Essays in International Macro-Finance and Banking

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Para mi familia.

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Abstract

This thesis examines the impact of various policy interventions in open economies aimed at mitigating disruptions in the financial sector and their effects on the broader economy. In the first chapter, I provide a stylized framework to study the role of the United States as the International Lender of Last Resort to global banks. 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. The second chapter takes a step back and endogeneizes the portfolio allocation of these global banks. Despite borrowing and investing in domestic currencies and in dollars, these banks may still be exposed to fluctuations in the exchange rate due to maturity mismatches in dollars. If this intervention is anticipated, it incentivizes global banks to rely more on dollar funding and to increase their investments in US assets. This situation poses a challenge for central banks in other countries. The third chapter is dedicated to the interaction between macroprudential instruments in a small open economy. We study the optimal policy rules involving dynamic capital and reserve requirements and find that the gains from adapting them to economic conditions are substantial, especially if financial stability is included as an objective of the central bank. Contrary to capital requirements, an increase in reserve requirements leads to higher inflation and has an ambiguous impact on output.

Resumen

Esta tesis estudia el impacto de diversas intervenciones de política en economías abiertas dirigidas a mitigar las disrupciones en el sector financiero y sus efectos en la economía en general. En el primer capítulo, presento un marco estilizado para estudiar el rol de los Estados Unidos como prestamista internacional de última instancia para los bancos globales. Argumento que un mundo con bancos globales no estadounidenses que piden prestado e invierten en dólares es propenso a crisis autocumplidas debido a la interacción entre el tipo de cambio y las restricciones financieras de estos bancos. Además, en medio de una crisis global, los bancos globales no estadounidenses tienen dificultades para recaudar fondos y el dólar se aprecia, lo que dificulta que los bancos centrales domésticos cubran sus necesidades de liquidez. En contraste, la Reserva Federal podría proporcionar la liquidez en dólares necesaria, pero podría no internalizar completamente los beneficios de dicha intervención para el mundo, ya que Estados Unidos disfruta de mayores y más baratos flujos de capital durante los períodos de estrés financiero global. El segundo capítulo da un paso atrás y endogeniza la asignación de la cartera de inversiones de estos bancos globales. A pesar de pedir prestado e invertir en monedas nacionales y en dólares, estos bancos pueden quedar expuestos a las fluctuaciones del tipo de cambio debido a los descalces de vencimientos en sus activos en dólares. Si los mercados anticipan esta intervención, se incentiva a los bancos globales a depender más de la financiación en dólares y aumentar sus inversiones en activos estadounidenses. Esta situación plantea un desafío para los bancos centrales de otros países. El tercer capítulo está dedicado a la interacción entre los instrumentos macroprudenciales en una economía pequeña y abierta. Estudiamos las reglas de política óptima que involucran requerimientos dinámicos de capital y reservas y encontramos que los beneficios de adaptar ambos a las condiciones económicas son sustanciales, especialmente si la estabilidad financiera se incluye como un objetivo del banco central. A diferencia de los requerimientos de capital, un aumento en los requerimientos de reservas conduce a una mayor inflación y tiene un impacto ambiguo en el producto.

Preface

This doctoral thesis consists of three chapters on policy implications, the financial sector, and the macroeconomy.

In the first chapter, I provide 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.

My second chapter provides a framework to study the portfolio composition of non-US global banks in the presence of an ILOLR, and how it affects the macroeconomic conditions of the countries in which they operate. First, I argue that even if these banks borrow and invest in dollars, the world might still be exposed to self-fulfilling crises from dollar liquidity shortages if this currency drastically appreciates and assets are difficult to sell. Unlike other central banks without broad access to dollars, the Fed can mitigate these shortages by providing dollars to the global financial system. Nevertheless, if this intervention is anticipated, the lower perceived risk loosens the financial constraints that global banks face, and allows them to borrow more in dollars -as it becomes a more affordable source of funding- and invest more in US assets. This situation poses a challenge for central banks in other countries. While it is always beneficial for them to prevent the collapse of global banks from an ex-post perspective, there are ex-ante drawbacks, as such intervention increases the potential losses if the risk is not fully mitigated and a financial crisis materializes.

In the third chapter -joint work with A. Contreras-, we analyze the interaction and effectiveness of two macroprudential instruments, reserve and capital requirements, under different anchor variables and central bank objectives. To do so we use a dynamic stochastic general equilibrium (DSGE) for a small open economy with nominal rigidities, financial frictions, a banking sector, and a central bank. Our findings suggest that under a price stability objective, the gains from adapting reserve and capital requirements to economic conditions are substantial when the economy faces nominal and financial frictions. When financial stability is included as a central bank objective, macroprudential policies become more relevant and can help mitigate output volatility in addition to credit fluctuations. Regarding the differences between the two instruments, the most important is that an increase in reserve requirements is associated with higher inflation, while tighter capital requirements lead to a drop in inflation. This result may be explained by the different channels through which reserve and capital requirements operate: reserve requirements influence banks' deposits, affecting deposit rates and consumption, while capital requirements impact banks' lending and investment.

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Chapter 1

THE UNITED STATES AS THE INTERNATIONAL LENDER OF LAST RESORT

1.1 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, 2022b) 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

[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 1.2 provides more details about this instrument.

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

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-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 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

[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.

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 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 Obstfeld (1996), Cole and Kehoe (2000), and more recently by Céspedes et al. (2017), Aguiar et al. (2017), Farhi and Maggiori (2018), Fornaro (2022), Bianchi and Coulibaly (2023) 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 Mag-

[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.

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

giori (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. 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 (2009b), Baba and Packer (2009a), Moessner and Allen (2013), and Aizenman and Pasricha (2010), perhaps the most comprehensive study so far is Bahaj and Reis (2022a), 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 related 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 (2022a) 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, 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 1.2 presents stylized facts that serve as the basis of the model. Section 1.3 describes the baseline model. Next, Section 1.4 discusses the multiple equilibria that might arise under this framework. The benefits of an international lender of last resort are presented in Section 1.5, while Section 1.6 provides a welfare analysis that motivates the intervention. Finally, Section 1.7 concludes.

[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).

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

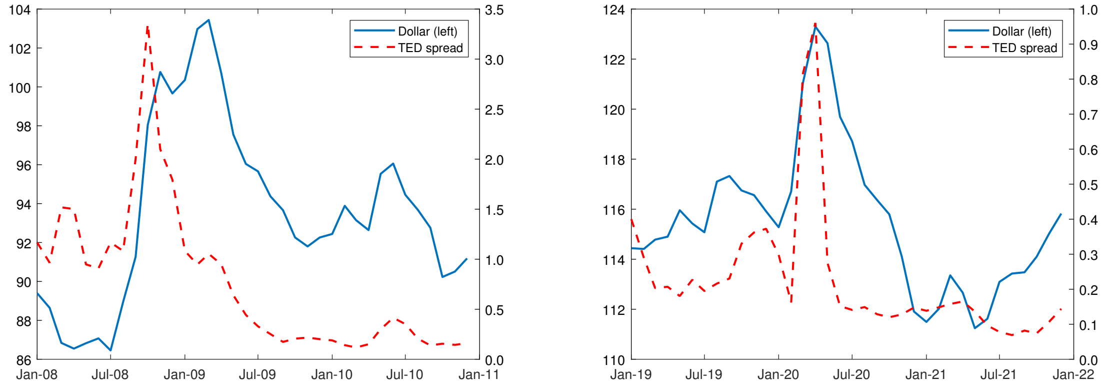


Figure 1.1: Dollar (index) and TED spread (%)

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.

1.2 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.

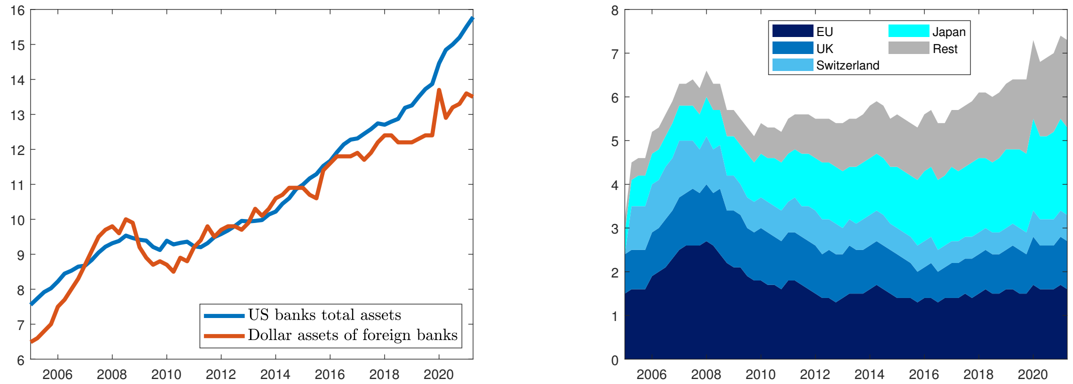
Fact 1: The dollar appreciates and liquidity shortages arise during a crisis.

As shown in Figure 1.1, 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 1.1. 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 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 1.2a. 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 1.2b 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



(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 1.2: 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.

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 have been largely financed with dollar-denominated debt, as depicted in Figure 1.3a. Despite showing a combination of large gross dollar positions but small net positions, these banks were 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 1.3a 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 1.3b 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.

[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.

[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 1.13 shows that non-US banks lost around $300 billion during the covid-19 turmoil, mostly from US markets.

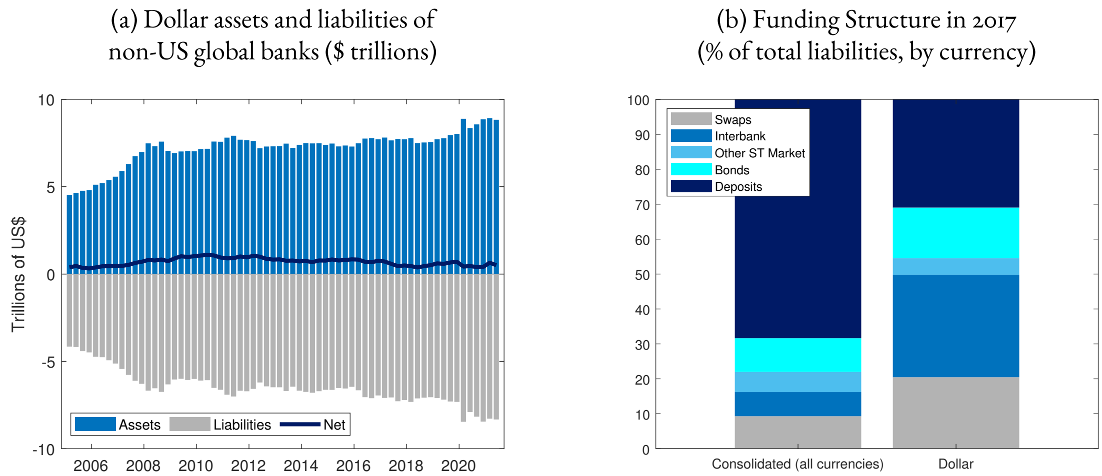


Figure 1.3: Dollar funding of non-US global banks

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).

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.

1.3 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

[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.

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[13] 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[14]. 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[15]. 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.

1.3.1 Households

Euro area households derive utility 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

$$\max_{C_t} \quad U = \ln(C_1) + \beta \mathbb{E} \ln(C_2) \tag{1.1}$$

subject to the budget constraint in both periods,

$$Y_1^N + p_1 Y_1^T + L = C_1^N + p_1 C_1^T + B \tag{1.2}$$

$$\Pi + Y_2^N + p_2 Y_2^T + R \cdot B = C_2^N + p_2 C_2^T \ , \tag{1.3}$$

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.

[13] A nominal version of the model can be found in Appendix 1.10.

[14] 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.

[15] 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.

The households' first-order conditions can be written as

$$p_1 C_1^T = \frac{1}{\beta R} p_2 C_2^T \tag{1.4}$$

$$p_t = \frac{C_t^N}{C_t^T} \frac{\omega}{1-\omega} \tag{1.5}$$

Equation (1.4) 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 (1.5) 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

$$\max_{C_t^*} \quad U^* = \ln(C_1^*) + \beta \ln(C_2^*) \tag{1.6}$$

subject to the budget constraint in both periods,

$$p_1^* Y_1^{*T} + Y_1^{*N} + L^* = p_1^* C_1^{*T} + C_1^{*N} + B^* \tag{1.7}$$

$$p_2^* Y_2^{*T} + Y_2^{*N} + R^* B^* = p_2^* C_1^{*T} + C_2^{*N}\,, \tag{1.8}$$

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

$$p_1^* C_1^{*T} = \frac{1}{\beta^* R^*} p_2^* C_2^{*T} \tag{1.9}$$

$$p_t^* = \frac{C_t^{*N}}{C_t^{*T}} \frac{\omega^*}{1-\omega^*}\,. \tag{1.10}$$

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.

1.3.2 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[16]. 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[17] mature in period 2 and have a gross return of A in euros and A^* in dollars.

[16] Chapter 2 extends the standard framework to discuss banks' optimal funding and investment decisions.

[17] 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:

$$L + e_1 L^* \leq B + e_1 B^* \,. \tag{1.11}$$

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

$$\Pi = A + e_2 A^* - RB - e_2 R^* B^* \,. \tag{1.12}$$

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:

$$\frac{1}{R}\Pi \geq \gamma(B + e_1 B^*) \tag{1.13}$$

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 (1.12) subject to the liquidity needs in (1.11) and the financial constraint in (1.13). The optimization problem results in the following no-arbitrage condition:

$$R = R^* \frac{e_2}{e_1} \tag{1.14}$$

which reflects that the uncovered interest parity (UIP) holds[18].

Exchange rate and banks' soundness

In an equilibrium in which banks operate, equation (1.11) holds with equality[19], so that combining the two restrictions and the UIP condition yields the following expression for the financial constraint, in terms of e_1:

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

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.

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

[19] 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 $e_1(B^* - L^*) = -(B - L)$.

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

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

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 (1.13) leads to the following Lemma.

Lemma 1.3.1. *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 $R = (A + Y_2^N)/\beta Y_1^N$ *and* $R^* = (A^* + Y_2^{*N})/\beta^* Y_1^{*N}$.

Proof. In Appendix 1.9.2. □

The threshold $\bar{e}$ can be interpreted as the maximum exchange rate that the banking system can tolerate[20]. 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 1.2. 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 $e_1 \leq \bar{e}$.

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[21] 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[22], 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

[20] Even if we consider banks that start period 1 with assets denominated in tradable goods, they can still be exposed to dollar fluctuations, as shown in Appendix 1.11.1.

[21] 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.

[22] 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.

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.

1.3.3 Market Clearing

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

$$\begin{aligned} Y_1^N &= C_1^N & Y_1^{N*} &= C_1^{*N} \\ Y_2^N + A &= C_2^N & Y_2^{*N} + A^* &= C_2^{*N} \end{aligned} \tag{1.15}$$

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 both periods,

$$Y_t^T + Y_t^{*T} = C_t^T + C_t^{*T} \, . \tag{1.16}$$

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 1.4, I provide a generalization of the model that relaxes these assumptions, maintaining the main results.

1.4 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.

1.4.1 No-run equilibrium

It is optimal for households to provide the funds needed to global banks only if they expect condition (1.13) to hold, otherwise banks would have incentives to divert those funds. Considering Lemma 1.3.1, 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* (1.2)*,* (1.3)*,* (1.4) *and* (1.5) *-plus their counterparts for the US economy-, the banks' roll-over needs, profits, credit constraint, and no-arbitrage condition in* (1.11),(1.12),(1.13) *and* (1.14)*, and the market clearing conditions in* (1.15) *and* (1.16)*, 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.

1.4.2 Run equilibrium

Contrary to the previous case, it is optimal for households not to save with global banks if they expect condition (1.13) 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 1.3. 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.

1.4.3 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.

1.4.4 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 non-operational. The full optimization problem for households can be found in Appendix 1.12.

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 (1.5) 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 (1.16) 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:

$$e_1(B) = \underbrace{\frac{\eta_1^*}{\eta_1}}_{\substack{\text{Endowment}\\ \text{component}}} + \underbrace{B \cdot \frac{1-\omega}{\omega} \cdot \frac{1}{\eta_1}}_{\substack{\text{Capital flows}\\ \text{component}}} . \tag{1.17}$$

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.

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 (1.12) can also be expressed in terms of e_1 by using the UIP condition and the roll-over needs in (1.11), 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 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 of in terms of e_1. In anticipation of the drop in prices and thus 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 1.3. 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 follows:

$$B = \mathcal{B}(e_1) = \begin{cases} \frac{\omega}{1-\omega}\beta\Big(\eta_2^* - e_1\eta_2\Big) - e_1\Big(\frac{A^*}{R^*} - L^*\Big) & \text{if } e_1 < \bar{e} \\ \frac{\omega}{1-\omega}\beta\Big(\eta_2^* - e_1\eta_2\Big) & \text{if } e_1 > \bar{e} \end{cases} \tag{1.18}$$

The equilibria of the model can be obtained by solving the system of two equations given by (1.17) and (1.18). 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 $\bar{e}$ be the value of e_1 that makes condition (1.13) 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. In Appendix 1.9.3. □

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, its currency will appreciate.

Figure 1.4 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 $\bar{e}$, 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:*

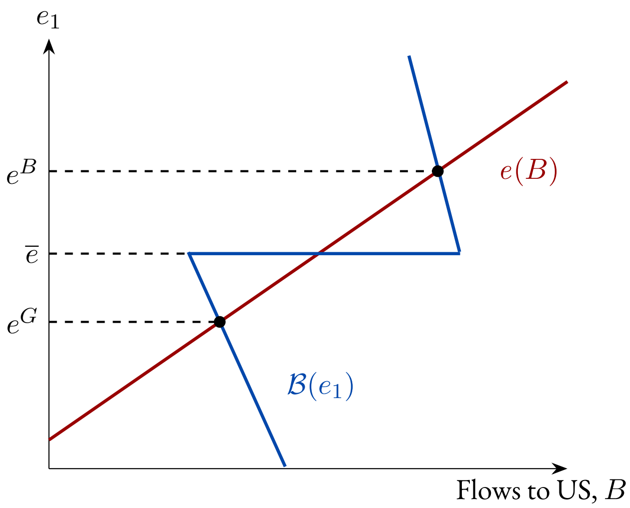


Figure 1.4: Multiple Equilibria

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 1.9.4. □

These results are in line with the evidence provided in Section 1.2 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[23], 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 ap-

[23]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.

preciation 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[24]. To illustrate this, Figure 1.5 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 1.6 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.

It is also important to mention that, even though in this simple framework I take the assets and liabilities of banks are given, the main results of the paper are unchanged if we endogenize their portfolio decision. Chapter 2 extends the basic model to show that even if non-US global banks could 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.

1.4.5 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.

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^*.

[24]Appendix 1.10 presents a nominal version of the model to show that a monetary policy contraction in the US would also tighten banks' financial constraint.

