Asymmetric Financial Regulation and International Portfolio Choice
(Preliminary work, please do not cite or distribute)

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Abstract

Less financially regulated economies tend to be net international borrowers with international portfolios characterized by equity assets and debt liabilities. To explain this empirical regularity, we build a two-country DSGE model with both Ricardian and non-Ricardian households and a rich array of financial assets. Non-Ricardian households borrow to maximize current consumption, but the government regulates their borrowing limit to prevent household bankruptcy. One of the countries (home) features perfectly competitive financial intermediaries that exhibit moral hazard due to explicit bailout guarantees in case of their bankruptcy. To mitigate such behavior and avoid intermediary bankruptcy, the government imposes a capital requirement on these entities. With restrictive financial regulations, non-Ricardians and intermediaries do not experience bankruptcy; however, as regulation is loosened, bankruptcy emerges endogenously for both. Reduced regulations on only the home non-Ricardians lead to *riskier local assets*, which the financial intermediaries offset by going long in safe foreign debt assets. Conversely, reduced regulations on only the intermediaries generate moral hazard, which encourages them to go long in risky equity and short in safe debt. Instead of having an offsetting effect, reducing regulation on both groups amplifies the moral hazard by generating more opportunities for bankruptcy, further increasing the home country's portfolio risk profile.

Keywords: international portfolio choice, portfolio risk, financial regulation, moral hazard
JEL Classification: D52, F21, F41, G11, G18

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1 Introduction

In the aftermath of the global financial crisis, many countries enhanced their macroprudential policies to increase the resiliency of their banking systems. Concurrently, and likely not coincidentally, the share of non-bank financial intermediation (NBFI) grew (Figure 1), potentially undermining the intended policy effects as capital flows could be channeled through institutions not subject to these regulations. The implementation of these policies has not been perfectly coordinated internationally, creating regulatory asymmetries across the globe. In an earlier paper, we studied the impact of such asymmetries to show that national (unilateral) financial deregulation is associated with greater gross holdings of international financial instruments, overall negative net foreign assets (NFA), and a portfolio characterized by net equity (NE) assets and net debt (ND) liabilities (de Araujo et al., 2015). In this paper, we offer a theoretical underpinning for these findings by constructing a two-country model with an optimizing financial intermediary subject to moral hazard to study the effects of national regulatory asymmetries on international portfolio holdings.

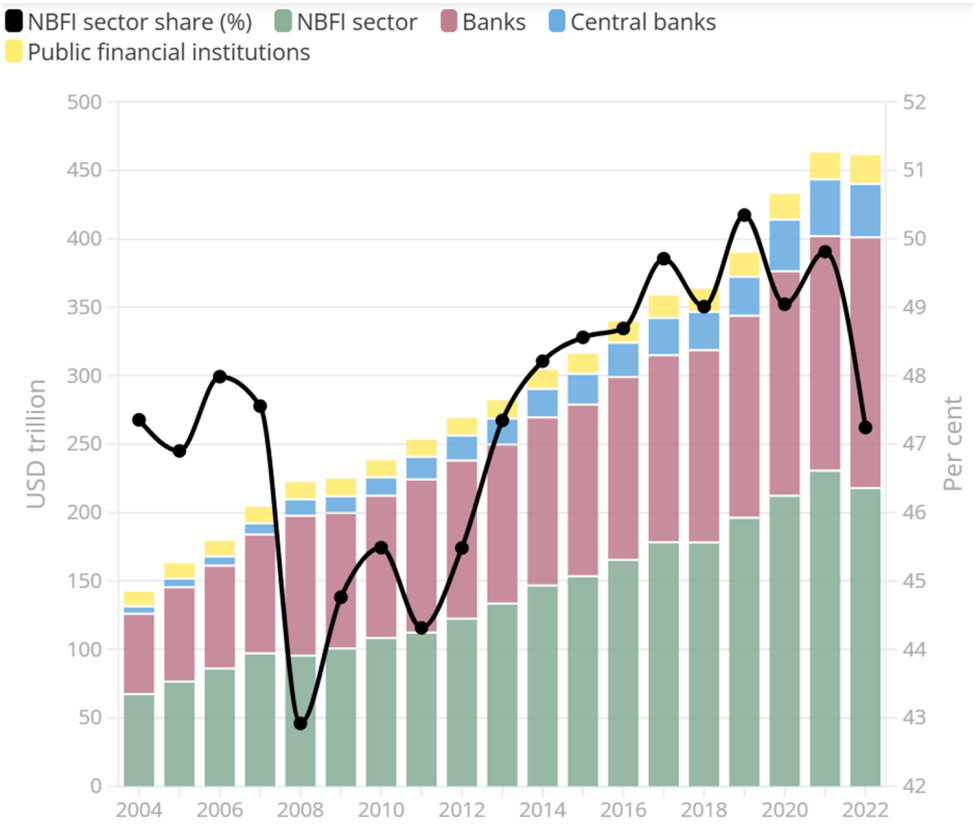


Figure 1: Borrowed from Financial Stability Board, 2023.

We begin our exploration of the relationship between regulatory asymmetries and the resulting capital holdings by first studying portfolio decisions of households who can trade in bonds and equity directly with each other in the absence of asymmetric information and financial intermediaries. In this simplified setting, we allow credit-constrained households to occasionally and endogenously default on their debts, and model financial regulation as a restriction on the amount of loans these households can take out. Contrary to the stylized facts presented in de Araujo et al. (2015), the less-regulated economy becomes a net international bond holder as unconstrained households offset the increased domestic risk by investing in safe foreign assets.

We next deepen the model by introducing perfectly competitive financial intermediaries that connect households within and across nations. We do not make an explicit distinction between banks and NBFIs and instead focus on the consolidated financial sector that participates in loan, bond, and equity markets. Viewing financial intermediaries as systemically important, national governments stand ready to bail them

out in the event of bankruptcy. The anticipation of a bailout in an adverse state of nature introduces moral hazard into the decision-making process of these institutions, which the governments aim to mitigate by regulating their capital-asset ratios. In the absence of international regulatory coordination, financial intermediaries endogenously rebalance their portfolio of local and international assets in such a way that the less-regulated economy goes long in equity and short in debt. This finding aligns with the work of Bengui and Bianchi (2022), who employ a small open endowment economy setting to show that macroprudential policies with asymmetric regulatory coverage tilt the profile of risky decisions from regulated to unregulated agents.

Interestingly, our model demonstrates an important nonlinearity in the impact of government regulation of *household* borrowing on international portfolio choice. When capital requirements on financial intermediaries are high, moral hazard is absent and relaxed restrictions on household borrowing lead to a net inflow of safe foreign bonds to offset the higher domestic risk of default. However, as capital requirements are lowered, domestic intermediaries experience moral hazard and adjust their portfolio composition to go long in NE and short in ND. This process becomes exacerbated by reduced borrowing restrictions on households. Higher rates of household default increase the likelihood of government bailout, amplifying moral hazard and shifting the national portfolio further towards positive NE and negative ND.

Although our model simulations indicate that a financially deregulated country may become a net borrow or lender, we are able to identify three mechanisms to explain the drivers of country indebtedness. First, when financial intermediaries suffer from moral hazard, they push down the yields on equities and raise the yields on bonds, causing their portfolio returns to decline. Second, because moral hazard places a wedge between the incentives of the financial intermediaries and the households who own them, a deregulated country tends to consume more and save less. Both of these mechanisms cause the country to become a net debtor; however, the third mechanism offsets these effects, as home bias in consumption causes income gains for the deregulated country as demand for its product rises when households lower savings.

Our work contributes to three related strands of literature. First, a growing set of papers have examined the patterns of international stocks of assets (Lane and Milesi-Ferretti, 2018) as well as the push and pull factors responsible for cross-border capital movements (Calvo et al., 1993, 1996; Fratzscher, 2012; Staveley-O'Carroll and Staveley-O'Carroll, 2017).

The second related strand of papers addresses the topics of macroprudential regulatory policies, national asymmetries in their application, and the resulting leakages of capital to the less-regulated financial entities. Many of the papers in this area focus specifically on bank regulation and the resulting bank investment decision (Ahnert et al., 2021; Bengui and Bianchi, 2018; Bruno and Shin, 2015; Gourinchas and Obstfeld, 2012; Krogstrup and Tille, 2018). In contrast, NBFIs have so far received less attention, although their sizable cross-border asset positions have been growing and in some countries, including the U.S., account for more than half of the entire financial sector (Financial Stability Board, 2023). Recent papers in this area include Avdjiev et al., 2020; Cerutti, Claessens, and Puy, 2019; Hashimoto and Krogstrup, 2019. In a setup close to ours, Gabaix and Maggiori (2015) use a two-country general equilibrium framework to study financiers who optimally adjust their balance sheets by trading in different currencies and thereby affect global risk allocation.

Third, our paper adds to the body of work examining moral hazard in the financial sector, which dates at last as far back as the contributions of Diamond and Dybvig (1983) and Kareken and Wallace (1978) and continues with the work of, among many others, Altinoglu and Stiglitz (2023), Dávila and Walther (2020), and Keister (2016).

The remainder of the paper is divided into two separate modeling sections, first without financial intermediaries (Section 2) and then with them (Section 3), followed by a discussion of the simulation results (Section 4) and concluding remarks (Section 5).

2 Frictionless financial markets: modeling endogenous default

The purpose of this paper is to provide a theoretical explanation for the empirical pattern of cross-border asset holdings described in Araujo et al. (2015): less financially regulated economies tend to be net international debtors with long positions in equity and short positions in bonds. To this end, we build a two-country dynamic stochastic general equilibrium (DSGE) model with both Ricardian and non-Ricardian households

in each country. Production is stochastic, exogenous, and governed by a discrete Markov process. The model contains a robust array of assets, yet not enough diversification options to form a complete market where risk is perfectly insurable. This is crucial, as incomplete markets are a necessary condition to allow for the relative wealth of the countries to evolve endogenously.

We begin this section by outlining a simplified version of the model in which neither country has a financial intermediary and the financial regulation targets the lending relationship between Ricardian and non-Ricardian households. Once we establish the baseline results of this setup, we will add a financial intermediary to the home country and use it to introduce moral hazard into the global asset market.

In our model, Ricardian households generally do not hit their borrowing constraints; we will refer to them as "unconstrained" using the subscript u. Non-Ricardian households, also known as hand-to-mouth consumers, reach their borrowing limit in each period and are thus "constrained," as we will indicate by the subscript r. The home country is denoted with h and foreign with f; however, whenever possible, we simplify the notation with home variables having no indicator and foreign variables identified with an *.

Finally, we assume complete price flexibility and abstract from any monetary policy considerations. We model all variables in real terms, priced in local CPI baskets.

2.1 Production

To reduce the number of state variables, we model both countries as endowment economies. Perishable output of each country is comprised of wages and dividends,

$$Y_t = W_t + D_t \tag{1}$$
$$Y_t^* = W_t^* + D_t^*, \tag{2}$$

each of which is determined exogenously by a two-state Markov process. Thus, home wages W_t can be either *low,* W_1, or *high,* W_2, and evolve according to the following symmetric transition matrix:

$$\Pr\left(W_t = W_1 | W_{t-1} = W_1\right) = \Pr\left(W_t = W_2 | W_{t-1} = W_2\right) = \lambda_w. \tag{3}$$

Home dividends, foreign wages, and foreign dividends follow processes analogous to (3) with parameters $\{D_1, D_2, \lambda_d\}$, $\{W_1^*, W_2^*, \lambda_w^*\}$, and $\{D_1^*, D_2^*, \lambda_d^*\}$, respectively. We link the two economies by assuming that the two dividend processes are correlated, and use the parameter $\rho_d = Corr\left(D_t, D_t^*\right)$ to control the strength of the relationship. Wages in each country are exogenously divided between unconstrained and constrained consumers:

$$W_{u,t} = \nu W_t \tag{4}$$
$$W_{r,t} = (1-\nu) W_t. \tag{5}$$

Perfectly competitive bundlers aggregate the two countries' outputs and make them available for consumption to the constrained and unconstrained consumers in the home and foreign countries, according to the CES aggregators[1]

$$C_{r,t} = \left[\phi_t^{1-\sigma}\left(C_{r,t}^{h,h}\right)^{\sigma} + (1-\phi_t)^{1-\sigma}\left(C_{r,t}^{h,f}\right)^{\sigma}\right]^{\frac{1}{\sigma}} \tag{6a}$$
$$C_{u,t} = \left[\phi_t^{1-\sigma}\left(C_{u,t}^{h,h}\right)^{\sigma} + (1-\phi_t)^{1-\sigma}\left(C_{u,t}^{h,f}\right)^{\sigma}\right]^{\frac{1}{\sigma}} \tag{6b}$$
$$C_{r,t}^* = \left[\phi_t^{1-\sigma}\left(C_{r,t}^{f,f}\right)^{\sigma} + (1-\phi_t)^{1-\sigma}\left(C_{r,t}^{f,h}\right)^{\sigma}\right]^{\frac{1}{\sigma}} \tag{6c}$$
$$C_{u,t}^* = \left[\phi_t^{1-\sigma}\left(C_{u,t}^{f,f}\right)^{\sigma} + (1-\phi_t)^{1-\sigma}\left(C_{u,t}^{f,h}\right)^{\sigma}\right]^{\frac{1}{\sigma}} \tag{6d}$$

The time-varying parameter ϕ_t captures the extent of home bias in consumption, and σ measures the constant elasticity of substitution between imports and exports. We assume that

$$\phi_t = \phi + e_t$$

[1] In this notation, $C_{r,t}^{h,f}$ indicates the current period (t) consumption (C) by the constrained (r) home (h) consumer of foreign (f) goods and services.

