Monetary Policy and Financial Stability: Transmission Mechanisms and Policy Implications

Álvaro Aguirre, Markus Brunnermeier, and Diego Saravia
editors

Banco Central de Chile / Central Bank of Chile

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The global financial crisis that broke out 10 years ago uncovered the buildup of risks during a period of price and output stability. It challenged the previous consensus that preserving price stability was the optimal way to ensure financial stability, and led to a surge of interest in the multiple interactions between monetary policy frameworks, financial vulnerabilities and financial stability. This volume contributes to the study of these issues as well as the convenience of incorporating financial stability considerations in monetary policy frameworks, bringing together a multinational group of distinguished scholars to discuss the latest research findings. It is of utmost importance to understand how monetary policy affects both financial conditions and financial vulnerabilities that amplify negative shocks, as well as the potential intertemporal policy trade-off between improving current conditions and exacerbating future financial vulnerabilities.

Araucarias
Onofre Jarpa (1849–1940)
Oil on canvas, 55 x 70 cms.
Collection of the Central Bank of Chile

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Monetary Policy and Financial Stability: Transmission Mechanisms and Policy Implications An Overview

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Financial stability, understood as a situation when the financial system smoothly performs its function of allocating capital and adverse shocks are unlikely to be amplified, has been for long a key concern for policymakers and, in particular, for monetary authorities. However, until 10 years ago, most central banks did not try to pursue the financial stability goal by using their main instrument, the short-term interest rate. Instead, they tried to do this through regulation and supervision of individual financial institutions, a process that was in most cases conducted by additional regulatory authorities. The consensus was that monetary policy should be conducted with an explicit commitment from the central bank to stabilize inflation, and perhaps with a complementary objective of output stabilization.

The main concern against this consensus was asset prices. The "lean versus clean" policy debate, generated after the recession following the stock-market boom in the U.S. in the late nineties, focused on whether monetary policy should react to signs of misalignment of prices from their fundamental values in a preemptive way, or should only counteract the adverse effects after a bubble bursting.

Monetary Policy and Financial Stability: Transmission Mechanisms and Policy Implications edited by Álvaro Aguirre, Markus Brunnermeier, and Diego Saravia, Santiago, Chile.

Overall, using monetary policy to address financial stability was perceived too costly relative to its uncertain benefits. The main view was that preserving price stability was the optimal way to maintain financial stability, and decades of successful central-banking practice reflected in output stabilization and anchored private agents' inflation expectations around policy targets reinforced the benefits of following this strategy.

However, the global financial crisis that started 10 years ago challenged this consensus. While financial supervisors deemed each individual institution to be sound, risks were building in the system, leading to inadequate levels of capitalization and liquidity. And the buildup of risks occurred during a period of price and output stability, during the so-called "Great Moderation" period, where low nominal interest rates that were consistent with the central bank commitment of CPI inflation stability, may have contributed to excessive risk-taking by financial intermediaries and to a raise in asset prices, while good economic conditions masked the growth of financial imbalances.

The increasing concern about financial conditions and the consequent reassessment of the macroeconomic policy framework was most evident with the implementation of macroprudential policies. The objective was to reduce potentially adverse asset and credit-boom effects, and they were aimed at the stability of the whole financial system instead of at the soundness of individual institutions, as financial-stability policies mostly did in the past. Unlike monetary policy, macroprudential policies can be targeted at certain sectors of the economy if the financial vulnerability is narrow, and have direct effects on specific measures such as capital requirements and loan-to-value ratios. Because of these advantages they have become the preferred instrument to mitigate financial vulnerabilities, while monetary policy has still maintained its focus on the inflation-real activity trade off. Many of the papers in this volume explore the implementation and effects of these macroprudential policies.

The developments over the last 10 years have led to a surge of interest in the relationship between monetary policy and financial vulnerabilities. The debate focuses on the broad question of whether and how monetary-policy frameworks should incorporate explicitly risks to financial stability.

Should monetary policy follow a tighter stance in normal times in order to avoid the build-up of risks? Should monetary policy *Lean against the wind* (LAW)? This strategy has been called this way since

1956, after the remark by the Federal Reserve Board of Governors Chairman William McChesney Martin Jr. when describing to the Congress the purpose of the Fed as "leaning against the winds of deflation or inflation, whichever way they are blowing".

On one side, a separable approach between monetary policy and policies aimed at financial stability, i.e., to continue with the current framework, is proposed. Financial imbalances are difficult to detect and hence they are best addressed with other tools such as macroprudential policies. The benefits of LAW are too uncertain, and the costs too high to consider modifying the prevailing policy framework.

On the other side, proponents of LAW emphasize the effects of monetary policy not only on financial stability but also on financial vulnerabilities—specific features leading to the amplification of adverse shocks that raise future risks to financial stability—, mainly through a risk-taking channel. Additionally, monetary policy would affect costs for all borrowers and lenders, and would have a wider reach than macroprudential policies, which may simply push certain activities into non-regulated sectors. Papers in this volume contribute to this ongoing debate.

To inform this fundamental debate, it is essential to explore the mechanisms through which monetary policy and financial stability are interlinked. In particular we need to understand the channels through which conventional monetary policy affects financial vulnerabilities and assess whether monetary policy can have substantial effects on financial vulnerabilities. Since macroprudential policies would be a part of the general framework, we need to understand their interaction with a monetary policy aimed at financial stability.

One of the most relevant monetary transmission channels in this debate relates to risk-taking behavior, through which, at times of economic expansion and low interest rates, monetary policy can lead to the creation of vulnerabilities via an endogenous increase in risk-taking. One way this can occur is through an institutional factor driven search-for-yield that may lead some fund managers to seek higher risk to maintain yields after rates on safer assets decline. High asset values could also lead financial institutions to underestimate risks. Alternatively, higher net worth of borrowers arising from high collateral values eases borrowing constraints and allows for excessive credit accumulation, or may incent carry trades based on short-term funding, thus leading to excessive maturity transformation.

Hence, through this risk-taking channel of monetary policy, a policy stance that is consistent with current financial stability can lead to financial vulnerabilities, thus reducing the resilience to financial shocks and raising future risks to financial stability.

The growing literature studying the interaction between monetary policy and financial risks acknowledge the channels through which monetary policy not only affects financial conditions, i.e. current borrowing costs, but also can lead to build-ups of financial vulnerabilities in the presence of financial frictions that amplify negative shocks. Under these conditions policymakers face an intertemporal trade-off, since improving current conditions may lead to future financial vulnerabilities. This raises the question: Are the net benefits of a LAW strategy large enough to reform monetary policy frameworks to cope directly with financial vulnerabilities?

Proponents of the separable approach presumed that monetary policy has small and uncertain effects on financial imbalances, and when weighted against the costs of slowing the economy, i.e. high unemployment rates, the trade-off is unfavorable. Proponents of LAW argue that relatively small changes in short-term interest rates may result in a large impact on financial intermediaries' risk-taking behavior. While the costs of LAW may appear as downward-biased business cycles, the benefits appear as less recurring and severe financial crises, episodes that in the absence of a preemptive strategy are much more costly than regular recessions.

Most of the developments mentioned so far have occurred in the developed world. In turn, in developing countries, financial vulnerabilities have been much more common, and monetary policy has been involved to a larger degree with financial stability objectives. Maintaining a certain level of the exchange rate and managing capital flows are perhaps the most common, particularly in countries with currency mismatches in the banking and corporate sectors due to episodes of very high inflation rates in the past.

In recent years, macroprudential policy has become an increasingly active policy area in developing countries as well. Many countries have adopted it as a tool to safeguard financial stability, in particular to deal with the credit and asset price cycles driven by global capital flows. Indeed most of the experience with macroprudential policies comes from emerging countries, which show however less complex financial systems, thus limiting the insights for developed countries.

In the following paragraphs, we provide a brief summary of the papers included in this volume.

In "***Negative Interest Rates: Lessons from the Euro Area***," Jens Eisenschmidt and Frank Smets explore whether the pass-through from policy rates on bank deposit and lending rates as well as loan volumes are affected by the existence of a negative interest rate policy.

They focus on the decision of the European Central Bank, starting in June 2014, to cut the rate on its deposit facility to -0.4 percent as part of the introduction of a more comprehensive monetary policy easing package. To explore the effect of this policy, the authors examine the behavior of bank loan and deposit rates and loan volumes before and after its introduction, using a confidential dataset containing balance sheet data for 256 selected euro-area banks at the monthly frequency.

The first fact the paper documents is that a zero lower bound on interest rates seems to exist only for interest rates on household deposits held at banks. This is consistent with the view that it is relatively cheaper for households to substitute deposits for cash. Therefore distortionary effects from a negative interest rate policy should be most visible for banks with high-reliance on household deposits, an observation that guides the empirical exploration in the paper. Furthermore, the analysis focuses on the differential response of the German banking sector, since due to its relatively low initial interest rates, it had the least room to lower them after the policy was implemented.

The statistical analysis uncover suggestive evidence that in the euro area the negative interest rate policy did not have a differential effect on lending behavior by banks that are reliant on household deposits, neither in terms of prices nor of quantities. By using panel estimations, they do not find evidence of a change in the pass-through of policy rates to bank lending rates during the negative interest rate policy. This evidence leads the authors to conclude that negative rates in the euro area were expansionary.

As short-term interest rates are close to the zero lower bound, more attention has been devoted to policies aiming at long-term rates to control inflation. In "***Central Banks Going Long***," Ricardo Reis evaluate the performance of central banks that in the past have turned their attention to long-term interest rates as a target or as a diagnosis of policy, by using a model where inflation and the yield curve are jointly analyzed.

The model restates the classic problem of monetary policy through interest-rate rules in a continuous-time setting where shocks follow diffusions in order to integrate the endogenous determination of inflation, long-term and short-term interest rates.

Then the paper uses the model to analyze two historical episodes when monetary policies relied on going long, significantly changing the composition of their balance sheets and adapting their procedures to focus monetary policy on long-term interest rates. The first of these episodes was the U.S. in 1942–51, when the Fed stood ready to buy and sell 90-day Treasury bills at a fixed rate and set a ceiling to the 10-year yield. Through the lens of the model, the way in which the Fed went long was ultimately unsustainable since it created a high-inflation equilibrium that might have been reached were it not for the change in policy.

The second episode is the U.K. in the 1960s, when monetary policy devoted itself first to stabilizing the exchange rate and capital flows through the setting of short-term interest rates, and second to managing the yield curve and the cost of government financing through the setting of long-term interest rates. Although using long-term interest rates is consistent with keeping inflation under control, the model suggests that without a precise understanding of the yield curve, its slope and how it responds to shocks, keeping inflation under control will be hard.

The analysis leads the author to conclude that there are several caveats to going long. First, unless it is implemented carefully, it can put the solvency of the central bank at risk or lead to much volatility in interest-rate markets. Second, a ceiling on long-term rates creates a stable equilibrium with high inflation to which the economy can easily escape if there are positive shocks to inflation. Third, a feedback rule for long rates requires very precise knowledge of the yield curve and how it changes with separate shocks. Fourth, making the slope of the yield curve the policy tool requires steepening the yield curve, raising long rates relative to short rates in order to raise inflation.

In "***Capital Flows, Macroprudential Policies and Capital Controls***," Álvaro Aguirre, Sofía Bauducco and Diego Saravia study how macroprudential policies and capital control measures affect capital inflows in developed and developing economies, over the 2004–2013 period. The main finding is that macroprudential policies, especially those targeted at financial institutions, have a positive impact on bond inflows in developing economies, while the effect is negative in developed ones. This result survives the introduction of different control variables, changes in the sample period considered and in the frequency of the macroprudential policy measures.

To further explore the mechanisms behind these findings the authors show additional results related to domestic credit and financial development. In particular they show that domestic credit is negatively influenced by macroprudential policies in developing economies, but not in developed ones, and that in developing countries with more developed financial systems, the effect of macroprudential policies on capital inflows is larger. This brings support to the idea that relatively small domestic firms see their funding needs curtailed by such policies.

These findings are broadly consistent with the hypothesis of carry-trade opportunities present in developing economies, which are intensified when macroprudential policies limit the ability of domestic financial institutions to provide credit to firms. Non-financial firms with access to international markets see an opportunity to obtain profits from interest rate differentials by bringing in external funds and acting as financial intermediaries in the domestic market.

In terms of capital controls, the econometric estimations show that these instruments exert a negative effect on capital inflows in developing economies, as it is expected, but also that capital controls impact negatively the volatility of equity inflows in these economies, the main goal of capital controls in developing economies.

In "***A Global Safe Asset for and from Emerging Market Economies***", Markus Brunnermeier and Lunyang Huang examine international capital flows induced by flight-to-safety and propose a new global safe asset for the emerging economies.

In their model, domestic investors have to co-invest in a safe asset along with their physical capital. At times of crisis, they fire-sell part of their capital and replace initially safe domestic government bonds with safe U.S. Treasuries. The reduction in physical capital lowers GDP and tax revenue, thus leading to default and a loss of the government bond's safe-asset status. There are two ways to mitigate this adverse scenario.

First, holding international reserves reduces the severity of a crisis, which they label the "buffer approach." Alternatively, one can modify the international financial architecture by adding a truly globally supplied safe asset in the form of a sovereign bond-backed security (SBBS). Such an asset pools sovereign bonds of many countries and tranches them into a senior and a junior bond. The newly created senior bond serves as a new global safe asset, referred to as GloSBies. Instead of leaning against capital outflows, this approach rechannels flight-to-safety capital flows from international cross-border flows to flows across two asset classes, from the junior to the senior bond. Since both the senior and junior bond are from emerging economies, the cross-border dimension of capital flows is reduced, thereby stabilizing the global economy.

In "***Capital Flow Management with Multiple Instruments***," Viral Acharya and Arvind Krishnamurthy examine theoretically the interaction between reserves management and macroprudential capital controls as tools to manage the capital-flow cycle in emerging markets.

The authors build a model with reserves management as an ex-post safeguard against sudden stops. Reserves may be deployed after these episodes to reduce fire-sales and stabilize the exchange rate. However, due to a form of moral hazard from the insurance provided by reserves, their potential effect is partially undone ex-ante by short-term capital flows, thus reducing its role as a buffer against sudden stops.

When introducing capital controls as an ex-ante safe guard, they offset the moral hazard distortion, thus increasing the benefit of holding reserves. This is the main conclusion of the paper: unlike much of the literature on capital-flow management where reserves management and capital controls are cast as alternative instruments to reduce sudden stop vulnerability, the model shows that they are complementary—better capital controls enable more effective reserve management.

With foreign investment flows into both domestic and external borrowing markets, the complementarity result holds between three instruments: reserves management and capital controls in external and domestic currency. If capital controls can only be introduced on one margin, say foreign-currency debt, then they cannot be too tight because of the prospect of arbitrage of capital controls between the two markets. With an additional instrument, say capital controls on domestic-currency debt, capital controls as a whole can be more effective, which then makes reserve polices also more effective.

The authors revise movements in foreign reserves, external debt, and the range of capital controls being employed in India through the lens of the model. This country has deployed a range of macroprudential measures to contain the impact of sudden stops and reversals of foreign capital flows, and the authors discuss how they map into the model's economic forces and implications.

In "***Foreign Exchange Intervention Redux***," Roberto Chang highlights the opposite views between academic research and policymakers with respect to the economic impact of foreign effect interventions. While theories predict insignificant effects on relevant variables, policymakers have intervened frequently and intensively, especially following the global financial crisis.

To close this gap the author explores a novel channel to analyze the effectiveness of sterilized foreign exchange interventions. Unlike the commonly studied channel through the currency composition of assets held by the public with imperfect substitutability between domestic- and foreign-currency bonds, the key channel in the model is that sterilized interventions change the net credit position of the central bank vis-à-vis financial intermediaries, thereby affecting external debt limits. In the model, private banks, which borrow from the world market and in turn extend credit to domestic households or the government, are subject to occasionally binding collateral constraints. In this context intervention has real effects if and only if it occurs when the constraints bind. At such times, a sterilized sale of official reserves, where central banks buy an offsetting amount of securities, relaxes the constraints by reducing the central bank's debt to domestic banks, thus freeing resources for the latter to increase the supply of credit to domestic agents.

The analysis yields several noteworthy implications for intervention policy, official reserves accumulation, and the interaction between intervention and monetary policy. Interventions can be an effective policy tool when financial constraints bind, even under perfect asset substitutability or if the economy is financially dollarized. Since credit spreads correlate strongly with the severity of financial constraints, a policy of intervention based on these is superior to a policy based on the level of the exchange rate. A trade-off emerges when deciding the optimal level of reserve accumulation; although a larger amount of these allow the central bank to respond more effectively when financial constraints are hit, they also make banks more vulnerable because of the corresponding large outstanding quantities of sterilization bonds. The cost of holding reserves is then that the constraint is hit more frequently by private banks. Finally, the analysis implies that intervention is an independent policy tool and complements conventional monetary policy.

In "***Interest Rate Policies, Banking and the Macroeconomy***," Vincenzo Quadrini analyzes the benefits of low interest rates as a stimulus for the real economy, beyond the well explored trade-off between spending stimulus and higher inflation. In particular, the paper explores two additional channels, namely, the reduction in the demand for liquid financial assets by savers and the increase in the incentives to leverage for financial intermediaries.

The analysis is done in a model in which banks play a central role in the intermediation of funds, and policy interventions by the monetary or fiscal authority take the form of asset purchases from financial intermediaries. Importantly, the wealth of savers is key for the demand of production inputs. In equilibrium, producers are net savers while households are net borrowers, thus capturing the fact that U.S. corporations hold volumes of financial assets in excess of their aggregate financial liabilities and household debt has grown significantly in the last years. In the model this is generated by the use of liquid assets as insurance against production risks. When firms hold more of these assets, they are willing to take more risks, which generates an increase in labor demand and economic activity. In this context, low interest rates discourage savings, with the resulting negative effects on the real sector of the economy.

In addition, low interest rates encourage financial intermediaries to issue more liabilities than equity. The increase in leverage on the other hand raises the cost of a crisis because it generates a bigger distribution of financial wealth from savers to borrowers, with the consequent negative effects on labor demand and economic activity. Therefore policies aimed at reducing the interest rate induce a fall in aggregate production and an increase in macroeconomic volatility.

The last two contributions to the volume contribute more directly to the important debate originated after the global financial crisis about the scope of monetary policy. In "***The Relation between Monetary Policy and Financial-Stability Policy***," Lars E.O. Svensson examines in detail the conduct, instruments, goals, and effects of both monetary and financial-stability policies, as well as how responsibility for achieving the goals and instruments can be assigned to the corresponding authorities. The analysis of these policies emphasizes their connection and differences, and ultimately evaluates the convenience of following a monetary policy aiming not only at inflation but also at asset prices and credit booms, i.e., a LAW policy.

Basing the analysis also in the Swedish experience of a transition between a LAW and a conventional monetary policy, as well as a cost-benefit analysis of LAW, the main conclusion is that monetary policy should not have financial stability as a goal. Instead, it should focus on stabilizing inflation and resource stabilization. The main reason is that monetary policy is not capable of achieving financial stability. This doesn't imply that there should not be an interaction between the two types of policies, but Svensson argues that the two should normally be conducted independently, i.e., by separate decisionmaking bodies, each held accountable for achieving its goals, similarly to the way monetary and fiscal policies are implemented. Also, as it is the case with monetary and fiscal policy, it is very important that each policy should be fully informed about and take into account the conduct of the other.

In "***Monetary Policy in the Grip of a Pincer Movement***", Claudio Borio, Piti Disyatat, Mikael Juselius, and Phurichai Rungcharoenkitkul, emphasize two macroeconomic developments that have laid bare some of the limitations of prevailing monetary policy frameworks, particularly in the analytical notions that have guided much of its practice. These developments consist, first, in the growing size of financial cycles. The pre-crisis experience has shown that, in contrast to common belief, disruptive financial imbalances could build up even alongside low and stable, or even falling, inflation.

The second development is the fact that the inflation process has become quite insensitive to domestic slack. Inflation was higher than expected during the Great Recession, given the depth of the slump, and lower than expected during the recovery. And it has been puzzlingly low especially more recently, as a number of economies have been reaching or even exceeding previous estimates of full employment.

In this context, putting the economy back onto a robust, balanced and sustainable path after the global financial crisis has proved to be much harder than expected for monetary policy. The authors argue that the natural rate of interest as a guidepost for monetary policy has a couple of limitations: the concept, as traditionally conceived, neglects the state of the financial cycle in the definition of equilibrium. In addition, it underestimates the role that monetary policy regimes may play in persistent real interest rate movements. These limitations may expose monetary policy to blindsiding by the collateral damage that comes from an unhinged financial cycle. The paper proposes a more balanced approach that recognizes the difficulties monetary policy has in fine-tuning inflation and responds more systematically to the financial cycle.

Negative Interest Rates: Lessons from the Euro Area

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In June 2014, the European Central Bank (ECB) decided to cut the rate on its deposit facility (DFR) by 10 basis points (bp) into negative territory, an unprecedented move as no major central bank had used negative rates before.[1] This decision was part of a more comprehensive monetary policy easing package, which eventually also included the introduction of targeted long-term refinancing operations (TLTROs) and a large-scale asset purchase programme (APP) of private and public sector bonds. Further rate cuts of 10 bps each followed in September 2014, December 2015, and March 2016, bringing the DFR to -0.40 percent.[2]

The ECB's decision to cut rates below zero was solely motivated by the desire to provide further monetary easing to the economy in response to emerging deflation risks. This contrasts with the declared aim of some other central banks that introduced negative rates to

The views expressed are those of the authors and do not necessarily reflect those of the ECB. We thank Klaus Schmidt-Hebbel and participants at the XXI Annual Conference of the Central Bank of Chile for their valuable comments. R. Tietz and L. Pagenhardt provided excellent research assistance.

1. This followed a similar decision by the Danish central bank (Danmarks Nationalbank) in July 2012. Subsequently, the Swiss National Bank and the Swedish Riskbank introduced negative policy rates in December 2014 and February 2015, respectively, see Jackson (2015). The Bank of Japan, as the second major central bank, followed in January 2016.

2. The negative rate is not only applied to the deposit facility, but to all parts of banks' current accounts with the Eurosystem in excess of their reserve requirements. The same applies to other potential "loopholes", e.g. the remuneration of government deposits as well as deposits in the context of reserve management services offered by the ECB were also lowered in the process to (at least) 0.40%.

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discourage capital inflows and thereby stabilise the exchange rate (e.g. Denmark and Switzerland). Given the ECB's focus on providing additional monetary policy accommodation with its negative DFR, it is natural to ask whether the policy was effective. This assessment is not straightforward, as the decision to implement a negative interest rate policy (NIRP) was accompanied by other easing measures such as the APP, which had a significant downward effect on long-term bond yields, and the TLTRO programme, which in its second version provided long-term funding to banks at negative interest rates under certain conditions. In this paper, we review the emerging literature on the impact of the NIRP in the euro area and try to shed additional light on the question of the effects of the NIRP by examining the behaviour of bank loan and deposit rates and loan volumes before and after the NIRP period.

We proceed in four steps. In section 1, we document that a zero lower bound on interest rates seems to exist only for interest rates on household deposits held at banks. Other interest rates, such as interbank money-market rates, interest rates on short-term government debt and even interest rates on bank deposits held by non-financial corporations (NFCs) do not appear to be subject to a hard zero lower bound and have fallen into negative territory as the DFR became negative. In fact, in the current negative interest rate environment, a large share of safe (typically government) securities at shorter maturities are trading at rates below the DFR and yield negative interest rates even at significantly longer maturities than O/N.[3]

This observation raises an important question: What is special about household deposits that banks do not apply negative rates to these deposits when other funding rates are negative? One explanation is that it is much easier for households to substitute deposits with cash, because individual household deposits are typically of smaller amounts (than e.g. NFC deposits) and therefore carry limited storage costs. As a result, banks charging negative rates would see a sharp outflow of household deposit funding, which could give rise to funding problems. More importantly, negative rates might undermine the business model and franchise value of retail banks, which, in normal times, provide

3. The observation that interest rates other than household deposit rates have traded below zero does not imply there is no lower bound on those rates. But the experience until now suggests that it is probably much lower than current policy rates and the bound may be different depending on the specific market.

liquidity services to households and use cheap household deposits to fund higher-yielding longer-term loans and other assets. Moreover, new liquidity regulations (in particular the Net Stable Funding Ratio—NSFR—regulation) have increased the value of household deposits as a funding source for banks. Not surprisingly, the importance of household deposits as a (stable) source of bank funding is also the focus of a new literature on the deposit channel of monetary policy (Drechsler and others, 2017a, 2017b).

The finding that the zero lower bound is mostly valid for household deposits and that banks refrain from letting those household deposits run off implies that any distortionary effects from an NIRP should be most visible for those banks whose business models rely to a large extent on household deposit funding. In large parts of the empirical literature and in this paper, this observation is used to identify the effects of negative interest rates.

In section 2, we review the small theoretical literature on the transmission of policy-controlled interest rates in a negative rate environment with sticky retail deposit rates (e.g. Brunnermeier and Koby, 2017). These papers generally find that in an environment with capital constraints for banks, which depend on current and expected profitability, a more negative market interest rate may tighten capital constraints and reduce the incentive or ability to lend by negatively affecting interest rate margins and the profitability of the bank. As a result, banks that are dependent on retail deposit funding may restrict lending and/or increase loan rates, particularly in an environment of excess liquidity, which exposes them to negative returns. Most recently, Eggertsson and others (2017) put a zero interest rate bound on bank deposits in an otherwise standard New Keynesian model and show that it may lead to contractionary effects of an NIRP. These findings contrast with the standard literature (e.g. Gertler and Karadi, 2010), which finds that lower interest rates release capital constraints by boosting asset values and may spur lending and risk-seeking behaviour. Overall, whether such negative effects on the economy dominate will depend on the health of the banking sector as well as the presence of other transmission channels that may boost the economy, increase the demand for loans, and improve the overall quality of the loan book.

In section 3, we review the empirical literature that examines bank level data in an NIRP environment, for example Heider and others (2018) and Demiralp and others (2018). In addition, we document the evolution of loan rates and loan volumes of banks with low and high-reliance on household deposits in response to the NIRP episode in the euro area. Using descriptive statistics and standard econometric tools, we provide suggestive evidence that—at least in the euro area—the NIRP has not led to counterproductive lending behaviour by banks that are reliant on household deposits.

Finally, in section 4, we report on other channels of negative interest rates in order to get a broader impression of the overall effect on bank lending, bank profitability, and the economy. In particular, we review a number of papers that aim to quantify the effects through simulation methods and using bank equity prices. One channel which is often overlooked in this literature is the exchange rate channel: Opening up the zero lower bound on interest rates has changed the possible future distribution of interest rates, thus implying different effects on the exchange rate than in normal times.

1. The Pass-Through of the Negative DFR to Market Rates and Retail Deposit Rates in the Euro Area

The ECB introduced negative rates in June 2014 by lowering the remuneration on its deposit facility to 0.10 percent. Subsequently, three further steps of 10-bp cuts were undertaken and the current level of 0.40 percent was reached in March 2016. Meanwhile, the rate applicable to liquidity providing operations (the MRO rate) was lowered to zero.

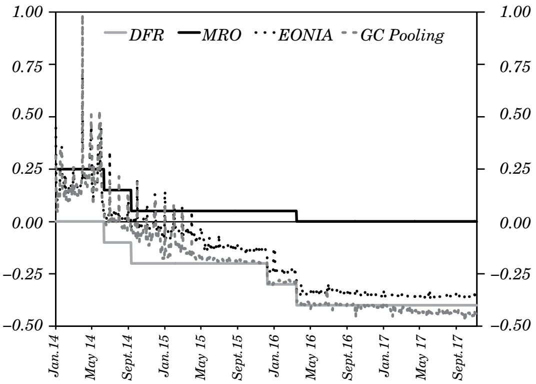
Excess liquidity in the system implied that the DFR cuts were passed on to short-term money-market rates (such as the Eonia rate). However, this process took longer than usual and was only completed in May 2015. The initially slow pass-through was likely related to the time needed by financial market participants to adjust to the new environment (e.g. changes to IT systems, legal documentation). All rate cuts after May 2015 did pass through immediately to the Eonia rate (figures 1 and 2). The overnight-index swap (OIS) curve is currently in negative territory for maturities of up to four years (figure 3) and short-term government bonds of the highest credit quality are trading at yields well below the DFR (figure 4), which evidences the by-now complete pass-through of negative rates to euro area financial markets.[4]

While the pass-through of negative policy rates to financial market rates is complete, a different picture emerges when looking at rates paid by banks for deposits of households and NFCs (figure 5).

4. This is partly due to the scarcity of such bonds created by the ECB's APP.

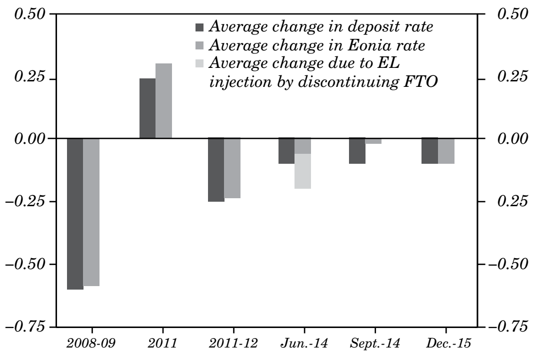
Comparing the distribution of deposit rates across a representative sample of euro area banks in June 2014 and June 2017, it is clear that both types of deposit rates have declined during the NIRP period, with both distributions now having most of their mass at zero. This piling up of deposit rates at zero suggests the existence of a zero lower bound for bank deposits, although there are some banks that do report rates below zero for their household and NFC deposits (see also table 1 for an overview of average deposit remuneration and their importance in bank funding by country).

Figure 1. Key Policy-Controlled Interest Rates and Interbank Overnight Rates



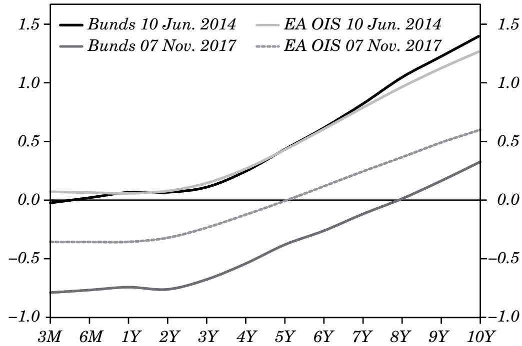
Source: Author's elaboration.

Figure 2. Eonia Rate Reaction to Policy Rate Changes in the First Maintenance Period After the Rate Change



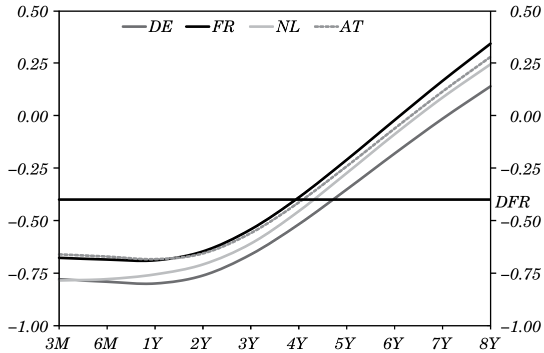
Source: Author's elaboration.

Figure 3. Term Structure of Risk-Free Rates



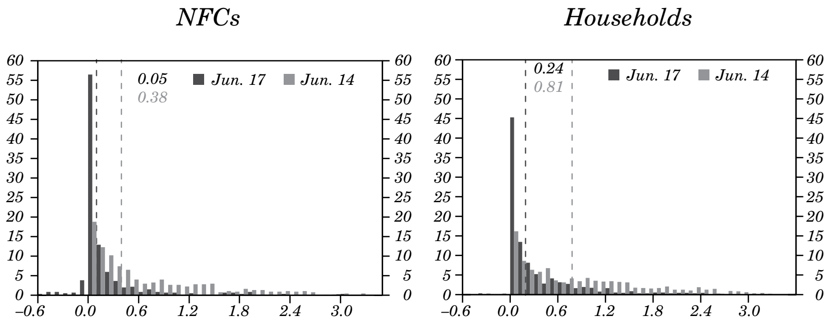
Source: Author's elaboration.

Figure 4. Term Structure of AAA-Rated Government Bonds
(zero coupon)



Source: Author's elaboration.

Figure 5. Distribution of the Remuneration of Household and NFC Deposits Across Banks in the Euro Area



Source: ECB.
Dashed lines represent mean of distribution.

Table 1. Deposit Rates (HH & NFC, Weighted Average) and Share of Retail Deposits (HH only) in Total Assets as of June 2014 by Country

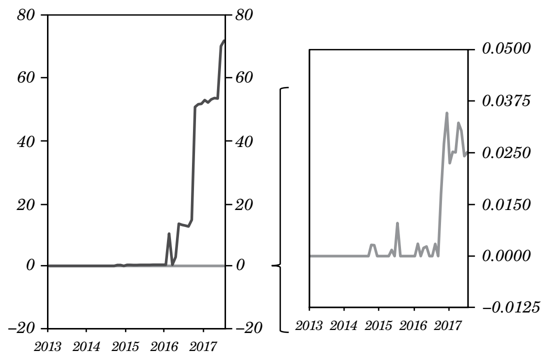
Core	*Deposit rate*	*Retail share*	*No. of banks*	*Periphery*	*Deposit rate*	*Retail share*	*No. of banks*
MT	0.940	0.510	4	PT	1.247	0.313	6
AT	0.565	0.192	9	SI	0.981	0.398	5
LU	0.461	0.126	8	ES	0.880	0.297	19
SK	0.226	0.457	3	IE	0.422	0.226	7
DE	0.165	0.203	50	IT	0.251	0.282	23
EE	0.118	0.274	4				
FI	0.070	0.177	5				
LV	0.068	0.209	5				
FR	0.032	0.244	22				
NL	0.009	0.206	9				
BE	0.007	0.402	9				

Source: Author's elaboration.
Note: Only banks that reported a deposit rate in June 2014 are included in the calculation. Reported rates are weighted by their respective bank's share in the country's deposit market. Retail shares are computed over the total balances of the banks included.

To further explore the pass-through of negative rates to bank deposit rates, we zoom in on the case of Germany, the country with the lowest sovereign yields and the highest level of excess liquidity of all euro area countries. While in many other euro area countries bank deposit rates had significant room to decline in response to the NIRP mainly due to higher bank deposit rates when negative rates were introduced, deposit rates in Germany were already close to zero at the beginning of the NIRP (figure 12). Furthermore, Dombret and others (2017) argue that low interest rates pose a particular challenge to German banks, as they are especially reliant on interest income. The German case may therefore be considered most representative for studying what a steady-state pass-through of negative policy rates to bank deposit rates looks like.

Figure 6 shows the share of overnight (O/N) bank deposits of households and NFCs that are remunerated below zero for a representative sample of German banks. Strikingly, while for household deposits the floor of zero appears firm even in the German case, there is significant pass-through of negative rates to NFC deposit rates: In July 2017, around 72% of O/N deposits by NFCs were (on average) remunerated at a rate below zero. Note, however, that the average level of remuneration of these deposits at 0.02 percent is only slightly negative (and still relatively far away from the DFR of 0.40 percent).

Figure 6. Share of Deposits Remunerated Below Zero



Source: Author's elaboration.

Overall, the available evidence suggests that the most relevant friction connected with the NIRP is a complete lack of pass-through to interest rates paid on banks' household deposits. Naturally, the question arises why banks are reluctant to pass on the negative rates to their household deposit base, particularly in light of the different treatment of NFC deposits.

The most obvious explanation is the availability of cash as an alternative to a bank deposit. Storage costs of cash (e.g. rent for vault space) and the inconvenience arising if cash needs to be used for (large) transactions are factors potentially driving a wedge between the zero remuneration offered by cash and the remuneration of the alternative bank deposit. The costs of holding (and having to use) cash are likely increasing in the size of the bank deposits that need to be replaced. Household deposits are normally smaller than NFC deposits, which is a likely key driver of the difference in pass-through. In the same vein, the inconvenience cost of having to process payments in cash is much higher for NFCs than for households.

If banks are unable to apply negative rates to household deposits, why wouldn't they simply reduce their amount of funding provided by household deposits? One answer lies in the observation that banks' funding models are strategic decisions which incur fixed costs (e.g. setting up offices to attract and serve customers) and, from an intertemporal perspective, a short spell of negative rates may not be enough to change the overall business logic of the banks' funding model.

Another reason, possibly more fundamental, is that banks generally perceive household deposits as a (cheap) source of stable and longer-term funding (see Drechsler and others, 2017b) which also receives favourable treatment under the new liquidity regulation (e.g. NFSR). The overall attractiveness of household deposits as a source of funding to banks appears to have increased since the start of the great financial crisis, manifesting itself in a secular increase of the share of household deposits in the balance sheets of euro area banks.

The importance of household deposits (and its consequences for the transmission of monetary policy) is also documented in a new literature on the value of deposits for U.S. retail banks (Drechsler and others, 2017a, 2017b). The authors show that retail deposits effectively protect banks from interest rate risk and that market power in retail deposit markets is a key factor in explaining the size of spreads of bank deposit rates over money-market rates.