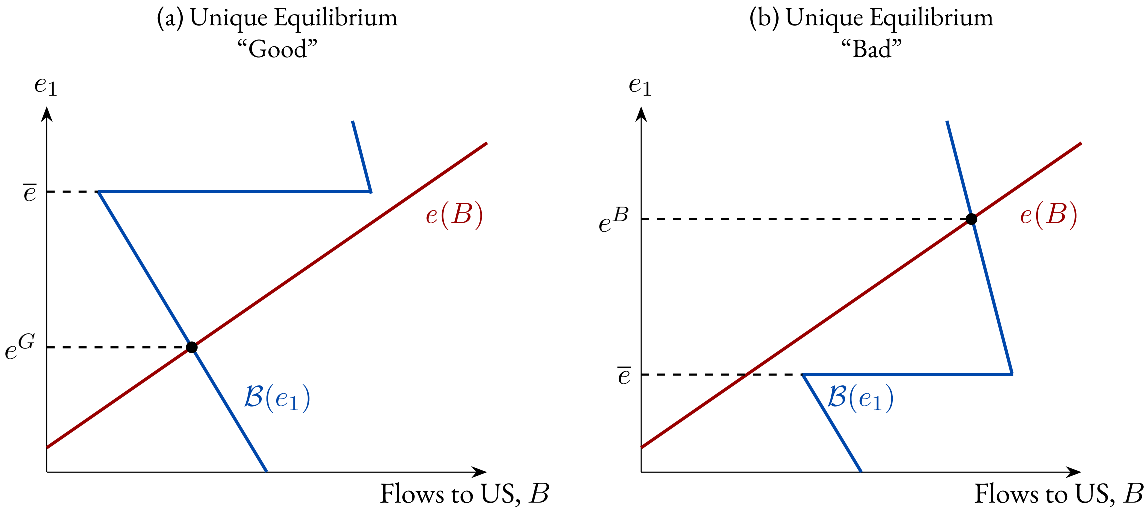


Figure 1.5: Unique Equilibria

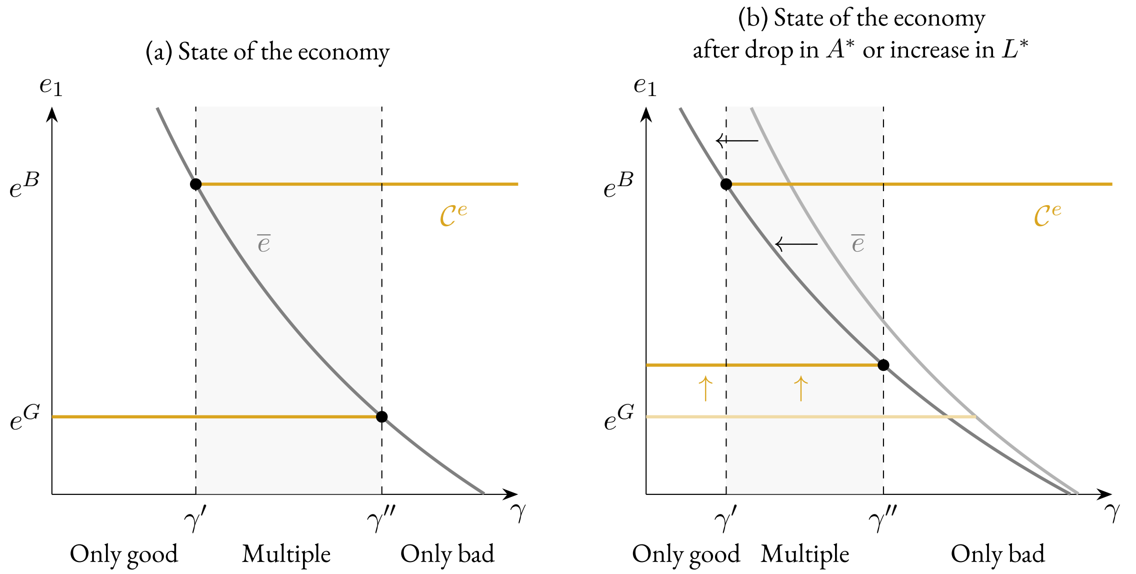


Figure 1.6: Exchange rate and severity of the financial friction

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 1.1. 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[25] respond in the expected direction, but they react slightly more drastically in

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

Table 1.1: 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 1.2: 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%

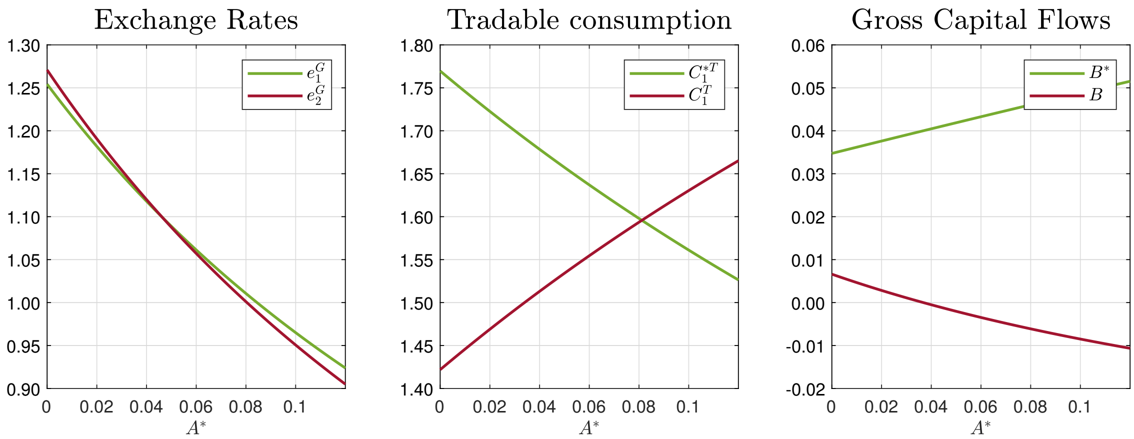


Figure 1.7: Key variables in the "good" equilibrium

the model compared to what the data suggests[26].

Finally, based on this simple calibration, Figure 1.7 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 (lower 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.

1.5 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

[26] Appendix 1.13 presents an extension of the model where households' have CES utility functions. By having more flexibility to calibrate the different elasticities in the households' problem, the exchange rate reacts more drastically to changes in consumption, which brings the model's results closer to the data.

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[27] 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.

1.5.1 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 in euros,

$$e_1 L^* = S\,, \quad \text{where } S = \tau Y_1^N \tag{1.19}$$

Finally, equation (1.19) 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[28] 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[29] 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 (1.19) and the tax limit, the next proposition captures this insight.

[27] 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.

[28] 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.

[29] Appendix 1.11.2 shows that the intervention by the ECB might still be unfeasible even if it could tax and transfer tradable goods to global banks.

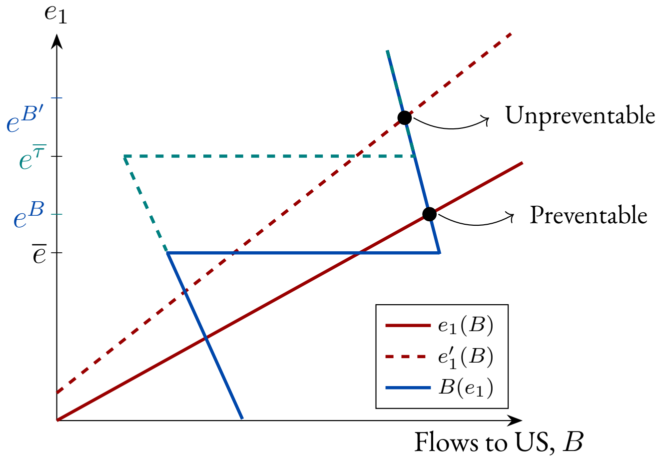


Figure 1.8: Equilibria under ECB intervention

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. In Appendix 1.9.5 □

A graphic illustration of the previous proposition is presented in Figure 1.8. 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 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 make a scenario with $e^{B'} > e^{\overline{\tau}}$ unpreventable.

1.5.2 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[30]. This transfer is financed with taxes τ^* on US households' non-tradable output (recall that $Y_1^N = Y_1^{*N}$). An important

[30] 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.

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 cover banks' dollar liabilities, such that

$$L^* = S^* , \quad \text{where } S^* = \tau^* Y^{*N} . \tag{1.20}$$

Equation (1.20) 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 1.2 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), "flight-to-safety" (Kekre and Lenel, 2021), or "scrambling-for-dollars" (Bianchi et al., 2023) 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:*

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

Proof. In Appendix 1.9.6 □

A graphic illustration of this proposition is presented in Figure 1.9. 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

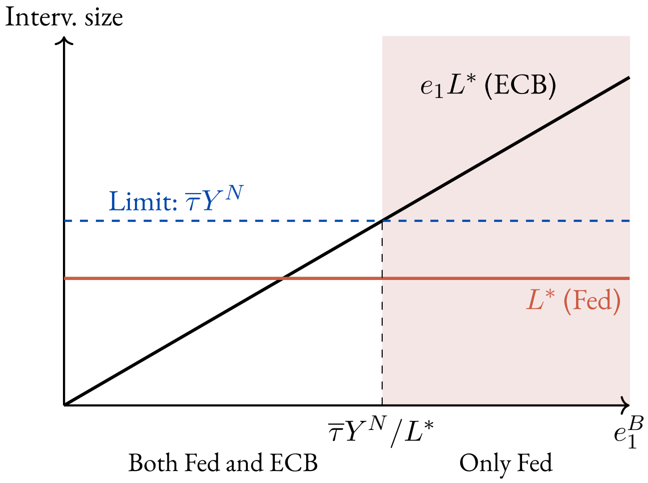


Figure 1.9: Intervention by Fed and ECB

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.

1.6 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.

1.6.1 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,

$$U_G - U_B = \underbrace{(1-\omega)\beta \ln\left(\frac{A + Y_2^N}{Y_2^N}\right)}_{NT \text{ goods}} - \underbrace{\omega \sum_{t=1}^{2} \beta^{t-1} \ln\left(\frac{C_{B,t}^T}{C_{G,t}^T}\right)}_{T \text{ goods}} \tag{1.21}$$

$$U_G^* - U_B^* = \underbrace{(1-\omega)\beta^* \ln\left(\frac{A^* + Y_2^{*N}}{Y_2^{*N}}\right)}_{NT^* \text{ goods}} - \underbrace{\omega \sum_{t=1}^{2} \beta^{*t-1} \ln\left(\frac{C_{B,t}^{*T}}{C_{G,t}^{*T}}\right)}_{T^* \text{ goods}} \tag{1.22}$$

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 (1.21) and (1.22).

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 1.4 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 (1.21) and (1.22). 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:

$$C_1^{*T} = Y_1^{*T} - \underbrace{\frac{1}{p_1^*}}_{\substack{\text{Price} \\ \text{effect}}} \cdot \underbrace{B^*}_{\substack{\text{Flows} \\ \text{effect}}} + \underbrace{\frac{1}{p_1^*} \cdot L^*}_{\substack{\text{Deposits} \\ \text{effect}}} \tag{1.23}$$

Equation (1.23) 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.

1.6.2 Trade-off for the Fed

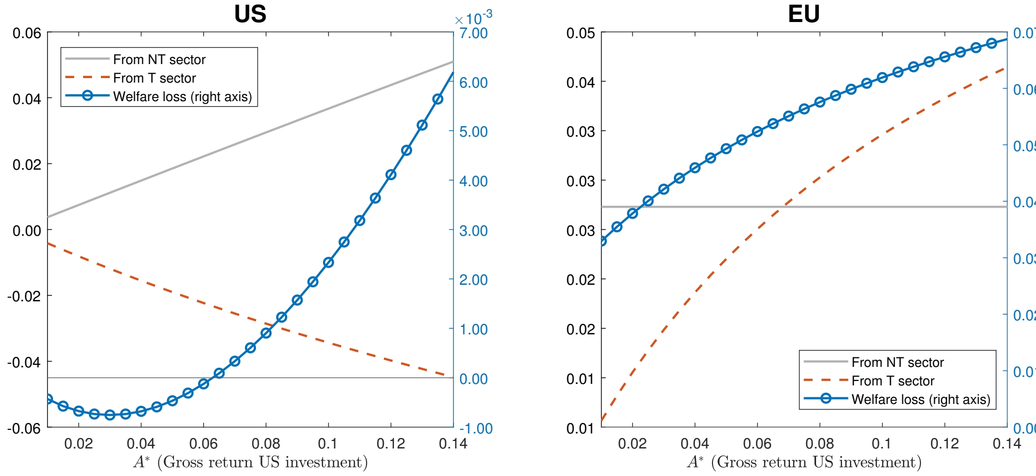
Whether US households experience an overall welfare gain or loss when global banks collapse will depend on the parameters of the model. Before analyzing the conditions under which this happens, I will relax one last assumption to further emphasize the general equilibrium forces at play. In particular, 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[31], 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.

[31] 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 1.10: Welfare Losses



Note: Considers the parameter values described in Section 1.4, and $\phi = 1$.

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:*

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

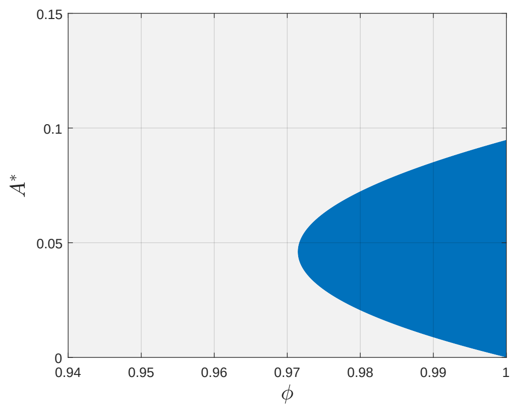
Proof. In Appendix 1.9.7 □

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 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 (1.21) and (1.22) using the calibration from Section 1.4. To focus first on the impact of A^*, I set $\phi = 1$. From Figure 1.10 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 1.11 plots, in the shaded area, all pairs of A^* and ϕ that result in welfare gains

Figure 1.11: 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.

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.

1.7 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 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.

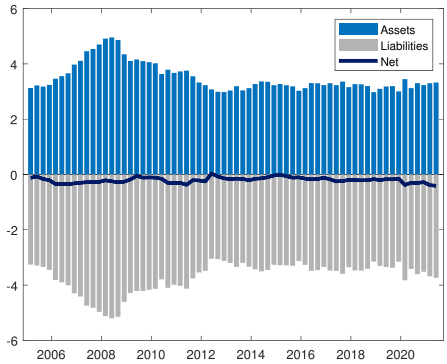
In this context, the world economy can benefit from a lender of last resort. However, in a state of the world where the dollar is strong relative to other currencies, and given the size of the balance sheets of global banks, non-US central banks without significant dollar reserves might lack the resources 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. Effectively addressing these issues is crucial for assessing the future of the dollar's global dominance, the risks that threaten it, and identifying the steps the US can take to mitigate those risks to maintain confidence in the dollar.

Appendix

1.8 Appendix 1: Additional Stylized Facts

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



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

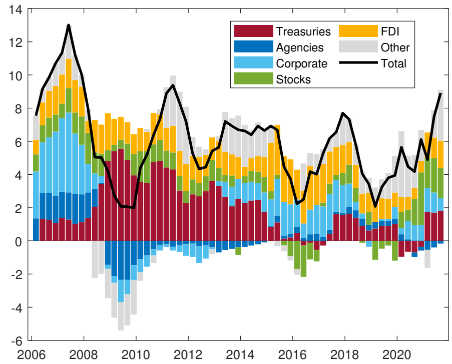
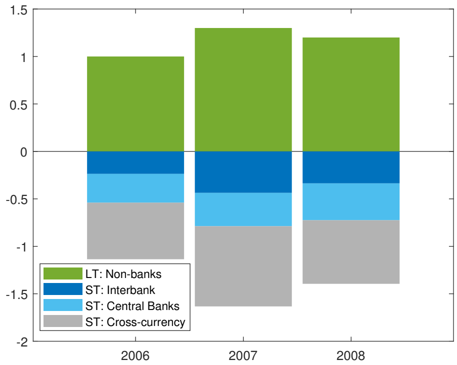


Figure 1.12: Dollar assets of non-US banks

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

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



(b) Money Market Funds funding ($ trillions)

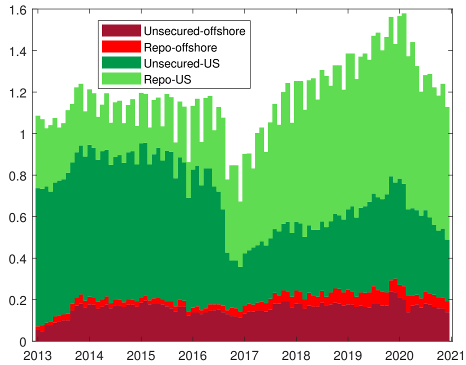


Figure 1.13: Dollar funding of non-US global banks

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).

1.9 Appendix 2: Proofs and derivations

1.9.1 Derivation of Equation 1.17

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:

$$p_1 = \frac{\omega}{1-\omega} \frac{1}{Y_1^T + Y_1^{*T}} \left[Y_1^{*N} e_1 + Y_1^N \right] \tag{1.24}$$

$$p_2 = \frac{\omega}{1-\omega} \frac{1}{Y_2^T + Y_2^{*T}} \left[e_2 C_2^{*N} + C_2^N \right]. \tag{1.25}$$

Finally, using the simplifying assumption that $Y_1^{*N} = Y_1^N = 1$, and combining (1.24) 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 $\eta_1^* \equiv 1 - \eta_1$.

1.9.2 Proof of Lemma 1.3.1

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 (1.13) 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. □

1.9.3 Proof of Proposition 1

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 (1.13) 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. Let us consider the first inequality. It follows from the proof of Lemma 1.3.1 that $e^G < \overline{e}$ is a necessary condition for the "good" equilibrium to exist. The second inequality states that $\overline{e} < e^B$ for the "bad" equilibrium to exist.

Assume that such equilibrium exists even if $e^B < \overline{e}$. 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 $\overline{e} < e^B$ in order for the "bad" equilibrium to exist. □

1.9.4 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 (1.17) 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.

□

1.9.5 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

$$e_1 L^* = S \tag{1.26}$$

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

$$\tau Y_1^N = S \tag{1.27}$$

Combining (1.26) and (1.27), 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, $\overline{\tau} < e_1^B L^* / Y_1^N$. □

1.9.6 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:*

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

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 $\tau = e_1^B \tau^* > \tau^*$. □

1.9.7 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:*

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

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

$$\Psi \equiv U_G - U_B = \underbrace{(1-\omega)\beta\ln\left(\frac{A+Y_2^N}{Y_2^N}\right)}_{NT\text{ goods}} - \underbrace{\omega\sum_{t=1}^{2}\beta^{t-1}\ln\left(\frac{C_{B,t}^T}{C_{G,t}^T}\right)}_{T\text{ goods}} \tag{1.28}$$

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

$$C_1^{*T} = (Y_1^T + Y_1^{*T})\frac{e_1}{1+e_1} \qquad C_1^T = (Y_1^T + Y_1^{*T})\frac{1}{1+e_1} \tag{1.29}$$

$$C_2^{*T} = (Y_2^T + Y_2^{*T})\frac{e_2 C_2^{*N}}{C_2^N + e_2 C_2^{*N}} \qquad C_2^T = (Y_2^T + Y_2^{*T})\frac{C_2^N}{C_2^N + e_2 C_2^{*N}} \tag{1.30}$$

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:

$$\Psi \equiv U_G^* - U_B^* = \underbrace{(1-\omega)\beta^*\ln\left(\frac{A^*+Y_2^{*N}}{Y_2^{*N}}\right)}_{NT^*\text{ goods}} - \underbrace{\omega\sum_{t=1}^{2}\beta^{*t-1}\ln\left(\frac{C_{B,t}^{*T}}{C_{G,t}^{*T}}\right)}_{T^*\text{ goods}} \tag{1.31}$$

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 (1.29) and (1.30), and then into (1.31), combined with the UIP condition $R = R^*\dfrac{e_2}{e_1}$, yields the inequality in Proposition 5. □

1.10 Appendix 3: Nominal version

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

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

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

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

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

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

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

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

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

$$\bar{e} \equiv \frac{A/R}{(1+\gamma)L^* - A^*/R^*} = \frac{A \cdot \beta m_t / m_{t+1}}{(1+\gamma)L^* - A^* \cdot \beta^* m_t^* / m_{t+1}^*}\,. \tag{1.32}$$

From (1.32) it is possible to see that $\downarrow m_t^* \rightarrow \uparrow R^* \rightarrow \downarrow \bar{e}$.

1.11 Appendix 4: Tradable goods

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

1.11.1 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

$$\Pi = e_2 A^* + a + p_2 T - e_2 R^* B^* - RB \tag{1.33}$$

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

$$e_1 \frac{1}{R^*}\underbrace{\left[A^* + \frac{T(A^* + Y_2^{*N})}{(Y_2^T + T + Y_2^{*T})}\frac{\omega}{1-\omega}\right]}_{W^*} + \frac{1}{R}\underbrace{\left[a + \frac{T(A + Y_2^N)}{(Y_2^T + T + Y_2^{*T})}\frac{\omega}{1-\omega}\right]}_{W} > (1+\gamma)e_1 L^* \quad (1.34)$$

Then, the exchange rate that makes (1.34) hold with equality, is

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

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.

1.11.2 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,

$$\tau^T p_1 Y_1^T > e_1^B L^* \quad (1.35)$$

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 (1.35), 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.

1.12 Appendix 5: 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.

1.12.1 EU households' problem

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

$$\max_{C_t} \quad U = \ln(C_1) + \beta \mathbb{E} \ln(C_2) - \zeta(\widetilde{B}) \tag{1.36}$$

subject to the budget constraint in both periods,

$$p_1 Y_1^T + Y_1^N = p_1 C_1^T + C_1^N + B + e_1 \widetilde{B} \tag{1.37}$$

$$\Pi + RB + e_2 R^* \widetilde{B} + p_2 Y_2^T + Y_2^N = p_2 C_2^T + C_2^N \,. \tag{1.38}$$

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.

1.12.2 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

$$e_1^{G'} = \frac{1-\eta_1+\beta(1-\eta_2)}{\eta_1+\beta\eta_2+\frac{1-\omega}{\omega}\frac{1}{Y_1^N}(\frac{A^*}{R^*}-L^*)} \tag{1.39}$$

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

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

$$p_2 C_2^T = \beta R^* \frac{e_2}{e_1} p_1 C_1^T \,. \tag{1.40}$$

Combining (1.40) 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:

$$e_2 = e_1 \frac{Y_1^{*N}}{Y_2^{*N}} \tag{1.41}$$

This equation substitutes the UIP condition (1.14) 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,

$$e_1 \widetilde{B} = p_1(Y_1^T - C_1^T) \tag{1.42}$$

$$e_2 R^* \widetilde{B} = p_2(C_2^T - Y_2^T) \,. \tag{1.43}$$

Using (1.41), (1.42), (1.43) and the households' optimality conditions, it is possible to find the exchange rate under the collapse scenario $e_1^{B'}$ as follows

$$e_1^{B'} = \frac{1 - \eta_1 + \beta(1 - \eta_2)}{\eta_1 + \beta\eta_2} \tag{1.44}$$

which is equivalent to $e_1^{G'}$ if we consider 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 $e_1^{B'} > \bar{e}$.

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 (1.42) 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.

1.13 Appendix 6: 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

$$\frac{1}{P_{T,t}} = \frac{1 - \omega}{\omega} \left(\frac{C_{T,t}}{C_{N,t}} \right)^{1/\rho} \tag{1.45}$$

$$U_N'(C_t) = \beta R E\{U_N'(C_{t+1})\} \tag{1.46}$$

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

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 1.3:

Table 1.3: Values of e_1^G

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

Note: Contains values of the exchange rate in period 1 in the "good" equilibrium. The calibration of the rest of the parameters comes from Section 1.4.

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.

Chapter 2

GLOBAL PORTFOLIOS AND THE INTERNATIONAL LENDER OF LAST RESORT

2.1 Introduction

The United States currently acts as the international lender of last resort (ILOLR) to the global financial system, a role that has been crucial during major crises. This function primarily involves supplying dollar liquidity to the global economy when other sources of financing dry up. The Federal Reserve, in particular, has stepped in during times of global market turmoil, extending bilateral swap lines to other major central banks, ultimately benefiting large non-US global banks that intermediate significant cross-border operations denominated in dollars.

