Online Appendix for

The United States as the International Lender of Last Resort

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A1 Additional stylized facts

Reconstructing global banks' dollar-needs from Figure 2a. Precisely calculating the short-term dollar needs of global banks is challenging due to the lack of data on banks' positions broken down simultaneously by nationality, currency, and maturity. Following the literature (McGuire et al., 2009, Aldasoro et al., 2020), however, a proxy measure of short-term dollar needs can be obtained using the BIS's counterparty sector classification, which provides information[35] (by country) on net dollar positions distinguishing between exposure vis-à-vis: non-banks (i.e. financial and non-financial firms, general government, and households), banks (i.e. interbank exposure net of related offices), and monetary authorities.

In particular, a proxy measure of risk from dollar-denominated maturity mismatch is the bank's net dollar position vis-à-vis non-banks. The validity of this proxy relies on two assumptions: (i) all positions vis-à-vis non-banks (both on the asset and liability side) are long-term and illiquid ; (ii) banks have no overall currency mismatches. Under these two assumptions, a net lending position (i.e. assets larger than liabilities) vis-à-vis non-banks gives rise to a corresponding short-term dollar need. The short-term dollar need can be covered by a combination of non-mutually exclusive: net borrowing position (i.e. liabilities larges than assets) on the interbank market; net borrowing from the monetary authority; net short position in foreign exchange (FX) derivatives. Given assumption (ii) above, and the fact that BIS data are not fully available for derivatives, the FX position is derived as the inverse of the algebraic sum of the net positions vis-à-vis non-banks, banks, and monetary authorities, so that overall currency mismatch is zeroed out.

[35] The BIS publishes two main datasets on international banking activity: the Locational Banking Statistics (LBS) and the Consolidated Banking Statistics (CBS). The LBS are compiled on a residency basis, capturing the cross-border positions of all banks located in a given country, regardless of the nationality of their parent group—for example, Unicredit's German branch is reported under Germany. In contrast, the CBS are compiled on a consolidated basis, attributing positions to the home country of the banking group and excluding intragroup positions between affiliates—in this case, Unicredit's German branch would be consolidated under Italy. Our results are presented based on banks' nationality (i.e., where the headquarters are based). Both datasets cover a wide set of internationally active banks—not just large global institutions, but all banks with significant cross-border activity as defined by national reporting requirements. Given their respective limitations, we draw on both datasets to maximize coverage. The CBS capture roughly 90–95% of global consolidated claims by internationally active banks, while the LBS represent approximately 95% of global cross-border banking activity, according to BIS estimates.

The countries considered in Figure 2a are: Australia, Belgium, Switzerland, France, Germany, Italy, Japan, Netherlands, Spain, and United Kingdom.

(a) Dollar-denominated assets and liabilities of EU banks ($ trillions)

(b) Purchases of US assets by foreigners (% of GDP)

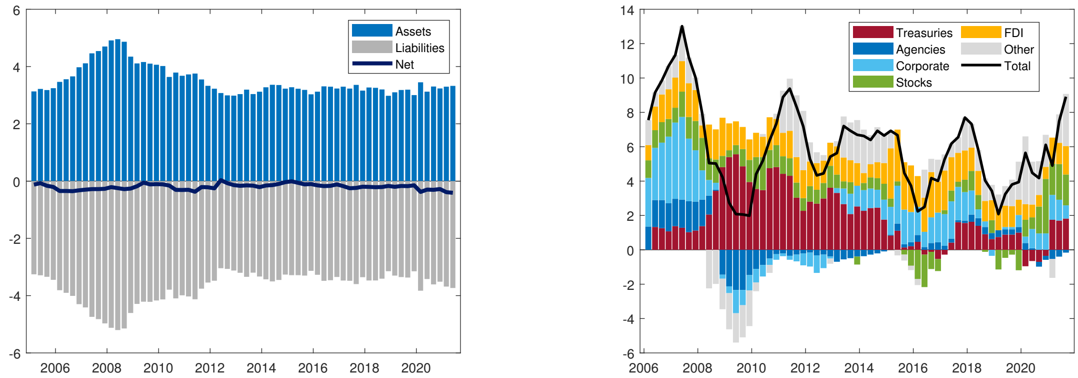


Figure 12: Dollar assets of non-US banks

Note: For Panel (a), estimates are constructed by aggregating the on-balance sheet cross-border and local positions reported by Belgian, Dutch, French, German, Italian and Spanish banks. For Panel (b), it is 4-quarter sums in % of GDP. As of April 2021, more than 90% of the Agency bonds were asset-backed securities. ***Source:*** BIS, US Department of the Treasury.

(a) Dollar assets and liabilities of non-US global banks ($ trillions)

(b) Funding Structure in 2017 (% of total liabilities, by currency)

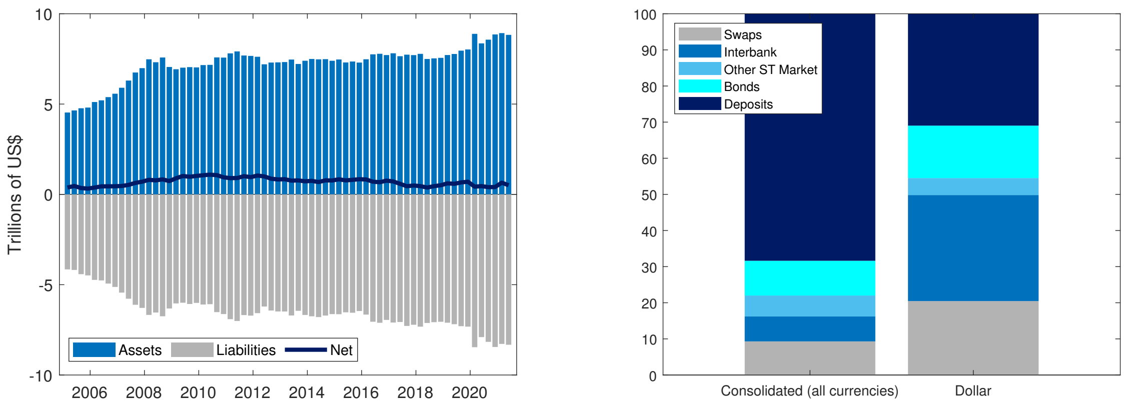
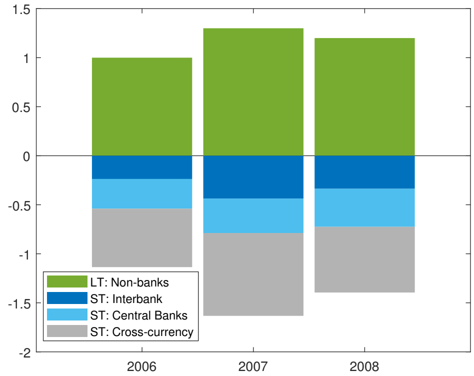


