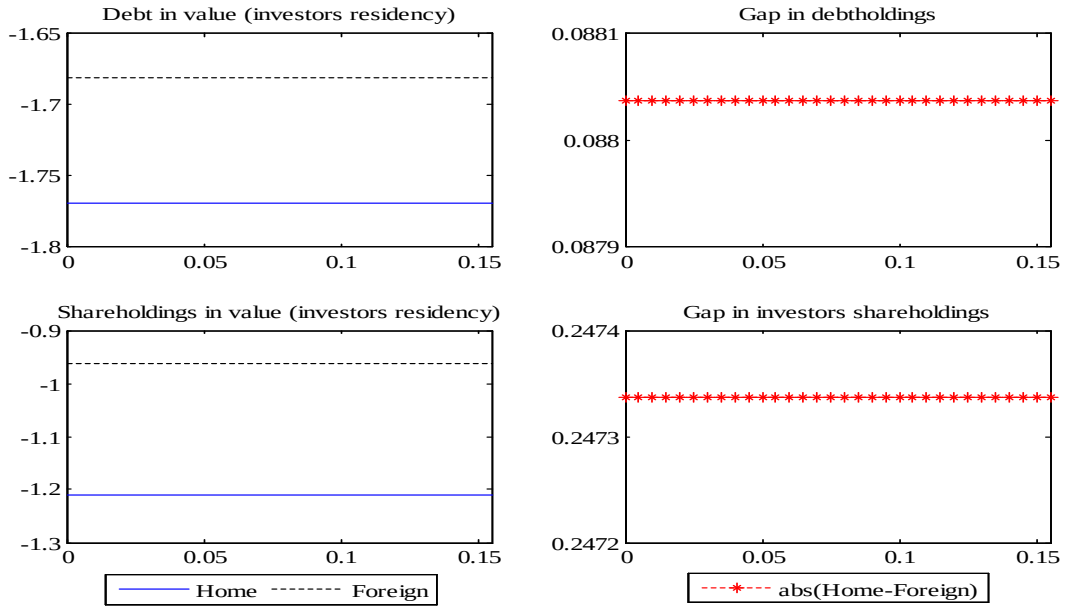
FIGURE 9. Decomposing the contribution of haircuts: Cumulative multipliers, lags 1-5



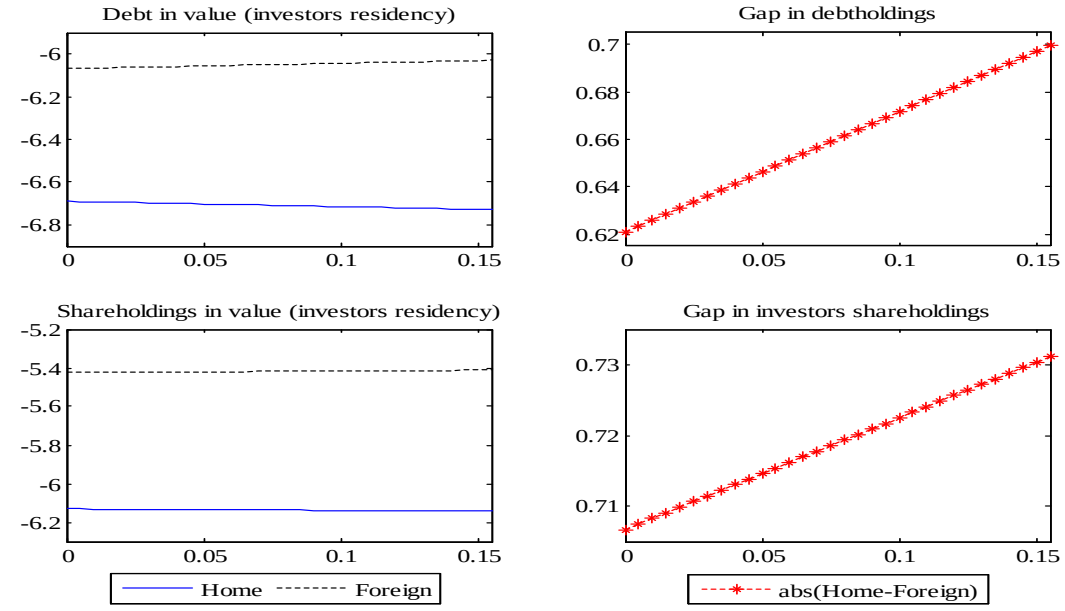
Note: ψ, ψ^* simultaneously increase in their respective ranges, with 23 steps each: $\psi \in [0, 0.126]$, $\psi^* \in [0, 0.185]$. The number of steps is on the x-axis.

FIGURE 10. Pledging collateral, a counterfactual: from financial integration to autarky

Impact multipliers



Cumulative multipliers, lags 1-5



Note: Complete financial integration is defined as $\psi = \psi^* = \bar{\kappa}/2$ and autarky as $\psi = \bar{\kappa}, \psi^* = 0$.