This intervention has become a cornerstone of international financial stability (Bahaj and Reis, 2022b), yet many questions remain around it, especially from a macroeconomic standpoint. In this paper, I address some of those related to the ex-ante implications of the United States (US) as the ILOLR. First, under which conditions is it rational for non-US global banks to be exposed to dollar shortages? Second, how does the Fed's intervention affect the portfolio allocation of these banks? And more importantly, do all central banks benefit from the intervention ex-ante, or are there any moral hazard issues arising from the international nature of the intervention?

This paper provides a framework to study the portfolio composition of non-US global banks in the presence of an ILOLR, and how it affects the macroeconomic conditions of the countries in which they operate. First, I argue that even if these banks borrow and invest in dollars, the world might still be exposed to self-fulfilling crises from dollar liquidity shortages if this currency drastically appreciates and assets are difficult to sell. Unlike other central banks without broad access to dollars, the Fed can mitigate these shortages by providing dollars to the global financial system. Nevertheless, if this intervention is anticipated, the lower perceived risk loosens the financial constraints that global banks face[1], and allows them to borrow more in dollars -as it becomes a more affordable source of funding- and invest more in US assets. In this context, while it is always beneficial for foreign central banks to prevent the collapse of non-US global

[1] Bahaj and Reis, 2022a find evidence that banks in the jurisdiction covered by the Fed's swap lines registered a significant increase in their average excess returns, and also increased their demand for dollar-denominated bonds.

banks from an ex-post perspective, there are ex-ante drawbacks. If the intervention is imperfect and does not fully mitigate the risk of a financial crisis, the welfare losses to the rest of the world coming from the potential collapse of the banking sector become larger.

To capture these insights, I develop a tractable and dynamic model of the world economy. I combine elements from the traditional self-fulfilling crises literature[2] with a modern perspective that places non-US global banks at the center of the international financial intermediation, following Gabaix and Maggiori (2015). This enables me to address a key distinction between a domestic and an international lender of last resort: the involvement of three types of agents—the two central banks and the commercial banks. The differing incentives among these agents, as well as the multiple funding and investing opportunities at play, can create complex incentive problems.

This paper contributes to our understanding of the ex-ante macroeconomic implications of the Fed's swap lines, which have predominantly been examined through a micro-empirical lens or with models focusing on their ex-post effects. I shed light on the potential costs associated with liquidity lines, an area that has been largely overlooked (Bahaj and Reis, 2022b). Central to the analysis are the distinct trade-offs faced by an international lender of last resort compared to a domestic one. The scenario I explore is one where the Fed prefers to commit in advance to bailing out non-US global banks in the event of a crisis, whereas central banks in other countries would rather avoid such a commitment and choose to intervene only when necessary.

I consider a world composed of two economies, the United States (US) and the Euro area (EU), each populated by a continuum of households. There are three periods. In the baseline model, global banks –owned by EU households- borrow and invest in dollars and euros in the initial period. They have access to long-term assets, while their funding sources are short-term. As a result, they must roll over their liabilities in the intermediate period to avoid a costly liquidation and secure profits in the last period. However, their ability to raise funds is constrained by an agency friction. Should these banks fail to secure the funding needed, they are forced to shut down, triggering a global financial crisis given their relevance in managing capital flows across borders.

In the intermediate period, the world can be exposed to self-fulfilling crises because of a two-way interaction between the exchange rate and the soundness of global banks, as in Chapter 1. Even without substantial currency mismatches, maturity mismatches in dollars can expose these banks to exchange rate fluctuations, if for instance, their liquidity needs are exacerbated by a sharp appreciation of the dollar while their dollar-denominated assets cannot be easily liquidated. If these banks are unable to repay their debts and are forced to shut down, the EU economy suffers directly from the resulting turmoil in its banking sector, leading to a drop in their aggregate demand and a weaker euro, appreciating the dollar even further. This feedback loop opens the door to multiple equilibria where fundamentals and animal spirits play a central role.

The novelty of this paper comes from studying the ex-ante portfolio decisions of households and global banks to evaluate if such imbalances can arise endogenously. Banks consider the probability of a financial crisis in the intermediate period as given[3] when choosing their portfolio in the initial period. On one hand, if a financial crisis is more likely, banks are more constrained, their investment and borrowing decrease as

[2] 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.

[3] Similarly to many bank-run or multiple equilibria models, banks ignore the fact that their individual decisions affect the overall occurrence of a crisis, since they are atomistic. If banks were able to coordinate, they could choose a different portfolio mix that would leave the financial system shielded against dollar fluctuations.

well as their expected profits, the relative wealth of EU households shrinks, and consequently the euro depreciates. In anticipation, global banks rely more on euro funding (as it is more affordable), making their imbalances smaller and effectively shielding them against dollar fluctuations.

On the other hand, the probability of financial crisis also depends on the maximum exchange rate that banks can tolerate. When the dollar is depreciated against other currencies, banks rely more on dollar funding, their imbalances grow larger and their resilience declines, and thus the likelihood of a crisis in the next period increases. I focus on the case where banks' portfolio choices are consistent with multiple equilibria in the intermediate period. In that case, the ex-ante probability of a financial crisis coincides with the probability that agents assign to pessimistic animal spirits prevailing.

Equipped with the baseline model, I then study how the presence of an ILOLR affects the portfolio decisions of global banks. If agents anticipate the intervention in the future and the possibility of a financial crisis is ruled out, banks are less constrained, and their balance sheet grows. Since their expected profits are larger due to the lower risk, and the euro is stronger from the changes in relative wealth across countries, banks borrow more in dollars to finance their investments. In the intermediate period, given the large amount of dollars needed to cover those short-term liabilities and the sharp dollar appreciation in times of stress, the Fed is the only central bank that can mitigate these shortages by providing dollar liquidity to the global financial system.

Lastly, I study the ex-ante welfare implications of the intervention. To do so, I consider an imperfect intervention on the Fed's part, such that they can bail out non-US global banks only with a certain probability of success. Therefore, while the lower risk of a crisis encourages banks to take larger positions, it also increases the potential losses that the rest of the world would face if the crisis materializes. While this is profitable for global banks, it may not align with the government's welfare priorities. For instance, if the ECB's objective is to minimize the welfare losses during a banking collapse, an interesting trade-off emerges. Even if it does not want to commit ex-ante, it is always convenient for the ECB to accept the swap lines ex-post, i.e. when a crisis hits. Interestingly, the commitment to not bail out global banks would be time-consistent if the Fed was not involved, since non-US central banks lack the resources for such a large-scale injection of dollars, particularly during periods of stress when the dollar drastically appreciates.

Related Literature. This paper is closely related to a long-standing literature studying self-fulfilling crises in open economies. As in Krugman (1999), Céspedes et al. (2017), Bocola and Lorenzoni (2020), Schmitt-Grohé and Uribe (2021), Fornaro (2022), and Bianchi and Coulibaly (2023), the exchange rate plays a crucial role in opening the door to multiple equilibria. In my framework, large non-US global banks with maturity mismatches in dollars might leave the global financial system exposed to dollar liquidity shortages. Given the size of their balance sheets and their relevance in intermediating capital flows across borders, the collapse of these global intermediaries has significant negative spillovers worldwide. I expand on Chapter 1, which takes these imbalances as given, by studying their ex-ante portfolio decisions to evaluate whether such imbalances can arise endogenously, similar to the approach of Bocola and Lorenzoni (2020).

Given the role that the Fed plays in my model, this paper also relates to the literature on bank-runs, as in Bagehot (1873), Bryant (1980), Diamond and Dybvig (1983), Allen and Gale (2000), Rochet and Vives (2004), and more recently Gertler and Kiyotaki (2015) or Amador and Bianchi (2021). Contrary to traditional models that focus on runs on individual banks, I consider runs on the entire banking system (as in Uhlig, 2010 or Gertler and Kiyotaki, 2015) that are linked to macroeconomic factors such as the exchange rate.

This paper also connects with the literature on swap lines, a topic primarily examined through micro-level empirical analyses[4]. Notable recent studies regarding the interventions during the Global Financial Crisis (GFC) include Baba and Packer (2009b), Baba and Packer (2009a), Moessner and Allen (2013), and Aizenman and Pasricha (2010). Among these, Bahaj and Reis (2022a) find evidence that banks in the jurisdiction covered by the Fed's swap lines registered a significant increase in their average excess returns, and also increased their demand for dollar-denominated bonds. My paper provides a theoretical framework to think about these effects.

The focus on the spillovers from US monetary policy to the rest of the world is shared with a growing set of studies. Bekaert et al. (2013), Bruno and Shin (2015), and Miranda-Agrippino and Rey (2020), among others, show that changes in global risk aversion and uncertainty are closely related to monetary policy in the US. Kalemli-Özcan (2019) and Camara et al. (2024) show that monetary policy divergence vis-a-vis the US has larger spillover effects in emerging markets than in advanced economies through its effect on global investors' risk perceptions. On the theoretical front, work on international monetary transmission and the global financial cycle has built on New-Keynesian models (for example Gertler et al., 2007, Gourinchas, 2018, and Mukhin, 2022). In my paper, the spillovers from the Fed acting as the ILoLR translate into lower risk perceptions, which affect the portfolio decisions of global banks, exchange rates, and their capital allocation across borders.

Given the role of the Federal Reserve in my model, this study is closely aligned with the literature on the international lender of last resort, particularly regarding the potential for moral hazard (Calomiris, 2004; Meltzer, 1997). Liquidity facilities can generate moral hazard by implicitly subsidizing banking activities, leading to ex-ante costs from fire sales (Lorenzoni, 2008), costly bail-outs (Farhi and Tirole, 2012), or aggregate demand effects (Farhi and Werning, 2016; Korinek and Simsek, 2016), among others. To tackle these issues, studies such as Goodhart and Huang (2000), Mishkin (2000), Corsetti et al. (2006), and Bastidon et al. (2008) propose different solutions, ranging from having a more selective ILOLR to employing constructive ambiguity when disbursing funds. Regarding the recent role of the Fed as the ILOLR, Morelli et al. (2015) argues that, in taking for granted the support of the Fed, the receiving countries reduced their holdings of official reserves, reinforcing their dependence on the US. I argue that the incentives of the US and the rest of the world might not be aligned if the intervention does not fully mitigate the risk, and it leads to larger losses in the event of a financial crisis.

The rest of the paper is organized as follows. Section 2.2 describes the baseline model. Next, Section 2.3 discusses the optimal portfolio allocation of banks and how it might open the door to multiple equilibria. The ex-ante implications of having an international lender of last resort are presented in Section 2.4, while Section 2.5 provides a welfare analysis when the intervention is anticipated. Finally, Section 2.6 concludes.

2.2 Baseline model

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

To benefit from the outcome of these projects, global banks need to roll-over their short-term liabilities

[4] Earlier research explored the swap lines that supported the Bretton Woods system and the Fed's reciprocal swap arrangements from 1962 to 1998, which were mainly used for foreign exchange interventions to maintain dollar pegs (e.g., Williamson, 1983; Obstfeld et al., 2009).

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

2.2.1 Households

Each household consumes and saves. EU Households derive utility from consuming tradable (C_t^T) and non-tradable (C_t^N) goods from a consumption basket defined as $C_t \equiv (C_t^N)^\theta (C_t^T)^{1-\theta}$. The relative price of the tradable good with respect to the non-tradable one in the EU is p_t. The parameter $0 < \theta < 1$ denotes their preference for the non-tradable good.

Households are free to buy and sell tradable goods in a frictionless goods market across countries. Non-tradable goods can only be traded domestically either with other households, or with global banks that use them as input for their domestic investments in $t = 0$. EU households save or borrow by trading bonds with global banks. Since financial markets are incomplete, these bonds are denominated in EU non-tradable goods ("domestic currency"). The households' optimization problem is then

$$\max_{C_t} \quad U = \sum_{t=0}^{2} \beta^t \ln(C_t) \tag{2.1}$$

subject to the budget constraint in each period,

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

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

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

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

Their first-order conditions can be written as

$$p_t C_t^T = \mathbb{E}\left[\frac{p_{t+1} C_{t+1}^T}{\beta \mathcal{R}_t}\right] \tag{2.2}$$

$$p_t = \frac{C_t^N}{C_t^T} \frac{\omega}{1 - \omega} \,. \tag{2.3}$$

The Euler equation in (2.2) simply states that as the interest rate increases, expenditure on tradables in period 1 decreases. Equation (2.3) determines the optimal distribution of consumption spending between tradable and non-tradable goods. It follows that keeping non-tradable consumption fixed, an increase in tradable consumption has to be accommodated by a drop in p_t.

US households face an analogous optimization problem[5], and US prices and quantities are denoted with (*). They consume a basket of goods defined as $C_t^* \equiv (C_t^{*N})^{1-\omega^*}(C_t^{*T})^{\omega^*}$. The only significant differences with EU households are that they do not receive profits from global banks, and trade bonds denominated in US non-tradable goods (B_t^*). As with the bond traded by EU households, $\mathcal{R}_0^* \in \{R_0^*, 0\}$ where $R_0^* > 0$ is realized with probability $1-\rho$. Their first-order conditions follow the same intuition as their EU counterpart and are given by

$$p_t^* C_t^{*T} = \mathbb{E}\left[\frac{p_{t+1}^* C_{t+1}^{*T}}{\beta \mathcal{R}_t^*}\right] \tag{2.4}$$

$$p_t^* = \frac{C_t^{*N}}{C_t^{*T}} \frac{\omega^*}{1-\omega^*}\,. \tag{2.5}$$

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. The law of one price (LOP) holds, and thus $p_t = p_t^* e_t$.

2.2.2 Global Banks

The banking sector characterized here corresponds best to large non-US global banks, which intermediate massive capital flows across borders between the US and other advanced economies.

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

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

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

$$\text{Max} \quad \mathbb{E}_0\left(\frac{1}{\mathcal{R}_0 \mathcal{R}_1}\Pi\right) = (1-\rho)\frac{1}{R_0 R_1}\Pi^G \tag{2.6}$$

$$\text{where} \quad \Pi^G = e_2 r^* K^* + rK - e_2 R_1^* B_2^* - R_1 B_2$$

[5] The full problem can be found in Appendix ??

subject to the following constraints,

$$\text{Initial investment} \qquad e_0 K^* + K = e_0 B_1^* + B_1 \tag{2.7}$$

$$\text{Roll-over needs} \qquad e_1 B_2^* + B_2 \geq \mathbb{E}_0(e_1 \mathcal{R}_0^* B_1^* + \mathcal{R}_0 B_1) \tag{2.8}$$

$$\text{IC constraints} \qquad \mathbb{E}_0(\frac{1}{\mathcal{R}_0 \mathcal{R}_1}\Pi) \geq \gamma(e_0 B_1^* + B_1) \qquad \text{in } t = 0 \tag{2.9}$$

$$\mathbb{E}_0(\frac{1}{\mathcal{R}_1}\Pi) \geq \gamma \mathbb{E}_0(e_1 B_2^* + B_2) \qquad \text{in } t = 1 \tag{2.10}$$

where I have ignored profits when banks shut down since they are 0. I will assume that the IC constraint in $t = 0$ binds so that banks' investment is limited[6]. The first-order conditions for this problem are intuitive,

$$\frac{\mathbb{E}(e_{t+1})}{e_t} = \frac{R_t}{R_t^*} \tag{2.11}$$

$$\frac{\mathbb{E}(e_2)}{e_0} = \frac{r}{r^*} \tag{2.12}$$

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

Aggregate imbalances

Banks are homogeneous, so aggregate variables correspond to their individual choices[7]. The exchange rate plays a key role in determining the ex-post soundness of the global banking system. Even if the IC constraint in (2.9) binds in period 0, banks might go bust in period 1 if condition (2.10) is violated. In case it is satisfied, banks are able to roll-over their debt and (2.8) implies that $e_1 B_2^* + B_2 \geq e_1 R_0^* B_1^* + R_0 B_1$. In addition, UIP conditions hold such that $e_{t+1}/e_t = R_t/R_t^*$. Combining the previous expressions, (2.10) can be rewritten as

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

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

2.2.3 Market Clearing

Market clearing conditions for the EU non-tradable good are

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

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

$$Y_0^N = C_0^N + K \tag{2.13}$$
$$Y_1^N = C_1^N \tag{2.14}$$
$$Y_2^N + rK = C_2^N\,, \tag{2.15}$$

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

$$Y_t^T + Y_t^{*T} = C_t^T + C_t^{*T}\,. \tag{2.16}$$

Definition 2 (Competitive Equilibrium)**.** *A competitive equilibrium is a path of real allocations* $\{C_t^T, C_t^N, C_t^{*T}, C_t^{*N}\}_t$ *and* $\{B_t, B_t^*\}_t$*, interest rates* $\{R_t, R_t^*\}_t$ *and exchange rate* $\{e_t\}_t$*, satisfying households' optimality conditions in* (2.2)–(2.5)*, the banks' optimality conditions in* (2.6)–(2.12)*, and the market clearing conditions in* (2.15) *and* (2.16) *-plus their counterparts for the US economy-, given a path of endowments* $\{Y_t^T, Y_t^N, Y_t^{*T}, Y_t^{*N}\}_t$*.*

2.3 Optimal allocation and multiple equilibria

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

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

Equilibria in $t = 1$

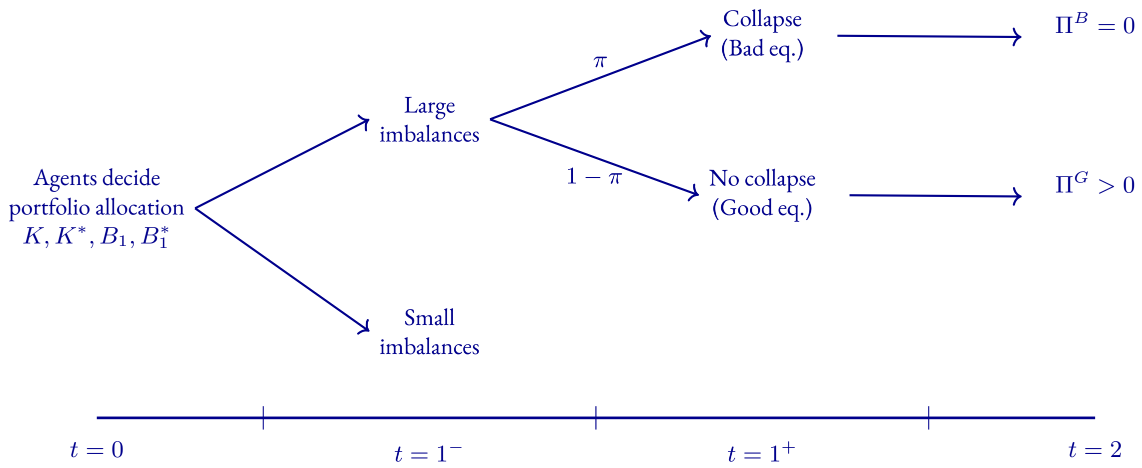
Consider a set of asset positions $\{K, K^*, B_1, B_1^*\}$. Under certain conditions that will be discussed later, global banks will be exposed to self-fulfilling expectations about the exchange rate, and two different equilibria[8] might arise in period 1.

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

Bad equilibrium. Another equilibrium features pessimistic households that do not provide the funds that banks need. This is the case if they expect a relatively strong dollar, $E_{1^-}(e_1) > \bar{e}$ that would increase

[8]These are equivalent to the two equilibria that arise in the model by Chapter 1.

Figure 2.1: Timing of the model



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

the incentives of banks to divert their funds. Banks collapse, their investment in US and EU assets is lost, and their profits Π become null. I refer to this as the "bad" equilibrium, with an exchange rate of e_1^B.

Figure 2.1 gives an overview of the timeline and the main events in the model.

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

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

2.3.1 Determination of the imbalances

I now study the optimal portfolio allocation of banks in $t = 0$, and how it might open the door to multiple equilibria in the next period. From the banks' optimality conditions in (2.6)-(2.10), investment is constrained and capital is allocated according to

$$K = K^* = \frac{\dfrac{(1-\rho)^2}{1-\rho+\gamma} Y_0^N - \dfrac{1}{r} Y_2^N}{1 + \dfrac{(1-\rho)^2}{1-\rho+\gamma}} . \tag{2.17}$$

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

Now, how does ρ affect the exchange rate in equilibrium? The market clearing conditions in (2.15) and (2.16), and households' intertemporal budget constraints imply

$$e_0 = \left(1 + \frac{1}{3/2-\rho} \cdot \frac{\theta}{1-\theta} \cdot \frac{\gamma}{1-\rho} \cdot \frac{K}{Y_0^N - K}\right)^{-1}, \tag{2.18}$$

where $\frac{K}{Y_0^N-K} = (r\frac{(1-\rho)^2}{1-\rho+\gamma}Y_0^N - Y_2^N)/(rY_0^N + Y_2^N)$. Although the relation between e_0 and ρ is highly non-linear, the simple numerical exploration provided in Figure 2.2 shows that for low values of ρ, the dollar appreciates when the probability of a crisis increases ($\partial e_0/\partial\rho > 0$). Intuitively, if a bank run is more likely, then the expected profits of banks drop. This generates a negative wealth effect on EU households in the future, depressing their aggregate demand and forcing a depreciation of the euro.