Figure 13: Dollar funding of non-US global banks

Note: Panel (a) considers countries in the G7 group, excluding the US (Canada, France, Germany, Italy, Japan, and the UK). Panel (b) includes all BIS reporting banks, except those from the US. It includes their dollar positions outside the United States plus those in US branches, but excluding US subsidiaries. For more details on the methodology, see Online Annex 1.2 at www.imf.org/en/Publications/GFSRT. ***Source:*** BIS, IMF Global Financial Stability Report (2018).

(a) Net dollar positions of EU banks, by counterparty ($ trillions)



(b) Money Market Funds funding ($ trillions)

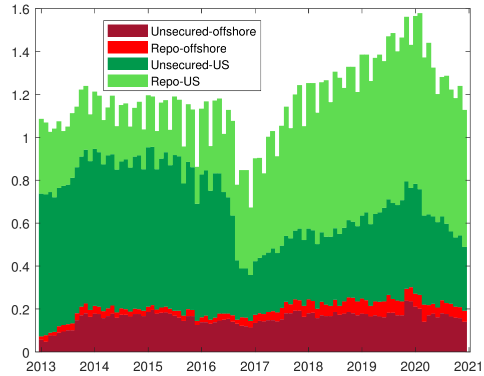


Figure 14: Dollar funding of non-US global banks

Note: In Panel (a), estimates are constructed by aggregating the on-balance sheet cross-border and local positions reported by Belgian, Dutch, French, German, Italian, Spanish, Swiss and UK banks' offices. An important assumption is that the positions with other banks, central banks, and cross-currency funding are mostly short-term. Panel (b) "Unsecured" refers to funding provided by prime funds, "repo" includes government and Treasury funds (which can only do repos), as well as repos by prime funds. For more details, see Aldasoro et al. (2021). ***Source:*** BIS, Aldasoro et al. (2021), McGuire and von Peter (2012).

A2 Households' problem

A2.1 US households' problem

By analogy with the EU case, US households' optimization problem is

$$\max_{C_t^*} \quad U^* = \ln(C_1^*) + \beta \ln(C_2^*) \tag{34}$$

subject to the budget constraint in both periods,

$$p_1^* Y_1^{*T} + Y_1^{*N} + \mathcal{L}^* = p_1^* C_1^{*T} + C_1^{*N} + B^* + \widetilde{B}^* \tag{35}$$

$$p_2^* Y_2^{*T} + Y_2^{*N} + R^* B^* + R^* \widetilde{B}^* = p_2^* C_2^{*T} + C_2^{*N} \ , \tag{36}$$

where starred variables denote US quantities and prices. R^* is the interest rate paid by the dollar-denominated bond, which can be traded with banks (B^*) or directly with EU households ($\widetilde{B}^*$). Y_t^{*T} and Y_t^{*N} are the endowments of tradable and non-tradable goods. Their first-order conditions follow the same intuition as their EU counterpart, and are given by

$$p_1^* C_1^{*T} = \frac{1}{\beta^* R^*} p_2^* C_2^{*T} \tag{37}$$

$$p_t^* = \frac{C_t^{*N}}{C_t^{*T}} \frac{\omega^*}{1-\omega^*} \ . \tag{38}$$

A2.2 Dollar bonds and non-pecuniary costs

To rationalize the households' preference for trading bonds with banks rather than engaging in cross-border trading themselves, I introduce a non-pecuniary cost that EU households face from holding/trading assets in foreign currency. This tries to capture, in a very reduced-form, additional costs in transactions when holding foreign currencies, in line with Schmitt-Grohé and Uribe (2001) and Gopinath and Stein (2018). Similarly to Kekre and Lenel (2024), my model features money-in-utility with foreign currency, by assuming that the non-pecuniary cost affects the utility of EU households directly. As mentioned in the main document, this could also be interpreted as households lacking the expertise and financial sophistication of global banks, which creates frictions in international financial access, as discussed in Brunnermeier and Sannikov (2014).

Given the non-pecuniary cost, EU households' problem is:

$$\max_{C_t} \quad U = \ln(C_1) + \beta \mathbb{E} \ln(C_2) - \zeta(\widetilde{B}) \tag{39}$$

subject to the budget constraint in both periods,

$$p_1 Y_1^T + Y_1^N = p_1 C_1^T + C_1^N + B + e_1 \widetilde{B} \tag{40}$$

$$\Pi + RB + e_2 R^* \widetilde{B} + p_2 Y_2^T + Y_2^N = p_2 C_2^T + C_2^N \ . \tag{41}$$

This problem shows that now they have access to euro bonds with banks B paying R, and to dollar bonds with US households, $\widetilde{B}$ paying R^*. Moreover, holding balances in foreign currency entails a small non-pecuniary cost:

$$\zeta(\widetilde{B}) = \begin{cases} \chi & \text{if } \widetilde{B} \neq 0 \\ 0 & \text{otherwise} \end{cases} , \qquad \chi > 0$$

Given that the UIP condition holds, euro and dollar bonds are perfect substitutes, and $\chi > 0$, households will always prefer $B \neq 0$ over $\widetilde{B} \neq 0$ when banks are fully operational.