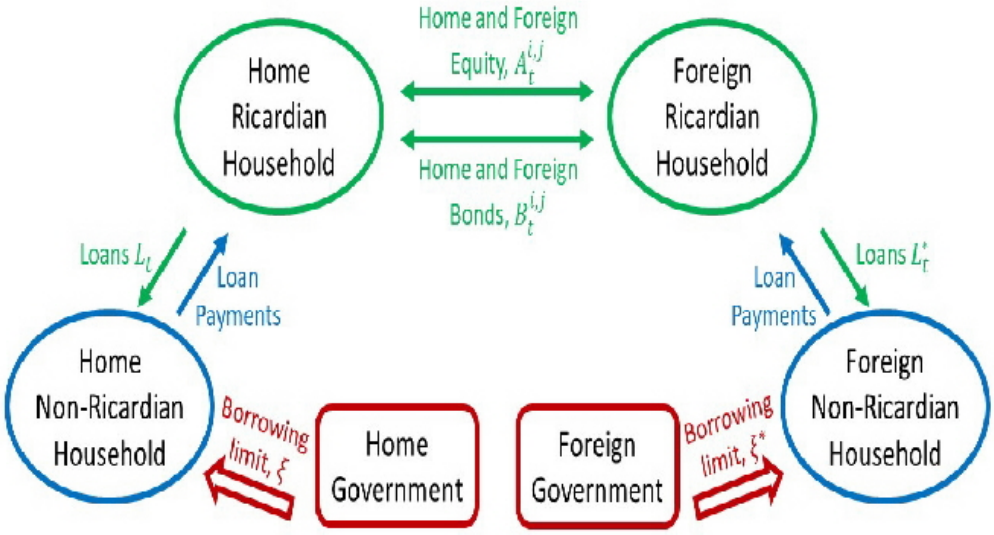


Figure 2: Capital flows without financial intermediation.

where e_t is an i.i.d. process with $e_t \in \{-e, e\}$.[2]

We define the exogenous state of the economy as $z_t = \{e_t, W_t, W_t^*, D_t, D_t^*\}$, which follows a first-order Markov process with finitely many states, $\mathcal{Z} = \{z_1, ..., z_{32}\}$.

Given the prices P_t^h and P_t^f of the home and foreign output measured in local currency, and assuming that the Law of One Price holds, the two countries' CPIs are

$$P_t = \left[\phi_t \left(P_t^h\right)^{\frac{\sigma}{\sigma-1}} + (1-\phi_t)\left(E_t P_t^f\right)^{\frac{\sigma}{\sigma-1}}\right]^{\frac{\sigma-1}{\sigma}} \tag{7}$$

$$P_t^* = \left[\phi_t \left(P_t^f\right)^{\frac{\sigma}{\sigma-1}} + (1-\phi_t)\left(E_t^{-1} P_t^h\right)^{\frac{\sigma}{\sigma-1}}\right]^{\frac{\sigma-1}{\sigma}}, \tag{8}$$

where E_t is the nominal exchange rate, expressed as the price of one unit of foreign currency in terms of home currency. In the rest of the paper, we normalize all prices on the local CPI level and write them using lower-case letters; we also define the real exchange rate as $q_t \equiv \frac{E_t P_t^*}{P_t}$.[3]

2.2 Households

The simplest version of the model contains four agents: home and foreign, Ricardian and non-Ricardian households trade assets with each other as summarized in Figure 2. This setting allows us to model the effects of borrowing constraints, generate endogenous bankruptcy, and introduce a government policy that limits borrowing to prevent bankruptcies. Once introduced, we can modify the stringency of the regulation to study its impact on financial markets.

[2] Judd, Kubler, and Schmedders (2003) show that in a standard Lucas tree model with time-separable preferences, complete asset markets, and no financial frictions, agents' portfolios are typically constant over time and states of nature; consequently, capital flows are absent in equilibrium. Since we want the net foreign asset positions of the two countries to evolve endogenously from *any* starting value in response to regulation asymmetries, we must move away from the assumption of complete markets. Having more shocks (two wage processes, two dividend processes, and home bias) than assets (two bonds and two stocks) is a sufficient condition for asset market incompleteness.

[3] Since we use our model to understand the dynamics of real prices and quantities, we could have alternatively designated the price of, for example, the home good as the numeraire and abstracted from nominal variables altogether. However, allowing each country to have its own currency results in a symmetric solution grid, which simplifies the interpretation of our results. Having normalized all prices on local CPIs, we solve the model in real terms.

Within each of the four groups, there are infinitely many perfectly competitive households on the unit interval; below, we focus on the representative household of each type. Because the model is symmetric, we only describe the home households.

2.2.1 Constrained Households

The representative Non-Ricardian Household (NRH) consumes its entire disposable income in each period by drawing on its wage endowment $W_{r,t}$, borrowing domestic output (L_t) at a competitive price $q_{l,t}$ from the domestic Ricardian households, and fully repaying previous loans:

$$C_{r,t} = p_t \left(W_{r,t} - L_{t-1} + q_{l,t} L_t \right), \tag{9}$$

where $p_t = P_t^h / P_t$ is the real price of a unit of domestic production. If the current wage is insufficient to cover their outstanding loans, Non-Ricardians default, and the Ricardian consumer recovers $W_{r,t}$ instead of L_{t-1}. The indicator variable $I_{r,t}$ identifies periods of default:

$$I_{r,t} = \begin{cases} 0 & if \quad W_{r,t} \geq L_{t-1} \\ 1 & if \quad W_{r,t} < L_{t-1} \end{cases} \tag{10}$$

Default at time t does not impact the constrained households' ability to borrow immediately (L_t need not be zero). This seemingly counterintuitive modeling choice is rooted in the observation that non-Ricardians do not suffer from moral hazard, since their default occurs exogenously as a result of a low wage shock. As rational actors, Ricardians price the low wage shock probability into the loan and do not penalize non-Ricardian default beyond that.

The NRH chooses the quantity L_t to maximize its consumption level $C_{r,t}$. If unconstrained, its choice of L_t tends to infinity and the price of the loan $q_{l,t}$ correspondingly falls to zero. To produce finite outcomes, we introduce a limited version of the government, which only exists to enforce financial regulations. Specifically, the government mandates that $L_t \leq \xi$, where ξ is the maximum amount non-Ricardian households are permitted to borrow in a given period. Given the NRH's desire to maximize consumption, the limit always binds:

$$L_t = \xi. \tag{11}$$

We can use this equation to evaluate the effects of the regulation. Three numerical thresholds define the pattern of defaults.

1. If $\xi \leq (1-\nu) W_1$, then NRH never default, and L_t is a risk-free loan.
2. For $(1-\nu) W_1 \leq \xi < (1-\nu) W_2$, NRH endogenously default following the low wage shock realization.
3. Finally, setting $\xi \geq (1-\nu) W_2$ results in NRH always defaulting on their future debt, such that the price of their loans tends to zero as ξ rises.

Combining equations (9), (10), and (11) pins down $C_{r,t}$ as follows:

$$C_{r,t} = \Omega_{r,t}^h + q_{l,t} p_t \xi, \tag{12}$$

where $\Omega_{r,t}^h$ is the starting wealth of the constrained home consumer,

$$\Omega_{r,t}^h \equiv p_t \left(1 - I_{r,t}\right) \left(W_{r,t} - \xi\right). \tag{13}$$

2.2.2 Unconstrained Households

The representative Ricardian Household (RH) maximizes its expected utility from an infinite stream of discounted consumption bundles using constant relative risk aversion (CRRA) preferences

$$\max E \left[\sum_{t=0}^{\infty} \beta^t \frac{\left(C_{u,t}\right)^{1-\theta}}{1-\theta} \right] \tag{14}$$

This decision is constrained by the amount of wealth ($\Omega^h_{u,t}$) at the start of the period and by the concurrent investment choices:

$$C_{u,t} + q_{l,t}p_t L_t + B^{h,h}_t + q_{h,t}A^{h,h}_t + q_t\left(B^{h,f}_t + q_{f,t}A^{h,f}_t\right) = \Omega^h_{u,t}, \tag{15}$$

where $B^{h,h}_t$ and $B^{h,f}_t$ are its purchases of home and foreign bonds, respectively, and $A^{h,h}_t$ and $A^{h,f}_t$ indicate its equity investments in the exogenous streams of home and foreign dividends, respectively. We normalize the total number of each country's equities to one, so $q_{h,t}$ ($q_{f,t}$) reflect the value of owning the entire home (foreign) dividend stream.

The wealth of the home RH is a continuous state variable. Its evolution is governed by the future value of the wage shock and the payouts of the previous portfolio of investments

$$\begin{aligned}\Omega^h_{u,t+1} \equiv\ & p_{t+1}\left\{W_{u,t+1} + \left[(1 - I_{r,t+1}) + I_{r,t+1}W_{r,t+1}/\xi\right]L_t\right\} \\ & + (1 + r_t)\,B^{h,h}_t + (q_{h,t+1} + p_{t+1}D_{t+1})\,A^{h,h}_t \\ & + q_{t+1}\left[(1 + r^*_t)\,B^{h,f}_t + \left(q_{f,t+1} + p^*_{t+1}D^*_{t+1}\right)A^{h,f}_t\right].\end{aligned} \tag{16}$$

Here $W_{r,t+1}/\xi$ is the fraction of the loan recovered in the case of NRH default, r_t and r^*_t are the yields on home and foreign bonds, respectively, and $p^*_t = P^f_t/P^*_t$. In addition, we restrict Ricardian households to hold non-negative equity positions and to maintain a non-negative wealth level

$$A^{h,h}_t \geq 0 \tag{17}$$

$$A^{h,f}_t \geq 0 \tag{18}$$

$$\min \Omega^h_{u,t+1} \geq 0. \tag{19}$$

The final constraint (19) can be expressed as a borrowing limit which guarantees that the household can always pay its debts regardless of which state of nature is realized next period

$$B^{h,h}_t \geq -\frac{1}{(1 + r_t)} \min \left\{ \begin{array}{c} p_{t+1}\left\{W_{u,t+1} + \left[(1 - I_{r,t+1}) + I_{r,t+1}W_{r,t+1}/\xi\right]L_t\right\} \\ + (q_{h,t+1} + p_{t+1}D_{t+1})\,A^{h,h}_t \\ + q_{t+1}\left[(1 + r^*_t)\,B^{h,f}_t + \left(q_{f,t+1} + p_{t+1}D^*_{t+1}\right)A^{h,f}_t\right] \end{array} \right\}. \tag{20}$$

Equation (20) implies the existence of another constraint, since a limit on home borrowing produces a limit on foreign lending (see Appendix A for proof):

$$B^{h,f}_t \geq \tilde{B}^{h,f}_t. \tag{21}$$

Here $\tilde{B}^{h,h}_t$ denotes the lower limit of $B^{h,h}_t$ (for which equation (20) holds with equality).

2.3 Closing the Model

The state of nature of the model economy in period t is given by the beginning-of-period wealth distribution of the two Ricardian households, $\Omega^h_{u,t}$ and $\Omega^f_{u,t}$, the five exogenous shocks $z_t = \{e_t, W_t, W^*_t, D_t, D^*_t\}$, and the government borrowing restrictions $\Xi = \{\xi, \xi^*\}$. Given the state of nature, a competitive equilibrium is a price system $\mathcal{P}_t \equiv \left\{p_t, p^*_t, q_t, q_{h,t}, q_{f,t}, q_{l,t}, q^*_{l,t}, r_t, r^*_t\right\}$, an allocation of goods $\mathcal{C}_t \equiv \left\{C_{r,t}, C_{u,t}, C^*_{r,t}, C^*_{u,t}\right\}$, and an asset position $\mathcal{A}_t \equiv \left\{A^{h,h}_t, A^{h,f}_t, A^{f,h}_t, A^{f,f}_t, B^{h,h}_t, B^{h,f}_t, B^{f,h}_t, B^{f,f}_t, L_t, L^*_t\right\}$ such that

1. given the price system, the allocations and asset positions solve the home and foreign unconstrained consumers' utility maximization problems, and
2. goods and financial markets clear:

$$\begin{aligned} Y_t &= C^{h,h}_{r,t} + C^{h,h}_{u,t} + C^{f,h}_{r,t} + C^{f,h}_{u,t} \\ Y^*_t &= C^{h,f}_{r,t} + C^{h,f}_{u,t} + C^{f,f}_{r,t} + C^{f,f}_{u,t} \\ 1 &= A^{h,h}_t + A^{f,h}_t = A^{h,f}_t + A^{f,f}_t \\ 0 &= B^{h,h}_t + B^{f,h}_t = B^{h,f}_t + B^{f,f}_t \end{aligned}$$

2.4 Solution Method

Given the structural complexity of the portfolio choice problem, the analytical derivation of consumer decision rules is very cumbersome. We instead rely on numerical simulations of the model to uncover the channels that link the financial regulation to the resulting patterns of international capital holdings. The model is solved globally over a compact state-space grid; the details of the methodology are presented in Staveley-O'Carroll and Staveley-O'Carroll (2017) and in Appendix B. Below we outline the steps necessary to reduce the endogenous state space and therefore the required computational time.

