The United States as the International Lender of Last Resort

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Abstract

This paper provides a stylized framework to study the role of the United States as the International Lender of Last Resort to global banks. The model captures a central feature of the international financial system, namely, non-US global banks that invest heavily in US assets but are exposed to dollar liquidity shortages. This situation can give rise to multiple equilibria, one of which resembles a global financial crisis, with a sharp appreciation of the dollar, tighter financial conditions in international markets, weaker global economic activity, and struggling banks. The self-fulfilling nature of the crisis stems from a feedback loop between the exchange rate and the capacity of non-US banks to raise funds. Since the liquidity needs of these banks are often denominated in dollars, the Federal Reserve is better equipped than other central banks to prevent the "bad" equilibrium when the dollar is strong. However, its incentives to intervene -through swap lines- may not be aligned with the rest of the world because of general equilibrium forces that drive larger and cheaper capital flows into the US during times of global financial stress.

Keywords: Exchange Rate, Swap Lines, Global Banks, Financial Crisis
JEL Codes: F33, F41, E44

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1. Introduction

In banking, a common practice is to finance long-term assets with short-term liabilities, which can expose banks to liquidity shortages. To prevent the amplification of this risk throughout the economy, a classic solution is to have a lender of last resort -typically the domestic central bank- that provides the liquidity needed in times of stress (Bagehot, 1873). Recent decades, however, have been marked by the rise of large global banks that operate in multiple regions and engage in maturity transformation on a global scale. Importantly, most of their cross-border transactions are denominated in dollars, even though many of these banks are non-US intermediaries. This situation poses difficulties for domestic lenders of last resort in covering the short-term needs of these banks, especially during a global crisis, when liquidity is scarce and the dollar appreciates sharply.

To address this challenge, the United States has adopted the role of the "international lender of last resort". Since the 2008 global financial crisis (GFC), the Federal Reserve (Fed) has provided dollar liquidity to several major central banks via bilateral swap lines[1]. Even though this intervention has now become a pillar of the international financial architecture (Bahaj and Reis, 2022*b*) and a key policy instrument during systemic financial stress episodes[2], there are still many open questions around it. First, what are the macroeconomic implications of the swap lines? Second, what are the differences between an international and a domestic lender of last resort during a global crisis? Lastly, are the incentives of the US to intervene always aligned with those of the rest of the world?

This paper presents a framework that rationalizes the role of the US as the international lender of last resort and its macroeconomic implications. First, I argue that a world with non-US global banks that borrow and invest in dollars is prone to self-fulfilling crises due to a two-way interaction between the exchange rate and the financial constraints of these banks. Furthermore, in the midst of a global crisis, non-US global banks struggle to raise funds and the dollar appreciates, making it difficult for domestic central banks to cover their liquidity needs. In contrast, the Fed could provide the necessary dollar liquidity, but it may not fully internalize the benefits of such intervention for the world, since the US enjoys higher and cheaper capital inflows during periods of global financial stress.

To formalize this insight, I develop a stylized model of the world economy that captures important features of the financial system. I combine elements from the traditional self-

[1]In short, a swap line is an agreement between two central banks to exchange currencies at a specific exchange rate, and for a short period of time. Section 2 provides more details about this instrument.

[2]For example, the European sovereign debt crisis, Covid-19 pandemic, and the Silicon Valley Bank collapse.

fulfilling crises[3] literature with a modern perspective that places non-US global banks at the centre of the international financial intermediation. This allows me to explore two understudied dimensions of the global financial system: the exposure of advanced economies to dollar fluctuations, and the subsequent international spillovers from this exposure to other advanced economies. Both are key to understand the role of the Fed in providing dollar liquidity to the world. In addition, my framework highlights the importance of general equilibrium forces in explaining the heterogeneous impact of global crises on different economies.

This paper contributes, from a theoretical perspective, to our understanding of the macroeconomic implications and incentives behind the swap lines, which have been primarily studied from a micro-level empirical approach. Moreover, it also offers a theory to explain the appreciation of the dollar during global crises. This is a relevant feature of the financial system that is often omitted or introduced exogenously in more traditional models within the literature.

I consider a world composed by two economies, the United States (US) and the Euro area (EU), each populated by a continuum of households. There are two periods. In the baseline model, both US and EU households invest with global banks through bonds denominated in their own domestic currency, following the empirical evidence on segmented financial markets from recent studies such as Maggiori et al. (2020). Since the focus of the paper is on the dollar imbalances of non-US intermediaries, I consider global banks that are owned by EU households[4].

The balance sheet of global banks initially consists of short-term liabilities and long-term assets, denominated in both dollars and euros. In order for them to continue operating and obtain profits in period 2, they are required to roll-over their initial liabilities in period 1. However, they may fail to do so because their ability to raise funds is limited by an agency friction. To highlight the importance of maturity mismatches in foreign currencies, I focus on the case in which global banks are solvent in dollars, but are nevertheless exposed to dollar liquidity shortages given the financial constraint and their initial imbalances.

In this context, an appreciation of the dollar translates into higher banks' profits when converted into euros, but it simultaneously tightens financial conditions for them. The reason behind this is that banks can divert a fraction of the funds they intermediate, and a significant share of their liabilities is denominated in dollars. As a result, their short-term

[3]This type of frameworks have been used to study mostly emerging markets, and were particularly relevant to understand the financial crises that they faced during the 90's.

[4]The reader can think of a US banking sector also operating in the background. In a more complex set up, these banks would intermediate the funds from US households, and then engage in cross-border operations with foreign banks. Since the model focuses on global banks and their balance sheet mismatches, the lending by US banks is immaterial to the results, so I leave it unspecified.

liquidity needs (which are exacerbated by the risk of fund diversion) are unevenly impacted by exchange rate fluctuations, compared to their expected profits. Consequently, if the dollar experiences a significant appreciation, global banks might not receive the funding they need to operate.

On the other hand, these banks also play an important role in how exchange rates are determined. If they do not receive the funds needed to meet their obligations, global banks are forced to shut down and liquidate their long-term assets. EU households, as owner of these banks, are directly affected by the loss of the potential profits that would have been generated if the banks had continued their operations. This represents a negative wealth shock to these households that could be interpreted as a banking crisis that affects the EU economy directly. As a response to this shock, EU households save more in period 1 and their aggregate demand drops, leading to a euro depreciation.

This two-way interaction between the exchange rate and the soundness of global banks opens the door to multiple equilibria in the spirit of Bocola and Lorenzoni (2020). In one equilibrium, the dollar remains at a relatively low level, banks intermediate capital flows across countries, and their long-term investments mature. The other equilibrium, on the contrary, resembles a global financial crisis, characterized by a sharp appreciation of the dollar, tighter conditions in global financial markets, an increase in capital flows towards the US, and lower aggregate demand in the rest of the world.

Interestingly, self-fulfilling expectations about the exchange rate can trigger global financial crises, which is the first key insight from my model. Households anticipate the constraints that banks face, and decide whether to provide the funds they need or not. If households are pessimistic and expect a significant exchange rate depreciation that would unevenly affect the short-term dollar liabilities of global banks, they decide not to provide those funds. As mentioned before, the collapse of these banks leads to a decline in aggregate demand in the EU, which is eventually accommodated by an exchange rate depreciation, validating households' initial pessimistic expectations. These self-fulfilling crises can be understood not as runs on individual banks (e.g. Diamond and Dybvig, 1983), but rather as runs on the entire banking system that are linked to macroeconomic factors such as the exchange rate.

Next, I study the role of governments or central banks in preventing a crisis. The particular intervention I consider is in the form of a lender of last resort. In my framework crises occur due to pessimistic expectations, preventing households from providing the funding that banks need to operate. If the central bank can credibly commit to provide the liquidity they need, even when the private sector holds pessimistic expectations, then agents rule out the possibility of a "bad" equilibrium, preventing it from materializing. This means that for the intervention to be successful, the lender of last resort must have ample resources. The second main result of the paper shows that, in a state of the world where the dollar is strong relative to other currencies, and since the liquidity needs of global banks are in dollars, non-US central banks without significant foreign currency reserves might lack the resources to prevent the financial crisis. Given its broad access to dollar liquidity, the Fed is better equipped to perform such an intervention, which can also be interpreted as a "bailout" for foreign banks.

Finally, I analyze the welfare implications of a global financial crisis, and the incentives that the US might have to act as the international lender of last resort. The consequences of the collapse of non-US banks can be divided into two groups. First, these banks were investing not only in the EU but also in the US. Therefore, there are direct effects coming from the liquidation of EU and US long-term assets that they were intermediating. In that sense, both economies experience the consequences of losing productive investments that would have otherwise contributed to the supply of non-tradable goods within each of them. Second, on the financial side, EU households lose potential profits (dividends) when EU banks fail, while US households lose any deposits that they initially held with them. Considering these effects, from a partial equilibrium perspective, both economies suffer when EU banks fail.

Nevertheless, there are important general equilibrium forces that are often overlooked but can tilt the scales in the opposite direction. In particular, during a global financial crisis, the US benefits from a higher relative wealth –coming from a stronger dollar- and cheaper capital flows from abroad –driven by lower aggregate demand in the rest of the world-. This mechanism resembles a scenario where the US is considered a safe haven during periods of stress. In my model, these effects allow US households to consume a larger share of tradable goods compared to the non-crisis scenario, which might even outweigh the negative consequences associated with the collapse of foreign global banks.

The final main result of the paper collects these insights. Even if the Fed can provide swap lines that are useful to bail out non-US global banks facing dollar shortages, the interests of the US to do so might not be aligned with the rest of the world. The incentives of the Fed to intervene are smaller if the investment of these banks on US assets is low, or if US households manage to recover a large portion of their initial deposits when they fail. One interpretation of these findings is that the trade-off that the US faces could result in an underprovision of dollar liquidity[5] to the world.

Lastly, I provide several extensions in which I explore different specifications for the main parts of the model. Most importantly, I use a three-period version of the baseline model to endogeneize the funding and investment decisions of non-US global banks. I show

[5]This result aligns with the argument in Farhi and Maggiori (2018) regarding the possibility of the US underproviding safe assets as the dominant global issuer.

that, despite banks can choose ex-ante whether to denominate their short-term debt in euros or in dollars, this does not necessarily rule out the possibility of multiple equilibria.

Related Literature. This study relates to several broad strands of the literature. First, it is directly related to papers studying self-fulfilling crises in open economies, starting with Calvo (1988) and followed by Schmitt-Grohé and Uribe (2016), Obstfeld (1996), Cole and Kehoe (2000), and more recently by Céspedes et al. (2017), Aguiar et al. (2017), Farhi and Maggiori (2018), Benigno and Fornaro (2018), and Bocola and Lorenzoni (2020), among others. The feedback loop that drives the results in my framework works similarly as in a "third-generation" currency crisis model (Krugman, 1999), but with a few important differences. These types of models have mostly been used to study emerging markets, and were particularly relevant to understanding the financial crises that they faced during the 90's. The novelty of this paper is that it focuses on global banks in a large economy such as the EU, which brings up two main differences with respect to traditional models. On the one hand, the liquidity shortages these banks face come from their maturity mismatches in dollars, rather than from currency mismatches, as in most emerging economies. Moreover, the collapse of these global intermediaries has significant spillovers to the international financial system, particularly to the US.

Given the role that the Fed plays in my model, this paper relates closely to the literature on bank-runs and the benefits of a lender of last resort, as in Bagehot (1873), Diamond and Dybvig (1983), or Rochet and Vives (2004). In recent decades, there has been a growing attention towards the need of an international lender of last resort, as for example in Fischer (1999), Goodhart and Huang (2000), Mishkin (2001), Lerrick and Meltzer (2003), and more recently in Obstfeld (2009), Landau (2014), Cecchetti (2014), McDowell (2017), among others. I argue that the Fed is better equipped than any institution to fulfill this role, given that the majority of the liquidity needs of the international financial system are denominated in dollars. Moreover, contrary to traditional models that focus on runs on individual banks, I consider runs on the entire banking system that are linked to macroeconomic factors such as the exchange rate.

The focus on global banking of this paper is shared with a growing set of mostly empirical studies[6] (Cetorelli and Goldberg, 2012; Shin, 2012; Bräuning and Ivashina, 2020; Aldasoro et al., 2019). The behavior of global banks and their role in the transmission of crises are modelled in Kalemli-Ozcan et al. (2013), Ivashina et al. (2015) and Morelli et al. (2022). I follow a similar theoretical approach to Gabaix and Maggiori (2015) in building a minimalistic real model with two countries, financial frictions, and global financial intermediaries at the centre of the capital flows and the exchange rate determination.

[6] Others include Acharya and Schnabl (2010), Correa et al. (2016), McGuire and von Peter (2012).

However, they do not consider potential imbalances in the balance sheet of the intermediaries, which in my model open the door to multiple equilibria and benefits from an international lender of last resort.

In this context, a key feature of this paper when assessing the role of global banks is the dollar dominance. Recent studies that incorporate this characteristic, especially when focusing on exchange rate determination include Bruno and Shin (2015), Gourinchas et al. (2010), Maggiori (2017), Itskhoki and Mukhin (2021), Kekre and Lenel (2021), among others. Many of these studies focus on the US as the "banker to the world", providing safe assets to the world. However, this traditional view predicts a dollar depreciation in times of crisis, which the authors try to challenge by incorporating "flight-to-safety" shocks (Kekre and Lenel, 2021) or exogenous trade costs that are linked to the banks' health (Maggiori, 2017), to mention a few. In contrast, this paper shifts the focus to non-US global banks, which played a crucial role in the intermediation of capital flows across developed countries in the run-up to the GFC. By doing so, the model is able to jointly explain the dollars' role as the reserve currency and its particular dynamics during a global crisis.

Finally, this paper also relates to the stream of literature on swap lines, most of which takes a micro-level empirical approach. From the studies focusing on this intervention[7] during the GFC, such as Baba and Packer (2009*b*), Baba and Packer (2009*a*), Moessner and Allen (2013), and Aizenman and Pasricha (2010), perhaps the most comprehensive study so far is Bahaj and Reis (2022*a*), who rely on a difference-in-difference identification to assess the effect of the Fed's swap lines on CIP deviations, portfolio flows, and the price of dollar-denominated corporate bonds. In a follow-up article (Bahaj and Reis, 2020), they study the impact on funding costs of the new swap lines introduced by the Fed during the Covid-19 pandemic, similarly to Aizenman et al. (2021), Goldberg and Ravazzolo (2022), and Ferrara et al. (2022). Considering all these studies, the overall consensus points to the swap lines effectively helping to ease strains in US dollar funding markets and addressing sudden stop type episodes for banking systems.

On the theory side, the number of references is more limited. Bahaj and Reis (2022*a*) provide a model of the market for FX forwards into a small-scale general equilibrium model and find that the Fed swap lines reduce bank funding risk and increase the investment in dollar-denominated assets of non-US banks. Eguren-Martin (2020) and Cesa-Bianchi et al. (2022) on the other hand, propose a medium-scale DSGE model with a bank currency portfolio problem to assess the capacity of the swap lines to mitigate the impact of dollar-shortage shocks to the economy and financial system. Kekre and Lenel (2021) find that,

[7] An older literature studied the swap lines that supported the Bretton Woods system as well as the Fed's reciprocal swap system between 1962 and 1998, when they were mainly used to finance foreign exchange rate interventions and keep currencies pegged to the dollar (e.g. Williamson, 1983; Obstfeld et al., 2009).

in a business cycle model of the international monetary system, "flight-to-safety" shocks generate a dollar appreciation and a decline in global output, and show that dollar swap lines help to mitigate these effects. Contrary to the others listed here, my paper offers a tractable model of the global economy that features multiple equilibria. This allows me to study the intervention from the perspective of a lender of last resort and as an instrument to prevent self-fulfilling crises.

