Online Appendix

Financial Intermediation, International Risk Sharing, and Reserve Currencies

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A.1 Appendix: Proofs, Details and Extensions

The Brownian motion in equation (1) is defined on a complete probability space and generates a filtration $\mathscr{F}$. Throughout this appendix, "adapted process" means $\mathscr{F}(t)$ adapted.

Lemma 1. Let me scale all variables by output. Then, given the conjecture that the saver's value function only depends on scaled deposits and scaled net transfers, $U(\tilde{D},\tilde{\Pi})$, the optimization problem is solved by the following Hamilton-Jacobi-Bellman (HJB) equation:

$$
\begin{aligned}
&0 = \sup_{\tilde{C}} \left\{ log(\tilde{C})dt - \rho U(\tilde{D},\tilde{\Pi})dt + E_t\left[dU(\tilde{D},\tilde{\Pi})\right] \right\} \\
&s.t. \quad d\tilde{D} = \tilde{D}(r_d - \mu + \sigma^2)dt + (\tilde{\Pi} - \tilde{C})dt - \tilde{D}\sigma dz \\
&\qquad\quad d\tilde{\Pi} = \{\tilde{N}\lambda(r_d - \lambda) + \tilde{Q}[\lambda(\mu_Q + \delta - r_d) - \delta\mu_Q - \sigma\sigma_Q(\lambda - \delta)] + \\
&\qquad\qquad\qquad + \tilde{\Pi}(\sigma^2 - \mu) + \delta\}dt + [\tilde{Q}\sigma_Q(\lambda - \delta) - \tilde{\Pi}\sigma]dz.
\end{aligned}
$$

The first order condition (FOC) is: $\tilde{C}^{-1} = U'_{\tilde{D}}$, where the left hand side (LHS) is the first derivative of U with respect to the scaled deposits. The verification that the value function only depends on $\{\tilde{D},\tilde{\Pi}\}$ follows by substituting the FOC back into the HJB equation, from the fact that:

$$
\tilde{N} = \frac{\tilde{\Pi} + \delta\tilde{D}}{\lambda - \delta}
$$
$$
\tilde{Q} = \frac{\tilde{\Pi} + \lambda\tilde{D}}{\lambda - \delta},
$$

and from the fact that $\{\tilde{Q},\mu_Q,\sigma_Q,r_d\}$ are going to only be functions of $\tilde{N}$ and can therefore be recovered by knowing $\{\tilde{D},\tilde{\Pi}\}$. The sufficiency of the HJB equation for the solution of the optimization problem follows standard steps from the Verification Theorem.[1] An explicit verification is omitted both here and in the following proofs.

To establish the claim that $-r_d\, dt = E_t\left[\frac{d\Lambda}{\Lambda}\right]$, I employ the approach in Cox, Ingersoll and Ross (1985). I take the difference between two expressions. The

[1] See (Øksendal, 2003, page 241).

first expression is obtained by using the FOC above to write $\Lambda = e^{-\rho t}\frac{U'_{\tilde{D}}}{Y}$, and by applying Ito's lemma to this function. The second expression is obtained by taking the partial derivative of the HJB equation above with respect to $\tilde{D}$ and by then multiplying it by $\frac{e^{-\rho t}}{Y}$. Taking the difference between the two expression establishes, after tedious but standard algebra, the claim.

Turning to the problem of the financier, notice that the appropriate discount factor in equation (3) is the marginal value of consumption of the agent receiving the dividends. The financier pays a dividend only once, when she is selected to switch role. The term $e^{-\lambda u}\lambda$ is the probability density function for this exponentially distributed event.

Lemma 2. Given the conjecture that the financier's value function depends on aggregate scaled net worth and the individual financier's net worth, $V(\tilde{N}, n)$, the optimization problem is solved by the following HJB equation:

$$
\begin{aligned}
&0 = \sup_{s} \left\{ \lambda \Lambda_{\lambda} n dt + E_t \left[d(\Lambda_{\lambda} V(\tilde{N}, n)) \right] + \chi(t) dt \, V(\tilde{N}, n) \right\} \\
&s.t. \; dn = s(dQ + Y dt) - r_d \, d \, dt \\
&\qquad d\tilde{N} = \left[\tilde{N}(r_d - \lambda - \mu + \sigma^2) + \tilde{Q}(\mu_q - r_d + \delta - \sigma \sigma_Q) \right] dt + (\tilde{Q}\sigma_Q - \tilde{N}\sigma) dz,
\end{aligned}
$$

where χ is the Lagrange multiplier. The FOC is:

$$\mu_Q - r_d = \sigma_C \sigma_Q - \sigma_\Omega \sigma_Q. \tag{A.1}$$

When substituting the FOC back into the HJB equation, I obtain a restriction that the function Ω has to satisfy for the conjecture of the value function to be valid:

$$0 = \lambda \frac{(1-\Omega)}{\Omega} + \mu_\Omega - \sigma_C \sigma_\Omega. \tag{A.2}$$

As long as $\{\tilde{Q}, \mu_Q, \sigma_Q, r_d\}$ only depend on $\tilde{N}$ in equilibrium, then the conjecture that Ω only depends on $\tilde{N}$ is verified.

Using the saver's Euler equation in equation (4) and equation (A.2), algebraic manipulations yield the result in equation (6). The additional use of the financier's FOC yields the result in equation (5).

Proposition 1. The concept of equilibrium is the standard Walrasian one.[2] The proofs of Lemma 1 and 2 state that to solve the saver's and financier's optimization problems one only needs to know the variable $\tilde{N}$, as long as $\{\tilde{Q}, \mu_Q, \sigma_Q, rd\}$ only themselves depend on that variable. The saver's Euler equation, equation (4), and the market clearing condition $C = Y$ together imply that the deposit rate is constant in equilibrium and is given by $r_d = \rho + \mu - \sigma^2$. Applying Ito's

[2]Consumption and investment decisions are adapted processes such that the financier's and saver's optimization problems are satisfied and markets clear.

lemma to $\tilde{Q} = \frac{Q}{Y}$ and to the conjecture $\tilde{Q}(\tilde{N})$ and matching the corresponding drift and diffusion terms yields:

$$\mu_Q(t) = \frac{1+\tilde{Q}[\mu+\tilde{Q}'(\delta-\mu-\rho)]+\tilde{N}\tilde{Q}'(\rho-\lambda)}{\tilde{Q}(1-\tilde{Q}')} + \frac{(\tilde{Q}-\tilde{N})\tilde{Q}'\sigma^2}{\tilde{Q}(1-\tilde{Q}')} + \frac{(\tilde{Q}-\tilde{N})^2\tilde{Q}''\sigma^2}{2\tilde{Q}(1-\tilde{Q}')^3}$$

$$\sigma_Q(t) = \frac{\tilde{Q}-\tilde{N}\tilde{Q}'}{\tilde{Q}(1-\tilde{Q}')}\sigma.$$

Substituting these expressions into the financier's FOC (equation (A.1)) yields the ODE for $\tilde{Q}(\tilde{N})$, reported in implicit form in equation (9), thus verifying that $\tilde{N}$ is the only state variable. The proof that the state variable is a strong Markov process follows from its dynamics in equation (7), where the drift and diffusion terms only depend on $\tilde{N}$ itself.

Equation (A.2) is the ODE for Ω reported in equation (9). The ODEs in equations (8-9) are implicit and I report here their explicit expressions:

$$\tilde{Q}'' = \frac{2(-1+\tilde{Q}')\left\{-(-1+\tilde{Q}')[1+\tilde{Q}(\tilde{Q}'\delta-\rho)+\tilde{N}\tilde{Q}'(-\lambda+\rho)]\Omega+(-\tilde{N}+\tilde{Q})(\tilde{Q}-\tilde{N}\tilde{Q}')\sigma^2\Omega'\right\}}{(\tilde{N}-\tilde{Q})^2\sigma^2\Omega} \tag{A.3}$$

$$\Omega'' = \frac{2(-1+\tilde{Q}')^2\lambda\Omega(-1+\Omega+\tilde{N}\Omega')+2\Omega'\left\{-(-1+\tilde{Q}')\left[(-1+\tilde{Q}')(\tilde{Q}\delta+\tilde{N}\rho)+(-\tilde{N}+\tilde{Q})\sigma^2\right]\Omega\right\}}{(\tilde{N}-\tilde{Q})^2\sigma^2\Omega} + \\ + \frac{2\Omega'(-\tilde{N}+\tilde{Q})(\tilde{Q}-\tilde{N}\tilde{Q}')\sigma^2\Omega'}{(\tilde{N}-\tilde{Q})^2\sigma^2\Omega}, \tag{A.4}$$

where the superscript $''$ denotes the second derivative of a function.

The system of ODEs has an intuitive interpretation. The ODE (8) implies that the Sharpe ratio is higher than in the Lucas Economy; this occurs because financiers are worried about losses of capital that could restrict their investment opportunity set. To see this, re-write equation (8) as

$$\frac{\mu_Q - r_d}{\sigma_Q} = \sigma - \sigma_\Omega.$$

The Sharpe ratio has two components. The first, the volatility of consumption, which in equilibrium is equal to σ, is the same as in the Lucas Economy. The second, σ_Ω, accounts for financiers' required compensation, measured per unit of risk, to take on risk that is correlated with their net worth. In equilibrium, $\sigma_\Omega < 0$ because the marginal value of net worth increases when financiers lose capital. The ODE (9) is a restriction on the dynamics of Ω; it ensures that financiers and savers agree on the pricing of risk-free deposits.[3]

[3]The saver's Euler equation (4) and the fact that, in equilibrium, consumption equals output together imply that the risk-free deposit rate equals the risk-free rate in the Lucas Economy. For financiers to agree on the pricing of the risk-free rate, the ODE (9) requires that the intertemporal (elasticity of substitution) and intratemporal (precautionary) effects of financial risk (Ω) on the risk-free rate exactly offset each other.

Lucas Economy: Equilibrium Details

Assuming that there are no frictions in the model removes the constraint $V(t) \geq 0$, by eliminating the incentives of the financiers to walk away from their intermediaries. Since financiers are unconstrained in raising deposits, $\Omega(\tilde{N}) = 1$ and $\tilde{Q}(\tilde{N}) = \frac{1}{\rho}$. These constant functions satisfy the ODEs in (A.3-A.4). The risk premium is constant and is given by $\mu_Q - r_d = \sigma^2$. Note that financiers can make arbitrarily large losses on their investment strategies because they are raising risk-free deposits with a positive interest rate, and investing in a risky asset with a positive (and finite) risk premium. As a technical condition, to ensure that the financier's optimization problem is well defined, I rule out the "doubling portfolio strategy" by restricting the set of admissible investment strategies to those that are square integrable.[4]

To confirm that the underlying micro-foundations of the model are economically sensible, I analyze the dynamics of $\hat{N} \equiv \frac{N}{Q}$:

$$d\hat{N} = (\lambda - \rho)(\frac{\delta}{\lambda - \rho} - \hat{N})dt + \sigma(1 - \hat{N})dz.$$

Under the restriction $\delta < \lambda - \rho$, the above stochastic process is mean-reverting and lies in the interval $(-\infty, 1)$.[5] The stochastic steady state is $\hat{N}^{SS} = \frac{\delta}{\lambda - \rho}$. Note that deposits are always positive.

Under the restriction $\delta = \lambda - \rho$ the process, started at $\hat{N}(t = 0) < 1$, will eventually drift to the absorbing upper boundary[6] of 1. Consequently, the stochastic steady state is $\hat{N}^{SS} = 1$. In this scenario, financiers eventually accumulate enough capital to purchase all shares in the output tree without having to raise deposits.

Notice that in this setting the constraint is violated with positive probability, but the intermediary losses are just accounting between financiers and savers with no effect due to the consumption risk sharing. Following investment losses, and even when net worth becomes negative, depositors are always repaid because when a financier with negative net worth is selected to switch roles, she pays negative net worth out to her household; that is, the household repays in full the selected financier's depositors. Alternatively, one could achieve the frictionless equilibrium by allowing intermediaries to be financed via equity instead of deposits (which is not allowed under the frictions), at which point shares in

[4] See (Duffie, 2001, 6.c) for details.

[5] A precise proof of the boundary behavior is beyond the scope of this paper. I only note that, given that financiers' starting net worth is less than the price of the risky asset, in the limit of financiers accumulating sufficient net worth for deposits to shrink to zero (i.e. $\hat{N} \uparrow 1$) the diffusion term of $\hat{N}$ approaches zero and the drift term is negative. See Karlin and Taylor (1981) for a precise proof of the boundary behavior.

[6] This occurs because the drift of the process approaching the upper boundary is positive and decreases to zero in the limit, while the diffusion term converges to zero. See Karlin and Taylor (1981) for a rigorous description.

the intermediaries and shares in the risky asset become identical.

Asset Pricing in the Banking Economy: Equilibrium Details

The financier's FOC yields:

$$\mu_Q - r_d = Cov_t\left[\frac{dC}{C}, \frac{dQ}{Q}\right] - \frac{\Omega'}{\Omega}\tilde{N}\, Cov_t\left[\frac{d\tilde{N}}{\tilde{N}}, \frac{dQ}{Q}\right].$$

This implies that assets are priced according to a two factor asset pricing model, where the risk factors are consumption and the financial system's net worth, that is:

$$\mu_Q(t) - r_d = \lambda_C \beta_C(t) + \lambda_{\tilde{N}}(t)\beta_{\tilde{N}}(t),$$

and where the prices of risk and betas are defined as:

$$\beta_C(t) \equiv \frac{Cov_t\left[\frac{dC}{C}, \frac{dQ}{Q}\right]}{Var_t\left[\frac{dC}{C}\right]}; \qquad \beta_{\tilde{N}}(t) \equiv \frac{Cov_t\left[\frac{d\tilde{N}}{\tilde{N}}, \frac{dQ}{Q}\right]}{Var_t\left[\frac{d\tilde{N}}{\tilde{N}}\right]}$$

$$\lambda_C \equiv Var_t\left[\frac{dC}{C}\right]; \qquad \lambda_{\tilde{N}}(t) \equiv -Var_t\left[\frac{d\tilde{N}}{\tilde{N}}\right]\frac{\Omega'}{\Omega}\tilde{N}.$$

The first term on the RHS of equation (A.5) is the CCAPM, where assets are risky if their returns covary positively with consumption. Compared to the CCAPM in the Lucas Economy, the volatility of asset prices varies endogenously and, consequently, the beta in the Banking Economy is time-varying. The second term implies that assets are riskier if they covary positively with the financial system's net worth. Both the market price and the beta of the financial risk factor are time-varying.

The risk-free deposit rate is constant and equal to the one in the Lucas Economy:

$$r_d = \rho + \mu - \sigma^2 - \underbrace{\lambda(1-\Omega) - \Omega'\mu_{\tilde{N}} - \frac{1}{2}\Omega''\sigma_{\tilde{N}}^2 + \Omega'\sigma\sigma_{\tilde{N}}}_{\text{=0 by ODE (9)}}.$$

The ODE (9) imposes that the increase in the risk-free rate that occurs because of the inter-temporal drift in the value of capital ($\mu_{\tilde{N}}$) and the role switching of financiers and savers ($\lambda(1-\Omega)$) is exactly offset by the precautionary motive to save that is induced by intra-temporal financial risk ($\sigma_{\tilde{N}}^2$) and the covariance between consumption and financial risk ($\sigma\sigma_{\tilde{N}}$). The result rests on three features of my set-up: savers are atomistic, savers and financiers share risks perfectly, and equilibrium consumption is exogenous. In the autarky model, there is no tension between a higher equity premium and a low and stable risk-free rate, thus accommodating the risk-free rate puzzle.

Even if dividends are a random walk, the model endogenously generates persistent effects of *iid* shocks and forecastable equity excess returns. This occurs because excess returns are a function of aggregate net worth, which in turn is persistent and pro-cyclical. For example, a negative shock results in a capital loss for financiers and increases the risk premium;[7] the only way to rebuild net worth is to earn the expected risk premium over time. Therefore, on impact, expected returns increase and then gradually decrease as financiers rebuild the stock of net worth.

As a technical note on the asset pricing properties of the equilibrium, notice that the FOC of the financiers and savers and the restriction on the dynamics of Ω imply that the financier is locally indifferent between the optimal investment strategy and investing in the risk-free rate. This occurs because the value function of the financier is linear in her own net worth. The property, however, does not survive globally because of the constraint on financiers' financing. The financier has access to investment opportunities that are attractive for a logarithmic agent, however, she cannot invest an unlimited amount since the intermediate losses cannot be financed due to the constraint.

I provide here more details on the closed economy dynamics. Figure A.1 shows that the effects of bank capitalization on the equilibrium are non-linear. The dynamics of the first region are described in the main text of the paper. I note here that, as in Shleifer and Vishny (1992), the financiers attempting to sell the asset depress its price because the "natural buyers", the other financiers, have also suffered capital losses and are also attempting to sell. The risky asset is non-redeployable since savers, by assumption, value it at zero (cannot hold it). Fire-sale transactions never occur in equilibrium; financiers' attempts to sell the asset reduce its price sufficiently to induce them to hold it. As in Kiyotaki and Moore (1997), a dynamic feedback effect amplifies this static effect. In my set-up, however, the dynamic effect arises from endogenous movements in the discount factor rather than in cash flows. Capital losses heighten intermediaries' concerns about further losses and increase their discount factor for the risky asset. Since capital cannot be immediately replenished, the increase in the discount factor is persistent. The higher discount factor for future cash flows dynamically feeds back into lower present asset prices, thus further lowering intermediaries' present net worth.