A3 Nominal version

The EU consumption basket now includes real money balances, M/P_t

$$C_t \equiv \left[(C_t^N)^{\theta}(C_t^T)^{\phi}(M_t/P_t)^{\omega}\right]$$

where M_t is the amount of money held by the HH, and P_t is the nominal price level. The budget constraint of EU households is

$$\sum_{t=1}^{2} R^{-t}(p_t^N Y_t^N + p_t^T Y_t^T + M_t^S) = \sum_{t=1}^{2} R^{-t}(p_t^N C_t^N + p_t^T C_t^T + M_t)$$

where M_t^S is the seigniorage rebated lump sum by the government, which is equal to M_t in equilibrium. The problem that US households face is equivalent. In order to focus on the effects of US monetary policy effects on the probability of a crisis, let us consider the first order conditions for US households. First, static optimization yields

$$\frac{M_t^*}{\omega} \equiv m_t^* = p_t^{*N} C_t^{*N} \frac{1}{\theta} = p_t^{*T} C_t^{*T} \frac{1}{\phi}$$

From the Euler equation, it is possible to see that the interest rate R_t^* now depends on current and future money supply,

$$E(m_{t+1}^*) = m_t^* \beta^* R_t^*$$

Therefore, a US monetary policy tightening in t pushes the the global economy closer to the bad equilibrium, by affecting $\bar{e}$:

$$\bar{e} \equiv \frac{A/R}{(1+\gamma)L^* - A^*/R^*} = \frac{A \cdot \beta m_t / m_{t+1}}{(1+\gamma)L^* - A^* \cdot \beta^* m_t^* / m_{t+1}^*} \ . \tag{42}$$

From (42) it is possible to see that $\downarrow m_t^* \to \uparrow R^* \to \downarrow \bar{e}$.

A4 Tradable goods

Throughout the main body of the paper, most of the analysis is centered around non-tradable goods. This is because the value of non-tradable goods can be interpreted as the *currency*, in a real model without a nominal side to it. However, for robustness, I will show that the main results of the paper still follow if we shift the focus to tradable goods. In particular, I will revisit two important elements of the model: i) Banks' balance sheets, and ii) central banks' intervention.

A4.1 Banks' balance sheet

Consider that banks hold pre-existing long-term assets denominated in tradable goods. Compared to the baseline model, we can assume that $A = a + p_2 T$, where A is now split in one part that remains as non-tradables (a), and another denominated in tradable goods (T). Profits are then

$$\Pi = e_2 A^* + a + p_2 T - e_2 R^* B^* - RB \tag{43}$$

From the market clearing of tradable goods, we get

$$p_2 = \frac{1}{Y_2^T + T + Y_2^{*T}}(C_2^N + e_2 C_2^{*N})\frac{\omega}{1-\omega}$$

Using UIP, we can rewrite condition (10), so that the necessary condition for banks to operate becomes:

$$e_1 \frac{1}{R^*} \underbrace{\left[A^* + \frac{T(A^* + Y_2^{*N})}{(Y_2^T + T + Y_2^{*T})}\frac{\omega}{1-\omega}\right]}_{W^*} + \frac{1}{R}\underbrace{\left[a + \frac{T(A + Y_2^N)}{(Y_2^T + T + Y_2^{*T})}\frac{\omega}{1-\omega}\right]}_{W} > (1+\gamma)e_1 L^* \tag{44}$$

Then, the exchange rate that makes (44) hold with equality, is

$$\overline{e}' = \frac{W/R}{(1+\gamma)L^* - W^*/R^*}$$

Even though $W^* > A^*$, we can still find pre-existing positions that open the door to multiple equilibria, as long as global banks are profitable ($W^*/R^* - L^* > 0$) but illiquid ($W^*/R^* - (1+\gamma)L^* < 0$) in dollars. In other words, despite having assets denominated in tradable goods (but lower EU non-tradable goods), banks might still be exposed to dollar shortages.

A4.2 Lender of Last Resort with tradable goods

Consider an intervention by the ECB taxing tradable endowment, instead of non-tradable, as it is stated in the main body of the paper. Denote the tax rate imposed as τ^T. Then, the intervention will be successful if,

$$\tau^T p_1 Y_1^T > e_1^B L^* \tag{45}$$

From the market clearing conditions, we know that

$$p_1 Y_1^T = \tfrac{\omega}{1-\omega}\eta_1(Y_1^N + Y_1^{*N} e_1)$$

Incorporating the previous equation into condition (45), we can rewrite it as

$$\frac{\tau^T Y_1^N \eta_1 \frac{\omega}{1-\omega}}{L^* - \tau^T \eta_1 \frac{\omega}{1-\omega} Y_1^{*N}} > e_1^B \ ,$$

Whereas from the standard intervention, the condition is

$$\frac{\tau Y_1^N}{L^*} > e_1^B \ .$$

Assume that $\tau = \tau^T$. If the endowment of tradables in the EU is low (η_1) or households value non-tradable goods a lot (low ω), transferring tradables goods might actually be less efficient. This goes to show that, even if the central bank was not restricted to transfer only non-tradable goods to global banks, it does not necessarily mean that its capacity to eliminate the "bad" equilibrium will improve.

A5 CES utility function

In order to allow for a higher response of the exchange rate to changes in the fundamentals, I will relax the assumption that households have log preferences. In particular, I assume CES utility functions, as follows

$$U(C_t) = \frac{C_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}$$
$$\text{where } C_t \equiv \left[\omega C_{T,t}^{1-1/\rho} + (1-\omega) C_{N,t}^{1-1/\rho}\right]^{\frac{\rho}{\rho-1}}$$

where ρ is the elasticity of substitution between tradable and non-tradable goods, and σ is the intertemporal elasticity of substitution.