2. Implication of a Zero-Lower Bound on Deposit Rates in an NIRP Environment

The presence of a zero lower bound on (household) deposit rates raises the question of how it affects bank profitability and banks' incentives to lend and adjust their assets and liabilities. In this section, we review the small theoretical literature on the transmission of policy-controlled interest rates in a negative rate environment. While lower interest rates may generally stimulate bank lending and increase risk taking, in the presence of a zero lower bound on deposit rates or, more generally, sticky deposit rates, there might be "tipping points" beyond which banks cannot tolerate further squeezes in their profits and adopt different strategies to avoid these squeezes (Bech and Malkhozov, 2016). This argument is further taken up in Brunnermeier and Koby (2017), who argue that below some level of the policy rate (the "reversal rate"), further reductions can in fact be contractionary owing to the negative effects of lower profitability on bank capital and the associated contractionary effects on bank lending. In their model, the exact level of the reversal interest rate depends on a bank's equity capitalisation and the tightness of financial regulation, its interest rate exposure (e.g. the level of excess liquidity), and the market structure of the financial sector, in particular on the deposit side. Brunnermeier and Koby (2017) also show that the negative effects may increase over time, as the positive effects through capital gains on the long-term bond portfolio are fading in importance.

Cavallino and Sandri (2017) discuss a general class of models in which the presence of borrowing constraints can lead to an "expansionary lower bound", defined as the interest rate below which monetary easing becomes contractionary. Their examples are mostly taken from international finance, where a borrowing constraint denoted in foreign currency may lead to contractionary effects of easier monetary policy if this policy leads to a depreciation of the exchange rate. This may exacerbate the borrowing constraint in domestic currency, thus counteracting the usual stimulative effects. In one model example inspired by Brunnermeier and Koby (2017), which includes heterogeneity of borrowers and savers and a monopolistically competitive banking sector, the presence of a net worth constraint on banks may lead to the existence of a reversal rate, subject to two conditions: Firstly, banks face a net worth constraint which is positively affected by current profits. Secondly, the stock of short-term government debt and excess liquidity is sufficiently large relative to deposits. For the empirical work, it is this ratio that will determine how costly negative rates are for banks in the short-term. Less binding borrowing constraints lower the reversal rate, while more competition in deposit markets increases the reversal rate.

Most recently, Eggertsson and others (2017) document for the Swedish case that the cuts in central bank policy rates into negative territory did not lead to a similar fall in bank lending rates (in contrast to what usually happens following a cut in policy rates in positive territory). To capture this effect, they develop a New Keynesian model as in Benigno and others (2014), with multiple interest rates and bank reserves as in Curdia and Woodford (2011). One key assumption is that the interest rate on household deposits cannot fall below a lower negative bound that is proportional to the storage costs of holding money. If storage costs are negligible, the lower bound on deposit rates will be zero. Another key assumption is that financial intermediation costs, which generate a spread between the remuneration of household deposits and the bank lending rate, depend negatively on current profits. This reduced-form assumption is meant to capture the established finding in the literature that links banks' net worth and profitability to their financing burden due to agency costs. As a result, a drop in demand that leads to an optimal reaction by the central bank to set the interest rate on reserves at a negative level will lead to a binding constraint on the deposit rate. As the bank lending rate is a mark-up over the deposit rate, the drop in the bank lending rate will be also bounded. However, as the banks also hold reserves, the negative interest rate on reserves reduces the profitability of the bank and thereby increases intermediation costs and reduces the interest rate margin, exacerbating the macro-economic effects of the shock.

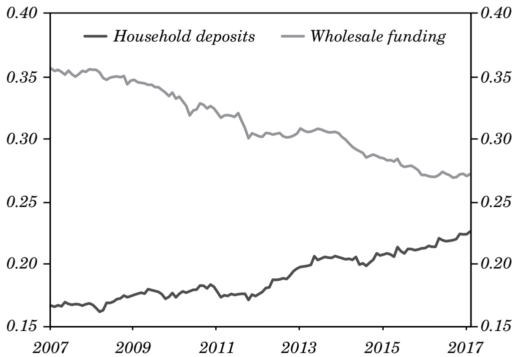
The theoretical analysis shows that whether an NIRP will have contractionary effects on bank lending is determined by the bank's reliance on household deposits versus wholesale funding on the liability side and the interest rate sensitivity of the bank's assets on the asset side. Figure 8 shows the aggregate balance sheet of the euro area banking sector. Over the NIRP period, the share of non-financial private sector deposits in the total balance sheet has increased from 26 to 30 percent, whereas the reliance on wholesale funding has decreased from 30 to 27 percent (figure 7), probably reflecting the new regulatory emphasis on stable funding. On the asset side, a major change has been the rise in excess liquidity held with the central bank from 0.6 to 5.6 percent of total assets as the ECB has embarked on its APP. The excess liquidity is remunerated at a negative rate of 0.4 percent. More generally, increasing excess liquidity will lead to increasing costs for banks to the extent that it is funded by an increasing share of (household) deposits.

The aggregate composition of the banks' balance sheets masks quite important differences across bank business models and across countries. As pointed out by Brunnermeier and Koby (2017) in a heterogeneous region model, an interest rate cut might be expansionary in one region and contractionary in another to the extent that banks in the first region borrow while the banks in the other region lend in the interbank market. In the euro area, excess liquidity mostly resides in the core countries, potentially giving rise to exactly such a regional structure as described in Brunnermeier and Koby (2017). In addition, the degree to which loans are priced at fixed or variable rates differs across countries, with banks situated in core countries using more long-term fixed-rate financing and banks in periphery countries applying more variable-rate financing (figure 9). This difference in interest rate fixation may also give rise to a differentiated impact of negative rates across euro area countries.[5] In the next section, we will use information on cross-sectional variation between banks to test whether the pass-through of the negative DFR in the euro area to bank loan rates and loan volumes differs across banks with low and high deposit shares.

In contrast to the recent literature on NIRP, which emphasises that the negative effects on bank interest rate margins and bank profitability may hamper the transmission of an NIRP, the more traditional literature on bank-lending and risk-taking channels suggests that an NIRP may strengthen these channels. Prominently, the *bank-lending channel* suggests that expansionary monetary policy measures will increase banks' willingness to provide loans. Under an NIRP, the incentive for banks to expand their supply of loans is strengthened by the fact that additional reserves injected by the central bank entail a charge on banks. Thus, while an NIRP might reduce the ability of banks to pass on interest rate changes to their retail deposits (Horwath and others, 2018), the policy amplifies the credit channel by increasing the cost of holding excess liquidity, in particular for banks with a high share of retail deposit funding on their balance sheet. Several papers support the notion that the bank-lending channel remains intact under an NIRP (e.g. Albertazzi and others, 2017; Bräuning and Wu, 2017; Demiralp and others, 2018; Basten and Mariathasan, 2018).

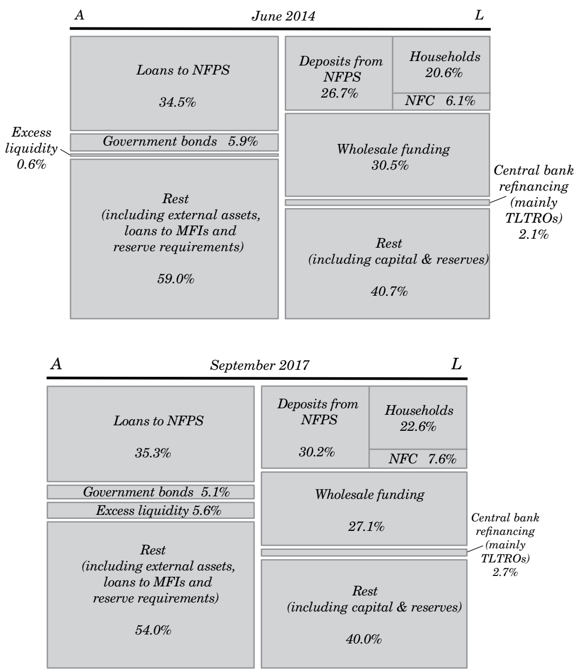
5. For reference, figures 10 and 11 give an overview of the distribution of deposit and excess liquidity shares in the euro area banking sector.

Figure 7. Evolution of Household Deposits and Wholesale Funding as Shares of Total Liabilities in the Euro Area since August 2007



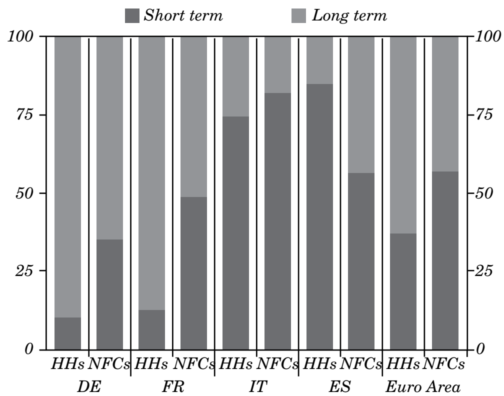
Source: Author's elaboration.

Figure 8. Total Euro Area Bank Balance Sheet



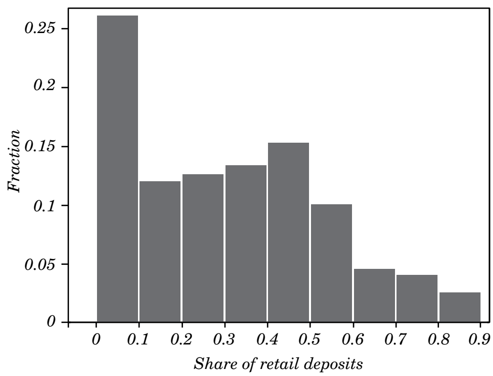
Source: Author's elaboration.

Figure 9. Share of Household and NFC Loans Fixed at Short- and Long-Term as of June 2017



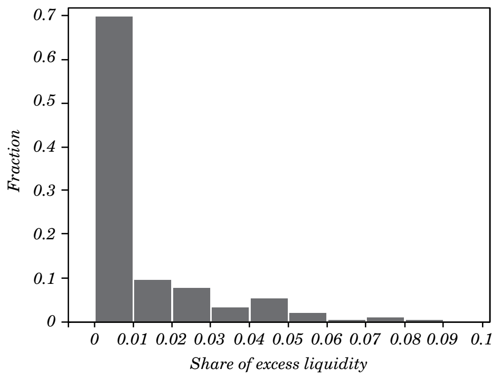
Source: Author's elaboration.

Figure 10. Distribution of Share of Retail Deposits in the Balance Sheet, All Banks Excluding Greece and Cyprus



Source: Author's elaboration.

Figure 11. Distribution of Share of Excess Liquidity, All Banks Excluding Greece, Cyprus and High EL Banks



Source: Author's elaboration.

The exchange of very safe assets such as central bank reserves for riskier assets like loans and bonds can also be seen through the lens of the *risk-taking channel*, which emphasises the role of risk perceptions and risk tolerance (Borio and Zhu, 2008; Adrian and Shin, 2009; Jimenez and others, 2012; Dell'Ariccia and others, 2016). The increase in asset prices and collateral values prompted by lower policy rates can increase banks' capacity and willingness to take on more risk. They may, for instance, choose to rely on risk measures that are based on market equity prices, such as expected default frequencies, and make use of Value-at-Risk frameworks for their asset-liability management, all of which are likely to point to lower risks in a lower rate environment. Moreover, "sticky" rate-of-return targets defined in nominal terms can prompt a *"search for yield"* effect when interest rates are reduced, which necessitates higher risk tolerance. In fact, the promotion of portfolio rebalancing by encouraging lenders to invest in riskier assets when the returns on safer assets decline is considered to be one of the objectives of quantitative easing policies (Aramonte and others, 2015; Heider and others, 2018). This channel is likely to be further reinforced by the prevalence of negative rates.

3. The Impact of Negative Rates on Euro Area Banks

This section briefly reviews the available empirical literature on the effects of the NIRP in the euro area and then discusses developments in euro area banks' lending behaviour over the NIRP period. In our search for the effects of negative rates, we progressively zoom in on (highly household deposit reliant) German banks. This strategy should lead us to the banks arguably most affected by the NIRP. Consequently, these banks should have the strongest incentives to react to the NIRP, thus giving us the best chances to identify its effects.

3.1 Empirical Studies with Focus on the Euro Area

There is a small literature devoted to the effects of negative rates in the euro area.[6] Heider and others (2018) start from the premise that banks relying more strongly on deposit funding have a disadvantage in a negative rate environment and, consequently, compare the lending behaviour of high- to that of low-deposit banks during the early phase of negative rates (from June 2014 to January 2015). Their results, which were obtained by focusing on syndicated loans and which are a relatively small subset of NFC loans, indicate that high-deposit banks react by decreasing their loan supply and start lending to riskier borrowers.

Demiralp and others (2018) use banks' exposure to the excess liquidity charge to identify the impact of negative policy rates on banks by employing a sample of 256 euro area banks covering around 70% of bank assets in the euro area. They find that high-deposit banks have reacted to negative rates by granting more loans.[7] Both Heider and others (2018), and Demiralp and others (2018) find that negative rates are expansionary. The discrepancy in findings between the two studies (with respect to the behaviour of high-deposit banks) could be related to the difference in the loan aggregate as well as the difference in the length of the NIRP considered in the papers: Heider and others (2018) focus on the very beginning of the negative interest rate period, while Demiralp and others (2018) consider the NIRP until October 2017.

Finally, Amzallag and others (2018) employ a sample of mortgage loans issued by Italian banks to investigate the effects of the NIRP on banks' loan-rate setting behaviour. Comparing fixed- and variable-rate mortgages issued before and after the onset of the NIRP, they

6. In a study based on a pre-NIRP sample, Buchholz and others (2017) already argue that banks with a more interest-sensitive business model are more responsive to declines in the deposit facility rate, reallocating their liquidity from reserves to loans.

7. Albertazzi and others (2017) also find that banks with more deposit funding expand their loan supply under unconventional monetary policy.

find that banks more dependent on deposit funding charge higher rates for fixed-rate loans after June 2014, while there is no effect on variable-rate loans.

3.2 Negative Rates in the Euro Area: Some Further Empirical Explorations

In order to further explore the behaviour of rates and volumes for bank loans in the euro area under the NIRP, we use a confidential dataset containing balance sheet data for 256 selected euro area banks at the monthly frequency (IBSI and IMIR). The dataset has been constructed to reach a high degree of representativeness of the euro area banking sector, by containing a broad range of banks of different sizes and specialisation from all euro area countries. Importantly, banks contained in the sample cover a large fraction of loans to the euro area economy (between 70% and 85% of all bank loans, depending on the country). We exclude banks from Cyprus and Greece (due to these banks being affected by domestic economic and banking crises), which leaves us with 241 banks.

3.2.1 Did the NIRP Change Banks' Lending Behaviour? The Case of Germany

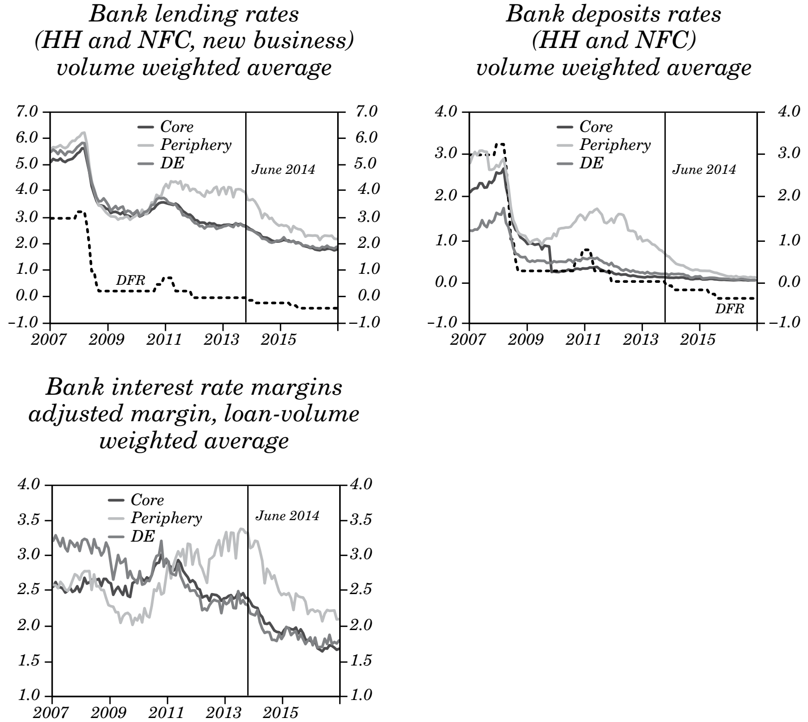
Figure 12 shows the evolution of bank lending rates[8], bank deposit rates, and the interest rate margin in both core and periphery countries of the euro area since 2007. A few observations are worth making: First, the decline in bank deposit and lending rates and interest rate margins was particularly pronounced in the peripheral countries (i.e., those countries most affected by the euro area sovereign debt crisis in 2010-2011), mainly because these countries were facing much higher deposit and lending rates in June 2014 due to the fall-out from the sovereign debt crisis. It is interesting to note that, following the comprehensive easing package of the ECB, deposit rates in the peripheral countries converged back almost fully to those of the core countries.

By contrast, bank lending and deposit rates in Germany were among the lowest in June 2014 and hence had least room to decline. Figure 12 confirms that retail deposit rates in the core countries were

8. Note that, in contrast to e.g. Amzallag and others (2018), our lending rates are a composition of both household and NFC loan rates, including a variety of maturities and purposes (such as house purchase, consumption, and the like).

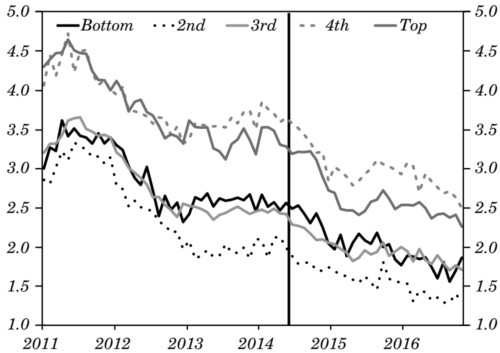
bound at zero and therefore did not follow the DFR cuts into negative territory from June 2014 onwards. Consequently, in what follows we will focus on the German banking sector, as with this strategy we stand the best chances to uncover the effects of negative rates on bank lending rates (and volumes).

Figure 12. Bank Lending Rates, Bank Deposit Rates and Interest Rate Margins in Core and Periphery Countries



Source:
Notes: Core countries include AT, BE, DE, EE, FI, FR, LU, LV, MT, NL, and SK. Periphery countries include ES, IE, IT, PT, and SI, whereas banks from Greece and Cyprus are excluded. Lending and deposit rates are weighted by their respective loan or deposit volumes. Margins are weighted by the respective bank's loan volumes.

Figure 13. Bank Lending Rates in Germany by Retail Deposit Share Quintile
(volume weighted average)



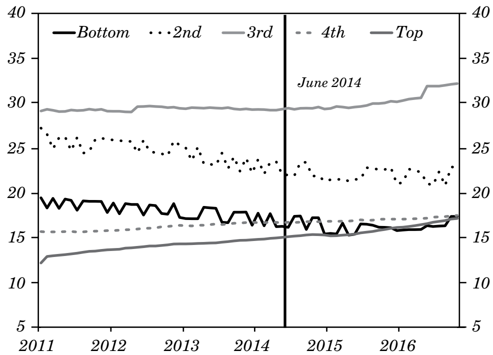
Source: Author's elaboration.
Notes: Calculated based on 59 German banks that report lending rates and volumes over the entire period. Lending rates are weighted by their respective loan volumes. Quintiles are formed based on the average retail deposit share of each bank in the year before the NIRP (June 2013 to May 2014).

The complete lack of pass-through of negative rates to retail deposit rates puts banks that are heavily reliant on these deposits at a disadvantage relative to less reliant banks.[9] As a consequence, we may expect that high deposit banks are less willing or able to decrease their loan rates, as found by Amzallag and others (2018) for the case of the Italian fixed-rate mortgage market, and may even be inclined to increase them. Figure 13 checks this hypothesis for the German banks in our sample by looking at weighted average bank lending rates of all quintiles of the distribution of their household deposit share over time. There is no *prima facie* evidence that banks with a high degree of reliance on retail deposits price their loans differently from banks with a lower degree of reliance under the NIRP.

Similarly, banks adversely affected by the NIRP may also reduce their lending or even contract their loan book (figure 14). Figure 15 shows the change in the loan market share of German banks according to the degree of banks' exposure to the NIRP. Again, as in the case with bank lending rates, we do not find evidence that highly affected banks are reducing their lending activity relative to less affected banks.

9. This argument is also supported by Arteta and others (2016).

Figure 14. Bank Lending Volumes in Germany by Retail Deposit Share Quintile
(mean, in EUR BN)

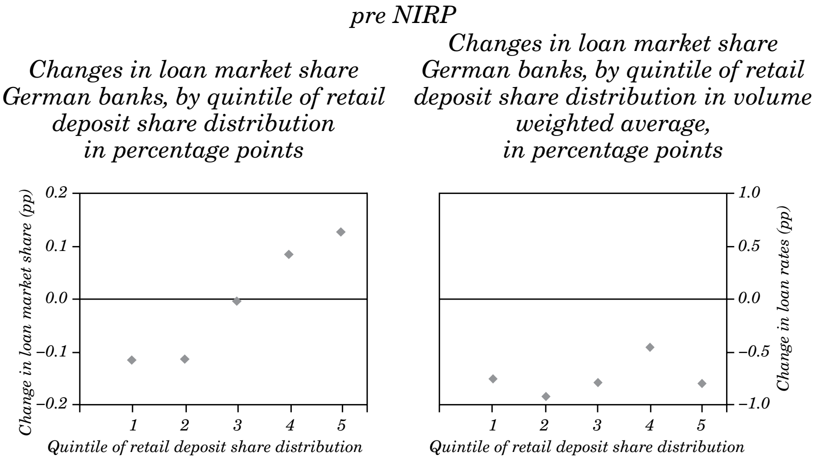


Source: Author's elaboration.
Notes: Calculated on the basis of the 59 German banks that report lending rates and volumes over the entire period. Quintiles are formed based on the average retail deposit share of each bank in the year before the NIRP (June 2013 to May 2014).

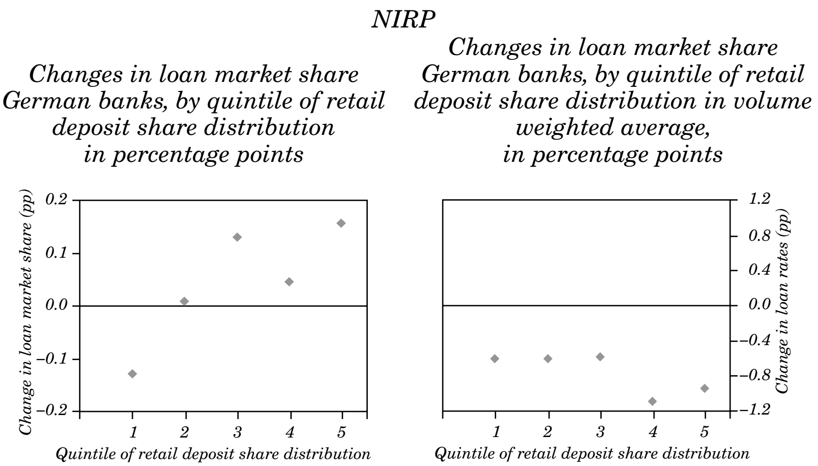
Figure 15 compares these changes in bank lending rates and loan market shares in the NIRP period with those following the earlier interest rate reductions in 2012 at positive levels. If anything, the cross-plots show that the lending rates of banks with a high deposit share have fallen by more than those with low deposit shares. Similarly, the loan market shares of high deposit banks have, if anything, have risen. But this reaction is not different from the earlier period of interest rate reductions in our sample (2012–2013). We therefore do not find *prima facie* evidence of a contractionary effect of the reductions in negative interest rates. Of course, this may partly be explained by the impact of the other components of the ECB's easing package. On the asset side, the reduction in both private and public sector bonds may have put pressure on the loan rates; for example, large firms found it easier to tap bond markets to obtain financing. At the same time, all banks are exposed in a similar fashion to the other simultaneous policy programmes conducted by the ECB and we would therefore expect banks particularly exposed to the friction associated with the NIRP to react differently than banks less exposed, even in the presence of other easing measures. Furthermore, as shown in section 3.2.2 below, the APP did not materially affect the pass-through of negative rates to bank lending rates.

Figure 15. Changes in Bank Lending Rates and Loan Market Shares in NIRP and PRE NIRP Period per Deposit Share Quintile

PRE NIRP: February 2012 to June 2014



NIRP: June 2014 to October 2016



Source:

This overall assessment is confirmed by *ad hoc* survey evidence from the euro area bank lending survey. The surveyed banks confirm that the negative interest rate has reduced their profitability, but at the same time has led to lower bank loan rates and easier lending conditions.[10]

3.2.2 Did the NIRP Change the Pass-Through of Policy Rates to Bank Lending Rates?

Bank lending rates of euro area banks generally display a strong co-movement with policy rates. In this section we employ a simple panel econometric exercise to see whether the introduction of the NIRP has changed this correlation. We follow the same logic used so far and concentrate our testing on the case of German banks, as these banks should be most affected by the negative interest rate policy.

Table 2 reports the estimates from a standard fixed-effects panel model estimated at quarterly frequency, using individual bank lending rate data.[11] In the main specification, quarterly changes in lending rates are regressed on changes in the DFR and its interaction with a variable marking the NIRP period. Column 1 in table 2 contains the pass-through coefficient from a univariate regression including only changes in the DFR. As expected, the estimated coefficient is positive and significant.[12]

Column 2 reports the main specification where the model is augmented with an interaction term of the changes in the DFR with a dummy variable capturing the NIRP period. Another interaction is created with the share of retail deposits on each bank's balance sheet. None of the interactions is significant and the overall size of the pass-through coefficient is unchanged, which confirms that the NIRP did not lead to a change in pass-through and that bank's retail deposit reliance does not change their reaction to monetary policy under the NIRP either.

10. See Altavilla and others (2017a).

11. The data used covers 256 banks from all euro area countries over a sample from 2009 to 2016 (IBSI and IMIR dataset) out of which 59 banks are from Germany. The data are at monthly frequency. Quarterly values are computed by averaging the original monthly values. Changes are then computed as the quarter-on-quarter changes of the quarterly values.

12. Since monetary policy responds to changes in aggregate demand, the coefficient in this univariate specification is likely biased upwards. A simple way to control for the business cycle would be to include time fixed effects. Indeed, this (e.g. year fixed effects) almost halves the coefficient but otherwise does not change our results.

Table 2. Interest Rate Pass-Through During NIRP and APP Period

	Change in composite loan rate		
	(1)	*(2)*	*(3)*
Change DFR	0.611***	0.625***	0.625***
	(0.068)	(0.145)	(0.145)
Change DFR x NIRP		0.609	0.454
		(0.572)	(0.605)
Change DFR x deposit share x NIRP		-0.009	-0.009
		(0.009)	(0.009)
Change DFR x APP			1.644***
			(0.835)
Observations	1,779	1,779	1,779
R^2	0.064	0.066	0.072
Adjusted R^2	0.064	0.062	0.067

Source:
Notes: *p<$0.1; **p<0.05; ***p<0.01. Sample covers 59 German banks from 2009Q1 to 2016Q3. Standard errors are White-Hubert heteroscedasticity robust.

Column 3 reports the estimation augmented with a control variable capturing the announcement effects of the APP. The APP dummy takes the value of 1 in January 2015 and the share of survey respondents expecting asset purchases by the ECB in 2014 Q3 and Q4 as provided in Blattner and Joyce (2016) before that date. This dummy variable is then interacted with the change in the DFR, to test for any changes in the interest rate pass-through during that period. As expected, the APP announcement had a strong impact on bank lending rates. However, the overall size of the pass-through coefficient, controlling for the NIRP period and APP announcement, is very similar to the one reported in column 2, which leads to the conclusion that the pass-through has not materially changed following the introduction of the NIRP and is not affected by the effects of the APP announcement.

4. Other Effects of Negative Rates

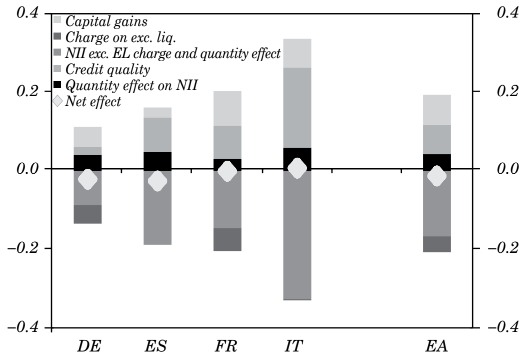
4.1. Bank Profitability

Several papers have investigated the effects of low and negative interest rates on overall bank profitability. For example, in a pre-NIRP study of 109 large international banks, Borio and others (2017) find a positive relationship between the short-term rate and bank profitability (as measured by the return on assets). In particular, whereas loan loss provisions decrease and non-interest income increases when interest rates go down, net interest income decreases, thus offsetting the positive effects. The authors conclude that very low rates erode bank profitability. Similar conclusions are drawn by Deutsche Bank (2013) and Dell'Ariccia and others (2017), who argue that profitability is lowered by reduced interest rate margins. In addition, Claessens and others (2016) find that low rates weakened bank profitability more in the euro area than, e.g., in Canada and the U.S. In a study based on stress testing scenarios of U.S. banks, Arseneau (2017) finds that the effect of negative rates on banks would depend on the bank business type, with banks primarily active in lending (liquidity provision to borrowers) expecting to lose from negative rates through a squeeze in lending rates. In contrast, banks focused on deposits expect to gain due to the reduction in funding costs.

Arteta and others (2016) suggest that bank profitability depends on the general health of the economy rather than on just monetary policy measures. In line with this reasoning, Altavilla and others (2017b) argue that low monetary policy rates and a reduced slope of the yield curve are associated with lower bank profits only if important variables, such as the expected macroeconomic developments and forward-looking credit risk, are omitted. If such controls are introduced, the positive impact of easier monetary policy on loan loss provisions and non-interest rate income largely offsets the negative one on net interest income.

Altavilla and others (2017a) also shed light on the question of the overall effect of the ECB's easing measures (including the NIRP) on euro area banks' profitability, disentangling several channels (figure 16). They find that the total effect of monetary policy measures on euro area banks' return on assets over the NIRP period (2014-2017) is broadly neutral, as positive and negative effects cancel each other out. Figure 16 also shows the effects per country. As expected, the negative effect through the charge on excess liquidity is largest in France and Germany. By contrast, Spain and Italy are most affected by the drop in interest rate margins due to the widespread prevalence of variable-rate loans. On the other hand, those countries also benefit most from the positive effects of lower market interest rates on the quality of the loans and the loan loss provisions.

Figure 16. Key Policy-Controlled Interest Rates and Interbank Overnight Rates



Source: Altavilla and others (2017a).

4.2. Bank Equity and Stock Prices

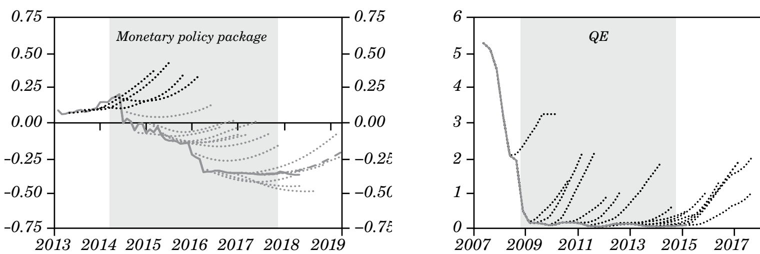
Ampudia and Van den Heuvel (2017) use the unexpected component of monetary policy shocks and investigate their effects on bank equity, represented by stock prices. They find that an unexpected decrease in policy rates in a positive rate environment raises bank equity, as also suggested by English and others (2014). However, in low and negative rate environments this effect is reversed: Further interest rate cuts at already low rates lead to lower bank equity prices. The authors attribute their findings to a squeeze in the interest rate margin due to the zero lower bound on deposit interest rates, as banks more dependent on deposit funding are more negatively affected by cuts. In contrast, Altavilla and others (2017b) find the opposite results. Bank equity prices responded positively to the drop in the DFR by 10 bp on 5 June 2014 and on 4 September 2014. In particular during the latter episode, bank equity prices responded more positively than other stock prices. Moreover, this paper also finds positive responses to expansionary APP announcements during the NIRP period (with the exception of the December 2015 event). The difference in the finding of Altavilla and others (2017b) to Ampudia and Van den Heuvel (2017) can be explained by the different focus of the paper. Altavilla and others (2017b) focus on a broad series of events including two interest rate changes in the negative rate period as well as a variety of non-standard measures, while Ampudia and Van den Heuvel (2017) analyse only changes in interest rates covering all policy meetings.

4.3 Interest Rates Expectations and Foreign Exchange Markets

In assessing the overall effects of the NIRP it is also important to take into account the alternative transmission channels beyond the bank lending channel of lower interest rates on the economy. One channel that has been operative in the euro area case is its signalling effect on the term structure. As shown in Rostagno and others (2016), lowering the policy controlled rate through the zero lower bound has the advantage of removing the non-negativity restriction on expected future short-term rates. As a result, the forward curve becomes flatter than it would be if short rates were expected to be constrained by a zero lower bound. Indeed, as shown in figure 17, the ECB's NIRP contributed to a flatter yield curve as from 2014 than was the case in the United States during the QE period.

Such stronger signalling effects may in turn lead to larger effects on the exchange rate. Results by Khayat (2015) suggest that negative interest rates put depreciation pressure on the currency, and that the effects are distinct from lowering rates in positive territory. Gräb and Mehl (2015) find that exchange rates of countries with negative policy rates tend to react more strongly to changes in their corresponding bond yield differentials *vis*-à-*vis* the U.S. For the euro area, their estimates suggest that a cut in the deposit facility rate by 20 bp is associated with a depreciation of the euro against the U.S. dollar which is around 0.5 percentage points larger in negative territory than in "normal" times. Overall, their empirical results suggest that negative interest rates make exchange rates more elastic to shocks.

Figure 17. Forward Curves During Periods of non-Conventional Monetary Policy
(with and without NIRP)



Source:

5. Conclusions

In June 2014 the ECB became the first major central bank to reduce one of its key policy rates to a level below zero. Naturally, the question arises whether the transmission of monetary policy is different when interest rates become negative. This paper offers an overview of the available research with a specific focus on the euro area. Furthermore, it documents the dynamics of deposit rates, lending rates and loan volumes of euro area banks in the recent NIRP period.

The paper first establishes that the friction associated with negative rates, at least in the euro area, is the zero lower bound on household deposits and, to a lesser extent, deposits by non-financial corporates. All other bank liabilities reprice in line with negative policy rates. A simple econometric exercise shows that the interest rate pass-through of policy rate changes to bank lending rates appears largely unchanged over the negative interest period. Moreover, this result also appears to hold for banks that are most affected by the friction associated with negative rates, i.e. those with a high reliance on retail deposits and which are situated in a country with overall low deposit rates. The same exercise for loan volumes (proxied by loan market share) finds that the most affected banks, if anything, increased their overall share in loan markets. This is in line with findings that the negative interest rate policy has induced most affected banks to increase their lending activities in a bid to reduce their excess liquidity holdings.

Studies focusing on specific markets and financial intermediaries tend to find differentiated effects, pointing to interesting side effects of negative rates within the banking sector. These effects are, however, quantitatively small and unlikely to change the overall picture that negative rates in the euro area have been expansionary. Finally, the paper discusses several studies dealing with other effects of negative rates like their impact on foreign exchange markets, bank equity prices, and bank profitability.

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Central Banks Going Long

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London School of Economics

Long-term interest rates have for long played an ambiguous role in the operation of monetary policy. The Federal Reserve Act of 1913 that created the Federal Reserve set the monetary policy objective to be: "... to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates." But, after the Treasury Fed accord of 1951, the Fed dropped the third of these objectives, and has since referred to itself as having a "dual mandate." More recently, when policymakers discuss the effect of new monetary policies, from forward guidance to quantitative easing, they commonly state their impact on longer-term interest rates as a proof of success. As short-term interest rates stay close to zero, policies that directly target long-term rates can be considered to control inflation, together with macroprudential policies that affect the risk premium in long-term bonds.

In principle, a central bank could issue reserves and make loans at one arbitrary maturity, and use its lending and deposit facilities together with open-market operations to target the market interest rate at this maturity. Almost all central banks choose very short maturities, from the traditional focus on the overnight Federal Funds rate by the Federal Reserve, to the one-week main refinancing operations of the European Central Bank.[1] In September 2016, the Bank of Japan announced a new policy of "yield-curve control," which targets a rate of 0% for the 10-year government yield. If inflation stays away from target for long, as it happened in Japan, other central banks may consider going long as well.

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1. An exception is the Swiss National Bank, whose target interest rate is a 3-month money-market rate.

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To evaluate these potential policies in the future, this paper looks at the past. During the late 1940s, the long-term interest rate played a crucial role in U.S. monetary policy, both in its operations and in its goals. The Federal Reserve was not unique in this regard, as the Bank of England focused policy in part on long-term interest rates, following the recommendations of the 1959 Radcliffe Report. This paper describes the context behind these two historical experiments, and analyzes their role in determining inflation through the lenses of a model of inflation with interest-rate rules. Each of these experiments was different, but each went well beyond just using the long-term interest rate as one of many indicators of the state of economy. Central banks went long, significantly changing the composition of their balance sheets and adapting their procedures to focus monetary policy on long-term interest rates. In the context of interest-rate rules, the long-term interest rate was not just one more variable on the right-hand side, but crossed to the left-hand side of the policy rule.