The rest of the paper is organized as follows. Section 2 presents stylized facts that serve as the basis of the model. Section 3 describes the baseline model. Next, Section 4 discusses the multiple equilibria that might arise under this framework. The benefits of an international lender of last resort are presented in Section 5, while Section 6 provides a welfare analysis that motivates the intervention. Finally, Section 7 concludes.

2. Stylized Facts

In this section I present three empirical facts that are distinctive features of the international financial system, and discuss briefly how I capture them in my model. Next, I elaborate on the usage and magnitude of the dollar swap lines, including the aspects of the intervention that I will highlight in the model.

Fact 1: The dollar appreciates and liquidity shortages arise during a crisis.

As shown in Figure 1, the dollar appreciated both during the global financial crisis and the Covid-19 crisis. This is a well-documented fact that traditional macro-finance models fail to capture and that is known as the reserve currency paradox (Maggiori, 2017; Chen, 2021). Moreover, dollar liquidity becomes scarce (Corsetti and Marin, 2020; Borio, 2020; FSB, 2020) as shown by the increase in the dollar funding costs in Figure 1. This reflects an increase in the demand for dollars in a context of high market volatility and risk aversion as market participants, who typically have a significant exposure to the dollar, hoard cash in anticipation of potential cash outflows to the real economy.

I introduce this fact in the model with a financial friction that limits the ability of global banks to raise funds. When these banks face maturity mismatches in foreign currency, a dollar appreciation unevenly increases their short-term needs, which represents a higher risk for investors and ultimately tightens the financial conditions they face.

Fact 2: Non-US global banks are key players in dollar markets.

In the run-up to the GFC, the total dollar assets of banks outside the US reached $10

(a) Global Financial Crisis (b) Covid-19 Crisis

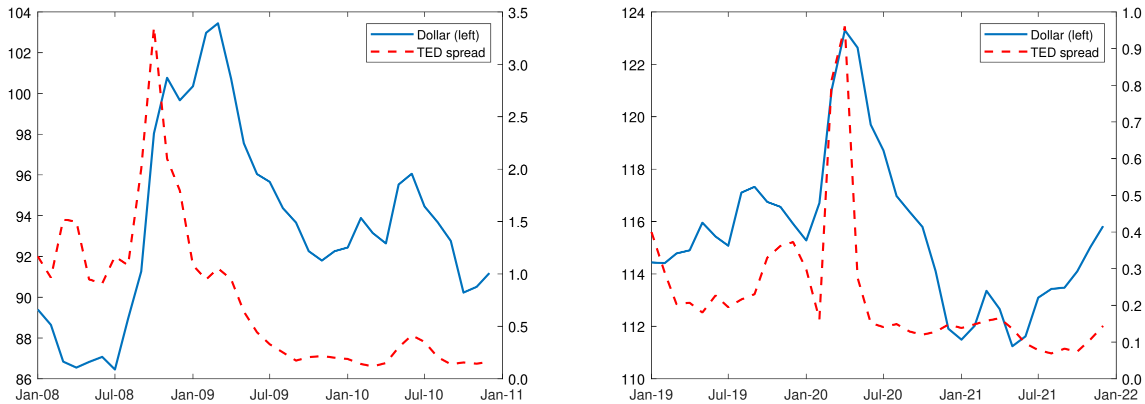


Figure 1: Dollar (index) and TED spread (%)

Note: The TED spread is defined as the difference between the 3-month LIBOR rate and the 3-month T-bill rate. An increase can be understood as an increase in the interest rates that banks have to pay to access dollar funding in the international markets. ***Source:*** Fed.

trillion, and increased up to almost \$14 trillion in 2021. Surprisingly, this is comparable to the current size of the aggregate commercial banking sector in the US, as seen in Figure 2a. As mentioned in Shin (2012), it is as if an offshore banking sector of comparable size to the US banking sector is intermediating dollar claims and obligations. To provide a clear idea of the extent of the intermediation activity conducted by non-US banks in the US, Figure 2b shows that foreign claims of BIS reporting banks on US counterparties reached \$7.3 trillion by mid-2021. When the figure is broken down by the nationality of the lending party, we see that EU banks are still one of the two largest groups of banks -closely behind Japanese ones- in financing US residents[8]. If UK and Swiss banks are considered as well, it becomes more clear that European global banks have substantial claims against US borrowers.

This phenomenon of non-US global banks playing an important role in the intermediation of dollar-denominated flows is an important feature of the international financial system in the run-up to the GFC. I incorporate this fact in my model by having global banks intermediating dollar funds from US households into productive long-term investments.

Fact 3: Dollar funding of these banks is short-term and fragile, which exposes them to liquidity shortages.

The dollar-denominated asset purchases by global banks in the last two decades has been largely financed with dollar-denominated debt, as shown in Figure 3a. Despite showing a combination of large gross dollar positions but small net positions, these banks were

[8]It is not surprising that, given their relevance in providing funding to the US, around 80% of the outstanding swap lines during the Covid-19 pandemic were directed to the ECB and the BOJ.

exposed to liquidity shortages given their reliance on short-term funding. McGuire and von Peter (2012) document that European banks' short term dollar funding gap (i.e. dollar roll-over needs) were at least 7% of US GDP at the onset of the GFC. Figure 3a shows that in 2007, the net short-term liabilities of non-US global banks in dollars were around $5.1 trillion. This situation has not changed drastically in recent years, as these banks still tend to rely on short-term or wholesale US dollar funding. Figure 3b shows that only around 30% of their dollar liabilities comes from deposits -which is a relatively stable source of funding- compared to the 70% that deposits represent in their consolidated balance sheet[9].

Motivated by these characteristics, the model features global banks with short-term dollar liabilities that need to be rolled-over. Combined with the financial constraint discussed previously and the illiquidity of their assets, an exchange rate depreciation might prevent global banks from obtaining the funding needed to cover their dollar obligations, forcing them to shut down.

Swap Lines. In a nutshell, a swap line is an agreement between two central banks to exchange currencies at a specific exchange rate, and for a short period of time. The recipient central bank then lends the dollars out to eligible banks in its jurisdiction. From the perspective of the Fed, the end result is a loan of dollars to foreign banks, which is the approach that I will follow when discussing the model in this paper. Given that the terms and interest rate as a spread over the policy rate are set when the contract is signed, there is no exchange rate or interest rate risk. Moreover, there is negligible credit risk, as the Fed deals only with selected foreign central banks, who guarantee these transactions[10].

The main objective of the Fed during the GFC was to address liquidity shortages worldwide. In that sense, it provided liquidity to both domestic (via the Term Auction Facility) and foreign banks (via swap lines[11]), as part of a far-reaching effort. Based on minutes from the FOMC meetings, the Fed's intervention tried to i) prevent a risky US-dollar assets fire-sale, ii) prevent a run down lending of EU banks in the US[12], and iii) calming the markets. In this paper I focus on the first two incentives.

[9] Aldasoro et al. (2021) show that with around $1.4 trillion, US and offshore money market funds (MMFs) represented around 12% of the on-balance sheet dollar funding for non-US banks at end-2019. MMFs are a flighty funding source: Figure A.2 shows that non-US banks lost around $300 billion during the covid-19 turmoil, mostly from US markets.

[10] To consider a scenario in which the foreign central bank might default on the swap line is more complex and unlikely to happen in the short-term.

[11] In total, 14 foreign central banks have been benefited from access to the Fed's swap lines. Usage peaked at $450 billion in late May 2020 compared to $598 billion drawn during the GFC. The aggregate combined usage of the Bank of Japan (BOJ) and ECB accounted for about 82% of the total peak.

[12] The Fed was also concerned about keeping mortgage rates low. Since the Libor rate was the benchmark for US corporate loans and adjustable-rate household mortgages, it was important to keep offshore rates low considering the US economic recovery.

(a) Dollar cross-border foreign currency claims and US banks' total assets ($ trillions)

(b) Foreign claims of BIS reporting banks on US counterparties ($ trillion)

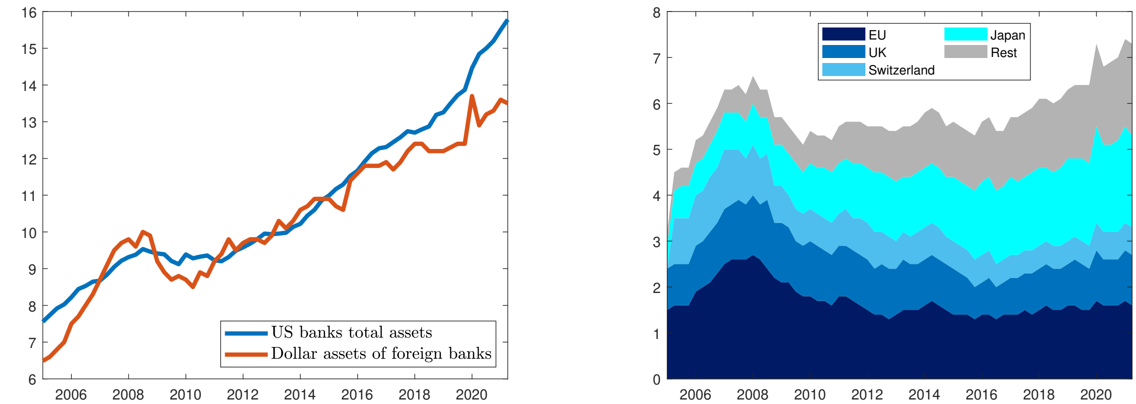


Figure 2: Dollar intermediation of non-US global banks

Note: In Panel (a), I consider US chartered commercial banks' total financial assets, and US dollar assets of banks outside the US. Panel (b) is based on the BIS Locational Statistics. ***Source:*** BIS, Flow of Funds, Fed.

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

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

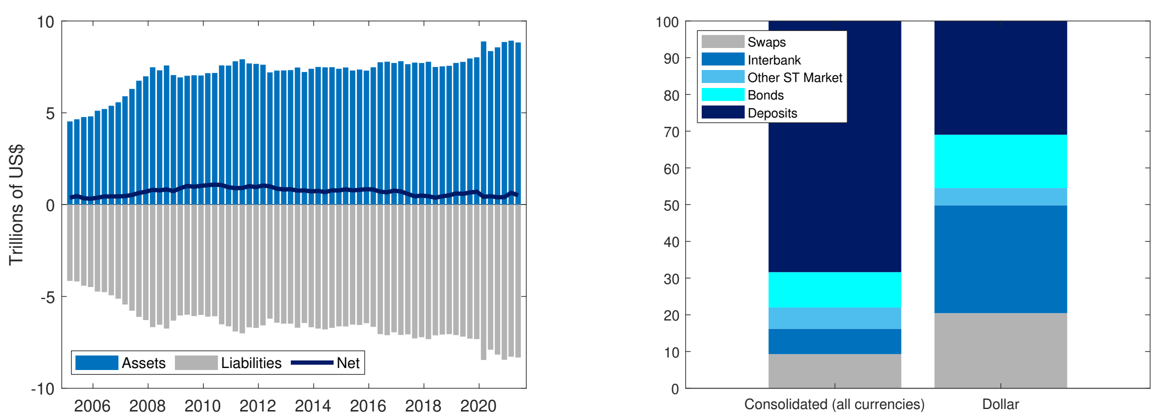


Figure 3: Dollar funding of non-US global banks

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), McGuire and von Peter (2012).

3. Baseline model

This section describes a simple model of the world economy with imperfect financial markets. For the sake of clarity, in this section I will make some simplifying assumptions that enhance the tractability of the model. These assumptions will be relaxed in the following sections.

Time is discrete and there are two periods, $t = 1, 2$, and two economies, the United States (US) and the Euro area (EU), each populated by a continuum of households. There are three goods: one single tradable good, which is traded internationally, and one non-tradable good in each economy. The non-tradable good serves as the numéraire within its respective economy. Since there is no nominal side to the model, I follow Gabaix and Maggiori (2015) in interpreting the words *dollar*- and *euro*-denominated as values expressed in units of US and EU non-tradable goods, respectively. There is a continuum of global banks owned by EU households that trade bonds with EU and US households in their own domestic currencies[13]. Global banks are financially constrained and can be exposed to bank-runs in period 1, as will be discussed in detail later. At the end of period 2, if no run takes place, global banks transfer all of their profits to EU households.

The model is built around three key ingredients. First, global banks facilitate the cross-border financial transactions resulting from households' saving decisions[14]. Second, they face an agency friction that limits their ability to raise funds and to roll-over their debt in order to operate. Third, their portfolio consists on short-term liabilities and illiquid long-term assets such that a maturity mismatch in dollars is formed. The last two ingredients combined result in tighter financial conditions if the dollar appreciates in the short-run. Also, by investing in long-term assets in the US, their operations have spillovers towards the US economy by boosting non-tradable output in that country when the investment matures.

I will offer a more comprehensive explanation of the households' decision to provide funds or not when examining the equilibrium of the model. I now turn to a detailed description of the environment, including each of the model's actors, their optimization problems, and some simplifying assumptions.

[13]This is in line with the empirical evidence provided -for example- by Maggiori et al. (2020), in which they establish that investor holdings are biased toward their own currencies to such an extent that countries typically hold most of the foreign debt securities denominated in their currency.

[14]When extending the model, households will be capable of trading bonds directly with each other, but incurring in a non-pecuniary cost that would otherwise be avoided if banks intermediated those flows.

3.1. Households

Euro area households derive utility from from consuming a consumption basket defined as $C_t \equiv (C_t^N)^{1-\omega}(C_t^T)^{\omega}$, where C_t^T and C_t^N are the EU consumption of the tradable good and its non-tradable good, respectively. The parameter $0 < \omega < 1$ denotes their preference for the tradable good, which has a relative price of p_t with respect to the non-tradable good in the EU.

Households can buy and sell tradable goods in a frictionless goods market across countries, but can only trade non-tradable goods within their domestic country. Financial markets are incomplete, and EU households can invest in domestic currency bonds with global banks. The households' optimization problem is then

$$\max_{C_t} \quad U = \ln(C_1) + \beta \mathbb{E} \ln(C_2) \tag{1}$$

subject to the budget constraint in both periods,

$$Y_1^N + p_1 Y_1^T + L = C_1^N + p_1 C_1^T + B \tag{2}$$

$$\Pi + Y_2^N + p_2 Y_2^T + R \cdot B = C_2^N + p_2 C_2^T \ , \tag{3}$$

where Y_t^T and Y_t^N are the households' endowments of the tradable and non-tradable goods, respectively. On the other hand, Π represents the profits that banks transfer to EU households at the end of the first period. R is the gross interest rate paid by the euro-denominated bond (B). Finally, L is a pre-existing euro-denominated position with global banks that has to be repaid or claimed in period 1.

The households' first-order conditions can be written as

$$p_1 C_1^T = \frac{1}{\beta R} p_2 C_2^T \tag{4}$$

$$p_t = \frac{C_t^N}{C_t^T} \frac{\omega}{1-\omega} \tag{5}$$

Equation (4) is the Euler equation in terms of the tradable consumption and prices, which simply states that an increase in the interest rate reduces the expenditure in tradables in period 1. Equation (5) determines the optimal allocation of consumption expenditure between tradable and non-tradable goods. It is straightforward to see from here that, keeping non-tradable consumption fixed, an increase in tradable consumption has to be accommodated by a drop in p_t.