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

$$B_1 = K - \tfrac{1-\theta}{\theta}\tfrac{1}{2}(Y_0^N - K)\Big(1 - e_0\Big) \tag{2.19}$$

$$B_1^* = K^* - \tfrac{1-\theta}{\theta}\tfrac{1}{2}(Y_0^{*N} - K^*)\left(1 - \frac{1}{e_0}\right). \tag{2.20}$$

Since $Y_0^N - K = Y_0^{*N} - K^* \geq 0$, a dollar appreciation ($\uparrow e_0$) increases B_1 and reduces B_1^*, holding investment constant. This is in line with banks funding their activities in the more affordable currency. Moreover, under reasonable conditions[9], a rise in K and K^* leads to an increase in B_1 and B_1^*, respectively, highlighting the desire of banks for minimal currency mismatches. It is straightforward to conclude that dollar funding from global banks decreases as ρ rises ($\partial B_1^*/\partial\rho < 0$), given its impact on K^* and on e_0. On the other hand, two competing forces determine the impact on B_1:

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

For relatively low values of ρ, equations (2.17) and (2.18) suggest that K is high and e_0 is low, strengthening the impact of $\partial K/\partial\rho$ compared to $\partial e_0/\partial\rho$, and resulting in $\partial B_1/\partial\rho < 0$, as shown in Figure 2.2.

Lastly, equations (2.17) to (2.20) pin down the optimal portfolio allocation $\{K, K^*, B_1, B_1^*\}$. Combining it with (2.10) yields the maximum exchange rate that banks can tolerate before shutting down,

$$\bar{e} \equiv \frac{rK/R_1 - R_0 B_1(1+\gamma)}{(1+\gamma)R_0^* B_1^* - r^* K^*/R_1^*} = f(\rho). \tag{2.21}$$

The relation between $\bar{e}$ and ρ is highly non-linear. The key insight here is that all sources of funding and investments will decrease with ρ, as more constrained banks are forced to shrink their balance sheets. However, the impact on B_1^* is larger than on B_1 due to fluctuations in the exchange rate, leading to $\partial\bar{e}/\partial\rho > 0$ as in Figure 2.2. In other words, higher risk increases banks' resilience to a dollar appreciation, as their imbalances are more limited.

Regarding the two potential equilibrium exchange rates in period 1, recall that UIP holds when banks operate, meaning that $e_1^G = e_0 R_0/R_0^*$. As for e_1^B, when banks collapse the economy reverts to autarky,

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

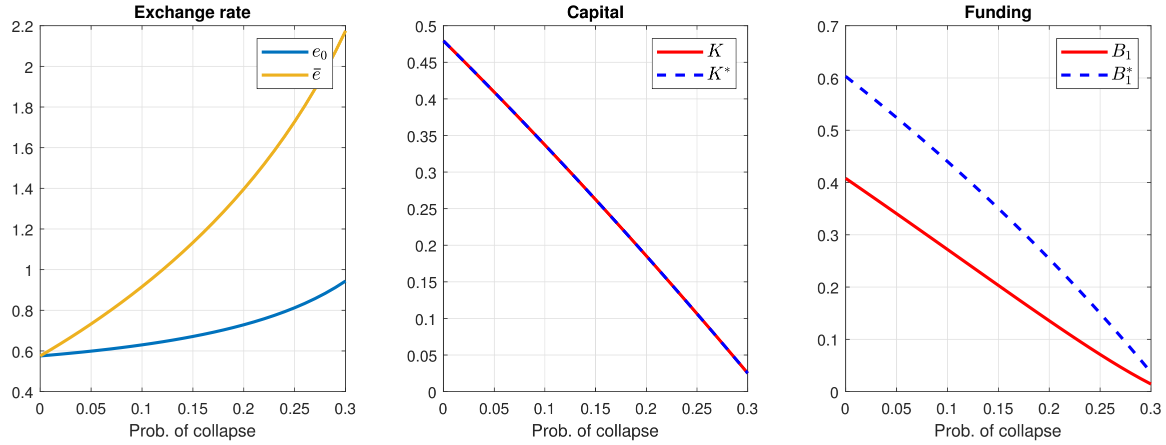


Figure 2.2: Impact of ρ on key variables

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

and therefore the exchange rate is determined entirely by countries' relative endowments. Therefore,

$$e_1^G = e_0 \frac{R_0}{R_0^*} = e_0 < 1 \tag{2.22}$$

$$e_1^B = \frac{Y_1^{*T}}{Y_1^T} = 1\,, \tag{2.23}$$

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

2.3.2 Probability of a crisis, ρ

The probability of a financial crisis depends on the fundamentals of the economy, the banking sector's positions, and households' expectations, but it can be characterized in terms of e_1. I focus first on two extreme cases. First, $\rho = 0$ if banks' portfolio allocation is such that $e_1^B < \bar{e}$, meaning that banks are resilient and can tolerate even a sharp dollar appreciation. On the other hand, a crisis is inevitable if imbalances are significantly large, such that $\bar{e} < e_1^G$. In this case, banks are too vulnerable to exchange rate fluctuations.

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

$$\rho = \begin{cases} 0 & \text{if } e_1^B < \bar{e} \\ \pi & \text{if } e_1^G \le \bar{e} \le e_1^B \\ 1 & \text{if } \bar{e} < e_1^G \end{cases} \tag{2.24}$$

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

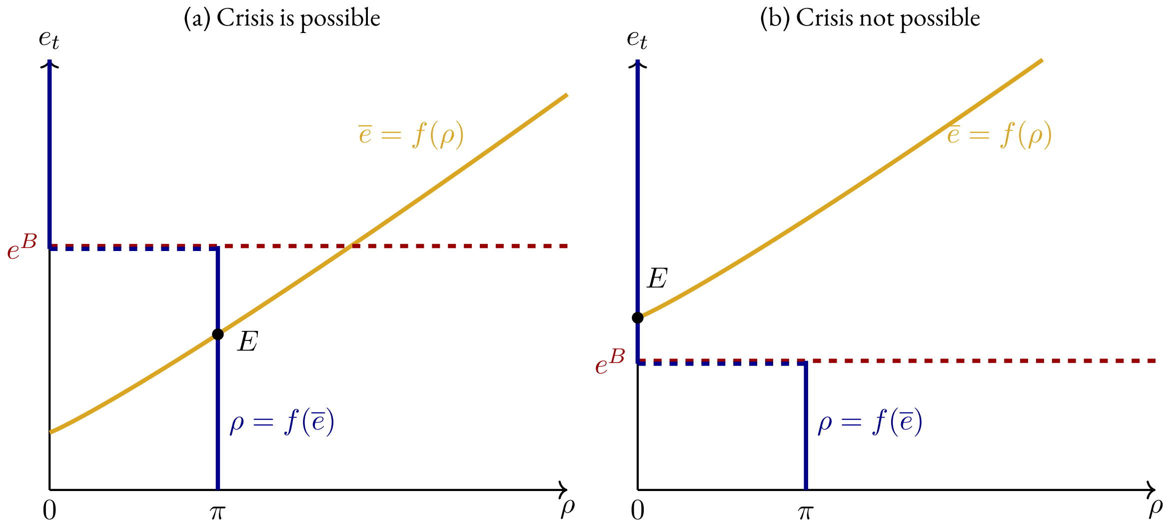


Figure 2.3: Probability of a financial crisis and exchange rates

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

2.3.3 Multiple equilibria

The equilibrium of the model can be characterized by solving the system of two equations given by (2.21) and (2.24), after incorporating (2.17)-(2.20). Agents are rational, so for a certain pair $(\rho, \bar{e})$ to be an equilibrium, it must be that $E_0(\rho) = \rho$ and $E_0(e_1) = \rho e_1^B + (1-\rho)e_1^G$.

I want to clarify the intuition behind these results. If we start from a point where $E_0(\rho) = 0$, banks face very little financial restrictions, and is then individually optimal for them to take more debt and invest more. If the exchange rate is low enough, debt denominated in dollars is relatively cheap and banks rely more on it, leaving them exposed to exchange rate fluctuations in $t = 1$, such that $e_1^G \geq \bar{e}$. Nevertheless, equation (2.24) shows that in that case, $\rho > 0$, and therefore $E_0(\rho) \neq \rho$.

If on the contrary, we start from a point where $E_0(\rho) \sim 1$ and thus a financial crisis is almost certain, banks face tight restrictions, limit their investments, and their profits are affected. Since EU households receive lower bank profits, their aggregate demand contracts and their currency depreciates. In the context of a stronger dollar, banks move away from dollar funding, making their exposure to exchange rate fluctuations low. In the model, this means that $\bar{e}$ is high, potentially to a point where $e_1^B < \bar{e}$. Equation (2.24) shows that $\rho = 0$ in that case, reflecting the fact that the exchange rate that forces banks to shut down is so high, that a collapse becomes impossible. Since $E_0(\rho) \sim 1 \neq \rho$, then this cannot be an equilibrium.

Figure 2.3 provides a graphical representation of these dynamics. In panel (a), even if global banks anticipate the possibility of a financial crisis, this might not be enough to prevent multiple equilibria from arising. This result is dependent on the fundamentals of the world economy. Panel (b), for example, depicts a case where $\bar{e} = f(0) > e_1^B$ and therefore no financial crisis can occur in equilibrium. The following proposition captures this insight.

Proposition 6. *Multiple equilibria are possible in $t = 1$ if $\exists\, \pi \in (0,1)$ such that $e_1^B > \bar{e} = f(\pi) \geq e_1^G = g(\pi)$, and $E_0(\rho) = \pi$, where π is the probability of $S = 1$ (pessimistic agents). In that case, one equilibrium features global banks operating, while in the other they cannot roll over their debt and go bust.*

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

2.4 International Lender of Last Resort

Consider the case where, initially, expectations are such that $E_0(\rho) = \pi$, so that multiple equilibria are possible. What can a central bank do in period 1 to prevent the "bad" equilibrium from materializing? The intervention I consider here is in the form of a lender of last resort. The idea is that crises occur due to pessimistic expectations, preventing households from providing the funding that banks need to roll over their short-term liabilities. If the lender of last resort can commit to providing the liquidity needed, and the commitment is credible, then households rule out the possibility of a financial crisis, and it never materializes. Importantly, the effect on the world's macroeconomic conditions depends on whether the intervention is anticipated in period 0 or not.

The simplest way to model this intervention is to follow Bocola and Lorenzoni (2020) and introduce a government that can make a transfer G to global banks in $t = 1$. 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 R^S (non-distortionary tax). A more detailed explanation is provided in Chapter 1. I also assume that fiscal capacity is limited in both countries in the following way.

Assumption 6. *There is an upper bound on the tax rate that the government can apply for this intervention, such that $\tau^* \leq \bar{\tau}^*$ in the US, and $\tau \leq \bar{\tau}$ in the EU. Moreover, $\bar{\tau} \to 0$.*

The reason behind setting $\bar{\tau} \to 0$ is that, for simplicity, I am considering otherwise perfectly symmetric countries, and therefore both would have the same ability to act as the LOLR. In contrast, Chapter 1 presents a framework where this symmetry does not hold due to general equilibrium forces. However, in this simplified model, I use this assumption to represent the Fed's intervention exclusively. This approach allows me to focus on the consequences of the Fed's intervention rather than its ability or incentives to intervene.

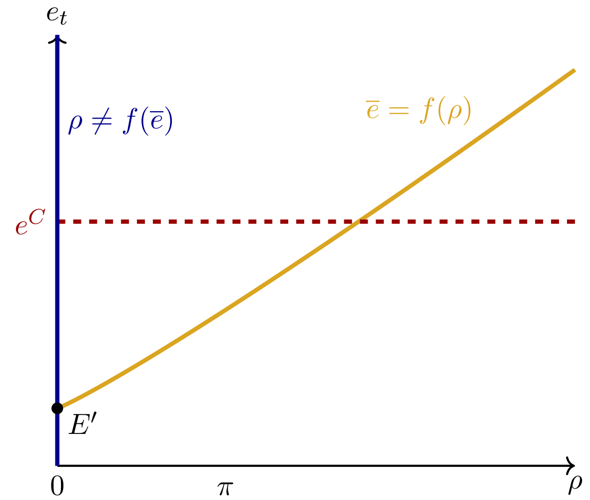
2.4.1 Unanticipated intervention

Imagine that households and banks are unaware in period 0 that any form of liquidity assistance is available in the future. Then, financial positions are taken under $E_0(\rho) = \pi$, opening the door to multiple equilibria. If a lender of last resort were to commit –at the beginning of period 1 and before the realization of the sunspot S– to providing the liquidity needed, and it is expected to have the resources to do so, the world economy converges to the "good" equilibrium, as the possibility of a banking collapse is ruled out. $\bar{\tau}^*$ is large enough so that the intervention is always feasible.

This is the case discussed in Chapter 1, where the initial portfolio allocation of banks is taken as given[10]. They argue that it is always beneficial for the ECB to bail out global banks with the help of the Fed, from an ex-post perspective. In this paper I am interested in the ex-ante perspective.

[10] I endogeneize the portfolio decisions of global banks such that the initial short-term liabilities are $L^* = R_0^* B_1^*$ and $L = R_0 B_1$, and the investment is $A^* = r^* K^*$ and $A = rK$.

Figure 2.4: Probability of a bank run and exchange rates



Note: The anticipated intervention breaks down the effect of $\bar{e}$ on ρ, as the probability of a financial crisis becomes independent of global banks' imbalances. The new equilibrium in $t = 0$ features a lower exchange rate e_0, and higher investment in EU and US assets.

2.4.2 Anticipated intervention

In a rational setting, agents should incorporate the potential intervention by the Fed into their expectations at $t = 0$. If the intervention is anticipated and credible, then $E_0(\rho) = 0 \neq f(e_t)$ and the portfolio allocation changes, allowing for a different equilibrium besides the "good" and the "bad" ones in $t = 1$. Figure 2.4 provides a graphic representation of a potential new equilibrium in the initial period using $(\bar{e}, \rho)$.

Equations (2.17)–(2.20) pin down the allocation $\{K, K^*, B_1, B_1^*\}_{\rho=0}$ and the exchange rate e_0 when $\rho = 0$. As discussed in Section 2.3, a lower risk of a financial crisis allows global banks to borrow and invest more, and generate larger profits. This positive effect on EU households' relative wealth strengthens EU aggregate demand and appreciates the euro compared to the dollar. As the relative cost of dollar funding drops, banks rely more on US households to finance their investments[11]. Consequently, their imbalances grow larger, and their resilience to dollar fluctuations is lower. Proposition 7 captures these results.

Proposition 7. *Consider initially that $E_0(\rho) = \pi$. If the intervention by the Fed is anticipated, the probability of a crisis is ruled out such that $E_0(\rho) = 0$, and we have that*

1. *The dollar depreciates ($\downarrow e_t$)*
2. *Banks take larger positions, K and K^*.*
3. *They increase their borrowing, B_1 and B_1^*, but especially in dollars.*
4. *Banks' imbalances are larger ($\downarrow \bar{e}$)*

As it currently stands, this situation is unequivocally beneficial for the EU. If the Fed eliminates the risk that limits the expected profits of banks, EU households' relative wealth increases. In the last section, I introduce a few changes to the baseline model to explore two scenarios where the ECB may not want to

[11] A similar result could be achieved also without a dollar depreciation, if we assume that it is easier to divert funds coming from foreign investors, as in many macro models.

commit ex-ante to receive liquidity assistance from the Fed.

2.5 Ex-ante Welfare

We now turn to the welfare implications of the Fed's intervention from an ex-ante perspective. Normally, a traditional lender of last resort might face moral hazard issues, as the indirect "subsidy" to banking activities pushes intermediaries to take riskier and larger positions that make the need for the intervention more likely and costly. It could be optimal then for the LoLR to commit not to intervene ex-ante, but to do so ex-post. In an open-economy setting, however, the incentives of policymakers around the world might not be aligned, and the decision of whether to intervene or not becomes no longer a fully independent choice.

In this section I will consider an imperfect intervention by the Fed. Specifically, I assume the following.

Assumption 7. *When multiple equilibria are possible, the Fed fails to contain the crisis, with an exogenous probability* $0 < \Omega < 1$.

This is meant to capture, in a very reduced form, that such a large-scale liquidity injection might not always be feasible from a political or economic point of view, or that it might not be enough to rule out pessimistic expectations. In terms of the equilibrium of the model, this means that now $\rho = \pi \cdot \Omega$, meaning that the probability of a crisis depends now on animal spirits and the Fed's imperfect intervention. If we set $\Omega = 1$ we are back to the standard case discussed in the previous section.

Now, it is possible to calculate the welfare losses from the collapse of global banks on the EU economy as the difference between the utility of households in both scenarios,

$$\Psi \equiv U_G - U_B = \theta\beta \underbrace{\ln\left(\frac{rK + Y_2^N}{Y_2^N}\right)}_{NT \text{ goods}} - (1-\theta) \underbrace{\sum_{t=1}^{2} \beta^{t-1} \ln\left(\frac{C_{B,t}^T}{C_{G,t}^T}\right)}_{T \text{ goods}} \tag{2.25}$$

As in Chapter 1, the consequences of a financial crisis can be broken down into two groups. First, there are direct effects coming from the forced liquidation of EU long-term assets. On the other hand, the loss of banks' profits and the negative impact on EU households' relative wealth forces them to consume fewer tradables, which is captured by the second term in (2.25).

How do U_G and U_B depend on ρ? Panel a) in Figure 2.5 provides a numerical representation that aligns with the intuition. A reduction in ρ increases welfare in the "good" equilibrium (U_G), that is if the crisis does not materialize. This is straightforward, as ex-ante less-constrained banks can invest more and at lower costs. On the other hand, welfare conditional on a banking crisis (U_B) is lower if ρ is relatively low, as having to liquidate such large portfolios entails significant costs. Overall, the first effect dominates and the ex-ante expected welfare increases when the probability of a crisis is reduced.

Nevertheless, even though this might seem profitable for global banks, it might not necessarily align with the objectives of a central bank. I will consider a non-US central bank whose objective is to min Ψ. This is consistent with a central bank wanting to minimize the welfare losses conditional on a financial crisis happening[12]. The relation between Ψ and ρ is presented in Panel b) in Figure 2.5. For the reasons discussed before, a reduction in ρ leads to larger welfare losses if a financial crisis materializes. This opens the door to an interesting trade-off for the ECB, which is captured in the following proposition.

[12] This modelling choice is made for clarity and I make no claim that it maps to welfare optimization

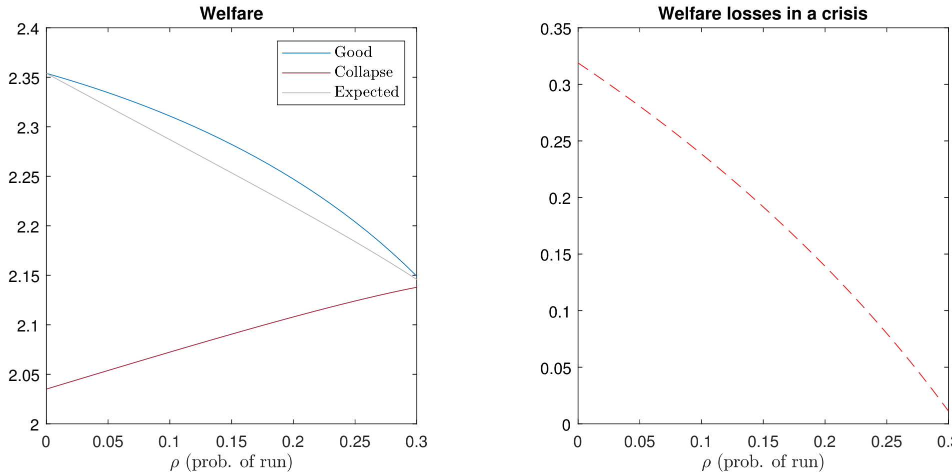


Figure 2.5: ECB Welfare losses

Proposition 8. *Consider that the ECB's objective is to minimize Ψ depicted in (2.25). Assume that multiple equilibria are possible, such that $E_0(\rho) = \pi$ with no intervention. The ECB will be time-inconsistent for them if*

$$\Psi(\pi) \leq \bar{\Psi} < \Psi(\pi\Omega)$$

where $\bar{\Psi}$ is the maximum welfare losses that are consistent with the ECB's objective.

Interestingly, if the Fed was not involved, it would be credible for the ECB not to commit to intervening, as it would lack the resources for such a large-scale injection of foreign currency, particularly during a crisis when the dollar appreciates. This highlights a problem that is only particular to an open-economy setting: when the domestic lender of last resort has no capacity to intervene ex-post and no incentives to intervene ex-ante, the presence of an international lender of last resort can bring them so a suboptimal equilibrium.

2.6 Conclusions

In this paper I develop a framework to study how the Fed acting as the international lender of last resort affects the portfolio decision of large non-US global banks, ultimately impacting capital allocation across borders.

Despite borrowing and investing in domestic currencies and in dollars, these banks may still be exposed to fluctuations in the exchange rate due to maturity mismatches in dollars. The US can solve this issue and prevent a self-fulfilling crisis by providing dollar liquidity to the global financial system in times of stress. However, if this intervention is anticipated, it incentivizes global banks to rely more on dollar funding and to increase their investments in US assets. This situation poses a challenge for central banks in other countries. While it is always beneficial for them to prevent the collapse of global banks from an ex-post perspective, there are ex-ante drawbacks, as such intervention increases the potential losses if the risk is not fully mitigated and a financial crisis hits.

Chapter 3

MACROPRUDENTIAL RULES IN A SMALL OPEN ECONOMY: A DSGE APPROACH

with A. Contreras

3.1 Introduction

The onset of the Global Financial Crisis (GFC) highlighted the importance of a macroprudential approach to banking regulation. Policymakers have since become more attuned to the close relationship between macroeconomic and financial stability. In this context, macroprudential tools are invaluable for targeting specific sources of financial imbalances, effectively addressing many of the limitations inherent in traditional monetary policy. However, there remains a limited understanding of the effectiveness of these policies, their calibrations, performance under different financial frictions, and the interactions between various macroprudential tools and monetary policy instruments (Claessens and Valencia, 2013).