Motivated by these historical episodes, this paper discusses different ways in which the familiar model of monetary policy can integrate long-term interest rates as a policy tool with the dynamics of inflation. While each case is different, the results brought together suggest that focusing on long-term interest rates leads to more volatile and less anchored inflation.

The economic analysis requires linking the dynamics of inflation, short-term nominal interest rates, and long-term yields. There is an extensive literature on the yield curve and inflation, including several tractable models and extensions that have successfully fit the data.[2] A barrier to merging them with the study of inflation is that they are mostly set in continuous time with shocks that follow diffusions, while most work in monetary economics uses linearized models in discrete time.[3] To overcome this barrier, this paper presents the classic inflation control problem in continuous model. This may prove to be useful in other contexts. Methodologically, it pushes forward a research agenda promoted by Brunnermeier and Sannikov (2017), who argue that bringing continuous-time tools to macroeconomics will allow models to better incorporate endogenous risk premia and financial frictions.

2. See Piazzesi (2010) for a survey and Smith and Taylor (2009) for an estimated model closer to the one in this paper.

3. On the study of inflation, Jones and Kulish (2013) and McGough, Rudebusch and Williams (2005) are the closest papers in the literature in their treatment of long rates, but they work with linearized discrete-time new Keynesian models. Gallmeyer, Hollifield and Zin (2005) are closer from the perspective of the yield curve.

Sections 1 to 3 of the paper set up the model, solve for the dynamics of inflation, and characterize the dynamics of the yield curve, respectively. Sections 4 and 5 discuss the two case studies of central banks going long, and applying the model to understand them. Section 6 discusses the recent Japanese experience. Section 7 concludes with lessons for central banks that consider going long, and discusses future research to integrate the study of monetary policy with long-term interest rates.

1. Controlling Inflation in Continuous Time

I first describe the choices facing the private sector, then the central bank's policies, and finally define the equilibrium interaction between the two. Subsection 1.4 provides general-equilibrium microfoundations.

1.1 The Private Sector

A representative household chooses how much to save in a real riskless bond that, in exchange for one unit of consumption today, returns for sure $R_t^{(s)}$ units of consumption s periods from now. Letting m_t denote the marginal utility of consumption at date t, then the optimal holdings of this bond must satisfy the Euler equation:

$$m_t = \mathbb{E}_t\left(m_{t+s}R_t^{(s)}\right). \tag{1}$$

Buying an extra unit of the bond lowers utility by the left-hand side of this equation, but is expected to raise it by the right-hand side. At the optimum, the net effect must be zero.

Taking the limit as s becomes a time interval dt that is infinitesimally close to zero, and since $R_t^{(s)}$ is known at date t, gives the continuous-time version of this equation:

$$\mathbb{E}_t\left(\frac{dm_t}{m_t}\right) = -r_t dt, \tag{2}$$

where r_t is the return on an instantaneous bond. Using the language of the Ramsey model, this equation states that marginal utility must decline at the same rate as the safe return to savings at an intertemporal optimum.

I assume that the utility function of the households is time-separable and has constant relative risk aversion. Therefore: $m_t = \beta^t c_t^{-\gamma}$, where

$\beta \in (0.1)$ is the discount factor, c_t is consumption, and $\gamma > 0$ is the coefficient of relative risk aversion. As in baseline new Keynesian economies, there is no capital or investment; therefore markets clear when consumption equals output y_t.

The key assumption in this economy is that prices are flexible, so the classical dichotomy holds. As illustrated in Woodford (2003), Cochrane (2011), or more recently in Hall and Reis (2016), the economic problem of pinning down the price level by using interest-rate rules is conceptually unchanged if there are nominal rigidities and a Phillips curve. Adding nominal rigidities complicates the expressions and may require linearizing the equilibrium conditions, but the qualitative conclusions on when inflation is pinned down remain unchanged.

Given this assumption, it is then a mere simplification to further assume that output is exogenous, as in an endowment economy. (For the unconvinced readers, subsection 1.4 endogenizes the evolution of output as a function of technology shocks.) In particular, I assume that output follows a random walk, that has normally distributed innovations with standard deviation σ_y, and a stochastic mean growth rate g_t.[4] This trend, in turn follows a stationary autoregressive process, with long-run mean $\bar{g}$, speed of mean reversion κ_g, and normal shocks with standard deviation σ_g. In continuous-time notation, this is compactly written as:

$$\frac{dy_t}{y_t} = g_t dt + \sigma_y dz_t^y, \tag{3}$$

$$dg_t = -\kappa_g (g_t - \bar{g})dt + \sigma_g dz_t^g. \tag{4}$$

The shocks are independent Wiener processes, so they are normally distributed with mean zero and variance $\mathbb{E}_0[(z_t^y)^2] = \mathbb{E}_0[(z_t^g)^2] = t$.

To solve for the real interest rate, note that market clearing in the goods market implies that: $m_t = \beta^t y_t^{-\gamma}$. Using Ito's lemma to take time derivatives of this expression:

$$\frac{dm_t}{m_t} = [\ln\beta - \gamma g_t + 0.5\gamma(\gamma+1)\sigma_y^2]dt - \gamma\sigma_y dz_t^y. \tag{5}$$

4. To be more precise, time is continuous, y_t is a stochastic variable defined on a filtered probability space, and Z_t^y is an adapted Brownian motion in this space. The same applies to all other stochastic variables in this paper.

Then, the Euler equation gives the solution for the real interest rate:

$$r_t = \gamma g_t - \ln\beta - 0.5\gamma(\gamma+1)\sigma_y^2. \tag{6}$$

The first two terms on the right-hand side are the standard ones from the Ramsey model: higher growth rates or more patient households increase the equilibrium real interest rate. The third term captures the precautionary savings effect that more uncertainty on output induces the consumer to save more and this lowers the real interest rate in equilibrium. A virtue of working in continuous time is that this precautionary savings term is present and analytic; in discrete-time linearized setups it is zero, and in numerical solutions it appears only as higher-order terms.

Collecting all the results gives the real equilibrium:

Lemma 1. *Real variables do not depend on monetary policy and the marginal utility of consumption and the real interest rate are given by:*

$$\frac{dm_t}{m_t} = -r_t dt - \gamma\sigma_y dz_t^y, \tag{7}$$

$$dr_t = -\kappa_g(r_t - \bar{r})dt + \gamma\sigma_g dz_t^g. \tag{8}$$

where $\bar{r} = \gamma\bar{g} - \ln\beta - 0.5\gamma(\gamma+1)\sigma_y^2$.

1.2 The Central Bank

Central banks take deposits from banks, commonly called reserves. This liability is crucial in the modern monetary system, because people make electronic payments by using cards and other means of payments issued by banks. These give rise to large gross cross-bank liabilities every day. Reserves are the settlement currency used by the banks to clear these transactions among themselves.

If the deposits at the central bank have maturity s, then the usual central-bank policy is to promise a safe nominal return of $I_t^{(s)}$ per unit of currency held as reserves. I assume that the demand for liquidity is satiated (Reis, 2016*a*), so that the central bank can perfectly choose this return and the private agents in the economy, represented by the representative consumer, choose to hold these deposits according to the optimality condition:

$$\mathbb{E}_t\left(\frac{m_{t+s}I_t^{(s)}}{p_{t+s}}\right) = \frac{m_t}{p_t}. \tag{9}$$

The price level p_t appears because reserves are the unit of account in the economy. In the extreme case where reserves are instantaneous deposits, then the differential version of this condition is:

$$\mathbb{E}_t\left(\frac{d(m_t / p_t)}{(m_t / p_t)}\right) = -i_t dt, \quad (10)$$

where i_t is the nominal interest rate on an instantaneous deposit at the central bank.

The central bank is independent, and its dividend rule is to rebate net profits every instant to the fiscal authority. By the result in Hall and Reis (2015), the central bank is therefore always solvent, as its reserves satisfy a no-Ponzi scheme condition. Fiscal considerations then play no role in the determination of inflation.[5]

Following a long line of work, I assume that the central bank adopts a feedback rule for the choice of the interest rate. The first component of this rule is a constant inflation target π^*.[6] A strict reading of the mandate of most central banks sets π^* to a constant equal to 2% at an annual rate.[7]

The central bank then responds to any deviation of actual inflation dp_t/p_t from this target by raising interest rates by an amount $\phi \geq 0$ in the next instant of time. The assumption that this is positive corresponds to the famous Taylor principle (since it corresponds to $e^{\phi} \geq 1$.)

Most central banks, however, do not engage in such strict inflation targeting, but rather adopt a policy of flexible inflation targeting. In any given period, they target an inflation rate different from π^* depending on the state of the economy. This is optimal in many models of nominal rigidities.[8] As a result, interest rates rise and fall to push inflation above or below the strict inflation target temporarily in order to stabilize real activity.

Moreover, when inflation is on target, then the nominal interest rate must mimic changes in real interest rates. Yet, most central banks find it difficult to measure the right real interest and respond to it instantly, or more generally to track the state of the business cycle. Errors in measurement lead to changes in interest rates.

5. For a discussion of the multiple fiscal channels between central banks and Treasuries, see Reis (2018).

6. Letting the target vary over time deterministically would make no difference to the results.

7. For instance, if a one-unit period in the model corresponds to one week, then $\pi^* = 0.02/52$.

8. See Woodford (2010) or Ball, Mankiw and Reis (2005).

Finally, almost no central bank follows a rule, but rather chooses a path for monetary policy from the aggregation of the opinions of different committee members. As opinions of the individuals in charge of decision, or the composition of the committee changes, this will lead to changes in interest rates.

Whether it is in response to desires to stabilize real fluctuations, due to mis-measurement of the actual state of the business cycle, or because of monetary policy shocks, then even if inflation is at π^*, nominal interest rates may vary. I capture the combination of all these factors through a random nominal interest rate target, or intercept x_t, that also follows a Markov process with long-run mean $\bar{x}$ and dz_t^x shocks .

Finally, central banks smooth interest rates at a rate $\rho > 0$.

Combining all these ingredients, and assuming for now that the central bank sets policy in terms of the instantaneous interest rate on reserves, gives the monetary policy rule:

$$d(i_t - x_t) = -\rho(i_t - x_t)dt + \phi\left(\frac{dp_t}{p_t} - \pi^* dt\right). \tag{11}$$

1.3 The Equilibrium

Because the classical dichotomy holds in this economy, all the real variables are already pinned down. What remains to determine is the price level. A rational expectations equilibrium is a path for the price level $\{p_t \in \Re^+ : t \geq 0\}$ given the real equilibrium in lemma 1 and the monetary policy rule in equation (11). Following a long literature on new Keynesian dynamic stochastic general equilibrium (DSGE) models of monetary policy, I focus on a narrower definition of equilibrium:

Definition 1. *A bounded homoskedastic Markov perfect equilibrium is a function for expected inflation* $\pi(r,x) : \Re^2 \to \Re$ *and three constants,* α_y, α_g, α_x *such that:*

$$\frac{dp_t}{p_t} = \pi(r_t, x_t)dt + \alpha_y \sigma_y dz_t^y + \alpha_g \sigma_g dz_t^g + \alpha_x \sigma_x dz_t^x, \tag{12}$$

where equations (7), (8) and (11) hold, and expected inflation satisfies:

$$\lim_{T\to\infty} \mathbb{E}_t \left(e^{-\varepsilon(T-t)} \pi(r_T, x_T)\right) = 0 \tag{13}$$

for any $\in > 0$.

There are restrictions imposed on this definition relative to the rational-expectations equilibrium. First, since the state of the economy is captured by the real interest rate and the nominal interest rate, and (r_t, x_t) follows a Markov process, the restriction to look only at a Markov equilibrium is natural. This rules out the possibility that sunspots drive inflation. Second, since all variances are independent of time, the definition imposes that the variance of inflation also do not depend on time. Therefore, the responses to shocks, stacked in the column vector $Z_t = (z_t^y, z_t^g, z_t^x)$ are given by a column vector of constants $\alpha = (\alpha_y\sigma_y, \alpha_g\sigma_g, \alpha_x\sigma_x)$ rather than by three functions of the state vector. I conjecture that allowing for sunspot shocks by letting inflation depend also on some other $\alpha_\epsilon dz_t^\epsilon$, or allowing the responses of inflation to shocks to depend on (r_t, x_t) would actually make no difference: in equilibrium, $\alpha_\epsilon = 0$ and the other αs would not depend on the state of the economy.

More important is the assumption of boundedness. Cochrane (2011) provides a scathing critique of this assumption as an equilibrium selection device. It is not micro-founded since it does not follow from optimal-behavior or market-clearing conditions. Moreover, it plays an important role, since variations of it can dramatically change the results. The long literature on interest-rate rules has proposed other related boundary conditions, Obstfeld and Rogoff (1983) being a famous example, and there is also an extensive literature using other monetary policies to control the price level (Reis, 2016*b*). I follow Woodford (2003) and the extensive literature after it in maintaining this assumption because there is little in the analysis that brings any new light to the issues involved.

Given the stochastic process for marginal utility in equation (7), and for prices in equation (12), Ito's lemma gives the expected rate of change in m_t/p_t. By the Euler equation (10), this is equal to the instantaneous nominal interest rate. This gives a modified Fisher equation as a no-arbitrage condition between nominal and real bonds:

$$i_t = r_t + \pi_t - \alpha'\alpha - \gamma\sigma_y^2\alpha_y. \tag{14}$$

As usual, the nominal interest rate is equal to the sum of the real interest rate and expected inflation, the two first terms on the right-hand side, respectively. However, shocks to inflation introduce two extra terms. First, because of the convexity of returns, more variable inflation subtract from the realized real returns on nominal bonds. Second, there is an inflation risk premium. If positive shocks to inflation come at times when the marginal utility of consumption is high, then nominal bonds will have a realized return that is lower when returns are more valuable. Thus, holding a nominal bond comes with risk, and so it must pay a higher nominal interest rate to compensate for this risk. The focus on a homoskedastic equilibrium makes this risk premium constant, which is counterfactual. Allowing for heteroskedasticity in the growth rate of output or in the shocks to monetary policy would easily lead to a time-varying risk premium, and future work should explore its role.

1.4 Where does the Price Level Come From?

Because reserves are the unit of account in the economy, their real value is, by definition, $1/p_t$. It is the absence of arbitrage between private bonds and reserves at the central bank that pins down the price level. Outside of equilibrium, if the price level were too high, then reserves would cost less, which would make banks want to sell private bonds and deposit more reserves at the central bank. As the supply of reserves is fixed by the central bank this "excess demand" for reserves would make their value fall, which comes through the price level rising back to equilibrium.

This description of equilibrium may strike some readers as odd in two ways. First, output was taken as exogenous, as in an endowment economy. Second, there was no mention of goods' prices. Both of these features resulted from not having any mention of firms selling goods and setting prices. This section shows how introducing these makes no difference.

Assume that the representative agent solves the following problem:

$$\max_{\{\{c_{t,j}\},l_t\}} \mathbb{E}_0 \int_0^\infty \beta^t \left(\frac{c_t^{1-\gamma}}{1-\gamma} - \frac{l_t^{1+\psi}}{1+\psi} \right) dt \tag{15}$$

$$\text{s.t. } c_t = \left(\int_0^1 c_{t,j}^{1/\mu} dj \right)^{\mu}, \tag{16}$$

$$d(b_t + v_t) = \left(i_t - \frac{dp_t}{p_t} \right) v_t + r_t b_t + (w_t l_t + k_t - c_t) dt. \tag{17}$$

The representative household chooses its consumption of a continuum of varieties ($c_{t,j}$) and hours worked (l_t) for a real wage (w_t) to maximize expected discounted utility, subject to its preference for different varieties and to a flow budget constraint where labor and investment income is complemented with dividends from firms (k_t). For simplicity, this assumes only instantaneous bonds (b_t) and reserves (v_t) are held, but allowing for higher maturities would not change the argument.

The optimal behavior of consumers is then characterized by the two Euler equations already presented in equations (2) and (10), the flow of resources combined with a transversality condition, and finally the optimality condition for labor supply:

$$c_t^{\gamma} l_t^{\psi} = w_t. \tag{18}$$

The real wage is equal to the marginal rate of substitution between labor and consumption.

A continuum of monopolistic firms operate a technology $y_{t,j} = a_t l_{t,j}$ to produce each variety of good subject to the common productivity a_t. Using their monopoly power, the optimal price they charge is a markup over costs:

$$\frac{p_{t,j}}{p_t} = \frac{\mu w_t}{a_t}. \tag{19}$$

A general equilibrium of this economy is a situation where households and firms behave optimally, and all market clear. There is a market for labor, so that $l_t = \int l_{t,j} dj$. In the goods market, $c_{t,j} = y_{t,j}$, which leads to $c_t = y_t$. Finally, the supply of real bonds and nominal reserves are both zero on net: $b_t = v_t = 0$.

This economy maps exactly into the price determination problem defined before. To see this, note that because prices are flexible, the symmetry of the problem leads to $p_{t,j} = p_t$. It then follows from combining equations (18) and (19) that:

$$\mu y_t^{\gamma+\psi} = a_t^{1+\psi}. \tag{20}$$

Therefore, given an exogenous stochastic process for technology such that a_t is a random walk in logs with a stochastic stationary trend, this maps exactly into the assumption on y_t. The model is fully microfounded with firms that choose prices.

The process by which an equilibrium price level is attained in the economy can be explained differently. If the price level is hypothetically too high, the private agents realize that the return on savings in reserves at the central bank is high. They therefore cut consumption to save more. But, as they cut consumption, this lowers the demand for goods, which in turn leads firms to want to cut their prices, thus making the price level fall back to equilibrium.

In Walrasian general equilibrium economies, either this story or the one at the start of this subsection are equally valid. All markets, for savings, for bonds, for reserves, for goods, and for labor must jointly clear, so excess demand or supply in any one of them comes with excess demand or supply in all others. Firms are choosing prices, and households are responding to them by consuming more or less, by saving more or less, and by depositing more funds at the central bank or not, all together and at once.

2. The Dynamics of Inflation

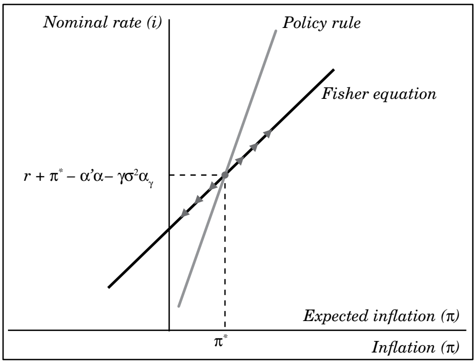
This section solves the mathematical problem set out in the previous section: to solve for the dynamics of inflation in equation (12), subject to the equilibrium Fisher equation (14), the policy Taylor rule in equation (11), and the boundary condition in equation (13).

2.1 A Phase Diagram for Expected Inflation

The Fisher equation is a linear relation between the nominal interest rate and expected inflation with slope 1 and vertical intercept $r_t - \alpha'\alpha - \gamma\sigma_y{}^2\alpha_y$. At a steady state with no shocks, the policy rule is also a line, with slope ϕ / ρ, so that if expected inflation is equal to π^*, then the nominal rate is x_t. Figure 1 shows the phase diagram for the dynamics of expected inflation. The equilibria are movements along the Fisher line, such that if the economy is above the policy rule, then the interest rate will fall, and rise conversely.

The dynamic system is clearly unstable as long as ϕ / ρ. Therefore, inflation must always stay at the intersection of the two lines. Otherwise, it would diverge to infinity violating the boundedness condition. This is the famous Taylor condition, adapted to account for interest-rate smoothing. Intuitively, as long as the central bank commits to raising interest rates when expected inflation increases from target, then, from the Fisher equation, this will raise expected inflation. But because this further raises inflation the next instant, it leads to a new rise in interest rates, and a further rise in expected inflation. If private agents in the economy rule out from their expectations these infinite forward-looking possibilities where inflation explodes at an accelerating pace, as captured in equation (13), then this disciplines their initial inflation expectations to not deviate from target.

Figure 1. Phase Diagram for Expected Inflation



Source: Author's elaboration.

The level of real interest rates r_t or monetary policy x_t together with shocks to both of them determines where expected and actual inflation are at a point in time. Understanding these responses requires moving beyond the phase diagram, fully solving the model.

2.2 Analytical Solution for Expected Inflation

Taking time differences of the Fisher equation gives:

$$di_t = dr_t + d\pi_t. \tag{21}$$

In turn, using the Fisher equation to replace i_t in the Taylor rule, and the dynamics of inflation to replace for dp_t/p_t gives:

$$di_t = dx_t - \rho(r_t + \pi_t - \alpha'\alpha + \gamma\sigma_y^2\alpha_y - x_t)dt + \phi\left(\pi_t dt + \alpha' dZ_t - \pi^* dt\right). \tag{22}$$

Equating the right-hand sides of the previous two equations and rearranging gives the law of motion for expected inflation:

$$d\pi_t = (\phi - \rho)(\pi_t - \pi^*)dt - d\varepsilon_t - \rho\varepsilon_t dt + \phi\alpha' dZ_t. \tag{23}$$

This expression defined a new variable: $\varepsilon_t = r_t - x_t + \pi^* - \alpha'\alpha - \gamma\sigma_y^2\alpha_y$. For now, take this as being just a convenient way to collect terms in what would otherwise be a long and messy expression.

Take expectations of the differential equation at date t, and let hatted variables denote the expected value of actual variables, e.g., $d\hat{\varepsilon}_t = \mathbb{E}_t(d\varepsilon_t)$. Expected inflation π_t then evolves according to:

$$d(\hat{\pi}_t + \hat{\varepsilon}_t - \pi^*) + (\rho - \phi)(\hat{\pi}_t + \hat{\varepsilon}_t - \pi^*)dt = -\phi\hat{\varepsilon}_t dt. \tag{24}$$

This is a standard ordinary differential equation that has the solution

$$\pi_t = \pi^* - \hat{\varepsilon}_t + e^{-(\phi-\rho)(T-t)}(\hat{\pi}_T + \hat{\varepsilon}_T - \pi^*) + \int_t^T \phi e^{-(\phi-\rho)(s-t)}\hat{\varepsilon}_s ds. \tag{25}$$

Taking the limits as T goes to infinity and imposing the boundary condition gives the solution for expected inflation:

$$\pi_t = \pi^* + \left(\frac{\rho}{\phi - \rho}\right)\varepsilon_t + \int_0^\infty \phi e^{-(\phi-\rho)s}\mathbb{E}_t(\varepsilon_{t+s} - \varepsilon_t)ds, \tag{26}$$

as long as $\phi > \rho$. Mathematically, equation (24) shows why the Taylor condition is necessary: it makes expected inflation an explosive process since positive deviations from target lead to further increases in the gap between expected inflation and target.

2.3 The Deviations of Expected Inflation from Target

Inflation deviates from target due to the terms on the right-hand side of equation (26). Recall that:

$$\varepsilon_t = (r_t + \pi^* - \alpha'\alpha - \gamma\sigma_y^2\alpha_y) - x_t. \tag{27}$$

If $\varepsilon_t = 0$ at all dates, then expected inflation will always be on target. An omniscient, long-lived, and inflation-nutter central bank would perfectly control inflation by choosing x_t to mimic one-to-one movements in real interest rates. Since x_t would be perfectly negatively correlated with r_t, the only state variable in the economy would be the real interest rate and monetary policy would introduce no extra source of uncertainty to any nominal variable.

But a central bank that has trouble tracking and measuring r_t in real time, that wants to use interest rates to have inflation deviate from the target in order to stimulate economic activity, or that in its deliberative process changes its views on the appropriate policy, will not be able or willing to set x_t to keep inflation at π^* at all dates. Extending the model to have a time-varying risk premium would make it even more unlikely for the central bank to measure in real time changes in $\sigma_t^2\alpha_y$ and adjust the interest rate in response to them.

The opposite case is one in which the setting of nominal interest rates by monetary policy is independent of the real interest rate. In this case, we can take x_t to follow an exogenous process:

$$dx_t = -\kappa_x (x_t - \overline{x})d_t + \sigma_x dz_t^x, \qquad (28)$$

where the shocks dz_t^x are independent from the shocks to output, dz_t^y and dz_t^g. The appendix covers the intermediate case where x_t only partially adjusts to changes in r_t.

Using the stochastic processes for real interest rates and policy interest rates in equations (8) and (28), one can evaluate the expectations and the integral in equation (26).[9] The final solution for expected inflation is:

$$\begin{aligned}\pi(r_t, x_t) &= \pi^* + \left(\frac{\rho}{\phi - \rho}\right)\left(\overline{r} + \pi^* - \alpha'\alpha - \gamma\sigma_y^2\alpha_y - \overline{x}\right)\\ &+ \left(\frac{\rho - \kappa_g}{\kappa_g + \phi - \rho}\right)(r_t - \overline{r}) - \left(\frac{\rho - \kappa_x}{\kappa_x + \phi - \rho}\right)(x_t - \overline{x}).\text{C.}\end{aligned} \qquad (29)$$

Expected inflation is a linear function of the two state variables.

The first line of this equation has the intercept for inflation. A central bank that cannot fully keep track of movements in real interest rates or in inflation risk premia still has to figure out what these are on average and then set its average interest rate appropriately. In times when secular changes in productivity may have led to changes in safe real rates, or when the long-run inflation risk premium may be changing due to financial crises, this normal interest rate to which monetary policy should converge is not easy to assess, but it plays a crucial role in keeping inflation on target.

The second line of the expression above shows the sensitivity of expected inflation to the state of the economy. Depending on the persistence of interest-rate changes, shocks to monetary policy can raise or lower expected inflation. This is to be expected because, of course, forever-higher nominal interest rates unambiguously raise inflation, since they correspond to an effective increase in the inflation

9. Simply recall that $\mathbb{E}_t(r_{t+s} - r_t) = (\overline{r} - r_t)(1 - e^{-\kappa_r s})$ and likewise for $\mathbb{E}_t(x_{t+s} - x_t)$, and that $\int_0^\infty e^{-\phi t} dt = 1/\phi$.

target. A different question is whether actual inflation rises or falls with positive shocks to nominal interest rates. I turn to this question next.

2.4 Shocks to Inflation

The final step is to solve for inflation's response to shocks in the vector α. Subtracting equation (23) from equation (24):

$$d\pi_t - d\hat{\pi}_t = d\hat{\varepsilon}_t - d\varepsilon_t + \phi\alpha' dZ_t \tag{30}$$

Using the solution for expected inflation in equation (29) and the definition of ε_t in equation (27), this equation becomes:

$$\begin{aligned} &\left(\frac{\rho - \kappa_g}{\kappa_g + \phi - \rho}\right)\gamma\sigma_g dz_t^g - \left(\frac{\rho - \kappa_x}{\kappa_x + \phi - \rho}\right)\sigma_x dz_t^x \\ &= -\gamma\sigma_g dz_t^g + \sigma_x dz_t^x + \phi\alpha_y\sigma_y dz_t^y + \phi\alpha_g\sigma_g dz_t^g + \phi\alpha_x\sigma_x dz_t^x. \end{aligned} \tag{31}$$

This equation must hold for all realizations of the shocks. Therefore, the solution is:

$$\alpha_x = -\frac{1}{\kappa_x + \phi - \rho} \tag{32}$$

$$\alpha_g = \frac{\gamma}{\kappa_g + \phi - \rho} \tag{33}$$

$$\alpha_y = 0. \tag{34}$$

The first interesting result is that a positive shock to the nominal interest rate lowers actual inflation. The effect is smaller the more aggressive the Taylor rule coefficient response in future periods is, the less persistent the shock is, and the more interest rates are smoothed. The higher the variance of these monetary policy shocks, the higher the variance of inflation deviations from target.

The second result is that permanent shocks to output that do not move real interest rates have no effect on inflation. Similarly, sunspot nominal shocks that do not move real interest rates would have no effect on inflation. Moreover, since all the responses to shocks depend on parameters that are time-invariant, the equilibrium has a constant variances of shocks to inflation. This justifies the conjecture that restricting attention to Markov homoskedastic equilibrium is not limiting.

A summary of the analytical solution of the model is in the next proposition:

Proposition 1. *The bounded homoskedastic Markov equilibrium has expected inflation* $\pi(x_t, r_t)$ *given by equation (29) and the response to shocks* α *given by equations (32)-(34).*

3. Equilibrium Interest Rates

Combining the solution for expected inflation in equation (29) with the Fisher equation in equation (14) gives the equilibrium dynamics of the short-term interest rate. The next lemma states it formally.

Lemma 2. *In equilibrium, the instantaneous nominal interest rate is:*

$$i_t = \theta_0 + \theta_x x_t + \theta_r r_t \tag{35}$$

where $\theta_0 = [\phi/(\phi-\rho)](\pi^* - \alpha'\alpha) + [\phi\kappa_x/(\phi-\rho)(\kappa_x + \phi - \rho)]\overline{x} - [\phi\kappa_g/(\phi-\rho)(\kappa_g + \phi - \rho)]\overline{r}$ *and* $\theta_x = (\kappa_x - \rho)/(\kappa_x + \phi - \rho)$ *and* $\theta_r = \phi/(\kappa_g + \phi - \rho)$.

In this simple model, the nominal interest rate is an affine function of the two state variables, the state of the real economy and the stance of monetary policy. Therefore, the model fits into the general family of affine models of the term structure (Piazzesi, 2010).

The key result from this literature then follows (and is proven in the appendix):

Lemma 3. *Define the yield on the bond as* $i_t^{(s)} = \log(I_t^{(s)})$. *In equilibrium, it is:*

$$i_t^{(s)} = \delta_0(s) + \delta_i(s) i_t + \delta_x(s) x_t \tag{36}$$

where $\delta_i(s) = (1 - e^{-\kappa_g s})/(\kappa_g s)$.

3.1 Two Limitations to Going Long

The relation between long and short rates in the lemma results from the absence of arbitrage along the yield curve. A central bank that follows a Taylor rule for the overnight rate cannot separately set an exogenous target for the long rate that disrespects the equation in this lemma. Otherwise, if $i_t^{(s)}$ were larger than the expression in the lemma, private banks and investors would all want to deposit long-dated reserves at the central bank and want to hold zero instantaneous reserves. If the inequality flipped, so would the balance sheet of the central bank suddenly, from long to short reserves. The central bank, pushed from one corner to the next, would have to adjust its assets correspondingly and quickly, otherwise it would be exposed to losses that could endanger its solvency.

Moreover, for long maturities, s is large, so $\delta_t^{(s)}$ is expected to be quite small as long as the shocks to real interest rates are not very persistent (so κ_g is not too small). This says that temporary changes in short-term interest rates move long rates less than one-to-one. Stated backwards, it means that if the central bank targets the long rate, then any policy decision to change it will have a large impact on short-term interest rates. Today, central banks change their policy rate infrequently in a lumpy way, say every so many weeks by 25 basis points. If they did the same while going long, then the days before any policy meeting would come with intense speculation on short bonds in the days before, as the short rate would be expected to move by several percentage points at the time of the policy announcement. Going long requires a large change in operating procedures, with more frequent meetings of policy committees that would make single-digit basis point decisions.

3.2 From the Model to the Data

Another implication of lemma 3 is that long-term interest rates are linear functions of the instantaneous interest rate.[10] This affine property of the model is very convenient on many accounts. First, this class of models has been extensively taken to the data on interest rates of different maturities. Second, it has been extended in different directions. One could, for instance, consider shocks to the long-run growth rate of the economy akin to news shocks, or stochastic volatility in the growth rate mapping into uncertainty shocks, and so incorporate these two recent popular business-cycle literatures into the determination of inflation and the study of long-term interest rate policies.

Third, we can easily incorporate other state variables. For instance, Greenwood, Hanson and Vayanos (2016) introduce limits to

10. Smith and Taylor (2009) impose this linearity and obtain a related result to lemma 3 to focus on how changes in affect $\delta_x^{(s)}$.

arbitrage in the bond market so that there are two extra linear factors corresponding to the actual bond holdings by the central bank and their expected mean at different maturities. In their model, when central banks go long in the sense of buying government bonds of different maturities, they affect long-term interest rates. In this paper instead, central banks go long directly by choosing the value of the long-term interest rate. Merging the two models would provide a rich theory for how quantitative easing policies can affect inflation.

4. The United States Pre-Accord: 1942-1951

The behavior of the Federal Reserve during the Great Depression is one of the most studied in monetary history. In turn, modern analyses of U.S. monetary policy almost exclusively focus on the behavior of the Fed after the Treasury-Fed Accord of 4 March 1951, described by Friedman and Schwartz (1963) as: "Few episodes in American monetary history have attracted so much attention in the halls of Congress and in academic quarters alike." Considerably less attention has been spent on the period that goes from World War II to the Accord. This was a period when the Federal Reserve went long.[11]

4.1 Pegging Interest Rates

The United States entered World War II on 8 December 1941. As almost always happens when a country enters a major war, the primary goal of economic policy became the financing of large war expenditures, and the Treasury was its leading executor. The Federal Reserve was a subordinate, as monetary policy's role was to ensure that the banks that it regulated and the financial markets in which it intervened would provide a steady demand for the government bonds. While the Treasury officially managed the public debt, the Federal Reserve was supposed to ensure that the government bonds were sold at a favorable price.

The particular approach implemented by the United States during this time was announced in April 1942. One part of this policy was that the Fed stood ready to buy and sell 90-day Treasury bills at a fixed rate of 3/8%. The T-bill rate then became the effective policy rate. Certificates of deposit could be discounted at rates that still changed

11. Standard references for the history of the Federal Reserve are Friedman and Schwartz (1963) and Meltzer (2010).

from time to time to respond to demands in the banking sector, but the peg on the T-bill rate was the focus of the policy. Correspondingly, Treasury bills, not reserves, became the major liquid asset in the balance sheet of banks. Knowing that these could be bought and sold from the Fed at a fixed price at any time, banks did not need reserves, for T-bills were just as liquid.

While much has been made of the policy of pegging interest rates, it actually lasted for a relatively short period of time. The Federal Reserve continuously clashed with the Treasury about raising the T-bill rate, especially at the end of the War when inflation accelerated. Eventually, in July 1947, the Fed raised the T-bill rate after striking a bargain with the Treasury that involved the payment to the Treasury of a significant share of the net income it had accumulated. Further increases immediately followed, so that by December the bill rate was 1%, and one year later, by the end of 1948, it was set at 1 1/8%.

Between 1949 and 1951, there was an intense political struggle between the Treasury, partly backed by the president, and the Fed. At times, it seems worthy of a political drama TV series (Hetzel and Leach, 2001). It started with the FOMC statement in June 1949 that it intended to change the interpretation of the mandate to keep a peg on interest rates. A crucial shock arrived in 1950 with the intensification of the Korean war. Real interest rates rose as a response, and large government deficits were expected. Moreover, the anticipation of price controls led to a sharp increase in inflation, mostly for durable goods. On one side, the Treasury became nervous about keeping the peg on the price of its debt, especially given the prospect of another long conflict. On the other side, the Fed worried that to keep its interest rates low, it would have to issue reserves to buy more government bonds, and that this would fuel credit and inflation. In 1951, in testimony to Congress, the chairman of the Federal Reserve system unequivocally stated that: *"As long as the Federal Reserve is required to buy government securities at the will of the market for the purpose of defending a fixed pattern of interest rates established by the Treasury, it must stand ready to create new bank reserves in unlimited amount. This policy makes the entire banking system, through the action of the Federal Reserve System, an engine of inflation."*[12]

The Treasury-Fed Accord of March 1951 declared a truce between the Treasury and the Fed. In spite of having little legal force, and in itself stating little of substance, Fed Chairman Martin masterfully

12. U.S. Congress 1951, p. 158.

interpreted it in a way that affirmed the independence of the Fed from the Treasury from then onwards. One fundamental implication of the Accord for the conduct of U.S. monetary policy was that supporting the national debt was no longer an objective for monetary policy, which became concentrated on macroeconomic and price stability. Another implication was that the peg on the bill rate was lifted and the Fed gained full autonomy over the setting of interest rates.

There was a third implication of the Treasury-Fed Accord. Since then and all the way until the adoption of quantitative easing in 2008, the Federal Reserve focused its attention on short-term interest rates and conducted the bulk of its open-market operations by using Treasury bills. This was not the case before the Accord.

4.2 Ceiling Policy

While the peg for the T-bill rate gets much of the attention, it only lasted for five years. More persistent, and arguably more significant, was a different part of the March 1942 policy, which remained in force until March 1953: an explicit ceiling of 2.5% for the 10-year yield. Friedman and Schwartz (1963) argue that, unlike the peg on the bill rate, the Fed was in general favorable to this policy. The bond support program, as it was called, had originated intellectually within the Fed.

While the War lasted, the yield on Treasury bills was low relative to the yield on longer-dated Treasury bonds. As a result, banks were happy to hold bonds earning higher returns, exchanging them for Treasury bills at the Fed whenever they needed liquidity. The Fed rarely needed to intervene, and its assets mostly consisted of Treasury bills.

This changed between 1945 and 1948. The Treasury started issuing many more long-term bonds with the goal of delaying the payment of the wartime debt. Yields rose, reaching 2.37% in November 1947 and forcing the Fed to step in with a large-scale purchase of bonds to keep the ceiling unbroken. In 24 December of that same year, the Fed released a mere suggestion that it might allow for small deviations from the ceiling, and the long-term yield immediately jumped to 2.45%, thus demonstrating the active role the Fed was playing in the bond market. As the slope of the yield curve shrank, the private sector shifted the composition of its portfolio towards Treasury bills. Correspondingly, the maturity of the Fed's bond portfolio expanded.