The first order conditions to this problem are

$$\frac{1}{P_{T,t}} = \frac{1-\omega}{\omega}\left(\frac{C_{T,t}}{C_{N,t}}\right)^{1/\rho} \tag{46}$$

$$U'_N(C_t) = \beta R E\{U'_N(C_{t+1})\} \tag{47}$$
$$\text{where } U'_N \equiv C_t^{\frac{\rho-1}{\rho}-\frac{1}{\sigma}}(1-\omega) C_{N,t}^{-\frac{1}{\rho}}$$

Now the exchange rate might be more sensitive to changes in the fundamentals of the economy, which might be relevant to analyze the potential welfare implications of the model. Just as an example, I compute e_1^G under different values of σ and ρ. In particular, I consider $\sigma \in \{0.5, 1\}$ and $\rho \in \{0.5, 1, 2\}$. The results are shown in Table 3:

The logaritmic preferences used in the main body of the paper are equivalent to the

Table 3: Values of e_1^G

	$\rho = 0.5$	$\rho = 1$	$\rho = 2$
$\sigma = 0.5$	0.984	0.979	0.979
$\sigma = 1$	1.00	0.994	0.990

Note: Contains values of the exchange rate in period 1 in the "good" equilibrium. The calibration of the rest of the parameters comes from Section 4.

case with $\rho = 1$ and $\sigma = 1$. In general, we see that the higher the elasticity of substitution between goods (ρ) or the lower the intertemporal elasticity of substitution (σ), the more appreciated is the exchange rate in equilibrium.

A6 Three-period model

Time is discrete and there are three periods, $t \in \{0, 1, 2\}$, and two economies, the United States (US) and the Euro area (EU). Each economy is populated by a continuum of households that consume tradable and non-tradable goods. Capital flows across countries are intermediated by a continuum of global banks owned by EU households. In $t = 0$, banks invest in productive long-term projects in the EU and the US, financed by short-term deposits from households in both regions.

To benefit from the outcome of these projects, global banks need to roll-over their short-term liabilities in $t = 1$. If they are unable to do so due to financial frictions, they are liquidated, their investment and profits are lost, banks' debtors are not repaid, and the world faces a global financial crisis. I denote $\rho \in [0, 1]$ as the probability of a global financial crisis in period 1, which each individual agent takes as given, even though it will be determined by their aggregate decisions.

A6.1 Households

In this extended version, the households' optimization problem becomes

$$\max_{C_t} \quad U = \sum_{t=0}^{2} \beta^t \ln(C_t) \tag{48}$$

subject to the budget constraint in each period,

$$
\begin{aligned}
Y_0^N + p_0 Y_0^T &= p_0 C_0^T + C_0^N + B_1 \\
Y_1^N + p_1 Y_1^T + \mathcal{R}_0 B_1 &= C_1^N + p_1 C_1^T + B_2 \\
\Pi + Y_2^N + p_2 Y_2^T + R_1 B_2 &= C_2^N + p_2 C_2^T \ ,
\end{aligned}
$$

where Y_t^T and Y_t^N are the households' endowments of the tradable and non-tradable goods, respectively. Π represents the profits that banks transfer to EU households in $t = 2$. The interest rate $\mathcal{R}_0$ on bonds B_1 can take two values depending on the state of the economy, such that

$$
\mathcal{R}_0 = \begin{cases} R_0 & \text{with prob. } 1-\rho \\ 0 & \text{with prob. } \rho \end{cases} .
$$

If a financial crisis hits, banks collapse and fail to repay depositors —consequently, the interest rate that households demand increases with ρ.

Their first-order conditions can be written as

$$
p_t C_t^T = \mathbb{E}\left[\frac{p_{t+1} C_{t+1}^T}{\beta \mathcal{R}_t}\right] \tag{49}
$$

$$
p_t = \frac{C_t^N}{C_t^T} \frac{\omega}{1-\omega} \ . \tag{50}
$$

US households face an analogous optimization problem. Their first-order conditions follow the same intuition as their EU counterpart and are given by

$$
p_t^* C_t^{*T} = \mathbb{E}\left[\frac{p_{t+1}^* C_{t+1}^{*T}}{\beta \mathcal{R}_t^*}\right] \tag{51}
$$

$$
p_t^* = \frac{C_t^{*N}}{C_t^{*T}} \frac{\omega^*}{1-\omega^*} \ . \tag{52}
$$

A6.2 Global Banks

In period 0, banks decide how much to invest in EU (K) and in US (K^*) assets, and how to finance these investments, between euro (B_1) and dollar (B_1^*) bonds. Banks have access to a technology that transforms one unit of EU and US non-tradable goods in period 0 into r and r^* units in $t = 2$, respectively.

In period 1, in order to operate and avoid a costly liquidation, banks are required to "roll-over" their short-term debt with new bonds (B_2 and B_2^*). However, they might fail to do so because of an agency friction that limits their ability to raise funds; after taking positions in $t = 1$, banks can divert a fraction of the funds they intermediate. If they divert those funds, banks are unwound, and the households that had lent to them recover a portion $(1-\gamma) \geq 0$ of their credit position $e_1 B_2^* + B_2$. This gives rise to an incentive compatibility (IC) constraint that must hold for banks to operate. If the IC is violated, banks do not receive the funding they need and are liquidated. For simplicity, I assume that the liquidation value of their assets K and K^* is 0, and that the outstanding liabilities $B_1 + e_1 B_1^*$ are not repaid. Consequently, their profits become null, $\Pi = 0$.