US households face a very similar optimization problem. The main differences with

EU households is that they trade dollar-denominated bonds, and they hold pre-existing dollar-denominated positions L^* with global banks that have to be claimed in period 1. By analogy with the EU case, US households' optimization problem is

$$\max_{C_t^*} \quad U^* = \ln(C_1^*) + \beta \ln(C_2^*) \tag{6}$$

subject to the budget constraint in both periods,

$$p_1^* Y_1^{*T} + Y_1^{*N} + L^* = p_1^* C_1^{*T} + C_1^{*N} + B^* \tag{7}$$

$$p_2^* Y_2^{*T} + Y_2^{*N} + R^* B^* = p_2^* C_1^{*T} + C_2^{*N} \ , \tag{8}$$

where starred variables denote US quantities and prices. R^* is the interest rate paid by the dollar-denominated bond. Households also receive endowments Y_t^{*T} and Y_t^{*N} in both periods. Their first-order conditions follow the same intuition as their EU counterpart, and are given by

$$p_1^* C_1^{*T} = \frac{1}{\beta^* R^*} p_2^* C_2^{*T} \tag{9}$$

$$p_t^* = \frac{C_t^{*N}}{C_t^{*T}} \frac{\omega^*}{1-\omega^*} \ . \tag{10}$$

The key variable in this real model is the exchange rate e_t. I follow Gabaix and Maggiori (2015) in defining the exchange rate as the relative price between the two non-tradable goods, or in other words, as the quantity of *euros* bought by one *dollar*. Consequently, an increase in e_t represents a dollar appreciation.

3.2. Global Banks

Global banks are owned by EU households, and serve two primary functions. First, they facilitate financial transactions across countries, and second, they hold investments in long-term projects that boost the availability of non-tradable goods in both economies. I will abstract from modelling the investment and funding decisions of these banks, and assume they have some pre-existing financial positions. In particular, banks have short-term liabilities, L in euros and L^* in dollars, that have to be repaid in period 1. Meanwhile, their long-term assets[15] mature in period 2 and have a gross return of A in euros and A^* in dollars.

[15]Since they are denominated in non-tradable goods, these assets can be thought as an investment in the housing sector. They can also be interpreted as if banks were financing firms that invest in the non-tradable sector.

Period 1 is crucial for global banks. In order to operate and avoid a costly liquidation, it is required that they roll-over their debt by trading bonds with EU (B) and US (B^*) households in their corresponding currencies, such that the following condition holds:

$$L + e_1 L^* \leq B + e_1 B^* \ . \tag{11}$$

If they succeed, banks enjoy positive profits in period 2 given by

$$\Pi = A + e_2 A^* - RB - e_2 R^* B^* \ . \tag{12}$$

The last two equations are expressed in euros, which is why dollar quantities are multiplied by the corresponding exchange rate. Finally, banks face an agency friction that limits their ability to raise funds. In each period, after taking positions, they can divert a fraction of the funds they intermediate. If they divert the funds, banks are unwound and the households that had lent to them in $t = 1$ recover a portion $1 - \gamma \geq 0$ of their credit position $B + e_1 B^*$. Since creditors -when lending to the banks- correctly anticipate their incentives to divert funds, banks are subject to a credit constraint of the form:

$$\frac{1}{R}\Pi \geq \gamma(B + e_1 B^*) \tag{13}$$

where $1/R$ comes from EU households' stochastic discount factor. Since the investment is fixed, bankers simply choose a combination of B and B^* to maximize the expected profits in (12) subject to the liquidity needs in (11) and the financial constraint in (13). The optimization problem results in the following no-arbitrage condition:

$$R = R^* \frac{e_2}{e_1} \tag{14}$$

which reflects that the uncovered interest parity (UIP) holds[16].

3.2.1. Exchange rate and banks' soundness

In an equilibrium in which banks operate, equation (11) holds with equality[17], so that combining the two restrictions and the UIP condition yields the following expression for the financial constraint, in terms of e_1:

$$\frac{A}{R} + e_1 \frac{A^*}{R^*} \geq (1 + \gamma)(L + e_1 L^*) \ .$$

[16]This no arbitrage condition arises from the fact that banks take R and R^* as given.

[17]In $t = 1$, banks only intermediate flows across countries, and do not invest. Therefore, in equilibrium, gross capital flows in both countries have to offset each other, such that $e_1(B^* - L^*) = -(B - L)$.

The magnitude and direction of the impact of exchange rate fluctuations on the incentive compatibility constraint will depend on the composition of banks' balance sheet. I will follow the literature of bank runs, where financial intermediaries might face liquidity issues but are otherwise solvent. Particularly, I will focus on the case where banks are solvent in dollars, but exposed to dollar liquidity shortages. This can be captured in the model by making the following assumptions.

Assumption 1. *The following conditions on the dollar portfolio of global banks hold:*

$$\begin{aligned} \textit{Dollar profitability:} \quad & \frac{A^*}{R^*} - L^* > 0 \\ \textit{Dollar liquidity:} \quad & \frac{A^*}{R^*} - (1+\gamma)L^* < 0 \end{aligned}$$

The previous two inequalities reflect that the discounted dollar profits of global banks might be large compared to their current dollar liabilities, suggesting no currency mismatches. However, they might be insufficient to cover their short-term dollar needs, which are determined also by γ. It is possible to interpret this parameter as capturing the market's risk intolerance, so that liquidity needs are larger when this intolerance is higher. With these conditions, the incentive compatibility constraint in (13) leads to the following Lemma.

Lemma 3.1. *Suppose that Assumption 1 holds. A necessary condition for all banks to operate in equilibrium is,*

$$e_1 \le \frac{A/R - (1+\gamma)L}{(1+\gamma)L^* - A^*/R^*} \equiv \bar{e} \ ,$$

where $R = (A + Y_2^N)/\beta Y_1^N$ *and* $R^* = (A^* + Y_2^{*N})/\beta^* Y_1^{*N}$.

Proof. In Appendix B.2. □

The threshold $\bar{e}$ can be interpreted as the maximum exchange rate that the banking system can tolerate. This shows that, although e_1 affects the return of dollar investments positively, it also unevenly increases the liabilities that banks need to roll-over, making diverting funds more appealing. Under the assumption that banks face dollar shortages, the overall result is that market conditions become tighter the higher is the exchange rate, in line with the evidence presented in Section 2. If the depreciation goes beyond the threshold $\bar{e}$, banks cannot roll-over their debt and go bust. Thus, an equilibrium that features operating global banks must be characterized by $e_1 \le \bar{e}$.

3.2.2. Costly Liquidation

As it will become clearer later, if households expect that the credit constraint of banks will be violated, they decide not to provide banks with deposits in period 1. In that case, banks are forced to shut down and liquidate their assets. These long-term assets exhibit two important features. First, they have no value if liquidated[18] in period 1, therefore banks cannot cover their liquidity needs by selling part of their assets. Secondly, they yield positive returns only if banks operate[19], and zero otherwise. This implies that $A, A^* > 0$ if banks operate, and they are zero otherwise. Moreover, given the lack of funds, their pre-existing positions with US and EU households are not repaid ($L, L^* = 0$). As a result, banks lose all profits when forced to shut down, hence $\Pi = 0$. This set up in which assets from global banks turn out to be worthless if the bank defaults, leaving them with no resources to pay any of its debts, is similar to Ivashina et al. (2015).

Bottom line, there are two possible scenarios for global banks: one in which the exchange rate is relatively low ($e_1 < \bar{e}$) and they operate, and one in which the dollar is strong ($e_1 > \bar{e}$) and they collapse. Households' expectations will play a key role in determining the likelihood of these two scenarios, as we will see when discussing the equilibria of the model.

3.3. Market Clearing

Market clearing for the non-tradable consumption good requires that in every country consumption is equal to the endowment:

$$\begin{aligned} Y_1^N &= C_1^N & \qquad Y_1^{N*} &= C_1^{*N} \\ Y_2^N + A &= C_2^N & \qquad Y_2^{*N} + A^* &= C_2^{*N} \end{aligned} \tag{15}$$

where the last two equations reflect 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. On the other hand, the market clearing condition for the tradable good requires that the world's endowment is equal to the world's demand in

[18]This assumption is in line with traditional bank-run models such as Diamond and Dybvig (1983) and Allen and Gale (2009) in which liquidating an asset before maturity entails significant costs. In my model, the assumption can be motivated by the fact that, in the run up to the GFC, global banks' dollar assets were mostly risky mortgage-backed securities and corporate bonds, which eventually suffered from significant negative devaluations when the crisis hit. The model in Clayton and Schaab (2022) also features global banks investing in illiquid long-term projects.

[19]As explained in Brunnermeier and Sannikov (2014), many macro-finance models with financial frictions consider banks as experts with a superior ability or greater willingness to manage and invest in productive assets. In this case, we could also think of investment complementarities, in which a long-term project needs a second round of investments before output is realized.

both periods,

$$Y_t^T + Y_t^{*T} = C_t^T + C_t^{*T} \ . \tag{16}$$

Simplifying assumptions and considerations. To streamline the algebra and concentrate on the relevant economic content, assume for now that both countries have the same preferences for non-tradables and the same discount factors, therefore $\omega = \omega^*$ and $\beta = \beta^*$. Moreover, I will assume that $Y_1^N = Y_1^{*N}$ and normalize them to 1. Besides the asymmetries related to bank profits and their initial portfolio, I will allow for different endowments of the tradable good in each country. Denote the share of the EU endowment of the tradable good in the world economy as $\eta_t \equiv Y_t^T/(Y_t^T + Y_t^{*T})$, while the share of the US endowment is then $\eta_t^* = 1 - \eta_t$. To further narrow the focus of the analysis to dollar shortages, I will assume for now that

$$L = 0 \ ,$$

so that no euro-denominated debt has to be rolled-over. In Section 4, I provide a generalization of the model that relaxes these assumptions, maintaining the main results.

4. Multiple equilibria and self-fulfilling crises

After outlining the model's environment and introducing the main actors, I will describe the equilibria that can emerge. The previous section showed how banks face two possible scenarios: one in which they operate, and one in which they shut down. It is essential to establish a clear timeline within the model to comprehend how households' decisions can influence these scenarios, and thereby, the potential equilibria.

Timeline. The sequence of events is the following:

i) Period 1: At the beginning of period 1, households decide whether to provide funds to global banks or not.

ii) If no funds are provided, global banks are liquidated and their assets are lost. If funds are provided, global banks intermediate financial flows across countries.

iii) Period 2: At the beginning of period 2, if global banks are operating, the return on their long-term assets materializes and they repay their debts.

iv) Any resulting profits from these activities are transferred to EU households.

I will now describe the two equilibria that might arise in the model. The particular values of certain variables in equilibrium, as well as the parametric conditions for the existence of the equilibria will be addressed in detail later.

4.1. No-run equilibrium

It is optimal for households to provide the funds needed to global banks only if they expect condition (13) to hold, otherwise banks would have incentives to divert those funds. Considering Lemma 3.1, households provide the funds when they expect a relatively low exchange rate, below $\bar{e}$. When this happens, banks are able to roll-over their initial liabilities. In the literature of bank-runs, this would be similar to a no-run equilibrium, which definition is the following.

Definition 1 (Competitive no-run Equilibrium). *A competitive no-run equilibrium is a path of real allocations* $\{C_t^T, C_t^N, C_t^{*T}, C_t^{*N}\}_t$ *and* $\{B, B^*\}$*, interest rates* R*,* R^* *and exchange rate* $\{e_t\}_t$*, satisfying the households' optimality conditions in* (2)*,* (3)*,* (4) *and* (5) *-plus their counterparts for the US economy-, the banks' roll-over needs, profits, credit constraint, and no-arbitrage condition in* (11)*,*(12)*,*(13) *and* (14)*, and the market clearing conditions in* (15) *and* (16)*, given a path of endowments* $\{Y_t^T, Y_t^N, Y_t^{*T}, Y_t^{*N}\}_t$*, and initial conditions* $\{L, L^*, A, A^*\}$*.*

I will refer to the "no-run" equilibrium as the "good" equilibrium, with an exchange rate in $t = 1$ denoted by e_1^G.

4.2. Run equilibrium

Contrary to the previous case, it is optimal for households not to save with global banks if they expect condition (13) to be violated. This is the case if they expect a relatively strong dollar in $t = 1$ ($e_1 > \bar{e}$) that would increase the incentives of banks to divert their funds, as explained in Section 3. Under these circumstances, banks collapse, their investment in US and EU assets is lost, and their profits Π become null. As will be discussed later, these expectations might be validated by the fact that, when banks go bust, the euro depreciates.

I will refer to the "run" equilibrium as the "bad" equilibrium, with an exchange rate in $t = 1$ denoted by e_1^B.

4.3. Exchange Rate as coordination device

In most models of bank-runs, depositors must decide whether to roll-over their debt or not, at the risk of losing their deposits if the actions of other agents leave the bank with not enough resources to repay them. My approach is different, as I focus on expectations about aggregate variables that might trigger a bank-run. Therefore, I consider households that use their expectations about the exchange rate as a coordination device (sunspot).

Particularly, households form expectations about the exchange rate at the beginning of period 1. As the next step, they evaluate if, for that level of the exchange rate, the incentive compatibility constraint of banks is violated. If it is, then households do not provide banks with the necessary funding to repay their short-term liabilities, and they shut down. If the condition is not violated, then it is optimal for them to invest with global banks.

4.4. Multiple Equilibria

To give a better sense of the forces driving the equilibria of the model, I will fully characterize them using two variables, the exchange rate and capital flows, and two equations. Both variables play a key role in financial crises, and eventually will drive most of intuition behind the main results of the model. In particular, I will focus on the exchange rate in period 1, and on EU savings, B. Since this is a two-country model, EU net savings are equivalent to capital flows to the US, so I will use both terms interchangeably.

Dollar Bonds. From here on, I will relax the assumption that households can only borrow and invest with global banks. Extending the model in this way is not crucial for any of the main results of the paper, but it will help to better rationalize the patterns of capital inflows to the US during a crisis, which will be relevant for the welfare analysis. In particular, I will assume the following.

Assumption 2. *Consider now that households in the EU and in the US can trade bonds directly with each other, incurring in a small non-pecuniary cost. The currency denomination of these bonds is irrelevant in equilibrium, but for simplicity, assume that they are denominated in dollars.*

From the perspective of an individual household, in principle these bonds are equivalent to the bonds offered by global banks (despite the different currencies). However, trading bonds across borders entails a non-pecuniary cost for households, since they lack the expertise and financial sophistication that global banks have, as pointed in Brunnermeier and Sannikov (2014). Thus, it is optimal for EU and US households to engage in direct trading only when global banks are nonoperational. The full optimization problem for households can be found in Appendix F.

4.4.1. Static determination of exchange rates and capital flows

First, I will analyze how capital flows affect the exchange rate in period 1. From the perspective of the EU, the trade balance -in euros- is defined as follows:

$$p_1(Y_1^T - C_1^T) = B \ ,$$

where B represents the net capital flows to the US. Focusing on the left-hand side of the previous expression, the households' optimality condition in (5) and the market clearing conditions for non-tradable goods tell us that their expenditure in tradables is fixed, so that $p_1 C_1^T = \frac{\omega}{1-\omega} Y_1^N = \frac{\omega}{1-\omega}$. Furthermore, simple derivations presented in the appendix show that tradable market clearing (16) and utility maximization imply that

$$p_1 = \frac{\omega}{1-\omega} \frac{1}{Y_1^T + Y_1^{*T}} (1 + e_1) \ ,$$

reflecting the fact that, when a country's exchange rate depreciates, consuming tradable goods becomes more expensive. Finally, rearranging the equations above to express e_1 as a function of B yields:

$$e_1(B) = \underbrace{\frac{\eta_1^*}{\eta_1}}_{\substack{\text{Endowment} \\ \text{component}}} + \underbrace{B \cdot \frac{1-\omega}{\omega} \cdot \frac{1}{\eta_1}}_{\substack{\text{Capital flows} \\ \text{component}}} \ . \tag{17}$$

This equation describes a very intuitive result. The first component shows that, absent capital flows, the exchange rate is determined simply by the relative endowment of tradable goods in each economy. More interestingly, the second component captures the idea that the larger the capital outflows towards the US (EU savings), the larger the trade balance that the EU needs in period 1 to cover those outflows. Ultimately, a stronger trade balance is achieved by a euro depreciation ($\uparrow e_1$). Another way to look at this idea is that a weaker euro makes EU exports more attractive in markets abroad.