In the past fifteen years, new prudential regulation has been established focusing especially on strengthening bank capital and liquidity requirements. The most prominent example is the fundamental reforms known as Basel III, introduced by the Basel Committee to address the market failures exposed during the GFC. Regarding capital requirements and the inherent procyclicality of the financial cycle, it is suggested to accumulate capital buffers during "good times" to absorb unexpected losses during periods of economic stress, ensuring these buffers can be released promptly when needed. This countercyclical capital buffer also offers the additional benefit of moderating credit growth during booms, by raising its cost (Ferreira et al., 2015; Basel Committee et al., 2010).

Regarding liquidity regulation, reserve requirements have been extensively used by policymakers in emerging economies. These can be considered a form of Basel III liquidity requirement[1] (Agénor et al., 2018). Although there is still an ongoing discussion about the correct use of reserve requirements, they have been used as a financial stability tool in many emerging economies, rather than as an unconventional

[1] Basel III introduced a minimum standard for managing liquidity risk: the liquidity coverage ratio (LCR), which requires each bank to hold a sufficient quantity of highly liquid assets to survive a 30-day period of market stress. It also introduced another minimum standard for managing liquidity risk, the net stable funding ratio (NSFR), which is viewed as complementary to the LCR.

monetary policy instrument for price stability –particularly when interest rates are constrained by the zero lower bound (Gray, 2011; Glocker and Towbin, 2012).

Despite their relevance, there is still no consensus regarding the appropriate mix of macroprudential policy instruments. The implementation of these measures generates second-order costs, thus an excessive use of them could represent a burden for the financial system in terms of efficiency. The appropriate combination of macroprudential tools should try to achieve its desired objective, while taking these costs into consideration.

We analyze the interaction and effectiveness of two macroprudential instruments, reserve and capital requirements, under different anchor variables and central bank objectives. To do so we use a dynamic stochastic general equilibrium (DSGE) for a small open economy with nominal rigidities, financial frictions, a banking sector, and a central bank. Our findings suggest that under a price stability objective, the gains from adapting reserve and capital requirements to economic conditions are substantial when the economy faces nominal and financial frictions.

When financial stability is included as a central bank objective, macroprudential policies become more relevant and can help mitigate output volatility in addition to credit fluctuations. Regarding the differences between the two instruments, the most important is that an increase in reserve requirements is associated with higher inflation, while tighter capital requirements lead to a drop in inflation. This result may be explained by the different channels through which reserve and capital requirements operate: reserve requirements influence banks' deposits, affecting deposit rates and consumption, while capital requirements impact banks' lending and investment. The overall impact on output is similar in magnitude, but more ambiguous in the case of reserve requirements, as it depends on the degree of price stickiness in the economy.

In terms of achieving the central bank's objectives, both instruments seem to perform similarly, and the benefits of complementing each other are not significant. However, in the scenario of a financial stability objective and strict separation of tasks, reserve requirements provide a slightly better response to the exogenous shocks in the economy than capital requirements.

Related Literature. Our work relates mainly to four strands of the literature. First, we contribute to the literature about countercyclical bank capital requirements. These requirements can prove useful when facing certain financial frictions, as for example the moral hazard problem between bankers and depositors, developed by Gertler and Karadi (2011). Standard capital requirements introduce important feedback loops between the real and financial sides of the economy (Gerali et al., 2010). On the one hand, during expansions, bank earnings tend to rise and so does capital accumulation, leading to an increase in loans (and a more dramatic expansion). As macroeconomic conditions deteriorate, banks' profits and hence capital might be negatively impacted —depending on the nature of the shock that hits the economy, banks might respond by reducing the outstanding loans to the private sector, thus exacerbating the original contraction. In a recent study, Lozej et al. (2018) evaluate different countercyclical capital buffer rules in a small open economy where monetary policy is completely shut off. Ferreira et al. (2015) focus on the anchor variable for the capital buffer using a DSGE model estimated for Brazil. They find that credit growth is the variable that performs best.

Second, our work contributes to understanding the theoretical effects of reserve requirements from a macroprudential perspective[2]. Among these studies, Glocker and Towbin (2012) considered required reserves as an additional policy instrument and variations in loans as an additional target into an open-economy model with nominal rigidities and financial frictions. Their results imply that reserve require-

[2]See for example Prada-Sarmiento (2008), Bianchi (2011), Kashyap and Stein (2012), Mimir et al. (2013), Alper et al. (2014), and Guzman and Roldos (2014).

ments favor the price stability objective only if financial frictions are nontrivial and are more effective if there is a financial stability objective and debt is denominated in foreign currency. Areosa et al. (2013) find a similar result by augmenting the model of Gertler and Karadi (2011) to include a compulsory reserve requirement ratio. They estimate a new-Keynesian DSGE model for the Brazilian economy, with financial intermediaries facing endogenous balance sheet constraints. The authors conclude that the effect of a monetary policy shock on the interest rate is much stronger than the one on the reserve requirement, despite both shocks yielding similar dynamics in the macroeconomic aggregates. More recently, Bustamante and Hamann (2015) also resorted to a DSGE model to shed light on the effectiveness of reserve requirements in mitigating business cycle fluctuations. Using a framework with risk-averse financial intermediaries and heterogeneous agents facing uninsurable idiosyncratic risks, they find that reserve requirements help reduce consumption volatility only if banks are sufficiently risk-averse.

Most of the papers that incorporate macroprudential policies in general equilibrium models focus on the interaction between these tools and traditional monetary policy (e.g., Angelini et al., 2011; Agénor et al., 2013; Kannan et al., 2012; Quint and Rabanal, 2013; Suh, 2012; Cecchetti and Kohler, 2012; Carvalho and Castro, 2017). Nevertheless, there has been recent efforts to study the interaction between different macroprudential tools, as in Frache et al. (2017). The authors assess the effectiveness of two macroprudential tools: countercyclical capital buffers and dynamic provisions[3], using a DSGE model estimated with data for Uruguay. Carvalho et al. (2014), on the other hand, try to understand the transmission mechanism of capital and reserve requirements under traditional and matter-of-fact financial frictions in Brazil, and find that both instruments have important quantitative effects. However, they do not evaluate countercyclical capital requirements[4] and consider only a closed economy, ignoring external financial and trade shocks that are important drivers in the business cycle of emerging economies.

Lastly, we contribute to the broad literature about the application of macroprudential tools, mostly in emerging economies. As indicated by Lim et al. (2011), two-thirds of the countries that responded to a survey prepared by the IMF have implemented this type of policy since 2008. Likewise, it is the emerging countries that have used these tools to a greater extent than developed countries. The authors suggest that the latter is because emerging countries need to mitigate certain market failures as a result of their lower financial development as well as the usual dominance by banks in the relatively small financial sector. As argued by Rey (2015), domestic monetary policy through interest rates may be ineffective in emerging markets with strong global capital flows, so instruments such as foreign reserve accumulation (Arce et al., 2019) or reserve requirements can be useful.

The remainder of this paper is organized as follows: Section 3.2 describes the model and calibration. Section 3.3 provides a first glance at how discretionary changes to macroprudential instruments affect the banking sector and the economy. Section 3.4 discusses the main results and provides an application, while Section 3.5 concludes.

3.2 The Model

The model is largely based on the work by Glocker and Towbin (2012), who incorporate reserve requirements to a relatively standard small open economy model with investment, sticky prices, and a financial

[3] The underlying principle behind dynamic provisioning is that loan loss provisions should be set in line with estimates of long-run, or through-the-cycle expected losses, breaking pro-cyclicality and creating countercyclical provision buffers (Mahapatra (2012)).

[4] They only consider Basel I and Basel II-type of requirements, which are not sensitive to the business-cycle. In particular, bank minimum capital requirements are modeled as an AR(1) process with a very high persistence.

accelerator mechanism. In order to accurately capture the dynamics of the banking sector, we introduce banking capital and balance sheet constraints into the model following Gerali et al. (2010). As it will be discussed later, this provides an additional financial friction, and further scope for macroprudential policy. The model is solved by log-linearization around the steady-state[5].

Household savings have to be intermediated through banks in order to reach firms. Banks make loans to entrepreneurs to finance their capital stock. They are subject to reserve and capital requirements set by the government[6]. Households consume a bundle of home and foreign goods and have access to an internationally traded bond to invest in.

3.2.1 The Banking Sector

Banks attract funding from households and lend to entrepreneurs. For ease of exposition, we analyze the tasks of lending and funding separately and consider lending units and deposit units. This separation is convenient especially to evaluate the effectiveness of our two macroprudential tools: deposit units will be subject to reserve requirements, while lending units will face capital requirements. Households' savings are remunerated at the deposit rate, while deposit units lend to lending units at the (risk-free) interbank rate. Lending units make risky loans to entrepreneurs[7].

Deposit Units

Deposit units collect deposits from households and lend a fraction to lending units on the interbank market and keep the rest as reserves with the central bank. They operate in perfectly competitive input and output markets, and their profits accrue to the banking sector's accumulation of bank capital.

The representative deposit unit collects deposits D_t from households and pays a gross deposit interest rate i_t^D. Next, the bank has two possibilities to use the deposits. It allocates a fraction $1 - \varsigma_t$ of deposits to lending in the interbank market and earns a gross return equal to $i_t^I B$. The remaining fraction of funds are defined as reserves, $Res_t = \varsigma_t D_t$, and they are placed into an account at the central bank, which is remunerated at the reserve rate i_t^R. The bank optimally chooses the composition of its assets, taking into account the minimum reserve requirement ratio ς^{MP} imposed by the monetary authority. The balance sheet of the deposit unit reads

$$Res_t + D_t^{IB} = D_t, \tag{3.1}$$

where $D_t^{IB} = (1 - \varsigma)D_t$ is interbank lending. Deposit units face convex costs in holding reserves G_t^ς:

$$G_t^\varsigma = \psi_1(\varsigma_t - \varsigma_t^{MP}) + \frac{\psi_2}{2}(\varsigma_t - \varsigma_t^{MP})^2, \tag{3.2}$$

where ψ_1 and ψ_2 are cost function parameters. The first linear term determines steady-state deviations from the required reserve ratio. Holding excess reserves may generate some benefits, for example, because it reduces the costs of liquidity management. In addition, the central bank may impose a fee for not fulfilling the reserve requirement. Both motivations imply that $\psi_1 < 0$. On the other hand, the quadratic term with $\psi_2 > 0$ guides the dynamics around the steady state. Glocker and Towbin (2012) discuss several

[5]The log-linearized equations of the model can be found in the Appendix.

[6]We assume that there are no other means of external finance. Possibilities to circumvent banks would obviously weaken the effects of reserve and capital requirements.

[7]Note that an alternative would be to consider banking units that both collect savings and lend to firms. The opportunity cost of attracting an additional unit of deposit would then correspond to the interbank rate.

motivations for such convex costs. First, the benefits from holding excess reserves may decline because of decreasing returns to scale. Second, the central bank may punish large negative deviations from its target with a larger penalty rate and phase out the remuneration of excess reserves at the same time.

The problem that the deposit unit faces is to maximize its profits, taking i_t^{IB}, i_t^D, and i_t^R as given, and subject to equation (3.2):

$$\max_{\{\varsigma_t, D_t\}} \Pi_t^S = \left[(1-\varsigma_t)i_t^{IB} + \varsigma i_t^R - i_t^D - G_t^{\varsigma}\right] D_t. \tag{3.3}$$

The first-order conditions of the optimization problem are:

$$-(i_t^{IB} - i_t^R) - \psi_1 = \psi_2(\varsigma_t - \varsigma_t^{MP}) \tag{3.4}$$

$$i_t^D = (1-\varsigma_t)i_t^{IB} + \varsigma_t i_t^R - G_t^{\varsigma}. \tag{3.5}$$

The bank's actual reserve ratio, ς_t, is determined by equation (3.4). It is decreasing in the spread between the interbank rate and the reserve rate and increasing in the required reserve ratio ς_t^{MP}. On the other hand, equation (3.5) shows that the deposit rate is a weighted average of the rates received from lending and reserve holdings, net of operating costs. Deposit units face opportunity costs by investing part of their assets in reserves, which is captured by the interest rate differential $i_t^{IB} - i_t^R \geq 0$. Therefore, it is possible to think of reserve requirements as a tax on the banking system. An increase in the monetary authority's target value of reserve requirements increases the opportunity costs. As a consequence, the spread between deposit and interbank rates rises[8].

Lending Units

Lending units do not interact with households. They finance themselves through the interbank market and with banking capital. They do not hold any deposits from households. Given this, they are not subject to reserve requirements, but to capital requirements.

Lending units operate in perfectly competitive input and output markets. They supply loans to entrepreneurs at the lending rate (i_t^L). The interaction between lending units and entrepreneurs are modeled through the financial contract as in Bernanke et al. (1998).

A key feature of our model is that lending units obey the following balance sheet identity:

$$L_t = D_t^{IB} + K_t^b, \tag{3.6}$$

stating that each lending unit can finance loans L_t using either fund from deposit units D_t^{IB} –at the cost of the interbank rate– or bank capital K_t^b. As in Gerali et al (2010), the two sources of funding are perfect substitutes from the point of view of the balance sheet. Lending units face costs related to the capital position of the bank. In particular, lending units pay a quadratic cost whenever the capital-to-assets ratio K_t^b/L_t moves away from a target value v^b, set by the financial regulator:

$$\Upsilon_t = \frac{\kappa}{2}\left(\frac{K_t^b}{L_t} - v^b\right)^2 K_t^b, \tag{3.7}$$

[8] In order to solve the model, we will make some assumptions about how the central bank conducts monetary policy, which will lead to the reserve supply to adjust endogenously.

with $\kappa > 0$. Bank capital is accumulated each period out of retained earnings according to

$$K_t^b = (1 - \delta^b)K_{t-1}^b + \Pi_{t-1}, \tag{3.8}$$

where $\Pi_t = \Pi_t^L + \Pi_t^D$ are the profits generated by the baking sector by adding profits from the lending units and the deposit units, respectively. δ^b measures resources spent in managing bank capital. This equation assumes that all profits are retained in the banking sector, so any potential dividends that could be accrued to the households (or other agents in the model) are zero. Given this law of motion, bank capital is not a choice variable for the bank.

On the lending unit's side, there are two financial frictions present: the financial accelerator, and the capital costs and dynamics. Therefore, it is helpful to separate the maximization process of the bank in two steps, to capture the different interest rate spreads that arise from the frictions. First, assume that there is no financial accelerator mechanism, so the problem for the lending unit is just to choose loans and funds from deposit units so as to maximize profits:

$$\max_{\{L_t, D_t^{IB}\}} \Pi_t^L = i_t^F L_t - i_t^{IB} D_t^{IB} - \frac{\kappa}{2}\left(\frac{K_t^b}{L_t} - v^b\right)^2 K_t^b, \tag{3.9}$$

subject to the balance sheet in equation (3.6), where i_t^F denote the lending rate in the absence of the financial accelerator, i.e. the risk-free lending rate. The first-order conditions deliver a condition linking the spread between friction-less rates on loans and on deposits to the degree of leverage, i.e.

$$i_t^F = i_t^{IB} - \kappa\left(\frac{K_t^b}{L_t} - v^b\right)\left(\frac{K_t^b}{L_t}\right)^2. \tag{3.10}$$

Equation (3.10) shows that the spread is inversely related to the overall capital-to-assets ratio of banks: in particular, when banks are scarcely capitalized and leverage increases, margins become wider. On the one hand, the higher the leverage, the wider (i.e. more positive) the spread between the risk-free loan rate and the interbank rate, the more the bank wants to lend, increasing profits per unit of capital (or return on equity). On the other hand, as leverage increases further, the deviation from v^b becomes more costly, reducing bank profits.

Equilibrium in the Financial Sector

Since all deposit units face the same interbank and reserve interest rates, as well as the same reserve requirement ratio, all of them will set the same deposit rate i_t^D and reserve rate ς_t. The same applies to the lending units. Based on these equilibrium conditions, the following consolidated financial sector balance sheet emerges:

$$L_t = (1 - \varsigma_t)D_t + K_t^b. \tag{3.11}$$

Now, to understand how monetary policy works in the model, note that equation (3.4) can be written as follows:

$$\varsigma_t = \varsigma_t^{MP} - \left(\frac{i_t^R - i_t^{IB} - \psi_1}{\psi_2}\right). \tag{3.12}$$

Denote Δ_t as the spread between the interbank rate and the rate paid on reserve balances: $\Delta_t \equiv i_t^{IB} - i_t^R$.

Following Glocker and Towbin (2012), we assume that the central bank maintains Δ_t equal to a constant $\Delta \geq 0$, which from equation (3.4) again, pins down the difference between effective reserves and required reserves to a constant

$$\varsigma_t - \varsigma_t^{MP} = -\left(\frac{\Delta - \psi_1}{\psi_2}\right) \equiv \Omega \geq 0. \tag{3.13}$$

While the spread between the rate on reserves and the interbank rate is constant, the spread between the rate paid on deposits and the interbank rate is determined by the zero-profit condition for deposit-taking banks:

$$i_t^D = (1-\varsigma_t) i_t^{IB} + \varsigma_t i_t^R - G^{\varsigma} = i_t^{IB} - \varsigma_t^{MP} - G^{\varsigma}, \tag{3.14}$$

where G^{ς} is the cost of holding reserves from equation (3.2), that is now also constant given Δ and Ω. From (3.14), it is easy to see that changes in the reserve requirements will have a direct negative impact on the deposit interest rates.

To conclude this subsection, since households do not hold cash, aggregate nominal reserves $\varsigma_t P_t D_t$ correspond to the monetary base in our model. Taking into account reserve remuneration, real seignorage revenue T_t^S is

$$T_t^S = \varsigma_t D_t - \frac{i_{t-1}^R}{\pi_t} \varsigma_{t-1} D_{t-1}.$$

All seignorage revenue is redistributed as a lump-sum transfer to households. The rest of the model follows the same structure as in Glocker and Towbin (2012), except for the entrepreneurs and the Government sector.

3.2.2 The Household Sector

There is a continuum of households. In a given period households derive utility from consumption C_t and disutility from working (h_t). Their instant utility function is $u(C_t, h_t) = \ln C_t - \Psi \frac{h_t^{1+\phi}}{1+\phi}$. Consumption is a Cobb-Douglas bundle of home C_t^H and foreign C_t^F goods: $C_t \propto (C_t^H)^{\gamma}(C_t^F)^{1-\gamma}$. The resulting price index reads $(P_t^H)^{\gamma}(P_t^F)^{1-\gamma}$. Households can invest their savings in real deposits D_t and foreign nominal bonds B_t, evaluated at the nominal exchange rate S_t. Because of limited capital mobility, acquiring foreign bonds entails a small holding cost[9] $\frac{\psi_B}{2}\left(\frac{S_t}{P_t}B_t\right)^2$. By supplying labor, households receive labor income $W_t h_t$. In addition, they receive gross interest payments on their deposits $i_{t-1}^D D_{t-1}$, interest payments on foreign bonds $i_{t-1}^* S_t B_{t-1}$, dividends from deposit units Π_t^S and intermediate goods producers Π_t^R, and lump-sum transfers T_t from the government. The budget constraint reads

$$\begin{aligned} P_t C_t + P_t D_t + S_t B_t = i_{t-1}^D P_{t-1} D_{t-1} + i_{t-1}^* S_t B_{t-1} + P_t W_t h_t + \\ + P_t \sum_{j \in (S,R)} \Pi_t^j + P_t T_t + \frac{\psi_B}{2} P_t \left(\frac{S_t}{P_t} B_t\right)^2. \end{aligned} \tag{3.15}$$

[9] The assumption ensures stationarity in small open-economy models (Schmitt- Grohé and Uribe 2003).

Households discount instant utility with β. They maximize their expected lifetime utility function subject to the budget constraint, which leads to the familiar optimality conditions:

$$1 = E_t \Lambda_{t,t+1} \frac{i_t^D}{\pi_{t+1}} \tag{3.16}$$

$$1 - \psi_B \frac{S_t}{P_t} B_t = E_t \left[\Lambda_{t,t+1} \frac{i_t^*}{\pi_{t+1}} \frac{S_{t+1}}{S_t} \right] \tag{3.17}$$

$$W_t = \Psi h_t^\phi C_t, \tag{3.18}$$

where the stochastic discount factor is given by $\Lambda_{t,t+1} = \beta^k \frac{C_t}{C_{t+k}}$ and $\pi_t = P_t / P_{t-1}$ is the gross inflation rate.

3.2.3 Capital Goods Producers

Capital goods producers build the capital stock, which is sold to entrepreneurs. They purchase the previously installed capital stock net of depreciation from entrepreneurs and combine it with investment goods to produce the capital stock for the next period. Investment goods have the same composition as final consumption goods. Capital is subject to quadratic adjustment costs according to $\frac{\chi}{2} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 K_{t-1}$, where δ is the depreciation rate of capital. The parameter χ captures the sensitivity of changes in the price of capital to fluctuations in the investment to capital ratio.

The market price of capital is denoted by Q_t. The optimization problem is to maximize the present discounted value of dividends by choosing the level of new investment I_t. Since the optimization problem is completely static, it reduces to

$$\max_{I_t} \left[(Q_t - 1) I_t - \frac{\chi}{2} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 K_{t-1} \right]. \tag{3.19}$$

The maximization problem yields the following capital supply curve: $Q_t = 1 + \chi \left(\frac{I_t}{K_{t-1}} - \delta \right)$. Finally, the aggregate capital stock evolves according to the following law of motion $K_t = (1 - \delta) K_{t-1} + I_t$.