In the list of the model's equilibrium equations (listed in Appendix B), the only endogenous state variables are the portfolio choices and their associated prices, contained in the sets $\mathcal{A}_t$ and $\mathcal{P}_t$. However, we do not need to keep track of these variables individually; we only need the aggregate value of portfolio holdings of the four agents, already defined as wealth levels $\Omega^h_{r,t}$, $\Omega^h_{u,t}$, $\Omega^f_{r,t}$, and $\Omega^f_{u,t}$. The constrained households always reach their borrowing limit, so that their wealths $\Omega^h_{r,t}$ and $\Omega^f_{r,t}$ are determined in period t. Thus, we only need to keep track of the evolution of the wealths of the two unconstrained cohorts, $\Omega^h_{u,t}$ and $\Omega^f_{u,t}$. Their sum, defined as $\Omega_{u,t} \equiv \Omega^h_{u,t} + q_t \Omega^f_{u,t}$, is also determined contemporaneously based on exogenous states and period-t control variables:

$$\begin{aligned} \Omega_{u,t} &= q_{h,t} + p_t \left[W_{u,t} + (1 - I_{r,t}) \xi + I_{r,t} W_{r,t} + D_t \right] \\ &\quad + q_t \left\{ q_{f,t} + p^*_t \left[W^*_{u,t} + \left(1 - I^*_{r,t}\right) \xi^* + I^*_{r,t} W^*_{r,t} + D^*_t \right] \right\} \end{aligned}$$

Finally, we conclude that the only endogenous state variable we must track across periods is the measure of the distribution of wealth between the Ricardian cohorts:

$$\omega^h_{u,t} \equiv \frac{\Omega^h_{u,t}}{\Omega_{u,t}}$$

The borrowing constraints (20) and (21) guarantee the compactness of the state space and restricts the wealth ratio $\omega^h_{u,t}$ to lie within the $[0, 1]$ interval.

The wealths of the non-Ricardians and the control variables $\mathcal{P}_t$, $\mathcal{A}_t$, and $\mathcal{C}_t$ can be expressed as functions of the exogenous state z_t, government regulations Ξ, and the endogenous state variable $\omega^h_{u,t}$. We define the state space of the model and the endogenous variables, respectively, as $x_t \equiv \left\{ \omega^h_{u,t}, z_t, \Xi \right\}$ and $y_t \equiv \{\mathcal{P}_t, \mathcal{C}_t, \mathcal{A}_t\}$, where the sets are contained in the space $\mathcal{X} : [0, 1] \times \mathcal{Z} \times 1$ and $\mathcal{Y} : R^9_+ \times R^4_+ \times R^{10}_+$. Additionally, we establish a transition map for the wealth distribution $\omega^h_{u,t+1} = \mathcal{O}(x_t, z_{t+1})$, such that $\mathcal{O} : \mathcal{X} \longrightarrow [0, 1]^{32}$. We then use a recursive process to find the optimal policy function $\psi : \mathcal{X} \longrightarrow \mathcal{Y}$ such that

$$\begin{aligned} 0 &= E\left[\Psi \left\{ \psi(x), x, \left[\psi(x(z'), z'), x(z'), z' \right]_{z' \in \mathcal{Z}} \right\} | x \right] \\ x(z') &= \mathcal{O}(x, z') \end{aligned}$$

where Ψ is a system of equilibrium conditions listed in Appendix B. The first of the above two expressions solves the model equations given the current and future state and control variables, and the second is the transition equation for the endogenous state variable $\omega^h_{u,t}$.

2.5 Calibration

The benchmark specification is described in Table 1. Unless otherwise indicated, all parameters describing the foreign economy are identical to the ones in the home country.

Each period in the model represents one year; we set the intertemporal discount factor $\beta = 0.96$ to produce the 4% annual real rate of return r commonly assumed in the business cycle literature. The CRRA preference parameter θ, which controls the degree of risk aversion and the elasticity of intertemporal substitution, governs Ricardian consumers' portfolio choices. We assume $\theta = 1$, resulting in log preferences.

Home and foreign goods are imperfect substitutes in consumption, $\sigma = 1/3$, and the average home bias is parameterized as $\phi = 0.75$.[4] The home bias shock e changes the degree of trade openness by 0.05.

Using the steps and data in Staveley-O'Carroll and Staveley-O'Carroll (2017), we use the moments of the annual series for U.S. compensation of employees and capital income to calibrate the processes for

[4] From the CES aggregator (??), the elasticity of substitution between Home and Foreign goods is equal to $\frac{1}{1-\sigma}$.

Table 1: Benchmark parameter values

Parameter	Description	Value
β	Intertemporal discount factor	0.96
θ	Relative risk aversion coefficient	1
ϕ	Average consumption home bias	0.75
σ	Import/export elasticity of substitution	1/3
e	Home bias shock	0.05
W_1, W_2	Wage realizations for low and high shocks	$0.974, 1.026$
D_1, D_2	Dividend realizations for low and high shocks	$0.406, 0.447$
λ_w	Persistence in the wage process	0.816
λ_d	Persistence in the dividend process	0.735
ρ	Within-country correlation between W and D	0.43
ν	Unconstrained households' share of W	0.5
ξ, ξ^*	Home and foreign constrained households' borrowing limit	$0.486, 0.486$

model wages and dividends. To this end, we set $\lambda_w = 0.816$ and $\lambda_d = 0.735$, equivalent to the annual wage and dividend autocorrelations of 0.62 and 0.47, respectively. We normalize the average wage and dividend in each country to 1 and 0.42 to match the share of capital to labor income in the U.S. Setting $\{W_1, W_2\} = \{0.974, 1.026\}$, $\{D_1, D_2\} = \{0.406, 0.447\}$, and $\rho = 0.43$ then matches the empirical volatility and autocorrelation of wages and dividends. We assume that wage income is split evenly between Ricardian and non-Ricardian households: $\nu = 0.5$.

Finally, the borrowing limits ξ and ξ^* prescribe how much home and foreign non-Ricardian households can borrow against their future earnings. Given the other parameter values, the three thresholds for the borrowing limit are $\xi_{nd} = \xi^*_{nd} < (1-\nu) W_1 = 0.487$ (no defaults), $\xi_{od} = \xi^*_{od} \in (0.487, 0.513)$ producing occasional default, and $\xi_{cd} = \xi^*_{cd} > 0.513$ resulting in chronic default. In the symmetric financial regulation (benchmark) scenario, we set $\xi_{nd} = \xi^*_{nd} = 0.486$ to maximize NRH borrowing in the no-default setting.

2.6 Results: global risk reallocation

We begin our analysis of the results by simulating the model under two separate parameterizations: the perfectly symmetric baseline with $\xi = \xi^* = 0.486$ and the asymmetric regulation case in which $\xi = 0.5$ such that home NRH default on their debt whenever $W_t = W_1$. Each specification is simulated 1,000 times for 1,100 periods starting at the symmetric time-zero cross-country wealth distribution $\Omega^h_{u,t} + \Omega^h_{r,t} = \Omega^f_{u,t} + \Omega^f_{r,t}$; we discard the first 100 time periods so that the initial conditions do not impact the overall results.

Table 2 displays the results of the simulations for four key home variables of interest: GAL/GDP, NE/GDP, ND/GDP, and NFA/GDP, defined as

$$\begin{aligned} GAL_t &= q_t \left(\left| b^{h,f}_t \right| + q_{f,t} A^{h,f}_t \right) + \left| b^{f,h}_t \right| + q_{h,t} A^{f,h}_t \\ NE_t &= q_t q_{f,t} A^{h,f}_t - q_{h,t} A^{f,h}_t \\ ND_t &= q_t b^{h,f}_t - b^{f,h}_t \\ NFA_t &= NE_t + ND_t \\ GDP_t &= p_t Y_t. \end{aligned}$$

We do not report the impact of wage and dividend shocks directly (for example, via an impulse response function), since the shocks have no steady-state or long-run equilibrium values. Instead, the data in the table are generated by computing the average of each variable over the 1,000 periods in each simulation and then finding the mean and the standard deviation of the average.

As column (I) shows, when the two countries are symmetric in all aspects, their net asset positions are virtually zero. When home NRH are able to occasionally default following financial deregulation, shown in column (II), home Ricardians rebalance their portfolios such that the home country has a negative NE position and a positive ND position.

	Frictionless Model	
	(I)	(II)
$\boldsymbol{\xi}$	**0.486**	**0.500**
GAL/GDP	2.6790	2.5186
	(0.000)	(0.000)
NE/GDP	-0.0047	-0.0438
	(0.416)	(0.074)
ND/GDP	-0.0003	0.0351
	(0.417)	(0.000)
NFA/GDP	-0.0050	-0.0087
	(0.416)	(0.393)

Table 2: International asset position of the home economy without financial intermediaries.
Notes. (a): One-sided p-values are reported in parenthesis.
(b): Each specification is simulated 1,000 times for 1,100 periods starting at the symmetric time-zero cross-country wealth distribution; we discard the first 100 time periods so that the initial conditions do not impact the overall results.

The reallocation of international assets is driven by home RH's desire to rebalance risk: as the payout of domestic loans becomes less certain, home RHs shift towards risk-free foreign bonds, sharing some of the domestic loan risk internationally. Notably, this is the opposite result of the three stylized facts described in de Araujo et al. (2015). We conclude that endogenous *household* default due to lower levels of financial regulation is not enough, in and of itself, to generate the empirically observed profiles of national portfolio holdings. This motivates our next exercise: the addition of financial intermediaries to the model.

3 Financial intermediation and moral hazard

We next augment the model to introduce financial intermediation. The existence of these intermediaries is motivated by an asymmetric information problem: it is too costly for the home RH to trade directly in equity and bond markets or issue loans (Bernanke, 1983). More specifically, we assume that households no longer interact with each other directly, either within or across borders, but are instead linked via a measure one continuum of perfectly competitive national Financial Intermediaries (FI); we outline the problems of home and foreign representative FIs. RHs own their local FI (in other words, they own their local FI's capital) and can deposit funds in a savings account. NRH obtain loans from the local FI. Finally, the home and foreign FIs trade with each other in the four international assets markets on their owners' behalf. This final assumption can be viewed as the FI playing the role of a mutual fund.

As long as the FI operate frictionlessly, the model described in this section (and visually summarized in Figure 3) is isomorphic to the one detailed above (and in Figure 2). The Euler equations governing asset flows between the FI and the RH (dashed arrows) use same pricing kernel, such that the individual asset holdings of the two agents become indeterminate. However, their combined asset holdings match the RH decisions in the model with no FI.

In order to separate the FI and RH investment decisions and to model asymmetric financial sector regulation, we introduce moral hazard by adding government bailout to the financial system. Compared to the frictionless version of the model, we expand the home RH's budget constraint, introduce the home FI's optimization problem, and augment the regulatory role of the home government. There are no changes to the production process or the NRH problem.

3.1 Home Unconstrained Household

Home RH maximizes (14) subject to a new budget constraint that captures their interaction with the home FI:

$$C_{u,t} + q_{k,t}K_t + S_t = \Omega^h_{u,t}, \tag{22}$$

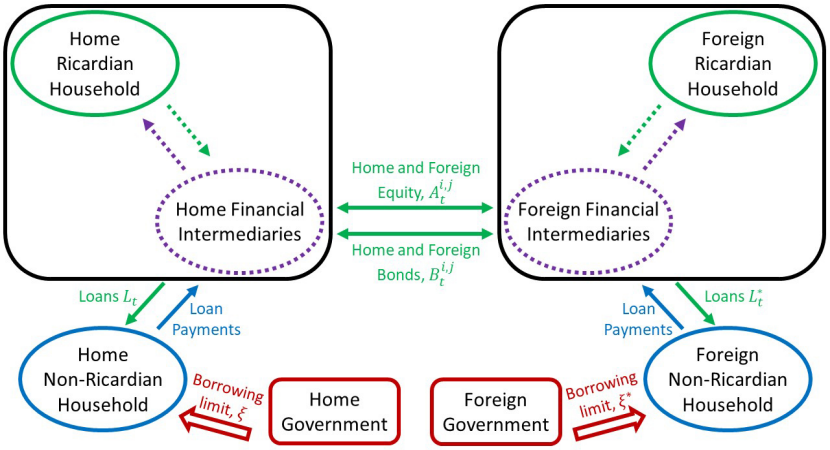


Figure 3: Capital flows with frictionless financial intermediaries.

where K_t is the capital investment in the FI, $q_{k,t}$ is the value of that capital, and S_t is the amount of savings deposited with the FI. The evolution of RH wealth is governed by the future value of the wage shock, profit from capital investment in the FI, Π_{t+1}, the yield on the savings account, $r_{s,t}$, and the lump-sum tax, T_{t+1}, imposed on the household to cover the cost of a bailout if the FI fails:

$$\Omega^h_{u,t+1} \equiv p_{t+1} W_{u,t+1} + \Pi_{t+1} K_t + (1 + r_{s,t}) S_t - T_{t+1}.$$

3.2 Home Financial Intermediary

In order to guarantee that the state space is isomorphic to the simple model, we assume that each period the FI pays out all of its portfolio investment returns to its owner, the home RH. The household then reinvests in the FI by saving and buying capital. The FI, operating on the behalf of its owner, uses these funds to create a new investment portfolio that maximizes the expected discounted profit (Π_{t+1}):

$$\max E\left[M_{t+1}\Pi_{t+1}\right]$$

such that the FI's investment portfolio is constrained by the value of its capital and saving deposits

$$p_t q_{l,t} L_t + B^{h,h}_t + q_{h,t} A^{h,h}_t + q_t \left[B^{h,f}_t + q_{f,t} A^{h,f}_t\right] = q_{k,t} K_t + S_t.$$

The FI uses the RH's discount factor $M_{t+1} = \beta \left(\frac{C_{t+1}}{C_t}\right)^{-\theta}$. Analogously to the borrowing restriction on the RH in the frictionless model, the FI is restricted to hold non-negative equity positions and to maintain a minimum level of wealth such that its owner's wealth level (RH) is non-negative.