4.4.2. Intertemporal determination of exchange rates and capital flows

Now let us consider how the exchange rate in period 2 affects capital flows. When banks operate, EU households receive their profits and thus the budget constraint they face in period 2 is

$$R \cdot B = p_2(C_2^T - Y_2^T) + C_2^N - Y_2^N - \Pi \ .$$

Following a similar procedure as for the trade balance in period 1, it is possible to rewrite their expenditure in tradables as $p_2 C_2^T = \frac{\omega}{1-\omega} C_2^N$ and the price of tradables as

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

Simple derivations described in the appendix show that the previous equation can be written in terms of e_1 by using the expressions for both interest rates, the UIP condition $e_2 R^* = e_1 R$, and the market clearing conditions for non-tradable goods, $C_2^N = Y_2^N + A$ and $C_2^{*N} = Y_2^{*N} + A^*$. Next, banks' profits Π given by equation (12) can also be expressed in terms of e_1 by using the UIP condition and the roll-over needs in (11), so that $\Pi = R\Big[e_1\Big(\frac{A^*}{R^*} - L^*\Big) + \frac{A}{R}\Big]$. Finally, combining all these expressions, the budget constraint in period 2 yields the following equation,

$$\mathcal{B}(e_1) = \frac{\omega}{1-\omega}\beta \underbrace{\left(\eta_2^* - e_1 \eta_2 \right)}_{\substack{\text{Endowment} \\ \text{component}}} \; - \; e_1 \underbrace{\left(\frac{A^*}{R^*} - L^* \right)}_{\text{\$ Profits}} .$$

The previous equation highlights the importance of wealth effects in determining capital flows and the exchange rates. The first term on the right-hand side shows that an exchange rate appreciation ($\downarrow e_2$) in the EU represents a drop in relative prices in that economy in period 2, which pushes EU households to increase future consumption by saving more (or borrowing less) in period 1, thus increasing capital outflows. This can be thought in terms of e_1. In anticipation of the drop in prices and thus an higher relative wealth, households will increase consumption today as well, which pushes the euro to also appreciate in period 1. The last term on the right-hand side shows that a dollar appreciation in $t = 2$ represents a positive wealth shock for EU households if the dollar profits they receive from banks are positive, which I will assume in the next section. This positive wealth effect reinforces the mechanism just discussed and leads to fewer capital outflows in $t = 1$, as EU households require less savings.

Now let us consider the scenario where global banks do not operate, which happens when $e_1 > \bar{e}$. In this context, there is one distinct force at play that will change the intertemporal relation between the exchange rate and capital flows. When banks go bust, their profits collapse to $\Pi = 0$ because of the costly liquidation of their long-term assets, and the failure to repay their short-term liabilities, as discussed in Section 3. This represents a negative wealth effect for EU households in period 2, leading them to demand more savings (fewer capital outflows) and consume less in period 1, for a given level of exchange rate. Considering these two cases, and the fact that households use the exchange rate as a coordination device, the intertemporal relation between the exchange rate and capital flows can be characterized as follow,

$$B = \mathcal{B}(e_1) = \begin{cases} \frac{\omega}{1-\omega}\beta\Big(\eta_2^* - e_1\eta_2\Big) - e_1\Big(\frac{A^*}{R^*} - L^*\Big) & \text{if } e_1 < \overline{e} \\ \frac{\omega}{1-\omega}\beta\Big(\eta_2^* - e_1\eta_2\Big) & \text{if } e_1 > \overline{e} \end{cases} \tag{18}$$

The equilibria of the model can be obtained by solving the system of two equations given by (17) and (18). Using the properties of these two schedules, we can conclude the following.

Proposition 1. *Suppose that Assumption 1 holds, $\eta_t = \eta \ \forall t$, and let $\overline{e}$ be the value of e_1 that makes condition (13) hold with equality. Then, multiple equilibria are possible if*

$$\underbrace{\frac{\eta^*}{\eta + \frac{1}{1+\beta}\frac{1-\omega}{\omega}(A^*/R^* - L^*)}}_{e^G} \leq \underbrace{\frac{A/R}{(1+\gamma)L^* - A^*/R^*}}_{\overline{e}} \leq \underbrace{\frac{\eta^*}{\eta}}_{e^B}$$

where $R = (A + Y_2^N)/\beta Y_1^N$ and $R^* = (A^* + Y_2^{*N})/\beta Y_1^N$.

Proof. In Appendix B.3. □

In Proposition 1, e^G and e^B represent the equilibrium exchange rate when banks operate and when they shut down, respectively. One important point to highlight is that banks' profits make the equilibrium exchange rate lower, which shows that relative wealth matters to determine the strength of a country's currency. In this framework, if a country is relatively wealthier, their currency will appreciate.

Figure 4 provides one example of the schedules derived previously. As explained before, $e(B)$ is increasing in B from a trade balance perspective. An increase in capital outflows towards the US has to be compensated by a stronger trade balance in the EU, which is achieved by a euro depreciation. On the other hand, $\mathcal{B}(e_1)$ is decreasing in e_1. However, if the dollar appreciates beyond $\overline{e}$, market conditions tighten to the point where banks shut down, affecting the EU economy and generating an abrupt contraction in capital flows. In cases in which this negative wealth effect is strong, multiple equilibria can arise. I interpret the "bad" equilibrium with a strong dollar (e^B) and collapsed banks as a financial crisis, and obtain a number of predictions about the behavior of consumption, output, the exchange rate, and capital flows during those events. The next proposition collects these predictions.

Proposition 2. *If there are three equilibria and we compare the two stable ones, we obtain the following predictions about the crisis equilibrium with respect to the standard equilibrium:*

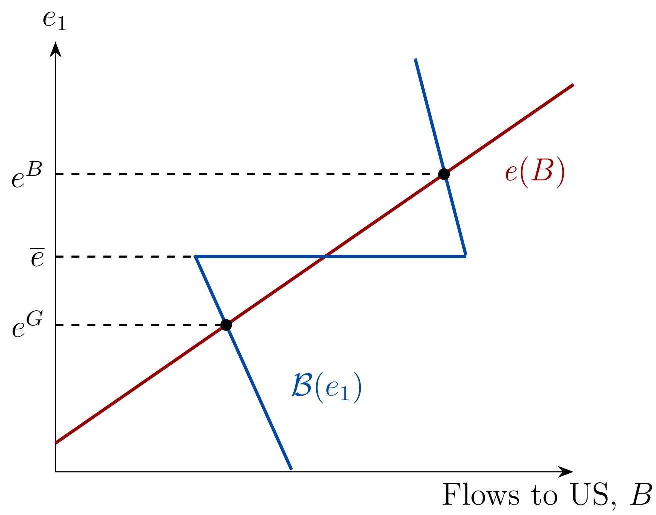


Figure 4: Multiple Equilibria

i. The dollar is more appreciated;

ii. Banks face tighter financial conditions and struggle to roll over their debt;

iii. Global output and relative wealth in the EU are lower;

iv. Net capital flows to the US are larger.

Proof. In Appendix B.4. □

These results are in line with the evidence provided in Section 2 and with other studies that rely on more complex models such as Kekre and Lenel (2021), Eguren-Martin (2020) and Maggiori (2017). A crucial element needed for this mechanism to work is that the exchange rate depreciates when global banks collapse. In the model, this happens because global banks suffer a "sudden stop" during a crisis, which ends up hurting the aggregate demand in the EU and eventually depreciating the euro. In that sense, capital flows to the US increase ($\uparrow B$), meaning that EU households have a higher willingness to save in $t = 1$, in anticipation of the reduction in wealth in the next period.

Self-fulfilling crises. In this context, expectations about e_1 -and the incentives of banks to divert funds- can become self-fulfilling. If households are pessimistic and expect a strong dollar (e_1^B), they will not provide banks with the funding to roll-over their debt, leading to a banking crisis in the EU and the loss of banks' profits in $t = 2$. Given the negative impact on their relative wealth in period 2, EU households cut down consumption in $t = 1$ and increase savings, leading to a euro depreciation, confirming the initial expectations of a high exchange rate. Overall, this mechanism works because agents are atomistic and ignore the consequences that their actions have on aggregate outcomes[20], as it is common in the literature studying self-fulfilling crises.

Importance of fundamentals

Notice that the existence of multiple equilibria depends on the fundamentals of the global economy. For example, when agents are impatient (low β), banks are more likely to divert funds, so that the dollar appreciation that makes banks collapse is even lower. Likewise, if the initial dollar short-term liabilities (L^*) are high, banks are more exposed to fluctuations in the exchange rate. Financial conditions also play a role: if they are tighter (high γ), the impact of an exchange rate depreciation on banks soundness is amplified, making multiple equilibria more possible. To illustrate this, Figure 5 shows two cases when the model features only a unique equilibrium. In panel (a), the "good" equilibrium is the only one possible. On the contrary, in panel (b) only the "bad" equilibrium can materialize. Such a situation is likely if, for example, γ is particularly high and thus $\overline{e}$ shrinks, making global banks less resilient to exchange rate depreciations.

For completeness, panel (a) in Figure 6 shows how different values of γ give rise to the three potential scenarios for the economy. Recall that this parameter can be interpreted as the risk aversion of investors, thus $\overline{e}$ is decreasing in γ, but the values of the exchange rate in equilibrium are unchanged (e^G and e^B). The interesting case that this paper focuses on is one in which $\gamma' < \gamma < \gamma''$ so that the correspondence $\mathcal{C}^e$, which captures the potential values of e_1 in equilibrium, accepts both e^G and e^B as solutions. Panel (b) on the other hand, highlights the role of A^* and L^* on determining the equilibrium. A drop in A^* or an increase in L^* have similar effects: everything else constant, they lower $\overline{e}$ because of the increase in the dollar liquidity needs, and in addition, they increase e^G because of the lower profits of global banks and thus weaker demand from EU households. As a result, $\gamma^{'}$ and $\gamma^{''}$ drop, enlarging the zone in which only the "bad" equilibrium materializes.

4.5. Numerical example

I now present a numerical example of a world economy that is exposed to multiple equilibria. The idea is to illustrate the workings of the model and show how key variables are affected by economic conditions in equilibrium. I will calibrate most of the parameters to match evidence on the euro depreciation during the GFC, the dollar liquidity shortages that banks were exposed to, and the interest rates in both currencies in the run-up to the crisis. Given the simplicity of the model, these numerical exercises are not precise estimates.

[20]The importance of lenders' expectations for global banks is also highlighted in Ivashina et al. (2015), where they can have a significant impact on foreign banks that depend on unsecured short-term dollar funding, in the presence of frictions in the FX forward markets.

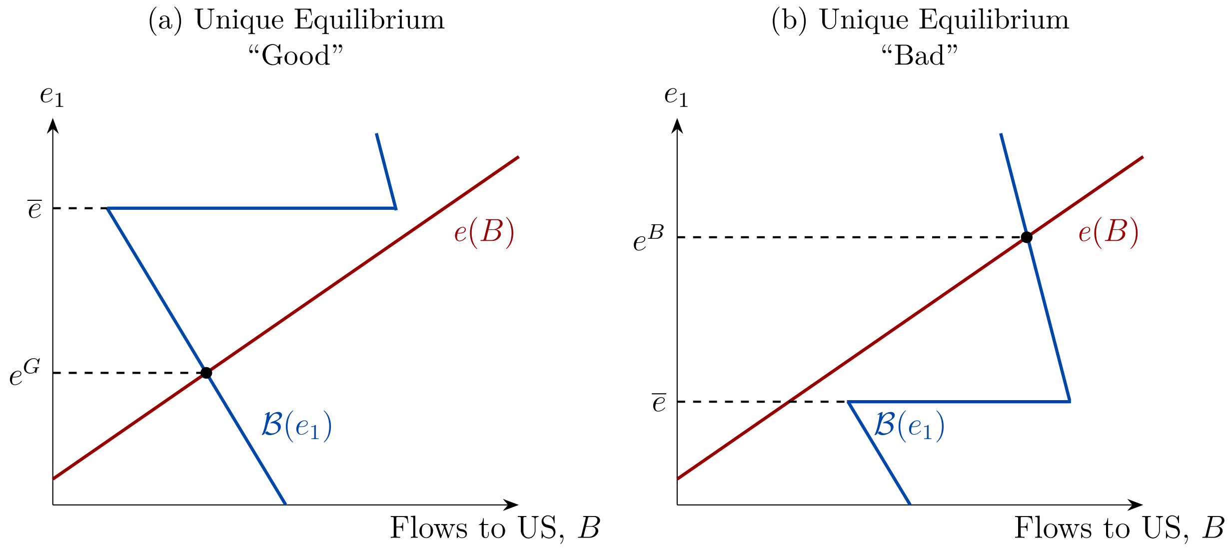


Figure 5: Unique Equilibria

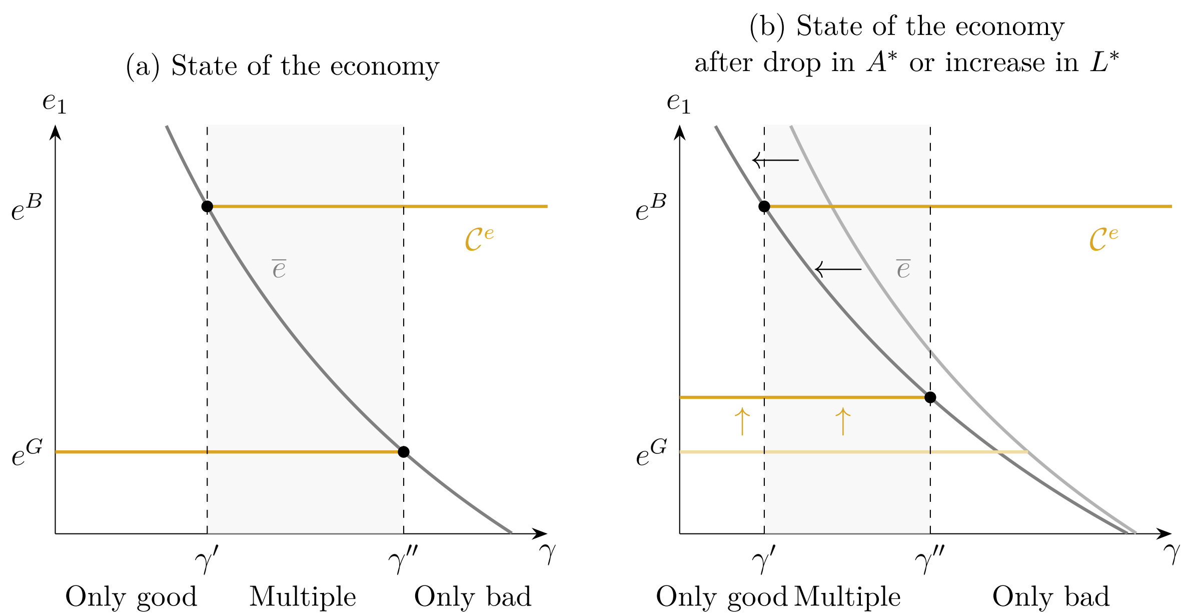


Figure 6: Exchange rate and severity of the financial friction

One period corresponds to one quarter. The period I am particularly interested in modeling is Q4-2008, because this is when the US economy suffered its sharpest quarterly output decline since the late 50's, but the dollar rallied against most currencies, including the euro. Data for the US are retrieved from the U.S. Bureau of Economic Analysis and the Board of Governors of the Federal Reserve System, while data for the EU area comes from Eurostat. BIS is the source for the data on global banks.

The target pre-crisis annualized interest rates in the US and in the EU are 2.5% and 3.5%, respectively. This is meant to capture the low interest rate environment characterizing the world economy in the years preceding the start of the GFC. On the other hand, McGuire and von Peter (2012) estimate that the major European banks' dollar funding gap reached around \$1.2 trillion prior to the GFC. In my model, this is equivalent to setting dollar shortages $(1+\gamma)L^* - A^*/R^*$ to be 15% of total dollar liabilitites, L^*.