Noticeably, while between 1947 and 1950 the Fed raised the bill rate several times and wanted to raise it more and more often, it always stayed committed to the ceiling on the bond rate. In fact, on 16 October 1947, the Board of Governors wrote a letter to the Treasury Secretary where, in the process of defending the change in the bill rate, it stated: *"We can assure you that these actions will not affect the maintenance of the 2 1/2 percent rate for the outstanding long-term government bonds."*

This changed with the Korean War. The flattening of the yield curve intensified the pressure for the Fed's balance sheet to grow and become longer. In 1950, Chairman Eccles advocated a relaxation of the ceiling on bond yields, but was strongly opposed by President Truman who, having imposed wage controls in 1951, was adamant that long-term mortgage rates would not increase. Moreover, the Treasury warned of a large financial crisis in bond markets if the ceiling was dropped. Following the Accord, the Fed did not explicitly abandon its interest rate ceiling; it did so only a full two years later, in March 1953. Only then did the Fed start selling bonds at a fast pace. Intellectual and policy support for a "bills-only" policy with regards to the Fed's balance sheet arose, and remained for many years to come, as the Fed moved completely away from its going-long policy.

4.3 Turning to the Model: Pegs

Focusing on the peg of short-term rates that lasted between 1942 and 1947, if the peg was expected to last forever, then inflation becomes indeterminate. This policy corresponds to $\phi = \rho = 0$ and to a constant x_t in the model. In this case, combining the Fisher equation in (14) with the policy rule, now gives:

$$\pi_t = \bar{x} - r_t + \alpha'\alpha + \gamma\sigma_y^2\alpha_y. \tag{37}$$

Since r_t is a stationary process, this satisfies the boundedness condition. Therefore, this equation is the sole condition with which to pin down the evolution of inflation. This is one equation in several variables: expected inflation and the response of inflation to each of the shocks. The result is indeterminacy.

This is not the classic indeterminacy result of Sargent and Wallace (1975). In a deterministic model, $\alpha = 0$, so the equation above uniquely pins down inflation. Sargent and Wallace (1975) instead emphasized that the initial price level is indeterminate, not inflation. With uncertainty, there is another form of indeterminacy (Nakajima and Polemarchakis, 2005). Monetary policy can at best pin down a risk-adjusted measure of expected inflation, the breakdown between expected inflation and the actual inflation response to shocks is indeterminate.

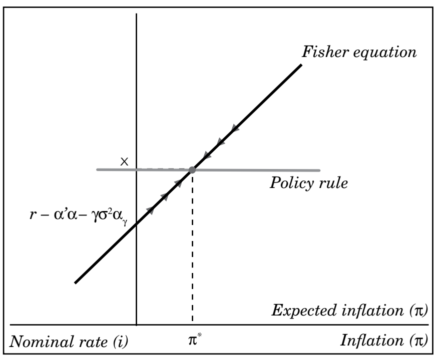
Figure 2 plots the phase diagram for this case, where the policy rule is now a horizontal line. Clearly, the system is globally stable: after a shock to the real economy (which shifts the Fisher relation) or a shock to monetary policy (which shifts the policy rule), inflation will converge back to the new intersection of the two lines. The boundedness condition puts no restriction on equilibrium. Yet, with risk, the change in inflation in response to the shocks (α) affects the location of the Fisher relation. Therefore, there are multiple possible combinations of inflation and its responsiveness to shocks that are consistent with equilibrium.

The Fed instead set policy in terms of the 90-day rate. A peg on a long rate implies that $i_t^{(s)}$ equals a constant ι. Using lemma 3, this implies that:

$$\iota = \delta_0(s) + (\delta_i(s) + \delta_x(s)). \tag{38}$$

Given the one-to-one correspondence between $\bar{x}$ and ι, the peg on a long rate can be analyzed by using the same phase diagram and the same mathematics as a peg on the short rate: it simply corresponds to a different choice of $\bar{x}$. Indeterminacy of inflation remains, and going long is immaterial.

Figure 2. A hard peg



Source: Author's elaboration.

4.4 Ceilings and Inflation

The supposed hard peg only lasted for a little over 5 years; by comparison, the policy rate was unchanged in the United States for 7 years, between December 2009 and December 2016. An alternative interpretation of the policy at the time is that the Fed followed a feedback rule for interest rates, as in equation (11), but with a very high extent of interest rate smoothing (low ρ) and a relatively low sensitivity of interest rates to inflation (low ϕ). However, the analysis of section 2 does not apply. For more than a decade, the Fed had a ceiling on long rates. That is, there was an exogenous ι for the 10-year rate such that monetary policy followed the feedback rule unless it implied a violation of the constraint $i_t^{(s)} \leq \iota$. If so, then the interest rate was unchanged.

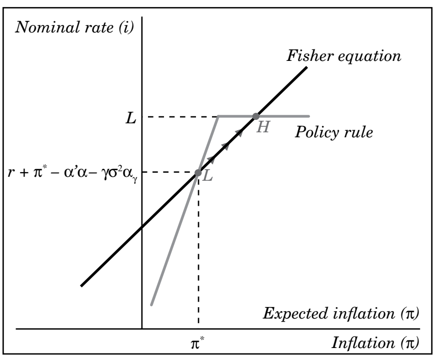
Figure 3 plots the phase diagram matching this case. For simplicity of the graph, consider the case where all shocks are zero, so that $i_t^{(s)} = \int_t^s i_j dj$ and take the intercept in the policy rule to be consistent with the inflation target: $x_t = \overline{x} = r + \pi^*$. Then, starting from a point where the short-term rate equals the long-term rate, the policy resembles a peg. Therefore, the policy rule at point *H* is horizontal and stays so up to the point where it intersects the feedback rule. Given the monotonicity of the interest rate in the dynamic system, it then follows that the interest rate will be at the bound for all levels of inflation between point H and the point where the ceiling intersects the unbounded policy rule.

There are now two equilibria: the previous unstable one, with inflation on target at point L, and a new globally stable equilibrium at point H, with persistently high inflation. This model allows one to make sense of the conflict between the Fed and the Treasury in the late 40s and of the dynamics of inflation at the time. At first, the economy was close to the L equilibrium. Given small shocks to the real interest rate that shifted the Fisher equation, the Fed would make small adjustments to the bill rate (changes in x_t) to shift the policy rule, and make sure that the interaction L still implied inflation at π^*. These adjustments had to be negotiated with the Treasury, but they were essential since, if the shocks pushed for higher inflation and the Fed was not quick to raise x_t and shift the policy rule, it risked being to the right of the L point and entering escape dynamics towards the H equilibrium. Post 1945, when these positive inflation shocks happened, the political tension between the Fed and the Treasury was therefore large, and concentrated on the level of the T-bill rate.

In 1950, the intensification of the Korea War implied a large increase in r_t shifting the Fisher equation upwards. Controlling inflation would require a sharp increase in the bill rate x_t to shift the policy rule upwards as well and keep inflation on target. The tension intensified and the Accord had to follow. The ceiling played a crucial role because as the two upward-sloping line segments shift upwards, any further positive shocks to inflation would quickly set in dynamics that ultimately lead to point H. Translating this into economics, as real and nominal rates rise, the yield curve flattens, and this reduces the room for further shocks to not make the ceiling put a binding constraint on short rates.

By 1953, it was clear that the Fed must let go of the ceiling. Even with control of short rates and potentially a more aggressive policy in the form of a higher ϕ, still there was a real danger that a future shock would start dynamics towards the H point. The statements by the Fed at the time, of fearing that the policy of pegging the long rate would lead to inflation getting out of hand, are justified by this simple model. The ceiling put a strain on monetary policy because any mistake in setting x_t too low, would lead the economy to enter a stable path where inflation monotonically rises and converges to the high-inflation equilibrium in point H. Abandoning the ceiling was the way to prevent the high-inflation stable equilibrium from becoming the dominant reality in the United States.

Figure 3. Long Ceiling Policy



Source: Author's elaboration.

According to the model, the way in which the Fed went long at the behest of the Treasury was ultimately unsustainable. It created a high-inflation equilibrium that might have been reached and set its stable roots in the U.S. were it not for the strong intervention of the Fed to break its ties with the Treasury.

5. The Radcliffe Commission and U.K. Monetary Policy in the 1960s

On 3 May 1957, the chancellor of the exchequer set up a "Committee on the Working of the Monetary System," headed by Lord Radcliffe. Its official goal was ambitious and wide-ranging: "to inquire into Britain's monetary and credit mechanism, and to make recommendations." It deliberated for more than two years, questioning more than two hundred witnesses, and receiving more than one hundred special memoranda, until the final report was presented in August 1959.

The Radcliffe Report's purported to explain how monetary policy worked and how it should work. Unsurprisingly, it attracted both strong support as well as violent disagreement across the globe. In the academic world, in 1960 alone, there were special articles in the *American Economic Review*, the *Journal of Finance*, and the *Review of Economics and Statistics* devoted to the Report. The prominent monetary economist Anna Schwartz for many years argued that the Report was misguided (Schwartz, 1987). Its policy principles explicitly guided the Bank of England's monetary policy during the 1960s, and were arguably influential for longer, so that the Report plays a central role in any history of the Bank of England in the XXth century.[13]

5.1 Prelude: Criticisms of Monetary Policy in the 1950s

Throughout the 1950s, the U.K. economy was still recovering from the devastating effects of World War II. There were many direct economic controls in place and a large stock of public debt outstanding. The maturity of that debt was low relative to what had been typical, which led to constant pressure to refinance bonds that would come due.

13. Good references for monetary policy in the period before and after the Report, drawing links to long-term interest rates, are Dimsdale (1991), Goodhart (1999), Batini and Nelson (2005), Capie (2010), and Allen (2014).

The Bank of England was not independent, since it operated under the control of the Treasury. Reducing unemployment was the dominant goal of economic policy, and following the prevalence of Keynesian thought, fiscal policy directed to controlling aggregate demand was perceived as the best way to achieve it. Monetary policy was mostly devoted to managing international reserves and preventing fluctuations in the value of the exchange rate. Therefore, almost all of the changes in the main policy rate—the rate at which the Bank of England lends to banks—came in response to international shocks that affected the exchange rate. This led to frequent accusations that the Bank was too short-sighted, since it focused on short rates as opposed to keeping long rates low, a policy of "cheap money" that was popular in Keynesian circles.

As in the United States, right after the war there was an explicit target for the 10-year rate on government bonds of 2.5%. However, it was implemented quite differently. If investors required higher returns to buy the bonds, the Treasury simply refused to sell them. As a result, when during the 1950s the Bank would increase short-term interest rates in response to foreign shocks while keeping long rates fixed, the market for long-term gilts would dry up, and the Treasury would issue mostly Treasury bills. This led to further criticism of the Bank for undermining the national goal of extending the maturity of the stock of government debt.

Academics were likewise critical of the Bank, as this was a time of fervent debate on the role of monetary policy. Students of the gold standard thought that the central bank should be solely in charge of setting an interest rate to affect currency markets. In turn, Treasury officials saw macroeconomic policy through the lenses of a tradeoff between unemployment and inflation, in the spirit of the Phillips curve. More dominant was the view that credit policies were the main tool for a central bank to affect financial markets, while only a minority argued that monetary aggregates were important.

Following large sudden increases in the bank rate in 1955 and 1957 partly to stop an outflow of international reserves and the 1957 rise to power of prime minister Macmillan, the Radcliffe Committee was formed to clarify the role of monetary policy and the functions of the Bank of England. The Radcliffe Committee's hearings became a public arena where competing views of monetary policy were debated.

5.2 The Report's View of Monetary Policy

While the Report was unanimously approved by its members, it did not offer a clear list of conclusions and recommendations. Still, most contemporary readers summarized its contribution in a list of five points. The first four of these have attracted much academic attention already. These are: First, the recommendation that monetary policy has many different goals, sprayed throughout the Report without any clear discussion of policy tradeoffs, and no clear connection between them beyond the fact that central bank actions could in principle be relevant to each of them. Second, the downplay of monetary aggregates or, more generally, of the role of money in affecting macroeconomic outcomes due to the combination of a view that velocity is infinitely elastic and a preference for a broader and looser concept of "liquidity" as the relevant influence on aggregate demand and inflation. Third, the preference for explicit credit policies and controls as the tool that the Bank of England should use to complement the role of fiscal policy in steering aggregate demand. Fourth, a conventional and unremarkable discussion of the role of international reserves and exchange-rate volatility.

The fifth conclusion concerned the role of interest rates, especially at longer maturities, in monetary policy. This is the part of the Radcliffe Report relevant for this paper. It is the most grounded and clearly argued of the five main points, because it builds and expands on the 1945 National Debt Enquiry. Unlike the targets for liquidity, which were never concretely implemented, the advice on interest rates was influential in the setting of Bank of England policy in the 1960s.

The Radcliffe Report saw the management of the public debt as a fundamental goal of monetary policy. This was to be done by setting interest rates at many different maturities since policymakers *"[…] must have and must consciously exercise a positive policy about interest rates, long as well as short, and about the relationship between them."*[14] The quantities of government bonds held at different maturities would then be decided in markets according to investors' demand. The Radcliffe Report implicitly rejected the no-arbitrage view of the term structure, and was closer instead to a clientele perspective, where in each maturity separately, the central bank could choose a price, and market forces would determine the finite quantity that cleared the market.

14. Radcliffe Report, page 337.

The Report went further and dismissed the idea that in setting interest rates, the central bank would have a significant effect on aggregate demand. It likewise dismissed a connection between money and interest rates. Finally, it was critical of the Bank of England for focusing on short-term interest rates, and blamed the failings of monetary policy in the previous decade on its neglect of active management of long-term interest rates.

Throughout the 1960s, U.K. monetary policy devoted itself first to stabilizing the exchange rate and capital flows through the setting of short-term interest rates, and second to managing the yield curve and the cost of government financing through the setting of long-term interest rates. The Radcliffe Report urged the central bank to estimate the "right level" for interest rates. While the Bank never explicitly embraced focusing on one particular long-term interest rate, it continuously estimated a perceived "trend" in yields, which throughout the 1960s kept on rising. Managing the issuance of bonds of different maturities, using credit controls, regulating banks, and adjusting the bank rate were all tools used to ensure that a steady demand for government bonds materialized at the desired target.

5.3 The Bank of England Going Long

One way to interpret U.K. monetary policy is as pegging around an exogenous ι_t. Inflation was not a target for monetary policy, and changes in ι_t either followed some statistically estimated trend, or occurred infrequently as a result of political compromises with the Treasury and changing views on the need to stimulate investment. The going-long policy consisted of focusing monetary policy operations on a long interest rate and choosing this somewhat independently of inflation or aggregate demand. The central bank focused instead on devising a target for the long rate, ι_t, which following Radcliffe, was exogenous to inflation.

It is not a big stretch though to instead model the Bank of England's policy as a feedback rule for the long rate:

$$d(i_t^{(s)} - \iota_t) = -\rho(i_t^{(s)} - \iota_t)dt + \phi_\iota\left(\frac{dp_t}{p_t} - \pi^* dt\right), \tag{39}$$

with a small ϕ_t and a large extent of smoothing ρ. The history of policy decisions at the time has some episodes where an increase in inflation expectations is followed by a discussion of whether to adjust the target for long-term interest rates.

Lemma 3 mapped long-term interest rates into the instantaneous rate. From this map follows the result:

Lemma 4. *The policy rule for long-term interest rates in equation (39) leads to inflation dynamics as in proposition 1 with* $\phi = \phi_t / \delta_i(s)$ *and*

$$x_t = \frac{\iota_t - \delta_0(s)}{\delta_i(s) + \delta_x(s)}. \tag{40}$$

The proof is as follows. Conjecture that the policy rule leads to a rule for instantaneous rates as in equation (11) for some ϕ and some x_t. Then, from lemma 3, we know that it $i_t^{(s)} - \iota_t = \delta_0(s) + \delta_i(s) i_t + \delta_x(s) x_t - \iota_t = \delta_i(s)[i_t - (\iota_t - \delta_0(s) - \delta_x(s) x_t)/\delta_i(s)]$. The conjecture will be verified if $\phi = \phi_\iota / \delta_i(s)$ and if

$$\delta_i(s) x_t = \iota_t - \delta_0(s) - \delta_x(s) x_t. \tag{41}$$

Rearranging gives the expression in the lemma.

In a sense, all central banks follow a rule of this type, as few set a truly instantaneous interest rate, but instead set overnight or one week interest rates. For these short maturities, $\delta_0(s)$ and $\delta_x(s)$ are close to zero, while $\delta_i(s)$ is close to 1. The result in lemma 4 shows that the properties of inflation derived in section 2 then applies with no modifications to these actual policies.

When the central bank goes long, instead, s is large and so $\delta_i(s)$ is small. Section 2 discussed three main determinants of inflation, which using lemma 4 we can now apply to the policy of targeting long-term interest rates.

First, it must be that $\iota > \delta_i(s)\rho$ for inflation to be determinate. Since $\delta_i < 1$, the condition for determinacy is therefore less stringent than it was for shorter rates.

Second, section 2 noted that it takes a precise setting of $\bar{x}$ to make inflation equal its target on average. This translates into an average target for the long-term rate $\bar{\iota}$ that follows the formula in the lemma above. To calculate accurately the real interest rate and the inflation risk premium, the policymaker must also now understand all the determinants of long-term yields, from their long-run average to their sensitivity to each shock. The problem is harder.

The third result in section 2 was that the variance of inflation depended on the variance of the interest rate. Given uncertainty on the parameters that determine the yield curve, setting the interest rate exactly to keep inflation on target (a choice of ι_t to hit $\varepsilon_t = 0$)

appears to be harder. Moreover, the insistence on lowering as much as possible the burden of paying for the national debt and the reluctance in linking interest rates to the evolution of inflation suggests that ι_t was not chosen to attempt to keep ε_t close to zero. Finally, exogenous shocks to ι_t may lead to a larger impact on inflation if $\delta_i(s)+\delta_x(s)<1$.

In conclusion, using long-term rates as the policy tool is consistent with controlling inflation and involves similar considerations as using short-term rates. In fact, the one-to-one map between long and short rates in lemma 3, implies that the set of equilibria that a going-long policy can achieve is the same as the set of equilibria that an equivalent policy for the short rate can achieve, in the sense of lemma 4. However, uncertainty on the shape of the yield curve suggest that this strategy likely comes with higher level and variability of inflation and nominal interest rates.

5.4 Spreads as Targets

At the same time, the Bank of England had multiple targets for different rates. As discussed in section 3, setting more than one interest rate independently would potentially create arbitrage opportunities across the yield curve. Instead, one can think of monetary policy as moving more than one interest rate in tandem to satisfy no-arbitrage. A simple way to model this is as a policy rule for the slope of the yield curve:

$$d(i_t^{(s)} - i_t - \iota_t) = -\rho(i_t^{(s)} - i_t - \iota_t) + \phi_\iota\left(\frac{dp_t}{p_t} - \pi^* dt\right). \tag{42}$$

Similar steps to those in lemma 4 show that

Lemma 5. *The policy rule for the slope of the yield curve in equation (42) leads to inflation dynamics as in proposition 1 with $\phi = \phi_\iota / (\delta_i(s) - 1)$ and:*

$$x_t = \frac{\iota_t - \delta_0(s)}{\delta_i(s) + \delta_x(s) - 1}. \tag{43}$$

Taking again the relevant case where s is large so $\delta_i(s)$ is small, the outcomes under a slope policy differ significantly from those under a long policy in one aspect. Pinning down inflation requires that $\phi > \rho$ and the higher is ϕ, the lower the variability of inflation in response to shocks. Using the result in the lemma, this requires ϕ_ι to be negative, and significantly so. That is, the model suggests that the central bank should commit to increasing its 10-year yield target by less than its overnight interest rate when inflation increases.

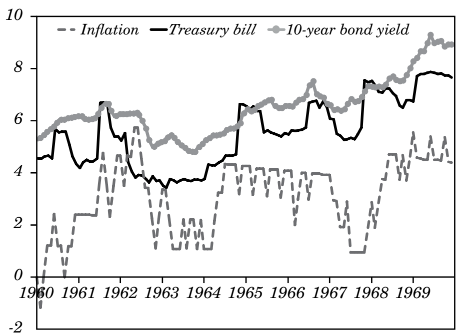
Controlling inflation requires flattening the yield curve in order to lower inflation. Conversely, stimulating inflation requires low overnight rates today that are expected to rise in the future.

To be clear, this result follows in this model because only monetary effects are at play. With nominal rigidities, lowering long rates by flattening the yield curve may stimulate investment which, through the Phillips curve, may raise inflation. Moreover, quantitative easing policies may instead lower term premium, which could affect inflation. Still, any model that has a Fisher equation and a feedback interest-rate rule will have the channel described above, according to which the slope of the yield curve should respond negatively to inflation.

5.5 Inflation Outcomes

To conclude, using long-term interest rates as the tools in feedback rules is consistent with keeping inflation under control. The conditions and economic logic are similar to those in the more familiar case where the policy rate is a short-term rate. However, the analysis suggested that without a precise understanding of the yield curve, its slope, and how it responds to shocks, keeping inflation under control will be hard.

Figure 4. U.K. Interest Rates and Inflation, 1960-70



Source: Author’s elaboration.

Figure 4 shows the path of interest rates and inflation during the 1960s in the U.K. Interest rates crept up from 1965 onwards, thus revealing the failure to pin them down at a natural rate. While, as the figure showed, the slope of the yield curve was small, the fiscal problems of the government persisted and intensified and, eventually, ended in a request for an IMF loan a few years later. Towards the end of the decade, inflation started accelerating, and by the early 1970s the Bank of England stopped going long, with the strategy deemed a failure.

6. The Bank of Japan Going Long

Since 1985, annual core CPI inflation in Japan only exceeded 2% in two years and inflation expectations were equally low. In response to fears of deflation, in 1997 the Bank of Japan (BoJ) gradually went long, making this policy explicit at the end of 2016.

Between July 1996 and March 1999, the BoJ expanded the size of its balance sheet by saturating the market for reserves. Starting from March 2001, the BoJ gradually introduced quantitative easing by committing to buy government bonds and to lend to banks in horizons that gradually rose all the way to 3 months. The interest-rate policy was clearly laid out in the Directive of 12 February 1999, which stated that: *"The Bank of Japan will provide more ample funds and encourage the uncollateralized overnight call rate to move as low as possible. To avoid excessive volatility in the short-term financial markets, the Bank of Japan will, by paying due consideration to maintaining market function, initially aim to guide the above call rate to move around 0.15%, and subsequently induce further decline in view of the market developments."* The BoJ repeatedly used forward guidance to state its intention to keep the overnight rate low until inflation expectations rose.

The first stage of this policy was unsuccessful insofar as the price level barely moved between 1997 and 2010, and inflation expectations stayed tightly anchored at 0. In a second stage, between 2010 and 2016, the BoJ rolled out a new policy, the qualitative and quantitative easing (QQE), committing to buy many other assets beyond government bonds. The balance sheet grew rapidly but, more importantly, it changed its composition to become more varied.

The second stage produced an increase in the rate of core inflation, from close to –2% in 2010 to slightly above 1% in 2015. Yet, after an initial jump in inflation in 2013, rising by 1.5% in a little over one year, inflation fell again throughout the second half of 2014 and 2015, so that by the middle of 2016, inflation was back to –0.5%. Consensus inflation expectations started falling since mid to end of 2015, far from their intended 2% inflation target. This led to a third stage in policy in September 2016: the yield-curve control.

The BoJ announced a target not just for the overnight central bank rate, but also for an intended yield on the 10-year government bond rate and, in the future, potentially other maturities as well. The BoJ announced a desired target of 0% for the 10-year government bond rate, while the target for the overnight rate was –0.1%. This was implemented by adjusting the purchase programs of bonds at the 10-year maturity to stay near the target.

It is too early to know how this policy will be pursued in the future. The analysis in this paper suggested that depending on whether the BoJ going long is formulated as: (i) a peg, (ii) a ceiling, (iii) a feedback rule for long rates, (iv) a rule for the term spread, or (v) something else, this has very different implications for how to stimulate inflation and for the dangers that may arise. Alternatively, perhaps the policy of the BoJ consists of separate pegs for the overnight and 10-year rate, as in the model of Reis (2017). Whichever way, if central banks follow the lead of the BoJ and go long, both history and theory should try to inform their policy choices.

7. Conclusion

In the past decade, it became common among policymakers to discuss monetary policies in terms of their impact on long-term interest rates. For instance, in her survey of the conduct of monetary policy and the role of quantitative easing by the Federal Reserve during the crisis, Chair Janet Yellen (2017) wrote: *"For this reason, the Committee turned to asset purchases to help make up for the shortfall by putting additional downward pressure on longer-term interest rates."* The Bank of Japan has gone further by announcing an explicit 0% target for the 10-year rate. Central banks have been going long by increasingly focusing on longer-term interest rates.

This paper went back in history to discuss the experience of the Federal Reserve in the 1940s and the Bank of England in the 1960s. They were different in interesting ways, and mapping them to explicit policies in a model is subject to interpretation. The analysis in this paper suggested several caveats to going long. First, unless it is implemented carefully, it can put the solvency of the central bank at risk or lead to much volatility in interest rate markets. Second, a ceiling on long-term rates creates a stable equilibrium with high inflation to which the economy can easily escape if there are positive shocks to inflation. Third, a feedback rule for long rates requires very precise knowledge of the yield curve and how it changes with separate shocks. Fourth, making the slope of the yield curve the policy tool requires steepening the yield curve, raising long rates relative to short rates, in order to raise inflation.

The analysis required linking long- and short-term interest rates, and inflation in a tractable way that keeps the effects of uncertainty and risk premiums. This suggested setting the problem of inflation control in an economy where shocks follow continuous-time diffusions. This opens the door for future work to introduce frictions, such as nominal rigidities and financial imperfections, in order to improve the model of the endogenous determination of inflation and term premia in the yield curve.

APPENDIX

A. Partial Adjustment to Real Interest Rates

Imagine now that nominal interest rates adjust only partially to real interest rates. This is achieved by having the policy choice of nominal interest rates, x_t, follow instead:

$$x_t - \overline{x} = \zeta(r_t - \overline{r}) + (1 - \zeta)\tilde{x}_t \tag{A1}$$

where, with a slight abuse of notation, now it is $\tilde{x}_t$ that follows an exogenous stationary process:

$$d\tilde{x}_t = -\kappa_x \tilde{x}_t d_t + \sigma_x dz_t^x. \tag{A2}$$

Finally, set $\overline{x} = \overline{r} + \pi^* - \alpha'\alpha - \gamma\sigma_y^2\alpha_y$, so that on average inflation is on target.

Now, if $\zeta = 1$, we are back in the first case covered in the text, in which $\varepsilon_t = 0$ at all dates (equation (27)). If $\zeta = 0$, we are in the second case, and the solution for inflation is the one given by equation (29).

Under this new rule:

$$\varepsilon_t = (r_t - \overline{r}) - (x_t - \overline{x}) = (1 - \zeta)(r_t - \overline{r} - \tilde{x}_t). \tag{A3}$$

If therefore follows that:

$$\mathbb{E}_t(\varepsilon_{t+s} - \varepsilon_t) = (1 - \zeta)(r_t - \overline{r})(e^{-\kappa_g s} - 1) - (1 - \zeta)\tilde{x}_t(e^{-\kappa_x s} - 1). \tag{A4}$$

Plugging this into equation (26) and rearranging gives the new solution for expected inflation:

$$\begin{aligned} \pi(r_t, x_t) = \pi^* &+ \left(\frac{\rho - \kappa_g}{\kappa_g + \phi - \rho}\right)(1 - \zeta)(r_t - \overline{r}) \\ &- \left(\frac{\rho - \kappa_x}{\kappa_x + \phi - \rho}\right)(1 - \zeta)\tilde{x}_t. \end{aligned} \tag{A5}$$

Clearly, if $\zeta = 1$, then inflation is on target, while if $\zeta = 0$, this equation is equivalent to equation (29), thus nesting the two cases in the text.

Finally, turning to the shocks on inflation, now equation (30) leads to:

$$\left(\frac{\rho-\kappa_g}{\kappa_g+\phi-\rho}\right)(1-\zeta)[dr-d\hat{r}]-\left(\frac{\rho-\kappa_x}{\kappa_x+\phi-\rho}\right)(1-\zeta)[d\tilde{x}_t-d\hat{x}_t]$$
$$=-\gamma\sigma_g dz_t^g+\sigma_x dz_t^x+\phi\alpha_y\sigma_y dz_t^y+\phi\alpha_g\sigma_g dz_t^g+\phi\alpha_x\sigma_x dz_t^x. \tag{A6}$$

Collecting terms this becomes:

$$\alpha_x=-\frac{1-\zeta}{\kappa_x+\phi-\rho} \tag{A7}$$

$$\alpha_g=\frac{\gamma(1-\zeta)}{\kappa_g+\phi-\rho} \tag{A8}$$

$$\alpha_y=0. \tag{A9}$$

This again matches the solution in the main text for the two polar cases.

B. Proof of Lemma 2

Combine equations (14) and (29) and simplify by grouping terms to get the solution.

C. Proof of Lemma 3

Start with the Euler equation:

$$\mathbb{E}_t\left(\frac{m_{t+s}p_t}{m_t p_{t+s}Q_t^{(s)}}\right)=1 \tag{A10}$$

where I have used the notation $Q_t^{(s)}\equiv\frac{1}{I_t^{(s)}}$, to denote the price (the inverse of the yield) of the s-long bond. The differential version of this equation is:

$$\mathbb{E}_t\left(\frac{dQ_t^{(s)}}{Q_t^{(s)}}-\frac{\partial Q_t^{(s)}/\partial s}{Q_t^{(s)}}dt\right)+\mathbb{E}_t(m_t/p_t)$$
$$+\mathbb{E}_t\left(\frac{d(m_t/p_t)}{(m_t/p_t)}\frac{dQ_t^{(s)}}{Q_t^{(s)}}\right)=0, \tag{A11}$$

where the second term inside the first parentheses takes into account the fact that an instant later, the bond's maturity is shorter.

Guess that $\log Q_t^{(s)} = a(s) - b(s) r_t - c(s) x_t$, with undetermined coefficients $a(s), b(s), c(s)$.

Then, using Ito's lemma, it follows that:

$$\frac{dQ_t^{(s)}}{Q_t^{(s)}} = -b(s)dr_t - c(s)dx_t + \frac{1}{2}\left(b(s)^2\gamma^2\sigma_g^2 dt + c(s)^2\sigma_x^2 dt\right). \tag{A12}$$

Using this to replace into the pricing condition, and evaluating the expectations gives a long expression, where each of the four lines matches each of the four terms in the pricing equation:

$$\begin{aligned} & b(s)\kappa_g(r_t - \bar{r})dt + c(s)\kappa_x(x_t - \bar{x})dt \\ & + \left(\frac{b(s)^2}{2}\right)\gamma^2\sigma_y^2 + \left(\frac{c(s)^2}{2}\right)\sigma_x^2 \\ & - (a'(s) - b'(s)r_t - c'(s)x_t) \\ & -(\theta_0 + \theta_r r_t + \theta_x x_t) \\ & -b(s)\gamma\sigma_g^2(\alpha_g + \gamma) - c(s)\alpha_x\sigma_x^2 = 0. \end{aligned} \tag{A13}$$

Since this equation must hold for each and every realization of the state variables, one can match the coefficients in x_t to get an ordinary differential equation:

$$b(s)\kappa_g + b'(s) - \theta_r = 0. \tag{A14}$$

Together with the boundary condition that $b(0) = 0$, this has the simple solution:

$$b(s) = \theta_r(1 - e^{-\kappa_g s}) / \kappa_g \tag{A15}$$

Similarly, one can easily solve for $a(s)$ and $c(s)$.

Finally, by the definition of the long rate:

$$i_t^{(s)} = \frac{\log(I_t^{(s)})}{s} = \frac{-\log(Q_t^{(s)})}{s} = \frac{-a(s) + b(s)r_t + c(s)x_t}{s} \tag{A16}$$

Using lemma 2 to replace out r_t, this delivers the expression in lemma 3, where $\delta_i(s) = b(s)/(s\theta_r)$.

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Capital Flows, Macroprudential Policies and Capital Controls

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Understanding the determinants and patterns of international capital flows is of crucial importance for the design of policies that enhance macroeconomic stability. Traditionally, capital flows have been very volatile in developing economies, with large inflows in times of economic booms, and large, sudden capital flow reversals in times of economic turmoil. This volatile behavior has prompted policymakers in these economies to impose controls, on either inflows or outflows, in an attempt to reduce the volatility of capital flows, thus decreasing the probability of a crisis generated by large flow reversals. More recently, as a result of the buildup of global systemic risks prompted by capital flows and the subsequent rapid and widespread transmission of a shock originated in a single economy (the U.S.) that characterized the last global financial crisis, capital flows, capital controls and, more prominently, macroprudential policies in developed economies have become a subject of great interest in the profession[1]. It is only natural, then, that these are topics that have been thoroughly researched by the economic profession in the last decades. Yet, many questions about the extent of the effects of policy measures such as capital controls and macroprudential policies remain without a definite answer.

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1. While macroprudential measures are typically designed to impact domestic credit and risk-taking by financial institutions, arguably they should also impact capital flows, though in a more indirect manner.

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In this paper we seek to understand how macroprudential policies and capital controls affect capital inflows, and what the main economic mechanisms driving the results are. To this end, we consider a panel of 39 countries over the 2004–2013 period, 21 of which are developed economies and 18 are developing ones. We derive results on the impact of these two types of economic policies, namely macroprudential policies and capital controls, on capital inflows for both types of economies.

Our main result is that macroprudential policies, especially those targeted at financial institutions, positively affect capital flows in developing economies, while their impact is negative in developed economies. This result appears to be quite robust to different econometric specifications and the inclusion of controls to account for possible reverse causality.

Following Bruno and Shin (2017), we argue that this outcome is broadly consistent with the hypothesis of carry-trade opportunities present in developing economies, which are intensified when macroprudential policies limit the ability of domestic financial institutions to provide credit to firms. Non-financial firms with access to international markets see an opportunity to obtain profits from interest rate differentials by bringing in external funds and acting as financial intermediaries in the domestic market[2].

While we do not explore the carry-trade mechanism explicitly[3], we base our interpretation of the results on two findings. First, domestic credit is negatively influenced by macroprudential policies in developing economies, but not in developed ones. Second, in developing countries with more developed financial systems, the effect of macroprudential policies on capital inflows is larger. This brings support to the idea that relatively small domestic firms see their funding needs curtailed by such policies.

2. De Gregorio and others (2017) argue that firms in emerging markets exploit interest rate differentials to accumulate international debt in order to increase their investments. While we do not explore this channel explicitly, we consider our findings and our hypothesis to be consistent with this evidence.

3. The reason for this is twofold: First, in order to test whether capital flows respond to interest rate differentials, we would need to take into account the interest rates at which firms take loans. These rates are different to the monetary policy rate in the economy and present quite a substantial degree of variance, so they are usually not necessarily well represented by the mean rate in the system. Second, even if we had a good measure of interest rate differentials, the presence of segmented markets in developing economies, by which some firms have ample access to domestic and international financial markets while others do not, makes it hard to test this channel by using a common equilibrium market price. Consequently, we consider this to be beyond the scope of the paper.

In terms of capital controls, we find that they exert a negative effect on capital inflows in developing economies, as it is expected from these types of measures. We also find that capital controls impact negatively on the volatility of equity inflows in these economies. This is an important result from the point of view of policy design, as the main goal of capital controls in developing economies is precisely the reduction of capital flow volatility.

This paper is organized as follows: section 1 reviews the related literature. Section 2 describes the data we use to perform our empirical analysis, and section 3 discusses our main empirical strategy. Our results are presented in section 4. Finally, section 5 concludes.

1. Related literature

After the global financial crisis of 2008–2009, there has been a renewed interest on the design and efficacy of macroprudential policies. Special attention has been given to their ability to promote financial stability[4] and their interaction with monetary policy as a stabilization tool.[5] In the recent past, there has been increasing interest in analyzing how macroprudential policies affect capital flows. A notable example is Bruno and others (2017).[6] In this paper, the authors identify the effects of domestic macroprudential policies and capital control measures on banking and bond inflows for a group of 12 Asia-Pacific economies over 2004–2013. Our analysis is related to theirs, but we focus on a larger group of 39 countries and we specifically investigate the effect of macroprudential policies on inflows associated to carry-trade operations.

Capital controls have received wide attention from the profession since the 1990s, praised and demonized at different points in time. While most papers in the early empirical literature on capital controls and financial liberalization focused on their effects on macroeconomic performance[7], the recent literature has focused on using rich datasets (cross-country or microdata within a country) to study the effectiveness of capital controls on net and gross measures of capital

4. See, among others, Galati and Moessner (2013), Claessens (2014), Cerutti and others (2015) and references therein.

5. See Smets (2014), Rubio and Carrasco-Gallego (2014), Angelini and others (2014), Bailliu and others (2015), and Mishkin (2011), among many others.