3.2.4 Entrepreneurs

Entrepreneurs are the critical link between intermediate goods producers and capital goods producers. They purchase capital from the capital goods producers at the beginning of the period and resell at the end of the period. They rent it to intermediate goods producers at rental rate z_t. The structure of this part of the model is the same as in Bernanke et al. (1998), so we will not go into details.

Entrepreneurs finance their capital purchases out of their net worth N_t and with bank loans from bank lending units. For this setting, we consider only the case where the loan from the lending unit is denominated in domestic currency $Q_t K_t = N_t + L_t$. The interaction between entrepreneurs and bank lending units is characterized by an agency problem: entrepreneurs' projects face idiosyncratic shocks that are not publicly observable and they have an incentive to underreport their earnings. Lenders can verify the idiosyncratic shock at a cost. The optimal financial contract delivers the following key equation that links the spread between the aggregate expected real return on capital $E_t r_{t+1}^K$ and the risk-free lending to the entrepreneurs' leverage:

$$Q_t K_t = f\left(\frac{E_t r^K_{t+1}}{i^F_t / E_t \pi_{t+1}}\right) N_t, \text{ with } f'(\cdot) > 0. \tag{3.20}$$

Contrary to the standard model in Glocker and Towbin (2012), the risk-free rate is not the interbank rate, but it is given by equation (3.10). Given this, equation (3.20) shows that the external finance premium is

$$\frac{E_t r^K_{t+1}}{\left(i^{IB}_t - \kappa\left(\frac{K^b_t}{L_t} - v^b\right)\left(\frac{K^b_t}{L_t}\right)^2\right) / E_t \pi_{t+1}},$$

and increases with the share of debt in total financing. The entrepreneur's real return on capital is given by

$$r^K_t = \frac{z_t + Q_t(1-\delta)}{Q_{t-1}}, \tag{3.21}$$

where z_t is the real rental cost of capital.[10]

With probability $1-\nu$, entrepreneurs leave the market and consume their net worth. They are replaced by new entrepreneurs who receive a small transfer $\bar{g}$ from the departing entrepreneurs. Aggregate net worth is given by the following expression:

$$N_t = \nu V_t + (1-\nu)\bar{g}, \tag{3.22}$$

where V_t denotes the net worth of surviving entrepreneurs. Different from Bernanke et al. (1998), but in line with Gertler et al. (2007), we assume that the lending rate is fixed in nominal terms in the respective currency. Since we are only considering deposits in domestic currency, the net worth of surviving entrepreneurs is

$$V_t = (1-\tilde{\mu}) r^K_t Q_{t-1} K_{t-1} - i^L_{t-1} \frac{P_{t-1}}{P_t} L_{t-1}, \tag{3.23}$$

where the term $\tilde{\mu}$ reflects the dead-weight cost associated with imperfect capital markets (see Bernanke et al. (1998) for further details) and i^L_t is the state-contingent nominal lending rate specified in the optimal financial contract (see appendix 1). Combining equations (3.22) and (3.23) yields a dynamic equation for aggregate net worth.

Movements in net worth stem from unanticipated changes in returns and borrowing costs. Changes in Q_t are likely to provide the main source of fluctuations in r^K_t, which stresses that changes in asset prices play a key role in the financial accelerator. On the liabilities side, unexpected movements in the price level affect ex-post borrowing costs. For instance, unexpected inflation increases entrepreneurs' net worth.

3.2.5 Intermediate Goods Producers

Intermediate goods producers buy labor input from households and rent capital from entrepreneurs. They produce differentiated intermediate goods and operate in competitive input and monopolistically compet-

[10] Equation (3.21) takes into account that in a model with investment adjustment costs and incomplete capital depreciation, one has to differentiate between the entrepreneur's return on capital (r^K_t) and the rental rate on capital (z_t). The return on capital depends on the rental rate as well as on the depreciation rate of capital, adjusted for asset price valuation effects (i.e., variations in Q_t/Q_{t-1}).

itive output markets. The production function of intermediate goods producer $i \in [0,1]$ is

$$y_t(i) = \xi_t^A K_{t-1}(i)^\alpha h_t(i)^{1-\alpha}, \tag{3.24}$$

where ξ_t^A is an aggregate technology term and follows an AR(1) process. Cost minimization implies $\frac{h_t(i)W_t}{z_t K_{t-1}(i)} = \frac{1-\alpha}{\alpha}$ and marginal costs are given by

$$mc_t \propto \frac{W_t^{1-\alpha} z_t^\alpha}{\xi_t^A}. \tag{3.25}$$

3.2.6 Final Goods Producers

Final goods producers buy differentiated intermediate domestic goods from intermediate goods producers and transform them into one unit of final domestic good. They resell these transformed goods to households as consumption goods and to capital goods producers as investment goods. The final good is produced using a constant elasticity of substitution (CES) production function with elasticity of substitution ϵ to aggregate a continuum of intermediate goods indexed by $Y_t = \left(\int_0^1 y_t(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}$. Final domestic goods producers operate in competitive output markets and maximize each period the following stream of profits $P_t^H Y_t - \int_0^1 p_t^H(i) y_t(i) di$, where $p_t^H(i)$ is the price of intermediate good i. The demand for each intermediate input good is $y_t(i) = (p_t(i)/Y_t)^{-\epsilon} Y_t$ and the aggregate price level satisfies $P_t^H = \left(\int_0^1 p_t^H(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$.

We assume that Calvo-type price staggering (Calvo (1983)) applies to the price-setting behavior of intermediate goods producers. The probability that a firm cannot reoptimize its price for k periods is given by θ^k. Profit maximization by an intermediate goods producer who is allowed to reoptimize his price at time t chooses a target price p_t^* to maximize the following stream of future profits:

$$\max_{\{p_t^*\}_{t\in\mathbb{Z}}} E_t \left[\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} \Pi_{t+k|t}^R(i)\right], \tag{3.26}$$

where profits are given by $\Pi_t^R(i) = \frac{p_t^*}{P_t} y_t(i) - mc_{t+k|t}(i) y_{t+k|t}(i)$. The first-order condition is

$$E_t \left[\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} y_{t+k|t}(i) \left(\frac{p_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon-1} mc_{t+k|t}(i)\right)\right] = 0. \tag{3.27}$$

Final import goods are provided in competitive markets and the foreign currency price is normalized to one: $P_t^F = S_t$.

3.2.7 Equilibrium in the Goods Market

The economy-wide resource constraint is given by

$$Y_t = \gamma \frac{P_t}{P_t^H}(C_t + I_t + G_t) + \frac{S_t}{P_t^H} X_t + \gamma \frac{P_t}{P_t^H} \Psi_t.$$

Foreigners buy an exogenous amount X_t (expressed in foreign currency) of domestic goods and $\Psi_t = K_{t-1}(\frac{\chi}{2}(\frac{I_t}{K_{t-1}} - \delta)^2 + \tilde{\mu} r_t^K Q_{t-1} + G_t^\varsigma(\cdot) + \frac{\psi_B}{2}(\frac{S_t}{P_t} B_t)^2$ captures adjustment costs. The balance of payment identity is

$$S_t B_t = P_t^H Y_t - P_t(C_t + I_t + G_t)(1 + i_{t-1}^*) S_t B_{t-1} + P_t \Psi_t.$$

3.2.8 Government

The Central Bank has two dimensions: the central bank's objective and the implementation of the policy. In terms of objectives, we will consider two exogenously given loss functions. In the first case, the monetary authority's loss function includes only the traditional objectives of output and price stability. The price stability loss function L_t^{PS} reads

$$L^{PS} = E(\hat{\pi}_t^2 + \lambda_Y (\hat{Y}_t)^2), \tag{3.28}$$

where $\hat{Y}_t$ is the log-deviation of output from its steady-state value and λ_Y reflects the policymakers' subjective weight of output stability relative to price stability. Moreover, we also consider the case where the central bank cares about financial stability, measured as the deviations from the stock of loans, yielding a loss function as follows:

$$L^{FS} = E(\hat{\pi}_t^2 + \lambda_Y (\hat{Y}_t)^2 + \lambda_L (\hat{L}_t)^2), \tag{3.29}$$

where $\hat{L}_t$ is the log-deviation of loans from their steady-state value and λ_L reflects the policymakers' subjective weight of loan stability relative to price stability.

As mentioned in the Introduction, it is reasonable to think that Central Banks may want to avoid abrupt fluctuations in credit, mainly because of the risk of a financial crisis. Studies from the Bank for International Settlements have pointed out that deviation of credit from its trend can predict financial crisis (Borio and Drehmann (2009), Borio et al. (2002)). Note, however, that we do not include a role for countercyclical capital buffers, for example, as there is no risk of a financial crisis.

In terms of instruments, we consider three: the interbank interest rate (i_t^{IB}), capital requirements (v_t^b), and reserve requirements (ς_t^{MP}). In practice, these instruments are used in many different ways by central banks and financial regulators. For example countries that use both reserve requirements and interest rates as policy tools include Brazil, Colombia, Peru, Turkey, and others. On the other hand, there are many different anchor variables for setting the level of the countercyclical regulatory capital requirements for banks. Drehmann et al. (2010) conclude that the best leading indicator is credit-to-GDP gap, whereas the best coincident indicator is banking spread. Still, the Basel Committee suggests the use of credit-to-GDP gap as an anchor variable for both periods. However, Repullo and Saurina Salas (2011) argue that the use of such variable may exacerbate procyclicality inherent in the financial system and recommend the use of output growth.

Having said that, we will consider several policy rules based on combinations of these instruments, that minimize the two loss functions proposed before. In particular, the general setting we consider is the following:

$$\begin{aligned}
\hat{i}_t^{IB} &= \phi_{\pi,i}\hat{\pi}_t + \phi_{Y,i}\hat{Y}_t + \phi_{L,i}\hat{L}_t \\
\hat{\varsigma}_t^{MP} &= \phi_{\pi,\varsigma}\hat{\pi}_t + \phi_{Y,\varsigma}\hat{Y}_t + \phi_{L,\varsigma}\hat{L}_t \\
\hat{v}_t^b &= \phi_{\pi,v}\hat{\pi}_t + \phi_{Y,v}\hat{Y}_t + \phi_{L,v}\hat{L}_t.
\end{aligned}$$

In this paper we are interested in the interaction between the macroprudential instruments, using monetary policy as a complement. There is a consensus in the literature about the effectiveness of macroprudential policy to amplify the effect of monetary policy (under certain conditions), but little has been said about the sustainability of different macroprudential instruments. For this reason, we will consider a simple Taylor-rule for the interest rate, meaning $\phi_{L,i} = 0$, so that credit deviations are mitigated directly by capital or reserve requirements, leaving monetary policy focus on inflation and output. In another specification, we will also consider the case of an even simpler rule, where the interest rate only reacts to changes in inflation, to test the extend of the effectiveness of macroprudential instruments. As for capital requirements, we will only consider output and loans as potential anchor variables, as it is not usual to target inflation with this instrument. Moreover, we will set $\phi_{\pi,\varsigma} = 0$ in all our specifications, as our main focus is the effectiveness of reserve requirements as a macroprudential tool, and not as an unconventional monetary policy instrument.

3.2.9 Shocks and Calibration

The economy's dynamics is driven by five shocks: a cost-push shock (ξ_t^{CP}), a technology (or productivity) shock (ξ_t^A), a government spending shock (G_t), a foreign interest rate shock (i_t^*), and a foreign export demand shock (X_t). As usual, all shocks follow AR(1) processes, and the persistence and variances for each of them are shown in the Appendix (Table 3.4). The values therein are taken from an estimated DSGE model as described in Christoffel et al. (2008). Most of the rest of the parameters are standard (see Table 3.3 in the Appendix).

Several parameters are not calibrated directly but specified such that they match model-specific variables to their empirical counterparts in a standard small-open-economy as in Glocker and Towbin (2012). We use the case of Peru to set the steady-state value of ς_t^{MP} to 0.09 (average of the last 8 years, in local currency), and the effective reserve ratio (ς_t) to 0.1. This is in line with banks wanting to comply with the requirement, as reputational and operational costs would be severe. The other coefficients are calibrated such that they imply an interest rate differential between the interbank rate (i_t^{IB}) and the interest rate on reserves (i_t^R) in the steady state of 150 basis points on a quarterly basis, as in Glocker and Towbin (2012). The steady-state leverage ratio of entrepreneurs is two. We choose the other parameters of the financial contract to generate a steady-state external finance premium of 50 basis points and an elasticity to leverage of $\eta = 0.05$ as in Christensen and Dib (2008) (standard in the literature).

Regarding the parameters on the lending units, we follow Gerali et al. (2010) for parameters such as the sensitivity to bank capital cost (κ), the debt-to-loans ratio, bank capital depreciation, and the target capital-to-loans ratio (v^b). Based on this, we set the steady-state capital ratio to be 0.11, above the requirement. This is a commonly observed fact in banking: they usually maintain more capital than the minimum that is required by regulation (see Allen and Rai (1996), Peura and Jokivuolle (2004), or Barth et al. (2013)).

3.3 Discretionary changes to macroprudential instruments

This section provides a set of simulation exercises to shed light on the transmission mechanism and potential effects of reserve and capital requirements on the financial system and the economy. Following Glocker and Towbin (2012) we assume that both variables follow an exogenous AR(1) process with autocorrelation 0.7 and we abstract from a systematic component in requirements' policy.

For this analysis, we will keep monetary policy as simple as possible[11], and will particularly pay attention

[11]In particular, we will assume a simple Taylor rule where the coefficient associated with the deviations of inflation, $\phi_{\pi,IB}$, is

to the role of the financial accelerator in amplifying (or dampening) the macroprudential shocks. In the case of a change in reserve requirements, two opposite effects are interacting. First, for a given monetary base, higher reserve requirements imply smaller broad money aggregates and we expect an economic contraction. On the other hand, if the rate of reserve remuneration lies below the market interest rate, then requirements also act as a tax on the banking sector, driving a wedge between deposit and lending rates.

In the case of capital requirements, an increase leads to an immediate contraction in credit, for a given spread between wholesale loan and interbank rate. Since banking capital accumulates only through the previous period's profits, the only possible action for the bank is to cut lending, and thus interbank deposits. This will lead, eventually, to an increase in consumption (decrease in deposits), and a decrease in investment. However, this process generates higher profits for the banking units, since the increase in the interest rate spread is stronger compared to the fall in loans and deposits, leading to an increase in the accumulation of capital in the next period.

The effects discussed above might depend both on financial and nominal frictions. Therefore, while analyzing the effects of the macroprudential measures, we will consider scenarios with and without the financial accelerator mechanism, and with various degrees of price stickiness[12]. Figure 3.1 shows the effects of a one standard deviation discretionary change of reserve requirements. As discussed before, the negative effect on the deposit rate (tax effect) implies an increase in consumption, which combined with an increase in the interbank rate, leads to a decrease in the stock of loans and investment. Additionally, we have that, contrary to a contractionary monetary policy shock, an increase in reserve requirements tightens credit conditions and depreciates the exchange rate simultaneously. Because of the uncovered interest parity, the decline in the deposit rate also leads to an exchange rate depreciation and a rise in exports. Given this, the effect on output is ambiguous: for our particular parametrization, the effect seems to be initially positive, while later becomes contractionary.

The financial accelerator appears to be relevant to the transmission mechanism of reserve requirements. In particular, it strengthens the effect on investment; because of movements in the external finance premium, net worth of entrepreneurs and investment become more sensitive to fluctuations in the interbank rate. As a final result, the impact on output is more severe than in the baseline case, with a sharper and more persistent decline in economic activity.

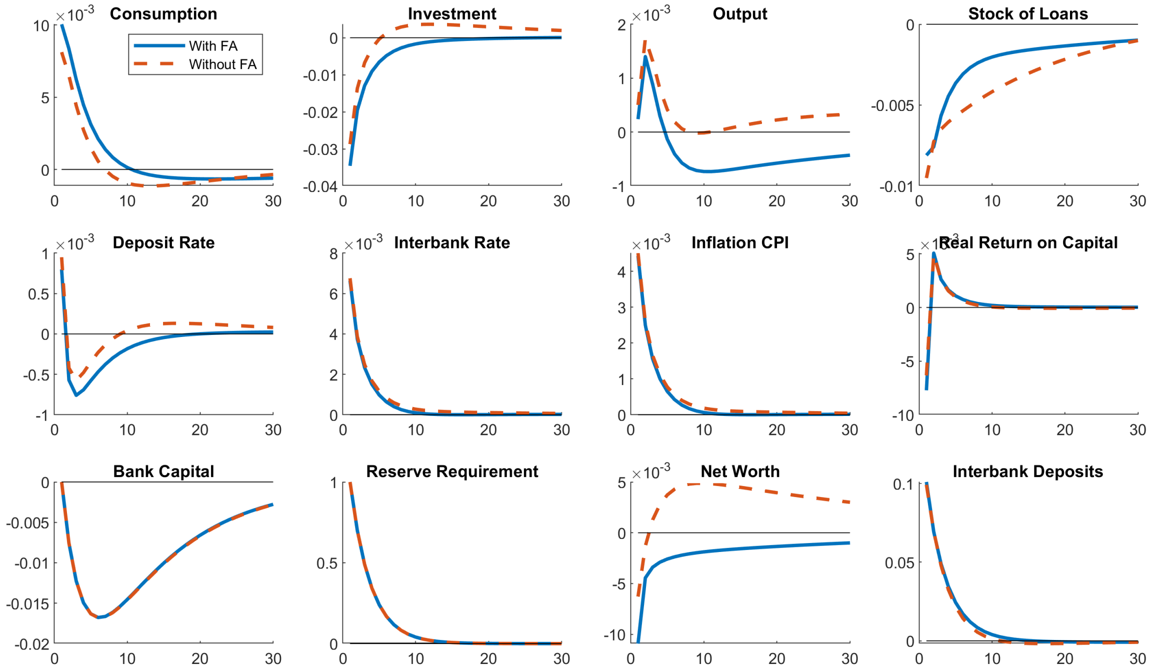
Regarding the effects of capital requirements, most of these are in line with the ones from the reserve requirements, both in direction and magnitude (see Figure 3.2), except with the bank balance sheet variables. An increase in capital requirements leads to a decrease in the stock of loans, which leads to a decrease in investment. The return on capital initially drops but tends to stabilize almost immediately. Although consumption and investment react in opposite ways as in the reserve requirement case, the effect on output is undoubtedly negative. On the other hand, as we discussed previously, an increase in capital requirements needs to be matched by the banks by reducing lending while increasing the accumulation of bank capital through a rise in profits. Thus, bank capital tends to increase, contrary to what we see after an increase in reserve requirements.

Finally, the main difference between the aggregate effect of both macroprudential measures can be seen in the impact on inflation. In the case of capital requirements, inflation tends to decrease, in line with a decrease in output. However, for our calibration, an increase in reserve requirements leads to an increase in inflation, contrary to the popular notion that reserve requirements can be increased to contain inflation.

1.5, and the other coefficients are zero.

[12] For the analysis with different degrees of price stickiness (see Figure 3.5 and 3.6 in the Appendix)

Figure 3.1: Reserve Requirement Shock and the Financial Accelerator



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in reserve requirements, considering scenarios with and without the financial accelerator mechanism. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

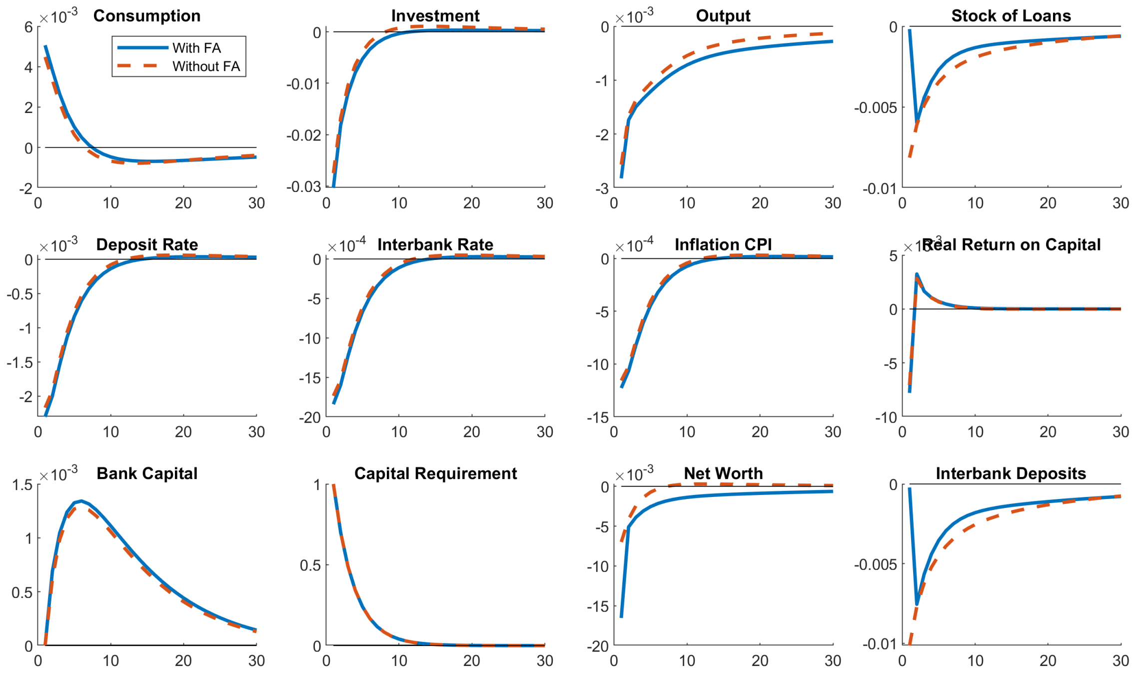
The increase in the tax on banks increases overall production costs, which puts upward pressure on the overall price level. The financial accelerator does not seem to influence significantly the transmission mechanism of capital requirements, aside from the magnitude of the decrease in lending and interbank borrowing.