The amplification also generates an increase in the volatility of asset prices. The diffusion terms of the stock and of scaled net worth can be written as

$$\sigma_Q = \frac{\phi - \tilde{Q}'}{\phi(1-\tilde{Q}')}\sigma; \qquad \sigma_{\tilde{N}} = \phi\ \sigma_Q - \sigma. \tag{A.5}$$

Endogenously, $\phi \geq 1$ and $\tilde{Q}' < 1$. Asset prices are more volatile than dividends

[7] I refer here to the region of the equilibrium away from zero net worth. The sign of predictability, i.e. that a low price-dividend ratio predicts high excess stock returns, is also maintained in the region close to zero net worth. However, the relationship between net worth and the price-dividend ratio is inverted.

whenever $\tilde{Q}'(\phi - 1) > 0$, with the extent of the amplification depending on financial intermediaries' leverage and on the reaction of the price-dividend ratio to changes in net worth.[8] There is no amplification only if financial intermediaries are not levered ($\phi = 1$) or if the price-dividend ratio does not react to changes in intermediary capital ($\tilde{Q}' = 0$). In the first region, amplification is positive since intermediaries are levered ($\phi > 1$) and the price-dividend ratio falls whenever intermediaries lose capital ($\tilde{Q}' > 0$).

The equilibrium dynamics in this first region illustrate common characteristics of financial crises. These dynamics change as further negative shocks push financial intermediaries into the second region, where their capital is close to zero. Recall that, in aggregate, the credit constraint takes the form $\Omega\tilde{N} \geq 0$. The tightness of the constraint is determined by the balance of two opposing effects: losses of capital, reflected in a lower $\tilde{N}$, induce increases in the value of capital, represented by a higher Ω.

In the first region, losses of capital outweigh the effect of increases in the value of capital and tighten the constraint almost linearly. As financial intermediaries' capital decreases further and we enter the second region, the increase in the value of capital alleviates the losses of capital and the constraint tightens more slowly. Intuitively, the higher Sharpe ratio mitigates the incentives of financiers to walk away from poorly capitalized financial intermediaries. This causes the price-dividend ratio to increase whenever there are intermediary capital losses ($\tilde{Q}' < 0$). In this case, equation (A.5) shows that capital gains have a stabilizing effect on losses of net worth and dampen the volatility of asset prices. The risky asset begins to mimic the risk-free one and, in the limit as net worth approaches zero, the risky asset is locally risk less.[9]

Under the restriction $\delta = \lambda - \rho$, the economy eventually converges to the Lucas Economy equilibrium. Intuitively, financiers accumulate net worth sufficiently quickly to reach a state where the entire supply of risky investments can be bought with the financial intermediaries' capital.[10] In this state, the absence

[8]This emphasizes, as in Brunnermeier and Pedersen (2008), the interaction of market liquidity, i.e. the price impact of transactions in the risky asset ($\tilde{Q}'$), and funding liquidity, i.e. the ability of financial intermediaries to raise capital for investment (ϕ).

[9]This second region of the state space provides an endowment economy equivalent to financial depressions, such as the one experienced in Japan starting in the early 1990s. Following the most acute phase of a crisis, where the stock market crashes and volatility increases, further losses of capital lead to a depression region. Here, stock prices are so high compared to dividends that risky investment returns are low. Consequently, existing financiers are not able to quickly escape this region by accumulating net worth through positive returns on investments. Figure A.3 confirms the intuition by showing a fall in the drift and volatility of aggregate financial net worth. In the limit, as $\tilde{N} \downarrow 0$, the drift approaches $\delta\tilde{Q}$ and can be set arbitrarily close to zero by choosing a low value of δ, and the volatility goes to zero. Brunnermeier and Sannikov (2014) provide a similar "area of attraction" in the low region of the state space. In my model, the main difference is that the depression is caused solely by endogenous changes in the discount factor, while cash flows are exogenous.

[10]The balance of three effects regulates the asymptotic accumulation of aggregate net worth:

of leverage induces the financial intermediaries' capital to move one-for-one with stock prices, and financiers are no longer concerned about losing their net worth. The equilibrium dynamics of this case are illustrated in Figure A.1. In contrast, under the restriction $\delta < \lambda - \rho$ financiers do not converge to the frictionless equilibrium. In this case, deposits are always strictly positive and the levered financiers are forever concerned about potential losses of net worth. The resulting equilibrium dynamics are illustrated in Figure A.2.

In both cases, the *stochastic* steady state[11] is the point in Figure A.3 where the drift of scaled net worth equals zero. In the first case, the stochastic steady state is the upper boundary of the state space: $\tilde{N}^{SS} = \frac{1}{\rho}$. The limiting distribution of scaled net worth is degenerate, with the entire probability mass concentrated at the stochastic steady state. In the second case, the stochastic steady state is in the interior of the state space; the stationary distribution of scaled net worth is reported in Figure A.4. The distribution has a fat left tail, since negative shocks are amplified more than positive shocks. Therefore, while fundamental shocks are *iid* Gaussian, the banking economy suffers from endogenous financial disasters. The distribution shows that the system does not spend substantial time near the zero net worth limit. This occurs because, while existing intermediaries might struggle to rebuild capital given their investment opportunity set, there is a continuous inflow of capital from households to incoming financiers. Recall that exiting financiers pay out their net worth, which of course is small in the limit of zero net worth, to households, while households provide capital to starting financiers at rate $\delta Q dt$. This net inflow of capital helps rebuild net worth and move the system back towards the steady state.

Lemma 3. Since the Home country is unconstrained, the proofs for the autarky case make clear that its consumption and portfolio problems are identical to those of a representative agent with logarithmic utility. The Euler equations in (12-14) are standard for such an agent. I focus here only on the optimization problems of Foreign agents.

Foreign savers solve a problem analogous to Lemma 1, so an entirely similar proof applies. Consider the problem of the representative financier in equation (10) for $t < t'$. Since the financier pays no net worth to the household for any $t < t'$, the discounted value of her intermediary needs to be a local martingale along the optimal path. The HJB equation is:

$$0 = \sup_{\{b^*(u), s^*(u)\}} E_t[d(\Lambda^* V^*)] + \chi(t) dt\, V^*,$$

financiers accumulate capital at the rate of time preference ρ, start-up capital allocated to new financiers increases aggregate net worth by δ, and net worth paid out by exiting financiers reduces aggregate net worth by λ.

[11] The stochastic steady state is defined as the point to which the state variable converges if shocks are possible but are not ever realized. This is in contrast to the most commonly analyzed *deterministic* steady state, which is defined as the point of convergence if the model features no shocks ($\sigma = 0$).

where χ is the Lagrange multiplier. Conjecture that the value of the intermediary only depends on its capital and aggregate Foreign scaled net worth: $V(\tilde{N}^*, n^*) = \Omega^*(\tilde{N}^*)n^*$. The FOCs are:

$$\mu_Q - r_d^* = \sigma_{C^*}\sigma_Q - \sigma_{\Omega^*}\sigma_Q \tag{A.6}$$

$$r_b = r_d^*. \tag{A.7}$$

Substituting the FOCs into the HJB equation leads to a restriction that Ω^* has to satisfy:

$$0 = \mu_{\Omega^*} - \sigma_{C^*}\sigma_{\Omega^*}. \tag{A.8}$$

Now consider the problem of the financier for $t > t'$. I conjecture that in this case $\Omega^* = 1$ and the financier will pay out her net worth when she is selected to switch roles. The HJB equation is:

$$0 = \sup_{\{b^*(u), s^*(u)\}} \left\{ \lambda \Lambda_\lambda^* n^* dt + E_t[d(\Lambda_\lambda^* V^*)] + \chi(t) dt\, V^* \right\},$$

where $\Lambda^{*\lambda} = e^{-(\rho+\lambda)t}\frac{1}{C^*}$. The FOCs are analogous to those above for the case $t < t'$, except that $\sigma_{\Omega^*} = 0$. Plugging the FOCs back into the HJB equation verifies the guess that $\Omega^* = 1$. However, for this conjecture to be an equilibrium, the upper boundary of the state space needs to be absorbing. This restriction is verified in Proposition 2.

It remains to be verified that for $t < t'$ an individual financier will not want to deviate from the HJB problem described above for the representative financier. An individual financier faces the possibility that at some time t^A, where $t < t^A < t'$, she will switch jobs and the net worth of her intermediary will be reinvested with an incoming financier. Consider intermediary A with capital $n^{*A}(t)$ that is liquidated at time t^A, the capital of which is inherited by intermediary B. At time t^A, the value of intermediary B is a linear function of its net worth. The linearity allows me to only concentrate on the capital inherited by intermediary A and, without loss of generality, to ignore the start up capital injected in intermediary B by the household. It follows that $V^{*B}(t^A) = \Omega^*(\tilde{N}^*(t^A))n^{*A}(t^A)$. Using the definition of the value of the intermediary and the law of iterated expectations one has:

$$\begin{aligned} V^{*A}(t) &= E_t\left[\frac{\Lambda^*(t^A)}{\Lambda^*(t)} V^{*B}(t^A)\right] = \\ &= E_t\left[\frac{\Lambda^*(t^A)}{\Lambda^*(t)} E_{t^A}\left[\int_{t'}^{\infty} \frac{\Lambda^*(s)}{\Lambda^*(t^A)} n^{*B}(s)\lambda e^{-\lambda(s-t')} ds\right]\right] = \\ &= E_t\left[\int_{t'}^{\infty} \frac{\Lambda^*(s)}{\Lambda^*(t)} n^{*A}(s)\lambda e^{-\lambda(s-t')} ds\right]. \end{aligned}$$

Since the chosen timing of the liquidation t^A is arbitrary, this argument holds for a generic intermediary. This proves that the maximization problem for an individual intermediary is equivalent to the problem of the representative intermediary.

Using the Foreign saver's Euler equation and the restriction on the dynamics of Ω^* in equation (A.8) yields the financier's pricing equation for the deposit rate in equation (16). Using equation (A.7) gives the result in equation (17). Equation (A.6), equation (16), and equation (A.8) together yield equation (15).

Proposition A.1 The Open Banking Economy features an equilibrium risk sharing condition of the form $\frac{C^*}{C} = \frac{\Omega^*}{\xi}$, with ξ a positive scalar.

The pricing equations for the Open Banking Economy (12-17) and the fact that bankers can trade both the risk-less interbank rate and the stock together impose that:

$$\frac{d\Lambda^*\Omega^*}{\Lambda\Omega^*} = -r_b\,dt - \frac{\mu_Q - r_b}{\sigma_Q}dz,$$
$$\frac{d\Lambda}{\Lambda} = -r_b\,dt - \frac{\mu_Q - r_b}{\sigma_Q}dz.$$

Recalling that $\Lambda = e^{-\rho t}\frac{1}{C}$ and $\Lambda^* = e^{-\rho t}\frac{1}{C^*}$, this in turn yields:

$$\frac{C^*}{C} = \frac{\Omega^*}{\xi},$$

where ξ is a positive scaling constant to be determined in equilibrium given the starting conditions.

Proposition 2. The verification that the equilibrium can be solved as a function of a single state variable, the scaled net worth of Foreign intermediaries, requires solving a system of equations. As for the autarky case, this is straightforward but algebra intensive. I provide here the steps of the substitutions that I follow, although the substitutions can clearly be made in different orders. To solve for the equilibrium I have normalized all variables for the size of the output tree, so that in the resulting system Y is no longer a state-variable. The equilibrium risk sharing condition in equation (20) shows that the ratio of the two countries' consumption is fully summarized by Ω^*. This relationship and the fact that the Home country is unconstrained together allow me to further reduce the number of state variables, since keeping track of Ω^* is sufficient to keep track of the ratio of net-wealth in the two countries.

The conjecture that Ω^* only depends on $\tilde{N}^*$ remains to be verified. The steps are as follows. Use the risk sharing condition and goods market clearing to derive expressions for the drift and diffusion of consumption in each country. To compute the stock and international bond portfolio for each country use the standard derivation, as in frictionless open economies with complete markets à la Lucas. The Home country net wealth is $W(t) = SQ - B$ and the consumption optimality condition and budget constraint imply $W(t) = \frac{1}{\rho}C(t)$. Applying Ito's lemma to both sides of this last equality and requiring the equality of the resulting LHS drift and diffusion terms with those of the dynamic Home net wealth budget constraint yields two equations linear in two unknowns: the stock position S, and international borrowing B. The market clearing conditions for stock and international bond (interbank loans) markets yield S^* and B^*.

Use the Home saver pricing equation (13) to derive an expression for the risk-free rate. Finally, use the conjecture that $\{\tilde{Q}, \Omega^*\}$ only depend on $\tilde{N}^*$ to derive expressions for the drift and diffusion of these processes using similar steps to those in the proof of Proposition 1. These operations produce a system of equations in $\{\mu_Q, \sigma_Q, r_b, S, B, S^*, B^*\}$; its solution expresses these variables as functions of $\tilde{N}^*$ and the level and first two derivatives of the functions $\{\tilde{Q}, \Omega^*\}$. Finally, substitute the variables in equations (A.6) and (A.8), the implicit ODEs reported in the main text, to obtain two coupled second order ODEs for $\{\tilde{Q}, \Omega^*\}$, thus verifying the conjecture. I report here the extensive form of the ODEs:

$$\begin{aligned}\tilde{Q}'' &= -\frac{2(-1+\tilde{Q}'S^*)^2((1+\xi)(1+\tilde{N}\tilde{Q}'\rho)+\tilde{Q}(\tilde{Q}'\delta-(1+\xi)\rho))}{(\tilde{N}-\tilde{Q}S^*)^2(1+\xi)\sigma^2}+ \\ &\quad -\frac{2(\tilde{Q}-\tilde{N}\tilde{Q}')(-1+\tilde{Q}'S^*)\Omega^{*'}}{(\tilde{N}-\tilde{Q}S^*)(\xi+\Omega^*)}-\frac{2(\tilde{Q}-\tilde{N}\tilde{Q}')\xi\Omega^{*'2}}{\Omega(\xi+\Omega^*)^2} \qquad \text{(A.9)}\end{aligned}$$

$$\begin{aligned}\Omega^{*''} &= \frac{2(-1+\tilde{Q}'S^*)\left(\tilde{N}-\tilde{Q}S^*-\frac{(-1+\tilde{Q}'S^*)(\tilde{Q}\delta+\tilde{N}(1+\xi)\rho)}{(1+\xi)\sigma^2}\right)\Omega^{*'}}{(\tilde{N}-\tilde{Q}S^*)^2}+ \\ &\quad +\frac{2(-\tilde{Q}S^*(\xi+\Omega^*)+\tilde{N}(\xi+\tilde{Q}'S^*\Omega^*))\Omega^{*'2}}{(\tilde{N}-\tilde{Q}S^*)\Omega^*(\xi+\Omega^*)}+\frac{2\tilde{N}\xi\Omega^{*'3}}{\Omega^*(\xi+\Omega^*)^2}. \qquad \text{(A.10)}\end{aligned}$$

The system of ODEs has an intuitive interpretation. The ODE (18) is a standard pricing equation: it shows that expected stock excess returns depend positively on the covariance between Home consumption and stock returns. The ODE (19) ensures that Foreign financiers and savers agree upon the price of risk-free deposits.

The scaling constant ξ is pinned down by requiring that the initial net wealth in each country equal the present value of future consumption. For the Home country, this implies the restriction $W(0) = \frac{1}{\rho}C(0)$. The starting conditions, $\{S(0) = 1/2, S^*(0) = 1/2, B(0) = 0, B^*(0) = 0, Y(0), N^*(0), D^*(0)\}$, are chosen so that countries are symmetric. Each country starts with half of the total shares in the stock and no interbank loans. Within each country, shares are held by its intermediaries, which have a starting balance sheet composed of $N(0)$ net worth and $D(0)$ deposits (where $1/2\ Q(0) = N(0) + D(0)$). Using the starting conditions and consumption rule for the Home country I have:

$$\frac{1}{2}\tilde{Q}(0) = \frac{\xi}{(\xi + \Omega^*(0))\rho}. \tag{A.11}$$

Given $\tilde{N}^*(0)$, the above equation pins down the value of ξ. As discussed in Appendix A.2, the solution for ξ is unique for all the numerical solutions of the model.

For the equilibrium to be well defined it remains to be verified that, having started the state variable such that $\tilde{N}^*(0) < \tilde{N}^{*SS} = \frac{1}{\rho(1+\xi)}$, the stochastic steady state (i.e. the upper boundary) is reached and is absorbing, and that V^* exists and is strictly positive for every $\tilde{N}^*(t)$ with $t < t'$. The imposed parameter restriction $\delta = \lambda - \rho$, as discussed in Appendix A.2, ensures that this is the case. The model cannot generate a long-run debtor position for the U.S. because the stochastic steady state is one where risk taking is symmetric.[12] The stochastic steady state in this model can be interpreted as a "very long run" outcome in which the RoW financial development and accumulation of capital make credit concerns irrelevant.