6. See also Ostry and others (2012), Unsal (2013), and Beirne and Friedrich (2017).

7. See Forbes (2007) for an excellent survey on the older literature on capital controls, financial liberalization and economic growth.

flows, oftentimes distinguishing by types of flows (mainly banking, bonds, and equity). Some examples in this literature are Magud and others (2011), Warnock (2012), Ahmed and Zlate (2014), Forbes and others (2015), and Forbes and others (2016). Results in this literature are usually conflicting—while some find that capital controls are associated with more stable capital flows (mainly through lower capital inflows), others find that these measures fail to accomplish their desired goals. We contribute to this literature in showing that some types of capital controls, specifically those targeted at equity flows, are associated with a lower volatility of equity inflows. Moreover, our results suggest that capital controls that affect bond inflows may have the desired effect, at least for non-developed countries.

Our work is also related to a newer strand of literature studying the patterns and determinants of international corporate debt issuance in emerging economies. In a nutshell, flows to emerging economies have shifted from being mainly used to finance public debt to finance corporate debt and, among the latter, from bank loans to bond issuance. The stylized facts associated to these changes are thoroughly documented in Turner (2014), Avdjiev and others (2014), Bruno and Shin (2017), and Caballero and others (2016a). The natural question that arises then is why we observe this new pattern of capital flows. There are two competing explanations for this phenomenon[8]: The first is that financially constrained firms in emerging markets have taken advantage of the relative abundance of global liquidity in the recent years to accumulate large stocks of funds, in anticipation of times in which market incompleteness would prevent them from covering their financial needs. This is dubbed as the *precautionary motive*. The second explanation posits that non-financial firms with access to international markets in these economies have undertaken a role of financial intermediation that heavily regulated banks cannot fulfill, thus taking advantage of macroeconomic conditions such as low international interest rates and local currency appreciation. This is the *carry-trade explanation* and is the one that seems to be supported in the data: Bruno and Shin (2017) use firm-level data on international bond issuance and other financial information and find that firms issuing U.S. dollar-denominated bonds use their proceeds to add to their cash holdings. This behavior is more prevalent in emerging markets and when carry-trade conditions are more favorable.

8. Other alternative explanations are the retreat of international banks from economies with weaker fundamentals and the presence of foreign firms in the U.S. market.

They interpret these findings as evidence supporting the carry-trade explanation. Caballero and others (2016b) link this result to the degree of financial openness of emerging markets. In particular, they find that carry-trade activities are prevalent in economies in which capital controls are tighter. We contribute to this ongoing debate by showing that, in emerging economies, domestic financial regulation also plays a prominent role in determining bond inflows. We argue that this is additional proof that such flows respond to carry-trade motives since macroprudential policies targeted at financial institutions provide a widened market in which non-financial firms can act as intermediaries, thus taking advantage of carry-trade opportunities.

2. Data

Following much of the recent empirical literature on capital flows, we use quarterly data on gross capital inflows on bonds and equity obtained from the Balance of Payments Statistics Database of the IMF.[9] We compute gross flows as the difference of two consecutive periods in the stock of liabilities reported in the international investment position of the country. Our preferred measure for the empirical analysis that follows is the gross flow scaled by the stock in $t-1$, i.e., the growth rate.

Our measure of macroprudential policies is obtained from Cerutti and others (2015). They document the use of macroprudential policies for 119 countries on a yearly basis over the 2000–2013 period. They construct 12 measures of macroprudential policies and assign to each one of them a value of 1 if the country had that policy in place in that year, and 0 otherwise. They synthesize the information by means of three main indices of macroprudential policies, depending on which economic agents these policies are targeted at: borrowers, financial institutions, or all (which is the sum of the previous two). Macroprudential policies targeted at borrowers include loan-to-value ratio caps and debt-to-income ratio limits, while those targeted at financial institutions include loan-loss provisions, countercyclical capital buffers, limits on leverage ratios, capital surcharges on systemically important financial institutions (SIFIs), limits on interbank exposure, concentration limits, limits on foreign currency loans, countercyclical reserve requirements, limits on domestic currency loans, and taxes on financial institutions.

9. See Gourinchas and Rey (2013) for a discussion.

We use measures of capital controls from Fernandez and others (2016), who document annual indicators of controls on inflows and outflows for ten categories of assets, for 100 countries, for the period 1995–2013, based on the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). As with macroprudential indices, here variables are assigned a value of 1 if there was a policy in place in that country and year, and 0 otherwise. For portfolio inflows, they group measures into those that affect assets purchased locally by non-residents and those that affect instruments sold or issued abroad by residents. Similarly, for outflows, they group measures into those that affect instruments sold or issued locally by non-residents and those that impact instruments purchased abroad by residents.

The rest of the variables we use are mainly macroeconomic controls obtained from the World Development Indicators of the World Bank, the St. Louis Fed, and Datastream. Appendix A contains a more detailed description of all variables and data sources used.

2.1 Summary Statistics

Table 1 shows summary statistics for the variables of interest used in the empirical estimations. Our sample consists of 39 countries—21 developed countries and 18 developing countries. In the latter group, there are six emerging countries according to the IMF classification.[10] We use an unbalanced panel of quarterly data from 2004 to 2013, requiring at least 12 observations for each country. On average, there are around 32 observations per country, which gives us a panel with 1239 observations, almost 60% of which correspond to developed countries.

The second panel of table 1 shows statistics related to the main dependent variable—capital inflows. On average, these are close to 1.9% of the stock of international assets, while their standard deviation is 6.7%. Capital inflows are larger and more volatile in developing countries than in developed ones, with an average size and a standard deviation of 2.3% and 7.1%, respectively, as compared with 1.5% and 6.4% shown by developed countries.

Almost all the countries in our sample have had some type of macroprudential policy in place during the period considered (i.e.

10. See table 11 in the appendix for the list of countries.

the macroprudential index, or MPI, has a positive value). The only countries without these types of policies in the sample period are the U.K. and Slovenia. The third panel of table 1 shows statistics for the two types of macroprudential policies we use in our estimations. Most of these policies are imposed on financial institutions, with 34 countries having a positive value in the corresponding index at some point. Countries with positive values in the index for borrowers are half this number. More important for the results are the number of countries that introduce or eliminate some measures during the years of our sample. These are 9 and 17 countries for borrowers and financial institutions, respectively. In terms of countries' classification these indicators are evenly spread between developed and developing countries.

Table 1. Summary Statistics

	All	*Developed*	*Developing*
Countries	39	21	18
Observations	1,239	728	511
Capital inflows			
Mean (%)	1.88	1.49	2.34
Standard deviation (%)	6.70	6.39	7.06
MPI			
Countries with MPI borrower	17	7	10
Countries with change in MPI borrower	9	5	4
Countries with MPI fin inst	34	16	18
Countries with change in MPI fin inst	17	8	9
Capital Controls			
Countries with CC non-residents	9	2	7
Countries with change in CC non-residents	6	2	4
Countries with CC residents	12	3	9
Countries with change in CC residents	4	1	3

Source: Author's elaboration.

The last panel of table 1 shows the same information but for capital controls. These policies are scarcer in the sample, with only 13 countries showing positive values for the indicators, eight of them using both types of controls, to residents and non-residents. Unlike the MPI, capital controls are significantly more common in developing countries. Indeed, these are so infrequently applied in developed countries that we are unable to identify their effects in this group when using our preferred specification, which needs not only variation in capital controls but also that they remain in place for more than one year. This we do not observe in the group of developed countries in our sample.

3. Econometric Specification

Our baseline specification takes the following form

$$f_{i,t} = \alpha_i + \eta_t + \beta X_{i,t} + \gamma_b \mathrm{MPI}^{b}_{i,t} + \gamma_{f_i} \mathrm{MPI}^{f_i}_{i,t} + \theta_{nr} \mathrm{CC}^{nr}_{i,t} + \theta_r \mathrm{CC}^{r}_{i,t} + \in_{i,t} \quad (1)$$

where f is the capital inflow variable, i and t denote country and period, respectively, and parameters α_i and η_t capture country-fixed and time-fixed effects, respectively. The vector X includes controls that are commonly used in the literature: total external debt to GDP, the fraction of external debt that is short-term, and the stock of reserves as a fraction of total external debt. The coefficients of interest are γ_b and γ_{fi} in the case of MPI for borrowers and financial institutions, and θ_{nr} and θ_r in the case of capital controls imposed on non-residents and residents, respectively. The residual is $\in_{i,t} \sim N(0,\sigma^2)$.

The specification above does not control for endogeneity problems related to reverse causality from capital inflows to policy measures. Although solving this problem and identifying a pure causal effect from policies to capital flows is out of the scope of this paper, we do try to minimize this issue. We do this by controlling for dummy variables that indicate country-year pairs when the value of each policy indicator changes. Following this approach, we control for the contemporaneous correlation between flows and the policy indicators, which we claim should be more contaminated by reverse causality.

This can be illustrated when considering capital controls to non-residents in developing countries. In figure 1 we plot the average path of capital inflows, without controlling for any other factor, in developing countries around the imposition of the capital control, defined as time 0 in the x-axis. Capital inflows rise significantly in the year the control is imposed, probably because policy reacts to the larger inflow. But in the year after the policy change, capital flows drop significantly, below the level observed before the control is imposed. This is explained more likely because of causality from policy to inflows, which is the relationship we are interested in capturing. Therefore, as we clean our estimations from the effects happening at time 0, our coefficients will be capturing this causality better than when not controlling for them. Indeed, as it is shown below, when not controlling for the change in capital controls, the coefficient θ_{nr}, which captures the relationship in figure 1, is positive and significant, while it becomes negative and significant when doing so.

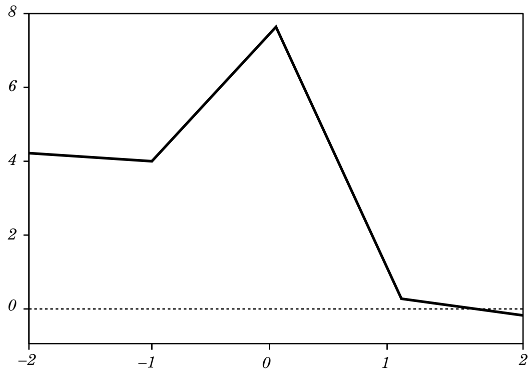
Hence we add dummies to equation (1) to obtain our preferred specification:

$$
\begin{aligned}
f_{i,t} = {} & \alpha_i + \eta_t + \beta X_{i,t} + \gamma_b \mathrm{MPI}^{b}_{i,t} + \gamma_{f_i} \mathrm{MPI}^{f_i}_{i,t} + \theta_{nr} \mathrm{CC}^{nr}_{i,t} + \theta_r \mathrm{CC}^{r}_{i,t} \\
& + \hat{\gamma}_b d\mathrm{MPI}^{b}_{i,t} + \hat{\gamma}_{f_i} d\mathrm{MPI}^{f_i}_{i,t} + \hat{\theta}_{nr} d\mathrm{CC}^{nr}_{i,t} + \hat{\theta}_r d\mathrm{CC}^{r}_{i,t} + \epsilon_{i,t}
\end{aligned}
\tag{2}
$$

where a d before the policy variable denotes a dummy that takes a value of 1 every year there is a change in the corresponding policy variable, and where γ_b, γ_{fi}, θ_{nr} and θ_r remain as the coefficients of interest.

We estimate this regression for the whole sample and use dummy variables to measure heterogeneous coefficients in developed and developing countries, and for different time-periods. We also vary the dependent variable keeping the explanatory variables unmodified.

Figure 1. Capital Flows in Developing Countries Around the Time of Implementation of Capital Controls



Source: Author's elaboration.

4. Results

Table 2 shows the results of our benchmark specifications. For all four columns, the dependent variable is quarterly bond inflows. All columns include an index of macroprudential policies targeted at borrowers and at financial institutions (*MPI borrower* and *MPI fin inst*, respectively), and an index of capital controls specifically targeted at restricting inflows, both for instruments purchased locally by non-residents (*Capital Controls non-residents* (*plbn*)) and for instruments sold internationally by residents (*Capital Controls residents* (*siar*)). Finally, all columns include controls for macroeconomic conditions, country fixed effects to control for unobservables at the country level, and quarterly time effects to control for global macroeconomic confounding factors.

Columns 1–3 of table 2 contain our baseline results. Macroprudential policies targeted at borrowers seem to exert a positive effect on bond inflows for the whole sample (column 1). When we split the sample into developed and developing economies, this effect is only present in developed economies. Moreover, macroprudential policies targeted at financial institutions have the opposite effect in these economies—they deter capital inflows (column 2). For developing economies, only macroprudential policies targeted at financial institutions have positive statistically significant effects. This last result brings support to the hypothesis that there are carry-trade opportunities in emerging economies that drive, at least partially, capital flows towards these economies—if macroprudential policies affect the lending activities of domestic financial institutions, alternative non-financial agents will find it profitable to bring in external capital to lend domestically. Developed economies are less prone to carry-trade operations (Bruno and Shin, 2017). Indeed, our results suggest that macroprudential policies targeted at financial institutions deter capital inflows in these economies, probably because less funds from international markets are channeled through financial institutions to domestic ones, while those targeted at borrowers promote them. This result is in line with the idea that firms that cannot finance themselves domestically will resort to international markets. Finally, capital controls to bonds purchased by non-residents appear with positive sign in column 2, which is contrary to the expected direct effect of this type of policies on capital inflows. We believe this positive coefficient might be the result of the problem of reverse causality that our analysis faces—greater capital inflows induce policymakers to implement capital controls, and not the other way round. Notice that this problem is much more likely to be present in the case of direct measures to control capital flows, rather than in that macroprudential measures aimed at enhancing domestic financial stability.

Columns 4–6 of table 2 include, in addition to all controls present in columns 1–3, the change in the *MPI* and *Capital Control* indices to control for the contemporaneous correlation between flows and policy indicators. As explained in the previous section, it is an attempt, though imperfect, to control for the reverse causality problem inherently present in this analysis. We can observe that the main results previously discussed survive—MPI measures targeted at financial institutions stimulate capital inflows in developing countries, while they deter them in developed ones. Moreover, now MPI measures targeted at borrowers appear to exert a negative effect on capital inflows in the former economies. This is probably due to a signaling effect of macroprudential policies—if the regulating authority imposes limits on borrowers because it perceives that credit is higher than desired, then foreign investors will be more reluctant to bring in capital in fear of financial distress that could negatively impact profitability. This also brings support to the hypothesis that firms in need of financing may resort to alternative sources, thus creating opportunities for carry-trade by non-financial firms.

Table 2. Capital Inflows, Macroprudential Policies and Capital Controls

	Baseline			*Controlling for year of implementation*		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd.* (2)	*Dving.* (3)	*All* (4)	*Devd.* (5)	*Dving.* (6)
MPI borrowers	0.0093*	0.013*	−0.011	0.0085	0.013	−0.020*
	(1.72)	(1.92)	(1.19)	(1.37)	(1.63)	(1.88)
MPI fin. inst.	−0.0060	−0.013***	0.020**	−0.0031	−0.011**	0.031***
	(1.54)	(3.13)	(2.57)	(0.71)	(2.33)	(3.42)
Capital controls non-residents (plbn)	0.013	0.068***	−0.0044	−0.012		−0.028*
	(1.24)	(2.99)	(0.35)	(0.86)		(1.86)
Capital controls residents (siar)	−0.023	0.021	−0.032	−0.034		−0.038
	(1.29)	(0.68)	(1.44)	(1.50)		(1.42)
R^2	0.33	0.34		0.34	0.35	
Observations	1,190	1,190		1,190	1,190	

Source: Author's elaboration.

Notes: The dependent variable is quarterly bond inflows. Additional controls not shown are external debt to GDP, short-term external debt as a fraction of total external debt, total reserves as a fraction of external debt, fixed and quarterly time effects. Equations 3 and 4 additionally include the change in the MPI and capital controls variables to control for any effects during the year of implementation. t-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Table 3. Bonds and Total Inflows

	Bonds			Total (Bonds + Equity)		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd.* (2)	*Dving.* (3)	*All* (4)	*Devd.* (5)	*Dving.* (6)
MPI borrowers	0.0085	0.013	−0.020*	0.011	0.028	−0.044*
	(1.37)	(1.63)	(1.88)	(0.86)	(1.63)	(1.94)
MPI fin. inst.	−0.0031	−0.011**	0.031***	0.0032	−0.0032	0.049***
	(0.71)	(2.33)	(3.42)	(0.35)	(0.31)	(2.64)
Capital controls non-residents (plbn)	−0.012		−0.028*	−0.063**		−0.090***
	(0.86)		(1.86)	(2.04)		(2.67)
Capital controls residents (siar)	−0.034		−0.038	0.15**		0.16*
	(1.50)		(1.42)	(2.10)		(1.87)
R^2	0.34	0.35		0.62	0.62	
Observations	1,190	1,190		1,051	1,051	

Source: Author's elaboration.
Notes: The dependent variables are quarterly bond inflows (equations 1 and 2) and total (bond plus equity) inflows (equations 3 and 4). Additional controls not shown are external debt to GDP, short-term external debt as a fraction of total external debt, total reserves as a fraction of external debt, the change in the MPI and capital controls variables, fixed and quarterly time effects. *t*-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Table 4. Bonds Inflows and Domestic Credit

	Capital Inflows (Bonds)			Domestic Credit		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd.* (2)	*Dving.* (3)	*All* (4)	*Devd.* (5)	*Dving.* (6)
MPI borrowers	0.0085	0.013	−0.020*	−0.059**	−0.097	0.0088
	(1.37)	(1.63)	(1.88)	(1.98)	(1.60)	(0.22)
MPI fin. inst.	−0.0031	−0.011**	0.031***	−0.045**	−0.030	−0.11***
	(0.71)	(2.33)	(3.42)	(2.57)	(1.51)	(3.38)
Capital controls non-residents (plbn)	−0.012		−0.028*	−0.016		−0.0068
	(0.86)		(1.86)	(0.32)		(0.14)
Capital controls residents (siar)	−0.034		−0.038	−0.13*		−0.16*
	(1.50)		(1.42)	(1.70)		(1.86)
R^2	0.34	0.35		0.54	0.55	
Observations	1,190	1,190		321	321	

Source: Author's elaboration.
Notes: The dependent variables are quarterly bond inflows (equations 1 and 2) and annual domestic credit as a percentage of GDP (equations 3 and 4). Additional controls not shown are external debt to GDP, short-term external debt as a fraction of total external debt, total reserves as a fraction of external debt, the change in the MPI and capital controls variables, fixed and quarterly time effects. *t*-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Capital controls to bonds purchased locally by non-residents is now statistically significant and has the expected negative sign for developing economies. The variable drops from the regression for developed countries, though. This is due to the fact that only two countries in our sample of developed economies implemented this type of controls, and they did it for only one year. This reinforces the idea that the positive sign in column 2 was probably driven by reverse causality.

Table 3 shows the same analysis, but now considering inflows in bonds and equity. For comparison purposes, columns 1–3 replicate columns 4–6 in table 2, while columns 4–6 in table 3 show results when the dependent variable is total quarterly inflows instead of only bonds. All results described for bond inflows survive when considering inflows in bonds and equity. Now, capital controls to bonds and equity sold internationally by residents are also positive and statistically significant for all countries. Once again, this unexpected result might reflect reverse causality.

Table 5. Effects on Volatility

	Volatility, Bonds			*Volatility, Equity*		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd.* (2)	*Dving.* (3)	*All* (4)	*Devd.* (5)	*Dving.* (6)
MPI borrowers	−0.0072	−0.0066	−0.0046	−0.017	−0.0071	0.021
	(1.21)	(0.86)	(0.40)	(1.46)	(0.52)	(0.93)
MPI fin. inst.	−0.0003	0.0006	−0.0038	−0.0095	0.0084	−0.070***
	(0.066)	(0.13)	(0.43)	(1.17)	(1.01)	(4.22)
Capital controls non-residents (plbn)	−0.019		−0.019	0.0024		0.030
	(1.39)		(1.29)	(0.084)		(1.02)
Capital controls residents (siar)	−0.025		−0.020	−0.12*		−0.27***
	(0.87)		(0.50)	(1.74)		(2.95)
R^2	0.35	0.36		0.35	0.46	
Observations	251	251		226	226	

Source: Author's elaboration.

Notes: The dependent variables are the annual volatility of bond inflows (equations 1 and 2) and equity inflows (equations 3 and 4). Additional controls not shown are the change in the MPI and capital controls variables, fixed and quarterly time effects. *t*-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

In order to provide further evidence in favor of the idea that macroprudential policies targeted at financial institutions boost capital inflows by providing carry-trade opportunities to non-financial firms, we analyze how domestic credit reacts to these types of measures. Table 4 shows the results. Once again, columns 1–3 replicate columns 4–6 of table 2, while columns 4–6 show results for the case in which the dependent variable is domestic credit as a percentage of GDP.

From columns 5–6 in table 4, we see that domestic credit reacts exactly as it would be expected if the carry-trade motive is the one governing capital inflows. In particular, macroprudential policies on financial institutions negatively affect domestic credit in developing economies, while there is no effect on developed ones. Indeed, this is the desired effect of these types of measures. Financing needs of domestic agents create opportunities for carry-trade operations, which results in capital inflows increasing with the *MPI fin inst* index. Finally, note that *Capital Controls residents* have a negative effect on domestic credit for the whole sample, driven by the effect on developing economies. This could be due to an indirect effect of capital controls on the availability of domestic lending funds through a diminished supply of capital inflows. The coefficient of *Capital Controls residents* on capital inflows is insignificant, though. It could also be due to a signaling effect, as capital controls may signal less future liquidity in the system, which translates into less domestic credit, or to an endogeneity problem.

Finally, we explore the idea that macroprudential policies and capital controls may have served as a stabilization tool by exerting a negative effect on the volatility of capital flows. Table 5 shows the results of regressing the annual volatility of bond (columns 1–3) and equity inflows (columns 4–6) on our measures of macroprudential policies and capital controls.

While the volatility of bond inflows does not seem to react to macroprudential policies or capital control measures, the volatility of equity inflows is negatively affected by some of these measures, depending on the type of country analyzed. *Capital Controls residents* seem to negatively affect the volatility in developing countries. This is an expected direct effect. In addition, the *MPI fin inst* negatively affects the volatility of equity inflows in these countries. By stabilizing domestic financial markets, macroprudential policies might also stabilize stock markets, especially so in economies where these are not strongly developed.

Table 6. Macroeconomic Conditions

	VIX *(1)*	*Ted Rate* *(2)*	*U.S. mpr r** *(3)*	*Local mpr r* *(4)*	*r–r** *(5)*	*GDP Gap* *(6)*	*GDP Growth* *(7)*
				Developed countries			
MPI borrowers	0.0006 (0.55)	0.022 (0.74)	0.0091 (0.97)	−0.013 (1.06)	−0.026** (2.24)	−1.43** (2.04)	−0.61* (1.65)
MPI fin. inst.	0.0001 (0.28)	0.0002 (0.025)	−0.0015 (0.68)	−0.0043 (1.52)	−0.0071* (1.93)	−0.14 (0.56)	−0.0045 (0.029)
				Developing countries			
MPI borrowers	0.0010 (1.42)	0.012 (0.89)	−0.0089* (1.90)	0.0003 (0.10)	0.0081** (2.20)	0.76** (2.37)	0.29 (1.26)
MPI fin. inst.	0.0005* (1.89)	0.0052 (0.92)	−0.0010 (0.47)	−0.0013 (0.76)	0.0004 (0.20)	0.041 (0.31)	−0.014 (0.16)
Capital controls non-residents (plbn)	0.0023* (1.74)	0.0034 (0.14)	−0.014** (2.06)	−0.0080 (1.23)	0.0038 (0.75)	0.69 (0.94)	−0.023 (0.041)
Capital controls residents (siar)	0.0022* (1.72)	0.018 (0.73)	−0.0099 (1.52)	−0.0033 (0.48)	0.0062 (1.02)	0.26 (0.51)	0.24 (0.43)

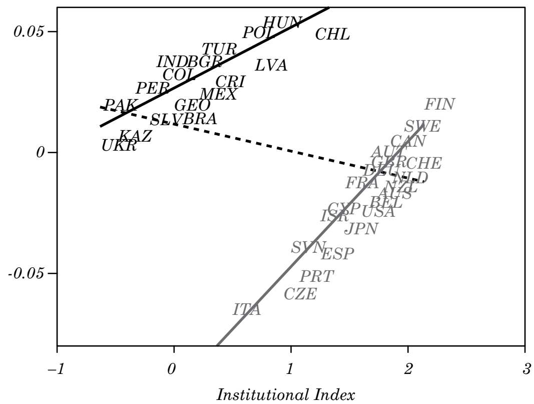
Source: Author's elaboration.
Notes: The dependent variable is quarterly bond inflows. Results shown are the coefficients on interactions between the variables defined in the upper panel and the corresponding indicator defined in the first column. Each interaction is introduced one at a time in the baseline specification, with the same additional controls plus the interaction multiplied by the dummy variable indicating the time at which the policy changes. t-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Table 7. Institutions and Financial Development

	All		*Developed*		*Developing*	
	Instit. (1)	*Fin. Dev. (2)*	*Instit. (3)*	*Fin. Dev. (4)*	*Instit. (5)*	*Fin. Dev. (6)*
MPI borrowers	0.0034	0.015	0.088**	0.052**	−0.091**	−0.18
	(0.35)	(1.38)	(2.33)	(2.23)	(2.24)	(1.09)
MPI fin. inst.	−0.011**	−0.022***	0.052***	0.0019	0.025	0.10**
	(2.30)	(2.79)	(3.38)	(0.11)	(1.23)	(2.04)
Capital Controls non-residents (plbn)	0.10***	0.27***			0.071*	0.37***
	(2.95)	(4.34)			(1.95)	(5.21)
Capital Controls residents (siar)	0.13**	0.37***			−0.078	0.45***
	(2.36)	(3.95)			(0.90)	(3.44)

Source: Author's elaboration.
Notes: The dependent variable is quarterly bond inflows. Results shown are the coefficients on interactions between the variables defined in the upper panel and the corresponding indicator defined in the first column. Instit is the index of government effectiveness from the World Governance Indicators database, and Fin Dev is domestic credit provided by financial sector as a % of GDP. In each case we use the average from 2000 so these don't vary over time. Each interaction is introduced one at a time in the baseline specification, with the same additional controls plus the interaction multiplied by the dummy variable indicating the time at which the policy changes. *t*-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Figure 2. Institutions and the Effects of MPI to Financial Institutions on Capital Inflows



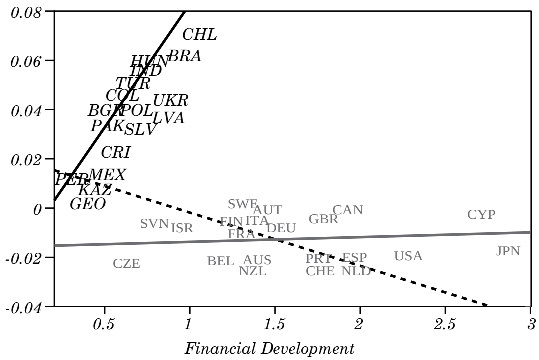
Source: Author's elaboration.
Note: Dash, grey and black lines are the conditional effects for all, developed, and developing countries, respectively, of MPI financial institutions on capital inflows. These are based on the results presented in table 7, in rows 3–4 and columns 1, 3, and 5.

4.1 Macroeconomic Conditions

In this section we explore the idea that certain macroeconomic conditions in the global or domestic economy may impact the effect that macroprudential or capital control measures have on capital inflows. To this end, we interact the indices of macroprudential policies and capital controls with different indicators of macroeconomic conditions, namely, the VIX index (a proxy for global uncertainty and market volatility), the TED spread (a proxy for global credit risk), the U.S. monetary policy rate to account for global liquidity availability, the local monetary policy rate, the spread between the latter two, a measure of output gap in the domestic economy computed as the log difference between real GDP and a trend GDP measure (where the trend is computed from applying the HP filter to the series), and finally the growth rate of the domestic economy.

Table 6 shows the results for both the group of developed economies and the group of developing economies. For developed economies, only a handful of interactions with macroprudential policies are significant.[11]

Figure 3. Financial Development and the Effects of MPI to Financial Institutions on Capital Inflows



Source: Author's elaboration.
Note: Dash, grey and black lines are the conditional effects for all, developed, and developing countries, respectively, of MPI financial institutions on capital inflows. These are based on the results presented in table 7, in rows 3–4 and columns 2, 4, and 6.

11. Notice that results for capital control measures are not reported because, as before, developed countries that implemented capital control measures did so for only one year.

In particular, a contractive monetary policy stance with respect to the U.S. reinforces the contractionary effect of macroprudential regulations, both for borrowers and for financial institutions, on capital inflows. This result is in line with Bruno and others (2017), who find that macroprudential policies are more successful when they are implemented in periods of monetary policy tightening. In line with this result, macroprudential policies targeted at borrowers are also more successful in deterring capital inflows when the economy is experiencing an expansion, either measured by a positive output gap or by GDP growth, which are times in which the monetary policy is expected to be tightened. Finally, global factors do not seem to play a role.

Today, in developing economies, global economic conditions do play a role in shaping the efficacy of macroprudential policies and capital controls. An uncertain economic environment, represented by a larger value of the VIX index, lowers the influence of macroprudential policies and capital controls in deterring capital inflows. On the other hand, a higher monetary policy rate in the U.S., which signals more stringent global liquidity conditions, aids macroprudential measures targeted at borrowers and capital controls on non-residents in discouraging capital inflows. Contrary to developed economies, now a higher spread between the domestic and the U.S. monetary policy rate impacts positively on the effect of macroprudential policies (targeted at borrowers) on capital inflows. A positive output gap exerts a similar effect. In these economies, an economic boom increases financing needs of local firms. Macroprudential regulations targeted at borrowers restrict the ability of firms to satisfy these needs domestically and may prompt them to look for funds in the international markets, thus fostering capital inflows. This explains the positive sign.

4.2 Institutions and Financial Development

Since macroprudential regulations seem to have distinctive effects on capital inflows depending on whether a country is developed or not, in this section we test the hypothesis that institutional and financial development may also play a role in shaping the effect of these measures. In the same spirit as the previous section, we interact our indices of macroprudential regulations and capital control measures with two variables of interest: *Instit*, an index of government effectiveness from the World Governance Indicators database, which is a proxy of institutional quality, and *Fin Dev*, which is the ratio of domestic credit provided by the financial sector to GDP. In each case, we use the variables' values of 2000, so they do not change over time.

Table 8. Sub-Samples: 2007

	2004–2006			2007–2013		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd.* (2)	*Dving.* (3)	*All* (4)	*Devd.* (5)	*Dving.* (6)
MPI borrowers	0.0084	0.074***	−0.060***	0.0079	0.0064	−0.022*
	(0.63)	(3.20)	(3.06)	(1.26)	(0.73)	(1.88)
MPI fin. inst.	−0.0080	−0.019***	0.044***	−0.0017	−0.014***	0.030***
	(1.39)	(2.85)	(3.17)	(0.37)	(2.67)	(3.15)
Capital controls non-residents (plbn)	−0.017		−0.068*	−0.012		−0.033**
	(0.61)		(1.66)	(0.83)		(2.10)
Capital controls residents (siar)	−0.031	0.0012	0.020	−0.034		−0.029
	(0.95)	(0.058)	(0.39)	(1.43)		(1.01)
R^2	0.34	0.36				
Observations	1,190	1,190				

Source: Author's elaboration.
Notes: The dependent variable is quarterly bond inflows. Results shown are the coefficients on interactions between the explanatory variables and time dummies for the period before and after 2007. Additional controls not shown are external debt to GDP, short-term external debt as a fraction of total external debt, total reserves as a fraction of external debt, the change in the MPI and capital controls variables, fixed and quarterly time effects. t-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Table 9. Sub-Samples: 2008

	2004–2007			2008–2013		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd.* (2)	*Dving.* (3)	*All* (4)	*Devd.* (5)	*Dving.* (6)
MPI borrowers	0.014	0.072***	−0.031*	0.0081	0.0074	−0.018
	(1.21)	(3.36)	(1.78)	(1.29)	(0.83)	(1.56)
MPI fin. inst.	−0.0083	−0.017***	0.028**	−0.0014	−0.011**	0.026***
	(1.57)	(2.58)	(2.24)	(0.31)	(2.09)	(2.70)
Capital controls non-residents (plbn)	−0.037		−0.048	−0.0074		−0.025
	(1.63)		(1.63)	(0.49)		(1.56)
Capital controls residents (siar)	−0.023	0.019	−0.021	−0.032		−0.038
	(0.78)	(0.96)	(0.55)	(1.36)		(1.41)
R^2	0.34	0.36				
Observations	1,190	1,190				

Source: Author's elaboration.
Notes: The dependent variable is quarterly bond inflows. Results shown are the coefficients on interactions between the explanatory variables and time dummies for the period before and after 2008. Additional controls not shown are external debt to GDP, short-term external debt as a fraction of total external debt, total reserves as a fraction of external debt, the change in the MPI and capital controls variables, fixed and quarterly time effects. t-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

Table 7 shows the results, and figures 2 and 3 provide a graphical representation of the effects of macroprudential policies targeted at financial institutions on capital inflows conditional on institutional index and financial development level, respectively. Figure 2 shows that the effect of these macroprudential policies becomes less negative, the higher the index of institutional quality of the developed country. For developing economies, the conditional effect is not statistically significant. This is probably due to the fact that countries with higher levels of institutional quality also have sounder financial systems in which macroprudential measures are less stringent. Conversely, figure 3 shows that the effect of macroprudential policies targeted at financial institutions becomes more positive the higher the level of financial development of the developing country. In this case, the effect is not significant for developed economies. This brings support to the idea that the channel through which macroprudential regulations affect capital inflows in developing economies has to do with carry-trade opportunities—countries in which the financial sector is more developed are more affected by these measures (either because they are more easily enforced or because of their wider coverage) and therefore present better opportunities for carry-trade operations. Notice that, when the effect of macroprudential policies conditional on institutional quality and financial development is estimated for all countries in the sample, it becomes more negative (or less positive) when either of these indicators increases. This because the interaction in this case is working as a proxy for the level of development of countries. Then, a country with higher institutional index/financial development is typically a more developed country, in which the effect of macroprudential policies targeted at financial institutions is negative. On the contrary, this effect is positive in less developed countries, which usually have a lower institutional index/financial development.

When considering macroprudential policies targeted at borrowers, the effects conditional on institutional quality and financial development are positive for developed economies and negative for developing ones. For the whole sample, capital controls, both to residents and non-residents, exert a more positive (or less negative) effect on capital inflows when the institutional quality and financial development of a given country is higher. Again, these indicators function as proxies for the level of development of a country. In developing economies, the effect of capital controls on inflows is less negative with higher financial development and institutional quality. Countries with sounder institutions and financial systems are likely to be less prone to volatile capital inflows seeking very short-term profitabilities, which are the targets of capital control measures.

Table 10. Robustness, Annual vs. Quarterly MPI indices

	Baseline			*Quarterly MPI*		
	Eq. 1	*Eq. 2*		*Eq. 3*	*Eq. 4*	
	All (1)	*Devd. (2)*	*Dving. (3)*	*All (4)*	*Devd. (5)*	*Dving. (6)*
MPI borrowers	0.0085	0.013	−0.020*	−0.0058	0.0021	−0.020**
	(1.37)	(1.63)	(1.88)	(1.28)	(0.39)	(2.36)
MPI fin. inst.	−0.0031	−0.011**	0.031***	0.0080	−0.041***	0.012**
	(0.71)	(2.33)	(3.42)	(1.55)	(3.08)	(2.35)
Capital Controls non-residents (plbn)	−0.012		−0.028*	0.0059		0.0052
	(0.86)		(1.86)	(0.39)		(0.34)
Capital Controls residents (siar)	−0.034		−0.038			
	(1.50)		(1.42)			
R^2	0.34	0.35		0.40	0.41	
Observations	1,190	1,190		1,035	1,035	

Source: Author's elaboration.
Notes: The dependent variable is quarterly bond inflows from IMF. In the left panel MPI variables are at an annual frequency, and in the right panel they are at a quarterly frequency. Additional controls not shown are external debt to GDP, short-term external debt as a fraction of total external debt, total reserves as a fraction of external debt, the change in the MPI and capital controls variables, fixed and quarterly time effects. *t*-values are reported below the coefficients. * means significant at 10%, ** significant at 5%, and *** significant at 1%.

4.3 Robustness Analysis

In this section we perform some robustness checks in order to test the stability of our results.

First, we divide the sample period into two subsamples to check whether there was a change in the way macroprudential and capital control measures affected capital inflows previous to the global financial crisis of 2008. Table 8 shows results for the case in which we divide the sample into years 2004–2006 and 2007–2013, while table 9 shows the same for the case in which we split the sample into years 2004–2007 and 2008–2013. As it is clear from the tables, our main results survive and are present in both sample sub-periods. The effect of macroprudential policies on the incentives to do carry trade and, through this channel, on capital inflows does not seem to have changed significantly before and after the global financial crisis.

Second, we use measures of macroprudential policies at quarterly frequency, instead of annual frequency. These measures are constructed in Cerutti and others (2017). Table 10 shows that our main results, namely that macroprudential policies targeted at financial institutions impact positively bond inflows in developing economies and negatively in developed ones, are robust to considering quarterly indices of macroprudential policies.

5. Conclusions

In this paper we have studied the effects of macroprudential policies and capital control measures on capital inflows in both developed and developing economies. Our main result is that macroprudential policies targeted at financial institutions impact bond inflows negatively in developed economies and positively in developing ones. This result is quite robust and survives when we control for the year in which the policy is implemented, to (partially) account for reverse causality. When considering total inflows (equity and bonds), the positive sign for developing economies survives, though, for developed ones, the coefficient is negative but not statistically significant. Splitting the sample in different time periods pre- and post- global financial crisis yields the same results.