The home government stands by to bail out the FI in case of bankruptcy, a setup which gives rise to moral hazard. The profit function depends on the realized portfolio return $\breve{\Pi}_{t+1}$ and the government bailout I_{t+1}, if any:

$$\Pi_{t+1} = (1 - I_{t+1}) \breve{\Pi}_{t+1} \tag{23}$$

where

$$\begin{aligned} \breve{\Pi}_{t+1} \equiv\ & p_{t+1}\left[(1 - I_{r,t+1}) + I_{r,t+1} W_{r,t+1}/\xi\right] L_t - (1 + r_{s,t}) S_t \\ & + (1 + r_t) B^{h,h}_t + (q_{h,t+1} + p_{t+1} D_{t+1}) A^{h,h}_t \\ & + q_{t+1}\left[(1 + r^*_t) B^{h,f}_t + \left(q_{f,t+1} + p^*_{t+1} D^*_{t+1}\right) A^{h,f}_t\right]. \end{aligned}$$

and

$$I_{t+1} \equiv \begin{cases} 0 & if \quad \breve{\Pi}_{t+1} \geq 0 \\ 1 & if \quad \breve{\Pi}_{t+1} < 0 \end{cases}.$$

The profit function is kinked at $\breve{\Pi}_{t+1} = 0$, at which point the FI cannot afford to pay back all of its debt to the foreign RH ($B_t^{h,h} < 0$ or $B_t^{h,f} < 0$) and/or to the home RH ($S_t > 0$). Since the profit function is not differentiable at $\breve{\Pi}_{t+1} = 0$, we use the approximation technique developed by Bertsekas (1975) to obtain the Euler equations for the FI. The new profit function can be approximated as

$$\Pi_{t+1} \approx \begin{cases} \breve{\Pi}_{t+1} - \varsigma/2 & if \quad \varsigma \leq \breve{\Pi}_{t+1} \\ \left(\breve{\Pi}_{t+1}\right)^2 / 2\varsigma & if \quad 0 < \breve{\Pi}_{t+1} < \varsigma \\ 0 & if \quad \breve{\Pi}_{t+1} \leq 0 \end{cases}, \tag{24}$$

where ς represents the profit level at which the FI recognizes that bankruptcy results in a government bailout. The derivative of this approximation becomes

$$\bigtriangledown \Pi_{t+1} \approx \begin{cases} \bigtriangledown \breve{\Pi}_{t+1} & if \quad \varsigma \leq \breve{\Pi}_{t+1} \\ \left(\breve{\Pi}_{t+1}/\varsigma\right) \bigtriangledown \breve{\Pi}_{t+1} & if \quad 0 < \breve{\Pi}_{t+1} < \varsigma \\ 0 & if \quad \breve{\Pi}_{t+1} \leq 0 \end{cases}. \tag{25}$$

The parameter ς partitions the decision space of the FI.

1. If $\breve{\Pi}_{t+1} \geq \varsigma$, then $\bigtriangledown \Pi_{t+1} = \bigtriangledown \breve{\Pi}_{t+1}$, which implies that the FI is unaffected by the promise of a bailout when making investment decisions.

2. For $0 < \breve{\Pi}_{t+1} < \varsigma$, the ratio $\breve{\Pi}_{t+1}/\varsigma$ is less than unity, which means the gradient of the profit function is lower than it would be if there were no government bailout. In this range, the FI suffers from *moral hazard* as it puts less consideration on the payouts of its investment decision in states of nature when it knows the chance of a future bailout is elevated.

3. For states where $\breve{\Pi}_{t+1} \leq 0$, the FI also suffers from *moral hazard* and places zero value on the yield of an investment decision because it knows it will be bailed out.

We capture the extend of the FI's moral hazard by defining a new stochastic discount factor

$$\breve{M}_{t+1} \equiv \left[I_{t+1}^u + \left(1 - I_{t+1}^u\right)\left(1 - I_{t+1}^l\right) \breve{\Pi}_{t+1}/\varsigma \right] M_{t+1}$$

where

$$\begin{aligned} I_{t+1}^u &\equiv \begin{cases} 1 & if \quad \breve{\Pi}_{t+1} \geq \varsigma \\ 0 & if \quad \breve{\Pi}_{t+1} < \varsigma \end{cases} \\ I_{t+1}^l &\equiv \begin{cases} 0 & if \quad \breve{\Pi}_{t+1} \geq 0 \\ 1 & if \quad \breve{\Pi}_{t+1} < 0 \end{cases} \end{aligned}.$$

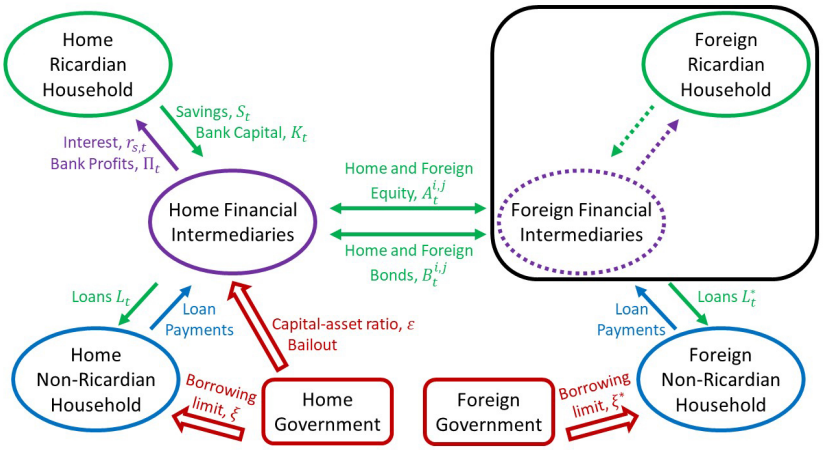
Recall that the model is solved over a discrete grid of 32 possible states of nature. The discount factors $\breve{M}_{t+1}$ and M_{t+1} are arrays of valuations of each of these future states by the FI and the RH, respectively. If *all* future states resulted in $I_{t+1}^u = 1$, so that the FI's profit was always above the bankruptcy threshold, the two arrays become identical, $\breve{M}_{t+1} = M_{t+1}$, and the individual asset holdings of the two agents are indeterminate. The model collapses down to the frictionless case described in Section 2 and Figure 2. However, as long as there exists *at least one* state where $I_{t+1}^u = 0$, the differences in the two discount factors gives rise to two distinct sets of investment decisions by the FI and the RH. We deepen and formalize the moral hazard channel in Section 3.5.

3.3 Home government

The home government now performs three regulatory tasks. First, it limits the borrowing capacity of the domestic NRH to ξ, just as discussed in the non-intermediated version of the model.

Second, if the FI declares bankruptcy, the government imposes a lump-sum tax on the home RH in order to cover the FI's losses:

$$T_{t+1} \equiv I_{t+1} \breve{\Pi}_{t+1}.$$



We normalize the amount of FI capital to $K_t = 1$. Notice that combining these two equations with the definition of the home RH's wealth (22) results in the same budget constraint (15) as in the simple model.

Third, the government regulates the FI to mitigate the effects of moral hazard. Specifically, the government exogenously sets the value of capital $q_{k,t}$ to ensure that the home FI has a high enough capital buffer to cover negative portfolio shocks. Ideally, this value would be determined endogenously via the Ricardian consumer optimally choosing K_t:

$$q_{k,t} = E\left[M_{t+1}\Pi_{t+1}\right] \tag{26}$$

However, for a given level of ς that is low enough, there exist current states of nature where $M_{t+1} = \breve{M}_{t+1}$, equation (26) can be constructed from the FI's Euler equations (29) and (23), causing $q_{k,t}$ to become indeterminate. Consequently, we either need to set ς so implausibly high that the FI's profits are always below the moral hazard threshold (in other words, the FI always experiences moral hazard) or determine $q_{k,t}$ exogenously. We choose the latter path.

We assume that the government sets a capital requirement ε such that the FI's capital-to-asset ratio is pinned down, allowing us to express $q_{k,t}$ as

$$q_{k,t} = \frac{\varepsilon}{1-\varepsilon}\left(\breve{S}_t - \breve{B}_t^{h,h} - q_t\breve{B}_t^{h,f}\right)$$

where the levels of the FI borrowing are given by

$$\begin{aligned}
\breve{S}_t &\equiv \begin{cases} S_t & if \quad S_t \geq 0 \\ 0 & if \quad S_t < 0 \end{cases} \\
\breve{B}_t^{h,h} &\equiv \begin{cases} 0 & if \quad B_t^{h,h} \geq 0 \\ B_t^{h,h} & if \quad B_t^{h,h} < 0 \end{cases} \\
\breve{B}_t^{h,f} &\equiv \begin{cases} 0 & if \quad B_t^{h,f} \geq 0 \\ B_t^{h,f} & if \quad B_t^{h,f} < 0 \end{cases}
\end{aligned} .$$

Figure 3.3 describes the capital flows and government regulations in the full version of the model. Note that as long as ε is set sufficiently high, the FI never suffers from moral hazard, and the model reverts to Figure 2. We assume this to be the case in the foreign country, which allows us to reduce complexity by only explicitly modeling FI in the home country. The foreign country, having sufficient financial regulation to avoid moral hazard, continues to be modeled as it was in Section 2.

3.4 Closing the model

The state space remains unchanged vis-à-vis the model in Section 2; the set of control variables is now larger to include to decisions of the FI:

$$\begin{aligned}\mathcal{P}_t &\equiv \left\{p_t, p_t^*, q_t, q_{h,t}, q_{f,t}, q_{l,t}, q_{l,t}^*, q_{k,t}, r_t, r_t^*, r_{s,t}\right\} : R_+^{11}\\ \mathcal{C}_t &\equiv \left\{C_{r,t}, C_{u,t}, C_{r,t}^*, C_{u,t}^*\right\} : R_+^4\\ \mathcal{A}_t &\equiv \left\{A_t^{h,h}, A_t^{h,f}, A_t^{f,h}, A_t^{f,f}, B_t^{h,h}, B_t^{h,f}, B_t^{f,h}, B_t^{f,f}, L_t, L_t^*, S_t, K_t\right\} : R_+^{12}.\end{aligned}$$

The market clearing condition

$$K_t = 1$$

normalizes FI's capital stock.

Appendix C lists the corresponding equilibrium equations. The only substantive changes to the model are the use of $\breve{M}_{t+1}$ instead of M_{t+1} in the home FI' Euler equations and the addition of an extra Euler equation to pin down the level of S_t.

3.5 Moral hazard

We now investigate more closely the approximated FI profit function 24: the decision space partition created by the parameter ς.

The model has 32 exogenous states of nature (two realizations each of the five elements of z_t) $s \in S$. As described in the Section 3.2, for all future states of nature s_i where $0 < \breve{\Pi}_i < \varsigma$, the gradient of the profit function is reduced by the fraction $\breve{\Pi}_i/\varsigma$, which is less than one by construction. Additionally, in states of nature s_i where $\breve{\Pi}_i \leq 0$, the gradient of the profit function is zero. Therefore, for any given current state of nature, we can partition the future states into three sets $s_i \in S^+$ such that $\breve{\Pi}_i \geq \varsigma$, $s_j \in S^-$ where $0 < \breve{\Pi}_j < \varsigma$, and $s_k \in S^0$ where $\breve{\Pi}_k \leq 0$, with $\left(S^+, S^-, S^0\right) = S$.

Consider as an example the simplified the Euler equation (29c) describing the FI's home equity holdings:

$$E\left\{\breve{M}_{t+1}\left[\left(q_{h,t+1} + p_{t+1}D_{t+1}\right) - \left(1 + r_{s,t}\right)q_{h,t}\right]\right\} = 0 \tag{27}$$

and partition it across the three sets S^+, S^-, and S^0:

$$E\left\{\begin{array}{c} M_i\left[\left(q_{h,i} + p_i D_i\right) - \left(1 + r_{s,t}\right)q_{h,t}\right] \\ \left(\breve{\Pi}_j/\varsigma\right) M_j\left[\left(q_{h,j} + p_j D_j\right) - \left(1 + r_{s,t}\right)q_{h,t}\right] \\ 0 \end{array}\right\} = 0 \qquad \text{for} \left\{\begin{array}{c} s_i \in S^+ \\ s_j \in S^- \\ s_k \in S^0 \end{array}\right\} \tag{28}$$

If all future states of nature are $s_j \in S^+$, then the home HR's and FI's discount factors and Euler equations become identical, and the FI's existence has no impact of the portfolio decision. However, as long as the set $\left(S^-, S^0\right)$ is non-empty, the portfolio choices of the two agents will diverge.