Banks are exposed to global financial crises. Their problem consists then of maximizing their expected discounted profits given ρ,

$$\begin{aligned} \text{Max} \quad & \mathbb{E}_0\left(\frac{1}{\mathcal{R}_0\mathcal{R}_1}\Pi\right) = (1-\rho)\frac{1}{R_0 R_1}\Pi^G \\ \text{where} \quad & \Pi^G = e_2 r^* K^* + rK - e_2 R_1^* B_2^* - R_1 B_2 \end{aligned} \tag{53}$$

subject to the following constraints,

$$\begin{aligned} &\text{Initial investment} && e_0 K^* + K = e_0 B_1^* + B_1 && (54)\\ &\text{Roll-over needs} && e_1 B_2^* + B_2 \geq \mathbb{E}_0(e_1 \mathcal{R}_0^* B_1^* + \mathcal{R}_0 B_1) && (55)\\ &\text{IC constraints} && \mathbb{E}_0(\tfrac{1}{\mathcal{R}_0\mathcal{R}_1}\Pi) \geq \gamma(e_0 B_1^* + B_1) \qquad \text{in } t=0 && (56)\\ & && \mathbb{E}_0(\tfrac{1}{\mathcal{R}_1}\Pi) \geq \gamma\mathbb{E}_0(e_1 B_2^* + B_2) \qquad \text{in } t=1 && (57) \end{aligned}$$

where I have ignored profits when banks shut down since they are 0. I will assume that the IC constraint in $t = 0$ binds so that banks' investment is limited[36]. The first-order conditions for this problem are intuitive,

$$\frac{\mathbb{E}(e_{t+1})}{e_t} = \frac{R_t}{R_t^*} \tag{58}$$

$$\frac{\mathbb{E}(e_2)}{e_0} = \frac{r}{r^*} \tag{59}$$

suggesting that UIP holds in every period as long as banks operate, and that the optimal choice of K and K^* requires that their returns are equalized, adjusting for the long-term exchange rate depreciation.

Aggregate imbalances

Banks are homogeneous, so aggregate variables correspond to their individual choices[37]. The exchange rate plays a key role in determining the ex-post soundness of the global banking system. Even if the IC constraint in (56) binds in period 0, banks might go bust in period 1 if condition (57) is violated. In case it is satisfied, banks are able to

[36] However, the IC in $t = 1$ can still be violated, as will be discussed in the next section.

[37] I focus on runs on the entire banking system, rather than idiosyncratic runs on individual banks.

roll-over their debt and (55) implies that $e_1 B_2^* + B_2 \geq e_1 R_0^* B_1^* + R_0 B_1$. In addition, UIP conditions hold such that $e_{t+1}/e_t = R_t/R_t^*$. Combining the previous expressions, (57) can be rewritten as

$$e_1 < \frac{rK/R_1 - R_0 B_1(1+\gamma)}{(1+\gamma)R_0^* B_1^* - r^* K^*/R_1^*} \equiv \bar{e} \ ,$$

where $\bar{e}$ can be interpreted as the maximum exchange rate that the banking system can tolerate before collapsing. Since banks' portfolios and interest rates are determined in $t = 0$, the previous condition depends only on e_1. A dollar appreciation in $t = 1$ tightens the financial constraint if $r^* K^*/R_1^* < (1+\gamma)R_0^* B_1^*$, which can be interpreted as banks' facing dollar liquidity shortages. In other words, long-term discounted dollar income is not enough to cover their short-term dollar needs, $(1+\gamma)R_0^* B_1^*$. I am interested in the case where conditions are such that $r^* K^*/R_1^* > R_0^* B_1^*$, meaning that a crisis might occur from liquidity problems, even when banks are solvent in dollars. This comes from the fact that short-term dollar needs are exacerbated by the risk of fund diversion, captured by γ.

A6.3 Market Clearing

Market clearing conditions for the EU non-tradable good are

$$Y_0^N = C_0^N + K \tag{60}$$

$$Y_1^N = C_1^N \tag{61}$$

$$Y_2^N + rK = C_2^N \ , \tag{62}$$

and analogous for the US economy. The first equation show that the endowment of non-tradables in each economy is divided between consumption and investment. The last equation indicates that the outcome of the long-term assets can increase the non-tradable output in both countries in $t = 2$, and thus could be interpreted as the result of a productive set of projects. The market clearing conditions for the tradable good are as follows:

$$Y_t^T + Y_t^{*T} = C_t^T + C_t^{*T} \ . \tag{63}$$

Definition 3 (Competitive Equilibrium)**.** *A competitive equilibrium is a path of real allocations* $\{C_t^T, C_t^N, C_t^{*T}, C_t^{*N}\}_t$ *and* $\{B_t, B_t^*\}_t$*, interest rates* $\{R_t, R_t^*\}_t$ *and exchange rate* $\{e_t\}_t$*, satisfying households' optimality conditions in* (49)–(52)*, the banks' optimality conditions in* (53)–(59)*, and the market clearing conditions in* (62) *and* (63) *-plus their counterparts for the US economy-, given a path of endowments* $\{Y_t^T, Y_t^N, Y_t^{*T}, Y_t^{*N}\}_t$.

A6.4 Optimal allocation and multiple equilibria

Since the focus of the paper is on the ex-ante implications of the intervention, I am interested in the equilibrium conditions in period $t = 0$ and how they might open the door to multiple equilibria. In the first part of the analysis I discuss briefly what are the potential equilibria that can arise in $t = 1$. Next, I turn to the previous period, with a focus on the exchange rate and the portfolio allocation of global banks.

Sunspot. To resolve the indeterminacy when dealing with multiple equilibria, I introduce an exogenous random variable S that takes on the values 1 with probability π or 0 with probability $1 - \pi$, where $\pi \in (0, 1)$. At the beginning of $t = 1$ if $S = 1$, then agents feel pessimistic, and if $S = 0$, then agents have an optimistic outlook. The variable S is known as a sunspot because its sole role is to coordinate agents' expectations. In $t = 0$ agents choose their portfolios, which might leave global banks exposed to fluctuations in the exchange rate, even without significant currency mismatches. If these imbalances are such that multiple equilibria are possible, the realization of S defines the equilibrium in $t = 1$.

Equilibria in $t = 1$

Consider a set of asset positions $\{K, K^*, B_1, B_1^*\}$. Under certain conditions that will be discussed later, global banks will be exposed to self-fulfilling expectations about the exchange rate, and two different equilibria[38] might arise in period 1.