Open Lucas Economy: Equilibrium Details

Assume that there are no frictions in the Foreign financial sector, so that the constraint $V^*(t) \geq 0$ is no longer present in the Foreign financier's optimization problem. Since Foreign financiers are unconstrained in raising deposits, $\Omega^*(\tilde{N}^*) = 1$ and $\tilde{Q}(\tilde{N}^*) = \frac{1}{\rho}$. These constant functions satisfy the ODEs in equations (A.9-A.10). The risk sharing condition in equation (20) now simplifies to the statement that consumption in the two countries is equal in every state (the equality follows from $\xi = 1$ since the two countries are symmetric). The risk premium is constant and equal to $\mu_Q - r_d = \sigma^2$. The equilibrium allocation is supported by international portfolios, where each country's financiers own half of the total stock and no interbank loans.

The stochastic steady state is $\tilde{N}^{*SS} = \frac{1}{2\rho}$, which is also the absorbing upper boundary of the state space.

An application of the model to the U.K. before the First World War

While the motivational evidence for this paper is focused on the U.S., the same theoretical framework also sheds light on the role of the U.K. as the key country before the First World War. London's funding markets were then the deepest in the world; this was a key factor in determining Britain's financial dominance (Bagehot (1873)). My model is related to Kindleberger's (1965) hypothesis that the asymmetric external balance sheet of Britain, with respect to its colonies, was due to differences in "demand for liquidity" and did not

[12] An extension of the paper could introduce mean reversion in the state variable, as was done in the closed economy, so that the U.S. has a permanent advantage in financial intermediation. Logic suggests that this would allow the U.S., in extreme cases, to run both an asymptotic trade deficit and a negative NFA position.

necessarily represent a form of exploitation.[13]

My model also explains the global flight to safety toward the London funding markets, described by Bagehot (1873) for the financial crises of the nineteenth century. In contrast to recent U.S. history, however, Britain ran a sizable trade surplus at the time. In order to reconcile this with my framework recall that, though it is the focus of my model, I am not suggesting that financial development is the only determinant of the trade balance. Instead, my framework indicates that the key country runs either more of a trade deficit or less of a trade surplus than it would have otherwise done, if differences in the extent of financial development were not present. This allows other facts, such as Britain's industrial base, to also play a role in determining the overall trade balance.

Open Economy, Two Trees: Static Optimization for Consumption Baskets

Consider the problem for the Home country:

$$\begin{aligned} &\max_{C_H, C_F} C_H^{\alpha}\, C_F^{1-\alpha} \\ &s.t. \quad C_H\, p + C_F\, p\, \tau = C\, P, \end{aligned}$$

where CP, aggregate expenditure, is given. Substituting the budget constraint for C_F, and re-arranging the FOC for C_H yields the results in equations (24-25). The price indices for each country are derived by substituting equations (24-25) in the consumption basket, imposing $C = 1$, and rearranging to yield:

$$P = p^{\alpha}(p^*\tau)^{1-\alpha}\ \alpha^{-\alpha}(1-\alpha)^{\alpha-1}; \qquad P^* = p^{1-\alpha}p^{*\alpha}\ \alpha^{-\alpha}(1-\alpha)^{\alpha-1}.$$

Simple algebra then yields the expression for the exchange rate as a function of the terms of trade.

Open Economy, Two Trees: The Home and Foreign Optimal Consumption and Investment Problems

As in the proof of Lemma 3, since Home agents do not face financial frictions their optimization problem is equivalent to that of a Home representative agent with logarithmic preferences. Since such an optimization problem is stan-

[13] The similar claim of exploitation, or "exorbitant privilege", that was later directed at the U.S. by the French Finance Minister Valéry Giscard d'Estaing, is often mentioned in connection with the stylized facts that concern my main analysis. I have shown how this can be demystified as the outcome of equilibrium risk sharing.

dard, I only report here the corresponding Euler equations:

$$0 = \Lambda \frac{pY}{P} dt + E_t \left[d(\Lambda Q) \right] \tag{A.12}$$

$$0 = \Lambda \frac{p^* Y^*}{P} dt + E_t \left[d(\Lambda \mathscr{E} Q^*) \right] \tag{A.13}$$

$$0 = E_t \left[d(\Lambda D_a) \right] \tag{A.14}$$

$$0 = E_t \left[d(\Lambda B_a) \right] \tag{A.15}$$

$$0 = E_t \left[d(\Lambda \mathscr{E} B_a^*) \right], \tag{A.16}$$

where $\Lambda \equiv e^{-\rho t} \frac{1}{C}$, D_a is the Home-currency deposit asset, B_a is the Home-currency interbank asset, and B_a^* is the Foreign-currency deposit asset with dynamics, respectively:

$$\frac{dD_a}{D_a} = r_d \, dt; \quad \frac{dB_a}{B_a} = r_b \, dt; \quad \frac{dB_a^*}{B_a^*} = r_b^* \, dt.$$

The no arbitrage condition implies that: $r_d = r_b$. Equation (27) is derived by rearranging equations (A.15-A.16) and using the dynamics of the exchange rate.

The Foreign saver solves a problem identical to that in the previous sections and the corresponding Euler equation is: $0 = E_t \left[d(\Lambda^* D_a^*) \right]$.

The representative Foreign financier's optimization problem in equation (26) is solved analogously to the proof of Lemma 3, so I only describe here the differences. For $t < t'$ the HJB equation is:

$$0 = \sup_{\{b^*(u), b(u), s^*(u), s(u)\}} E_t[d(\Lambda^* V^*)] + \chi(t) dt \, V^*,$$

where χ is the Lagrange multiplier. Conjecture that the value of the intermediary has the form: $V(\tilde{N}^*, n^*) = \Omega^*(\tilde{N}^*) n^*$. The FOCs are:

$$\mu_{Q^*} - r_d^* = \sigma_{C^*} \sigma_{Q^*}^T - \sigma_{\Omega^*} \sigma_{Q^*}^T \tag{A.17}$$

$$\mu_Q - \mu_{\mathscr{E}} + \sigma_{\mathscr{E}} \sigma_{\mathscr{E}}^T - \sigma_Q \sigma_{\mathscr{E}}^T - r_d^* = \sigma_{C^*} (\sigma_Q - \sigma_{\mathscr{E}})^T - \sigma_{\Omega^*} (\sigma_Q - \sigma_{\mathscr{E}})^T \tag{A.18}$$

$$r_b^* - r_b + \mu_{\mathscr{E}} - \sigma_{\mathscr{E}} \sigma_{\mathscr{E}}^T = \sigma_{C^*} \sigma_{\mathscr{E}}^T - \sigma_{\Omega^*} \sigma_{\mathscr{E}}^T \tag{A.19}$$

$$r_b^* = r_d^*. \tag{A.20}$$

Substituting the FOCs into the HJB equation leads to a restriction that Ω^* has to satisfy:

$$0 = \mu_{\Omega^*} - \sigma_{C^*} \sigma_{\Omega^*}^T. \tag{A.21}$$

The problem for $t > t'$ follows the same logic as in the proof of Lemma 3 and requires $\Omega^*(t') = 1$. Using the FOCs and the Foreign saver's Euler equation

I obtain the Foreign representative financier's Euler equations:

$$0=\Lambda^*\Omega^*\frac{pY}{P^*}dt+E_t\left[d(\Lambda^*\Omega^*\frac{Q}{\mathscr{E}})\right] \tag{A.22}$$

$$0=\Lambda^*\Omega^*\frac{p^*Y^*}{P^*}dt+E_t\left[d(\Lambda^*\Omega^*Q^*)\right] \tag{A.23}$$

$$0=E_t\left[d(\Lambda^*\Omega^*D_a^*)\right] \tag{A.24}$$

$$0=E_t\left[d(\Lambda^*\Omega^*\frac{B_a}{\mathscr{E}})\right] \tag{A.25}$$

$$0=E_t\left[d(\Lambda^*\Omega^*B_a^*)\right]. \tag{A.26}$$

Proposition 3. The pricing equations (A.12-A.16,A.22-A.26) and the fact that bankers can trade at least three independent assets imply that $\Lambda=\Lambda^*\frac{\Omega^*}{\xi\mathscr{E}}$ and therefore:

$$\frac{P^*\,C^*}{P\,C}=\frac{\Omega^*}{\xi},\qquad \text{where } \xi \text{ is a scaling constant to be determined.}$$

Substituting the demand functions for the consumption of each individual good in equations (24-25) and using the goods' market clearing conditions, $C_H+C_H^*=Y$ and $\tau C_F+C_F^*=Y^*$, yields the consumption allocations in equations (32-33).

The proof that the equilibrium can be solved as a function of a single state variable, the scaled net worth of Foreign intermediaries, follows steps similar to the proof of Proposition 2. The substitutions are algebra intensive but straightforward and are omitted in the interest of space. The ODEs, reported in implicit form in Proposition 3, are obtained by using: the Home Euler equations (A.12,A.15) to derive the Home financier's trade off between the Home stock and the Home interbank interest rate, which is the ODE in equation (28); the Home Euler equations (A.13,A.15) to derive the Home financier's trade off between the Foreign stock and the Home interbank rate, which is the ODE in equation (29); and the restriction on Ω^* in equation (A.21), which is the ODE in equation (30). The explicit form of the ODEs is omitted here because of the length of the expressions, but can be derived based on the information provided in this proof and is available in the accompanying numerical solution code.

In the models in Sections II and III, logarithmic preferences were mainly a matter of convenience. In the present section, logarithmic preferences permit one further simplification as agents have no desire to hedge their purchasing power risk (movements in the real exchange rate), thus allowing the model to be solved without introducing the ratio of the two trees as a state variable (see Coeurdacier and Gourinchas (2016), Pavlova and Rigobon (2007)). The downside of this simplification is that the equilibrium portfolios do not reflect this extra hedging demand, which would occur under general CRRA preferences. The central results of the paper, however, focus on how the portfolios are affected by the demand to hedge financial risk, which is not materially affected by the simplification to logarithmic preferences.

The international asset market structure of the model includes, by design, redundant assets. Since the fundamental source of risk is the two-dimensional vector of Brownian motions $\vec{z}$, three assets with linearly independent returns are sufficient for a complete international asset market. For $\alpha > 0.5$ the two stocks are linearly independent and, therefore, the addition of either the Home or Foreign interbank asset is potentially sufficient to implement the equilibrium risk sharing. Various combinations are theoretically possible. The implementation that is of interest for this paper is the one where agents are not allowed to short-sell arbitrary large positions in the stocks and where the Foreign interbank market is shut-off. To derive the portfolio implementation of the equilibrium risk sharing recall that since the Home representative agent has logarithmic preferences one has: $W(t) = \frac{1}{\rho}C(t)$. Applying Ito's Lemma to both sides of this equation and using the Home dynamic budget constraint one has:

$$\text{(A.27)} \qquad \left[Q\sigma_Q^T,\; Q^*\mathscr{E}(\sigma_e+\sigma_{Q^*})^T, -\sigma_{\mathscr{E}}^T\right][S_H,\; S_F,\; B_F]^T = \frac{C}{\rho}\sigma_C,$$

and B_H can be obtained as the residual term in the Home budget constraint. The portfolios are derived by solving this linear system of equations and by imposing restrictions on $\{S_H, S_F, B_F, B_H\}$.

Note that in the economy with frictions, financial markets are necessary for risk sharing despite agents having log preferences as in Cole and Obstfeld (1991). Recall that savers cannot directly hold claims to the dividends of the trees so that they have to use the financial intermediaries in order to accumulate claims on output. Similarly to the autarky model, this makes sure that there is a rationale for financial intermediation in the model.

The scaling constant ξ is pinned down in a fashion similar to the proof of Proposition 2. Recall that for the Home country one has $W(0) = \frac{1}{\rho}C(0)$. The starting conditions

$$\{S_H(0) = 1, S_F^*(0) = 1, B_H(0) = 0, B_F(0) = 0, Y(0) = Y^*(0), N^*(0), D^*(0)\}$$

are chosen so that countries are symmetric. Each country starts with all the shares in the domestic-tree stock and no interbank loans. Within each country, the shares are held by its intermediaries, which have a starting balance sheet composed of $N(0)$ net worth and $D(0)$ deposits (where $Q(0) = N(0) + D(0)$). Using the starting conditions and the consumption allocation for the Home country I have:

$$\tilde{Q}(0) = \frac{\xi}{(\alpha\xi + (1-\alpha)\Omega^*(0))\rho}. \tag{A.28}$$

Given $\tilde{N}^*(0)$, the above equation pins down the value of ξ. The solution for ξ is unique for all the numerical solutions of the model.

The stochastic steady state of this economy is $\tilde{N}^{*SS}\frac{1}{\rho(1+\xi)}$. Given the restriction $\delta = \lambda - \rho$, Appendix A.2 verifies that this is the absorbing upper bound of the state space. The steady state stock positions $\{\bar{S}_H, \bar{S}_F\}$ are defined as the limits of the positions approaching the steady state.

Case $\alpha = 0.5$

In the absence of home bias, stock returns, expressed in the same currency, are perfectly correlated. Therefore I focus on the intermediaries' holdings of the aggregate stock market.[14] The portfolio implementation of the equilibrium risk sharing can be derived using equations (A.27) and by imposing $B_F = 0$ and collapsing $\{S_H, S_F\}$ into a single world stock market position S. Equations (A.27), in this case, are a system of two equations in one unknown (S), but they admit a unique solution since the two equations are linearly dependent. This proves the claim in the main text that two assets are sufficient to implement the equilibrium allocation.

Cole and Obstfeld Economy: Equilibrium Details

In their classic analysis of the irrelevance of asset markets for international risk sharing, Cole and Obstfeld (1991) show that in an open economy with differentiated goods, agents with logarithmic preferences, and no trade costs, the central-planner's allocation can be achieved even without trade in asset markets.[15]

If there are no frictions, then the equilibrium of my model reduces to that of the Cole and Obstfeld Economy. Intuitively, if Foreign financiers face no frictions then: $\Omega^*(t) = 1$, so that the Euler equations and the demand equations for goods simplify to those in the frictionless world of Cole and Obstfeld.

As is well known, the Cole and Obstfeld equilibrium features: perfectly correlated Home and Foreign stock markets, symmetric aggregate stock market portfolio holdings,[16] zero holdings of risk-free bonds,[17] equal consumption state

[14] The drawback is that in this case the NFA and CA are indeterminate because the equity holdings of each stock are indeterminate. Only aggregate equity holdings in each country are determinate. Determinacy of the NFA and CA can be restored via stronger assumptions on the composition of the equity portfolio.

[15] This occurs because the endogenous response of the ToT to supply shocks to the two goods is sufficient to implement the international wealth transfers that support the central planner's consumption allocation.

[16] Individual stock market positions are indeterminate since the two stocks are perfectly correlated, but each country's holding of the aggregate stock market is determinate.

[17] In my setting there are zero holdings in the interbank market, which is equivalent to the

by state, zero NX, and indeterminate[18] NFA and CA. The exchange rate is either constant ($\alpha = 0.5$) or positively related to the ToT ($\alpha > 0.5$). These results are a far cry from the stylized facts in *Facts 1-4*.

More formally, in this economy one has $\Omega^*(\tilde{N}^*) = 1$ and $\tilde{Q}(\tilde{N}^*) = \tilde{Q}^*(\tilde{N}^*) = \frac{1}{\rho}$. These constant functions satisfy the ODEs in equations (28-30). The risk sharing condition in equation (31) now simplifies to the statement that consumption in the two countries is equal in every state (the equality follows from $\xi = 1$ since the two countries are symmetric). The two stocks have perfectly correlated returns: $Q = Q^*\mathscr{E}$. The equilibrium allocation can be implemented with no trading in the stock and in the interbank market, and trading only in the deposit and goods markets.

The stochastic steady steady state is $\tilde{N}^{*SS} = \frac{1}{2\rho}$, which is also the absorbing upper boundary of the state space.

The Exchange Rate Paradox I expand here on the statement of the paradox in the main text.

Consider a loss of net worth for Foreign financiers, this leads to an increase in the marginal value of net worth Ω^*. The equilibrium risk sharing condition, equation (31), implies that the real value of Foreign consumption goes up relative to Home consumption expressed in the same units. Equation (34) correspondingly shows the impact of this relative shift in consumption/wealth on the ToT and the exchange rate. A necessary condition for the ToT to depend positively on Ω^* is that $\alpha > 0.5$: $sign\left(\frac{\partial ToT}{\partial \Omega^*}\right) = 2\alpha - 1$. Similarly, if $\alpha > 0.5$ the real exchange rate depends positively on the ToT: $sign\left(\frac{\partial \mathscr{E}}{\partial ToT}\right) = 2\alpha - 1$. This shows that an increase in Ω^* is associated with a contemporaneous Home ToT deterioration and a Home currency depreciation. Note that, as in the statement in the text, the trade frictions are assumed to be absent ($\tau = 1$) so that the exchange rate only depends on the terms of trade.