Because the FI is constrained to only hold non-negative amounts of the home equity $A_t^{h,h}$, the lowest values of its profit $\breve{\Pi}_{t+1}$ will occur in states in which the home dividend realization D_{t+1} is low. Therefore, whenever the set $S^-$is non-empty, we know that $\left(q_{h,j} + p_j D_j\right) < \left(q_{h,i} + p_i D_i\right)$; analogously, a non-empty set S^0 implies that $\left(q_{h,k} + p_k D_k\right) < \left(q_{h,i} + p_i D_i\right)$. The existence of the bailout guarantee makes the FI under-weigh its negative returns in the associated states j (adjusting them down by $\breve{\Pi}_j/\varsigma$, less than one by construction) and k (setting them to zero). Because of these adjustments, the left side of equation (27) becomes positive: the discounted expected return from investing in home equity is higher than the expected cost when accounting for the possibility of a future bailout. The FI is thus prompted to increase its holding of the domestic equity, raising its price $q_{h,t}$ and thereby rebalancing the equation. This mechanism is self-reinforcing, since increasing home equity holdings mean FI profit $\breve{\Pi}_i$ is more exposed to domestic dividend fluctuations, such that bankruptcy becomes possible in ever more future states of nature.

The rise in the price of home equity assets relative to the value of the debt assets disincentivizes the foreign RH from holding home equities.

Analogous intuition applies to the Euler equations describing foreign equity holdings; the mechanism works in reverse for Euler equations describing bond holdings, loans, and saving accounts. For example, as the FI leverages to buy more equity, the yield on savings, $r_{s,t}$, rises as well. This makes the expected return on domestic bonds (the left side of the Euler equation below) negative, incentivizing the FI to lower their holdings of debt assets until r_t rises to equal $r_{s,t}$.

$$E\left\{\breve{M}_{t+1}\left[(1+r_t)-(1+r_{s,t})\right]\right\}=0.$$

4 Simulation results

As in Section 2.6, each specification is simulated 1,000 times for 1,100 periods starting at a symmetric time-zero cross-country wealth distribution $\Omega^h_{u,t}+\Omega^h_{r,t}=\Omega^f_{u,t}+\Omega^f_{r,t}$. We discard the first 100 time periods so that the initial conditions do not impact the overall results.

4.1 Calibration

Table 3 augments the set of parameters set out in Section 2.5.

Table 3: Benchmark parameter values

Parameter	**Description**	**Value**
ε	FI's required capital-to-asset ratio	0.1
ς	Strength of moral hazard	0.001

The key parameters of the expanded model, ε and ς, govern the behavior of the home FI. We initially set the capital-to-asset ratio $\varepsilon=0.1$, such that the FI must hold a 10% capital buffer against its assets. The implied leverage ratio of ten roughly corresponds to the historical average for the U.S. commercial banks.[5]

Parameter ς controls the approximation technique used to smooth the FI's profit function with a bailout. This parameter has a fairly simple interpretation: as long as $\breve{\Pi}_t$ is above ς, the FI does not suffer from moral hazard because the possibility of bankruptcy is very remote. We set $\varsigma=0.001$ to avoid inducing moral hazard when the threat of bankruptcy is low.

4.2 Global risk rebalancing

For ease of comparison, the first two columns of Table 4 reproduce the results of the frictionless model discussed in Section 2.6. The third column offers support to our assertion that the frictionless model is isometric to the model with a financial intermediary when the capital requirement is high enough to avoid moral hazard: note that columns (I) and (III) are virtually identical. The last three columns of the table pertain to the extended model with the financial intermediary when the capital requirement is reduced to four percent. At this level, there is enough moral hazard to induce endogenous *intermediary* default when $\omega^h_{u,t}=0.5$.

Before delving into the main results, we must briefly discuss the impact of relative home RH wealth on FI default. In our simulations, default becomes much more frequent as $\omega^h_{u,t}$ approaches its corner values of 0 and 1. In these regions of high wealth inequality, the model solution becomes unstable for values of the parameter ξ (borrowing restriction on the domestic NRH) below a certain threshold. To preclude this computational issue, we assume that the government always maintains the baseline capital requirement of $\varepsilon=0.1$ when $\omega^h_{u,t}\leq 0.2$ or $\omega^h_{u,t}\geq 0.8$. This restriction allows us to focus on the FI default that arises endogenously at the relatively symmetric wealth ratio $\omega^h_{u,t}\approx 0.5$. We motivate this assumption by arguing that regulators are very likely to respond to increased default activity by raising capital requirements.

[5] We use the series "Residual (Assets Less Liabilities), All Commercial Banks" (FRED code RALACBW027SBOG) to capture bank capital. The series "Total Assets, All Commercial Banks" (FRED code TLAACBW027SBOG) measures aggregate bank assets. The ratio between the two gives us the measure of bank leverage; its average quarterly value between 1973 and 2024 is 8.4 percent.

	Frictionless Model		Financial Intermediary			
	(I)	(II)	(III)	(IV)	(V)	(VI)
ε			**0.1**	**0.04**	**0.04**	**0.04**
ξ	**0.486**	**0.500**	**0.486**	**0.486**	**0.493**	**0.500**
GAL/GDP	2.6790	2.5186	2.6791	5.6313	5.6536	5.7504
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
NE/GDP	-0.0047	-0.0438	-0.0048	1.3089	1.6597	1.6601
	(0.416)	(0.074)	(0.415)	(0.052)	(0.027)	(0.036)
ND/GDP	-0.0003	0.0351	-0.0003	-1.1848	-1.4179	-1.3856
	(0.417)	(0.000)	(0.416)	(0.000)	(0.000)	(0.000)
NFA/GDP	-0.0050	-0.0087	-0.0051	0.1241	0.2419	0.2745
	(0.416)	(0.393)	(0.415)	(0.439)	(0.379)	(0.371)

Table 4: International asset position of the home economy with financial intermediaries.
Notes. (a): One-sided p-values are reported in parenthesis.
(b): Each specification is simulated 1,000 times for 1,100 periods starting at the symmetric time-zero cross-country wealth distribution; we discard the first 100 time periods so that the initial conditions do not impact the overall results.

Column (IV) in Table 4 maintains the same borrowing restrictions on home NRH as the baseline parameterization, such that there is no possible *household* default; however, the FI capital requirement is reduced to four percent, allowing endogenous *intermediary* default to occur. This change produces a strong and significant effect on the international asset position of the home country. First, the activity of the FI dramatically increases gross international assets and liabilities, raising GAL from 270% of GDP in the baseline model to 563% of GDP with moral hazard. This result suggests that financial system deregulation may have contributed to the rise in gross international asset holdings, as reported in de Araujo et al. (2015).

Second, incorporating moral hazard into our model allows us to replicate two other key results from de Araujo et al. (2015). Insured against default risk, the FI increases the risk profile of its asset portfolio, causing the home country to go long in equity and short in debt assets. However, contrary to de Araujo et al. (2015), the NFA position of the home country is slightly positive on average and statistically insignificant from zero. We explore the theoretical mechanics driving this result in Section 4.4. Finally, because the FI experiences greater windfall profits and larger losses, all four variables are much more volatile than in previous parameterizations (with the inadvertent effect of reducing the statistical significance of our results).

Columns (V) and (VI) combine FI moral hazard with a more relaxed borrowing limit of the home NRH ($\xi = 0.493$ and $\xi = 0.500$). In these columns, default occurs endogenously for both *households* and *intermediaries*. Relative to column (IV), we see that lower domestic financial regulations results in larger gross asset positions of the home country. Because the home NRH may occasionally default on its debt, the FI balance sheet carries more risk. This risk increases the chance that the FI, the issuer of the loans to the NRH, may declare bankruptcy. Exacerbating the extent of the FI moral hazard, causes the equity position to become more positive and the net debt position to become more negative.

Thus, moral hazard reverses the impact of loose financial regulation on international portfolio choice. As reported in column (II), when *FI* does not suffer from moral hazard, deteriorating lending standards (an increase in ξ) increase the risk of domestic loans, which the RH attempts to offset by going long in international bonds and short in international equities. However, once moral hazard is introduced to the model, a positive probability of NRH default increases the volatility of the FI's profit. This implies that more states of nature involve moral hazard, and the FI goes even longer in equity and shorter in debt. Thus, moral hazard has a nonlinear impact on the effect of financial deregulation on international portfolio risk.

4.3 Robustness checks

The preceding section highlighted the key role played by moral hazard (governed by the parameter ε) in international capital reallocation. In our model, a decrease in the FI capital requirement ε triggers two simultaneous changes: an increase in both the extent of moral hazard and in the likelihood of intermediary bankruptcy. We disentangle the two effects and introduce moral hazard into the model without inducing

bankruptcy by leveraging one of the features of the solution methodology. As discussed in section 3.2, the Bertsekas (1975) approximation makes the FI profit function continuously differentiable by adding the adjustment parameter ς, which captures the profit level at which the FI internalizes moral hazard. Higher values of this parameter cause an increases in moral hazard *without* increasing the incidence of bankruptcy. Specifically, in our first robustness check we set $\varsigma = 0.8$, the lowest value that generates moral hazard for $\omega^h_{u,t} = 0.5$. The results are summarized in Table *5.*

	Financial Intermediary			
	(IV)	(VII)	(VIII)	(IX)
$\boldsymbol{\varepsilon}$	**0.04**	**0.10**	**0.10**	**0.04**
$\boldsymbol{\xi}$	**0.486**	**0.486**	**0.500**	**0.486**
$\boldsymbol{\theta}$	**1.0**	**1.0**	**1.0**	**1.1**
$\boldsymbol{\varsigma}$	**0.001**	**0.800**	**0.800**	**0.001**
GAL/GDP	5.6313	2.8576	2.9533	5.8640
	(0.000)	(0.000)	(0.000)	(0.000)
NE/GDP	1.3089	0.2722	0.3374	1.7196
	(0.052)	(0.000)	(0.002)	(0.031)
ND/GDP	-1.1848	-0.2620	-0.3097	-1.4386
	(0.000)	(0.003)	(0.0011)	(0.000)
NFA/GDP	0.1241	0.0102	0.0278	0.2810
	(0.439)	(0.475)	(0.449)	(0.366)

Table 5: International asset position of the home economy, robustness checks.
Notes. (a): One-sided p-values are reported in parenthesis.
(b): Each specification is simulated 1,000 times for 1,100 periods starting at the symmetric time-zero cross-country wealth distribution; we discard the first 100 time periods so that the initial conditions do not impact the overall results.

Comparing column (IV), taken directly from Table 4, to column (VII), we note that we can replicate the qualitative features of the home country's international portfolio by relying solely on the FI moral hazard mechanism.[6] Specifically, the FI suffers from moral hazard in both cases, but *intermediary* bankruptcy only occurs in column (IV). Thus, we can identify moral hazard, rather than bankruptcy, as the primary driver of our results.

In the previous section, we noted that the effects of moral hazard (there modeled via a decrease in the FI capital requirement $\boldsymbol{\varepsilon}$) on portfolio holdings are amplified by lower lending standards for the home NRH. Column (VIII) confirms this amplification when moral hazard is instead generated by the adjustment parameter ς. An increase in *household* default risk resulting from a higher credit limit ($\xi = 0.5$) increases the size of NE and ND positions.

We next explore the effects of CRRA parameterization on our findings. As the CRRA parameter θ rises, the home RH becomes more risk averse and their elasticity of intertemporal substitution falls. In other words, RH wants to hold less risk and reduce consumption fluctuations across time. Comparing columns (IV) and (IX), we observe that an increase in θ from 1 to 1.1 produces a perverse effect on the behavior of the FI. The more the home RH wishes to reduce risk, the riskier the FI makes its portfolio, going longer in risky equity assets and funding this risk by borrowing via safe debt assets.

This can be explained by examining the connection between the home RH's stochastic discount factor M_{t+1} and the moral hazard mechanism. The states of nature k in which bankruptcy occurs are those with lower dividend payments and thus lower future consumption C_k, which means $M_k = \beta \left(\frac{C_k}{C_t}\right)^{-\theta}$ is relatively high. Increasing θ thus increases the weight M_k that RH puts on these states of nature when making their investment decisions. However, the moral hazard mechanism described in Equation (28) causes the FI to completely disregard these very same states: $\breve{M}_k = 0$. The Euler equation imbalance becomes larger at higher values of θ, and the FI picks up even more equity, financing it by going short in debt.

[6] We cannot directly compare the numerical magnitudes of columns (IV) and (VII) due to differences in the model parameterization.