The parameters of the model are calibrated to match this data. I follow Gabaix and Maggiori (2015) in setting $\omega = \omega^* = 0.1$ so that non-tradables account for 90% of the consumption basket. I set $\beta = \beta^* = 0.985$ which are relevant to match the interest rates of $R = 1.015$ and $R^* = 1.013$, quarterly. The financial friction is set to $\gamma = 0.64$. The rest of the parameters are set such that countries are very similar: $\eta_1 = 0.47$, $\eta_2 = 0.5$, $Y_1^N = 2.58$, $Y_1^{*N} = 2.55$, $Y_2^N = Y_2^{*N} = 2.5$, $A = .07$, $L = .04$, $A^* = .05$, $L^* = .03$

The results of this exercise are shown in Table 1. This simple model is able to match the behavior of key variables around the GFC, such as the output decline in the EU, the dollar appreciation with respect to the euro, and ex-ante interest rates in both economies. Some relevant untargeted variables such as the drop in EU and US output[21] respond in the expected direction, but they react slightly more drastically in the model compared to what the data suggests.

Finally, based on this simple calibration, Figure 7 shows how the exchange rates, consumption, and gross capital flows react to changes in A^*, in the "good" equilibrium. For the exchange rate, the results are in line with the intuition that larger gross returns on US assets represent higher profits for banks, which in turn increase the relative wealth of EU households. This effect is accommodated by a euro appreciation (or a reduction in the exchange rate) in both periods. As for the distribution of tradable consumption, following the same logic of an increase in EU aggregate demand coming from higher bank profits, C_t^T increases while C_t^{*T} drops. The impact on gross capital flows is in line with the previous results.

[21]The quarterly output drop in the US during Q4-2008 was 2.2%, while it was 1.8% for the EU.

Table 1: Targeted variables

Variable	Description	Target	Model
$\frac{e^H - e^L}{e^L}$	ER depreciation	12.5%	12.5%
	\$ shortage (%)	15%	15%
R^*	US interest rate	1.013	1.013
R	EU interest rate	1.015	1.015

Table 2: Untargeted variables

Variable	Description	Data	Model
$\frac{A^*}{A^*+Y_2^{*N}}$	US output loss	2.2%	2.0%
$\frac{A}{A+Y_2^N}$	EU output loss	1.8%	2.9%

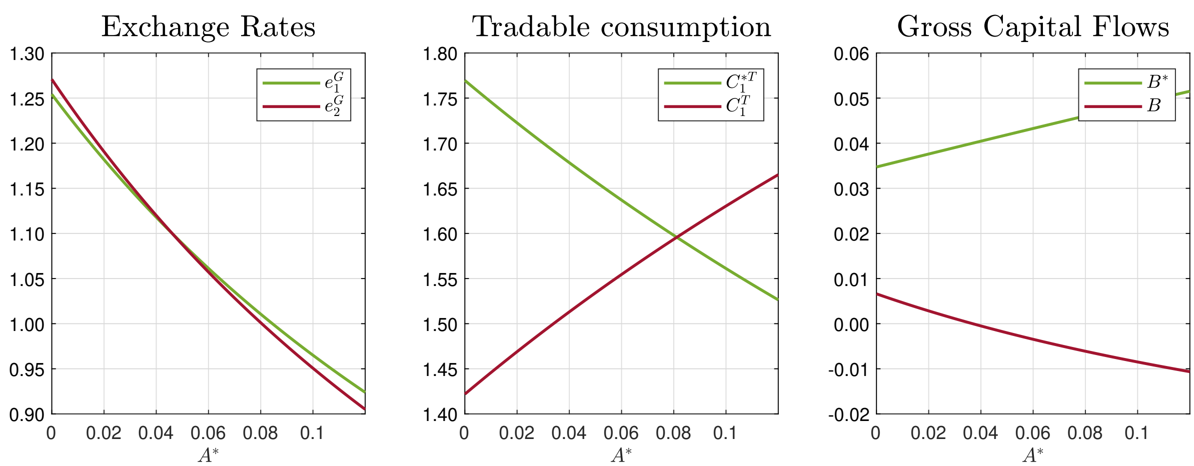


Figure 7: Key variables in the "good" equilibrium

5. Lending of Last Resort

In this section I introduce a government in each economy that intervenes in financial markets in period 1, discuss the motives behind these interventions, and find under what conditions governments can prevent the collapse of global banks.

An economy that is exposed to a "bad" equilibrium driven by pessimistic expectations could usually benefit from the intervention of a benevolent government, a social planner, or in this case, a lender of last resort. I follow Bocola and Lorenzoni (2020) and Gertler and Kiyotaki (2015) in modelling the lender of last resort and introduce a government that can make a transfer S to global banks in period $t = 1$. This transfer is financed by imposing a tax τ on consumers' endowment of non-tradables Y_1^N, which is later transferred back to the households with interests[22] R^S (non-distortionary tax).

Intuitively, the intervention is successful if the lender of last resort has the capacity to provide the liquidity that banks need, so that households rule out the possibility of a banking collapse from their expectations, and are willing to provide banks with deposits. As it is common in these type of models, the intervention might not need to materialize, as long as the government can convince the markets that its commitment to prevent the collapse scenario is credible (Céspedes et al., 2017). Naturally, the credibility of this claim depends on the resources that the government can access.

5.1. Intervention by the ECB

Consider first the case where the central bank in the EU (ECB) acts as the lender of last resort to global banks. This is a starting scenario, where a central bank tries to bail out domestic banks and avoid a collapse of the domestic financial system. For now, I will not motivate this intervention with potential welfare gains, but assume that it is part of the central bank mandate to avoid a financial crisis.

Recall that for simplicity, I set $L = 0$ so that all the initial debt held by banks is denominated in dollars (L^*). The ECB then sets R^S and transfers S to banks such that their profits are

$$\Pi = e_2 A^* + A - R^S S \ ,$$

meaning that the full amount of the initial liabilities in dollars is covered with the transfer

[22] I will not focus on how the interest rate is set, but simply assume that the central bank charges the same interest rate as households would, had they decided to provide the funding.

in euros,

$$e_1 L^* = S \ , \quad \text{where } S = \tau Y_1^N \tag{19}$$

Finally, equation (19) shows that the size of the intervention $\tau Y_1^N = e_1 L^*$ depends, crucially, on the exchange rate. A stronger dollar means that the amount of euros that the ECB needs to cover the initial dollar liabilities from global banks is larger. Naturally, the intervention is limited by the amount of resources in the economy, which in this case is given by Y_1^N. On top of that, I follow Bocola and Lorenzoni (2020) and assume that fiscal capacity is limited[23] in the following way.

Assumption 3. *There is an upper bound on the tax rate that the government can apply for this intervention, such that $\tau \leq \overline{\tau}$.*

As I mentioned previously, in order for the intervention to be successful, agents must believe that the lender of last resort has enough resources to prevent the "bad" equilibrium at all costs. In this framework, that means that the ECB must have enough tax income to cover the banks' dollar liabilities, even in the sate of the world where the dollar is largely appreciated (in other words, when the exchange rate is e_1^B). This comes from the fact that, when a central bank intervenes, it takes the exchange rate as given, even though -eventually- its actions will affect this variable. Considering equation (19) and the tax limit, the next proposition captures this insight.

Proposition 3. *Consider the ECB sets transfers S in euros to cover banks' dollar liabilities L^* and that Assumption 3 holds. These transfers are financed with taxes on EU households' non-tradable endowment such that $S = \tau Y^N$. The intervention will eliminate the "bad" equilibrium if it is credible, which happens when the following condition holds:*

$$\overline{\tau} Y^N > e_1^B L^* = \frac{\eta^*}{\eta} L^* \ .$$

Moreover, if the commitment to intervene is credible, the ECB would not have to intervene to prevent the collapse scenario.

A graphic illustration of the previous proposition is presented in Figure 8. If a fixed tax limit is considered, it is possible to analyze how the fundamentals of the global economy might give rise to unpreventable equilibria, from the perspective of the ECB. Denote $e^{\overline{\tau}}$ as

[23]This can be motivated in many ways. From the point of view of a central bank, this limit could represent a maximum level of inflation that can be tolerated given the massive liquidity injection, or an upper bound to the potential losses that the bank can take given a (very) low default risk.

the maximum exchange rate that the central bank can handle, given $\overline{\tau}$. Consider a "bad" equilibrium such as the one given by the blue and solid red line. Since the exchange rate during a collapse (e^B) is lower than $e^{\overline{\tau}}$, the ECB can effectively prevent the financial crisis from materializing, as shown by the dotted green. Now, for instance, if the endowment of tradables goods (η_1) in the EU is lower, relative prices in that economy will be higher, which leads to an increase in the exchange rate in both equilibria, as shown by the red dotted line. The limitations of the central bank makes a scenario with $e^{B'} > e^{\overline{\tau}}$ unpreventable.

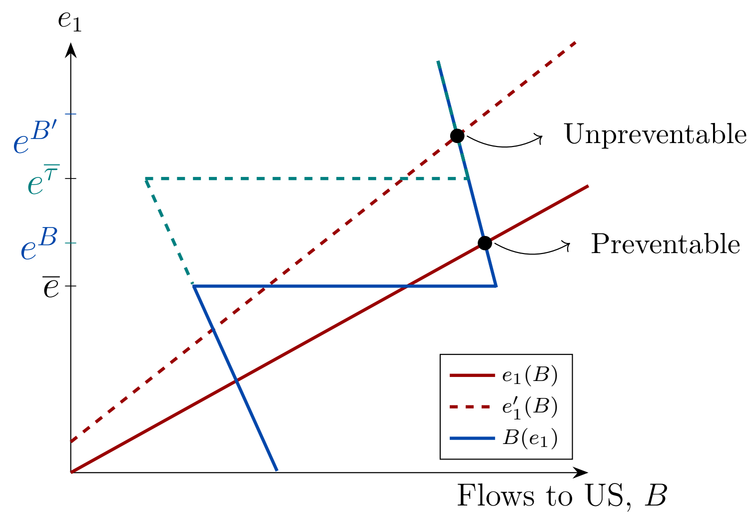


Figure 8: Equilibria under ECB intervention

5.2. Intervention by the Fed (Swap Lines)

Consider now the intervention from the Fed instead of the ECB. In the model, the motivation for the Fed to intervene will come mainly from preventing a collapse of productive investments in the US and a subsequent decline in US non-tradable output in period 2, but a more comprehensive analysis of the welfare implications is left for the next section. The mechanism to intervene is the same as the one described before, but now the Fed is the one transferring resources S^* directly to global banks[24]. This transfer is financed with taxes τ^* on US households' non-tradable output (recall that $Y_1^N = Y_1^{*N}$). An important difference between these two central banks is that one provides euros (EU non-tradable goods), while the other provides dollars (US non-tradable goods). The Fed then transfers S^* dollars to

[24]In practice the transfer from the Fed goes to the foreign central bank, which eventually distributes the resources to the domestic banks. However, in the absence of additional frictions, this would be equivalent to the Fed directly helping foreign banks.

cover banks' dollar liabilities, such that

$$L^* = S^* \ , \quad \text{where } S^* = \tau^* Y^{*N} \ . \tag{20}$$

Equation (20) shows that, unlike the case for the ECB, the size of the intervention $Y^{*N}\tau^* = L^*$ by the Fed does not depend on the exchange rate. This is a key difference with any other central bank in the world. When banks operate, we have that $e_1^G < 1$ so one unit of EU non-tradable goods has more value than one unit of US non-tradable goods, i.e. one *euro* is worth more than one *dollar*.

Nevertheless, during a financial crisis, the situation changes. Whenever banks go bust and the exchange rate appreciates to $e_1^B > 1$, the dollar is stronger than the euro. Again, this is consistent with the evidence shown in Section 2 suggesting a large appreciation of the dollar during a crisis, and is also in line with the "dash-for-dollars" (Cesa-Bianchi and Eguren-Martin, 2021) or "flight-to-safety" (Kekre and Lenel, 2021) phenomena, in which the demand for dollars increase during turbulent episodes. The implications of a weaker euro for the ECB are that now the required intervention is larger than under "good" times. Meanwhile, the required size of the Fed's intervention remains unchanged. To compare the Fed's and the ECB's interventions, I will further assume the following.

Assumption 4. *Both governments face the same tax limit, such that* $\tau, \tau^* \leq \overline{\tau}$.

Considering this, a very particular case might arise: one in which the Fed has the resources to engineer a credible intervention, while the ECB does not. The next proposition summarizes these results and the conditions for this to happen.

Proposition 4. *Consider that Assumption 4 holds, countries receive the same amount of non-tradable endowments* $Y_1^N = Y_1^{*N}$*, and that the exchange rate during a financial crisis is* $e_1^B > 1$*. To be effective, the intervention from the ECB requires setting* $\tau Y^N \equiv e_1^B L^*$*, which is higher than the required tax rate that the Fed has to impose* $\tau^* Y^N = L^*$*. Moreover, only the Fed will be able to eliminate the "bad" equilibrium, if the following condition holds:*

$$\underbrace{\frac{\eta^*}{\eta} L^*}_{\substack{\textit{Liq. needs} \\ \textit{in euros}}} \quad > \quad \underbrace{\overline{\tau} Y^N}_{\substack{\textit{Maximum} \\ \textit{intervention}}} \quad > \quad \underbrace{L^*}_{\substack{\textit{Liq. needs} \\ \textit{in dollars}}}$$

A graphic illustration of this proposition is presented in Figure 9. For any level of exchange rate in the "bad" equilibrium that is below the limit $\overline{\tau} Y^N / L^*$, both the Fed and the ECB can intervene credibly. However, if e_1^B is higher than that limit, we enter a zone in which only the Fed has the resources to prevent a financial crisis.

These results provide a theoretical explanation -in a very reduced form- as to why the Fed provided the required liquidity to non-US banks during the GFC and the Covid-19 crisis, and not the corresponding domestic central banks. In practice, such a massive intervention would have imposed significant costs on them and strained fiscal resources during periods of economic turbulence. Additionally, it is also reasonable to think that an injection of euros from the ECB to bail-out the struggling banks could have triggered an even larger depreciation with respect to the dollar, amplifying the initial shock.

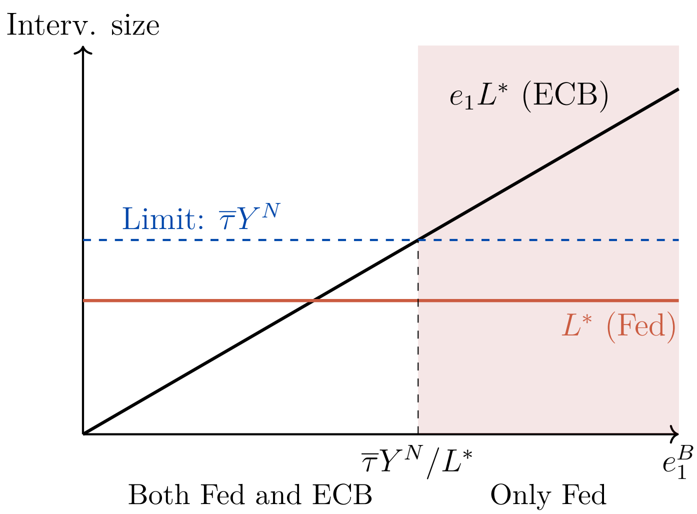


Figure 9: Intervention by Fed and ECB

6. Welfare and Incentives

So far, this paper has described the mechanism through which governments or central banks can bail-out global banks, without much discussion about the incentives behind these interventions. I will shed light on this crucial aspect by focusing on the welfare implications from converging to each of the stable equilibria featured in the model.