Equation (27) illustrates the ex ante consequences of the expected positive association between the marginal value of net worth and the exchange rate:

$$r_b^* - r_b + \mu_{\mathscr{E}} - \sigma_{\mathscr{E}}\sigma_{\mathscr{E}}^T = -Cov_t\left(\frac{d\Lambda^*\Omega^*}{\Lambda^*\Omega^*}, \frac{d\mathscr{E}}{\mathscr{E}}\right)$$

All else equal, a positive covariance between the marginal value of net worth and exchange rate changes makes the Home currency riskier for Foreign fi-

risk-free international bonds in Cole and Obstfeld (1991), but the deposit market is still active. However, note that without frictions trading in the deposit market is merely a matter of internal accounting between the savers and financiers in each country, without any real effects. In this sense, the Cole and Obstfeld (1991) result on the irrelevance of international asset markets for risk sharing holds in my set-up when there are no frictions.

[18] The NFA indeterminacy is a consequence of the indeterminacy of the portfolio holdings of each stock. The CA is indeterminate because it is the change in NFA.

nanciers. The Home currency depreciates in states of the world in which financiers' marginal value of capital is higher and this ex-ante induces them to require higher expected returns (a risk premium) for holding Home currency.

A.2 Numerical Solution Methods

The systems of ODEs in this paper are solved as boundary value problems (BVP) using the Matlab routine *bvp4c*.

Section II: Autarky

The system of coupled second order ODEs in equations (A.3-A.4) is to be solved over the interval $(0, \bar{\tilde{N}})$, where $\bar{\tilde{N}}$ is unknown. The ODEs are singular at both boundaries of the interval. To deal with the singularity, I use asymptotic approximations to derive the boundary conditions. The boundary conditions are:[19]

$$\tilde{Q}\left(\bar{\tilde{N}}\right) = \bar{\tilde{N}} \tag{A.29}$$

$$\tilde{Q}\left(\bar{\tilde{N}}\right) = \frac{1}{\rho + \tilde{Q}'\left(\bar{\tilde{N}}\right)(\lambda - \delta - \rho)} \tag{A.30}$$

$$\Omega\left(\bar{\tilde{N}}\right) = \frac{\lambda + \Omega'\left(\bar{\tilde{N}}\right)\tilde{Q}\left(\bar{\tilde{N}}\right)(\delta + \rho - \lambda)}{\lambda} \tag{A.31}$$

$$\tilde{Q}(\varepsilon) = a - \sqrt{\frac{a\sigma^2}{\delta}}\ \varepsilon^{\frac{1}{2}} \tag{A.32}$$

$$\tilde{Q}'(\varepsilon) = -\frac{1}{2}\sqrt{\frac{a\sigma^2}{\delta}}\ \varepsilon^{-\frac{1}{2}} \tag{A.33}$$

$$\Omega(\varepsilon) = 1 + \frac{e[1 - a(\rho + \sigma^2)]}{\lambda\sqrt{\frac{a\sigma^2}{\delta}}} + e\ \varepsilon^{\frac{1}{2}} \tag{A.34}$$

$$\Omega'(\varepsilon) = \frac{1}{2}\ e\ \varepsilon^{-\frac{1}{2}}, \tag{A.35}$$

where $\{a, e\}$ are unknown parameters, and ε is "small". The boundary condition in equation (A.29) is obtained by imposing that $\sigma_{\tilde{N}}(\bar{\tilde{N}}) = 0$. The boundary conditions in equations (A.30-A.31) are obtained by imposing that $\lim_{\tilde{N}\to\bar{\tilde{N}}} \tilde{Q}''(\tilde{Q} - \tilde{N}) = 0$ and $\lim_{\tilde{N}\to\bar{\tilde{N}}} \Omega''(\tilde{Q} - \tilde{N}) = 0$. Intuitively, these conditions require $\bar{\tilde{N}}$ to

[19]Intuitively, seven boundary conditions are required to solve the system: four boundary conditions because it is a system of two second order ODEs, one boundary condition to pin down the unknown parameter $\bar{\tilde{N}}$, and two boundary conditions to pin down the unknown parameters $\{a, e\}$ introduced by the asymptotic approximations of the ODEs at the lower boundary.

be an upper bound for the state space and, since intermediaries are highly capitalized, the solutions to change "smoothly" when approaching this upper bound.

The boundary conditions in equations (A.32-A.35) are obtained by using Laurent asymptotic approximations of the ODEs[20] in the limit as $\tilde{N}$ approaches zero, and by requiring zero to be a reflective boundary.

To adapt the problem to the Matlab routine *bvp4c*, I re-write the system of ODEs by changing variables. Letting $x = \frac{\tilde{N}}{\bar{\tilde{N}}}$, I solve for the functions $\{\tilde{Q}(x), \Omega(x)\}$ on the interval$[\varepsilon, 1-\varepsilon]$.

Note that simpler boundary conditions can be used under the parameter restriction $\delta = \lambda - \rho$. In this case, $\bar{\tilde{N}} = \frac{1}{\rho}$ and the upper boundary conditions are $\tilde{Q}(\frac{1}{\rho}) = \frac{1}{\rho}$ and $\Omega(\frac{1}{\rho}) = 1$. Intuitively, in this case the upper bound of the state space is absorbing and coincides with the Lucas Economy equilibrium.

The upper boundary conditions impose that $\sigma_{\tilde{N}}(\bar{\tilde{N}}) = 0$; it remains to be verified that $\mu_{\tilde{N}}(\bar{\tilde{N}}) \leq 0$. An inspection of the dynamics of $\tilde{N}$ in equation (7) confirms that under the parameter restriction $\delta = \lambda - \rho$ one has $\mu_{\tilde{N}}(\bar{\tilde{N}}) = 0$, and under the restriction $\delta < \lambda - \rho$ one has $\mu_{\tilde{N}}(\bar{\tilde{N}}) < 0$.

Section III: Open Economy Single Tree

The system of coupled second order ODEs in equations (A.9-A.10) is to be solved over the interval $(0, \frac{1}{\rho(1+\xi)}]$. The ODEs are singular at both boundaries of the interval. To deal with the singularity, I use asymptotic approximations to derive the boundary conditions. The boundary conditions are:[21]

$$\tilde{Q}\left(\frac{1}{\rho(1+\xi)}\right) = \frac{1}{\rho} \tag{A.36}$$

$$\Omega^*\left(\frac{1}{\rho(1+\xi)}\right) = 1 \tag{A.37}$$

$$\frac{\tilde{Q}''(\varepsilon)\,\varepsilon}{\tilde{Q}'(\varepsilon)} = -\frac{1}{2} \tag{A.38}$$

$$\frac{\Omega^{*''}(\varepsilon)\,\varepsilon}{\Omega^{*'}(\varepsilon)} = -\frac{1}{2}, \tag{A.39}$$

where ε is "small". The boundary conditions in equations (A.36-A.37) are the equilibrium solutions for the Open Lucas Economy. Intuitively, the upper bound of the state space is absorbing and coincides with the Lucas Economy equilibrium. The boundary conditions in equations (A.38-A.39) are obtained by using Laurent asymptotic approximations of the ODEs in the limit as $\tilde{N}^*$ approaches

[20] I report here the first two terms of the approximations, which I found to be sufficient in practice for an accurate numerical solution. I have also experimented with including higher order terms.

[21] Intuitively, four boundary conditions are required to solve the system of two second order ODEs.

zero and by requiring zero to be a reflective boundary.[22]

The upper boundary conditions impose that $\sigma_{\tilde{N}^*}(\frac{1}{\rho(1+\xi)}) = 0$; it remains to be verified that the upper bound of the state space is the absorbing stochastic steady state of the model. This is achieved by requiring that $\delta = \lambda - \rho$. Under this restriction, the numerical solution shows that $\mu_{\tilde{N}^*} > 0$ on the open interval $(0, \frac{1}{\rho(1+\xi)})$ and that $\mu_{\tilde{N}^*}(\frac{1}{\rho(1+\xi)}) = 0$. Intuitively the state variable, having started at $\tilde{N}^*(0) < \tilde{N}^{*SS}$, drifts toward the upper bound of the state space and remains there once it has been reached. Finally, the numerical solution shows that $\Omega^*(t) > 1 \ \forall\, t < t'$, thus confirming that V^* exists and is non-zero.

As with the autarky case, to deal with the singularities I solve the system on the interval $[\varepsilon, \frac{1}{\rho(1+\xi)} - \varepsilon]$.

For simplicity, instead of selecting a starting value $\tilde{N}^*(0)$, I guess a value for ξ, solve the ODE system, and then back out the implied value for $\tilde{N}^*(0)$ using equation (A.11). In all my numerical trials the implied value for $\tilde{N}^*(0)$ is unique.

Section IV: Open Economy Two Trees

The system of coupled second order ODEs in equations (28-30) is to be solved over the interval $(0, \frac{1}{\rho(1+\xi)}]$. The ODEs are singular at both boundaries of the interval. To deal with the singularity, I use asymptotic approximations to derive the boundary conditions. The boundary conditions are:[23]

$$
\begin{aligned}
\tilde{Q}\left(\frac{1}{\rho(1+\xi)}\right) &= \frac{1}{\rho} \\
\tilde{Q}^*\left(\frac{1}{\rho(1+\xi)}\right) &= \frac{1}{\rho} \\
\Omega^*\left(\frac{1}{\rho(1+\xi)}\right) &= 1 \\
\frac{\tilde{Q}''(\varepsilon)\,\varepsilon}{\tilde{Q}'(\varepsilon)} &= -\frac{1}{2} \\
\frac{\tilde{Q}^{*''}(\varepsilon)\,\varepsilon}{\tilde{Q}^{*'}(\varepsilon)} &= -\frac{1}{2} \\
\frac{\Omega''(\varepsilon)\,\varepsilon}{\Omega'(\varepsilon)} &= -\frac{1}{2},
\end{aligned}
$$

[22]In contrast with the autarky model, where the first two terms of the approximations are used as boundary conditions, it is sufficient for an accurate numerical solution to provide the numerical solver with information about the rate at which the solutions move approaching zero (i.e. the exponent of the series expansion, which I find to be equal to $\frac{1}{2}$).

[23]Intuitively, six boundary conditions are required to solve the system of three second order ODEs.

where ε is "small". The intuition for the boundary conditions, the solution method, and the verification of the stochastic steady state are analogous to those for the Open Banking Economy with a single tree in the previous section.

A.3 Appendix: Data Sources, Empirical Methodology, and Robustness Checks

This appendix details all data sources and methodologies, as well as provides further descriptions and robustness checks of the empirical results in the main text of the paper.

A Data and Methodology For Figure 4

I describe here the data sources and methodology used to generate the aggregate financial holdings described in Figure 4. I used three main data sources:

1. The Bureau of Economic Analysis (BEA) data on the U.S. International Investment Position. These data provide U.S. foreign assets and liabilities, divided into broad asset classes. The data are annual since 1976 and quarterly since 2006.

2. The Treasury International Capital (TIC) System provides annual detailed surveys of U.S. foreign assets and liabilities for portfolio holdings of securities. The surveys on "Foreign Portfolio Holdings of U.S. Securities" are available annually (in June) for the period 2002-2015. Two earlier surveys of lower quality from March 2000 and December 1997 are also available. Similarly, surveys on "U.S. Residents' Portfolio Holdings of Foreign Securities" are available annually (in December) for the period 2003-2015, with three earlier surveys of lower quality available from December 2001, 1999, and 1997. The detailed data used in this paper are only available in the TIC surveys' "appendix tables" for the years 2003-2015, hence I do not use data from the earlier ad-hoc surveys.

3. The Financial Accounts of the United States (Z.1) data released by the Federal Reserve and, in particular, the flow of funds and balance sheet account data. I use the quarterly releases for the period 2002-2015.

Sources and Methodology for Top Panel in Figure 4. This figure plots the foreign portfolio holdings of: debt securities issued by the U.S. government, debt securities issued by U.S. financial institutions, and other debt-like instruments (deposit and loans) that are liabilities of U.S. financial institutions. All data are from TIC. Publicly available TIC reports include a table that provides a breakdown of foreign holdings of U.S. securities by the U.S. sector of issuance.[24]

The foreign portfolio holdings of U.S. government debt securities primarily include U.S. Treasuries, as well as some bonds issued by state and local governments.[25] TIC specifies that "*when state and local bonds are clearly associated with a particular industry, such as utilities or education, they are classified by that industry*" (Department of the Treasury (2015)).

The foreign portfolio holdings of debt securities issued by U.S. financial institutions include debt securities issued by firms classified as "financials" in the Global Classification Industry Standard Code (GICS) developed by Morgan Stanley Capital International and Standard & Poor's. For the years 2002-2014, I have included debt issued by the sector Total Financials (code: 4000), with subsectors: Commercial Banks (401010), Thrifts and Mortgage Finance (401020), Diversified Financial Services (402010), Consumer Finance (402020), Capital Markets (Mutual Funds) (402030), Insurance (403010), Real Estate Investment Trusts (REITS) (404020), Real Estate Management and Development (404030).[26] Starting with the 2015 survey, TIC switched its sector classification to the North American Industry Classification System (NAICS) developed by the U.S. Census Bureau. For the year 2015, I have included debt issued by the following sectors: Depository Credit Intermediation (Banking) (code: 5221), Other Financial (codes: 5222-5239, including Real Estate Credit, Investment Banking, and Other Credit Intermediated as sub-codes), Insurance (code: 524), Funds, Trusts, and Other Financial Vehicles (code: 525).

The foreign holdings of U.S. "Deposits, Loans and Other" debt-like financial instruments as reported from banks are from TIC. This series includes deposits, brokerage balances, loans, repurchase agreements, and trade payables and advance receipts. The data are from Table 20 of the June 2015 TIC report, which also makes available historical data starting from 2002.[27]

Interestingly, the Top Panel in Figure 4 shows a strong increase in the value of U.S. government debt held by foreigners since the 2008 financial crisis: the

[24] Unfortunately, the numbering of this table in TIC PDF reports changes from year to year. As guidance for the reader, the Table is number 19 in the 2015 TIC report (and number A11 in the related appendix) and number 20 in the 2014 TIC report (and number A11 in the related appendix).

[25] My model could be extended to formally account for the role of the government and government securities. Alfaro, Kalemli-Ozcan and Volosovych (2014) show that a number of foreign central banks are official holders of U.S safe assets. The model can accommodate this phenomenon by introducing a Foreign central bank that buys the Home safe asset and then issues safe bonds to domestic financial intermediaries. Future research could also build on this framework by explicitly modeling governments and their policies to study the international monetary system.

[26] In earlier surveys, 2002-2007, the last two codes are aggregated in a broader sector called "Real Estate".

[27] Data on deposits, loans, and other reported in this table are themselves sourced from the TIC reporting on forms BL1, BL2, BQ2, CQ1, and CQ2.

value of the holdings doubled from \$3trn in 2006 to \$6trn in 2015. This increase in holdings is consistent with an increased (precautionary) motive for RoW to hold the ultimate safe asset in the aftermath of the financial crisis. RoW holdings of debt issued by U.S. financial institutions show a marked increase from \$1trn to over \$3trn in the years just preceding the global financial crisis (2004-2007). This pattern is consistent with the U.S. private sector and, in particular, the financial sector expanding its supply of safe assets in response to increased foreign demand. However, the marked increase (especially 2006 and 2007) has to be viewed with caution: several authors (Bernanke et al. (2011), Shin (2012)) have commented on European financial institutions performing a kind of off-shore financial intermediation vis-à-vis the U.S. during this period. More specifically, European financial institutions borrowed in the U.S. wholesale funding market via their U.S. branches, and transferred the funds to Europe to then reinvest them in the U.S. in higher yielding debt securities. Since International Investment Position and TIC data are based on the residency principle, these transactions affect the data, even though from an economic perspective it is ambiguous whether they should be classified as U.S. domestic financial intermediation.[28] Similarly, the residency principle of the statistics means that foreign holdings are affected by off-shore financial centers. For example, if a U.S. resident institution (or individual) holds a U.S. debt security via an account in an off-shore financial center (e.g. Cayman Islands), then the security is incorrectly classified as an external liability of the U.S. rather than as a domestic transaction (Bernanke et al. (2011), Shin (2012), Department of the Treasury (2015)). Even with these reasonable caveats about overstating the foreign financial sector holdings of U.S. securities, a pattern emerges of substantial holdings both before and after the 2008 financial crisis.

Sources and Methodology for Middle Panel in Figure 4. The middle panel of Figure 4 builds on the series in the top panel of the same figure, described above. The middle panel plots the foreign portfolio holdings of U.S. debt securities issued by each sector, i.e. the government and financial institutions, as a fraction of the total outstanding stock of debt issued by that sector. I estimate the total outstanding stock of debt issued by the U.S. government and U.S. financial institutions using the Financial Accounts of the United States (Z.1) data released by the Federal Reserve.

For government securities, the middle panel of Figure 4 plots the percentage of marketable U.S. Treasury debt held by foreign residents. I follow the TIC reports' methodology and source the total outstanding stock of marketable U.S. Treasury debt from the Bureau of Public Debt, Table 1, Summary of Public

[28] Since the focus of my paper is on explaining the aggregate U.S. international position, I have grouped the RoW intermediaries into one homogenous class. This simplification allows the model to sharpen its focus on aggregate flows, and leaves it to future research to also model the heterogeneity of the RoW intermediaries.