We argue throughout the paper that this result is a reflection of carry-trade opportunities present in developing economies, which are intensified when macroprudential policies limit the ability of domestic financial institutions to provide credit to firms. Large, non-financial firms see an opportunity to obtain profits by exploiting interest rate differentials and bring in external funds that they use to lend to local firms that do not have access to international capital markets. Two elements support our hypothesis: domestic credit is negatively influenced by macroprudential policies in developing economies (but not in developed ones) and the degree of financial development of the country reinforces the positive effect of such policies on capital inflows. These findings point to the fact that these economies see their domestic credit provision significantly affected by macroprudential regulations. Alternative hypotheses, such as precautionary savings by credit-constrained firms, do not seem to be supported by our data, as the stance of the economic cycle does not seem to exert any effect on our results.[12]

12. The carry-trade hypothesis is very well explained in Bruno and Shin (2017). They find support for it when using firm-level data for a group of developed and emerging economies. We see our analysis as complementary to theirs.

Appendix

A. Data

A.1 Balance of Payment Statistics Database (IMF)

We obtain from here the capital flow variables. This database contains the financial account quarterly per country, classified by functional category, by type of financial instrument (equity, debt, and others), and presents the data separately by financial assets (net acquisition of assets) and liabilities (net incurrence of liabilities). Also, this database contains data of International Investment Position (IIP) that consist in stock of assets and liabilities at the end of each quarter. We compute gross flows as the difference of two consecutive periods in the stock of liabilities reported in the international investment position of the country. Our preferred measure for the empirical analysis that follows is the gross flow scaled by the stock in t−1, i.e., the growth rate. We drop those countries that have less than 12 observations in the sample. Also, we winsorize the sample at the 95 percentile.

A.2 Macroprudential Policies database

We use the macroprudential policy database from Cerutti and others (2015). This database documents the use of macroprudential policies for 119 countries over the 2000–2013 period on a yearly basis. The authors construct 12 measures of macroprudential policies, presented as dummy variables that take the value of 1 if the country had that policy in place in that year, and 0 otherwise. They summarize the information through three main indices of macroprudential policies, depending on which economic agents these policies are targeted at: borrowers, financial institutions, or all (which is the sum of the previous two).

A.3 Capital Controls database

We use measures of capital controls from Fernandez and others (2016). This database documents separate annual indicators of controls on inflows and controls on outflows for ten categories of assets for 100 countries, in the period 1995–2013, based on the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER).

As in the case of macroprudential indices, variables in this case are assigned a value of 1 if there was a policy in place in that country and year, and 0 otherwise. For portfolio inflows, they group measures into those that affect assets purchased locally by non-residents, and those that affect instruments sold or issued abroad by residents. Similarly, for outflows, they group measures according to whether they affect instruments sold or issued locally by non-residents, and those that impact instruments purchased abroad by residents. These indices are available for bonds and equity separately.

A.4 World Development Indicators (World Bank)

Data from the World Development Indicators (WDI, World Bank). It provides information at the country-year level. The data is in yearly frequency.

- We use the following variables for our analysis:
- GDP per capita, PPP
- GDP constant
- GDP current
- GDP per capita
- External debt stocks, total
- External debt stocks, short-term
- Total reserves
- Bank capital to assets ratio
- Bank liquid reserves to bank assets ratio
- Bank nonperforming loans to total gross loans
- Domestic credit provided by financial sector
- Domestic credit to private sector
- Market capitalization of listed domestic companies
- Stocks traded, total value
- Stocks traded, turnover ratio of domestic shares

A.5 Datastream

From here we obtain the Monetary Policy Rate (monthly) per country.

A.6 Fred - St. Louis FED

We use the following variables:

- TED Spread: the difference between the interest rates on interbank loans and on short-term U.S. government debt ("T-bills") (value at the end of each month)
- VIX Index: S&P 500 CBOE Volatility Index (value at the end of each month)
- Federal Funds Effective Rate (monthly): Monetary Policy rate from the U.S.

A.7 NBER

We use the crisis dummy from the NBER Dating Committee that takes the value of 1 if the quarter t had a crisis (according to the NBER Dating Committee), and 0 otherwise.

A.8 Institutional quality

1. Freedom House database: We use the Political Rights and Civil Liberties indices. Both of them go from 1 to 7, with 1 representing the highest degree of freedom, and 7, the lowest. Then, we compute the freedom house index, that is the mean between these others two indices.
2. Polity IV database: We use the Polity Index that goes from -10 to 10, from democracy to autocracy, and the Executive Constraints variable that explicitly measures how constrained the executive is in making arbitrary decisions.
3. World Governance Indicators database (World Bank): We use the Voice Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law and, Control of Corruption variables. They all go from -2.5 (weak) to 2.5 (strong) governance performance.

A.9 Countries in the sample

Developed Countries			*Developing Countries*		
France	Japan	Sweden	Hungary	Pakistan	Poland
Switzerland	Canada	Spain	Brazil	Kazakhstan	India
Austria	U.S.	U.K.	Colombia	Mexico	Ukraine
Israel	Belgium	Finland	Latvia	Costa Rica	Turkey
New Zealand	Germany	Australia	Bangladesh	Chile	
Italy	Cyprus	Slovenia	Peru	El Salvador	
Czech Republic	Portugal	Netherlands	Bulgaria	Georgia	

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A Global Safe Asset for and from Emerging Market Economies

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International capital flows are fickle. Short-term debt funding is especially subject to sudden stops. Sudden flight into safe-haven currencies can cause large disruptions and sharp currency movements, ultimately leading to a crisis. When markets shift from a risk-on to a risk-off mood, cross-country capital flows are triggered if the safe asset is not supplied symmetrically across counties. Advanced economies, which supply safe assets, experience capital inflows, while most emerging economies suffer sudden outflows. Hence, the design of global safe assets is paramount in creating a stable global financial architecture.

The focus of the international monetary system has, so far, been on leaning against these flight-to-safety capital flows. The International Monetary Fund offers various lending facilities that allow governments to borrow, in order to counterbalance these capital outflows. Similarly, international swap-line arrangements among various central banks allow central banks to offset sudden capital outflows. Absent these facilities, countries' primary precautionary strategy is to acquire large reserve holdings in good times that they can deploy in crisis times in order to lean against sudden outflows. The South East Asia crisis in

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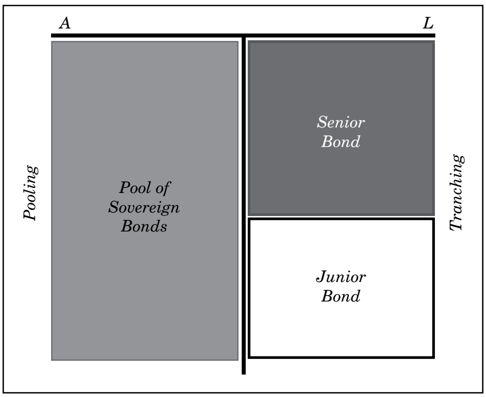
1997 was a wake-up call for most emerging economies. IMF funding was attached with conditionality and hence was not very popular in Asia. Many emerging countries subsequently opted for a self-reliant precautionary buffer approach by building-up large reserve holdings. This resulted in global imbalances, which possibly distorted interest and exchange rates. Holding reserves also incurs carry-cost for the emerging economy, as the interest on safe foreign-reserve assets is typically significantly lower than on domestic assets. This drains resources, lowers a country's fiscal space, and hence paradoxically can make a crisis more likely. However, when a crisis occurs, reserve holdings soften the severity of a crisis as they can be used to lean against the sudden capital outflows.

An alternative, more direct approach is to address the root of the problem, namely, that safe assets are asymmetrically supplied, since only a few advanced economies supply them. Our proposed solution is to use sovereign bond-backed securities (SBBS) to rechannel the destabilizing flight-to-safety capital flows. Instead of facing cross-border flows from emerging economies to some advanced economies, one could redirect these capital flows to move across different asset classes.

Figure 1. Structure of GloSBies



Source: Author's elaboration.

Even a single country on its own could create SBBS by setting up a special-purpose vehicle (SPV) that buys some of the country's sovereign bonds and tranches them into a senior bond and a junior bond. The junior bond absorbs the losses and protects the senior bond. As long as the junior bond tranche is sufficiently thick and covers the maximum haircut of the sovereign debt, the senior bond is free of default risk and can acquire a safe-asset status. With SBBS, investors can at times of crises flee into the senior bond instead of, say, the U.S. dollar.

Tranching a diversified pool of emerging-market government bonds, instead of those of a single country, exploits diversification benefits if the pool contains bonds from sufficiently heterogeneous countries. This allows for a "thinner" junior bond tranche without sacrificing the safety of the senior bond. The senior bond serves as an additional global safe asset.

Such a global safe asset follows the same idea as the SBBS or the European Safe Bonds (ESBies) proposal for the Euro area, proposed by Brunnermeier and others (2011). The Euro area suffered similar flight-to-safety capital flows from its peripheral countries to a few core countries. While within the Euro area there is no exchange rate risk, for the global SBBS the junior bond also has to absorb currency risk if the underlying national bonds are denominated in local currency. SBBS have a second advantage besides rechanneling flight-to-safety capital flows: as shown in Brunnermeier and others (2016), SBBS can eliminate the doom (diabolic) loop between sovereign and banking risks that arises when banks hold domestic sovereign bonds that are subject to default risk. As default risk rises and the sovereign bond price tanks, banks suffer losses, which increases the likelihood that the government has to bail them out, which in turn lowers the sovereign bond price. Brunnermeier and others (2017) studies diversification and contagion interactions, carries out numerical simulations, and analyzes various implementation details of SBBS for Europe.[1]

In Asia, the Executives' Meeting of East Asia-Pacific Central Banks (EMEAP)[2], is involved in the so-called Asian Bond Fund. This fund pools bonds from 11 countries, but does not tranche the pooled cash flows into a senior bond that could serve as a regional safe asset[3].

1. The European Union Commission refined the SBBS proposal and, in May 2018, it put forward the necessary regulatory changes.

2. See http://www.emeap.org.

3. In 2009, the introduction of a similarly structured Latin America Bond Fund was studied.

Metaphorically, tranching is like building a second, stronger line of defense within a fort. With only a single defense line, some knights might be tempted to flee for safety, thereby weakening the overall defense of the fort. Having a "safe haven" within the same fort, like the keep of a castle to withdraw to, lowers the knights' temptation to flee and thereby reduces the fort's overall vulnerability.

In this paper, we formally examine the flight-to-safety mechanism. Firms and banks hold safe assets in addition to physical capital for precautionary reasons. The domestic bond is considered safe if its default probability is very small, say, below 1%. Since the domestic bond's yield is significantly higher than that of the U.S. Treasury, firms prefer the former as their safe asset in normal times. After an adverse shock, the probability of domestic-sovereign-bond default rises and the domestic bond loses its safe-asset status. Consequently, firms try to swap all their domestic-bond holdings for U.S. Treasuries. By doing so, they suffer losses on their bond position, which also forces them to shed some of their physical capital at fire-sale prices. As they scale back their production capacity, the domestic government's tax revenues also decline. This, in turn, leads to a partial default of the sovereign bond, which justifies the initial loss of the domestic bond's safe-asset status.

Going beyond the baseline setting, we analyze the implications of foreign-reserve holdings, the "buffer approach," whose objective is to insulate the economy from sudden stops. If the government initially issues more sovereign bonds in order to hold U.S. Treasuries as reserves, it has to pay the interest-rate differential, but enjoys capital gains after an adverse shock. The "buffer approach" lowers the severity of a crisis, but the interest-rate differential makes it an expensive proposition. In contrast, the "rechanneling approach" involves tranching the domestic sovereign bond into a junior and a senior bond. Since the latter does not lose its safe-asset status, this is a strictly superior solution. After an adverse shock, firms hold on to their senior bonds and fire-sales are avoided. Production capacity—and, with it, tax revenue—remains high and consequently a default is also averted.

As the safe-asset status plays a crucial role in our analysis, it begs the question of what defines a safe asset. In our setting, an asset is considered safe if its Value at Risk entails no losses, i.e., losses occur only with a probability smaller than, say, 1%. Brunnermeier and Haddad (2012) argue that safe assets possess the following two characteristics: the "good friend analogy" and the "safe-asset tautology". Similar to a good friend who is around when needed, a safe asset is valuable and liquid exactly when needed. Like gold, a safe asset holds its value or even appreciates in times of crisis. While a risk-free asset is risk-free at a particular horizon, e.g., overnight or over 10 years, a safe asset is valuable at an *ex-ante* random horizon, when one needs it. They are, therefore, held as a precautionary buffer in addition to risky assets. Indeed, holding a safe asset allows one to scale up risky investment. The second property of safe assets is the safe-asset tautology. A safe asset is safe because it is perceived to be safe. Paradoxically, a safe asset might appreciate even though its fundamental value declines. For example, in August 2011, the U.S. Congress seemed likely to refuse to lift the U.S. debt ceiling, U.S. Treasuries were about to default and the S&P rating agency downgraded them; nevertheless, the same Treasuries appreciated in value. Similarly, the German Bund gained in value during the Euro Crisis even though Credit Default Swap (CDS) spreads indicated that the German bund default risk was rising. In sum, safe assets share some features of bubbles or multiple equilibria. That is, the link to the assets' fundamentals is weak.

Dang and others (2010) emphasize the feature that safe assets are informationally insensitive to shifts in fundamentals. Hence, asymmetric information frictions like Akerlof's lemons problem are limited. Gorton and others (2012) argue that the share of safe assets as a fraction of total assets is roughly stable over time. In Caballero and others (2017), safe assets are held by very risk-averse individuals who do not want to hold any risky investments, and a shortage of safe assets arises when monetary policy is constrained by the zero lower bound. He and others (2017) model the safe-asset tautology in a global games framework. Our paper is also related to the literature on international debt crisis featuring multiple equilibria, e.g., Calvo (1988) and Cole and Kehoe (2000). While this strand of literature emphasizes the strategic default of the government due to limited commitment friction, our work focuses on the safe-asset demand of domestic entrepreneurs and the default in our model is a mechanical outcome of tax revenue (output) losses.

1. Baseline Model

In our baseline model, domestic entrepreneurs demand safe assets to complement their risky capital investment. Initially, the domestic sovereign bond is more attractive, since it offers a higher yield than the U.S. Dollar Treasury. After an adverse shock, one of two possible equilibria can emerge. In the flight-to-safety equilibrium, the public suddenly expects that the domestic bond might default. Hence, it loses its safe-asset status and entrepreneurs flee to dollars to meet their demand for safe assets. The price of the domestic bond drops as more patient domestic investors dump domestic bonds to less patient foreign investors. If the decline in the domestic-bond price is severe, proceeds from selling the domestic bond are not sufficient to buy enough U.S. Treasuries as safe assets. Domestic entrepreneurs are thus forced to fire-sell capital to foreigners as well. The economy's output (and with it the government's tax revenue) declines, justifying the possible default of the domestic bond. This vicious cycle makes the flight-to-safety equilibrium self-fulfilling. In the second equilibrium, the fundamental equilibrium, no fire-sales occur, production and tax revenue remain high, and the absence of any default ensures that the domestic bond does not lose its flight-to-safety status.

In this section we study the baseline model before examining the implications of reserve holdings ("the buffer approach") in section 2, national tranching in section 3, and pooling and tranching in section 4. We evaluate and compare these settings according to two criteria: (i) vulnerability/likelihood of a flight-to-safety crisis and (ii) severity of the crisis.

1.1 Model Setup

Consider a small open economy with three dates $t \in \{0,1,2\}$ and three types of agents: domestic entrepreneurs, domestic households, and foreign investors.

Physical capital produces $A_t K_1$ units of a single output good at date $t = 2$, where K_t is the physical capital employed in period t and A_t is the random productivity of that capital. Productivity can take one of the following three values:

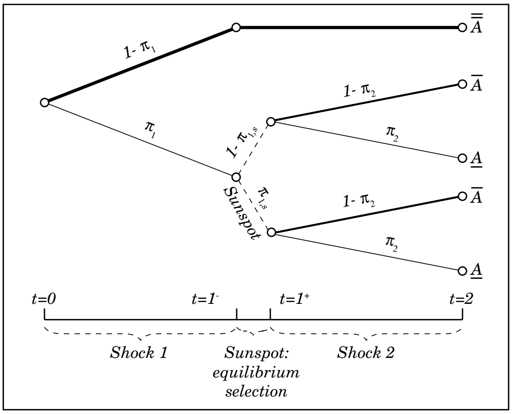
$$\underline{A} < \bar{A} < \bar{\bar{A}}. \tag{1}$$

Uncertainty unfolds over time as depicted in figure 2.

At $t = 1$, either the "worry-free" productivity state $\bar{\bar{A}}$ realizes or an adverse shock occurs with probability π_1. In that case, uncertainty remains and is only resolved at the final date $t = 2$: Productivity will either be $\underline{A} < \bar{A}$ with probability π_2. It turns out that, in the case at $t = 1$ in which uncertainty remains, two subgame equilibria can arise: a fundamental equilibrium and a flight-to-safety equilibrium. We assume that a sunspot arriving with probability $\pi_{1,s}$ selects the flight-to-safety (subgame) equilibrium. Both fundamental shocks and the sunspot shock are assumed to be independent.[4]

4. Note that we introduce the adverse shock at time $t = 1$ only to ensure the adverse scenario is sufficiently unlikely such that the domestic bond enjoys safe-asset status at $t = 0$.

Figure 2. Timeline



Source: Author's elaboration.

1.1.1 Assets

Agents can trade three assets in the economy: physical capital, domestic bonds, and a foreign safe asset, the U.S. dollar. All assets pay off only at $t = 2$ and cannot be sold short.

Real investment. Domestic entrepreneurs have investment opportunities to build physical capital at time $t = 0$. The investment is a constant return to scale, and one unit of capital requires a physical investment of the consumption good at time $t = 0$. Both domestic entrepreneurs and foreign investors can trade physical capital at $t = 0$ and $t = 1$. At $t = 2$, output is produced. Domestic entrepreneurs have projects that pay off $\tilde{A}$ consumption goods per unit of capital, where $\tilde{A}$ is the statedependent productivity at time $t = 2$ specified above. In contrast, foreign investors face lower productivity levels; they produce only a fraction $\eta < 1$ of output $\tilde{A}$ per unit of capital.

Domestic bonds. At time $t = 0$, the government issues zero-coupon domestic bonds with a total face value of B_0, which mature at time $t = 2$. At time $t = 0$, the price is p_0. At time $t = 1$, in the "worry-free" (uneventful) state, i.e., when no adverse shock hits at $t = 1$, the debt price is $p_{1,u}$. After an adverse shock, the fundamental price at $t = 1$ is $p_{1,f}$ and, if a sunspot occurs, the flight-to-safety price at $t = 1$ is denoted by $p_{1,s}$. For convenience, we also use subscripts $\{1,u\}, \{1,f\}, \{1,s\}$ to distinguish various variables across the scenarios in $t = 1$.

Our analysis will show that the domestic bond fully pays off its face value B at $t = 2$, except in the flight-to-safety (subgame) equilibrium. In the flight-to-safety equilibrium, domestic bonds may partially default and only repay a fraction $1-h$ proportion of their face value. That is, a haircut h is subtracted since government tax revenue is not sufficient to fully pay off the debt.

The government can levy a lump-sum tax up to τ fraction of potential output at $t=2$. Specifically, total "fiscal space" is

$$T_2 = \tau \tilde{A} K_1^E , \tag{2}$$

where K_1^E is the capital held by domestic entrepreneurs at the end of $t=1$ and $\tilde{A}$ is the realized productivity at $t=2$. If the collected tax revenue falls short of the bond's face value, the domestic government bond defaults and pays off only partially. For simplicity, we assume that capital that was "fire-sold" to foreign investors is shipped abroad and therefore does not contribute to domestic tax revenue.[5]

U.S. Dollar Treasury. There is an outside storage technology in the form of U.S. Treasuries offering return $R^{\$}$ in every period regardless of the state. That is, U.S. dollar Treasuries are always perfectly safe.

1.1.2 Agents

There are three groups of investors: domestic entrepreneurs, domestic households, and foreign investors. They trade at times $t=0$ and $t=1$.

Domestic entrepreneurs. The continuums of domestic entrepreneurs are risk-neutral and have a time-preference discount factor β:

$$\max \mathbb{E}_0\left[C_0 + \beta C_1 + \beta^2 C_2 \right]. \tag{3}$$

Entrepreneurs have an initial wealth W_0^E at $t=0$ at their disposal and can invest in all three assets.

Importantly, they have to complement physical investment with some safe-asset holdings. Specifically, they have to hold a quantity of safe assets in their portfolio that exceeds a risk measure α times their capital holdings, i.e.,

5. This assumption is innocuous. If the government can also tax output produced with foreign-held capital, one obtains a qualitatively similar outcome.

$$S_t^E \geq \left(\beta^{2-t}\right)\alpha K_t^E, \tag{4}$$

where S_t^E is the market value of holdings of safe assets. This "safe-asset requirement" can be justified simply by bank regulation or as a shield to fend off bank runs.

Our analysis focuses on parameter values for which both the domestic bond and U.S. Treasuries are safe at $t = 0$. Strictly speaking, domestic bonds still have default risk as long as $\pi_{1,s} > 0$, but an asset is considered safe as long as its default risk is negligible. For example, an asset is considered safe as long as its Value at Risk is sufficiently low, where the Value at Risk neglects tail risk that occurs with a probability of less than, say, 1 %.[6]

Domestic households. Households are similar to entrepreneurs. They have the same preferences, but they cannot produce with or hold physical capital. Also, their initial wealth W_0^H at time $t = 0$ is large enough to buy all residual domestic bonds net of demand from entrepreneurs. This allows us to vary the total indebtedness of the country without affecting the initial domestic bond price.

Foreign investors. Foreign investors can buy all three assets. They are also risk-neutral, but less patient than domestic agents. They solve

$$\max \mathbb{E}_0 \left[C_0 + \beta^* C_1 + (\beta^*)^2 C_2\right]. \tag{5}$$

Foreign investors that are potentially invested in the emerging country are less patient than domestic investors. They also find the low U.S. Treasury yield $R^\$$ unattractive, that is,

$$\frac{1}{R^\$} > \beta > \beta^*. \tag{6}$$

Patient home investors value assets more than less patient foreign/international investors. When domestic investors dump assets to foreign investors, a fire-sale discount arises. The dollar is a perfectly safe but unattractive outside option. Its yield is very low since "other investors" that are never active in our emerging economy enjoy some convenience yield from holding the U.S. Treasury.

6. Formally, we can define the safe asset as an asset with default probability lower than threshold. With sufficiently small probability of $\pi_1\pi_{1,s}$, this condition always holds.

Let B_0 be the face value of the domestic bond and B_0^E and B_0^H the part of the face value of the bond held by entrepreneurs and households. The key state variable in our model is the country's debt-to-GDP ratio, which is proportional to the country's indebtedness relative to physical capital. We denote the debt-to-capital ratio with d and the ratio held by entrepreneurs and households by b^E and b^H, respectively. That is,

$$d = \frac{B_0}{K_0}, b^E = \frac{B_0^E}{K_0}, b^H = \frac{B_0^H}{K_0}. \tag{7}$$

Note that

$$d = b^E + b^H, \tag{8}$$

where we refer to the ratio d simply as the total bond level outstanding and b^E and b^H as bond positions held by entrepreneurs and households, respectively.

Assumptions: We make the following parametric assumptions:

1. $\alpha < d < \bar{d} =: \tau\underline{A}, \underline{A} < \bar{A}\dfrac{\eta\beta^*\mathbb{E}_1[A] + (1-\pi_2)\beta^*\alpha}{\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^*\pi_2\dfrac{\alpha}{\tau\underline{A}}}$,

2. $\tau\underline{A} < \dfrac{\beta}{\beta^*}\alpha$,

3. $\beta > \beta^*(1+\alpha)$ *and* $\beta^2\{(1-\pi_1)\bar{\bar{A}} + \pi_1\mathbb{E}_1[A]\} > 1$,

4. $W_0^H > \beta^2(B_0 - \alpha K_0)$,

5. $\dfrac{1}{\eta\beta^*} > \dfrac{\mathbb{E}_1[A] + \alpha\beta R^\$}{\beta^*\eta\mathbb{E}_1[A] + \alpha\beta} > \dfrac{1}{\beta^*}$,

6. $\pi_{1,s} = 0$ (unanticipated crisis),

where $\mathbb{E}_1[A] = \pi_2\underline{A} + (1-\pi_2)\bar{A}$. Assumption 1 guarantees that fire-sales of physical capital are necessary for the domestic bond to partially default. Assumption 2 ensures that there exists $\bar{d}$ such that there are multiple equilibria whenever $d \in [\alpha, \bar{d}]$. Assumption 3 ensures entrepreneurs choose to hold capital with safe assets at $t=0$ instead of selling capital to foreigners, buying U.S. Treasuries, or consuming. Assumption 4 ensures households have enough initial wealth to buy all residual domestic bonds at $t=1$. Assumption 5 concerns the behavior of entrepreneurs in the debt crisis. It posits that entrepreneurs prefer to hold capital with a binding safe-asset constraint to holding price-depressed domestic bonds. Assumption 6 states that the flight-to-safety crisis due to a sunspot occurs with zero probability. This assumption significantly simplifies the analysis but can be relaxed. In appendix A.3 we show that our main results continue to hold for a sufficiently small but strictly positive likelihood of a crisis.

1.2 Equilibrium

This section characterizes the equilibrium allocation and prices for our baseline setting, in which there are no reserve holdings, tranching, or pooling.

Equilibrium at $t=0$. Assumptions 3 and 4 imply that domestic entrepreneurs invest their initial wealth W_0^E in physical capital and hold along with it $\beta^2 \alpha K_0^E$ of the domestic bond at $t=0$ as an accompanying safe-asset investment. Since entrepreneurs perceive little risk in the future, they reduce their low-yielding safe-asset holdings to the minimum given by the safe-asset constraint (4). Formally, entrepreneurs' bond holdings are

$$b^E = \alpha. \tag{9}$$

Meanwhile, the domestic bond, which is not expected to default, carries a price of

$$p_0 = \beta^2. \tag{10}$$

Consequently, the initial physical capital holding is

$$K_0 = K_0^E = \frac{W_0^E}{1 + \alpha\beta^2}. \tag{11}$$

Since initial capital investment is a deterministic function of initial wealth, we will use K_0 instead of initial wealth W_0 as the key exogenous parameter hereafter. Alternatively, capital K_0 could be viewed as an initial endowment.

Domestic households buy the remaining supply of the domestic bond and plan to hold it until maturity. They consume the rest of their wealth, since U.S. Treasuries are unattractive as a saving vehicle. To ensure that domestic households are indifferent between consuming at $t=0$ and buying a domestic bond and consuming in $t=2$, the equilibrium return of the domestic bond over two periods is $\frac{1}{\beta^2}$. Hence,

$$p_0 B_0^E = \alpha\beta^2 K_0^E. \tag{12}$$

The following proposition summaries our results for time $t=0$.

Proposition 1. *The time $t=0$ equilibrium allocation is*

$$\begin{array}{lll} K_0^E = K_0, & K_0^H = 0,\ K_0^* = 0, & \\ B_0^E = b^E K_0, & B_0^H = B_0 - b^E K_0, & B_0^* = 0, \\ \$_0^E = 0, & \$_0^H = 0, & \$_0^* = 0. \end{array} \tag{13}$$

Debt ratios are

$$b^E = \alpha,\ b^H = d - \alpha. \tag{14}$$

The equilibrium domestic bond price is $p_0 = \beta^2$.

Next, we analyze three subgame equilibria: First, the subgame at $t=1$ when no initial adverse shock, i.e., $A = \bar{A}$, realizes. After an adverse shock, the expected total factor productivity (TFP) is $\mathbb{E}[A]$, and either a fundamental equilibrium or a sunspot equilibrium with flight to safety can arise.

$\bar{A}$-Subgame Equilibrium at $t=1$. If at $t=1$ no adverse shock occurred, the economy's fundamentals are sufficiently positive to rule out any crisis. In this subgame, capital and domestic bonds have the same return $\frac{1}{\beta}$. Domestic agents will be indifferent between holding the asset and consuming. Foreign investors strictly prefer not to buy any assets. Proposition 2 summarizes the result.[7]

7. Note that there are also other (subgame) equilibria with the same allocation but different equilibrium prices. For example, any capital price $\eta\beta^* A < q_{1,u} < \beta A$ would be a valid equilibrium price. In these equilibria, domestic entrepreneurs prefer to invest in projects, but are wealth-constrained. This equilibrium price indeterminacy is innocuous to our result.

Proposition 2. *($\overline{\overline{A}}$-Equilibrium at $t=1$) Absent an adverse shock, the allocation remains unchanged compared to $t=0$. The price of capital changes to*

$$q_{1,u} = \beta\overline{\overline{A}}. \tag{15}$$

The price of domestic bonds changes to

$$p_{1,u} = \beta \tag{16}$$

due to time discounting.

After an initial adverse shock, two possible subgame equilibria can emerge: a fundamental equilibrium and a self-fulfilling flight-to-safety equilibrium with (partial) default. If no sunspot occurs, the subgame ends up in the "fundamental equilibrium" at $t=1$.

Fundamental $\mathbb{E}1[A]$-Equilibrium at $t=1$. The fundamental equilibrium resembles the $\overline{\overline{A}}$-equilibrium and results in the same allocation. Also, the domestic bond and dollar bond are default-free. Only the economic fundamentals are worse, since expected productivity is $\mathbb{E}1[A]$ instead of $\overline{\overline{A}}$. Proposition 3 characterizes the fundamental (subgame) equilibrium.[8]

Proposition 3 (Fundamental equilibrium at $t=1$)**.** *After an adverse $t=1$ shock, a (default-free) fundamental equilibrium exists for debt levels $d \in [\alpha,\tau]\underline{A}$. The equilibrium allocation remains unchanged compared to $t=0$ while equilibrium prices adjust to*

$$q_{1,f} = \beta\, \mathbb{E}1[A], \tag{17}$$

and

$$p_{1,f} = \beta. \tag{18}$$

Flight-to-Safety Equilibrium at $t=1$. For a high enough debt level, there also exists a flight-to-safety equilibrium after a negative shock at $t=1$. The domestic bond partially defaults and hence loses its safe-asset status. As a consequence, only U.S. Treasuries remain as safe assets. Domestic entrepreneurs fire-sell their domestic bonds

8. Similar to the $\overline{\overline{A}}$-Subgame Equilibrium, there is an indeterminacy in equilibrium prices, which is irrelevant to our results.

and scale back their physical capital holdings as well. This lowers total output and tax revenue, which in turn is the cause of the partial default. As foreigners become the marginal investors in physical capital and domestic bonds, their prices drop to

$$q1,s = \beta^{*}\eta E1[A], \tag{19}$$

$$p1,s = \beta^{*}(1-\pi_2 h). \tag{20}$$

Recall that foreigners are less patient ($\beta^{*}<\beta$) and less productive at operating physical capital by a factor η.

Since holding the dollar bond yields a low return, domestic entrepreneurs hold just enough dollars to satisfy the safe-asset constraint $S_1 \geq \alpha\beta K_1^E$. That is, for each unit of capital, the entrepreneur must spend $q_{1,s}$ for capital plus $\alpha\beta$ on U.S. Treasuries. With a net worth of $q_{1,s}K_0+p_{1,s}B_0$ in crisis times, the entrepreneur can only hold capital

$$K_{1,s}^{E} = \frac{q_{1,s}K_0 + p_{1,s}B_0}{q_{1,s} + \alpha\beta} = \frac{\beta^{*}\eta\mathbb{E}_1\left[A\right] + \beta^{*}\left(1-\pi_2 h\right)b^{E}}{\beta^{*}\eta\mathbb{E}_1\left[A\right] + \alpha\beta} K_0 . \tag{21}$$

Due to the flight to safety, the capital holdings of entrepreneurs are linearly decreasing in entrepreneurs' expectations of the haircut h. Recall that the government only collects tax revenue proportional to entrepreneurs' capital holdings. The tax revenue in the lowest productivity state ($\tilde{A}=\underline{A}$) thus is also decreasing in h:

$$T\left(h\right) = \tau\underline{A}K_{1,s}^{E}\left(h\right) / K_0 . \tag{22}$$

Figure 3 illustrates how the domestic bond haircut h is determined in equilibrium. The black dot is the fundamental $\mathbb{E}1[A]$ equilibrium. Since the minimal tax revenue $\tau\underline{A}$ is larger than the required debt repayment d, the domestic bond remains safe, i.e., $h=0$.

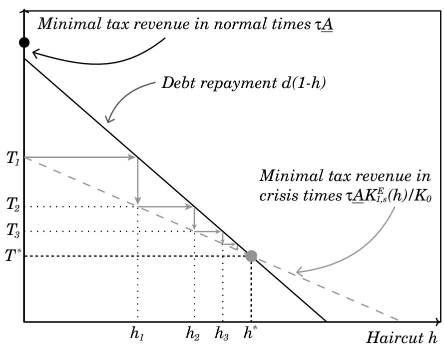
There is another possibility, namely, the flight-to-safety equilibrium denoted by the grey dot. The black line plots the government's debt repayment after a partial default, $d(1-h)$. The dashed line plots tax revenue $T(h)$ against the haircut. The equilibrium haircut level h^{*} can be seen as a result of a vicious loop between tax revenue and the debt haircut. This loop occurs in four steps:

1. With the possibility of any haircut $h > 0$, domestic bonds become unsafe. Entrepreneurs then no longer have a reason to hold them and sell them off to impatient domestic investors, who value them less (at price $\frac{1}{\beta^*}(1\text{–h})$).
2. Entrepreneurs take losses on their domestic bond positions and are forced to sell capital.
3. Tax revenue declines and the government faces a shortfall on its debt repayment.
4. The expected haircut on government debt increases, after which the loop restarts from step (2).

In figure 3, the revenue shortfall after the initial fire-sale of capital (when the debt is considered unsafe but the perceived haircut is near zero) is the distance between the black line and the point $(0, T_1)$. Once investors realize the government will not be able to repay its debt, the perceived haircut is updated to h_1. Then entrepreneurs take further losses and sell more capital, which decreases revenues to T_2, and so forth. This continues until the haircut reaches h^* such that

$$d(1-h^*) = T(h^*). \tag{23}$$

Figure 3. Determination of Domestic Bond Haircut *h*



Source: Author's elaboration.

Proposition 4 (Flight-to-safety equilibrium at $t=1$)**.** *The flight-to-safety equilibrium at $t=1$ exists only if $d \in [\max\{\underline{d}, \alpha\}, \tau\underline{A}]$ ($\underline{d}$ defined below). In this equilibrium the domestic bond loses its safe-asset status, and entrepreneurs fire-sell the domestic bond and physical capital to foreign investors, thus causing a loss of output and with it a decline in tax revenues, which, in turn, causes the partial default of the domestic bond. The equilibrium allocation is*

$$K_{1,s}^{E} = \frac{\eta\beta^{*}\mathbb{E}_1[A] + (1-\pi_2)\beta^{*}b^{E}}{\eta\beta^{*}\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^{*}\pi_2 \dfrac{b^{E}}{b^{E}+b^{H}}} K_0, \quad K_{1,s}^{H} = 0, \quad K_{1,s}^{*} = K_0 - K_{1,s}^{E}$$

$$B_{1,s}^{E} = 0, \quad B_{1,s}^{H} = B_0 - \alpha K_0, \quad B_{1,s}^{*} = \alpha K_0,$$

$$\$_{1,s}^{E} = \beta\alpha \frac{\eta\beta^{*}\mathbb{E}_1[A] + (1-\pi_2)\beta^{*}b^{E}}{\eta\beta^{*}\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^{*}\pi_2 \dfrac{b^{E}}{b^{E}+b^{H}}} K_0, \quad \$_{1,s}^{H} = 0, \quad \$_{1,s}^{*} = 0. \tag{24}$$

with $b^E=\alpha$, $b^H=d-\alpha$. Foreign investors are the marginal holders of both capital and domestic bonds and hence the asset prices are

$$q1,s=\beta^{*}\eta\ [A], \tag{25}$$

$$p_{1,s}=\beta^{*}(1-\pi_2 h), \tag{26}$$

with a haircut of domestic bonds

$$\begin{aligned} h\left(b^{E}, b^{H}\right) &= 1 - \frac{\tau\underline{A}}{b^{E}+b^{H}} \frac{K_{1,s}^{E}}{K_0} \\ &= 1 - \tau\underline{A} \frac{\eta\beta^{*}\mathbb{E}_1[A] + (1-\pi_2)\beta^{*}b^{E}}{\left(b^{E}+b^{H}\right)\left(\eta\beta^{*}\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^{*}\pi_2 b^{E}} \end{aligned} \tag{27}$$

The minimal debt level for the flight-to-safety crisis $\underline{d}$ is

$$\underline{d} = \tau\underline{A} \frac{\beta^{*}\eta\mathbb{E}_1[A] + \beta^{*}\alpha}{\beta^{*}\eta\mathbb{E}_1[A] + \beta\alpha}. \tag{28}$$

Equation (27) reveals that the haircut is decreasing with $K^E_{1,s}K_0$, the fraction of physical capital that entrepreneurs can retain after their fire-sales.