6.1. Consequences of a financial crisis

Denote with a subscript G variables in the "good" equilibrium, and with B those in the "bad" one. Welfare losses from the collapse of global banks are given by the difference between the utility of households in both scenarios,

$$U_G - U_B = (1-\omega)\beta \underbrace{\ln\left(\frac{A + Y_2^N}{Y_2^N}\right)}_{NT \text{ goods}} - \omega \underbrace{\sum_{t=1}^{2} \beta^{t-1} \ln\left(\frac{C_{B,t}^T}{C_{G,t}^T}\right)}_{T \text{ goods}} \tag{21}$$

$$U_G^* - U_B^* = (1-\omega)\beta^* \underbrace{\ln\left(\frac{A^* + Y_2^{*N}}{Y_2^{*N}}\right)}_{NT^* \text{ goods}} - \omega \underbrace{\sum_{t=1}^{2} \beta^{*t-1} \ln\left(\frac{C_{B,t}^{*T}}{C_{G,t}^{*T}}\right)}_{T^* \text{ goods}} \tag{22}$$

The consequences of a financial crisis can be broken down into two groups. First, there are direct effects coming from the forced liquidation of US and EU long-term assets. Both countries suffer from the loss of productive investments that would otherwise boost the availability of non-tradable goods in $t = 2$. In that sense, C_2^N and C_2^{*N} shrink by A and A^*, respectively. These direct effects are captured by the first term in (21) and (22).

On the other hand, there are financial losses to consider. EU households lose the potential profits that global banks would have earned, while US households lose the deposits they initially held with these banks. Therefore, from a partial equilibrium perspective, both economies are impacted negatively when EU banks fail. However, there are large general equilibrium forces that determine the distribution of tradable consumption between countries. As Section 4 showed, when a crisis hits, capital flows to the US increase, and the dollar appreciates. This allows US households to consume more tradables. On the contrary, the relative wealth of EU households drops from the collapse of global banks, which limits the amount of tradable goods they can consume. These effects are captured by the second term in (21) and (22). Importantly, they reduce welfare losses for US households, but amplify them in the case of EU households.

To fully understand the strength of these general equilibrium effects and how they impact consumption, it is worth decomposing C_1^{*T} as follows:

$$C_1^{*T} = Y_1^{*T} - \underbrace{\frac{1}{p_1^*}}_{\substack{\text{Price}\\\text{effect}}} \cdot \underbrace{B^*}_{\substack{\text{Flows}\\\text{effect}}} + \underbrace{\frac{1}{p_1^*} \cdot L^*}_{\substack{\text{Deposits}\\\text{effect}}} \tag{23}$$

Equation (23) shows that, in case of a collapse, the loss of L^* reduces the disposable income that US households can allocate to consumption. But on the other hand, they experience larger capital inflows ($\downarrow B^* < 0$), and lower relative prices ($\downarrow p_1^*$) from the appreciation of the dollar. Overall, these two effects lead two an increase in C_1^{*T}. In period 2, C_2^{*T} increases as well during a crisis, mostly because of the drop in interest rates $\downarrow R^*$.

If we put these effects together, it is possible to draw some interesting conclusions. On one hand, preventing the collapse of EU-owned global banks is always beneficial for the EU, since they consume fewer non-tradable and tradable goods in the "bad" equilibrium, compared to the "good" one. On the other hand, the US faces two opposite forces going in different directions. US households are negatively affected by the loss of non-tradable goods, but this is mitigated by the gain from higher consumption of tradable goods, coming from lower relative prices and a stronger dollar due to weaker demand in the EU.

6.2. Trade-off for the Fed

Whether US households experience an overall welfare gain or loss when global banks collapse will depend on the parameters of the model. Before analyzing the conditions under which this happens, I will relax one last assumption to further emphasize the general equilibrium forces at play. In particular, I assume the following.

Assumption 5. *When global banks collapse, depositors recover a fraction $0 \leq \phi \leq 1$ of their pre-existing positions. In that case, EU households (owners of the banks) have to cover those costs.*

This is not crucial for any of the normative analysis done before. However, it leads to a higher exchange rate under the collapse scenario[25], since the negative impact on EU households' relative wealth is now larger. Considering Assumption 5, the following proposition collects the parameters that determine the welfare implications for the US.

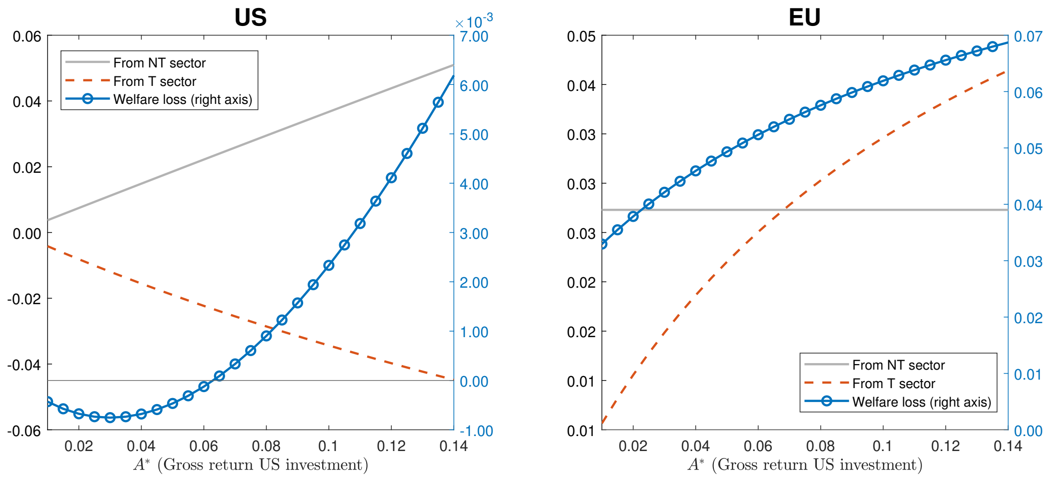
Proposition 5. *Comparing the utility obtained by households under the "good" and the "bad" equilibria, EU households always experience a welfare loss ($U_G - U_B > 0$). On the contrary, US households might benefit from higher tradable consumption, but face lower consumption from non-tradable goods. Overall, the Fed will lack the incentives to intervene and provide the liquidity required to foreign global banks if ($U_G^* - U_B^* < 0$), which happens if:*

$$\tfrac{(1-\omega)\beta^*}{\omega(1+\beta^*)} \ln\left(1 + \frac{A^*}{Y_2^{*N}}\right) < \ln\left(\frac{1 + \beta^* + \frac{1-\omega}{\omega}\left(\frac{A^*\beta^*}{A^*+Y_2^{*N}} - L^*\right)}{1 + \beta^* - \frac{1-\omega}{\omega}\phi L^*}\right)$$

Two parameters are key for this condition to hold. First, since ϕ measures the fraction of their initial deposits that US households recover after a collapse, it is natural that a higher

[25]In particular, the exchange rate in the "bad" equilibrium becomes $e^B = \dfrac{\eta^*}{\eta - \frac{1}{1+\beta}\frac{1-\omega}{\omega}\phi L^*}$.

Figure 10: Welfare Losses



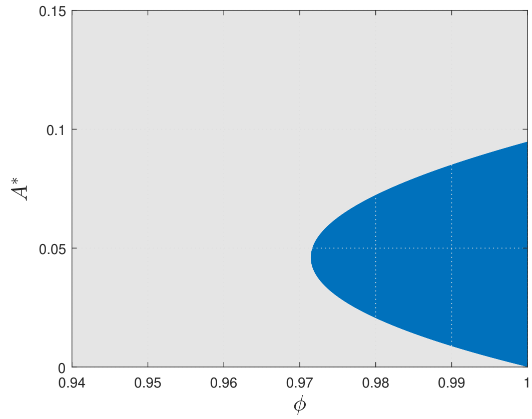
Note: Considers the parameter values described in Section 4, and $\phi = 1$.

ϕ reduces the incentives of the Fed to bail out foreign banks. The second key parameter is the gross return on US assets, A^*. On one hand, keeping everything else constant, a higher A^* represents an increase in banks' profits and therefore a positive wealth effect on EU households, which discourages the Fed from intervening. On the other hand, it also increases the supply of non-tradable goods in the US, which benefits US households.

To give a better idea of this trade-off I provide a simple numerical example of (21) and (22) using the calibration from Section 4. To focus first on the impact of A^*, I set $\phi = 1$. From Figure 10 it is straightforward to see that, for US households, the loss from the lower consumption of non-tradables is increasing in A^*. On the contrary, the benefits coming from lower prices are decreasing in A^* because of its effects on the equilibrium exchange rate. EU households on the other are impacted negatively from both sides, and thus welfare losses are increasing in both components. The main takeaway from here is that, as long as the investment from non-US global banks in US assets A^* is large enough and provide a significant boost to the US economy, the Fed will have incentives to act as the international lender of last resort.

Finally, let us examine the impact of ϕ on this trade-off. The idea is to see if there is a scenario where the Fed chooses not to extend the swap lines, even if US households recover only a fraction $\phi < 1$ of their initial deposits L^*. Figure 11 plots, in the shaded area, all pairs of A^* and ϕ that result in welfare gains for the US when a financial crisis hits. In line with the intuition, the incentives of the Fed to intervene are smaller if the investment of these banks on US assets is low, and if US households expect to recover a large portion ($> 97\%$) of their initial deposits.

Figure 11: Pairs of A^* and ϕ
and Fed's incentives to intervene



Note: The blue area represents the combination of parameters for which the Fed decides not to intervene.

7. Conclusions

In this paper I develop a framework to study the global macroeconomic implications of the Fed's swap lines to foreign central banks in times of crisis. Non-US global banks act as "bankers of the world" by intermediating flows between the US and the rest of the world in their respective currencies, and investing in dollar-denominated assets. However, given pre-existing balance sheet imbalances and financial constraints, they can be exposed to exchange rate fluctuations. Therefore, a significant dollar appreciation could lead to a banking crisis, generating a drop in the aggregate demand and a further currency depreciation in the rest of the world. I argue that this mechanism opens the door to self-fulfilling crises driven by pessimistic expectations.

In this context, the world economy can benefit from a lender of last resort. However, in a state of the world where the dollar is strong relative to other currencies, and given the size of the balance sheets of global banks, non-US central banks without significant dollar reserves might lack the resources to prevent the "bad" equilibrium. The Fed, on the other hand, can intervene by providing dollar liquidity directly. Nevertheless, its incentives to bail out foreign global banks might not be in line with the interests of the rest of the world. The reason is that there are general equilibrium forces at play that could benefit the US and mitigate the consequences of a global financial crisis on their economy.

I believe this framework represents a useful starting point to think about the macroeconomic implications and incentives around the US as the international lender of last resort. However, there are still many aspects left to explore. An exciting avenue that I am currently working on is to understand the moral hazard issues that could arise from such an intervention, not only for the US, but also for the receiving countries. Ultimately, addressing these issues is crucial for examining the future of the dollar's global dominance and the risks that threaten it, as well as determining the steps the US can take to mitigate those risks and maintain the confidence in the dollar.

Appendix

A. Additional Stylized Facts

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

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

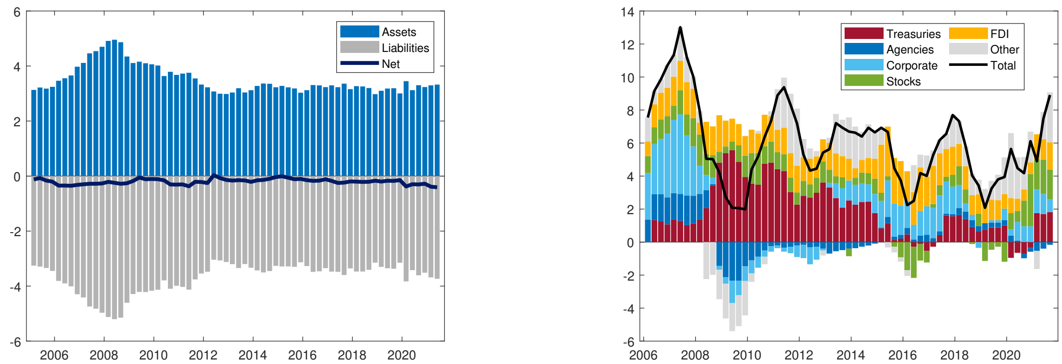


Figure A.1: Dollar assets of non-US banks

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

(b) Money Market Funds funding ($ trillions)

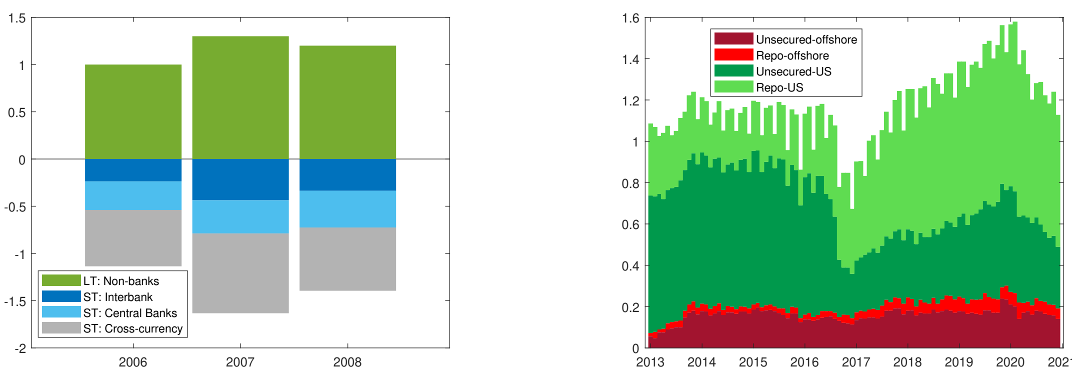


Figure A.2: Dollar funding of non-US global banks

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).

B. Proofs and derivations

B.1. Derivation of Equation 17

From the households' optimality conditions we obtain that $p_t C_t^T = \frac{\omega}{1-\omega} C_t^N$ and $p_t^* C_t^{*T} = \frac{\omega}{1-\omega} C_t^{*N}$. Now consider the tradable market clearing condition,

$$C_t^T + C_t^{*T} = Y_t^T + Y_t^{*T}$$

and multiply both sides of the equation by p_t. Combining all these expression, the market clearing condition for non-tradable goods, and the law of one price $e_t p_t^* = p_t$, we get the following expressions for the price of tradable goods in both periods:

$$p_1 = \tfrac{\omega}{1-\omega} \frac{1}{Y_1^T + Y_1^{*T}} \left[Y_1^{*N} e_1 + Y_1^N \right] \tag{24}$$

$$p_2 = \tfrac{\omega}{1-\omega} \frac{1}{Y_2^T + Y_2^{*T}} \left[e_2 C_2^{*N} + C_2^N \right] . \tag{25}$$

Finally, using the simplifying assumption that $Y_1^{*N} = Y_1^N = 1$, and combining (24) with the households' optimality condition and the trade balance in period 1 given by $p_1(Y_1^T - C_1^T) = B$, we get

$$e_1 = \frac{\eta_1^*}{\eta_1} + B \frac{1-\omega}{\omega} \frac{1}{\eta_1} ,$$

where $\eta_1 \equiv \frac{Y_1^T}{Y_1^T + Y_1^{*T}}$ and $\eta_1^* \equiv 1 - \eta_1$.

B.2. Proof of Lemma 3.1

Lemma 3.1. *Suppose that Assumption 1 holds. A necessary condition for all banks to operate in equilibrium is,*

$$e_1 \leq \frac{A/R - (1+\gamma)L}{(1+\gamma)L^* - A^*/R^*} \equiv \bar{e} ,$$

where $R = (Y_2^N + A)/\beta Y_1^N$ *and* $R^* = (Y_2^{*N} + A^*)/\beta^* Y_1^{*N}$.

Proof. Let us consider condition (13) expressed in terms of e_1,

$$\frac{A}{R} + e_1 \frac{A^*}{R^*} \geq (1+\gamma)(L + e_1 L^*)$$

It is straightforward to see that an increase in e_1 will increase both the left-hand-side (LHS) and the right-hand-side (RHS) of the previous inequality. However, under Assumption 1, the LHS increases at a slower rate (A^*/R^*) than the RHS $((1+\gamma)L^*)$. Therefore, $\exists e_1$ large enough such that the inequality no longer holds.