Debt, Summary of Treasury Securities Outstanding. The middle panel of Figure 4 plots the series reported in TIC (Table 2 of the 2015 report) for "Marketable U.S. Treasury Debt - Percent Foreign-owned". Total marketable debt is debt held by the public, including the Federal Reserve System but excluding Treasury Bills. I focus on the percentage of Treasury debt held by foreigners, rather than all government debt, because TIC does not provide an exact account of local and state government debt holdings by foreigners; it is therefore not possible to build the corresponding stock of outstanding debt. Overall, focusing on Treasuries rather than total government debt does not appear problematic, since foreign holdings of marketable U.S. Treasury debt account for the vast majority (80%) of all government debt holdings by foreigners. On the one hand, one might think that excluding state and local government debt may overstate the fraction owned by foreigners, since foreigners might be more likely to buy treasury debt than local or state debt. On the other hand, one can think that including Fed holdings of Treasuries in the marketable stock (the denominator) might understate the fraction owned by foreigners, since inter-holdings of U.S. government agencies should be netted out and not be considered debt issuance. Nonetheless, these reasonable concerns are unlikely to change the overall conclusion that a substantial fraction (between 40-60%) of U.S. government debt is held by foreigners.

Foreigners have historically held more U.S. Treasuries than agency debt (both in absolute terms, and as a percentage of the available stock).[29] For example, TIC analysts estimate that foreigners owned \$880bn of agency debt (11.9% of the total stock) compared to \$5,450bn of treasuries (48.2% of the stock) in 2015. This pattern holds more generally over the 2002-2015 period, during which foreigners owned on average 14.5% of total agency debt, compared to 51.5% of marketable Treasuries. Foreign holdings of U.S. agency debt reached their zenith in the years preceding the global financial crisis: holdings in 2007 and 2008 were \$1,304bn and \$1,464bn, or 20.7% and 20.8% of the stock, respectively.[30] Bernanke et al. (2011) showed that these heightened holdings were largely related to European financial institutions buying agency debt while funding themselves in the U.S. with short-term wholesale debt, a form of off-shore financial intermediation. Since these patterns are not the main focus of this paper, I have not focused on agency debt in the main body of the paper.

The middle panel of Figure 4 also plots the percentage of long-term debt issued by U.S. financial institutions and held by foreign residents. I built this series by dividing the foreign holdings of long-term debt issued by U.S. financial institutions by the total stock of long-term debt securities issued by these institutions. The foreign holdings of long-term debt issued by U.S. financial in-

[29]Agencies include U.S. government agencies and corporations as well as federally sponsored enterprises, such as the Federal National Mortgage Association.

[30]The statistics reported in this paragraph on foreign holdings of U.S. government agency debt are from Department of the Treasury (2015)[Table 2] .

stitutions are almost entirely identical to the total holdings (both short and long term), as reported in the top panel of Figure 4 and described above. In this case, I exclude short-term (less than 1 year) debt holdings to make the numerator most comparable to the denominator estimated below the using Flow of Funds data. This adjustment is minimal, since long-term debt holdings accounted for an average of 98% of total holdings of debt issued by U.S. financial institutions over the period 2002-2015. I obtain the total stock of debt for U.S. financial institutions by adapting the procedure used by TIC analysts to estimate the stock of total corporate debt (financial and non-financial). I use the Federal Reserve Statistical Release Z.1, Financial Accounts of the United States.

Starting from Table L.213 Corporate and Foreign Bonds, I first estimate the stock of financial liabilities by removing "Nonfinancial Corporate Business" (series: Z1/Z1/FL103163003.Q, row 2 of Table L.213) and "Rest of the World" (series: Z1/Z1/LM263163005.Q, row 11 of Table L.213) from "Total Liabilities" (series: Z1/Z1/FL893163005.Q, row 1 of Table L.213). This stock still includes debt issued by state and local government entities and classified as corporate. In estimating the total stock of corporate debt (financial and non-financial), TIC analysts then proceed by further subtracting "Long-term Debt Securities issued by State and Local Governments" (series: Z1/Z1/FL213162200.Q, row 21 of Table L.107). While I follow this procedure in producing the data for Figure 4 in the main text, I report in Figure A.5 a robustness check that does not exclude from the denominator (the total stock of debt issued by U.S. financial institutions) debt issued by "Long-term Debt Securities issued by State and Local Governments". In computing foreign holdings of debt issued by state and local governments, TIC analysts exclude situations "*when state and local bonds are clearly associated with a particular industry, such as utilities or education, [and those bonds are then] classified [as being issued] by that industry*" (Department of the Treasury (2015)). This opens up the possibility, however remote, that a substantial portion of state and local government debt is being classified as debt issued by financial institutions because it is associated with that industry. If this were the case, the procedure adopted in producing Figure 4 in the main text would overstate the percentage of bonds issued by U.S. financial institutions and held by foreigners, because it would include state and local government bonds classified as financials in the numerator and not in the denominator. Figure A.5 illustrates what would happen if I made, incorrectly, the extreme assumption that all debt by state and local governments should be included in the denominator. The fraction of U.S. financial institution debt held by foreigners would clearly be lower, but still substantial at 20% to 30%.

When buying corporate debt (which includes financial institutions), foreigners predominantly focus on U.S. financial institutions. Indeed, TIC reports that foreigners held 26% of all U.S. corporate debt in 2015, but the fraction (which I estimated above) is considerably higher at 47% when focusing on debt issued by U.S. financial institutions. The pattern holds more generally: for the period 2008-2015, foreigners on average held 23% of all U.S. corporate debt, but a higher 44% of the subset of corporate debt issued by U.S. financial institutions.[31] This shows that foreigners are providing a substantial part of the debt financing (leverage) of U.S. financial institutions, more so than they do directly for non-financial U.S. corporations.[32]

Sources and Methodology for Bottom Panel in Figure 4. This panel plots the foreign holdings of debt securities issued by the U.S. government and U.S financial institutions as a percentage of total foreign holdings of U.S. debt securities. The foreign holdings of debt securities issued by the U.S. government and U.S financial institutions are those illustrated in the top panel in Figure 4 and described above. The total holdings of U.S. debt securities by foreign residents are sourced from the BEA (U.S. Liabilities, Debt Securities). The bottom panel in Figure 4 also plots the foreign holdings of debt-like securities issued by the U.S. government and U.S financial institutions as a percentage of total foreign holdings of U.S. debt-like securities. This expands on the previous series by adding to the numerator the foreign holdings of U.S. "Deposits, Loans and Other" debt-like financial instruments from TIC (as illustrated in the top panel in Figure 4 and described above) and by adding to the denominator the total holdings of "Other Investment" by foreign residents sourced from the BEA (U.S. Liabilities, Other Investment, subcategories: Currency and Deposits, Loans, Insurance Technical Reserves, Trade Credit and Advances, Special Drawing Rights Allocations).

B RoW Financial Sector Holdings in the U.S. in Table 1

I provide here further details, robustness checks, and data sources, and describe the methodologies used to produce the results reported in Table 1.

Data Sources. I use the Coordinated Portfolio Investment Survey (CPIS) to analyze the importance of the foreign financial sector in portfolio investment in the U.S.; in particular, I focus on foreign financial sector holdings of U.S. debt securities. CPIS is collected and published by the International Monetary Fund. The IMF has recently revamped this survey and, in particular, has encouraged more countries to provide data on sectoral holdings of foreign securities. These data allow me to analyze the fraction of U.S. debt liabilities to foreigners that is held by foreign financial institutions. These more detailed data are available for more countries bi-annually in June and December, starting with the enhanced

[31] The statistics reported in this paragraph on foreign holdings of U.S. corporate debt are from Department of the Treasury (2015)[Table 2].

[32] U.S. financial institutions might pass on part of the foreign funding (leverage) to U.S. corporates via lending agreements.

survey in June 2013. Therefore, in this paper I use the data release of May 2016, and focus on the surveys between June 2013 and June 2015.

CPIS data provide bilateral holdings of debt (long-term and short-term) and equity for countries that participate in the survey. For the purpose of this paper, I focus on the subset of the data containing countries' investments in the United States. These data are obtained by focusing on foreign countries' assets in the U.S., which are measured directly in the surveys, rather than on U.S. liabilities, which are derived from the asset-side of the remaining countries. For example, U.S. foreign liabilities are derived from investments in the U.S. reported (on the foreign-asset side) by other countries included in the survey. To avoid redundancies, I only focus on investments in the U.S. by other countries.[33] I include only the subset of the survey data beginning June 2013 and ending June 2015, as only few countries reported sectoral holdings, often on an infrequent basis, prior to the June 2013 update to the survey methodology (see also Galstyan et al. (2015)).

Financials Shares. For each country and asset class I focus on the total holdings of securities by the following sectors: Central Bank, General Government, Other Financial Corporations, Nonfinancial Corporations, Households and NPISHs, Depository-taking Corporations except the Central Bank. From these original sectors, I aggregate the data into a new set of sectors called: Government, Financials, Nonfinancials. The mapping from CPIS classification to this paper's classification is intuitive and summarized in Table A.1. The CPIS field "Other Financial Corporations" includes the sub-fields: Insurance Corporations and Pension Funds, Money Market Funds, and Other.
For each instance of the survey t, country i, and asset class j, I build the share of portfolio investment in the U.S. held by each of the three sectors s as:

$$\phi_{i,j,s,t} = \frac{X_{i,j,s,t}}{X_{i,j,ToT,t}}, \tag{A.40}$$

where $X_{i,j,s,t}$ is the investment in the U.S. in asset class j from country i's sector s for the survey period t, and $X_{i,j,ToT,t} = \sum_s X_{i,j,s,t}$ is the total investment across all sectors.[34]

For robustness, I exclude records that appear very likely to have been incor-

[33] I also exclude the few instances in which short positions are recorded on the asset side. Excluding short positions does not alter the results, as they comprise less than 0.01% of the dataset in value terms.

[34] For approximately 5% of the dataset, the sum of reported subtotals across sectors does not match the corresponding reported total in CPIS. In these instances of internal inconsistency in CPIS, I use the reported total in the denominator of equation (A.40) rather than the sum of the subtotals. Either using the sum of the subtotals or dropping these data points completely does not have a significant effect on the results in this paper.

rectly filled out in the surveys, using as a guiding principle that no country's financial sector can account for either exactly 100% or 0% of the country's portfolio investment. I clean the data from these spurious records using the following procedure:

1. If for *all* surveys the values of $\phi_{i,j,Financials,t}$ for a specific country and asset class combination are all either equal to 0 or 1, or larger than 1, I treat $\phi_{i,j,Financials,t}$ as missing for that country and asset class for all surveys.[35]

2. If for *any* survey the value of $\phi_{i,j,Financials,t}$ is either equal to 0 or 1 or larger than 1, and at the same time also further than 1 standard deviation from the mean financial share for that country and asset class across surveys, I then treat that specific observation as missing.

The first step in this procedure drops the debt holdings for the following 15 countries: Bahamas, Belarus, Bolivia, Cayman Islands, Curacao and St. Maarten, Egypt, India, Republic of Kosovo, Kuwait, Lebanon, Malta, Netherlands Antilles, New Zealand, Pakistan, and Vanuatu. The second step in the procedure drops a subset of observations on debt holdings for the following 17 countries (on average, 2.2 of the 5 surveys are dropped for each of these; in total 12% of all observations are dropped): Australia, Kingdom of Bahrain, Bangladesh, Barbados, Belgium, Bermuda, Brazil, Colombia, Guernsey, Honduras, Jersey, Norway, Russian Federation, Spain, Sweden, United Kingdom, and Uruguay.

In addition to the above two rules, I also drop Ireland's records due to its inconsistent reporting style. Ireland does not report its holdings of U.S. securities for the debt and equity asset classes, although it does report its total holdings. In the first and second surveys of each year, it reports 0% and 99.7% of its holdings as being in the financial sector, respectively. While these data are not excluded under the above rules, I remove them as the reporting style appears to be inconsistent. Importantly, the exclusion of Ireland does not have any effect on the results in Table 1 in the main paper, since Ireland only reported its total holdings of assets in the U.S. but not the debt/equity breakdown. The exclusion only affects the result in Table A.4 for the category Total (third row).

Country Weights. Each country is assigned a weight corresponding to its share of portfolio investments in the U.S. in each asset class, compared to total investments in the U.S. in that asset class by all countries. The weights are computed according to:

[35]Due to survey rounding, I allow a margin of 0.0001 around the values of 0 and 1. This means that a value of 0.0001 is considered equivalent to 0, and similarly a value of 0.9999 is considered equivalent to 1.

$$\theta_{i,j} = \frac{1}{5}\sum_{t=1}^{5} \frac{X_{i,j,ToT,t}}{\sum_i X_{i,j,ToT,t}}.$$

In building the weights, I only use values of $X_{i,j,ToT,t}$ for which $\phi_{i,j,Financials,t}$ is not missing. Therefore, if fewer than 5 observations are available for a country-asset-class pair, then the average share is defined over the available observations.

Building Table 1, Further Details, Robustness Checks. Panel A of Table 1 summarizes the fraction of U.S. foreign debt held by foreign financial institutions. The average reported in the first column is obtained by first averaging $\phi_{i,Debt,Financials,t}$ across countries (i) for each survey instance t, and then averaging the resulting numbers across the different survey periods (t). The average reported in the second column follows the same procedure, except that when averaging across countries for each instance of the survey, countries are weighted by their corresponding share of debt investment ($\theta_{i,Debt}$).

Panel B of Table 1 first selects the five countries with the highest reported value of average debt holdings in the U.S. for the period 2013-2015. This corresponds to selecting the highest values across countries (i) of the statistic

$$\frac{1}{5}\sum_{t=1}^{5} X_{i,Debt,ToT,t}.$$

These values are reported in the second column of Panel B of Table 1. The first column reports the average share of U.S. debt held by each country's financial sector, compared to the country's total holdings:

$$\bar{\phi}_{i,Debt,Financials,t} \equiv \frac{1}{5}\sum_{t=1}^{5} \phi_{i,Debt,Financials,t}.$$

Table A.2 provides further details by reporting these shares ($\bar{\phi}_{i,Debt,Financials,t}$) for all countries in the dataset. While the foreign financial sector accounts for a large share of most countries's debt holdings in the U.S., there appear to be three broad patterns. The share is lowest for countries such as Chile, Norway, and Kazakhstan (17%, 12%, 4%, respectively), which have large sovereign wealth funds that invest wealth related to commodity exports. The share is highest for off-shore financial centers such as Bermuda, Guernsey, Jersey (99.94%, 99.79%, 99.98%, respectively), which, by design, have wealth entirely concentrated in the financial sector. These countries are problematic in many ways for the analysis, since they do not invest their own wealth but are largely a conduit for investment from third-party countries. The possibility that U.S. residents might actually hold U.S. debt via off-shore accounts in these centers is a well known problem with U.S. international investment position data that are based on the residency principle. For this reason, I have performed a robustness check that drops the major off-shore financial centers in CPIS: Barbados, Bermuda, Guernsey, Jersey.[36] The results of repeating the analysis in Table 1 Panel A excluding off-shore financial centers are little changed, especially when using the weighted average, which is then lower at 85.13%, compared to 85.85% reported in Table 1 Panel A. The final pattern shows that the share is relatively high even among developed nations with substantial debt holdings in the U.S.: France 92%, Germany 80%, Italy 71%, Japan 96%, and the U.K. 98%. Overall, it is important to emphasize that there is selection in which countries decide to participate in the IMF surveys for CPIS. For example, China, one of the largest holders of U.S. debt and a country with very large government holdings, does not participate in CPIS. While the absence of such countries in CPIS biases upward the average fraction of U.S. debt held by RoW financial sector, the importance of RoW financial sector in understanding U.S. debt holdings is nonetheless based on evidence from a broad set of countries and still holds (Table A.2).

Table A.3 shows the average financial share across countries for each survey between June 2013 and June 2015. This table expands on Table 1 in the main text by providing not only the average financial share over all surveys (as reported in Table 1 Panel A) but also the financial share for each individual survey. Both the equally weighted (column one of Table A.3) and the debt-weighted (column two) financial share are stable over the different surveys, oscillating between 65% and 69% for the equally weighted measure and 83% and 88% for the debt-weighted measure.

C Data and Methodology for Measuring RoW Financial Net Worth

I provide here data sources, methodologies, and further robustness checks for the construction of the empirical proxy for RoW financial net worth $\tilde{N}^*$ used in the regressions that are reported in Table 2 and Figures 5 and 6.

Data Sources. I use Thomson Reuters Datastream (TRD) data for the aggregate value of foreign financial firms, the World Bank Databank (WBD) data on world and individual countries or geographic areas GDP, and the Bureau of Economic Analysis (BEA) data on the U.S. international investment position and net exports of good and services. Table A.5 outlines the data sources, including individual series' codes.