Good equilibrium. In one equilibrium, households are optimistic and provide the funds that global banks need at the beginning of period 1 to operate. This is consistent with the IC constraint in $t = 1$, meaning that $E_{1^-}(e_1) < \bar{e}$. In this scenario, banks are able to roll-over their initial liabilities, and no collapse occurs. I refer to this as the "good" equilibrium, with an exchange rate of e_1^G.

Bad equilibrium. Another equilibrium features pessimistic households that do not provide the funds that banks need. This is the case if they expect a relatively strong dollar, $E_{1^-}(e_1) > \bar{e}$ that would increase the incentives of banks to divert their funds. Banks collapse, their investment in US and EU assets is lost, and their profits Π become null. I refer to this as the "bad" equilibrium, with an exchange rate of e_1^B.

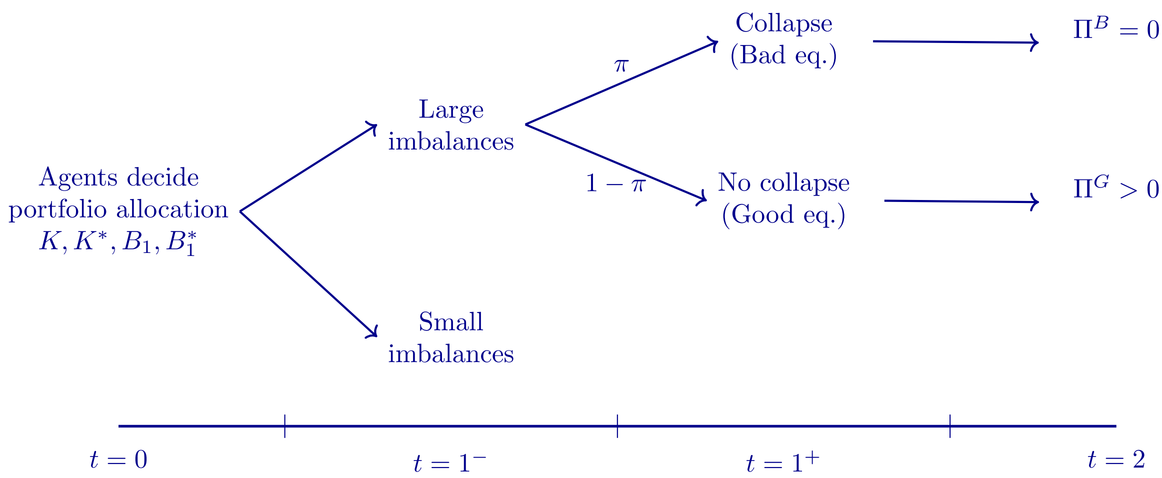
Figure 15 gives an overview of the timeline and the main events in the model.

The interesting case that I study is when fundamentals are such that $e_1^B > \bar{e} > e_1^G$, i.e. when both equilibria are possible. Since there is no uncertainty other than the realization of S and agents are rational and have perfect foresight conditional on the sunspot variable, it must be that $E_{1^-}(e_1 \mid S = 1) = e_1^B$ and $E_{1^-}(e_1 \mid S = 0) = e_1^G$.

To facilitate the exposition and focus on how the portfolio allocation depends on the

[38] These are equivalent to the two equilibria that arise in the 2-period version of the model.

Figure 15: Timing of the model



Note: When imbalances are small, global banks can tolerate sharp appreciations of the dollar and still manage to cover their short-term liquidity needs. I will not study this case.

exchange rate and the risk of a financial crisis, I will assume for now that both economies are symmetric in preferences, endowments, and asset returns. This implies that $\omega = \omega^*$, $\beta = \beta^*$, $r = r^*$, and $Y_t^T = Y_t^{*T}$ and $Y_t^N = Y_t^{*N}$ for all t. I also set $\beta = \beta^* = 1$.

A6.5 Determination of the imbalances

I now study the optimal portfolio allocation of banks in $t = 0$, and how it might open the door to multiple equilibria in the next period. From the banks' optimality conditions in (53)-(57), investment is constrained and capital is allocated according to

$$K = K^* = \frac{\dfrac{(1-\rho)^2}{1-\rho+\gamma} Y_0^N - \dfrac{1}{r} Y_2^N}{1 + \dfrac{(1-\rho)^2}{1-\rho+\gamma}} \,. \tag{64}$$

Importantly, K and K^* are affected by ρ in two ways. First, an increase in ρ increases the cost of funding, as households require higher interest rates to compensate for the additional risk. On the other hand, banks' expected profits drop, since the chances of a collapse -and thus obtaining no profits- are more likely. Overall, these two forces tighten the financial constraint and reduce the amount of investment that banks can carry out.

Now, how does ρ affect the exchange rate in equilibrium? The market clearing conditions in (62) and (63), and households' intertemporal budget constraints imply

$$e_0 = \left(1 + \frac{1}{3/2-\rho} \cdot \frac{\theta}{1-\theta} \cdot \frac{\gamma}{1-\rho} \cdot \frac{K}{Y_0^N - K}\right)^{-1} , \tag{65}$$

where $\frac{K}{Y_0^N-K} = (r\frac{(1-\rho)^2}{1-\rho+\gamma}Y_0^N - Y_2^N)/(rY_0^N + Y_2^N)$. Although the relation between e_0 and ρ is highly non-linear, the simple numerical exploration provided in Figure 16 shows that for low values of ρ, the dollar appreciates when the probability of a crisis increases ($\partial e_0/\partial\rho > 0$). Intuitively, if a bank run is more likely, then the expected profits of banks drop. This generates a negative wealth effect on EU households in the future, depressing their aggregate demand and forcing a depreciation of the euro.