4.4 Net foreign wealth

We set out to build a model that would enable us to replicate the three empirical patterns in international portfolio holdings reported in de Aruajo et al. (2015): a lower degree of national financial regulation results in positive levels of net equity supported by negative levels of net debt and the overall negative level of the NFA. So far, we were able to replicate the first two of these; however, our simulations produce NFA levels just above zero, although not statistically significantly so. In this section, in an effort to bring our findings closer to the data, we further investigate the three main drivers of national savings that in turn contribute to changes in NFA. These are (a) the consumption choices of the home households at a given level of national income, and the income effects associated with changes in (b) the returns on the home investment portfolios and (c) the value of home wages. Before we can proceed, we must define the percent returns of each asset in the FI's portfolio:

$$\begin{aligned}
R_t^{ahh} &= 100\left[\frac{(q_{h,t}+p_tD_t)-q_{h,t-1}}{q_{h,t-1}}\right] \\
R_t^{ahf} &= 100\left[\frac{q_t\left(q_{f,t}+p_t^*D_t^*\right)-q_{t-1}q_{f,t-1}}{q_{t-1}q_{f,t-1}}\right] \\
R_t^{bhh} &= 100\left[r_{t-1}\right] \\
R_t^{bhh} &= 100\left[\frac{q_t\left(1+r_{t-1}\right)-q_{t-1}}{q_{t-1}}\right] \\
R_t^{lh} &= 100\left[\frac{p_t-p_{t-1}q_{l,t-1}}{p_{t-1}q_{l,t-1}}\right] \\
R_t^{sh} &= 100\left[r_{s,t-1}\right].
\end{aligned}$$

We now can explore the effects of moral hazard on the three drivers of NFA while controlling for the effects of the five shocks $(\phi_t, W_t, W_t^*, D_t, D_t^*)$. For consumption and goods prices, we calculate the percent difference between their value in the baseline model parameterization, corresponding to column (III) of Table 4, and the value once moral hazard is introduced, corresponding to column (IV). For example, the change in RH consumption is calculated as

$$\Delta C_{u,t} = 100\left(\frac{C_{u,t}^{IV}-C_{u,t}^{III}}{C_{u,t}^{III}}\right).$$

For asset returns, we calculate the simple difference between parameterization (III) to (IV) as, for example, $\Delta R_t^{ahh} = R_t^{ahh,IV} - R_t^{ahh,III}$. We regress these differences on the demeaned realizations of the exogenous shock processes using all 1,000 observations from all 1,000 simulations. The results of the regressions are presented in Table 6. We first focus on the top line of the results (the constant terms), offering an intuitive explanation for the effects of household and FI choices on the home country's NFA. Later, we delve deeper into the bottom portion of the table to gain a more nuanced understanding of the model mechanics.

We begin with the first NFA driver: home consumption. The positive and significant coefficients on the two corresponding constant terms indicate that the average consumption of both household types is higher in the presence of moral hazard. The intuition for RH is fairly straightforward: moral hazard misaligns the incentives of FI and RH (as detailed in Section 3.5), reducing the latter's desire to save. Understanding the effect of moral hazard on NRH requires digging a bit deeper into the behavior of asset prices and returns, which we explore below. In the aggregate, the addition of moral hazard causes both household types to consume more, reduces national savings, and thereby lowers the level of NFA.

The next set of columns shows the impact of moral hazard on home asset returns. When the FI suffers from moral hazard, it goes long in risky assets ($A_t^{h,h}$, $A_t^{h,f}$, and L_t) and short in safe instruments ($B_t^{h,h}$, $B_t^{h,f}$, and S_t), as detailed in Section 3.5. The constant terms show the fall in the average returns on all assets except for foreign bonds $B_t^{h,f}$ when we add moral hazard to the model. Moreover, considering the magnitude of the changes, the average home FI portfolio earnings are lower when it suffers from moral hazard. Its higher demand for equities bids up their prices and squeezes their returns, whereas lower demand for bonds works to raise their yields. Home RH, as the owners of FI, experience a negative income effect, reducing its savings, which then lowers the NFA position of the home country.

	Home Consumption		Returns on Home Assets						Goods Prices	
	$\Delta C_{u,t}$	$\Delta C_{r,t}$	ΔR_t^{ahh}	ΔR_t^{ahf}	ΔR_t^{bhh}	ΔR_t^{bhf}	ΔR_t^{lh}	ΔR_t^{sh}	Δp_t	Δp_t^*
Constant	**0.9053**	**0.1699**	**-0.0083**	**-0.0069**	**-0.0009**	**0.0034**	**-0.0012**	**-0.0008**	**0.1658**	**-0.1326**
	(0.0000)	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0461)**	**(0.0022)**	**(0.0137)**	**(0.0742)**	**(0.000)**	**(0.000)**
$D_t - \bar{D}$	4.0412	0.6309	0.8642	-1.0362	-0.0196	-1.0370	0.3930	-0.0192	0.6221	-0.6616
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.2470)	(0.0000)	(0.0000)	(0.2517)	(0.000)	(0.000)
$D_t^* - \bar{D}^*$	5.1551	0.8411	0.9942	-1.1752	0.0247	-1.0278	0.5297	0.0292	0.8389	-0.7778
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.1933)	(0.0000)	(0.0000)	(0.1529)	(0.000)	(0.000)
$W_t - \bar{W}$	2.8443	0.4584	0.4337	-0.2692	0.0184	-0.2555	0.1381	0.0197	0.4034	-0.4413
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.2084)	(0.0000)	(0.0000)	(0.1925)	(0.000)	(0.000)
$W_t^* - \bar{W}^*$	2.4240	0.3818	0.2111	-0.0732	0.0041	-0.1300	0.0583	0.0050	0.3685	-0.3436
	(0.0000)	(0.0000)	(0.0000)	(0.0120)	(0.4268)	(0.0043)	(0.0050)	(0.4122)	(0.000)	(0.000)
$\phi_t - \bar{\phi}$	-1.9969	-1.1457	-1.1005	-1.0431	-0.0076	-2.7546	0.1353	-0.0077	0.1502	-0.0033
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.2384)	(0.0000)	(0.0000)	(0.2378)	(0.000)	(0.4412)

Table 6: Impact of moral hazard on the drivers of net foreign assets.
Notes. (a): One-sided p-values are reported in parenthesis.
(b): Each specification is simulated 1,000 times for 1,100 periods starting at the symmetric time-zero cross-country wealth distribution; we discard the first 100 time periods so that the initial conditions do not impact the overall results. Thus, the regressions use 1,000,000 observations.

The last two columns of Table 6 display the effects of moral hazard on home and foreign wages, which are denominated in domestic goods. When domestic goods become more expensive, the value of wages correspondingly increases, and vice versa. The constant terms show that the average price of home goods is higher and the average price of foreign goods is lower in the model with moral hazard. A few paragraphs earlier, we explained that moral hazard increases home consumption, since home RH are less inclined to save when the domestic FI takes on excessive risk. Since household consumption baskets include home bias, as per equations 6, higher consumption demand results in relatively higher home goods prices (notice the positive coefficient on the constant term for Δp_t and the corresponding negative coefficient on Δp_t^*). In turn, higher local goods prices imply that home RH's and NRH's wage income becomes more valuable. The resulting positive income effect leads to higher national savings and increases the level of home NFA.

We now can explain the conundrum of moral hazard causing the home country to increase its NFA position, contrary to the empirical patterns we set out to replicate. Although home RH and NRH both increase their consumption (creating a downward pressure on NFA) and RH earns less on its portfolio returns (also lowering the NFA level), the rise in the value of home wages and therefore savings offsets these effects, as seen in Tables 4 and 5. We can hypothesize that countries with lower levels of home bias tend to see a deterioration in their NFA levels following financial deregulation. This conjecture is supported by the effects of the home bias shock, $\phi_t - \bar{\phi}$, on the behavior of home and foreign goods prices (last row of Table 6): an increase in preference for domestic goods exacerbates the effects of moral hazard on prices and further amplifies the positive effect of moral hazard on home NFA.

A few other interesting details emerge from a closer examination of Table 6. First, although home NRH are not directly affected by the investment choices and the portfolio composition of the home FI, the addition of moral hazard increases the value of their wages and lowers the average interest rate on their loans L_t, allowing them to consume more (captured by the positive constant term on $\Delta C_{r,t}$). Second, the somewhat puzzling negative impact of higher foreign dividends $D_t^* - \bar{D}^*$ on foreign equity yields ΔR_t^{ahf} is caused by the lower value of foreign goods in the presence of moral hazard, which in turn reduces the value of the foreign dividend stream. Finally, a positive home bias shock increases the value of domestic wage income, leading to higher demand for assets and reducing their yields.

5 Conclusions

We construct a two-country DSGE model in which some of the households can participate in global bond and stock markets. Credit-constrained households are excluded from these markets and instead borrow from their financial intermediaries to maximize current consumption; they occasionally default of their debts. National governments regulate their level of borrowing and, in the expanded version of the model, enforce capital requirements of financial intermediaries. The latter make their portfolio choices in the presence of moral hazard due to the safety net of government bailouts. In the baseline version of the model without financial intermediation, lower financial regulation leads to a positive net debt and a negative net equity position in the home country, contrary to the empirical patterns of global asset holdings. Once we add financial intermediaries, however, the less-regulated economy switches to a long equity and a short net debt position, in line with the international data. Moreover, we identify three main mechanisms that govern the level of the deregulated country's net foreign wealth. Ultimately, it is the level of home bias that, in our model, determines whether the country's net international position will be positive (high bias) or negative (low bias).

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A Appendix A

Let $\tilde{}$ indicate that we are analyzing the lower bound of $B_t^{h,h}$ defined as

$$\tilde{B}_t^{h,h} \equiv -\frac{1}{(1+\tilde{r}_t)} \left\{ \begin{array}{c} \tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}\right] \\ +\tilde{q}_{t+1}\left(1+\tilde{r}_t^*\right)\tilde{B}_t^{h,f} \end{array} \right\},$$

where $\tilde{A}_t^{h,h} = \tilde{A}_t^{h,f} = 0$. We also define the combined wealth of the home and foreign Ricardian households when the home Ricardian household hits its borrowing constraint

$$\begin{aligned} \tilde{\Omega}_{u,t+1} \quad \equiv \quad & \tilde{q}_{h,t+1} + \tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1} + \tilde{D}_{t+1}\right] \\ & +\tilde{q}_{t+1}\left\{\tilde{q}_{f,t+1} + \tilde{p}_{t+1}^*\left[\tilde{W}_{u,t+1}^* + \left(1-\tilde{I}_{r,t+1}^*\right)\xi^* + \tilde{I}_{r,t+1}^*\tilde{W}_{r,t+1}^* + \tilde{D}_{t+1}^*\right]\right\}. \end{aligned}$$

The domestic constraint on borrowing implies a foreign constraint on lending

$$\max \Omega_{u,t+1}^f \leq \tilde{\Omega}_{u,t+1}/\tilde{q}_{t+1},$$

which can be rearranged using the definition of $\Omega_{u,t+1}^f$ to get

$$B_t^{f,f} \leq \frac{1}{(1+r_t^*)}\left[\tilde{\Omega}_{u,t+1}/\tilde{q}_{t+1} - \max\left\{\begin{array}{c} p_{t+1}^*\left[W_{u,t+1}^* + \left(1-I_{r,t+1}^*\right)\xi^* + I_{r,t+1}^* W_{r,t+1}^*\right] \\ +\left(q_{f,t+1} + p_{t+1}^* D_{t+1}^*\right)A_t^{f,f} \\ +\left[\left(1+r_t\right)B_t^{f,h} + \left(q_{h,t+1} + p_{t+1}D_{t+1}\right)A_t^{f,h}\right]/q_{t+1} \end{array}\right\}\right].$$

Using the bond and equity market clearing conditions, this implies an additional constraint on domestic borrowing

$$B_t^{h,f} \geq -\frac{1}{(1+\tilde{r}_t^*)}\left[\tilde{\Omega}_{u,t+1}/\tilde{q}_{t+1} - \left\{\begin{array}{c} \tilde{p}_{t+1}^*\left[\tilde{W}_{u,t+1}^* + \left(1-\tilde{I}_{r,t+1}^*\right)\xi^* + \tilde{I}_{r,t+1}^*\tilde{W}_{r,t+1}^*\right] \\ +\left(\tilde{q}_{f,t+1} + \tilde{p}_{t+1}^*\tilde{D}_{t+1}^*\right) \\ +\left[\left(1+\tilde{r}_t\right)\tilde{B}_t^{f,h} + \left(\tilde{q}_{h,t+1} + \tilde{p}_{t+1}\tilde{D}_{t+1}\right)\right]/\tilde{q}_{t+1} \end{array}\right\}\right].$$

Next, we combine the new constraint with the definition of $\tilde{\Omega}_{u,t+1}$ to find

$$B_t^{h,f} \geq \frac{1}{(1+\tilde{r}_t^*)}\left\{\left(1+\tilde{r}_t\right)\tilde{B}_t^{f,h} - \tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}\right]\right\}/\tilde{q}_{t+1}.$$

We can exploit the bond market clearing condition and the definition of $\tilde{B}_t^{h,h}$ as follows

$$\begin{aligned} B_t^{h,f} \quad &\geq \quad -\frac{1}{(1+\tilde{r}_t^*)}\left\{\left(1+\tilde{r}_t\right)\tilde{B}_t^{h,h} + \tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}\right]\right\}/\tilde{q}_{t+1} \\ B_t^{h,f} \quad &\geq \quad -\frac{1}{(1+\tilde{r}_t^*)}\left\{\begin{array}{c} -\tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}\right] \\ -\tilde{q}_{t+1}\left(1+\tilde{r}_t^*\right)\tilde{B}_t^{h,f} \\ +\tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}\right] \end{array}\right\}/\tilde{q}_{t+1} \\ B_t^{h,f} \quad &\geq \quad -\frac{1}{(1+\tilde{r}_t^*)}\left\{-\tilde{q}_{t+1}\left(1+\tilde{r}_t^*\right)\tilde{B}_t^{h,f}\right\}/\tilde{q}_{t+1}. \end{aligned}$$

Finally, the constraint simplifies

$$B_t^{h,f} \geq \tilde{B}_t^{h,f}.$$

B Appendix B

The model is solved globally over a compact state space grid following the methodology outlined in Stepanchuk and Tsyrennikov (2015). First, we complete the state space as follows:

$$\begin{aligned} z_t &\equiv \{e_t, W_t, W_t^*, D_t, D_t^*\} : \mathcal{Z} \\ x_t &\equiv \left\{\omega_{u,t}^h, z_t\right\} : [0,1] \times \mathcal{Z} \end{aligned}$$