The key state variable in the model, $\tilde{N}^*$, measures the RoW financial sector's net worth scaled by output. I construct a proxy for this variable by dividing the

[36]Note that a number of off-shore financial centers were also dropped earlier due to missing or incorrect data (e.g. Cayman Islands and Bahamas).

market value of RoW financial firms by measures of economic activity for the world excluding the U.S.:

$$\tilde{N}^*_{i,j,t} \equiv \frac{MV_{i,j,t}}{Y_{i,t}},$$

where $MV_{i,j,t}$ is the market value of financial firms in index j for geographical region i in month t, and $Y_{i,t}$ is a measure of economic activity for the same geographic region. In the benchmark measure, I use the market value of firms included in the Datastream Financial Equity World ex U.S. index (code: FINWUS), and proxy economic activity by GDP for the World ex U.S. provided by the World Bank.[37] Both the denominator and numerator are expressed in U.S. dollars, but notice that by taking the ratio the currency of denomination is neutral. In robustness checks I vary both the geography, the sub-sector of financial corporations being included, and the measure of economic activity.

For geographies I consider: World ex-developed Europe and U.S., World ex-Japan and U.S., and World ex-U.K. and U.S..[38] For sub-sectors of financial firms I consider: Financials ex-Banks, Financials ex-Insurance, and Financials ex-Financial Services. Data for each of these sub-sectors are available from Datastream and use the classification structure based on the Industry Classification Benchmark jointly created by FTSE and Dow Jones. For alternative measures of economic activity I consider: Dividends, Cash Flows, and Earnings. It is convenient to normalize RoW financial net worth by global output in the theoretical model; however, it is potentially important to consider different measures in the data since these would have behaved similarly in the model, but potentially not in the data. The proxy for $\tilde{N}^*$ should capture the level of intermediary net worth compared to a measure of potential need for financial intermediation services. It therefore appears appropriate to consider normalizing $N^*_{i,j,t}$ by measures of the dividends, cash flows, or earnings of the financial firms in geography i and sub-sector j. I build the values of dividends, earnings, and cash flows for each geography and sub-sector using the raw data from Datastream according to:

$$\begin{aligned} D_{i,j,t} &= DY_{i,j,t} * MV_{i,j,t}, \\ E_{i,j,t} &= MV_{i,j,t}/PE_{i,j,t}, \\ CF_{i,j,t} &= MV_{i,j,t}/PCF_{i,j,t}, \end{aligned}$$

[37] I build the series for $\tilde{N}^*_{i,j,t}$ at monthly frequency. Since U.S. GDP data are annual, I linearly interpolate GDP during the 12 months of the year. Note that this interpolation does not affect any of the results in the regressions, since those are run at annual frequency due to data availability for the U.S. net investment position (dependent variable).

[38] For each of these areas, the corresponding GDP was built by subtracting the GDP of the stated country (e.g. Japan) and the United States from World GDP, with the exception of developed Europe, which was proxied by the European Union.

where D is the dollar value of dividends, E is the dollar value of earnings, CF is the dollar value of cash flows, DY is the dividend yield, PE is the price-to-earnings ratio, and PCF is the price-to-cash-flow ratio.

The independent variable for the regressions reported in Table 2 and Figure 6 and for the robustness regressions in Table A.7 is then built by taking log differences of $\tilde{N}^*_{i,j,t}$:[39]

$$\Delta\tilde{N}^*_{i,j,t} \equiv \ln\left(\frac{MV_{i,j,t}}{Y_{i,j,t}}\right) - \ln\left(\frac{MV_{i,j,t-1}}{Y_{i,j,t-1}}\right). \tag{A.41}$$

Figure A.6 plots different proxy measures of $\tilde{N}^*_{i,j,t}$. The top left panel plots the times series of the benchmark measure (RoW financials normalized by RoW GDP). Financial net-worth shows a clear upward trend compared to GDP for the period 1976 to 2016, which is consistent with the secular trend of an increase in financial intermediation and growth of the financial sector as a share of the overall economy. To filter out the historical upward trend in financial net-worth and prevent issues related to non-stationary regressors, I perform all regressions using first differences of $\tilde{N}^*_{i,j,t}$, as in equation (A.41). The other most notable pattern in the empirical proxy for net worth, especially for the purpose of this paper, is that financial net worth tends to collapse during adverse economic events. The global financial crisis of 2007-2008 provides a particularly dramatic example, with financial net worth dropping from a high of 22% of RoW GDP to a low of 7%. Similar patterns also emerge for the dot-com stock-market collapse in the early 2000s and for the 1998 LTCM crisis. This behavior is consistent with my theoretical model, in which scaled net worth is a pro-cyclical variable ($\sigma_{\tilde{N}^*} > 0$): levered financial intermediaries are long risky assets and funded in short term safe assets and lose capital as a result of negative shocks in the world economy. I confirm the pro-cyclicality of RoW financial net worth more generally in Table A.9, which shows net worth to be positively correlated with world stock market returns (0.88) and U.S. consumption growth (0.28), and negatively correlated with implied volatility as proxied by VIX (-0.592). The other noticeable pattern in the top left panel of Figure A.6 is the strong increase in financial net worth compared to world GDP in the second half of the 1980s. As I explain below, this strong increase is in large part due to the Japanese stock market boom of those years.

The remaining three panels of Figure A.6 plot various robustness measures of $\tilde{N}^*_{i,j,t}$. The top right panel plots the measure $\tilde{N}^*_{i,j,t}$ for different geographies (i). While the measure is clearly highly correlated across geographies, the most

[39] I have used log differences in the benchmark regression, but taking level differences does not materially affect results. When running the regression in Table 2 column one using a measure of $\Delta\tilde{N}^*_{i,j,t}$ obtained with level differences, the coefficients are: $\alpha = .007$, $S.E.(\alpha) = .006$, $\beta = 1.170$, $S.E.(\beta) = .156$ with a R^2 of .49.

noticeable pattern is the boom of stock market valuations of Japanese financial institutions in the late 1980s and the subsequent reversal in the early 1990s. This large stock market boom-bust cycle and the large overall capitalization of Japanese financial institutions means that the pattern is reflected in my benchmark measure for RoW. Therefore, in Table A.7 Panel A third column I verify that the benchmark results in Table 2 are robust to excluding Japanese financial firms from the RoW financial net worth measure. The bottom left panel of Figure A.6 plots the measure $\tilde{N}^*_{i,j,t}$ for different sub-sectors of financial firms (j). All sub-sectors are highly correlated; the most noticeable pattern is the quantitative importance of banks, since these firms account for a large share of the overall market value of all financial firms. The bottom right panel of Figure A.6 plots the measure $\tilde{N}^*_{i,j,t}$ for different measures of economic activity. Purely for visualization purposes, the series in this panel have been rescaled by a constant such that all series have the same mean. All series have largely similar behavior, with the correlation being particularly high for series scaled by earnings, cash flows, and dividends. The main difference is that measures of $\tilde{N}^*_{i,j,t}$ built by scaling by earnings, cash flows, or dividends, rather than GDP, do not display a strong upward trend. The economics behind this finding is simple to understand: measures of earnings, cash flows, or dividends for financial firms scale with the overall size of the financial sector. If the financial sector grows as a share of the overall economy, scaling net worth by GDP does display an upward trend, while scaling net worth by financial firms earnings, cash flows, or dividends does not.

Table A.6 confirms the broadly similar and robust behavior of my empirical proxies for RoW financial net worth by reporting the pairwise correlation between log-changes of all the proxies. Correlations between the benchmark measure and each of the alternative measures are high, often exceeding 0.9, and never lower than .88. Similarly, pairwise correlations are high among each of the alternative measures, with the lowest correlation (0.75) resulting from excluding Japan and Europe as geographical areas. I have discussed above the role of Japan in generating Japan-specific variation in the aggregate RoW measures.

Table 2 and Figures 6 in the main text report the results of the regression specification in equation (21). Table 2 provides the main result, the positive association between U.S. NFA net of net-exports and RoW financial net worth, as well as subsample robustness checks. I explore here further robustness of the main result by using the alternative measures of RoW net worth discussed above. Table A.7 shows that U.S. NFA net of net-exports are positively associated with all 9 alternative proxies for RoW financial net worth. The estimated coefficients and resulting R^2 are stable across all the different robustness checks. This confirms that the main result holds across broad definitions of the financial sector (banks, insurance, financial services), geographical areas (excluding: U.K., Japan, Europe), and different scaling variables for RoW net worth (earnings, cash flows, dividends).

Table A.8 builds on the main result in Table 2 by adding controls for measures of U.S. fundamentals to the regression specification in equation (21). The aim is to verify that RoW financial net worth has independent explanatory power from U.S. fundamentals in explaining the dynamics of U.S. NFA. In particular, I focus on U.S. consumption growth as a measure of U.S. fundamentals since it is a natural summary of economic conditions in aggregate representative agents models (such as the Lucas Economy) and should be strongly associated with risk premia, including those driving movements in U.S. NFA. I use the log-growth of U.S. real consumption expenditure, and provide a robustness check by excluding expenditure on durable goods.[40] Columns 4 and 5 of Table A.8 show that U.S. consumption growth is not associated with changes in U.S. NFA net of net-exports: the regression coefficients are not statistically significant and the R^2 is extremely low. Similarly, columns 2 and 3 of Table A.8 show that controlling for U.S. consumption growth leaves the explanatory power of RoW financial net worth essentially unchanged, and that U.S. consumption growth remains statistically not significant (it even changes sign from columns 4 and 5). This confirms that RoW financial net worth, while positively correlated with U.S. consumption growth (correlation coefficient of 0.28), has independent information about global imbalances, especially the part associated with global risk premia. This is consistent with the long-standing failure of consumption based models to explain global risk premia, and the more favorable evidence that is emerging, and to which this paper contributes, for measures of financial net worth (Adrian, Etula and Muir (2014), Muir (2016), He, Kelly and Manela (2017)).

[40]U.S. real personal consumption expenditure (series code: PCECCA) is available from the BEA. I build real personal consumption expenditure excluding durable goods by summing nominal expenditure on non-durable goods (series code: PCNDA) and services (series code: PCESVA), and deflating them by the total personal consumption expenditure deflator. Durable goods are generally excluded from empirical tests of U.S. consumption behavior due to the lumpiness of durable purchases, the consumption benefits of which are then spread over several periods.

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Table A.1: Aggregation of CPIS Categories

Sectors in this Paper	Corresponding Sectors in CPIS
Government	General government, Central bank
Financials	Deposit-taking corporations except for the central bank, Other financial corporations
Nonfinancials	Nonfinancial Corporations, HHs and NPISHs

Notes. Mapping of the sectors in the Coordinated Portfolio Investment Survey of the International Monetary Fund to the sectors used for the empirical analysis in this paper.

Table A.2: U.S. Debt Held by Financial Institutions by Country, Survey Average

Country	Financial Share (percent)	Country	Financial Share (percent)
1. Argentina	0.28	28. Indonesia	67.55
2. Aruba	83.38	29. Israel	32.78
3. Australia	85.82	30. Italy	70.64
4. Austria	88.58	31. Japan	95.97
5. Bahrain, Kingdom of	98.85	32. Jersey	99.98
6. Bangladesh	25.11	33. Kazakhstan	4.00
7. Barbados	99.06	34. Korea, Republic of	81.43
8. Belgium	88.07	35. Latvia	96.89
9. Bermuda	99.94	36. Lithuania	88.53
10. Brazil	80.89	37. Malaysia	59.59
11. Bulgaria	98.52	38. Mexico	6.68
12. Chile	16.63	39. Netherlands	94.45
13. China, P.R.: Macao	13.90	40. Norway	12.52
14. Colombia	76.67	41. Poland	8.83
15. Costa Rica	64.03	42. Portugal	57.24
16. Cyprus	87.88	43. Romania	99.18
17. Czech Republic	83.97	44. Russian Federation	87.60
18. Denmark	97.94	45. Slovak Republic	96.16
19. Estonia	92.57	46. Slovenia	34.15
20. Finland	50.82	47. South Africa	94.27
21. France	92.12	48. Spain	69.07
22. Germany	79.70	49. Sweden	59.77
23. Greece	41.31	50. Thailand	63.74
24. Guernsey	99.79	51. Turkey	50.74
25. Honduras	62.60	52. United Kingdom	98.10
26. Hungary	27.38	53. Uruguay	72.02
27. Iceland	99.38	54. Venezuela, Republica de	10.97

Notes. Country shares are constructed by dividing U.S. debt held by the foreign country's financial sector by total U.S. debt held by the country, averaged over time. The financial sector includes sectors defined as "Deposit-taking corporations except the central bank" and "Other financial corporations". Data are sourced from the Coordinated Portfolio Investment Survey published by the International Monetary Fund, using the June 2013 through June 2015 surveys.

Table A.3: Average Share of U.S. Debt Held by Foreign Financial Institutions, by Survey

	Mean Financial Share (Unweighted, percent)	Mean Financial Share (Weighted, percent)
2013Q2	64.59	82.74
2013Q4	65.78	85.43
2014Q2	63.20	87.53
2014Q4	68.97	85.65
2015Q2	66.63	87.90
Mean	65.83	85.85

Notes. Individual country shares are first constructed by dividing U.S. debt held by the foreign country's financial sector by total U.S. debt held by the country. Country shares are weighted by equal weights in the unweighted column, and by the country's total holdings of U.S. debt in the weighted column. The financial sector includes sectors defined as "Deposit-taking corporations except the central bank" and "Other financial corporations". Data source is the Coordinated Portfolio Investment Survey published by the International Monetary Fund, using the June 2013 through June 2015 surveys.

Table A.4: Average Share of U.S. Portfolio Investment Held by Foreign Financial Institutions, by Asset Class.

	Mean Financial Share (Unweighted, percent)	Mean Financial Share (Weighted, percent)
Debt	65.83	85.85
Equity	65.04	82.03
Total	64.45	83.83

Notes. Financial sector shares for each asset class are first constructed by dividing portfolio investments in the U.S. held by the financial sector by total portfolio investments in the U.S. for each time period. Country shares are averaged using equal weights to create an average share within each time period in the unweighted column, and are weighted by the country's total holdings of U.S. securities in each asset class in the weighted column. Time periods are then weighted equally. The financial sector includes sectors defined as "Deposit-taking corporations except the central bank" and "Other financial corporations". Data are sourced from the Coordinated Portfolio Investment Survey published by the International Monetary Fund, using the June 2013 through June 2015 surveys.

Table A.5: Data Sources Summary

Provider	Name / Series ID	Period	Periodicity	Aggregation
TRD	**Geography:** $\{$WORLD-DS,WORLD EX DEV.EUR-DS., WORLD EX JAPAN-DS, WORLD EX UK-DS, WORLD EX US-DS, US-DS$\}$ $\times$ **Sector:** $\{$Financials, Banks, Insurance, Real Estate, Financial Svs, Market$\}$: **Field:** MV (Market Value)	1976 $\rightarrow$ 2016	Monthly	End of period
TRD	**Geography:** $\{$WORLD-DS,WORLD EX DEV.EUR-DS., WORLD EX JAPAN-DS, WORLD EX UK-DS, WORLD EX US-DS, US-DS$\}$ $\times$ **Sector:** $\{$Financials, Banks, Insurance, Real Estate, Financial Svs, Market$\}$: **Field:** PE (Price to Earnings)	1976 $\rightarrow$ 2016	Monthly	End of period
TRD	**Geography:** $\{$WORLD-DS,WORLD EX DEV.EUR-DS., WORLD EX JAPAN-DS, WORLD EX UK-DS, WORLD EX US-DS, US-DS$\}$ $\times$ **Sector:** $\{$Financials, Banks, Insurance, Real Estate, Financial Svs, Market$\}$: **Field:** DY (Dividend Yield)	1976 $\rightarrow$ 2016	Monthly	End of period
TRD	**Geography:** $\{$WORLD-DS,WORLD EX DEV.EUR-DS., WORLD EX JAPAN-DS, WORLD EX UK-DS, WORLD EX US-DS, US-DS$\}$ $\times$ **Sector:** $\{$Financials, Banks, Insurance, Real Estate, Financial Svs, Market$\}$: **Field:** PC (Price to Cash Flow Ratio)	1976 $\rightarrow$ 2015	Monthly	End of period
WBD	World Development Indicators (GDP (Current US$): $\{$WLD, USA, GBR, JPN, EUU$\}$)	1976 $\rightarrow$ 2015	Annual	Per period flow
BEA	Table 1.1. U.S. Net International Investment Position (Net international investment position)	1976 $\rightarrow$ 2015	Annual, Quarterly since 2006	End of period
BEA	Table 1.1.5. Gross Domestic Product (Gross domestic product)	1976 $\rightarrow$ 2015	Quarterly	Per period flow
BEA	Table 4.1. Foreign Transactions in the NIPA (Exports of goods and services - Imports of goods and services)	1976 $\rightarrow$ 2015	Quarterly	Per period flow

Notes. Table describes data sources, series codes, sample size, and frequency for data sources used to measure proxies of RoW financial net worth.