1.3 Crisis Vulnerability and Severity

We evaluate various domestic bond market settings based on two criteria: (i) the vulnerability of the economy to a crisis and (ii) the severity of the crisis.

Definition. For an emerging economy parameterized by x,
(i) the **crisis vulnerability region** is the set of debt-to-capital ratios d defined as

$$\mathrm{V}(x) = [\alpha, \tau\underline{A}] \cap \{d \mid \text{A flight-to-safety equilibrium exists}\}, \tag{29}$$

(ii) the **crisis severity** $S(d,x)$ is defined as the fraction of physical capital that has to be fire-sold, i.e.,

$$S(d,x) \equiv 1 - \frac{K^E_{1,s}(d,x)}{K_0}. \tag{30}$$

Note that, in our model, alternative measures of crisis severity such as total debt losses $(b^E + b^H)h = dh$ or output losses $\underline{A}\left(1 - \frac{K^E_{1,s}}{K_0}\right)$ all map one-to-one to our measure S, which is based on the fraction of fire-sold capital.

As a benchmark, proposition 5 derives the crisis vulnerability region and severity denoted with a superscript B for baseline setting.

Proposition 5.
(i) The crisis vulnerability region is $\mathrm{V}^B = [\max\{\underline{d}, \alpha\}, \tau\underline{A}]$, *and*
(ii) the crisis severity in the baseline model is

$$S^B(d) = \max\left\{0, \frac{\eta\beta^*\mathbb{E}_1[A] + (1-\pi_2)\beta^*\alpha}{\eta\beta^*\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^*\pi_2\dfrac{\alpha}{d}}\right\}. \tag{31}$$

The following sections show that central bank reserve holdings, tranching, and pooling and tranching alter the crisis vulnerability region as well as the severity of the crisis.

2. Reserve Holdings: The "Buffer Approach"

Financial crises associated with flight-to-safety capital flows have historically led to large economic dislocations and social hardship. The Southeast Asia crisis of 1997 and the Euro crisis beginning in 2008 are two prominent examples of crises in which flight to safety played a significant role. Especially after the Southeast Asia crisis, many emerging economies in Asia decided to accumulate large holdings of foreign reserves as a precautionary measure. By 2018, these holdings amounted to 6.45 trillion dollars, of which 3.42 trillion are held by China.[9] Emerging economies try to fend off crises, but also to mitigate the consequences of cross-border flight-to-safety capital flows. This section analyzes the implications of holding safe assets in the form of foreign reserves as a precautionary measure. Specifically, we examine, within our model, how U.S. Treasury holdings funded by the issuance of extra domestic bonds affect equilibrium outcomes. Interestingly, we find that foreign reserve holdings do not necessarily reduce the likelihood of a crisis, but they do make the crisis less severe when it occurs.

2.1 Model Setup with Official U.S. Treasury Holdings

We generalize our baseline model by allowing the government to raise some additional funds. It can now issue additional domestic bonds at $t=0$ and promise to repay an additional $b^R K_0$ at $t=2$. Since households have sufficient wealth at $t=0$, they cut back their $t=0$ consumption as long as the bond yields a (gross) interest rate of $1/\beta$. The government invests the proceeds of $(1/\beta)^2 b^R K_0$ into U.S. Treasuries yielding $R^\$$ per period. That is, reserve holdings come with a cost of carry of $(1-(\beta R^\$)^2)$. Total debt is now $d=b^E+b^H+b^R$, where b^E is held by entrepreneurs and b^H+b^R by domestic households.

2.2 Equilibria

Fundamental Equilibrium. Absent any flight to safety, the equilibrium allocation and prices are essentially the same as in the baseline model, but with an important difference: the cost of carry of

9. The source is IMF data template on International Reserves and Foreign Currency Liquidity (IRFCL). See http://www.imf.org/external/np/sta/ir/IRProcessWeb/index.aspx.

U.S. Treasuries funded by issuing extra domestic bonds reduces the government's "fiscal space," as part of the tax revenue has to be used to finance the extra carry costs. This additional fiscal burden lowers the maximal sustainable debt level. Moreover, domestic households consume less in $t=0$ and hold a larger amount of the domestic bond.

Proposition 6. *The (non-flight-to-safety) fundamental equilibrium with a reserve policy* b^R *exists if and only if* $d \in [\alpha, \tau\underline{A} - (1-(\beta R^{\$})^2)b^R]$, *i.e., the maximal sustainable debt level is lower than the one in the baseline model. Households' domestic bond holdings increase to* $(b^R+b_0-\alpha)K_0$, *and*

(i) at $t=0$ *the allocation and prices are as in proposition 1,*
(ii) at $t=1$ *after a positive shock, the* $\overline{A}$*-equilibrium is as in proposition 2,*
(iii) at $t=1$ *after a negative shock, the fundamental* $\mathbb{E}_1[A]$*-equilibrium is as in proposition 3.*

Flight-to-Safety (Subgame) Equilibrium at $t=1$**.** Reserve holdings help to mitigate the flight-to-safety crisis. As before, in a flight-to-safety equilibrium, domestic entrepreneurs sell off domestic bond holdings and reduce their physical capital to

$$K_{1,s}^E = \frac{q_{1,s}K_0 + p_{1,s}^s B_0^E}{q_{1,s} + \alpha\beta} = \frac{\beta^*\eta\mathbb{E}_1[A] + \beta^*\left(1-\pi_2 h^R\right)b^E}{\beta^*\eta\mathbb{E}_1[A] + \alpha\beta} K_0, \tag{32}$$

where h^R denotes the haircut for the case with government reserve holdings. The government budget constraint in the low fundamental state (when $\underline{A}$ realizes in $t=2$) now generalizes to

$$(b^E + b^H + b^R)(1-h^R) = \tau\underline{A}(K_{(1,s)}^E)/K_0 + b^R(\beta R^{\$})^2, \tag{33}$$

$$\Leftrightarrow \left(b^E + b^H\right)\left(1-h^R\right) - b^R h^R = \tau\underline{A}\frac{K_{1,s}^E}{K_0} + b^R\left[1-\left(\beta R^{\$}\right)\right]^2,$$

where the second equation simply rearranges terms such that the left-hand side reflects the government's repayment after debt restructuring in the baseline model minus the debt reduction that arises from partial default on the extra debt raised for reserve holdings, and the right-hand side reflects tax revenue minus the cost of carry. Next, we modify figure 3 to be the new figure 4. The debt repayment after restructuring is reduced by $b^R h^R$, i.e., the slope of the black solid line becomes more negative compared to the baseline model. The grey dashed line reflects the minimum tax revenue in crisis time, which now has to be further reduced by the cost of carry $b^R[1-(\beta R^{\$})^2]$, hence the parallel shift in the light grey line.

The fact that the fundamental equilibrium (grey dot in figure 4) is now closer to the black debt-repayment line reflects the fact that the cost of carry reduces the sustainable debt level.

Formally, Equations (32) and (33) lead to an endogenous haircut with reserve holdings of

$$h^R\left(b^E,b^H,b^R\right)= \tag{34}$$
$$1-\tau\underline{A}\frac{\eta\beta^*\mathbb{E}_1\left[A\right]+\left(1-\pi_2\right)\beta^*b^E+b^R\frac{\left(\beta R^{\$}\right)^2}{\tau\underline{A}}\left(\beta^*\eta\mathbb{E}_1\left[A\right]+\alpha\beta\right)}{\left(b^E+b^H+b^R\right)\left(\eta\beta^*\mathbb{E}_1\left[A\right]+\alpha\beta\right)-\tau\underline{A}\beta^*\pi_2 b^E}.$$

Note that the new haircut h^R is only lower than the one in the baseline model h if the latter exceeds the cost of carry. In this case, the benefit from haircut reduction outweighs the extra cost of carry.

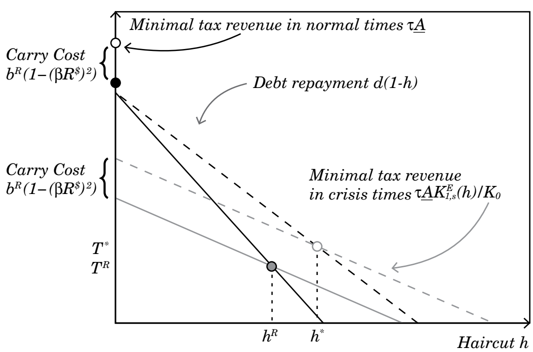
Lemma 1. *If equilibrium haircuts absent reserve holdings are sufficiently large, then reserve holdings reduce the haircut in case of a flight-to-safety crisis. Formally,*

(i) $h^R(b^E,b^H,b^R)<h(b^E,b^H) \quad \Leftrightarrow h(b^E,b^H)>1-(\beta R^{\$})^2.$

(ii) $h^R(b^E,b^H,b^R)$ *is decreasing in* $b^R \quad \Leftrightarrow h(b^E,b^H)>1-(\beta R^{\$})^2.$

We defer to the appendix the full characterization of the flight-to-safety (subgame) equilibrium at $t=1$, as it does not add much economic insight beyond that discussed above.

Figure 4. Determination of Domestic Bond Haircut *h*



Source: Author's elaboration.

2.3 Crisis Vulnerability and Severity with Reserves

Interestingly, the cost of carry of foreign reserve holdings makes the economy *more* vulnerable to a flight-to-safety crisis. Importantly, however, the severity of the crisis is lower if the haircut exceeds the cost of carry. Proposition 7, which follows directly from lemma 1, states these results formally.

Proposition 7. *Reserve holdings b^R lead to*

(i) a vulnerability region that is at least as large as in the baseline model due to reserves' cost of carry,

$$V^R\left(b^R\right) \supset V^B = [max\{\underline{d}, \alpha\}, \tau\underline{A}]. \tag{35}$$

(ii) a reduced crisis severity compared to the baseline model if and only if the haircut in the baseline model is greater than the cost of carry $1-(\beta R^{\$})^2$,

$$S^R\left(d, b^R\right) \leq S^B\left(d\right) \Leftrightarrow h \geq 1-\left(\beta R^{\$}\right)^2 \tag{36}$$

The fact that the reserve holdings b^R reduce the severity of the flight-to-safety crisis raises the question of why individual households do not hold U.S. Treasuries on their own. Why does it require a government intervention to hold reserves? Recall that the U.S. Treasury's yield is very low compared to the expected yield of the (safe, but ultimately tail-risk afflicted) domestic bond. This makes individual investors reluctant to hold U.S. Treasuries despite their awareness that the total holding of U.S. Treasuries reduces the severity of a possible flight-to-safety crisis. Each household prefers to free-ride on other households' U.S. Treasury holdings. Individually, they do not internalize the positive externality that reserve holdings would have on the whole economy.[10]

3. Tranching

Instead of building up reserves, a country could split its debt into a senior and a junior bond. While it might be legally difficult for a country to commit to a specific seniority structure, it is always possible for an

10. In a more general model, households might even want to undo government reserve holdings by taking on a carry trade that shorts the low-yielding U.S. Treasury and investing in the higher-yielding domestic government bond.

international private-sector bank to set up special purpose vehicles (SPV) that purchases some of a country's government bond and issues a senior and a junior bond. The issued securities are referred to as sovereign bond-backed securities (SBBS). Any losses due to partial default are then first absorbed by the junior bond. Only after the junior bond is fully wiped out does the senior bond begin to take losses. It is easy to see that the senior bond (with a yield higher than that of the U.S. Treasury) is much less likely to lose its safe-asset status. Hence, domestic entrepreneurs, who hold the senior bond as a safe asset, do not have to fire-sell any bond or any physical capital. They can keep operating at full capacity and consequently tax revenues will be high enough to fully pay off not only the senior bond but even the junior bond as well. Our main result in this section is that the government's debt capacity with tranching is the same as if the country had only senior bonds outstanding.

3.1 Model Setup with Tranching of Domestic Bonds

In a setting with tranching, we maintain the assumptions of the baseline model of section 1. For simplicity, we switch off the reserve holdings, i.e., $b^R=0$. We denote the (total) face value of the senior bond by $B_0^S=sK_0$ in total and hence the junior bond's face value is $B_0^J=B_0-sK_0=(d-s)K_0$. We assume there is a sufficient amount of the senior bond outstanding such that entrepreneurs can fully satisfy their safe-asset requirement, i.e., $s\geq\alpha$, and focus on the case in which the entrepreneurs only hold senior debt at time $t=0$. For convenience, we use the capital letters S and J as superscripts for variables related to the senior and junior bonds, respectively. For example, the debt holdings (relative to K_0) of entrepreneurs and households are $b^{S,E}$, $b^{S,H}$, $b^{J,E}$, $b^{J,H}$.

3.2 Equilibria Outcomes with Tranching

Tranching makes the senior bond a much more stable asset. Since it is protected by the junior bond, it is much less likely to default and, if it does so, the haircut h^S is smaller.

Allocation and fundamental equilibrium. At time $t=0$, the fundamental equilibrium allocation is the same as in the baseline model. We only have to adjust households' and entrepreneurs' bond holdings. Note that with unanticipated sunspots ($\pi_{1,s}=0$), investors consider the senior and junior bonds as perfect substitutes. We assume that entrepreneurs have a slight preference for the senior bond at time $t=0$.[11] The remaining senior bonds and all junior bonds are purchased by households. Formally, the fundamental equilibrium is summarized by the following proposition.

Proposition 8. *The (non-flight-to-safety) equilibrium with tranching features a debt capacity as if only senior bonds were outstanding and*

(i) at $t=0$ the allocation and prices $\underline{\underline{are}}$ as in proposition 1,

(ii) at $t=1$ after a positive shock, the $\overline{A}$-equilibrium allocation is as in proposition 2,

(iii) at $t=1$ after a negative shock, the fundamental $\mathbb{E}_1[A]$-equilibrium is as in proposition 3, while debt holdings and prices with tranching are

$$B_{1,f}^{S,E}=b^{S,E}B_0, \qquad B_{1,f}^{S,H}=sK_0-b^{S,E}K_0, \qquad B_{1,f}^{S,*}=0, \tag{37}$$
$$B_{1,f}^{J,E}=0, \qquad B_{1,f}^{J,H}=B_0-sK_0, \qquad B_{1,f}^{J,*}=0.$$

with $b^{S,E}$. Bond prices are

$$p_t^S=\beta^{2-t}, \quad p_t^J=\beta^{2-t}, \quad t\in\{0,1\}. \tag{38}$$

Flight-to-safety (subgame) equilibrium at $t=1$. Despite the fact that the senior bond, the safe asset supplied by the emerging market economy in this section, is protected by the junior bond, it might still be subject to default and suffer a haircut of h^S. In this (more extreme) case, entrepreneurs fire-sell physical capital and senior bonds to foreign investors, who have a lower discount factor β^*. The senior bond price is then given by

$$p_{1,s}^S=\beta^*\left(1-\pi_2 h^S\right). \tag{39}$$

Since this will only happen if junior bonds are completely wiped out, the government only repays senior bonds partially. The government budget constraint in the lowest productivity state, $\underline{A}$, is then

$$sK_0\left(1-h^S\right)=\tau\underline{A}K_{1,s}^E. \tag{40}$$

11. In the more general case with positive sunspot probability, entrepreneurs strictly prefer senior bonds. As one lets the sunspot probability $\pi_{1,s}$ go to zero, entrepreneurs maintain this preference. In short, our assumption would be the natural outcome of a refinement argument.

Note that, compared to equation (23) in the baseline model, we now have sK_0 instead of dK_0.

The share of physical capital retained by the domestic entrepreneurs is

$$K_{1,s}^{E} = \frac{q_{1,s}K_0 + p_{1,s}^{s}B_0^{S,E}}{q_{1,s} + \alpha\beta} = \frac{\beta^{*}\eta\mathbb{E}_1\left[A\right] + \beta^{*}\left(1 - \pi_2 h^{S}\right)b^{S,E}}{\beta^{*}\eta\mathbb{E}_1\left[A\right] + \alpha\beta}K_0\,, \tag{41}$$

which differs from equation (21) in the baseline model: now we have a smaller haircut h^S on the senior bond and b^E is replaced by $b^{S,E}$. In fact, the debt haircut function h^S is

$$h^S(b^{S,E}, b^{S,H}, b^{J,H}) = h^S(b^{S,E}, b^{S,H}) = h(b^{S,E}, b^{S,H}), \tag{42}$$

that is, the senior bond's haircut depends only on senior bond holdings. This observation leads to the following proposition:

Proposition 9. *For $\alpha < s < d < \tau\underline{A}$, after an adverse shock at $t = 1$ a flight-to-safety equilibrium can exist. The equilibrium allocation and senior bond price are as in the baseline flight-to-safety equilibrium of proposition 4 after replacing the total debt d with only the senior debt s. The junior bonds are held by households and foreigners with a flight-to-safety price*

$$p_{(1,s)}^{J} = \beta^{*}(1 - \pi_2). \tag{43}$$

Proposition 9 states that the flight-to-safety equilibrium with tranching is almost as if junior bonds do not exist. To understand the intuition, recall that in times of crisis the entrepreneurs sell capital and domestic bonds to gain enough liquidity to buy safe assets. Domestic bonds have two roles. First, domestic bonds are quasi-safe assets backed by the government's fiscal capacity. At $t = 1$ they might lose their safe-asset status. Second, the domestic bond also serves as a liquid asset at $t = 1$ that can be counted on even when the only remaining safe asset is the U.S. Treasury. In other words, even when the price of the senior bond is somewhat depressed, it can still be sold and transformed into U.S. Treasury holdings. The junior bond plays neither role in the flight-to-safety equilibrium.

Note also that entrepreneurs only hold senior bonds, the amount of junior bonds is irrelevant for the liquidity entrepreneurs receive when they fire-sale bonds. In sum, junior bonds neither act as a fiscal burden *ex-post* at $t=2$ nor provide liquidity in the interim period $t=1$. As a result, they play no role in the fire-sale of capital and, consequently, in most aspects of the equilibrium. We relegate to the appendix a full characterization of equilibrium, including the more general case with a strictly positive sunspot probability.

3.3 Crisis Vulnerability and Severity with Tranching

The next proposition follows directly from proposition 9.

Proposition 10.

1. *With tranching into a senior and junior bond,*

(i) *if* $\alpha \leq \underline{d}$*, the optimal tranching policy is* $s \in [\alpha, \underline{d}]$*. The crisis region is empty following optimal tranching policy.*

(ii) *if* $\alpha > \underline{d}$*, the optimal tranching policy is* $s = b = \alpha$*, for which the crisis vulnerability region is*

$$V^T(s) = [\alpha, \tau \underline{A}], \tag{44}$$

2. *The crisis severity* $S^T(d,s)$ *is as if the senior s is the only debt in the baseline model,*

$$S^T(d,s) = S^B(s) \leq S^B(d). \tag{45}$$

Tranching can either completely eliminate crises or mitigate the magnitude of the flight to safety. Interestingly, higher total outstanding debt does not make the economy more crisis-prone as long as the additional debt is financed with the junior bond. This is the case, since the junior bond can be wiped out without adverse consequences. The junior bond provides a cushion and ensures that the senior bond maintains its safe-asset status. As a result, tranching shrinks the crisis vulnerability region. Moreover, even if a flight to safety occurs nevertheless, the haircut of the senior bond is significantly smaller, as the junior bond is fully wiped out first. This feature reduces the fire-sale of physical capital and stabilizes the overall economy.

Finally, note that $s = b^{S,E} = \alpha$ is the best tranching policy among all the possible ones. Setting $s = \alpha$ as the tranching point (subordination level) maximizes the size of the loss-absorbing cushion provided by the junior bond, while ensuring that entrepreneurs' total demand, α, for safe assets is met by the senior bond supply.

4. Pooling and Tranching

So far, we have focused on a single country. Next, we turn to an international setting with many countries to show that pooling several countries' government bonds and subsequently tranching the pool can lead to an even better outcome. The pooling and tranching can be done by an international bank setting up an SPV, acquiring government bonds from several countries (weighted according to relative GDP), and issuing a senior and a junior bond.

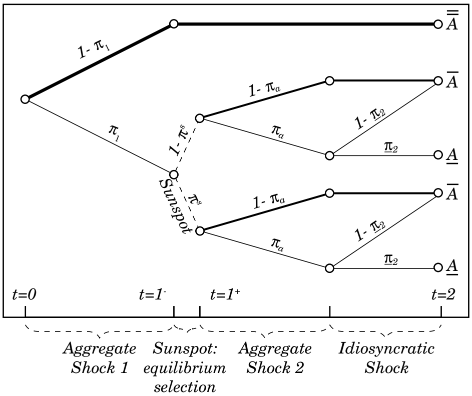
4.1 Model Setup with Pooling and Tranching

To study pooling and tranching, we generalize our baseline framework to a setting with a continuum of *ex-ante* identical countries indexed by m. The environment within each country is the same as in the baseline framework. However, we modify the structure of shocks: (i) sunspot shocks are perfectly correlated across countries, while (ii) productivity A-shocks are imperfectly correlated. The fundamental productivity shock at $t=1$ is assumed to be perfectly correlated and occurs with probability π_1. After an adverse shock, the productivity shock at $t=2$ follows in two waves. The first wave at $t=2$ is an aggregate shock and hits all countries the same way with probability π_2^a. Meanwhile, the second wave is purely idiosyncratic across countries occurring with probability π_2^i. If the aggregate shock is not realized, no further idiosyncratic shock happens and all countries enjoy a productivity level of $\overline{A}$. The details of the shock structure are depicted in figure 5. We assume emerging economies do not trade with each other. Within each country, three groups of agents trade with each other at the beginning of time $t=0$ and time $t=1$.

4.2 Crisis Vulnerability and Severity with Tranching and Pooling

Combining pooling and tranching does make a difference. The economic intuition is that combining both policy tools exploits the fact that *ex-post* there is only a fraction of countries that truly default. In this case, we need a much smaller cushion to ensure the safety of senior bonds. We retain earlier superscripts S and J for the two classes of bonds. Let *GloSBies* be the superscript for this global safe-asset policy. Recall $\underline{d}$ defined in equation (28) is the threshold of the crisis vulnerability region in the baseline model.

Figure 5. Timeline for Pooling Case



Source: Author's elaboration.

Proposition 11. *Combining pooling and tranching yields the following:*

1. *With tranching into a senior and junior bond,*[12]

(i) *If* $\alpha \leq (1-\pi_2^i)d + \pi_2^i \underline{d}$, *the optimal tranching policy is* $s \in [\alpha,(1-\pi_2^i)d + \pi_2^i \underline{d}]$ *and the crisis vulnerability is eliminated.*

(ii) *If* $\alpha > (1-\pi_2^i)d + \pi_2^i \underline{d}$, *the optimal tranching policy is* $s = b^{S,E} = \alpha$ and *the economy is still vulnerable to a less severe crisis.*

2. *Whenever a crisis exists after adopting any tranching policy s, the crisis severity* $S^{GloSBies}(d,s)$ *is*

$$S^{GloSBies}(d,s) = S^B(s) - \frac{\beta^* \pi_2^a \alpha d\left(1-\pi_2^i\right)}{\left(\beta^* \eta \mathbb{E}_1[A] + \alpha\beta\right)s - \beta^* \pi_2^a \pi_2^i \tau \underline{A}\alpha} \leq S^B(s) \leq S^B(d), \quad (46)$$

where $S^B(\cdot)$ *is defined in equation (31) with .*

Notice that, with pooling, the tranching-only threshold for the vulnerability region $\underline{d}$ is replaced by $(1-\pi_2^i)d + \pi_2^i \underline{d}$. Recall that without

12. In the appendix, we also show the vulnerability region is

$$V^{GloSBies}(s) = \left[\max\{\alpha, \underline{d}\}, \min\left\{\frac{s-\pi_2^i \underline{d}}{1-\pi_2^i}\tau\underline{A}\right\}\right], \qquad d \geq s \geq \alpha .$$

We find such a measure is less intuitive for comparison purposes, since the crisis existence condition $\alpha \leq \left(1-\pi_2^i\right)d + \pi_2^i \underline{d}$ is better described in the two-dimensional (s,d) space. In contrast, crisis region is defined as the set of possible d for a fixed policy s.

pooling, the relevant condition to eliminate the crisis vulnerability was $\alpha \leq \underline{d}$ (proposition 10), and for $d \leq \underline{d}$ there was no crisis vulnerability even in the benchmark economy (section 1.3). In the nontrivial case $d \geq \underline{d}$, pooling yields a relaxed condition compared to the tranching-only case. The intuition for this is straightforward: to avoid a flight to safety, we need to guarantee a sufficient supply of safe assets α even during a crisis. A fraction $(1-\pi_2^i)$ of countries that do not default repay their full debt of d, while a fraction π_2^i of countries defaulting in a crisis repay only $\underline{d}$, the amount of tax revenue the governments in these countries can collect. Combining both improves their capacity to back safe assets. Given a total demand α of safe assets, the required supply of safe assets is

$$\left(1-\pi_2^i\right) \underbrace{d}_{\substack{\text{repayment of} \\ \text{default-free countries}}} + \pi_2^i \underbrace{\underline{d}}_{\substack{\text{repayment of} \\ \text{default countries}}} \geq \alpha \tag{47}$$

Notice that the global safe-asset policy precisely exploits the fact that *ex-post* some country will be safe and thus a good supplier of safe assets. The same intuition extends to the case when a crisis does occur. The sovereign bonds that do not default provide a good source of liquidity. Entrepreneurs can sell these sovereign bonds in exchange for dollars at a favorable price. Consequently, entrepreneurs need to sell less capital and the severity of the crisis is mitigated.

5. Conclusion

Flight to safety is a major contributor to financial crises. This paper sets up a simple three-period model in which entrepreneurs hold a safe asset in addition to physical capital. When the domestic government bond loses its safe-asset status, domestic entrepreneurs shed it and replace it with U.S. Treasuries. The resulting losses force entrepreneurs to also reduce their productive capital holdings. The associated loss in aggregate output and tax revenue makes a default in government bonds likely, which justifies the initial loss of the safe-asset status.

The current global financial architecture relies on a "buffer approach" to avoid cross-border flight-to-safety capital flows. The most prominent such method is self-insurance via a buildup of precautionary foreign reserves, to a large extent in the form of U.S. Treasury holdings.

This is, however, costly as they yield a lower interest rate compared to the domestic government bond. These extra costs do not make crises less likely, but they do significantly reduce their severity.

This paper argues in favor of a "rechanneling approach," which is less costly and self-stabilizing. This approach requires a global safe asset that is symmetrically supplied, including by emerging economies. Sovereign bond-backed securities could be such a global safe asset. While the sovereign bond of an emerging economy might lose its safe-asset status after an adverse shock, a senior bond that is backed by several sovereign bonds does not. Hence, flight-to-safety capital flows do not have to leave the country. By pooling many sovereign bonds and tranching the pool, governments can exploit diversification benefits and increase the size of the senior tranche, thereby increasing the total quantity of safe assets (GloSBSies) supplied by and for emerging economies.

APPENDIX

A.1 Detail on the Flight-to-Safety Equilibrium under Different Policies

Proposition A.1 characterizes the flight-to-safety equilibrium with reserves policy.

Proposition A.1. *(Assume unexpected crisis) The flight-to-safety equilibrium at $t=1$ exists if and only if $d \in [\max\{\underline{d}^R(b^R), \alpha\}, \tau\underline{A}]$. The minimal threshold for total debt level $\underline{d}^R(b^R)$ is defined as*

$$h^R(\alpha, \underline{d}^R - \alpha, b^R) = 0. \tag{48}$$

The equilibrium allocation is

$$K^E_{1,s} = \frac{\eta\beta^*\mathbb{E}_1[A] + (1-\pi_2)\beta^* b^E + b^R \frac{(\beta R^\$)^2}{\tau\underline{A}}(\beta^*\eta\mathbb{E}_1[A] + \alpha\beta)}{\eta\beta^*\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^*\pi_2 \frac{b^E}{b^E + b^H + b^R}} K_0, \tag{49}$$

$$K^H_{1,s} = 0, \qquad K^*_{1,s} = K_0 - K^E_{1,s},$$

$$B^E_{1,s} = 0, \qquad B^H_{1,s} = b^R K_0 + B_0 - \alpha K_0, \qquad B^*_{1,s} = \alpha K_0,$$

$$\$^E_{1,s} = \beta\alpha \frac{\eta\beta^*\mathbb{E}_1[A] + (1-\pi_2)\beta^* b^E + b^R \frac{(\beta R^\$)^2}{\tau\underline{A}}(\beta^*\eta\mathbb{E}_1[A] + \alpha\beta)}{\eta\beta^*\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^*\pi_2 \frac{b^E}{b^E + b^H + b^R}} K_0,$$

$$\$^H_{1,s} = 0, \qquad \$^*_{1,s} = 0.$$

with $b^E = \alpha$ and $b^H = d - \alpha$. Foreign investors are the marginal holders for both domestic bonds and capital and hence the asset prices are

$$q_{1,s} = \beta^*\eta\ \mathrm{E1}[A], \tag{50}$$

$$p_{1,s} = \beta^*(1 - \pi_2 h^R(\alpha, \mathrm{d} - \alpha, \mathrm{b}^R)), \tag{51}$$

*with a haircut of domestic bonds $h^R(b^E, b^H, b^R)$ defined in equation (*34*).*

Proof. See section A.2.

Proposition A.2 characterizes the flight-to-safety equilibrium with tranching policy.

Proposition A.2. *(Assume unexpected crisis) For* $\alpha < s < d < \tau\bar{A}$*, a flight-to-safety equilibrium exists if and only* $s \in [\max\{\underline{d}, \alpha\}, \tau\bar{A}]$*. The equilibrium allocation is*

$$K_{1,s}^{E} = \frac{\eta\beta^{*}\mathbb{E}_1[A] + (1-\pi_2)\beta^{*}b^{S,E}}{\eta\beta^{*}\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^{*}\pi_2\dfrac{b^{S,E}}{s}}K_0, \quad K_{1,s}^{H} = 0, \quad K_{1,s}^{*} = K_0 - K_{1,s}^{E}, \tag{52}$$

$$B_{1,s}^{S,E} = 0, \qquad B_{1,s}^{S,H} = sK_0 - b^{S,E}K_0, \qquad B_{1,s}^{S,*} = b^{S,E}B_0,$$

$$B_{1,s}^{J,E} = 0, \qquad B_{1,s}^{J,H} = B_0 - sK_0, \qquad B_{1,s}^{J,*} = 0,$$

$$\$_{1,s}^{E} = \beta\alpha\frac{\eta\beta^{*}\mathbb{E}_1[A] + (1-\pi_2)\beta^{*}b^{S,E}}{\eta\beta^{*}\mathbb{E}_1[A] + \alpha\beta - \tau\underline{A}\beta^{*}\pi_2\dfrac{b^{S,E}}{s}}K_0, \qquad \$_{1,s}^{H} = 0, \qquad \$_{1,s}^{*} = 0.$$

with $b^{S,E} = \alpha$*. Foreign investors are the marginal holders for both domestic bonds and capital and hence the asset prices are*

$$q_{1,s} = \beta^{*}\eta\mathbb{E}_1[A], \tag{53}$$

$$p_{1,s}^{S} = \beta^{*}\left(1 - \pi_2 h(\alpha, s-\alpha)\right), \tag{54}$$

$$p_{1,s}^{J} = \beta^{*}\left(1 - \pi_2\right). \tag{55}$$

Proof. See section A.2.

A.2 Proofs of Results in Main Text

To ease exposition, we introduce two lemmas first.

Lemma A.1. *Households always hold domestic bonds they bought at* $t=0$ *to maturity* ($t=2$)*. Entrepreneurs hold their asset position unchanged at* $t=1$ *as long as there is no fire-sale.*

Proof. We argue households will not sell domestic bonds in time 1. There are two cases. First, if foreigners hold some domestic bonds at $t=1$, the bonds must have expected return $\frac{1}{B^{*}}$ since foreigners are risk neutral and wealth unconstrained. Since $\beta > \beta^{*} > \frac{1}{R^{\$}}$, households prefer holding domestic bonds over holding dollars and consumption.

Second, if foreigners hold no bonds at $t=1$, there are no fire-sales in both capital and bonds. By assumption, entrepreneurs weakly prefer holding capital over holding bonds. They do not sell capital unless the bonds are unsafe in the first place. As a result, there is no resource exchange between the domestic economy and the foreigners. Since there is no production in $t=1$, the total consumption of domestic agents at $t=1$ is zero. Since entrepreneurs do not sell their capital or consume, they do not have extra wealth to buy additional bonds. We therefore have entrepreneurs and foreigners buy no additional bonds. Entrepreneurs' asset positions are unchanged at $t=1$. To clear the bonds market, households must keep their bond holdings unchanged.

Lemma A.2. *In time 0, the domestic bonds price is*

$$p_0=\beta^2, \tag{56}$$

and bond positions held by entrepreneurs are

$$b^E=\alpha. \tag{57}$$

Proof of Lemma A.2. The proof is already outlined in the main text. By assumptions, entrepreneurs are not wealthy enough to buy all domestic bonds at $t=0$. The residual bonds must be purchased either by households or the foreigners. With short-sales constraint, the households have a higher discount rate and therefore buy residual domestic bonds. Because domestic bonds have finite supply, households consume the rest of their wealth.

The above discussion together with lemma A.1 implies households consume only at $t=0$ and $t=2$. They must be indifferent about consuming at $t=0$ and at $t=2$. Explicitly, they face a reduced optimization problem between date 0 and date 2.

$$\max C_0 + \beta^2 C_2,$$

$$\text{subject to } W_0 = C_0 + p_0 B_0^H,$$

$$B_0^H = C2.$$

The Euler equation between $t=0$ and $t=2$ is

$$\beta^2 \frac{1}{p_0} = 1 \Rightarrow p_0 = \beta^2.$$

This proves the first part. For the second part, notice that entrepreneurs have binding safe-asset constraints at $t=0$,

$$p_0 B_0^E = \alpha\beta^2 K_0 \Rightarrow \beta^2 b_0^E = \alpha\beta^2 \Rightarrow b_0^E = \alpha.$$

Proof of Proposition 1. Following lemma A.2 , $b^E=\alpha$ and $b^H=d-\alpha$. This gives the allocation of domestic bonds. For capital allocation, we verify that entrepreneurs strictly prefer to hold capital instead of selling it to foreigners at $t=0$. The return of a portfolio of capital and safe assets from $t=0$ to $t=1$ is

$$\frac{\mathbb{E}(q_1)+\alpha\beta^2\dfrac{\mathbb{E}(p_1)}{p_0}}{1+\alpha\beta^2}.$$

At $t=0$, for each unit of capital, entrepreneurs invest 1 into capital and $\alpha\beta^2$ in domestic bonds. $E(p_1)/p_0=\frac{1}{\beta}$ is the expected return of domestic bonds since default is unexpected at $t=0$. $\mathbb{E}(q_1)$ is the expected price of capital. It is also the expected return of capital because of the unit marginal cost of investment at $t=0$. If capital is sold to foreigners, the selling price of capital at $t=0$ would be $\beta^*\mathbb{E}(q_1)$ due to their impatience. Entrepreneurs prefer holding capital if[13]

$$\beta\frac{\mathbb{E}(q_1)+\alpha\beta}{1+\alpha\beta^2} > \beta^*\mathbb{E}(q_1),$$

which holds under assumption 3, $\beta > \beta^*(1+\alpha)$. We therefore know entrepreneurs hold all capital at $t=0$. At last, no agents would prefer to buy dollars due to their low yield (equation (6)).

Proof of Proposition 2. By assumption 1, there are no fire-sales with sufficiently good fundamentals. By lemma A.1, entrepreneurs and households keep their asset positions unchanged at $t=1$. The equilibrium allocation is the same as in proposition 1. Also notice that, given the asset prices in proposition 2, households and entrepreneurs will be indifferent between consumption and holding assets. Any finite demand is possible. Consequently, the asset market clears.

13. Here we implicitly assume the marginal utility of the wealth of entrepreneurs to be 1, which is the case when entrepreneurs are not wealth-constrained in any future states. In a flight-to-safety equilibrium at $t=1$, entrepreneurs are indeed wealth-constrained when there are price-depressed assets available for purchase. However, since a crisis is unexpected, this case has a probability weight of 0 *ex-ante*.

Proof of Proposition 3. An argument similar to that for proposition 2 gives the equilibrium allocation. The capital price is different now since the expected dividend of unit capital changed even though the expected return from $t=1$ to $t=2$ is still $\frac{1}{\beta}$. The bond price is β as there is no default. For the existence result, a negative fundamental equilibrium can be constructed as specified in the proposition. It is straightforward to verify the optimization problems and market-clearing conditions.