Figure 3.3 captures these insights and provides a visual representation of the different transmission mechanisms behind macroprudential policy. For instance, reserve requirements, by directly influencing the distribution of deposits and reserves in banks' balance sheets, typically exert a more substantial and immediate impact on deposit rates. As a result, households adjust their savings decisions, thereby affecting aggregate consumption. On the other hand, changes in capital requirements directly impact the stock of loans and, consequently, lending interest rates. Entrepreneurs, reliant on bank loans to fund their projects, adjust their investment decisions in response to the changes in borrowing costs. Lastly, the monetary policy rate plays a pivotal role in mediating the interaction between deposit and lending units, exerting a direct influence on both sides. In the absence of financial frictions and nominal rigidities, the distinctions between these transmission mechanisms would dissipate.

3.4 Optimal Policy rules and applications

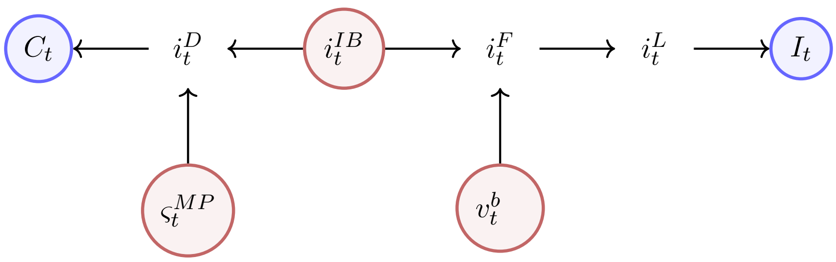
In this section we analyze the optimal macroprudential policy rules considering two different objectives and plausible sensitivities in the different instruments. In particular, we seek to find the optimal parameters for the different policy rules described in section 3.2.8 based on the loss functions provided there. The approach we follow is a grid-search-type optimizing process, with reasonable boundaries for the parameters to be plausible in a policy-making context.

Figure 3.2: Capital Requirement Shock and the Financial Accelerator



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in capital requirements, considering scenarios with and without the financial accelerator mechanism. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

Figure 3.3: Transmission Mechanism of Macroprudential Policy



Note: The variables in red represent the monetary and macroprudential instruments at the disposal of the policy-makers. i_t^D, i_t^F, i_t^L are the deposit, risk-free, and state-contingent lending interest rates, respectively. Due to the various frictions inherent in the model, the transmission mechanisms of each instrument may vary, leading to heterogeneous effects on aggregate variables such as consumption and investment.

Regarding the parameters of the Taylor-rule, we use the following search intervals. For $\phi_{Y,IB}$ we set it to $[0, 3]$ following[13] Schmitt-Grohé and Uribe (2007). On the other hand, the coefficient associated to inflation, $\phi_{\pi,IB}$, is set to be between $[1.1, 3.5]$ since values between 0 and 1 are not compatible with a rational expectations equilibrium. Note that we will not consider the case where the monetary policy rate reacts directly to loans, since our interest relies on the interaction between the two macroprudential instruments in addressing financial volatility.

For the $\phi_{\pi,\varsigma}$ and $\phi_{\pi,v}$ parameters associated with the reserve requirements and the capital require-

[13] Although the authors apply this criteria to a welfare-based analysis, the same mechanism applies.

ments, we will follow the results[14] from Glocker and Towbin (2012) and set the search interval to $[0, 31.9]$. This is also plausible from a policy-making perspective, since in countries such as Peru, reserve requirements have more than tripled in the aftermath of the global financial crisis. For the case of the parameters $\phi_{Y,\varsigma}$ and $\phi_{Y,v}$ we set the search interval for the capital requirement parameters to $[0, 13]$.

3.4.1 Price Stability Objective

First, we will consider a traditional central bank that only monitors fluctuations in output and inflation and does not respond to volatility in loans. The optimized coefficients in the policy rule and the value of the resulting loss function (in absolute value) are reported in Table 3.1, and we denote it as policy AI. The optimal coefficients we get are in line with Glocker and Towbin (2012) and Benes and Kumhof (2015).

Now, consider the case where the central bank is still only focused on the price stability objective, but uses another instrument that reacts to the deviations of the stock of loans. Note that here the central bank responds to loans because they contain information about the state of the economy, not because the containment of loan fluctuations is an end in itself. We denote AII as the policy where the reserve requirement ratio (ς_t^{MP}) is the instrument that reacts to loans. The estimated coefficient $\phi_{L,\varsigma}$ obtained is 31.9, the upper bound of the search interval set. This is not surprising, since we have seen that reserve requirements have a direct impact on variables such as investment, output and the stock of loans (which eventually lead to effects on economic activity). Moreover, in the previous section, we showed that although an increase in reserve requirements seems to cause an increase in inflation, it is not significant in magnitude and thus the usual trade-off between price and output stability should not be an issue. Policy AII represents a reduction in the lost function of almost 8% with respect to the benchmark case. This is not surprising, as the central bank has three instruments for only two objectives.

Finally, we turn to the case where the central bank uses the capital requirements to respond to deviations in the stock of loans. The estimated coefficient $\phi_{L,v}$ obtained is 31.9, following the same logic as in the reserve requirements' case. We obtain very similar results in terms of minimizing the loss function focused only on output and inflation. These findings suggest that the two macroprudential instruments analyzed are useful even for a central bank that does not have financial stability as an objective. Moreover, they have the same effect when it comes to contributing to price and output stability by reacting to changes in the stock of loans.

3.4.2 Financial Stability Objective

In this section we consider a case where the central bank explicitly wants to stabilize the fluctuations in loans, as reflected in the loss function L_t^{FS} in section 3.2.8. The results are displayed in Table 3.2. The block of specifications denoted by B are similar to the previous setting, but with the only difference of an additional objective in the central bank's loss function. As it was expected, including financial stability into the equation, without having an instrument specifically to target that variable, ends up being costly, as shown with Policy BI. Note that the coefficients related to inflation and output in the original Taylor-rule change with respect to the benchmark with only a price stability objective. This is explained by a potential trade-off between credit and the rest of the variables, and a lack of instruments.

Including any of the macroprudential instruments to target credit directly provides significant gains in terms of minimizing the loss function. In the case of reserve requirements, ς^{MP}, the loss function is

[14] In their study, the authors consider the difference in levels of the reserve requirements as the policy instrument, thus the coefficients in the policy rules can only be compared when multiplying them by the steady state of the reserve requirements in our calibration (9%).

Table 3.1: Optimal Policy Rules under a Price Stability Objective

Policy	Instrument	Coefficient			L^{PS}
		ϕ_L	ϕ_Y	ϕ_π	
AI	i^{IB}	-	1.37	2.86	**5.34**
	ς^{MP}	-	-	-	
	υ^b	-	-	-	
AII	i^{IB}	-	1.28	3.50	**4.94**
	ς^{MP}	31.90	-	-	
	υ^b	-	-	-	
AIII	i^{IB}	-	1.30	3.50	**4.95**
	ς^{MP}	-	-	-	
	υ^b	31.90	-	-	

Table 3.2: Optimal Policy Rules under a Financial Stability Objective

Policy	Instrument	Coefficient			L^{FS}
		ϕ_L	ϕ_Y	ϕ_π	
BI	i^{IB}	-	0.19	1.10	**7.13**
	ς^{MP}	-	-	-	
	υ^b	-	-	-	
BII	i^{IB}	-	1.20	3.50	**5.61**
	ς^{MP}	31.90	-	-	
	υ^b	-	-	-	
BIII	i^{IB}	-	0.40	1.62	**6.02**
	ς^{MP}	-	-	-	
	υ^b	31.90	-	-	
CI	i^{IB}	-	-	3.50	**5.33**
	ς^{MP}	31.9	13.00	-	
	υ^b	31.9	13.00	-	
CII	i^{IB}	-	-	1.10	**5.96**
	ς^{MP}	31.9	-	-	
	υ^b	-	13.00	-	
CIII	i^{IB}	-	-	3.50	**6.17**
	ς^{MP}	-	13.00	-	
	υ^b	31.9	-	-	

reduced by 21%. Similarly, adding capital requirements, υ^b, that depend positively on the deviations of credit provides a 16% decrease in the central bank's loss function. These results are in line with Glocker and Towbin (2012), who find that the use of reserve requirements as a policy tool leads to substantially lower loss function values in the presence of financial frictions.

To conclude, we also analyze the case with a strict separation of tasks, where interest rates react solely to inflation fluctuations, while the macroprudential instruments respond to output and loans. Policy CI shows that using reserve and capital requirements as instruments that depend both on loans and output has a significant impact on the loss function. Nevertheless, such a policy could be difficult and confusing to implement, and besides could lead to excessive volatility in the instruments. More plausible setting are shown as Policy CII and CIII, which exhibit a higher loss function (on average 14% higher) than the one from the overcrowded specification. However, if we compare them to the case with no separation of tasks (BII and BIII), we see that the gains are very similar. Given that CII and CIII are more feasible options, they could be preferred from a policy-making perspective.

Based on the evidence presented in this section, we can draw some conclusions about the optimal macroprudential rules. First, even under a price stability objective framework, reserve and capital requirements can be beneficial if they are incorporated to a traditional Taylor-rule. Second, if financial stability is included as an objective of the central bank, the effects of macroprudential policies become more important, reducing the target loss function up to 21%. Additionally, they seem to be useful to target output fluctuations, not only credit. Finally, in the scenario of a financial stability objective and strict separation of tasks, reserve requirements provide a slightly better response to the exogenous shocks in the economy than capital requirements.

3.4.3 Application: technology shock

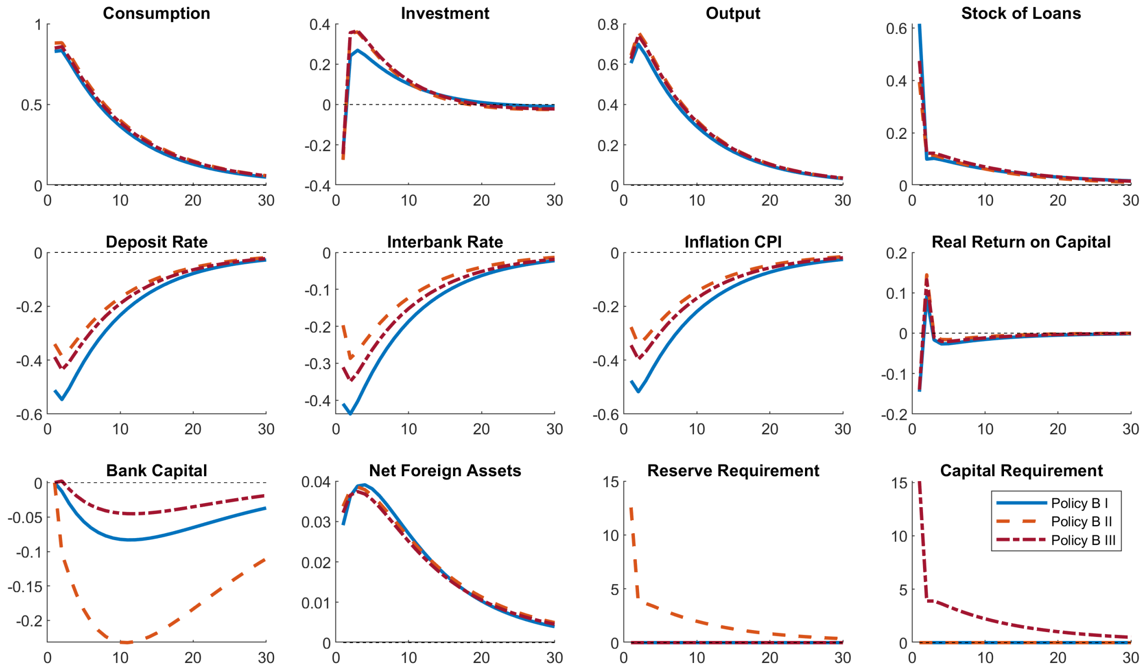
To illustrate the differences in the optimal policy rules described in the previous subsections, we show here how the economy reacts to a technology shock under these rules, as depicted in Figure 3.4. The natural transmission channel tells us that the expansionary shock triggers a decline in inflation and an increase in loans. A policy aiming to stabilize inflation would favor a decline in the interbank interest rate in order to keep real rates low. At the same time, with the objective of stabilizing output, interbank interest rates should increase. Hence, even if the central bank does not monitor credit growth, two goals should be implemented with one policy instrument: the interbank rate should increase and decrease at the same time. This becomes more dramatic if we include a financial stability objective such as in policy type B.

Macroprudential instruments, under such a scenario, proved to be helpful in stabilizing credit and some aggregate components of output. Due to the calibration of the optimal rules, the interbank rate reacts almost one-to-one to the decline in inflation. On the other hand, the positive effect on investment is reduced by around 33% if any of the macroprudential instruments is active (policies BII and BIII). The natural increase in loans is also dampened by and increase in capital or reserve requirements, which induce tighter conditions in the credit market. Moreover, an important difference between the two macroprudential instruments, in their effect on bank capital after a technology shock. We can see that the use of capital requirements (BIII) produces less volatility in the bank capital, compared to the cases in which this instrument is inactive (policies BI and BII). As mentioned before, this is due to the fact that the increase in the stock of loans induces an increase in the capital requirements, undercutting the negative profits from the banking sector.

3.5 Conclusion

This paper analyzes the interaction and effectiveness of two macroprudential instruments under different anchor variables and central bank's objectives. We build on a small open-economy model with nominal rigidities, financial frictions, a banking sector that is subject to reserve requirements, and include banking capital and capital requirements.

Figure 3.4: Technology shock under different Policy Rules and a Financial Stability Objective



Note: The figure reports quarterly impulse responses to a 1-std deviation positive technology shock, considering a scenario with a financial accelerator mechanism and different policy rules, as described in the legend. The y-axis denotes the deviation in percent from the steady state.

Under a price stability objective, the gains from adapting reserve and capital requirements to economic conditions are substantial when the economy faces nominal and financial frictions. The more traditional financial accelerator mechanism is complemented by the inherent procyclicality of banking capital accumulation, leaving scope for macroprudential measures.

On the other hand, if financial stability is included as an objective of the central bank, the effects of macroprudential policies become more relevant. These instruments are not only useful to target credit fluctuations but also to stabilize output. Regarding the differences between the two instruments, the most important is that an increase in reserve requirements is associated with higher inflation, while tighter capital requirements lead to a drop in inflation. The overall impact on output is similar in magnitude, but more ambiguous in the case of reserve requirements, as it depends on the degree of price stickiness in the economy. Nevertheless, in terms of achieving the central bank's objectives, both instruments seem to perform similarly, and the benefits of complementing each other are not significant.

Lastly, in the scenario of a financial stability objective and strict separation of tasks, reserve requirements provide a slightly better response to the exogenous shocks in the economy than capital requirements. However, it is important to notice that the role of capital requirements is not necessarily to stabilize credit growth, but to force banks to build buffers that can be used in recessions. This dimension is not captured by the model, as there is no risk of a financial crisis, but it should be taken into consideration for future work.

Appendix

3.6 Appendix 1: The log-linearized equations

Households

- Consumption-saving decision:

$$E_t\hat{C}_{t+1} - \hat{C}_t = \hat{i}_t^D - E_t\hat{\pi}_{t+1}$$

- Uncovered interest parity condition:

$$\hat{i}_t^D + \psi_B\hat{B}_t = \hat{i}_t^* + E_t\Delta\hat{s}_{t+1}$$

- Labor supply:

$$\hat{w}_t = \phi\hat{h}_t + \hat{C}_t$$

Deposit Units

- Reserve requirements:

$$\hat{i}_t^{IB} = \frac{i^R}{i^{IB}}\hat{i}_t^R - \psi_2(\tilde{\varsigma}_t - \tilde{\varsigma}_t^{MP})$$

- Deposit rate:

$$\hat{i}_t^D = \left((1-\varsigma)\frac{i^{IB}}{i^D} + \varsigma\frac{i^R}{i^D}\right)\hat{i}_t^{IB} - \frac{i^{IB} - i^R}{i^D}\hat{\varsigma}_t^{MP}$$

- Reserves:

$$\hat{R}_t = \tilde{\varsigma}_t + \hat{D}_t$$

Lending Units

- Balance Sheet:

$$\hat{L}_t = \frac{D^{IB}}{L}\hat{D}_t^{IB} + \frac{K^b}{L}\hat{K}_t^b$$

- Bank capital dynamics

$$\hat{K}_t^b = (1-\delta^b)\hat{K}_{t-1}^b + \delta^b\hat{\Pi}_{t-1}$$

- Risk-free interest rate

$$\hat{i}_t^F = \frac{i^{IB}}{i^F}\hat{i}_t^{IB} - \kappa\frac{(K^b/L)^2}{i^F}\left((\frac{3K^b}{L} - 2v^b)(\hat{K}_t^b - \hat{L}_t) - v^b\hat{v}_t^b\right)$$

- Profits

$$\hat{\Pi}_t = \frac{i^L}{\delta^b}\frac{L}{K^b}(\hat{i}_t^L + \hat{L}_t) + \frac{i^R}{\delta^b}\frac{\varsigma D}{K^b}(\hat{i}_t^R + \hat{R}_t) - \frac{i^D}{\delta^b}\frac{D}{K^b}(\hat{i}_t^D + \hat{D}_t)$$
$$- \frac{\kappa K^b}{2}\left(\frac{K^b}{L} - v^b\right)^2\left(\kappa\left(\frac{K^b}{L}\right)^2\left(\frac{3K^b}{L} - 2v^b\right)\left(\hat{K}_t^b - \hat{L}_t\right) - v^b\hat{v}_t^b + \hat{K}_t^b\right)$$

Financial contract

- Leverage and external finance premium:

$$E_t\hat{r}^K_{t+1} - \hat{i}^F_t + E_t\hat{\pi}_{t+1} = \eta(\hat{Q}_t + \hat{K}_t - \hat{N}_t)$$

- Loan rate (nominal and real):

$$\hat{r}^L_t = \hat{Q}_t + \hat{K}_t + E_t\hat{r}^K_{t+1} - \hat{L}_t$$

$$\hat{i}^L_t = \hat{r}^L_t + E_t\hat{\pi}_{t+1}$$

Entrepreneurs

- Balance Sheet:

$$\hat{Q}_t + \hat{K}_t = \epsilon_L\hat{L}_t + (1-\epsilon_L)\hat{N}_t$$

- Net Worth:

$$\hat{N}_t = \nu\hat{N}_{t-1} + (1-\nu)(\hat{Q}_{t-1} + \hat{K}_{t-1}) + \hat{r}^K_t + \nu\frac{\epsilon_L}{1-\epsilon_L}(\hat{r}^K_t - (\hat{i}^L_{t-1} - \pi_t))$$

Intermediate Goods Producers

- Production function:

$$\hat{y}_t = \hat{\xi}^A_t + \alpha\hat{K}_{t-1} + (1-\alpha)\hat{h}_t$$

- Marginal costs:

$$\hat{mc}_t = \alpha\hat{z}_t + (1-\alpha)\hat{W}_t - \hat{\xi}^A_t$$

- Cost minimization:

$$\hat{h}_t + \hat{W}_t = \hat{z}_t + \hat{K}_{t-1}$$

- Price setting:

$$\hat{\pi}^d_t = \beta E_t\hat{\pi}^d_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta}\hat{mc}_t + \hat{\xi}^{CP}_t$$

Capital Goods Producers

- Investment Demand:

$$\hat{Q}_t = \chi(\hat{I}_t - \hat{K}_{t-1})$$

- Price of capital:

$$\hat{r}^K_t + \hat{Q}_{t-1} = \frac{MPK}{r^K}\hat{z}_t + \frac{1-\delta}{r^K}\hat{Q}_t$$

  where MPK is the marginal product of capital.