Table A.6: Correlation Among Different Proxies for RoW Financial Net Worth

		Alternative Geographical Regions			Alternative Scaling Variables			Alternative Financial Sub-sectors		
	Benchmark	**Ex-{US, Developed Europe}**	**Ex-{US, Japan}**	**Ex-{US, UK}**	**Dividends**	**Earnings**	**Cash Flows**	**Ex Banks**	**Ex Insurance**	**Ex Financial Services**
Benchmark		0.924	0.916	0.996	0.939	0.885	0.926	0.972	0.993	0.989
Ex-{US,Developed Europe}			0.751	0.942	0.904	0.833	0.849	0.873	0.954	0.886
Ex-{US,Japan}				0.890	0.846	0.821	0.857	0.925	0.886	0.908
Ex-{US,UK}					0.940	0.884	0.923	0.966	0.993	0.981
Dividends						0.932	0.951	0.911	0.941	0.919
Earnings							0.919	0.850	0.889	0.880
Cash Flows								0.941	0.909	0.898
Ex Banks									0.947	0.944
Ex Insurance										0.976
Ex Financial Services										

Notes. Pairwise correlation among different proxy measures for RoW financial net worth ($\tilde{N}^*$). Correlations are for the logarithmic change in each proxy measure. The benchmark measure is built by dividing the total equity market valuation of financial firms included in the Datastream Financial Equity World ex U.S. index (code: FINWUS) by GDP for the world ex U.S. provided by the World Bank. The first robustness check varies the geographical areas of the RoW that are included in the measure $\tilde{N}^*$. The second robustness check varies the measure of economic activity that is used to scale financial net worth $\tilde{N}^*$. The third robustness check varies the sub-sectors of financial firms that are included in the measure $\tilde{N}^*$. Appendix A.3.C provides further details on these alternative measures. All data are annual from 1976 to 2015, except for the cash-flow-based measure, which starts in 1980.

Table A.7: U.S. NFA and RoW Financial Net Worth: Robustness Checks

	Benchmark	**Panel A: Alternative Geographic Areas**		
	Ex U.S.	Ex U.S. & Developed Europe	Ex U.S. & Japan	Ex U.S. & U.K.
α	0.0040	0.0042	0.0033	0.0040
	(0.0062)	(0.0056)	(0.0063)	(0.0061)
β	0.1189	0.1195	0.1131	0.1170
	(0.0266)	(0.0290)	(0.0248)	(0.0275)
R^2	0.4031	0.4488	0.3886	0.4059
	Benchmark	**Panel B: Alternative Measures of Economic Activity**		
	GDP	Dividends	Earnings	Cash Flows
α	0.0040	0.0095	0.0098	0.0054
	(0.0062)	(0.0063)	(0.0067)	(0.007)
β	0.1189	0.1231	0.1055	0.1333
	(0.0266)	(0.0301)	(0.0295)	(0.0403)
R^2	0.4031	0.3866	0.3020	0.3336
	Benchmark	**Panel C: Alternative Sub-sectors of Financial Firms**		
	Financials	Ex-Banks	Ex-Insurance	Ex-Financial Services
α	0.0040	0.0044	0.0040	0.0036
	(0.0062)	(0.0063)	(0.0061)	(0.0065)
β	0.1189	0.1098	0.1193	0.1222
	(0.0266)	(0.0293)	(0.0248)	(0.0335)
R^2	0.4031	0.3727	0.4289	0.3519

Notes. The dependent variable is the annual change in the net foreign asset position of the U.S. minus net exports, expressed as a share of U.S. GDP: $\frac{NFA_t - NX_t}{GDP_t}$. In the benchmark columns, regressors are: a constant and the logarithmic change in RoW financial net worth as a fraction of RoW GDP, $\Delta\tilde{N}^*$. The measure $\tilde{N}^*$ is built by dividing the total equity market valuation of financial firms included in the Datastream Financial Equity World ex U.S. index (code: FINWUS) by world GDP ex U.S. provided by the World Bank. Panel A varies the geographical areas of the RoW that are included in the measure $\tilde{N}^*$. Panel B varies the measures of economic activity that are used to scale financial net worth N^*. Panel C varies the sub-sectors of financial firms that are included in the measure $\tilde{N}^*$. Appendix A.3.C provides further details on these alternative measures. Net exports of goods and services and net foreign assets of the United States are from the Bureau of Economic Analysis. All regressions use annual data from 1976-2015 except for the "Cash Flow" measure of GDP, which uses annual data from 1980. Standard errors are reported in parenthesis and are built with the Newey-West procedure including one lag.

Table A.8: U.S. NFA, RoW Financial Net Worth, and U.S. Consumption

	(1)	(2)	(3)	(4)	(5)
$\Delta\tilde{N}^*$	0.1189	0.1272	0.1228		
	(0.0266)	(0.0257)	(0.0261)		
ΔC		-0.4620		0.0792	
		(0.2810)		(0.5048)	
ΔC_{ex-D}			-0.4190		0.0227
			(0.4157)		(0.6741)
Constant	0.0040	0.0170	0.0164	0.0087	0.0103
	(0.0062)	(0.0099)	(0.0134)	(0.0184)	(0.0234)
R^2	0.4031	0.4269	0.4158	0.0008	0.000

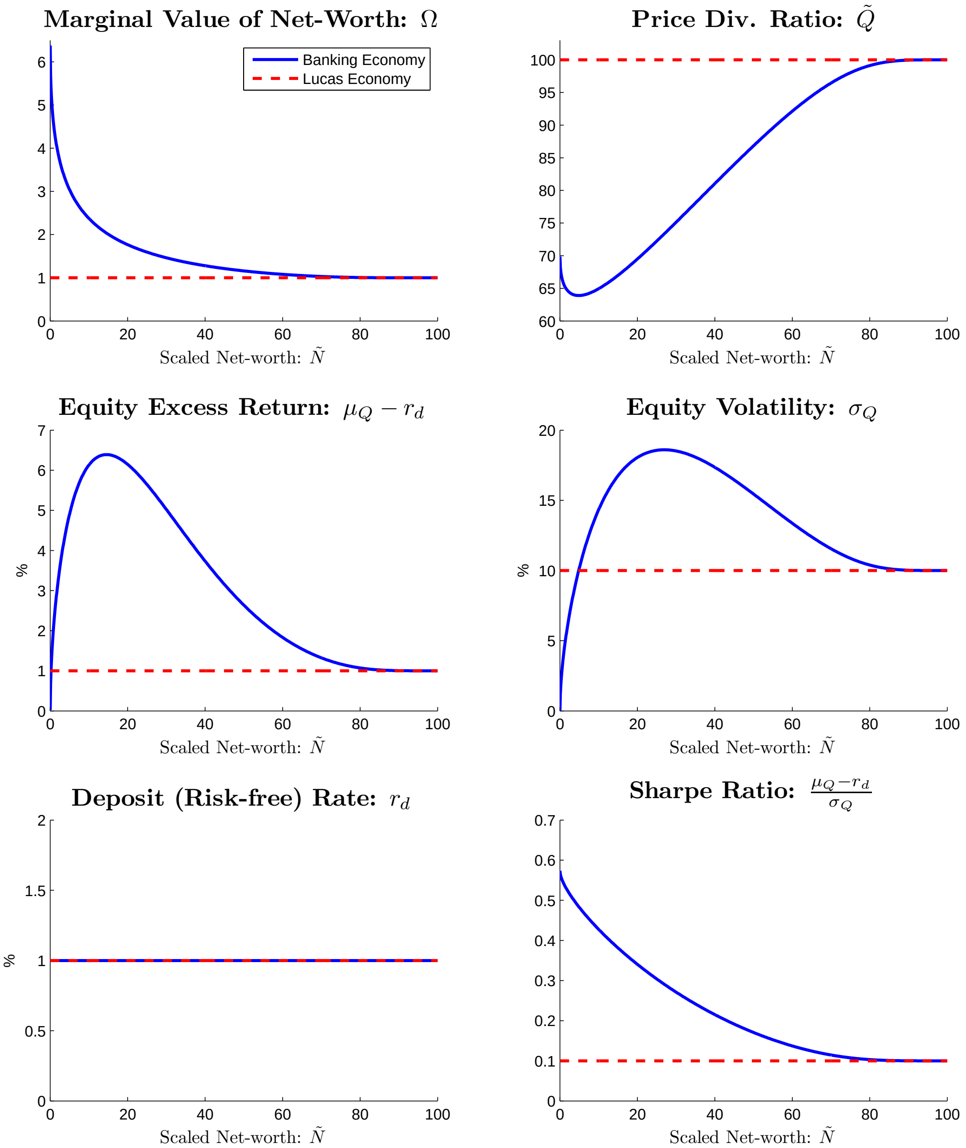
Notes. The dependent variable is the annual change in the net foreign asset position of the U.S. minus net exports, expressed as a share of U.S. GDP: $\frac{NFA_t - NX_t}{GDP_t}$. Column (1) reports the benchmark regression. Regressors are: a constant and the logarithmic change in RoW financial net worth as a fraction of RoW GDP, $\Delta\tilde{N}^*$. The measure $\tilde{N}^*$ is built by dividing the total equity market valuation of financial firms included in the Datastream Financial Equity World ex U.S. index (code: FINWUS) by world GDP ex U.S. provided by the World Bank. Column (2) adds to the regression in column (1) the log-change in U.S. real personal consumption expenditure. Column (3) adds to the regression in column (1) the log-change in U.S. real personal consumption expenditure, excluding durable goods. Columns (4) and (5) use as regressors only the consumption measures and exclude the financial net-worth measure. Personal consumption expenditure data are from the Bureau of Economic Analysis. Standard errors are reported in parenthesis and are built with the Newey-West procedure including one lag.

Table A.9: Pro-cyclical Behavior of RoW Financial Net Worth

Correlation	VIX	World Equity Returns	ΔC
$\Delta\tilde{N}^*$	-0.592	0.883	0.28

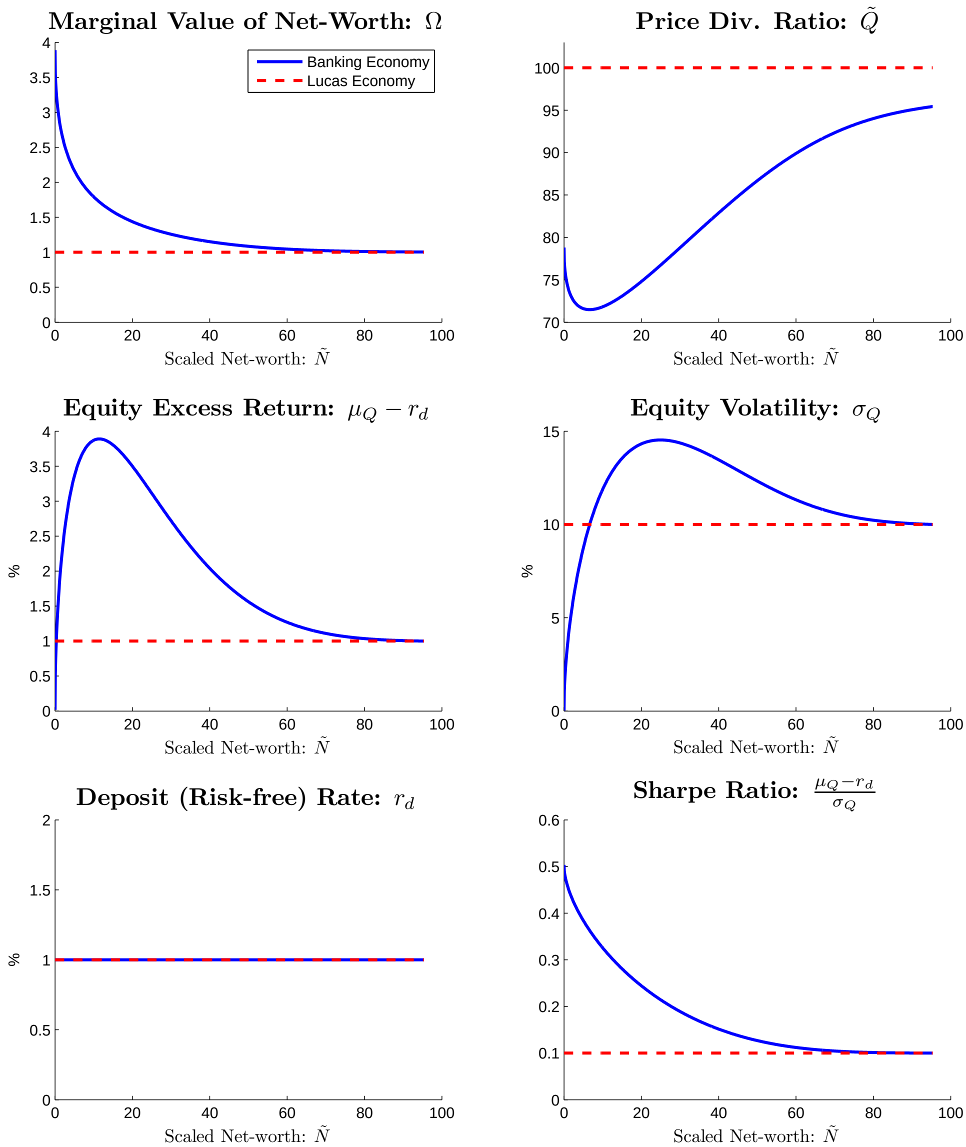
Notes. Correlation coefficients between changes in RoW financial net worth and VIX, World equity returns, and U.S. consumption growth. World equity returns are total returns for the World Equity Index provided by Datastream (code: WORLD-DS). U.S. consumption data are Personal Consumption Expenditures from the BEA. All data series are annual 1976 to 2015, except VIX which starts in 1990.

Figure A.1: Autarky Equilibrium



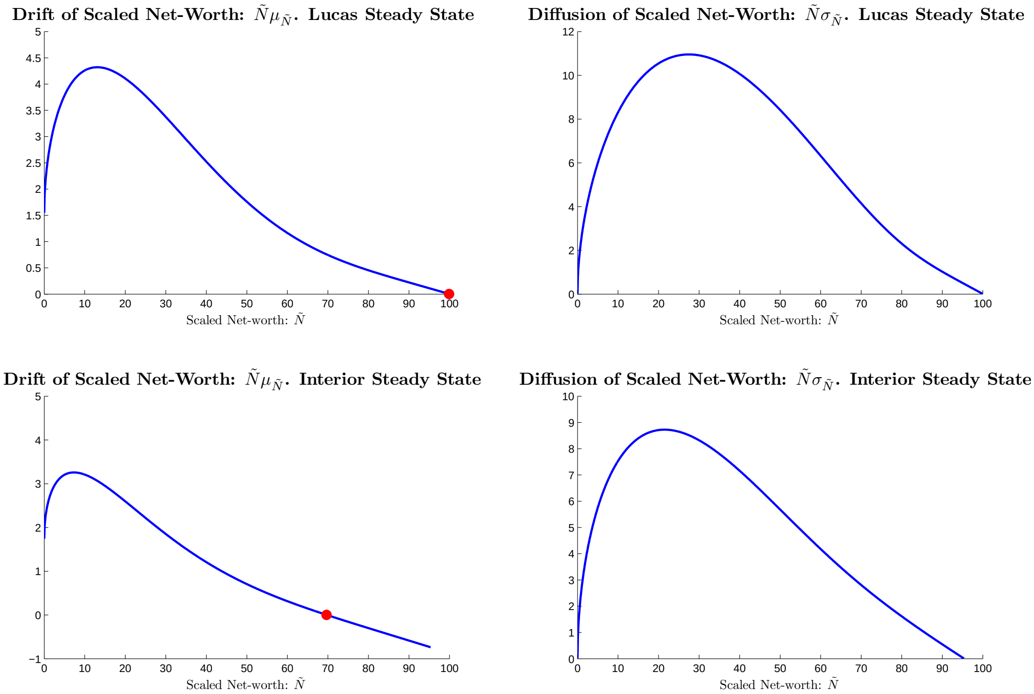
Notes. Numerical solution for the equilibrium in Section II for the case $\delta = \lambda - \rho$: the Banking Economy eventually converges to the Lucas Economy. Parameter values: $\rho = 0.01,\ \delta = 0.022,\ \mu = 0.01,\ \sigma = 0.1$. Note that the graphs plot the solution for the state space of the Banking Economy, the range of the state variable $\tilde{N}$. The Lucas Economy solution is plotted over the same state space for comparison purposes, but the state space of the Lucas Economy extends beyond the one of the Banking Economy. The state space of the Banking Economy is $(0, \frac{1}{\rho}]$, and the stochastic steady state is $\frac{1}{\rho}$.