Regarding the sources of funding, it is intuitive to think that higher risk results in overall lower borrowing capacity for banks. However, the optimal funding mix between B_1 and B_1^* depends on K, K^*, and e_0,

$$B_1 = K - \tfrac{1-\theta}{\theta}\tfrac{1}{2}(Y_0^N - K)\Big(1 - e_0\Big) \tag{66}$$

$$B_1^* = K^* - \tfrac{1-\theta}{\theta}\tfrac{1}{2}(Y_0^{*N} - K^*)\left(1 - \frac{1}{e_0}\right) . \tag{67}$$

Since $Y_0^N - K = Y_0^{*N} - K^* \geq 0$, a dollar appreciation ($\uparrow e_0$) increases B_1 and reduces B_1^*, holding investment constant. This is in line with banks funding their activities in the more affordable currency. Moreover, under reasonable conditions[39], a rise in K and K^* leads to an increase in B_1 and B_1^*, respectively, highlighting the desire of banks for minimal currency mismatches. It is straightforward to conclude that dollar funding from global banks decreases as ρ rises ($\partial B_1^*/\partial\rho < 0$), given its impact on K^* and on e_0. On the other hand, two competing forces determine the impact on B_1:

$$\frac{\partial B_1}{\partial \rho} = \underbrace{\frac{\partial K}{\partial \rho}}_{<0} \cdot \underbrace{\left(1 + \frac{1-\theta}{2\theta}(1-e_0)\right)}_{>0} + \underbrace{\frac{\partial e_0}{\partial \rho}}_{>0} \cdot \frac{1-\theta}{2\theta} \underbrace{(Y_0^N - K)}_{>0}$$

For relatively low values of ρ, equations (64) and (65) suggest that K is high and e_0 is low, strengthening the impact of $\partial K/\partial\rho$ compared to $\partial e_0/\partial\rho$, and resulting in $\partial B_1/\partial\rho < 0$, as shown in Figure 16.

Lastly, equations (64) to (67) pin down the optimal portfolio allocation $\{K, K^*, B_1, B_1^*\}$. Combining it with (57) yields the maximum exchange rate that banks can tolerate before shutting down,

$$\bar{e} \equiv \frac{rK/R_1 - R_0 B_1(1+\gamma)}{(1+\gamma)R_0^* B_1^* - r^* K^*/R_1^*} = f(\rho) . \tag{68}$$

[39]This is true as long as $1 > \frac{\omega}{1-\omega}\frac{1}{2}(1/e_0 - 1)$ and $1 > \frac{\omega}{1-\omega}\frac{1}{2}(e_0 - 1)$.

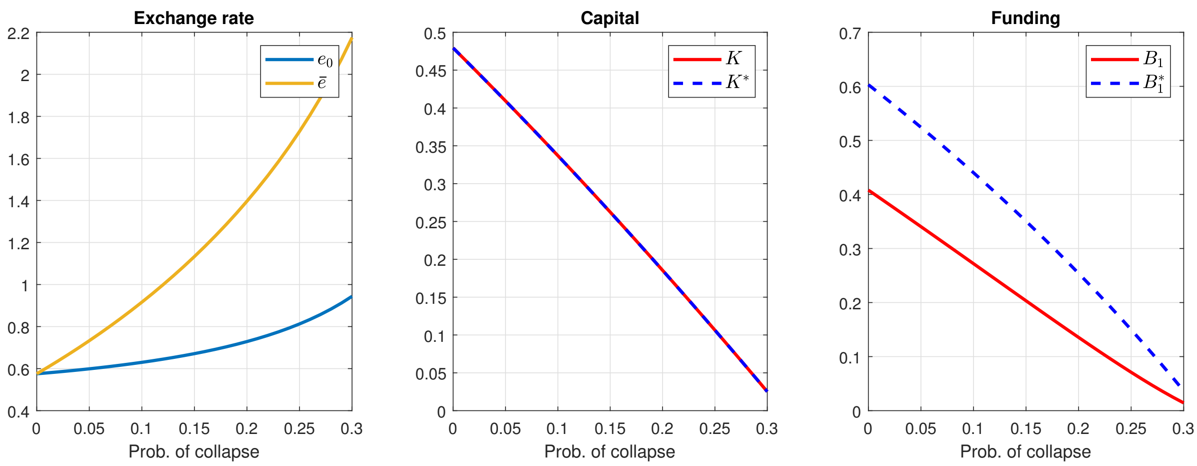


Figure 16: Impact of ρ on key variables

Note: For this illustrative example the parameters used were $r^*r = 1.25$, $\beta^* = \beta = 0.9$, $Y_0^N = Y_0^{*N} = 3.5$, $Y_1^N = Y_1^{*N} = 2.62$, $Y_2^N = Y_2^{*N} = 1.2$, $\omega = \omega^* = 0.1$, $\gamma = 0.7$, $Y_t^T = Y^{*T} = 1.5$.

The relation between $\bar{e}$ and ρ is highly non-linear. The key insight here is that all sources of funding and investments will decrease with ρ, as more constrained banks are forced to shrink their balance sheets. However, the impact on B_1^* is larger than on B_1 due to fluctuations in the exchange rate, leading to $\partial\bar{e}/\partial\rho > 0$ as in Figure 16. In other words, higher risk increases banks' resilience to a dollar appreciation, as their imbalances are more limited.