Additionally, we define the three sets (prices, consumption, and asset positions) of endogenous control variables:

$$\begin{aligned} \mathcal{P}_t &\equiv \left\{p_t, p_t^*, q_t, q_{h,t}, q_{f,t}, q_{l,t}, q_{l,t}^*, r_t, r_t^*\right\} : R_+^9 \\ \mathcal{C}_t &\equiv \left\{C_{r,t}, C_{u,t}, C_{r,t}^*, C_{u,t}^*\right\} : R_+^4 \\ \mathcal{A}_t &\equiv \left\{A_t^{h,h}, A_t^{h,f}, A_t^{f,h}, A_t^{f,f}, B_t^{h,h}, B_t^{h,f}, B_t^{f,h}, B_t^{f,f}, L_t, L_t^*\right\} : R_+^{10}. \end{aligned}$$

As outlined below, we use many equations to limit the number of unknowns in our nonlinear minimization problem. We end up needing to solve for the following thirteen control variables

$$\left\{q_t, q_{h,t}, q_{f,t}, q_{l,t}, q_{l,t}^*, r_t, r_t^*, a_t^h, a_t^f, b_t^h, b_t^f, B_t^{h,f}, B_t^{f,h}\right\},$$

as well as the ensuring that $\omega_{u,t+1}^h$ follows the transition map for the wealth distribution $\mathcal{O}(\cdot)$ for all 32 exogenous possible future states of nature. Five grids are required to find future values of $\left\{q_{t+1}, q_{h,t+1}, q_{f,t+1}, C_{u,t+1}, C_{u,t+1}^*\right\}$ over the state x_{t+1}. Initial guesses for these grids are calculated by assuming an end period $t = T$ at which point

$$q_{T+1} = q_{h,T+1} = q_{f,T+1} = C_{u,T+1} = C_{u,T+1}^* = 0$$

for all states of nature. It is then a simple minimization problem to determine $\left\{q_T, q_{h,T}, q_{f,T}, C_{u,T}, C_{u,T}^*\right\}$, which act as the starting guesses. In a sense, we are solving the model through backwards iteration from a distant future end point T.

We next solve the system of the model equations for the endogenous variables in $\mathcal{P}_t$, $\mathcal{C}_t$, and $\mathcal{A}_t$. First, because the hand-to-mouth consumers by assumption maximize their borrowing

$$\begin{aligned} L_t &= \xi \\ L_t^* &= \xi^*. \end{aligned}$$

Using the Garcia-Zangwill (1981) redefinition of the Lagrange multiplier allows the model to reach corner solutions for the equity shorting constraints

$$\begin{aligned} a_t^{h,h} &\equiv \max\left\{0, -a_t^h\right\} \\ a_t^{h,f} &\equiv \max\left\{0, a_t^f - 1\right\} \\ a_t^{f,h} &\equiv \max\left\{0, a_t^h - 1\right\} \\ a_t^{f,f} &\equiv \max\left\{0, -a_t^f\right\}, \end{aligned}$$

where a_t^h and a_t^f, as well as the equity market clearing conditions, determine the equity positions

$$\begin{aligned} A_t^{h,h} &\equiv \min\left\{\max\left\{a_t^h, 0\right\}, 1\right\} \\ A_t^{f,f} &\equiv \min\left\{\max\left\{a_t^f, 0\right\}, 1\right\} \\ A_t^{h,f} &= 1 - A_t^{f,f} \\ A_t^{f,h} &= 1 - A_t^{h,h}. \end{aligned}$$

When $a_t^{h,h} = a_t^{h,f} = a_t^{f,f} = a_t^{f,h} = 0$, the shorting constraints do not bind and $A_t^{h,h} = a_t^h$ and $A_t^{f,f} = a_t^f$. When the home country's shorting constraint binds for its own equity, $a_t^h < 0$, which implies that $a_t^{h,h} > 0$,

$A_t^{h,h} = 0$, and $A_t^{f,h} = 1$. When the foreign country's shorting constraint binds for the home equity, $a_t^h > 1$, which implies that $a_t^{f,h} > 0$, $A_t^{h,h} = 1$, and $A_t^{f,h} = 0$. The same logic holds for the foreign equity positions and Lagrangian multipliers.

The definitions of the CPI can be used to solve for home and foreign price of goods

$$\begin{aligned} p_t &= \left[\frac{\phi_t - (1-\phi_t)\,(q_t)^{\frac{\sigma}{\sigma-1}}}{2\phi_t - 1}\right]^{\frac{\sigma-1}{\sigma}} \\ p_t^* &= \left[\frac{\phi_t - (1-\phi_t)\,(q_t)^{\frac{\sigma}{1-\sigma}}}{2\phi_t - 1}\right]^{\frac{\sigma-1}{\sigma}} . \end{aligned}$$

The same equations can be iterated forward to solve for p_{t+1} and p_{t+1}^* for all possible future states of nature. The definitions of constrained household default determine $I_{r,t}$, $I_{r,t}^*$, $I_{r,t+1}$, and $I_{r,t+1}^*$, and the combined wealth of the unconstrained households, $\Omega_{u,t}$ and $\Omega_{u,t+1}$, can be found as well.

To generate the Lagrange multipliers for borrowing constraints, we must first define the borrowing and lending limits for both Ricardian households. To do this, we denote variables at which the home country has reached its borrowing limit, $\tilde{B}_t^{h,h}$, and the foreign country has reached its lending limit, $\tilde{B}_t^{f,f}$, with $\tilde{}$; likewise, we employ $\hat{}$ when foreign households have reached their borrowing limit, $\hat{B}_t^{f,f}$, and home households have reached their lending limit, $\hat{B}_t^{h,h}$.

$$\begin{aligned} \tilde{B}_t^{h,h} &\equiv -\frac{1}{(1+\tilde{r}_t)} \left\{ \begin{array}{c} \tilde{p}_{t+1}\left[\tilde{W}_{u,t+1} + \left(1-\tilde{I}_{r,t+1}\right)\xi + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}\right] \\ +\tilde{q}_{t+1}\,(1+\tilde{r}_t^*)\,\tilde{B}_t^{h,f} \end{array} \right\} \\ \tilde{B}_t^{f,f} &\equiv \frac{1}{(1+\tilde{r}_t^*)} \left[\tilde{\Omega}_{u,t+1}/\tilde{q}_{t+1} - \left\{ \begin{array}{c} \tilde{p}_{t+1}^*\left[\tilde{W}_{u,t+1}^* + \left(1-\tilde{I}_{r,t+1}^*\right)\xi^* + \tilde{I}_{r,t+1}^*\tilde{W}_{r,t+1}^*\right] \\ +\left(\tilde{q}_{f,t+1} + \tilde{p}_{t+1}^*\tilde{D}_{t+1}^*\right) \\ +\left[(1+\tilde{r}_t)\,\tilde{B}_t^{f,h} + \left(\tilde{q}_{h,t+1} + \tilde{p}_{t+1}\tilde{D}_{t+1}\right)\right]/\tilde{q}_{t+1} \end{array} \right\} \right] \\ \hat{B}_t^{f,f} &\equiv -\frac{1}{(1+\hat{r}_t^*)} \left\{ \begin{array}{c} \hat{p}_{t+1}^*\left[\hat{W}_{u,t+1}^* + \left(1-\hat{I}_{r,t+1}^*\right)\xi^* + \hat{I}_{r,t+1}^*\hat{W}_{r,t+1}^*\right] \\ +(1+\hat{r}_t^*)\,\hat{B}_t^{f,h}/\hat{q}_{t+1} \end{array} \right\} \\ \hat{B}_t^{h,h} &\equiv \frac{1}{(1+\hat{r}_t)} \left[\hat{\Omega}_{u,t+1} - \left\{ \begin{array}{c} \hat{p}_{t+1}\left[\hat{W}_{u,t+1} + \left(1-\hat{I}_{r,t+1}\right)\xi + \hat{I}_{r,t+1}\hat{W}_{r,t+1}\right] \\ +\left(\hat{q}_{h,t+1} + \hat{p}_{t+1}\hat{D}_{t+1}\right) \\ +\hat{q}_{t+1}\left[(1+\hat{r}_t^*)\,\hat{B}_t^{h,f} + \left(\hat{q}_{f,t+1} + \hat{p}_{t+1}^*\hat{D}_{t+1}^*\right)\right] \end{array} \right\} \right] \end{aligned}$$

We employ the same Garcia-Zangwill (1981) trick to define Lagrange multipliers for the borrowing constraints

$$\begin{aligned} b_t^{h,h} &\equiv \max\left\{0, -\left(b_t^h - \tilde{B}_t^{h,h}\right)\right\} \\ b_t^{h,f} &\equiv \max\left\{0, b_t^f - \tilde{B}_t^{f,f}\right\} \\ b_t^{f,h} &\equiv \max\left\{0, b_t^h - \hat{B}_t^{h,h}\right\} \\ b_t^{f,f} &\equiv \max\left\{0, -\left(b_t^f - \hat{B}_t^{f,f}\right)\right\}. \end{aligned}$$

When b_t^h drops below the minimum borrowing limit $\tilde{B}_t^{h,h}$, then the multiplier $b_t^{h,h}$ becomes positive; likewise, when $b_t^f < \hat{B}_t^{f,f}$, then $b_t^{f,f} > 0$. Similarly, $b_t^{h,f}$ and $b_t^{f,h}$ are the multipliers on the foreign and home lending constrains, respectively. When b_t^f rises above the maximum $\tilde{B}_t^{f,f}$, then the multiplier $b_t^{h,f}$ becomes positive; likewise, when $b_t^h > \hat{B}_t^{h,h}$, then $b_t^{f,h} > 0$. The agents' borrowing constraints only bind in the edge cases where $\omega_{u,t}^h = 0$ or $\omega_{u,t}^h = 1$. When $b_t^{h,h} > 0$ ($b_t^{f,f} > 0$), it implies that $b_t^{h,f} > 0$ ($b_t^{f,h} > 0$) as well, so that borrowing and lending constraints bind simultaneously.

Next, we use the variables b_t^h and b_t^f, along with the definitions of the minimum and maximum bond values, to identify the bond holdings

$$\begin{aligned} B_t^{h,h} &= \min\left\{\max\left\{b_t^h, \tilde{B}_t^{h,h}\right\}, \hat{B}_t^{h,h}\right\} \\ B_t^{f,f} &= \min\left\{\max\left\{b_t^f, \hat{B}_t^{f,f}\right\}, \tilde{B}_t^{f,f}\right\}. \end{aligned}$$

When $b_t^{h,h} = b_t^{h,f} = b_t^{f,f} = b_t^{f,h} = 0$, the borrowing constraints do not bind and $B_t^{h,h} = b_t^h$ and $B_t^{f,f} = b_t^f$. When the home country's borrowing constraint binds, $b_t^h < \tilde{B}_t^{h,h}$ and $b_t^f > \tilde{B}_t^{f,f}$, which implies that $b_t^{h,h} > 0$ and $b_t^{h,f} > 0$ as well as $B_t^{h,h} = \tilde{B}_t^{h,h}$ and $B_t^{f,f} = \tilde{B}_t^{f,f}$. Likewise, when the foreign country's borrowing constraint binds, $b_t^h > \hat{B}_t^{h,h}$ and $b_t^f < \hat{B}_t^{f,f}$, which implies that $b_t^{f,h} > 0$ and $b_t^{f,f} > 0$ as well as $B_t^{h,h} = \hat{B}_t^{h,h}$ and $B_t^{f,f} = \hat{B}_t^{f,f}$.