- Capital dynamics:

$$\hat{K}_t = (1-\delta)\hat{K}_{t-1} + \delta\hat{I}_t$$

Monetary and Macroprudential Policy

- Taylor-rule:

$$\hat{i}_t^{IB} = \phi_{\pi,i}\hat{\pi}_t + \phi_{Y,i}\hat{Y}_t + \phi_{L,i}\hat{L}_t$$

- Reserve requirements:

$$\hat{\varsigma}_t^{MP} = \phi_{\pi,\varsigma}\hat{\pi}_t + \phi_{Y,\varsigma}\hat{Y}_t + \phi_{L,\varsigma}\hat{L}_t$$

- Capital requirements:

$$\hat{v}_t^{b} = \phi_{\pi,v}\hat{\pi}_t + \phi_{Y,v}\hat{Y}_t + \phi_{L,v}\hat{L}_t$$

Market Clearing

- Goods market:

$$\hat{Y}_t = \gamma(c_y\hat{C}_t + i_y\hat{I}_t + g_y\hat{G}_t + (1-\gamma)\hat{\epsilon}_t) + (1-\gamma)(\hat{\epsilon}_t + \hat{X}_t)$$

- Balance of payments

$$\hat{B}_t = \hat{Y}_t - (c_y\hat{C}_t + i_y\hat{I}_t + g_y\hat{G}_t + (1-\gamma)\hat{\epsilon}_t) + i^*\hat{B}_{t-1}$$

- Real exchange rate:

$$\hat{\epsilon}_t - \hat{\epsilon}_{t-1} = \Delta\hat{s}_t - \hat{\pi}_t^d$$

- CPI inflation rate:

$$\hat{\pi}_t = \gamma\hat{\pi}_t^d + (1-\gamma)\Delta\hat{s}_t$$

3.7 Appendix 2: Calibration

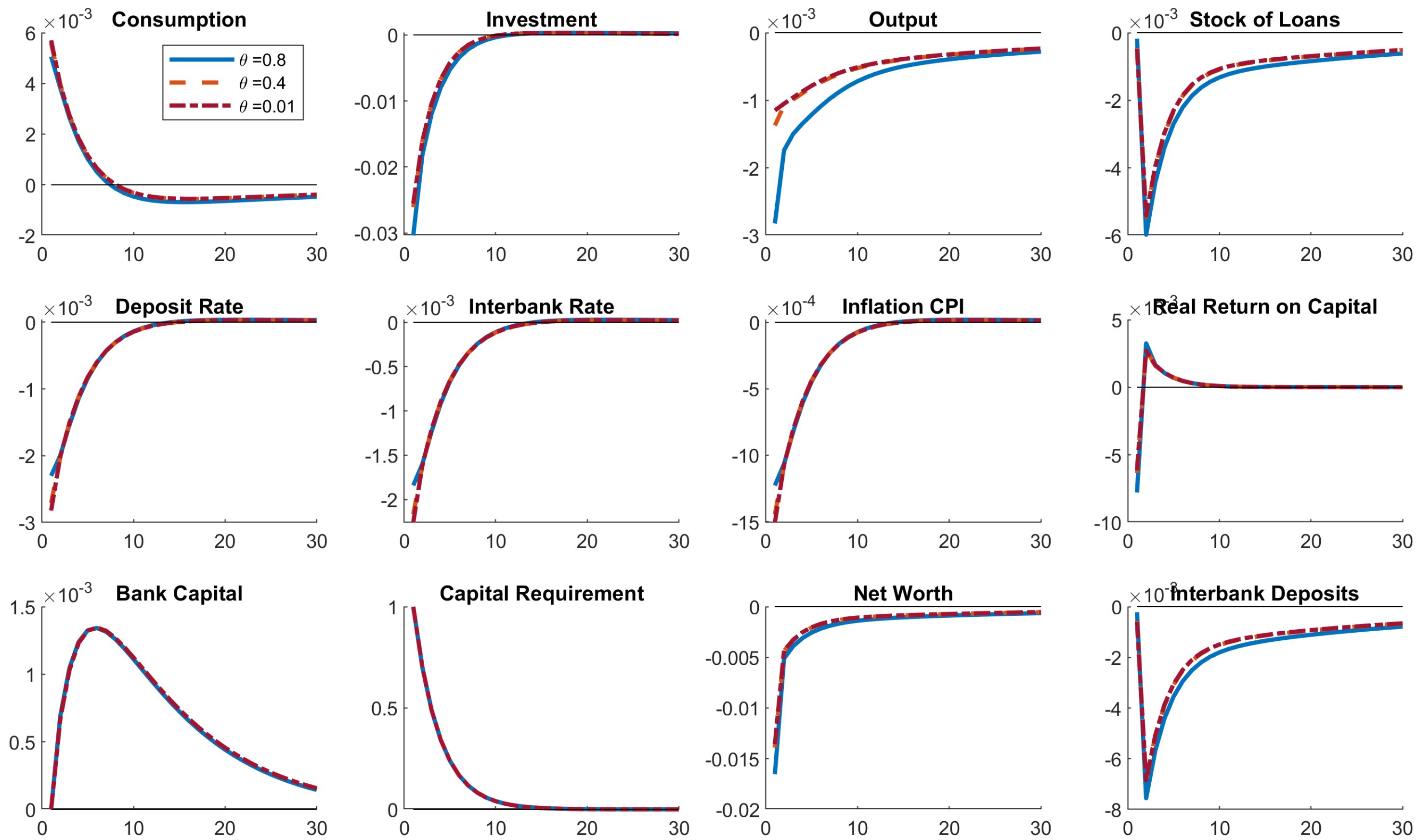
Table 3.3: Calibration

Param.	Value	Description
δ	0.025	Depreciation Rate of Capital
β	0.985	Discount Factor
α	0.33	Capital Share in Production
ϕ	3.00	Inverse of Frish Labor Supply Elasticity
θ	0.75	Degree of Price Stickiness
ν	0.97	Survival Rate of Entrepreneurs
χ	0.25	Capital Adjustment Costs
η	0.05	Elasticity of External Finance Premium
ψ_B	0.02	Adjustment Costs for Net Foreign Assets
γ	0.75	Share of Domestically Produced Goods
c_y	0.55	Share of consumption on output
i_y	0.22	Share of investment on output
g_y	0.23	Share of gov. spending on output
δ^b	0.1049	Bank capital depreciation
v^b	0.09	Target capital-to-loans ratio
K^b/L	0.11	Actual capital-to-loans ratio
κ	10	Sensitivity to bank capital cost

Table 3.4: Calibration of the Shocks

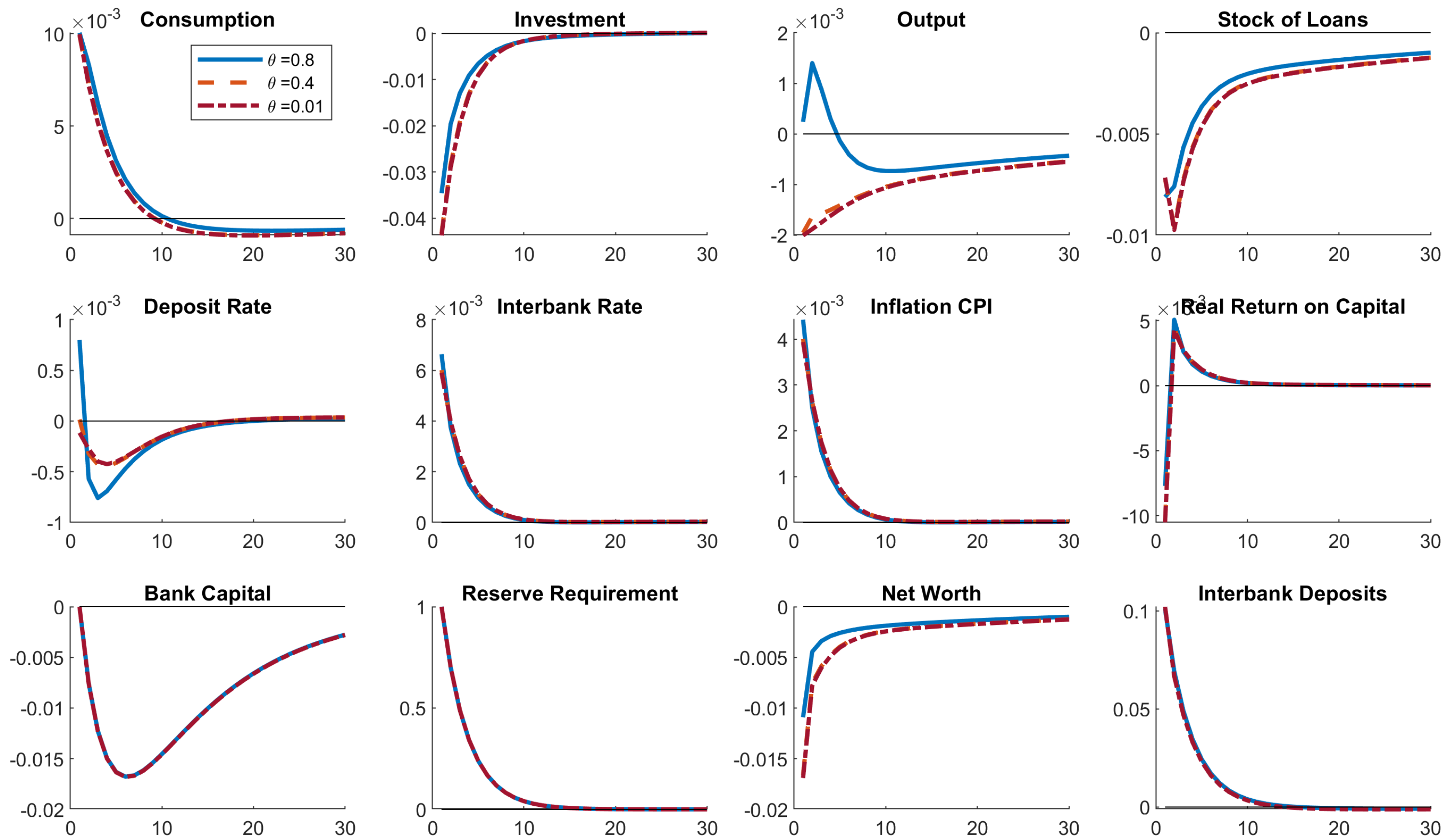
ρ	σ^2	Description
0.89	1.13	Technology Shock
0.40	0.14	Cost-Push Shock
0.86	4.63	Government Expenditures Shock
0.88	0.43	Foreign Interest Rate Shock
0.80	5.01	Export Demand Shock

Figure 3.5: Capital Requirement Shock and the degree of Price Stickiness



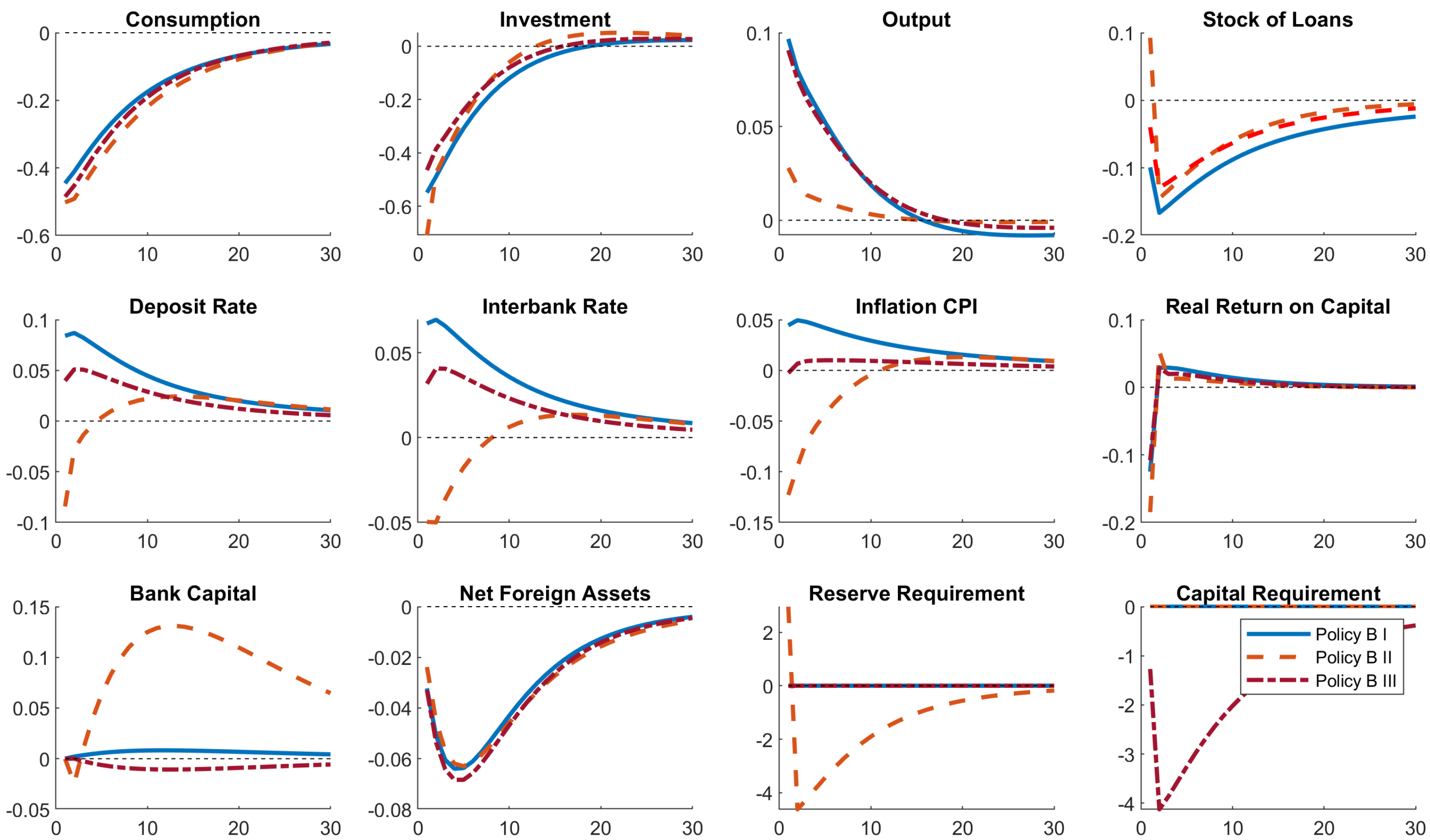
Note: The figure reports quarterly impulse responses to a 1-std deviation increase in capital requirements, considering a scenario with a financial accelerator mechanism and different values of θ. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

Figure 3.6: Reserve Requirement Shock and the degree of Price Stickiness



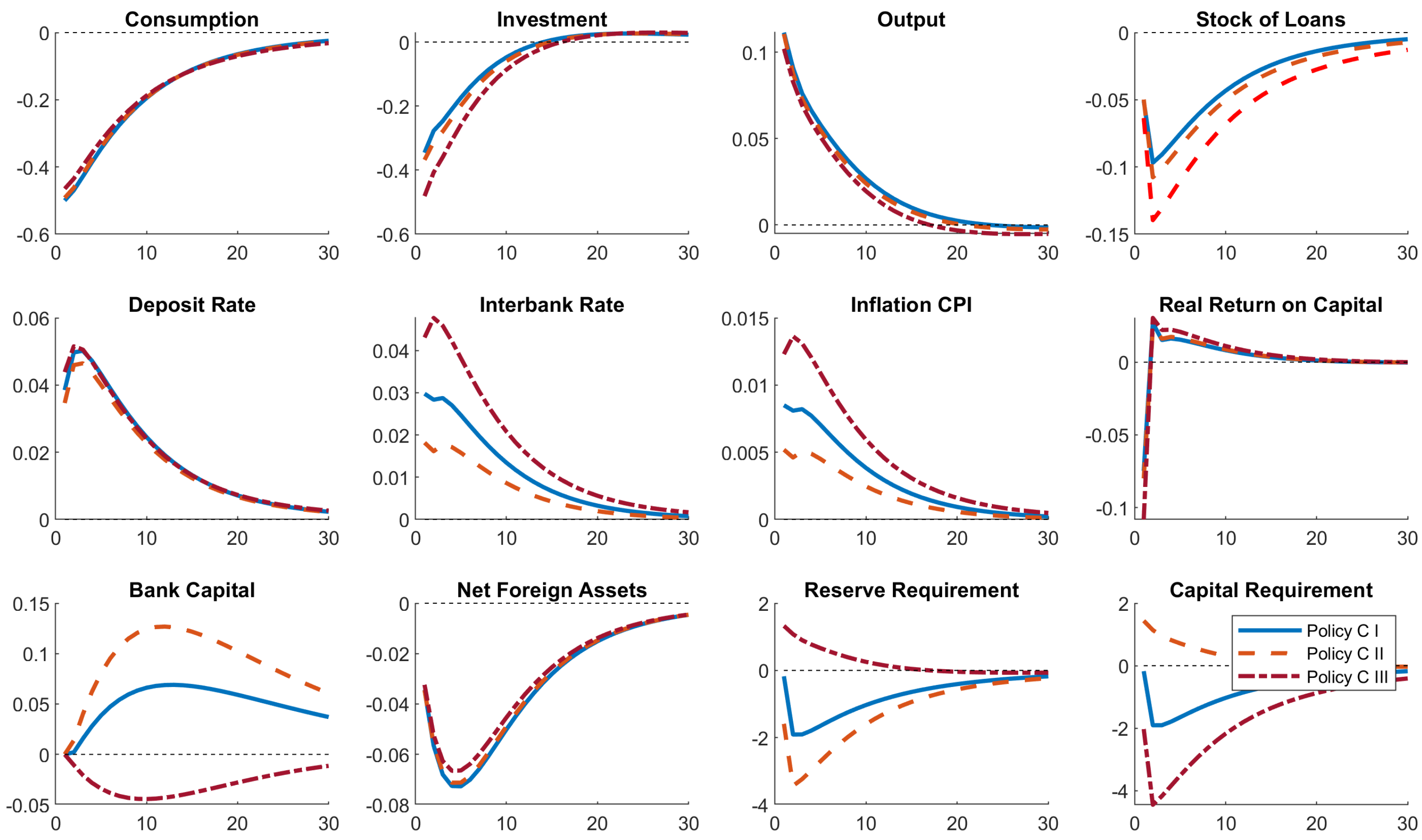
Note: The figure reports quarterly impulse responses to a 1-std deviation increase in reserve requirements, considering a scenario with a financial accelerator mechanism and different values of θ. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

Figure 3.7: Government shock under different Policy Rules and a Financial Stability Objective



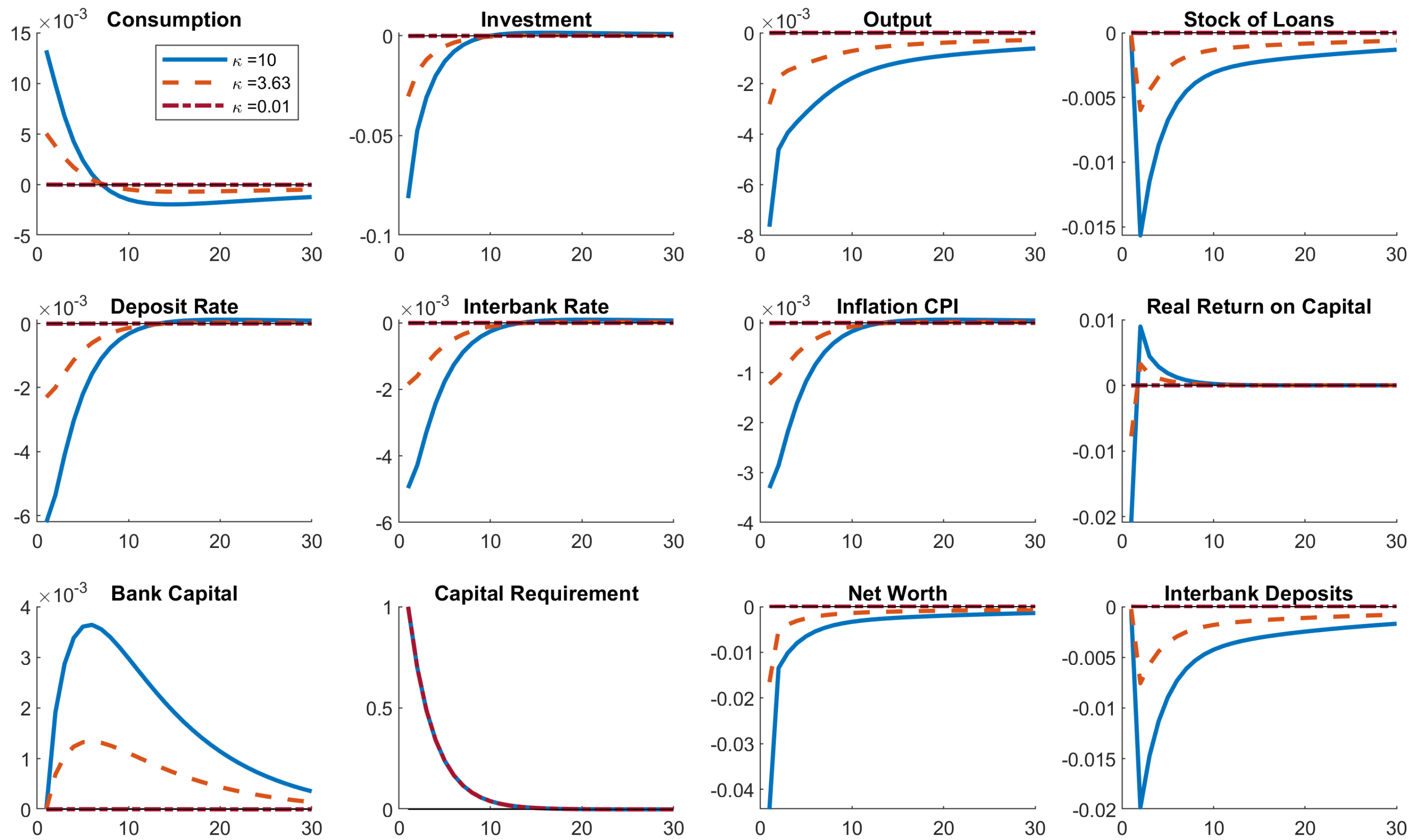
Note: The figure reports quarterly impulse responses to a 1-std deviation increase in government expenditure, considering a scenario with a financial accelerator mechanism and different policy rules, as described in the legend. The y-axis denotes the deviation in percent from the steady state.

Figure 3.8: Government shock under different Policy Rules and a Financial Stability Objective



Note: The figure reports quarterly impulse responses to a 1-std deviation increase in government expenditure, considering a scenario with a financial accelerator mechanism and different policy rules, as described in the legend. The y-axis denotes the deviation in percent from the steady state.

Figure 3.9: Capital requirement shock under different degrees of bank capital adjustment cost



The figure reports quarterly impulse responses to a 1-std deviation increase in capital requirements, considering different values for κ, the adjustment cost on bank capital. Monetary policy is specified by an interest rate rule for the interbank interest rate as defined in section 2.8 with $\phi_{\pi,i} = 1.5$ and the other coefficients equal 0. The y-axis denotes the deviation in percent from the steady state.

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