Regarding the two potential equilibrium exchange rates in period 1, recall that UIP holds when banks operate, meaning that $e_1^G = e_0 R_0/R_0^*$. As for e_1^B, when banks collapse the economy reverts to autarky, and therefore the exchange rate is determined entirely by countries' relative endowments. Therefore,

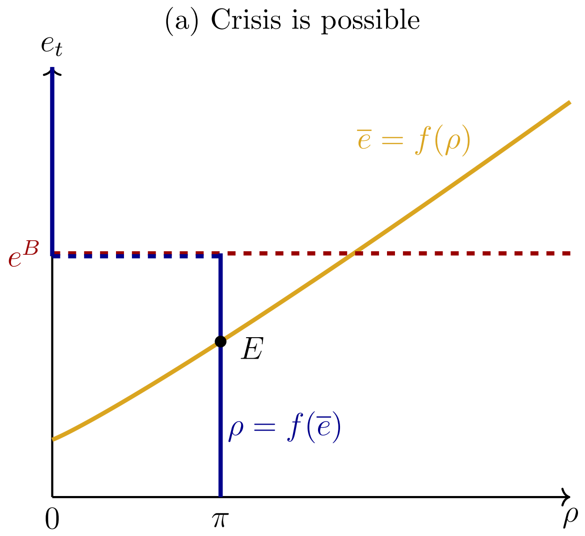
$$e_1^G = e_0 \frac{R_0}{R_0^*} = e_0 < 1 \tag{69}$$

$$e_1^B = \frac{Y_1^{*T}}{Y_1^T} = 1 \ , \tag{70}$$

where I have used the fact that $R_0 = R_0^*$ and $Y_t^{*T} = Y_t^T$ in this simplified scenario.

A6.6 Probability of a crisis, ρ

The probability of a financial crisis depends on the fundamentals of the economy, the banking sector's positions, and households' expectations, but it can be characterized in terms of e_1. I focus first on two extreme cases. First, $\rho = 0$ if banks' portfolio allocation is such that $e_1^B < \bar{e}$, meaning that banks are resilient and can tolerate even a sharp dollar



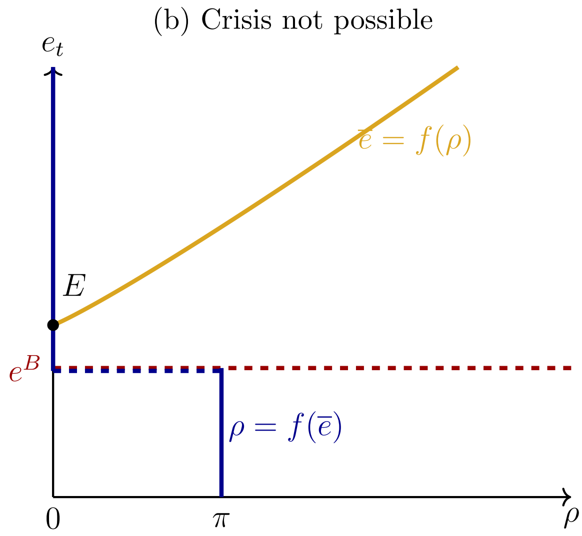


Figure 17: Probability of a financial crisis and exchange rates

Note: The case of $\rho = 1$ is not depicted, as it would imply that banks do not borrow or invest at all in period 0.

appreciation. On the other hand, a crisis is inevitable if imbalances are significantly large, such that $\overline{e} < e_1^G$. In this case, banks are too vulnerable to exchange rate fluctuations.

The third and most interesting case arises when banks' positions in $t = 0$ are such that multiple equilibria are possible ($e_1^G \leq \overline{e} \leq e_1^B$). In that case, the equilibrium in the last two periods will depend on the realization of the sunspot variable S, which coordinates agents' expectations. The probability of a financial crisis is given by

$$\rho = \begin{cases} 0 & \text{if } e_1^B < \overline{e} \\ \pi & \text{if } e_1^G \leq \overline{e} \leq e_1^B \\ 1 & \text{if } \overline{e} < e_1^G \end{cases} \tag{71}$$

where π is the probability of $S = 1$ (i.e. agents bearing pessimistic expectations).

A6.7 Multiple equilibria

The equilibrium of the model can be characterized by solving the system of two equations given by (68) and (71), after incorporating (64)-(67). Agents are rational, so for a certain pair $(\rho, \overline{e})$ to be an equilibrium, it must be that $E_0(\rho) = \rho$ and $E_0(e_1) = \rho e_1^B + (1-\rho)e_1^G$.

I want to clarify the intuition behind these results. If we start from a point where $E_0(\rho) = 0$, banks face very little financial restrictions, and is then individually optimal for them to take more debt and invest more. If the exchange rate is low enough, debt denominated in dollars is relatively cheap and banks rely more on it, leaving them exposed to exchange rate fluctuations in $t = 1$, such that $e_1^G \geq \bar{e}$. Nevertheless, equation (71) shows that in that case, $\rho > 0$, and therefore $E_0(\rho) \neq \rho$.

If on the contrary, we start from a point where $E_0(\rho) \sim 1$ and thus a financial crisis is almost certain, banks face tight restrictions, limit their investments, and their profits are affected. Since EU households receive lower bank profits, their aggregate demand contracts and their currency depreciates. In the context of a stronger dollar, banks move away from dollar funding, making their exposure to exchange rate fluctuations low. In the model, this means that $\bar{e}$ is high, potentially to a point where $e_1^B < \bar{e}$. Equation (71) shows that $\rho = 0$ in that case, reflecting the fact that the exchange rate that forces banks to shut down is so high, that a collapse becomes impossible. Since $E_0(\rho) \sim 1 \neq \rho$, then this cannot be an equilibrium.

Figure 17 provides a graphical representation of these dynamics. In panel (a), even if global banks anticipate the possibility of a financial crisis, this might not be enough to prevent multiple equilibria from arising. This result is dependent on the fundamentals of the world economy. Panel (b), for example, depicts a case where $\bar{e} = f(0) > e_1^B$ and therefore no financial crisis can occur in equilibrium. We can conclude that multiple equilibria are possible in $t = 1$ if $\exists\, \pi \in (0, 1)$ such that $e_1^B > \bar{e} = f(\pi) \geq e_1^G = g(\pi)$, and $E_0(\rho) = \pi$, where π is the probability of $S = 1$ (pessimistic agents). In that case, one equilibrium features global banks operating, while in the other they cannot roll over their debt and go bust.

A corollary of this result is that agents are atomistic and consequently overlook the impact of their actions on the aggregate outcome. For instance, global banks take the probability of a financial crisis as given, even though their imbalances are what create the conditions for the "bad" equilibrium to materialize.