The budget constraints for the non-Ricardian households determine their consumption levels, $C_{r,t}$ and $C_{r,t}^*$. Furthermore, the goods market clearing conditions can be used to find the Ricardian cohorts' consumptions levels:

$$\begin{aligned} C_{u,t} &= \frac{1}{(2\phi_t - 1)}\left[\phi_t \left(p_t\right)^{\frac{1}{1-\sigma}} Y_t - (1-\phi_t)\left(q_t p_t^*\right)^{\frac{1}{1-\sigma}} Y_t^*\right] - C_{r,t} \\ C_{u,t}^* &= \frac{1}{(2\phi_t - 1)}\left[\phi_t \left(p_t^*\right)^{\frac{1}{1-\sigma}} Y_t^* - (1-\phi_t)\left(\frac{p_t}{q_t}\right)^{\frac{1}{1-\sigma}} Y_t\right] - C_{r,t}^*. \end{aligned}$$

For ease of notation, we can now define the stochastic discount factors for each Ricardian cohort:

$$\begin{aligned} M_{t+1} &\equiv \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\theta} \\ M_{t+1}^* &\equiv \beta\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\theta}. \end{aligned}$$

Finally, we define the function $\Psi(\cdot)$ as residual of the Euler equations, of the Ricardian cohorts' budget constraints, and of the home bond market clearing condition (the foreign bond market clearing condition

holds by Walras' law).

$$
\begin{aligned}
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}\left(1+r_t\right)\right]-1 \\ +b_t^{h,h}\left(1+\tilde{r}_t\right)\left(C_t\right)^{\theta} \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(B_t^{h,h}-\bar{B}_t^{h,h}\right) \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}\left(1+r_t^*\right)q_{t+1}\right]/q_t-1 \\ +\left[b_t^{h,h}\left(1+\tilde{r}_t^*\right)\tilde{q}_{t+1}+b_t^{h,f}\right]\left(C_t\right)^{\theta}/q_t \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(B_t^{h,f}-\bar{B}_t^{h,f}\right) \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}\left(q_{h,t+1}+p_{t+1}D_{t+1}\right)\right]/q_{h,t}-1 \\ +\left[b_t^{h,h}\left(\tilde{q}_{h,t+1}+\tilde{p}_{t+1}\tilde{D}_{t+1}\right)+a_t^{h,h}\right]\left(C_t\right)^{\theta}/q_{h,t} \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(A_t^{h,h}-\bar{A}_t^{h,h}\right) \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}\left(q_{f,t+1}+p_{t+1}^*D_{t+1}^*\right)q_{t+1}\right]/q_{f,t}q_t-1 \\ +\left[b_t^{h,h}\left(\tilde{q}_{f,t+1}+\tilde{p}_{t+1}^*\tilde{D}_{t+1}^*\right)\tilde{q}_{t+1}+a_t^{h,f}\right]\left(C_t\right)^{\theta}/q_{f,t}q_t \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(A_t^{h,f}-\bar{A}_t^{h,f}\right) \\
0 &= E\left\{M_{t+1}\left[\left(1-I_{r,t+1}\right)+I_{r,t+1}W_{r,t+1}/\xi\right]p_{t+1}\right\}/q_{l,t}p_t-1 \\
&\quad +b_t^{h,h}\left[\left(1-\tilde{I}_{r,t+1}\right)+\tilde{I}_{r,t+1}\tilde{W}_{r,t+1}/\xi\right]\tilde{p}_{t+1}\left(C_t\right)^{\theta}/q_{l,t}p_t \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}^*\left(1+r_t^*\right)\right]-1 \\ +b_t^{f,f}\left(1+\tilde{r}_t^*\right)\left(C_t^*\right)^{\theta} \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(B_t^{f,f}-\bar{B}_t^{f,f}\right) \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}^*\left(1+r_t\right)/q_{t+1}\right]q_t-1 \\ +\left[b_t^{f,f}\left(1+\tilde{r}_t\right)/\tilde{q}_{t+1}+b_t^{f,h}\right]\left(C_t^*\right)^{\theta}q_t \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(B_t^{f,h}-\bar{B}_t^{f,h}\right) \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}^*\left(q_{f,t+1}+p_{t+1}^*D_{t+1}^*\right)\right]/q_{f,t}-1 \\ +\left[b_t^{f,f}\left(\tilde{q}_{f,t+1}+\tilde{p}_{t+1}^*\tilde{D}_{t+1}^*\right)+a_t^{f,f}\right]\left(C_t^*\right)^{\theta}/q_{f,t} \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(A_t^{f,f}-\bar{A}_t^{f,f}\right) \\
0 &= \tau \left\{ \begin{array}{c} E\left[M_{t+1}^*\left(q_{h,t+1}+p_{t+1}D_{t+1}\right)/q_{t+1}\right]q_t/q_{h,t}-1 \\ +\left[b_t^{f,f}\left(\tilde{q}_{h,t+1}+\tilde{p}_{t+1}\tilde{D}_{t+1}\right)/\tilde{q}_{t+1}+a_t^{f,h}\right]\left(C_t^*\right)^{\theta}q_t/q_{h,t} \end{array} \right\} \\
&\quad -\left(1-\tau\right)\left(A_t^{f,h}-\bar{A}_t^{f,h}\right) \\
0 &= E\left\{M_{t+1}^*\left[\left(1-I_{r,t+1}^*\right)+I_{r,t+1}^*W_{r,t+1}^*/\xi^*\right]p_{t+1}^*\right\}/q_{l,t}^*p_t^*-1 \\
&\quad +b_t^{f,f}\left[\left(1-\tilde{I}_{r,t+1}^*\right)+\tilde{I}_{r,t+1}^*\tilde{W}_{r,t+1}^*/\xi^*\right]\tilde{p}_{t+1}^*\left(C_t^*\right)^{\theta}/q_{l,t}^*p_t^* \\
0 &= C_{u,t}+q_{l,t}p_t\xi+B_t^{h,h}+q_{h,t}A_t^{h,h}+\left(B_t^{h,f}+q_{f,t}A_t^{h,f}\right)q_t-\Omega_{u,t}^h \\
0 &= C_{u,t}^*+q_{l,t}^*p_t^*\xi^*+B_t^{f,f}+q_{f,t}A_t^{f,f}+\left(B_t^{f,h}+q_{h,t}A_t^{f,h}\right)/q_t-\Omega_{u,t}^f \\
0 &= B_t^{h,h}+B_t^{f,h}
\end{aligned}
$$

The above thirteen equations are used to solve for the remaining control variables as identified at the start of this Appendix. As outlined in Schmedders (1998), the use of homotopy eliminates the possibly of asset returns becoming collinear during the minimization procedure. Starting guesses for homotopy are indicated by $^-$ and the punishment coefficient is denoted τ. The system is initially solved with a starting guess for

$\tau < 1$, then those results are used as new starting guess for a larger τ. Eventually, the model with solved with $\tau = 1$ and the true solution is determined.

The transition map for the wealth distribution $\mathcal{O}(\cdot)$ is given by

$$\omega^h_{u,t+1} = \frac{1}{\Omega_{u,t+1}} \left\{ \begin{array}{c} p_{t+1}\left[W_{u,t+1} + (1 - I_{r,t+1})\,\xi + I_{r,t+1} W_{r,t+1}\right] \\ +(1+r_t)\,B^{h,h}_t + (q_{h,t+1} + p_{t+1} D_{t+1})\,A^{h,h}_t \\ +q_{t+1}\left[(1+r^*_t)\,B^{h,f}_t + \left(q_{f,t+1} + p^*_{t+1} D^*_{t+1}\right) A^{h,f}_t\right] \end{array} \right\}$$

The solution grid is defined over the entire state space $\mathcal{X}$ using a number of uniform steps, n, on the home Ricardian's wealth ratio $\omega^h_{u,t}$, such that the step size is $\frac{1}{n-1}$; thus, the grid space is $n \times 32$. We set $n = 11$. An initial guess is selected for the policy functions $\Psi(\cdot)$; B-spline interpolation allows us to approximate future values of the wealth distribution, $\omega^h_{u,t+1}$, between the grid points. We iterate on the policy function $\psi(x)$ until $\left\|\psi_i(x) - \psi_{i-1}(x)\right\| < 10^{-4}$.

C Appendix C

We end up needing to solve for the following fifteen control variables

$$\left\{q_t, q_{h,t}, q_{f,t}, q_{l,t}, q^*_{l,t}, r_t, r^*_t, r_{s,t}, a^h_t, a^f_t, b^h_t, b^f_t, B^{h,f}_t, B^{f,h}_t, S_t\right\}.$$

We maintain the same borrowing constraints as in the simple model; however, those constraints are imposed on the domestic financial sector instead of the home Ricardian households. The constraints continue to guarantee a compact state space by limiting the Ricardian households' wealth ratio to $\omega^h_{u,t} \in [0,1]$.

The government capital-to-asset ratio restriction on the domestic financial sector pins down $q_{k,t}$. We can then apply definitions to find $\breve{\Pi}_{t+1}$, I^u_{t+1}, and I^l_{t+1}. These definitions allow us to calculate $\breve{M}_{t+1}$.

The new Euler equations for the home Ricardian households and the home financial intermediaries follow:

$$\begin{aligned} 0 &= \tau\left\{E\left[M_{t+1}(1+r_{s,t})\right] - 1\right\} \\ &\quad -(1-\tau)\left(S_t - \bar{S}_t\right) \end{aligned}$$

$$\begin{aligned} 0 &= \tau\left\{E\left\{\breve{M}_{t+1}\left[(1+r_t) - (1+r_{s,t})\right]\right\} + b^{h,h}_t(1+\tilde{r}_t)\right\} && \text{(29a)} \\ &\quad -(1-\tau)\left(B^{h,h}_t - \bar{B}^{h,h}_t\right) \\ 0 &= \tau\left\{E\left\{\breve{M}_{t+1}\left[(1+r^*_t)\,q_{t+1}/q_t - (1+r_{s,t})\right]\right\} + \left[b^{h,h}_t(1+\tilde{r}^*_t)\,\tilde{q}_{t+1} + b^{h,f}_t\right]/q_t\right\} && \text{(29b)} \\ &\quad -(1-\tau)\left(B^{h,f}_t - \bar{B}^{h,f}_t\right) \\ 0 &= \tau\left\{\begin{array}{c} E\left\{\breve{M}_{t+1}\left[(q_{h,t+1} + p_{t+1}D_{t+1})/q_{h,t} - (1+r_{s,t})\right]\right\} \\ +\left[b^{h,h}_t\left(\tilde{q}_{h,t+1} + \tilde{p}_{t+1}\tilde{D}_{t+1}\right) + a^{h,h}_t\right]/q_{h,t} \end{array}\right\} && \text{(29c)} \\ &\quad -(1-\tau)\left(A^{h,h}_t - \bar{A}^{h,h}_t\right) \\ 0 &= \tau\left\{\begin{array}{c} E\left\{\breve{M}_{t+1}\left[\left(q_{f,t+1} + p^*_{t+1}D^*_{t+1}\right)q_{t+1}/(q_{f,t}q_t) - (1+r_{s,t})\right]\right\} \\ +\left[b^{h,h}_t\left(\tilde{q}_{f,t+1} + \tilde{p}^*_{t+1}\tilde{D}^*_{t+1}\right)\tilde{q}_{t+1} + a^{h,f}_t\right]/(q_{f,t}q_t) \end{array}\right\} && \text{(29d)} \\ &\quad -(1-\tau)\left(A^{h,f}_t - \bar{A}^{h,f}_t\right) \\ 0 &= E\left[\breve{M}_{t+1}\left\{\left[(1-I_{r,t+1}) + I_{r,t+1}W_{r,t+1}/\xi\right]p_{t+1}/(q_{l,t}p_t) - (1+r_{s,t})\right\}\right] && \text{(29e)} \\ &\quad +b^{h,h}_t\left[\left(1-\tilde{I}_{r,t+1}\right) + \tilde{I}_{r,t+1}\tilde{W}_{r,t+1}/\xi\right]\tilde{p}_{t+1}/(q_{l,t}p_t) \end{aligned}$$

In addition, the home Ricardian households and the domestic FIs have new budget constraints

$$\begin{aligned} 0 &= C_{u,t} + q_{k,t} + S_t - \Omega^h_{u,t} \\ 0 &= q_{l,t} p_t \xi + B^{h,h}_t + q_{h,t} A^{h,h}_t + \left(B^{h,f}_t + q_{f,t} A^{h,f}_t \right) q_t - q_{k,t} - S_t. \end{aligned}$$

These eight equations replace the five Euler equations and single budget constraint for the home Ricardian household in function $\Psi(\cdot)$ from the simple model. The two additional equations allow us to solve for the two additional control variables $r_{s,t}$ and S_t.

Solving the model with endogenous FI default and moral hazard is not as straightforward as solving the frictionless version of the model. Assume, for example, that iterating on the policy function $\psi_i(x)$ results in $q_{h,i} > q_{h,i-1}$. Because $q_{h,i-1}$ is used to populate the $q_{h,t+1}$ grid and $q_{h,i}$ is the current guess for $q_{h,t}$, this step can induce an endogenous default by the FI. Essentially, the model believes the value of the asset will fall in the future state. This default would end up justifying $q_{h,i} > q_{h,i-1}$ so the guess $q_{h,t}$ would appear to be correct.

However, the iterative process must eventually conclude with $q_{h,i} \approx q_{h,i-1}$, which may no longer imply an endogenous FI default. During the iteration process, when an state which has default vanishes, $q_{h,i} < q_{h,i-1}$, which justifies a lower current price of the asset because moral hazard was reduced.

The model can end up cycling through this process of rising and falling equity prices for particular states of nature which are very close to suffering from moral hazard. As a result, the error term never may not fall monotonically.

This problem is worst in states when one country has significantly more wealth than the other. If the home country is poor, then moral hazard causes it to leverage its portfolio with negative bond holding and positive equity positions. This causes FI bankruptcy to become more common the lower $\omega^h_{u,t}$ falls. Conversely, if the home country is rich, then moral hazard causes it to hold both long equity and bond positions, but with significantly more weight on equity assets. This also causes FI bankruptcy to become more common the higher $\omega^h_{u,t}$ rises. As a result, FI bankruptcy is least likely when $\omega^h_{u,t} = 0.5$.

To address these two issues, we first alter the government capital-to-asset requirement, ε, so that it has two values. When $\omega^h_{u,t} \leq 0.2$ or $\omega^h_{u,t} \geq 0.8$, then $\varepsilon = \bar{\varepsilon}$. We set $\bar{\varepsilon}$ high enough that the FI will not face any states of natural with endogenous bankruptcy. This assumption seems justifies since a government that is facing constant FI collapse would most likely change its policy prescriptions to stricter regulations. On the other hand, when $0.2 < \omega^h_{u,t} < 0.8$, the capital-to-asset ratio, ε, can be set to allow for rare states of endogenous default.

Once we update the government policy to eliminate frequent default, the issue of fluctuating equity prices as we iterate on $\psi(x)$ is reduced but not eliminated. As a result, we iterate on the policy function $\psi(x)$ until $\left\| \psi_i(x) - \psi_{i-1}(x) \right\| < 10^{-2}$. We demonstrate via a robustness check that further iteration beyond this threshold does not result in either lower error or a change in simulation results.