Figure A.2: Autarky Equilibrium: Interior Stochastic Steady State



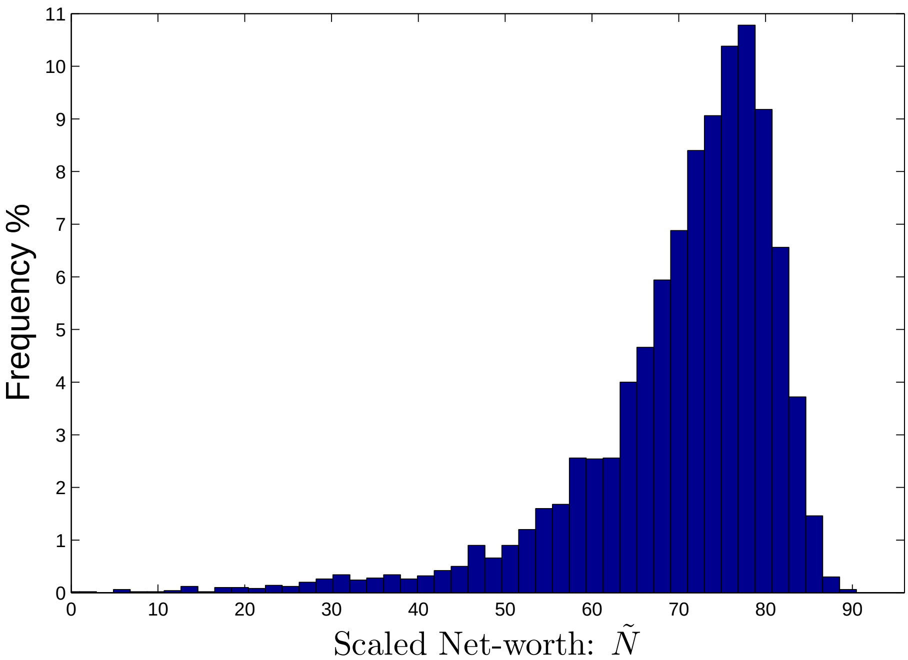
Notes. Numerical solution for the equilibrium in Section II for the case $\delta < \lambda - \rho$: the Banking Economy has an interior stochastic steady state. Parameter values: $\rho = 0.01$, $\delta = 0.022$, $\lambda = 0.0398$, $\mu = 0.01$, $\sigma = 0.1$. Note that the graphs plot the solution for the state space of the Banking Economy, the range of the state variable $\tilde{N}$. The Lucas Economy solution is plotted over the same state space for comparison purposes, but the state space of the Lucas Economy extends beyond the one of the Banking Economy. The state space of the Banking Economy is $(0, 95.43)$, and the stochastic steady state is 69.76.

Figure A.3: Autarky Equilibrium: Stochastic Steady State



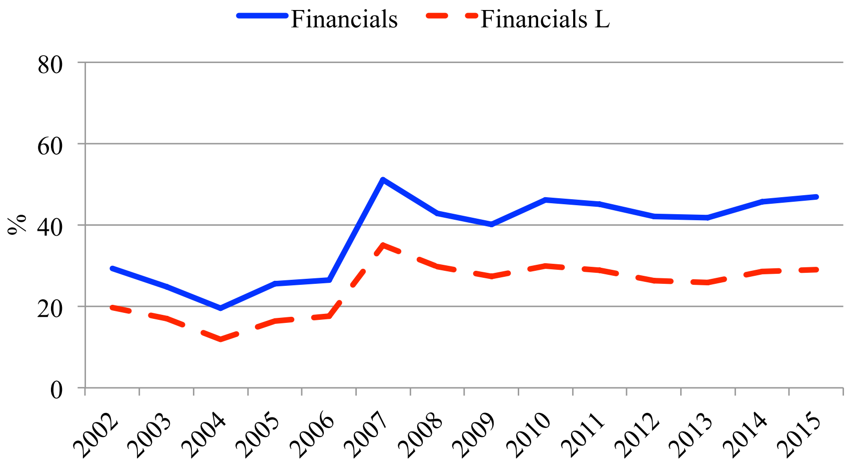
Notes. Numerical solution for the equilibrium in Section II for the case $\delta = \lambda - \rho$ (top two graphs) and $\delta < \lambda - \rho$ (bottom two graphs). Parameter values for the first case: $\rho = 0.01,\ \delta = 0.022,\ \lambda = 3.98,\ \mu = 0.01,\ \sigma = 0.1$. These are the drift and diffusion of the state variable, scaled net-worth $\tilde{N}$, for the equilibrium in Figure A.1. Parameter values for the second case: $\rho = 0.01,\ \delta = 0.022,\ \lambda = 0.0398,\ \mu = 0.01,\ \sigma = 0.1$. These are the drift and diffusion of the state variable, scaled net-worth $\tilde{N}$, for the equilibrium in Figure A.2. The red dot in the two graphs on the left corresponds to each case's stochastic steady state. The state space of the case $\delta = \lambda - \rho$ is $(0, \frac{1}{\rho}]$, and the stochastic steady state is $\frac{1}{\rho}$. The state space of the case $\delta < \lambda - \rho$ is $(0, 95.43)$, and the stochastic steady state is 69.76.

Figure A.4: Autarky Equilibrium: Stationary Distribution



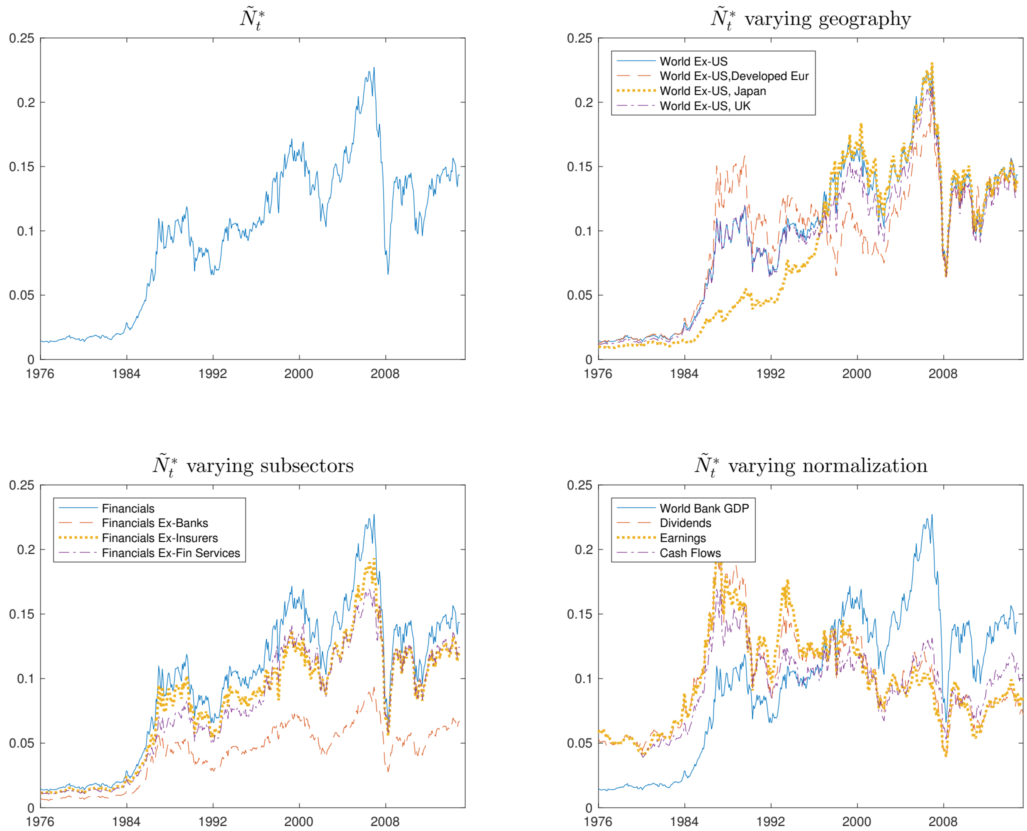
Notes. Plot of the limiting stationary distribution of the state variable, scaled net-worth $\tilde{N}$, for the equilibrium in Section II for the case $\delta < \lambda - \rho$. Parameter values: $\rho = 0.01$, $\delta = 0.022$, $\lambda = 0.0398$, $\mu = 0.01$, $\sigma = 0.1$. This is the stationary distribution for the equilibrium in Figure A.2. The state space is $(0, 95.43)$, and the stochastic steady state is 69.76. The approximation to the stationary distribution is obtained by simulating 5,000 paths for 100 years at daily frequency (36,500 periods) for the process $\tilde{N}$.

Figure A.5: Foreign Portfolio Holdings as Percentage of U.S. Debt Securities: Robustness Check



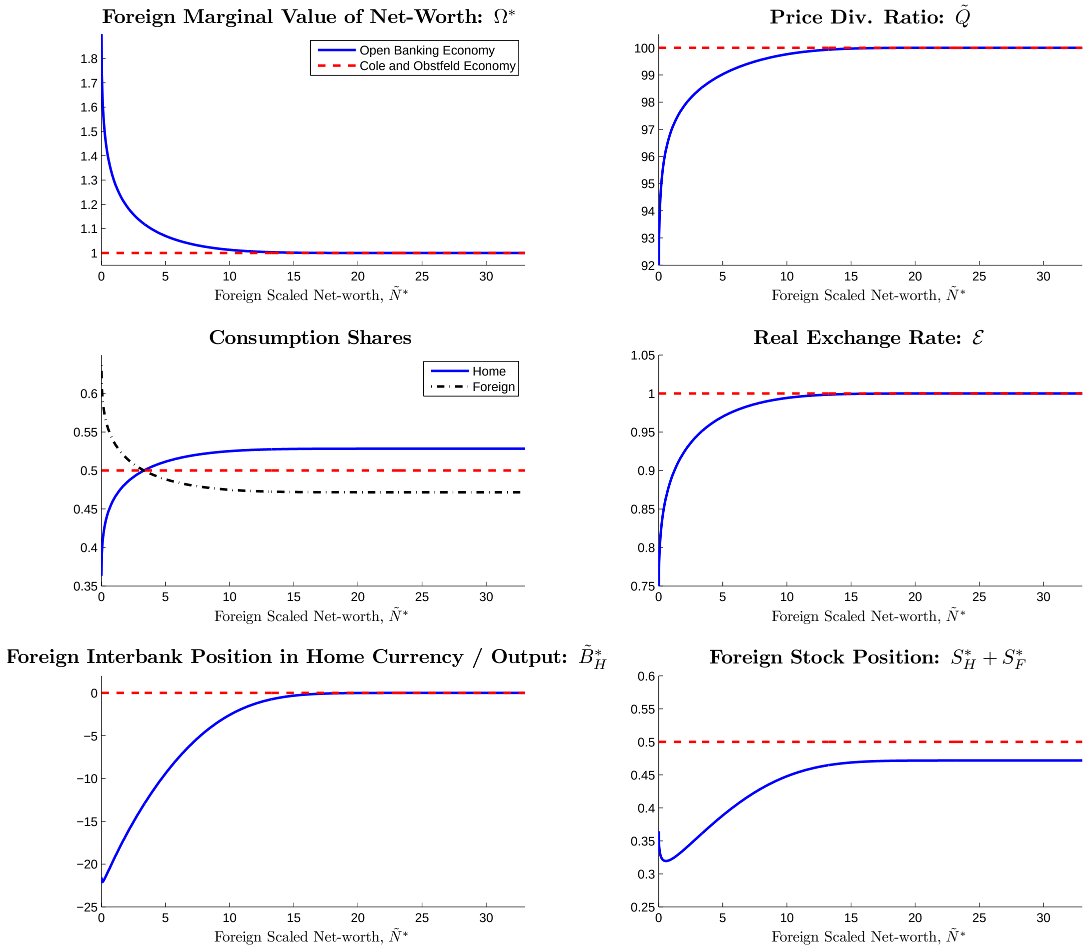
Notes. RoW portfolio holdings of debt securities issued by U.S. financial institutions as a fraction of the total outstanding stock of debt issued by that sector. "Financial" is the benchmark estimate, as reported in the middle panel of Figure 4. "Financial L" is a robustness check that includes all U.S. debt issued by state and local governments in the denominator. Data on RoW securities holdings in the U.S. are from TIC and data on the stock of securities are from the Flow of Funds (annual June 2002 to June 2015). See Appendix A.3.*A* for full details on data sources and methodology.

Figure A.6: Empirical Proxies for RoW Financial Net Worth: $\tilde{N}^*$



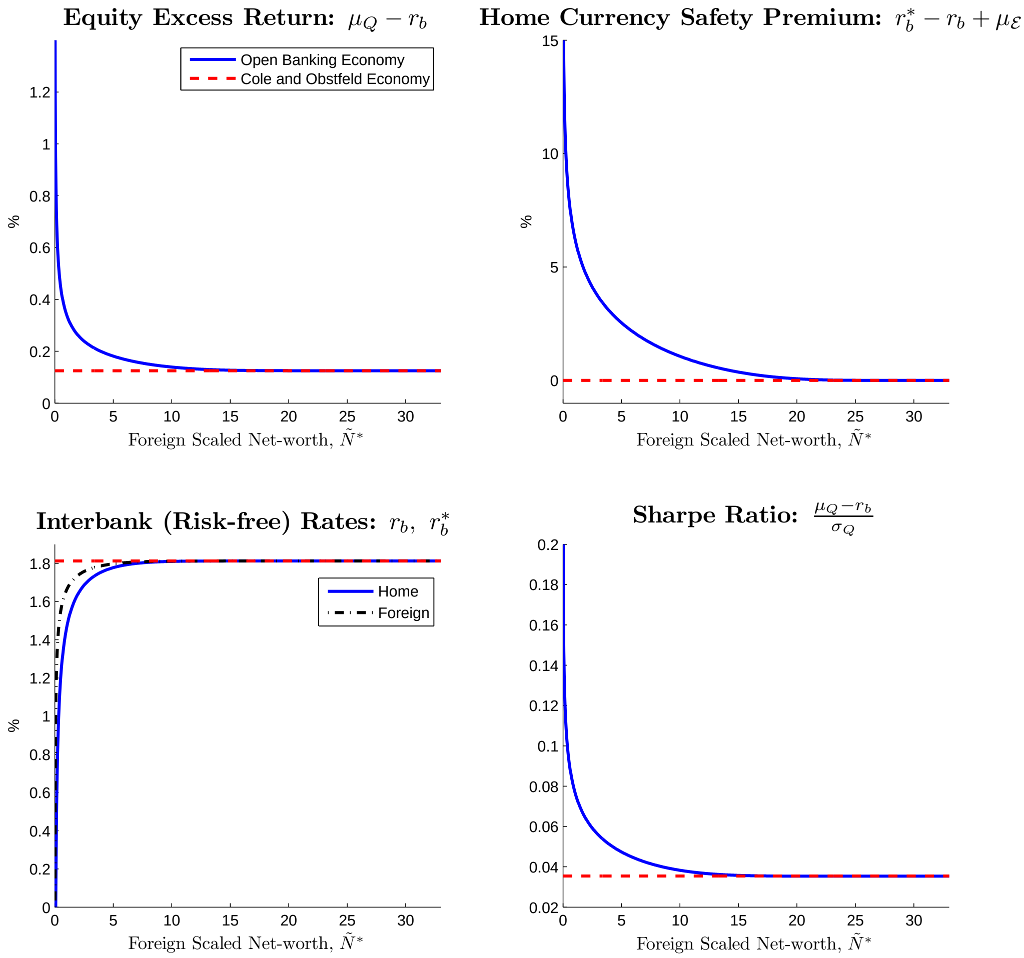
Notes. Top left panel plots the benchmark proxy of $\tilde{N}^*$, which is built by dividing the market value of firms included in the Datastream Financial Equity World ex U.S. index (code: FINWUS) by the world ex U.S. GDP provided by the World Bank. Top right panel plots alternative specifications of $\tilde{N}^*$ that exclude further geographical areas in both the numerator and denominator: Developed Europe, Japan, and the U.K.. Bottom left panel plots alternative specifications of $\tilde{N}^*$ that exclude sub-sectors of financial firms from the numerator: Banks, Insurers, Financial Services. Bottom right panel plots alternative specifications of $\tilde{N}^*$ that use different proxies of economic activity in the denominator: dividends, cash-flows, earnings. Purely for visualization purposes, the series in the bottom right panel have been rescaled by a constant such that all series have the same mean. All data series are monthly between January 1976 to June 2016. See Appendix A.3.*C* for full details on data sources and methodology.

Figure A.7: Open Economy Equilibrium, Two Trees, No Domestic Bias: Allocations



Notes. Numerical solution for the equilibrium in Section IV. Parameter values: $\rho = 0.01$, $\delta = 0.004$, $\lambda = 0.014$, $\mu = 0.01$, $\sigma_z = \sigma_{z^*} = 0.05$, $\alpha = 0.5$. The starting scaled net-worth is $\tilde{N}^*(0) = 3.5$, which results in $\xi = 1.12$. Note that the graphs plot the solution for the state space of the Open Banking Economy with two trees, the range of the state variable $\tilde{N}^*$. The Cole and Obstfeld Economy solution is plotted over the same state space for comparison purposes, but the state space of the Cole and Obstfeld Economy extends beyond the one of the Open Banking Economy. The state space of the Open Banking Economy is $(0, \frac{1}{\rho(1+\xi)}]$; in the figures above it has been cut on the right to allow for better visualization. The stochastic steady state is $\frac{1}{\rho(1+\xi)}$.

Figure A.8: Open Economy Equilibrium, Two Trees, No Domestic Bias: Asset Prices



Notes. Numerical solution for the equilibrium in Section IV. Parameter values: $\rho = 0.01$, $\delta = 0.004$, $\lambda = 0.014$, $\mu = 0.01$, $\sigma_z = \sigma_{z^*} = 0.05$, $\alpha = 0.5$. The starting scaled net-worth is $\tilde{N}^*(0) = 3.5$, which results in $\xi = 1.12$. Note that the graphs plot the solution for the state space of the Open Banking Economy with two trees, the range of the state variable $\tilde{N}^*$. The Cole and Obstfeld Economy solution is plotted over the same state space for comparison purposes, but the state space of the Cole and Obstfeld Economy extends beyond the one of the Open Banking Economy. The state space of the Open Banking Economy is $(0, \frac{1}{\rho(1+\xi)}]$; in the figures above it has been cut on the right to allow for better visualization. The stochastic steady state is $\frac{1}{\rho(1+\xi)}$.