Next, if we further assume that $A/R > (1+\gamma)L$, that value is positive. Combining these two facts, we can conclude that all banks will be able to operate only if e_1 is below a certain threshold. $\square$

B.3. Proof of Proposition 1

Proposition 1. *Suppose that Assumption 1 holds, $\eta_t = \eta\ \forall t$, and let $\bar{e}$ be the value of e_1 that makes condition (13) hold with equality. Then, multiple equilibria are possible if*

$$\underbrace{\frac{\eta^*}{\eta + \frac{1}{1+\beta}\frac{1-\omega}{\omega}(A^*/R^* - L^*)}}_{e^G} \leq \underbrace{\frac{A/R}{(1+\gamma)L^* - A^*/R^*}}_{\bar{e}} \leq \underbrace{\frac{\eta^*}{\eta}}_{e^B}$$

where $R = (A + Y_2^N)/\beta Y_1^N$ and $R^* = (A^* + Y_2^{*N})/\beta Y_1^N$.

Proof. Let us consider the first inequality. It follows from the proof of Lemma 3.1 that $e^G < \bar{e}$ is a necessary condition for the "good" equilibrium to exist. The second inequality states that $\bar{e} < e^B$ for the "bad" equilibrium to exist.

Assume that such equilibrium exists even if $e^B < \bar{e}$. In that case, and given that households have perfect foresight, it must be that they expected e^B, and decided not to provide the funds to global banks, leading to their collapse. However, this contradicts households' rationality. The reason is that, since they use the exchange rate as a coordination device, if they expected an exchange rate that would not violated the incentive compatibility constraint of banks, they would have given them the funds they need, avoiding the collapse. It follows that $\bar{e} < e^B$ in order for the "bad" equilibrium to exist. $\square$

B.4. Proof of Proposition 2

Proposition 2. *If there are three equilibria and we compare the two stable ones, we obtain the following predictions about the crisis equilibrium with respect to the standard equilibrium:*

i. The dollar is more appreciated;

ii. Banks face tighter financial conditions and struggle to roll over their debt;

iii. Global output and wealth in the EU are lower;

iv. Net capital flows to the US are larger.

Proof. The proof for each item in the proposition will be provided separately.

i. Follows from the conditions in Proposition 1: $e_1^B > e_1^G$.

ii. Follows from the fact that banks collapse in the "bad" equilibrium.

iii. When banks do not operate, non-tradable output in the US is simply given by the endowments in both periods, $Y_1^{N*} + Y_2^{N*}$. On the contrary, if US assets owned by global banks materialize, non-tradable output in the US increases to $Y_1^{N*} + Y_2^{N*} + A^*$. The equivalent occurs in the EU. As for wealth in the EU, they experience higher relative prices ($e_1^B > e_1^G$) and they lose banks profits $\Pi > 0$ when a crisis hits. This represents lower relative wealth.

iv. Consider equation (17) and rearrange it in terms of e_1,

$$B = \frac{\omega}{1-\omega}\left(\eta_1(1+e_1) - 1\right) \ .$$

From the previous equation, since $e_1^B > e_1^G$, it must be that $B^B > B^G$, meaning that capital flows to the US in the "bad" equilibrium are larger that in the "good" one.

□

B.5. Proof of Proposition 3

Proposition 3. *Consider the ECB sets transfers S in euros to cover banks' dollar liabilities L^* and that Assumption 3 holds. These transfers are financed with taxes on EU households' non-tradable endowment such that $S = \tau Y^N$. The intervention will eliminate the "bad" equilibrium if it is credible, which happens when the following condition holds:*

$$\overline{\tau} Y^N > e_1^B L^* = \frac{\eta^*}{\eta} L^* \ .$$

Moreover, if the commitment to intervene is credible, the ECB would not have to intervene to prevent the collapse scenario.

Proof. The liquidity needs from global banks $e_1 L^*$ have to be cover by euro transfers from the ECB, thus

$$e_1 L^* = S \tag{26}$$

Moreover, these transfers are funded by taxes on EU households non-tradable endowment, thus

$$\tau Y_1^N = S \tag{27}$$

Combining (26) and (27), we get that $e_1 L^* = \tau Y_1^N$. Since τ is increasing in e_1, and given the upper bound on the tax rate, $\tau < \overline{\tau}$, the intervention will eliminate the "bad" equilibrium if it is credible, which happens when the following condition holds, $\overline{\tau} < e_1^B L^*/Y_1^N$. $\square$

B.6. Proof of Proposition 4

Proposition 4. *Consider that Assumption 4 holds, countries receive the same amount of non-tradable endowments $Y_1^N = Y_1^{*N}$, and that the exchange rate during a financial crisis is $e_1^B > 1$. To be effective, the intervention from the ECB requires setting $\tau Y^N \equiv e_1^B L^*$, which is higher than the required tax rate that the Fed has to impose $\tau^* Y^N = L^*$. Moreover, only the Fed will be able to eliminate the "bad" equilibrium, if the following condition holds:*

$$\underbrace{\frac{\eta^*}{\eta} L^*}_{\substack{\textit{Liq. needs}\\ \textit{in euros}}} \quad > \quad \underbrace{\overline{\tau} Y^N}_{\substack{\textit{Maximum}\\ \textit{intervention}}} \quad > \quad \underbrace{L^*}_{\substack{\textit{Liq. needs}\\ \textit{in dollars}}}$$

Proof. To be effective, the intervention from the ECB requires setting $\tau = e_1^B \frac{L^*}{Y_1^N}$, while the Fed requires setting $\tau^* = \frac{L^*}{Y_1^N}$. Since $e_1^B = \eta^*/\eta > 1$, then $\tau = e_1^B \tau^* > \tau^*$. $\square$

B.7. Proof of Proposition 5

Proposition 5. *Comparing the utility obtained by households under the "good" and the "bad" equilibria, EU households always experience a welfare loss ($U_G - U_B > 0$). On the contrary, US households might benefit from higher tradable consumption, but face lower consumption from non-tradable goods. Overall, the Fed will lack the incentives to intervene and provide the liquidity required to foreign global banks if ($U_G^* - U_B^* < 0$), which happens if:*

$$\tfrac{\theta\beta^*}{(1-\theta)(1+\beta^*)} \ln\left(1 + \frac{A^*}{Y_2^{*N}}\right) < \ln\left(\frac{1 + \beta^* + \frac{\theta}{1-\theta}\left(\frac{A^*\beta^*}{A^* + Y_2^{*N}} - L^*\right)}{1 + \beta^* - \frac{\theta}{1-\theta}\phi L^*}\right)$$

Proof. EU households' welfare is given by the consumption of tradable and non-tradable goods in both periods:

$$\mathcal{U} = (1-\omega)\ln(C_1^N) + \omega \ln(C_1^T) + \beta(1-\omega)\ln(C_2^N) + \beta\omega \ln(C_2^T)$$

Using the fact that non-tradable consumption is the same under the collapse and the normal scenario in $t = 1$, and the households' first order condition $C_t^T = C_t^N \frac{\omega}{1-\omega}\frac{1}{p_t}$, the welfare loss is given by

$$\Psi \equiv U_G - U_B = \underbrace{(1-\omega)\beta \ln\left(\frac{A + Y_2^N}{Y_2^N}\right)}_{NT \text{ goods}} - \underbrace{\omega \sum_{t=1}^{2} \beta^{t-1} \ln\left(\frac{C_{B,t}^T}{C_{G,t}^T}\right)}_{T \text{ goods}} \tag{28}$$

Now, notice that in equilibrium, tradable consumption across countries is determined by e_t as follows:

$$C_1^{*T} = (Y_1^T + Y_1^{*T})\frac{e_1}{1+e_1} \qquad C_1^T = (Y_1^T + Y_1^{*T})\frac{1}{1+e_1} \tag{29}$$

$$C_2^{*T} = (Y_2^T + Y_2^{*T})\frac{e_2 C_2^{*N}}{C_2^N + e_2 C_2^{*N}} \qquad C_2^T = (Y_2^T + Y_2^{*T})\frac{C_2^N}{C_2^N + e_2 C_2^{*N}} \tag{30}$$

The previous equations show that, the higher the exchange rate (stronger dollar), the fewer tradables the EU consumes in equilibrium. Since $e_t^B > e_t^G$, we will have that $C_{B,t}^{*T} > C_{G,t}^{*T}$ while $C_{B,t}^T < C_{G,t}^T$. Therefore, $U_G - U_B > 0$.

For the US, welfare losses are as follows:

$$\Psi \equiv U_G^* - U_B^* = \underbrace{(1-\omega)\beta^* \ln\left(\frac{A^* + Y_2^{*N}}{Y_2^{*N}}\right)}_{NT^* \text{ goods}} - \underbrace{\omega \sum_{t=1}^{2} \beta^{*t-1} \ln\left(\frac{C_{B,t}^{*T}}{C_{G,t}^{*T}}\right)}_{T^* \text{ goods}} \tag{31}$$

Now, from Proposition 1 we have already established that

$$e_1^G = \frac{\eta^*}{\eta + \frac{1}{1+\beta}\frac{1-\omega}{\omega}(A^*/R^* - L^*)} \ ,$$

while in the case of e_1^B, considering that $\phi \leq 1$, we get

$$e_1^B = \frac{\eta^*}{\eta - \frac{1}{1+\beta}\frac{1-\omega}{\omega}\phi L^*} \ .$$

Replacing the values of e_1^G and e_1^B into (29) and (30), and then into (31), combined with the UIP condition $R = R^* \dfrac{e_2}{e_1}$, yields the inequality in Proposition 5.

□

C. Tradable goods: in profits and in the intervention

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.

C.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

$$\Pi = e_2 A^* + a + p_2 T - e_2 R^* B^* - RB \tag{32}$$

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 (13), so that the necessary condition for banks to operate becomes:

$$e_1 \frac{1}{R^*} \underbrace{\left[A^* + \frac{T(A^* + Y_2^{*N})}{(Y_2^T + T + Y_2^{*T})} \frac{\omega}{1-\omega} \right]}_{W^*} + \frac{1}{R} \underbrace{\left[a + \frac{T(A + Y_2^N)}{(Y_2^T + T + Y_2^{*T})} \frac{\omega}{1-\omega} \right]}_{W} > (1+\gamma) e_1 L^* \tag{33}$$

Then, the exchange rate that makes (33) 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.

C.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,

$$\tau^T p_1 Y_1^T > e_1^B L^* \tag{34}$$

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 (34), 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.

D. 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

$$\frac{1}{P_{T,t}} = \frac{1-\omega}{\omega}\left(\frac{C_{T,t}}{C_{N,t}}\right)^{1/\rho} \tag{35}$$

$$U_N'(C_t) = \beta R E\{U_N'(C_{t+1})\} \tag{36}$$

$$\text{where } U_N' \equiv C_t^{\frac{\rho-1}{\rho}-\frac{1}{\sigma}}(1-\omega)C_{N,t}^{-\frac{1}{\rho}}$$

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:

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

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

E. 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 $\overline{e}$:

$$\overline{e} \equiv \frac{A/R}{(1+\gamma)L^* - A^*/R^*} = \frac{A \cdot \beta m_t / m_{t+1}}{(1+\gamma)L^* - A^* \cdot \beta^* m_t^* / m_{t+1}^*} \ . \tag{37}$$

From (37) it is possible to see that $\downarrow m_t^* \rightarrow \uparrow R^* \rightarrow \downarrow \overline{e}$.

F. Access to dollar bonds

In this Appendix I extend the standard model in the following ways. First, I allow households in the EU and in the US to trade *dollar*-denominated bonds with each other and without the need for intermediation. From the perspective of the US, in principle these bonds are equivalent to the bonds offered by global banks. For EU households, however, this implies that they have access to bonds in their domestic and in foreign currency.

I also 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 (2021), my model features money-in-utility with foreign currency, by assuming that the non-pecuniary cost affects the utility of EU households directly. I will show that in equilibrium, this cost could be interpreted as the negative impact of a banking crisis, from the perspective of the domestic country.

The reason I introduce these extensions is to better rationalize the patterns of capital inflows to the US during the GFC and the Covid-19 crisis. Even though this is not needed to demonstrate how the basic mechanism of the model opens the door to multiple equilibria, the dynamics of capital flows are relevant to fully understand the trade-offs that the Fed face when acting as the international lender of last resort. Intuitively, when banks are operating and the exchange rate is low, EU households prefer to trade euro-denominated bonds rather than paying the non-pecuniary cost and saving in dollars. When banks collapse, their only savings vehicle are the dollar bonds. Given the negative wealth shock to which these households are exposed, and the consequent drop in aggregate demand, they will tend to increase savings in the form of a higher demand for dollar bonds.

F.1. EU households' problem

Given the extensions discussed previously, EU households face now a similar but more complex problem:

$$\max_{C_t} \quad U = \ln(C_0) + \beta \mathbb{E} \ln(C_1) - \zeta(\widetilde{B}) \tag{38}$$

subject to the budget constraint in both periods,

$$p_1 Y_1^T + Y_1^N = p_1 C_1^T + C_1^N + B + e_1 \widetilde{B} \tag{39}$$

$$\Pi + RB + e_2 R^* \widetilde{B} + p_2 Y_2^T + Y_2^N = p_2 C_2^T + C_2^N \ . \tag{40}$$

This problem shows that now they have access to euro deposits 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:

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

In addition to the changes to the EU households' problem, I will allow the share of tradable endowment in EU to change over time. As in the previous section, let $\eta_t \equiv \frac{Y_t^T}{Y_t^T + Y_t^{*T}}$. Now, instead of setting $\eta_1 = \eta_2$ as a simplifying assumption, I will focus on the case where $\eta_1 > \eta_2$. This parametrization will generate positive net capital flows to the US during a crisis, which can be seen empirically and is the focus of this section.

F.2. Multiple equilibria

Normal times

The equilibrium under "normal" times will be similar to the one in the standard model, with the small difference in the parameter η_1. The reason for the similarity is that when the financial frictions do not bind, households prefer to trade bonds in their own currency and avoid the non-pecuniary cost of holding balances in foreign currency. This will be the case for any $\chi > 0$. In particular, if I set $\chi \to \infty$, the model converges back to the standard version, since EU households would not demand any dollar bonds, even if banks collapse. I will assume for this section that χ is small enough so that EU households find it optimal to trade dollar bonds if banks collapse.

In this state of the world, the equilibrium exchange rate is then

$$e_1^{L'} = \frac{1 - \eta_1 + \beta(1 - \eta_2)}{\eta_1 + \beta\eta_2 + \frac{1-\omega}{\omega}\frac{1}{Y_1^N}(\frac{A^*}{R^*} - L^*)} \tag{41}$$

while by the UIP condition $e_2^{L'} = e_1^{L'}\frac{R}{R^*}$. Under a similar parametrization as for the standard model, this is also a stable equilibrium such that $e_1^{L'} < \bar{e}$. The capital flows to the US (in euros) in this case are again given by $B = e_1^{L'}(B^* - L^*) < 0$.

Collapse

I will focus now on the case when banks go bust. Most of the equations presented so far still apply to this case, except for a few that I present here. The EU households' euler equation, for example, becomes

$$p_2 C_2^T = \beta R^* \frac{e_2}{e_1} p_1 C_1^T \ . \tag{42}$$

Combining (42) with the usual euler condition of the US households gives an expression for the exchange rate in period 2 in terms of the exchange rate in period 1:

$$e_2 = e_1 \frac{Y_1^{*N}}{Y_2^{*N}} \tag{43}$$

This equation substitutes the UIP condition (14) that emerges when banks operate. It is important to mention that, since $A^* \to 0$ in this scenario, $R^* = \frac{Y_2^{*N}}{\beta^* Y_1^{*N}}$ which is lower than the dollar interest rate when banks operate. Moreover, contrary to the case in the standard framework, the exchange rate in period 1 is affected by the intertemporal decisions of the households even in the collapse scenario. As explained before, a negative wealth shock in the future leads EU households to save more (or borrow less) and drop consumption in period 1, which is accommodated by an increase in the price of tradables p_1 and thus a euro depreciation ($\downarrow e_1$). These dynamics are captured by the corresponding budget constraints,

$$e_1\widetilde{B} = p_1(Y_1^T - C_1^T) \tag{44}$$

$$e_2R^*\widetilde{B} = p_2(C_2^T - Y_2^T)\ . \tag{45}$$

Using (43), (44), (45) and the households' optimality conditions, it is possible to find the exchange rate under the collapse scenario $e_0^{H'}$ as follows

$$e_1^{B'} = \frac{1 - \eta_1 + \beta(1 - \eta_2)}{\eta_1 + \beta\eta_2} \tag{46}$$

which is equivalent to $e_1^{L'}$ considering that $A^*, L^* \to 0$ when banks collapse. On the other hand, $e_1^{B'} = e_2^{B'}$. In order for this to be an equilibrium, it must be that $e_1^{B'} > \overline{e}$.

Turning now to the capital flows, in the standard model it was shown that the exchange rate e_1^B was the one that cleared the market of tradables such that both countries were running balanced current accounts. It is possible to rewrite equation (44) in terms of the exchange rate to see this clearly,

$$\widetilde{B} = \frac{\omega}{1-\omega}Y_1^N\left(\frac{\eta_1(1+e_1) - 1}{e_1}\right)$$

where $\widetilde{B} = 0$ if and only if $e_1 = e_1^B$. Considering this, to generate positive capital flows to the US during a collapse it must be that $e_1^{B'} > e_1^B$, which can be achieved with the following condition

$$\eta_1 > \eta_2\ .$$

The fact that EU tradable endowment is relatively lower in period 2 will force EU households to transfer more resources from period 1 and increase their demand for dollar bonds. Ultimately, US households benefit from this as they have access to "cheap" funding from abroad. These dynamics will eventually be reflected in prices, meaning that if one country has more affordable access to funding to buy a certain good, the price of that good should be lower in that country.

G. Fragility and dollar funding

In this section I will extend the simple model presented in the paper for two main reasons. First, I will relax some of the simplifying assumptions imposed in the main body of the paper for tractability to show that the key results hold under a more general setting. Second, I want to study the equilibrium determination of banks' assets and liabilities, since this is key for the analysis of a global financial crisis. Similarly to Bocola and Lorenzoni (2020), my main objective here is to show that even though non-US global banks can choose ex-ante whether to denominate their debt in euros or in dollars, this does not rule out the possibility of multiple equilibria. In other words, despite a maturity mismatch in dollars opens the door to a "bad" equilibrium, banks do not necessarily have sufficient ex-ante incentives to reduce their exchange rate exposure.

In terms of the model, the idea of this section is to endogeneize key variables for the determination of the equilibria, such as the banks' liabilities L and L^*, and also their investments A and A^* in both currencies. Particularly, I want to show that -under certain circumstances- it is rational for banks to take dollar and euro positions such that

$$e_1^G \leq \underbrace{\frac{A/R - (1+\gamma)L}{(1+\gamma)L^* - A^*/R^*}}_{\overline{e}} \leq e_1^B \ , \tag{47}$$

which is the condition for the existence of multiple equilibria.

G.1. Extended model

The extended model features a very similar environment as the simple one, with a few important additions. There are now three periods, such that $t \in \{0, 1, 2\}$. In period 0, banks will face two decisions: 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 1 unit of EU and US NT goods in period $t = 0$ into r and r^* units in $t = 2$, respectively.

An important difference with the simple model is that now I introduce a sunspot variable ξ that coordinates agents' expectations. It is realized at the beginning of $t = 1$, and takes two values

$$\xi = \begin{cases} 1 & \text{with prob. } 1-\rho \\ 0 & \text{with prob. } \rho \end{cases}$$

If $\xi = 0$, agents have pessimistic expectations, households do not provide the required liquidity to banks, so they are unable to roll-over their debt and collapse. On the other hand, if $\xi = 1$, agents are optimistic and banks are able to raise the liquidity needed to operate. The probability ρ will be determined by banks' fragility, as will be discussed in the next section.

G.1.1. Households

Households now consume in $t = 0$ as well, and decide how much to save. They receive endowments of tradables and non-tradables as in the other periods. The budget constraint for EU households is

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

Importantly, the interest rate on their euro bonds B_1 might take two values, depending on the sate of the economy. US households face a similar problem, and the interest rate on their dollar bonds B_1^* also depends on the state of the economy. We can express both conditions jointly as

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

To shed more light on the interest rates that will help pin down our variables of interest B_1 and B_1^*, we turn to the households' Euler equation. In addition to the ones presented in the previous section, the first order conditions in $t = 0$ show that

$$R_0 = \frac{1}{1-\rho} \frac{C_1^N}{\beta C_0^N} \qquad\qquad R_0^* = \frac{1}{1-\rho} \frac{C_1^{*N}}{\beta^* C_0^{*N}} \ .$$

The interest rates paid on the euro and dollar bonds are higher if the probability of a collapse is larger, showing that households are compensated for the risk they are taking. Finally, to highlight the connection with the simplified model described in the previous sections, this approach endogeneizes L and L^* as $\mathcal{R}_0 B_1 \equiv L$ and $\mathcal{R}_0^* B_1^* \equiv L^*$.

G.1.2. Banks

In the simplified version, banks only had to decide how to repay their initial short-term liabilities. Now, banks must also chose how much to invest in $t = 0$ and how to finance that initial investment. They maximize their expected profits given the sunspot variable ξ, and using the discount factor M_t:

$$\begin{aligned}
\text{Max} \quad & \mathbb{E}_0(\tfrac{1}{\mathcal{R}_0\mathcal{R}_1}\Pi) \equiv (1-\rho)\tfrac{1}{R_0R_1}\Pi^G \\
\text{where} \quad & \Pi^G = e_2 r^* K^* + rK - e_2 R_1^* B_2^* - R_1 B_2 \quad \text{, s.t}
\end{aligned}$$

$$\begin{aligned}
&\text{(Initial investment)} \qquad && e_0 K^* + K = e_0 D_1^* + D_1 \\
&\text{(Roll-over needs)} \qquad && e_1 B_2^* + B_2 \geq e_1 \mathcal{R}_0^* B_1^* + \mathcal{R}_0 B_1 \\
&\text{(IC constraints)} \qquad && \mathbb{E}_0(\tfrac{1}{\mathcal{R}_0\mathcal{R}_1}\Pi) \geq \gamma(e_0 B_1^* + B_1) \quad \text{ in } t=0 \\
& && \mathbb{E}_0(\tfrac{1}{\mathcal{R}_1}\Pi) \geq \gamma \mathbb{E}_0(e_1 B_2^* + B_2) \quad \text{ in } t=1
\end{aligned}$$

where variables with the superscript ξ depend explicitly on the realization of the sunspot, and M_1 and M_2 are the 1- and 2-period discount factors that come from EU households' preferences. Note that since profits during a banking crisis are zero and they can be ignored, for ease of notation I will mostly refer to profits under the "normal" scenario as Π (same for the corresponding M_t). I will assume, without loss of generality, that the IC constraint in $t=0$ binds so that banks' investment is limited. The first order conditions for this problem are intuitive,

$$\frac{\mathbb{E}(e_{t+1})}{e_t} = \frac{R_t}{R_t^*} \tag{48}$$

$$\frac{\mathbb{E}(e_2)}{e_0} = \frac{r}{r^*} \tag{49}$$

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. Similarly to the case of the liabilities, this setup endogeneizes A and A^* from the simplified model as $rK \equiv A$ and $r^*K^* \equiv A^*$.

G.1.3. Market Clearing

Market clearing conditions for the EU non-tradable good are now

$$Y_0^N = C_0^N + K \tag{50}$$

$$Y_1^N = C_1^N \tag{51}$$

$$Y_2^N + rK = C_2^N \ , \tag{52}$$

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 two equations follow the same logic as in the simple version of the model, where 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 remains unchanged in every period.

G.2. Optimal Exposure

G.2.1. Determination of the imbalances

With the optimality conditions from households and banks, we can proceed to analyze the equilibrium values for K, K^*, B_1 and B_1^*. The optimal investment is constrained and given by

$$K = \frac{r\beta^2 \frac{(1-\rho)^2}{1-\rho+\gamma} Y_0^N - Y_2^N}{r\left(1 + \beta^2 \frac{(1-\rho)^2}{1-\rho+\gamma}\right)}$$

where K^* has an equivalent expression but with $(*)$. Importantly, K is 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 if ρ increases, since the chances of a collapse -and thus obtaining no profits- are more likely. Overall, these two forces tighten the financial constraint, and thus reduce the amount of investment that banks can afford.

Next, to fully understand how the optimal exposure is determined in equilibrium, first we need to see how the exchange rate is affected by the probability of a bank run. Following similar steps when finding the equilibrium in section 4, we get that

$$e_0^G = \frac{(1-\eta)(1+(1-\rho)(\beta+\beta^2))}{\eta(1+(1-\rho)(\beta^*+\beta^{*2})) + \frac{\theta}{1-\theta}\frac{\gamma}{(1-\rho)}\frac{K^*}{Y_0^{*N}-K^*}} \cdot \frac{Y_0^N - K}{Y_0^{*N} - K^*}$$

where I have used $\eta_t \equiv \eta$ simply for ease of notation. Although the relation between e_0 and ρ is highly non-linear, a simple numerical exploration shows that for low values of ρ we have that the dollar appreciates when the probability of a bank run increases ($\partial e_0/\partial\rho > 0$). Intuitively, if a bank run is more likely, then the expected profits of banks drop given higher funding costs and limited investment capacity. This generates a negative wealth shock to EU households in the future, which eventually depreciates the euro.

Dollar liquidity shortages are also affected by ρ. Recall that for multiple equilibria to exist, banks must be exposed to dollar liquidity shortages, as in equation (47). We can re-express the threshold $\overline{e}$ from that condition as

$$\overline{e} \equiv \frac{rK/R_1 - R_0 D_1(1+\gamma)}{(1+\gamma)R_0^* B_1^* - r^* K^*/R_1^*} = f(\rho) \ , \tag{53}$$

which shows another non-linear link, this time between $\overline{e}$ and ρ. As in the case of e_0^G, a numerical exploration reveals some intuitive results. First, dollar liquidity shortages given by the numerator of the previous expression are negatively affected by an increase in the probability of a collapse. This follows the same logic as what happens with the exchange rate: more constrained banks are forced to shrink their expositions. Eventually, the effect of lower dollar shortages dominates and leads to an increase in $\overline{e}$, so that $\partial\overline{e}/\partial\rho > 0$. In other words, higher risk decreases banks' resiliance to dollar appreciations. A numerical example showing these relations is provided in Figure G.1.

(a) Exchange rates

(b) Investment and funding (as % of Y_0^N and Y_0^{*N})

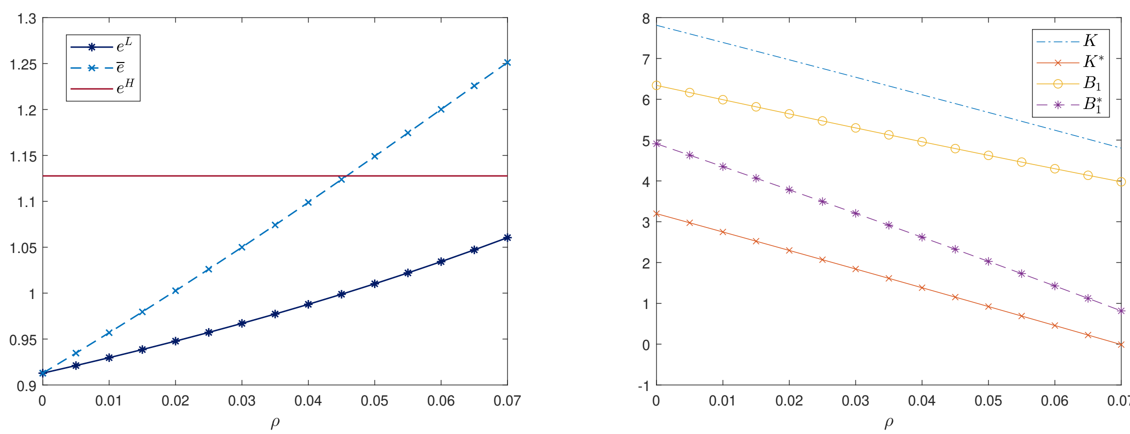


Figure G.1: Impact of ρ on key variables

Note: For this illustrative example the parameters used were $r^* = 1.3$, $\beta^* = 0.91$, $Y_0^{*N}/Y_2^{*N} = 1.75$, $r = 1.2$, $\beta = 0.9$, $Y_0^N/Y_2^N = 2.3$, $Y_1^N = Y_1^{*N} = 2.5$, $\omega = \omega^* = 0.1$, $\gamma = 0.7$, $\eta_0 = 0.45$, $\eta_1 = 0.47$, $\eta_2 = 0.55$.

G.2.2. Determination of the probability of a crisis

The probability of a financial crisis should depend, at least partially, on the fragility of the banking sector. Even in my model, where there is an exogenous sunspot variable that coordinates households' expectations, rational expectations suggest that if there is no mismatch of any kind in banks' balance sheets, then agents should assign a zero probability to a crisis. The exact opposite extreme case occurs if the imbalances are so large that even if optimistic expectations are ruled out, a crisis is inevitable ($\rho = 1$). This relation can be expressed as

$$\rho = \begin{cases} \sim 1 & \text{if } \bar{e} < e_1^G < e_1^B \\ (0,1) & \text{if } e_1^G < \bar{e} < e_1^B \\ 0 & \text{if } e_1^G < e_1^B < \bar{e} \end{cases} \tag{54}$$

where the magnitude of $\bar{e}$ with respect to the exchange rate in both states of the world gives us a measure of banks' imbalances. Intuitively, if $\bar{e}$ is above e_1^B, banks can tolerate even a very sharp depreciation, thus a crisis is not possible and $\rho = 0$. On the other hand, if $\bar{e} < e_1^G$, then banks are too exposed to a dollar appreciation, to a point where a collapse is practically a certain event.

G.2.3. Multiple equilibria

The objective of this section is to show that even though non-US global banks can choose ex-ante whether to denominated their debt in euros or in dollars, this does not rule out the possibility of multiple equilibria. By combining (53) and (54) we can determine the ex-ante probability of a financial crisis ρ and global banks' imbalances $\bar{e}$ in $t = 0$. If in equilibrium $0 < \rho < 1$, then both "good" and "bad" equilibria are possible in $t = 1$.

I want to clarify the intuition behind these results. Start from a point where $\rho = 0$, so that banks face very little financial restrictions. In that case, it is optimal for them to take more debt to invest more. If the exchange rate is low enough, debt denominated in \$ is relatively cheap, so banks will be exposed to dollar liquidity shortages, and $e_1^G = \bar{e}$. Nevertheless, a financial crisis is a possibility whenever $e_1^G \leq \bar{e} < e_1^B$, thus we can conclude that in an equilibrium with certain parameters, $\rho > 0$. In other words, under certain fundamentals of the world economy -and without any kind of policy intervention- a financial crisis cannot be ruled out.

If on the contrary we start from a point where a financial crisis is almost certain ($\rho \sim 1$), banks face tight restrictions and can only take limited debt and thus invest less. Given their limited ability to invest and the higher cost of funding, their exposure to dollar liquidity shortages is relatively low. In other words, banks' profit maximization when $\rho \sim 1$ leads to smaller imbalances, so $\bar{e}$ is high. But when $e_1^B < \bar{e}$, it means that the exchange rate that forces banks to shut down is so high, that a collapse is not possible. Following this logic, it must be that $\rho < 1$ so that a financial crisis is not the only possible outcome in equilibrium.

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