Proof of Proposition 4. Substituting equations (21) and (22) into equation (23), we have

$$\left(b^E+b^H\right)(1-h)=\tau\underline{A}\frac{\beta^*\eta\mathbb{E}_1[A]+\beta^*\left(1-\pi_2 h\left(b^E,\ b^H\right)\right)b^E}{\beta^*\eta\mathbb{E}_1[A]+\alpha\beta},$$

from which we solve the haircut $h(b^E,b^H)$,

$$h\left(b^E+b^H\right)=1-\tau\underline{A}\frac{\eta\beta^*\mathbb{E}_1[A]+(1-\pi_2)\beta^*b^E}{\left(b^E+b^H\right)\left(\eta\beta^*\mathbb{E}_1[A]+\alpha\beta\right)-\tau\underline{A}\beta^*\pi_2 b^E},\tag{58}$$

The haircut can be rewritten as

$$h\left(b^E+b^H\right)=\frac{\tau\underline{A}-\left(b^E+b^H\right)}{b^E+b^H}\frac{1}{-\frac{\frac{\partial T(h)}{\partial h}}{b^E+b^H}-1},$$

with $-\frac{\partial T(h)}{\partial h}$ being the sensitivity of tax revenue to the bond haircut h (in absolute value), which highlights the haircut spiral. Given the haircut $h(b^E,b^H)$, we can solve $K^E_{1,s}$ from equation (21). The entrepreneurs' dollar holdings follow from the binding safe-asset constraint $\$^E_{1,s}=\alpha\beta K^E_{1,s}$. Households have their domestic bond positions unchanged by lemma A.1. Because foreigners demand return $1/\beta$ for both capital and domestic bonds, the asset prices follow from discounting the expected dividend at $t=2$ ($1-\pi_2 h$ for domestic bonds and $\mathbb{E}_1[A]$ for capital).

It remains to be verified that the government (partially) defaults and domestic investors fire-sale part of their physical capital, i.e.,

$h(b^E, b^H) > 0$ and $K_{1,s}^E < K_0$. Since at $t = 0$, $b^E = \alpha$, $b^H = d - \alpha$. For a fixed α, the haircut function $h(\alpha, \mathrm{d} - \alpha)$ is increasing in d. That is, a higher *ex-ante* total debt level leads to a larger *ex-post* default. To see that, define $h_2(d)$ as

$$h_2(d) = h(\alpha, d - \alpha) = 1 - \tau \underline{A} \frac{\eta\beta^* \mathbb{E}_1[A] + (1 - \pi_2)\beta^* \alpha}{d(\eta\beta^* \mathbb{E}_1[A] + \alpha\beta) - \tau \underline{A}\beta^* \pi_2 \alpha}.$$

By assumptions 1 and 2, the denominator $d(\eta\beta^* \mathbb{E}_1[A] + \alpha\beta) - \tau\underline{A}\beta^*\pi_2 b^E$ is positive and to verify $\frac{\partial h_2(d)}{\partial d} > 0$ is straightforward. Since $h(\alpha, \mathrm{d} - \alpha)$ is increasing in d, there is a unique debt level $\underline{d}$ such that $h(\alpha, \underline{d} - \alpha) = 0$. Solving $\underline{d}$ yields equation (28). Assumptions 1 and 2 ensure $\underline{d} \le \tau\underline{A}$. By definition,

$$h(\alpha, \mathrm{d} - \alpha) > 0 \Leftrightarrow d > \underline{d}.$$

From equation (21),

$$h > 0 \Rightarrow K_{1,s}^E / K_0 < 1.$$

Together the flight-to-safety equilibrium exists if and only if $d \in [\max\{\underline{d}, \alpha\}, \tau\underline{A}]$.

Proof of Proposition 6. We first show the characterization of equilibrium allocation and prices assuming equilibrium existence and then proceed to verify the condition for equilibrium existence.

At $t = 0$, the only difference between the setup with reserves and the baseline model is the extra domestic debt issuance. Similar to the baseline model, households buy all the residual old debt and all new debt at $t = 0$, i.e.,

$$B_0^H = \underbrace{B_0 - \alpha K_0}_{\textit{Residual old debt}} + \underbrace{b^R K_0}_{\textit{All new debt}}.$$

This proves the first claim.

At $t = 1$, note that lemma A.1 still holds. Conditional on no fire-sales, domestic agents keep their positions unchanged. The equilibrium allocation follows from the $t = 0$ allocation. It is straightforward to verify that equilibrium prices are the same as those in the baseline model. This proves the second and third claims.

For the existence result, we need to check that domestic bonds do not default in the state with the lowest productivity at $t = 2$, i.e., the lowest tax revenue plus reserves is enough to cover maturing debt.

$$\underbrace{\tau \underline{A} K_0}_{\textit{tax revenue}} + \underbrace{\beta^2 b^R K_0 \left(R^{\$}\right)^2}_{\textit{Reserves}} \geq \underbrace{d K_0}_{\textit{the old debt}} + \underbrace{b^R K_0}_{\textit{the new debt}} .$$

Rearrange the equation to get

$$d \leq \tau \underline{A} - (1 - \beta^2 (R^{\$})^2) b^R, \tag{59}$$

which is the upper bound for the existence region. The lower bound follows from the model's assumption.

Proof of Lemma 1. To prove the first claim, notice that the difference between the two haircut functions is

$$h^R\left(b^E, b^H, b^R\right) - h^R\left(b^E, b^H\right) =$$

$$\frac{b^R\left(\eta\beta^* \mathbb{E}_1[A] + \alpha\beta\right)\left\{\tau\underline{A}\left(\eta\beta^*\mathbb{E}_1[A] + (1-\pi_2)\beta^* b^E\right)\right.}{\left[\left(b^E + b^H\right)\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^*\pi_2 b^E\right]}$$

$$\frac{\left.-\left[\left(b^E + b^H\right)\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^*\pi_2 b^E\right]\left(\beta R^{\$}\right)^2\right\}}{\left[\left(b^E + b^H + b^R\right)\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^*\pi_2 b^E\right]}$$

$$= \frac{b^R\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right)\left(1 - h\left(b^E, b^H\right) - \left(\beta R^{\$}\right)^2\right)}{\left(b^E + b^H + b^R\right)\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^*\pi_2 b^E}.$$

It follows

$$h^R\left(b^E, b^H, b^R\right) - h\left(b^E, b^H\right) < 0 \Leftrightarrow 1 - \left(\beta R^{\$}\right)^{2<} h\left(b^E, b^H\right).$$

For the second claim, the partial derivative is

$$\frac{\partial h^R\left(b^E, b^H, b^R\right)}{b^R} = \frac{\left(1 - h^R\left(b^E, b^H, b^R\right) - \left(\beta R^{\$}\right)^2\right)\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right)}{\left(b^E + b^H + b^R\right)\left(\eta\beta^*\mathbb{E}_1[A] + \alpha\beta\right) - \tau\underline{A}\beta^*\pi_2 b^E},$$

which implies

$$\frac{\partial h^R\left(b^E,b^H,b^R\right)}{b^R}<0\Leftrightarrow 1-\left(\beta R^{\$}\right)^2<h^R\left(b^E,b^H,b^R\right).$$

Also notice

$$h^R\left(b^E,b^H,b^R\right)-\left(1-\left(\beta R^{\$}\right)^2\right)$$

$$=\frac{\left(\beta R^{\$}\right)^2-1+h\left(b^E,b^H\right)}{\left[\left(b^E+b^H\right)\left(\eta\beta^*\mathbb{E}_1\left[A\right]+\alpha\beta\right)-\tau\underline{A}\beta^*\pi_2 b^E\right]}$$
$$\frac{\left(\beta R^{\$}\right)^2-1+h\left(b^E,b^H\right)}{\left[\left(b^E+b^H+b^R\right)\left(\eta\beta^*\mathbb{E}_1\left[A\right]+\alpha\beta\right)-\tau\underline{A}\beta^*\pi_2 b^E\right]},$$

which implies

$$\frac{\partial h^R\left(b^E,b^H,b^R\right)}{\partial b^R}<0\Leftrightarrow 1-\left(\beta R^{\$}\right)^2<h^R\left(b^E,b^H,b^R\right)$$
$$\Leftrightarrow 1-\left(\beta R^{\$}\right)^2<h^R\left(b^E,b^H\right).$$

Together, the second result is proved.

Proof of Proposition A.1. We first show the equilibrium allocation and prices assuming equilibrium existence. Then we proceed to verify the condition of equilibrium existence.

The proof here is similar to the one for proposition 4. Substituting equation (32) into equation (33), we solve $K^E_{1,s}$ and h^R (equation (34)). Entrepreneurs' dollar holdings can be solved from the binding safe-asset constraint. Households have their domestic bond positions from $t=0$ unchanged by lemma A.1. Because foreigners demand return $1/\beta^*$ for both capital and domestic bonds, the asset prices follow from discounting the expected dividend at $t=2$ ($1-\pi_2 h$ for domestic bonds and $\mathbb{E}1[A]$ for capital).

For the existence result, we need to verify that domestic bonds have default risk, i.e., $h>0$. From equation (34), the equilibrium haircut $h^R(\alpha,\mathrm{d}-\alpha,\mathrm{b}^R)$ is increasing in d. Define $\underline{d}^R(b^R)$ as the unique solution of

$$h^R(\alpha,\underline{d}^R-\alpha,\mathrm{b}^R)=0. \tag{60}$$

The flight-to-safety equilibrium exists if and only if $d \in [\max\{\alpha, \underline{d}^R\}, \tau\underline{A}]$.

Proof of Proposition 7. For the first claim, we can compute the crisis region directly. Following proposition A.1, the crisis region with tranching policy b^R is $V^R(b^R) = [\max\{\alpha, \underline{d}^R(b^R)\}, \tau\underline{A}]$ whereas the one in the baseline is $V^B = [\max\{\alpha, \underline{d}\}, \tau\underline{A}]$. It therefore suffices to show

$$\underline{d}^R\left(b^R\right) \leq \underline{d} \tag{61}$$

It can be verified that $h^R(\alpha, d - \alpha, 0) = h(\alpha, d - \alpha)$. It follows that $\underline{d}^R(0) = \underline{d}$. We show that $\underline{d}^R(b^R)$ is decreasing in b^R and the conclusion follows. By implicit function theorem,

$$\frac{\partial \underline{d}\left(\alpha, b^R\right)}{\partial b^R} = \frac{\dfrac{\partial h^R\left(b^E, \underline{d}\left(b^E, b^R\right) - b^E, b^R\right)}{\partial b^R}}{\left.\dfrac{\partial h^R\left(b^E, \underline{d}\left(b^E, b^R\right) - b^E, b^R\right)}{\partial b^H}\right|_{b^H = \underline{d}\left(b^E, b^R\right) - b^E}}$$

By the second result in lemma 1, the numerator is positive. It is straightforward to check that $\dfrac{\partial h^R\left(b^E, b^H, b^R\right)}{\partial b^H} > 0$. Consequently, the denominator in the equation above is also positive. We have

$$\frac{\partial \underline{d}\left(\alpha, b^R\right)}{\partial b^R} < 0,$$

which proves the first claim.

For the second claim, we note that the share of fire-sold capital $S^R(d, b^R)$ is linked to haircut $h^R(\alpha, d - \alpha, b^R)$ through entrepreneurs' wealth. Specifically, equation (32) implies

$$S^R\left(d, b^R\right) = 1 - \frac{K^E_{1,s}}{K_0} = 1 - \frac{\beta^* \eta \mathbb{E}_1\left[A\right] + \beta^*\left(1 - \pi_2 h^R\left(\alpha, d - \alpha, b^R\right)\right)\alpha}{\beta^* \eta \mathbb{E}_1\left[A\right] + \alpha\beta}. \tag{62}$$

The counterpart for the baseline is

$$S^R\left(d\right) = 1 - \frac{\beta^* \eta \mathbb{E}_1\left[A\right] + \beta^*\left(1 - \pi_2 h\left(\alpha, d - \alpha\right)\right)\alpha}{\beta^* \eta \mathbb{E}_1\left[A\right] + \alpha\beta}. \tag{63}$$

Therefore

$$S^R\left(d,b^R\right)<S^B\left(d\right)\Leftrightarrow 1-\pi_2 h^R\left(\alpha,d-\alpha,b^R\right)>1-\pi_2 h\left(\alpha,d-\alpha\right)$$

$$\Leftrightarrow h^R\left(\alpha,d-\alpha,b^R\right)<h\left(\alpha,d-\alpha\right).$$

By lemma 1,

$$h\left(\alpha,d-\alpha\right)-h^R\left(\alpha,d-\alpha,b^R\right)<0\Leftrightarrow h\left(\alpha,d-\alpha\right)<1-\left(\beta R^{\$}\right)^2.$$

We therefore conclude that

$$S^R\left(d,b^R\right)<S^B\left(d\right)\Leftrightarrow h^R\left(\alpha,d-\alpha,b^R\right)>1-\left(\beta R^{\$}\right)^2,$$

which proves the second claim.

Proof of Proposition 8. Since the crisis is unexpected at $t=0$, junior bonds and senior bonds are perfect substitutes at $t=0$. All results except for bond holdings in proposition 1 hold, with the additional restriction on entrepreneurs' preference for senior bonds. The bond holdings are naturally pinned down. A similar argument holds for all non-flight-to-safety equilibria at $t=1$.

Proof of Proposition 9. Similar to the baseline, the haircut of senior bonds h^S can be solved from equations (40) and (41), which is

$$\left(b^{S,E},b^{S,H}\right)=h^S\left(b^{S,E},s-b^{S,E}\right)=h\left(b^{S,E},s-b^{S,E}\right). \tag{64}$$

The equilibrium allocation and prices other than the part for junior bonds follows the same argument for proposition 4 with the replacement of domestic bonds as senior bonds. For the allocation and price of junior bonds, one feasible equilibrium is that households hold all junior bonds at $t=1$ and the junior bonds have a return equal to $1/\beta^*$. In this case, the households are indifferent between junior bonds and senior bonds, but they prefer holding bonds over consumption and holding dollars. The market clears since households simply hold their initial bond positions unchanged.

In general, we argue that junior and senior bonds are perfect substitutes in the flight-to-safety equilibrium. By perfect substitutes, we mean that they both are risky assets and have the same return $1/\beta^*$. They are equivalent as far as portfolio choice is concerned. The idea is as follows: Since entrepreneurs prefer to hold no domestic bonds, bonds are held by households and foreigners. To trigger a flight to safety, there have to be some bonds sold to foreigners, which have an expected return $1/\beta^*$. Therefore households can obtain returns no lower than $1/\beta^*$ by investing in particular bonds. As a result, households strictly prefer holding bonds over consumption and holding dollars. Since households' wealth is stored in bonds at the beginning of $t=1$, they have to buy the same market value of bonds from the market. This implies that they must hold both junior and senior bonds as their initial wealth is larger than the total market value of junior bonds. This happens only when the expected return is equalized between the two bonds. The pricing of junior bonds immediately follows from their expected return $\frac{1}{\beta^*}$ and expected dividend $1-\pi_2$.

The above discussion shows that there is equilibria indeterminacy up to the bond holdings that divides between households and foreigners. In all these equilibria, both senior bonds and junior bonds have the same expected return $\frac{1}{\beta^*}$ and asset price. The indeterminacy is innocuous to our main insight.

Proof of Proposition 11. The characterization of non-crisis states are standard following the discussion in the baseline model. We focus on the flight-to-safety equilibrium here. When the adverse $t=2$ aggregate shock hits, the global junior bonds are wiped out and the global safe assets default partially. This leads to a flight to safety at $t=1$. The price of the global senior bond at $t=1$ is

$$p_{1,s}^{S}=\beta^*\left(1-\pi_2^a h^S\right).$$

As in the case of a single economy with tranching, entrepreneurs sell all of their senior bonds in exchange for dollars. The capital holdings at the end of $t=1$ are

$$K_{1,s}^{E}=\frac{q_{1,s}K_0+p_{1,s}^{S}B_0^{S,E}}{q_{1,s}+\alpha\beta}=\frac{\beta^*\eta\mathbb{E}_1\left[A\right]+\beta^*\left(1-\pi_2^a h^S\right)b^{S,E}}{\beta^*\eta\mathbb{E}_1\left[A\right]+\alpha\beta}K_0. \tag{65}$$

Because the crisis is unanticipated, we know $b^{S,E}=\alpha$ following the argument in the case of a single-economy model with tranching. After the adverse $t=2$ aggregate shock, the idiosyncratic shock follows. $1-\pi_2^i$ fraction of countries have final productivity $\overline{A}$. They do not default and repay their debt in full value dK_0. In contrast, the remaining π_2^i

fraction of countries have final productivity $\underline{A}$. They default and repay recovery value $\tau\underline{A}\,K^E_{1,s}$. We have the balance sheet identity for SUV sector (scaled) as

$$\left(1-\pi_2^i\right)d+\pi_2^i\tau\underline{A}\frac{K^E_{1,s}}{K_0}=\left(1-h^S\right). \tag{66}$$

We can solve h^S from equations (65) and (66), which is

$$h^S\left(d,s\right)=1-\frac{\tau\underline{A}\left(\beta^*\eta\mathbb{E}_1\left[A\right]+\beta^*\left(1-\pi_2^a\right)\alpha\right)+\dfrac{d\left(1-\pi_2^i\right)}{\pi_2^i}\left(\beta^*\eta\mathbb{E}_1\left[A\right]+\alpha\beta\right)}{\left(\beta^*\eta\mathbb{E}_1\left[A\right]+\alpha\beta\right)\dfrac{s}{\pi_2^i}-\beta^*\pi_2^a\tau\underline{A}\alpha}.$$

We need to verify $h^S(d,s)\geq 0$ and $\tau\underline{A}\,K^E_{1,s}/K_0<d$. The second condition states that countries experience adverse idiosyncratic shock default. This condition coincides with the first haircut condition in the case of a single country. The first condition can be simplified as

$$s>\left(1-\pi_2^i\right)d+\pi_2^i\tau\underline{A}\frac{\beta^*\eta\mathbb{E}_1\left[A\right]+\beta^*\alpha}{\beta^*\eta\mathbb{E}_1\left[A\right]+\beta\alpha}=\left(1-\pi_2^i\right)d+\pi_2^i d.$$

Notice $s\leq d$. The first condition implies $\underline{d}<d$, which further implies $\tau\underline{A}\,K^E_{1,s}/K_0<d$. Therefore,

$$s>\left(1-\pi_2^i\right)d+\pi_2^i\underline{d} \tag{67}$$

is the necessary sufficient condition for flight-to-safety equilibrium existence. The existence condition can be written in terms of vulnerability region $V^{GloSBies}(s)$:

$$V^{GloSBies}\left(s\right)=\left[\max\left\{\alpha,\underline{d}\right\},\min\left\{\frac{s-\pi_2^i\underline{d}}{1-\pi_2^i}\right\},\tau\underline{A}\right],\ d\geq s\geq\alpha \tag{68}$$

The first claim follows naturally from the above more general results. As for the second claim, the share of fire sold capital $S^{GloSBies}(d,s)$ is computed from equation (65) once we know $h^S(d,s)$:

$$S^{GloSBies}(d,s) = 1 - \frac{\beta^*\eta\mathbb{E}_1[A] + (1-\pi_2)\beta^*\alpha}{\beta^*\eta\mathbb{E}_1[A] + \alpha\beta - \beta^*\pi_2\tau\underline{A}\frac{\alpha}{s}} - \frac{\beta^*\pi_2^a\alpha d(1-\pi_2^i)}{(\beta^*\eta\mathbb{E}_1[A] + \alpha\beta)s - \beta^*\pi_2^a\pi_2^i\tau\underline{A}\alpha} \tag{69}$$

$$= S^B(s) - \frac{\beta^*\pi_2^a\alpha d(1-\pi_2^i)}{(\beta^*\eta\mathbb{E}_1[A] + \alpha\beta)s - \beta^*\pi_2^a\pi_2^i\tau\underline{A}\alpha}$$

The last equality follows from $S^B(d,s) = 1 - \frac{\eta\beta^*\mathbb{E}_1[A] + (1-\pi_2)\beta^*\alpha}{\eta\beta^*\mathbb{E}_1[A] + \alpha\beta - \beta^*\pi_2\tau\underline{A}\frac{\alpha}{s}}$ with

$$(b^{S,E}, b^{S,H}) = h^S(b^{S,E}, s - b^{S,E}) = h(b^{S,E}, s - b^{S,E}).$$

A.3 Extension to Anticipated Flight to Safety

In this appendix, we (partially) relax the assumption that flight to safety is unanticipated at $t=0$. Our major results hold as long as the *ex-ante* probability of flight to safety is sufficiently small. This can be due to either the fundamental being strong (π_1 is small) or a sunspot unlikely ($\pi_{1,s}$ is small). The interpretation is that no shock outcome captures normal times, and the $t=1$ productivity shock is *ex-ante* unlikely to be initial bad news, from which things might grow worse.

We maintain all earlier assumptions, except for the assumption of unanticipated crisis. In addition, we restrict ourselves to equilibria that two more properties hold. First, entrepreneurs optimally choose to hold capital at $t=0$. Second, households optimally choose to hold only domestic bonds at $t=0$. The first property requires that the investment opportunity of capital have sufficiently high yield compared to other means. The second property requires that the perceived likelihood of crisis in $t=0$ is low such that dollar is not too attractive even in $t=0$. [14]. We verify that the two properties hold for sufficiently small $\pi_1\pi_{1,s}$.

14. The two properties listed make sure that $t=0$ is a tranquil period for the economy. If any of the properties are not true, then flight to safety already happens at $t=0$, which is ill-suited for our purpose of characterizing a possible flight to safety at $t=1$.

A.3.1 Baseline Model

To fix ideas, recall that $\pi_{1,s}$ is the sunspot probability. For $\pi_{1,s}>0$, we have a new lemma generalizing the results in lemma A.2.

Lemma A.3. *Suppose equilibria exist. At $t=0$, the domestic bonds price is* [15]

$$p_0=\beta^2(1-\pi_1\pi_{1,s}\pi_2 \max\{0,h(b^E,d-b^E)\}), \tag{70}$$

and entrepreneurs' bond positions are

$$b^E=\frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2\ \max\{0,h(b^E,d-b^E)\}}. \tag{71}$$

Proof. Notice lemma A.1 still holds, since the argument is only about equilibrium at $t=1$. Following the same argument for lemma A.2, households must be indifferent between consuming at $t=0$ and $t=2$. The only difference here is that households expect bonds to default with probability $\pi_1\pi_{1,s}\pi_2$. Therefore, a bond with unit face value is sold at price p_0 at $t=0$ and gives full face value 1 when debt is safe and recovery value $1-h$ when there is default at $t=2$. The expected payoff at $t=2$ is

$$1(1-\pi_1\pi_{1,s}\pi_2)+(1-h)\pi_1\pi_{1,s}\pi_2=1-\pi_1\pi_{1,s}\pi_2 h.$$

The Euler equation for households between $t=0$ and $t=2$ is

$$\beta^2\frac{1-\pi_1\pi_{1,s}\pi_2 h}{p_0}=1\Rightarrow p_0=\beta^2\left(1-\pi_1\pi_{1,s}\pi_2 h\right),$$

which gives the price of domestic bonds at $t=0$. Since entrepreneurs have a binding safe-asset constraint,

$$p_0B_0^E=\alpha\beta^2K_0\Rightarrow\beta^2\left(1-\pi_1\pi_{1,s}\pi_2 h\right)b_0^E=\alpha\beta^2\Rightarrow\frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2 h}.$$

At $t=0$, the likelihood of flight to safety is $\pi_1\pi_{1,s}$. As the likelihood of flight to safety increases, the *ex-ante* price of domestic bonds decreases

15. The max operator is to incorporate the case where no flight-to-safety equilibrium exists. In such a case, the equation has solution $b^E=\alpha$ and $h(\alpha,d-\alpha)<0$.

to reflect the crisis and entrepreneurs buy more bonds as safe assets.[16] Formally, define entrepreneurs' endogenous bond positions at $t=0$ as functions of probability of flight to safety and total debt (ratio): $b^E(\pi_1\pi_{1,s},d)$. We have following lemma:

Lemma A.4. *For each* $\alpha \le d \le \tau A$, there exists a threshold for the probability of flight to safety $\pi^*(d)$. *For* $\pi_1\pi_{1,s} \in [0,\pi^*(d)]$*, there exists a solution* $b^E(\pi_1\pi_{1,s},d) \in [\alpha,\mathrm{d}]$ *to equation (*71).

Proof. Rewrite equation (71) as

$$b^E\left(1-\pi_1\pi_{1,s}\pi_2 max\{0,h\left(b^E,d-b^E\right)\}\right)=\alpha. \tag{72}$$

Since $h(b^E,d-b^E)$ is decreasing in b^E (equation (27)), the left-hand side of the above equation is strictly increasing in b^E. The equation therefore has at most one solution. To ensure $b^E \in [\alpha,d]$, we show this holds if and only if $\pi_1\pi_{1,s} \in [0,\pi^*(d)]$ for some threshold level $\pi^*(d)$. For $\pi > \pi^*(d)$, the domestic bonds are so cheap that entrepreneurs buy all domestic bonds and might even buy additional dollars to meet the safe-asset constraint.

Define function $F(b,\Pi,d)$ to be

$$b^E\left(1-\pi_1\pi_{1,s}\pi_2 max\{0,h\left(b^E,d-b^E\right)\}\right)=\alpha. \tag{73}$$

$F(b,\Pi,d)$ is non-increasing in Π and strictly increasing in b. For given Π and d, function $F(b,\Pi,d)=0$ has at most one solution for $b^*(\Pi,d)$. Notice $F(\alpha,\Pi,d)\le 0$ and $F(d,0,d)=d-\alpha>0$. There are two cases. First, if $F(d,1,d)>0$, we know

$$0<F(d,1,d)\le F(d,\Pi,d).$$

Intermediate value theorem applies and there exists unique solution $b^*(\Pi,d)\in[\alpha,\mathrm{d}]$ for $\Pi\in[0,1]$. Second, if $F(d,1,d)<0$, we can define $\pi^*(d)$ such that

$$F(d,\pi^*(d),d)=0 \tag{74}$$

since $F(d,0,d)>0$ and the function is continuous in Π. In this case, for $\Pi\in[0,\pi^*(d)]$, we know that

$$F(\alpha,\Pi,d)\le 0 \qquad \text{and} \qquad F(d,\Pi,d)\ge F(d,\pi^*(d),d)=0.$$

16. Entrepreneurs still buy the same market value of bonds, but the total face value of bonds they bought increases.

Apply the intermediate value theorem to augment b of function $F(b,\Pi,d)$. We have unique solution $b^*(\Pi,d) \in [\alpha,\mathrm{d}]$. If we defined the thresholds, $\pi*(d) = 1$ for the first case. We have shown the claim.

The following propositions characterize results parallel to those in section 1 when $\pi_1\pi_{1,s}$ is strictly positive but sufficiently small.

Proposition A.3. *We obtain the following results regarding the baseline model with the anticipated flight to safety.*

For sufficiently small $\pi_1\pi_{1,s}$, *the flight-to-safety equilibrium exists (crisis vulnerability region) if and only if* $h(b^E(\pi_1\pi_{1,s},d), d-b^E(\pi_1\pi_{1,s},d)) > 0$. *The characterization of equilibria in propositions 1, 2, 3, and 4 hold as long as* b^E *and* b^H *are replaced with a unique pair of solutions from equations*

$$b^E = \frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2 \ \max\{0, h(b^E, d-b^E)\}}, \tag{75}$$

$$b^H = d - b^E \tag{76}$$

and the bond price at $t=0$ *is replaced with the one in lemma A.3.*

The result is continuous at $\pi_1\pi_{1,s} = 0$ *provided* $\pi_1 > 0$.

Proof. It is straightforward that the second claim follows from the first claim.

For the first claim, we have following observation. If we assume entrepreneurs optimally choose to hold capital and bonds at $t=0$ and households optimally choose to hold bonds at $t=0$, the allocation and prices at $t=0$ are by construction pinned down as long as we know b^E and p_0, which are provided in lemma A.3. Besides, the arguments for propositions 2, 3, and 4 go through as long as we replace b^E with the one defined in equation 69. Lemma A.4 shows that b^E exists for sufficiently small $\pi_1\pi_{1,s<}\pi^*(d)$.

To finish the proof, we must verify the optimality of entrepreneurs' and households' choices at $t=0$. In the non-flight-to-safety equilibria at $t=1$, both types of agents have marginal utility of wealth (MUW) of 1. However, when flight to safety happens, entrepreneurs invest all their wealth in capital and dollars for the high return in times of asset fire-sales. Households invest all their wealth in domestic bonds similarly. The optimality of such actions is ensured by assumption 5. Consequently, the marginal utility of wealth in crisis times is higher than 1 for both agents. For households, their MUW is

$$\xi_{1,s}^H = \frac{\beta}{\beta^*} > 1,$$

since domestic bonds have an expected return $\frac{1}{\beta^*}$ in a flight-to-safety episode. For entrepreneurs, their MUW is

$$\xi_{1,s}^{E} = \beta \frac{\mathbb{E}_1[A] + R^{\$}\alpha\beta}{\beta^* \eta \mathbb{E}_1[A] + \alpha\beta} > \xi_{1,s}^{H} > 1,$$

where letter ξ stands for marginal utility of wealth. $\xi_{1,u}^{E} = \xi_{1,f}^{E} = \xi_{1,u}^{H} = \xi_{1,f}^{H} = 1$.

At $t = 0$, households optimally choose to consume and buy domestic bonds instead of buying dollars, which requires

$$1 = \beta \mathbb{E}\left(\xi_1^H \frac{p_1}{p_0} \right) > \beta\left(\xi_1^H R^{\$} \right).$$

The first equality states that households are indifferent between consumption and holding domestic bonds.

For entrepreneurs, their available options are 1) holding capital and using domestic bonds as safe assets, 2) building capital and selling to foreigners, 3) holding domestic bonds only, 4) holding dollars only, and 5) consuming only. We need to ensure they optimally choose to hold capital and use domestic bonds as safe assets, i.e., the marginal utility of wealth from holding capital and using domestic bonds as safe assets is the highest among the five possible choices. We have four inequalities:

$$\beta \mathbb{E}\left(\xi_1^H \frac{q_1 + \alpha\beta^2 \frac{p_1}{p_0}}{1 + \alpha\beta^2} \right) > \beta \mathbb{E}\left(\xi_1^E \frac{q_1 + \alpha\beta^2 R^{\$}}{1 + \alpha\beta^2} \right) \tag{77}$$

$$\beta \mathbb{E}\left(\xi_1^H \frac{q_1 + \alpha\beta^2 \frac{p_1}{p_0}}{1 + \alpha\beta^2} \right) > \beta^* \mathbb{E}(q1) \tag{78}$$

$$\beta \mathbb{E}\left(\xi_1^H \frac{q_1 + \alpha\beta^2 \frac{p_1}{p_0}}{1 + \alpha\beta^2} \right) > 1 \tag{79}$$

$$\beta\mathbb{E}\left(\xi_1^H \frac{q_1+\alpha\beta^2\frac{p_1}{p_0}}{1+\alpha\beta^2}\right) > \beta\mathbb{E}\left(\xi_1^E R^{\$}\right). \tag{80}$$

Notice all inequalities hold strictly if $\pi_{1,s}=0$ by assumptions 1–5. In that case, the inequalities reduce to

$$\beta\frac{\beta\mathbb{E}(A)+\alpha\beta}{1+\alpha\beta^2} > \beta\frac{\beta\mathbb{E}(A)+\alpha\beta^2 R^{\$}}{1+\alpha\beta^2}$$

$$\beta\frac{\beta\mathbb{E}(A)+\alpha\beta}{1+\alpha\beta^2} > \beta^*\mathbb{E}(A)$$

$$\beta\frac{\beta\mathbb{E}(A)+\alpha\beta}{1+\alpha\beta^2} > 1 > \beta R^{\$}\cdot$$

By continuity, there exists a threshold $\pi^{**}(d) \leq \pi^*(d)$ such that equations (77)–(80) hold.[17]

Proposition A.3 shows that our main results hold in the neighborhood of an unanticipated flight to safety for a sufficiently small *ex-ante* likelihood of flight to safety.

For future reference, we characterize the crisis vulnerability and crisis intensity for the baseline model in the following proposition.

Proposition A.4. *We obtain the following results regarding crisis vulnerability and intensity.*
1. The crisis vulnerability region V^B *is*

$$V^B = [\max\{\alpha, \underline{d}^*\}, \tau\underline{A}], \tag{81}$$

where $\underline{d}^*$ *is the unique solution of* $h(b^E(\pi_1\pi_{1,s}, \underline{d}^*), \underline{d}^* - b^E(\pi_1\pi_{1,s}, \underline{d}^*)) = 0$.
2. The crisis intensity SB is

$$S^B = 1 - \frac{K_{1,s}^E}{K_0} = 1 - \frac{\beta^*\eta\mathbb{E}_1[A] + \beta^*\left(1-\pi_2 h\left(b^E, d-b^E\right)\right)b^E}{\beta^*\eta\mathbb{E}_1[A] + \alpha\beta}. \tag{82}$$

17. $\pi^{**}(d) \leq \pi^*(d)$ is required to ensure that the valid solution b^E exists for equation (71).

Proof. We only need to verify

$$h\left(b^E\left(\pi_1\pi_{1,s},d\right),d-b^E\left(\pi_1\pi_{1,s},d\right)\right)>0 \Leftrightarrow d>\underline{d}^*.$$

The rest follows from earlier analysis. It suffices to show $h(b^E(\pi_1\pi_{1,s},d),d-b^E(\pi_1\pi_{1,s},d))$ is increasing in d. We only sketch the key steps here. By using the implicit function theorem in (71), we can show $b^E(\pi_1\pi_{1,s},d)$ is increasing in d. The result then follows as h must decrease if b^E increases to ensure equation (71) holds.

A.3.2 Reserves

The analysis for the reserves case is similar. Lemma A.5 characterizes bond holdings and pricing at $t=0$.

Lemma A.5. *Suppose equilibria exist. At* $t=0$*, the domestic bond price is given by*

$$p_0=\beta^2(1-\pi_1\pi_{1,s}\pi_2\max\{0,h^R(b^E,d-b^E,b^R)\}), \tag{83}$$

and bond positions held by entrepreneurs are

$$b^E=\frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2\ \max\{0,h^R(b^E,d-b^E,b^R)\}}. \tag{84}$$

where haircut $h^R(b^E,b^H,b^R)$ *is defined in equation (*34*).*

Proof. The same proof of lemma A.3 applies here with haircut $h(b^E,d-b^E)$ replaced by haircut function $h^R(b^E,d-b^E,b^R)$ under reserve policies.

Lemma A.6 shows equation (84) has a unique solution for a sufficiently small probability of crisis $\pi_1\pi_{1,s}$.

Lemma A.6. *For each* $\alpha\le d\le\tau A$ and given reserve policy b^R*, there exists a threshold for the probability of flight to safety* $\pi^{R,*}(d,b^R)$*. For* $\pi_1\pi_{1,s}\in[0,\pi^{R,*}(d,b^R)]$*, there exists a solution* $b^E(\pi_1\pi_{1,s},d,b^R)\in[\alpha,d]$ *to equation (*84*).*

Proof. Notice in the proof of lemma A.4 that we only need the comparative static that $h(b,d-b)$ is decreasing in b. The same comparative static is true for function $h^R(b^E,d-b^E,b^R)$. As a result, we can apply the proof of lemma A.4 with function $h(b^E,d-b^E)$ replaced by $h^R(b^E,d-b^E,b^R)$.

Proposition A.5 characterizes the flight-to-safety equilibrium, which generalizes proposition A.1.

Proposition A.5. *We obtain the following results regarding the case of an anticipated flight to safety with reserve policies.*
1. For sufficiently small $\pi_1\pi_{1,s}$, *the (non-flight-to-safety) fundamental equilibrium exists if and only if* $d \in [\alpha, \tau\underline{A} - (1-\beta^2(R^\$)^2)b^R]$, *whereas the flight-to-safety equilibrium exists if and only if* $h^R(b^E, d-b^E, b^R) > 0$. *The characterizations of equilibria in propositions 6 and A.1 hold as long as* b^E *and* b^H *are replaced with a unique pair of solutions from equations*

$$b^E = \frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2 \max\{0, h^R(b^E, d-b^E, b^R)\}}, \tag{85}$$

$$b^H = d - b^E \tag{86}$$

2. Result 1 is continuous at $\pi_1\pi_{1,s} = 0$ *provided* $\pi_1 > 0$.
Proof. The proof is almost the same as the one for proposition A.3. The result of equilibria at $t=1$ in proposition A.1 is still valid as long as we pin down endogenous domestic bond positions b^E at $t=0$. And we already show there is a solution to the b^E given in lemma A.5 if $\pi_1\pi_{1,s} \leq \pi^{R,*}(d, b^R)$ (lemma A.6). At last, we can check that the optimality of entrepreneurs' and households' actions at $t=0$ holds given sufficiently small $\pi_1\pi_{1,s}$.

Notice lemma 1 still holds, as only function h^R is concerned. The following proposition gives the policy implication of the reserves policy, which generalizes proposition 7.

Proposition A.6. *Given a reserve policy* b^R, *in equilibria characterized in proposition A.5,*
1. the crisis vulnerability region is not smaller than the crisis vulnerability region in the baseline model,

$$V^R\left(b^R\right) \supset V^B = [\max\{\underline{d}^*, \alpha\}, \tau\underline{A}], \tag{87}$$

2. the crisis intensity is less than that in the baseline model if and only if the haircut before implementing the policy is greater than $1-(\beta R^\$)^2$,

$$S^R\left(\pi_1\pi_{1,s}, d, b^R\right) \leq S^B\left(\pi_1\pi_{1,s}, d\right) \Leftrightarrow h\left(b^E, d-b^E\right) \geq 1-\left(\beta R^\$\right)^2, \tag{88}$$

where b^E *is implicitly defined in equation (*84*).*

Proof. To prove the first claim, define function $F(d, b^R)$ as

$$F(d, b^R) = h^R(b^E(\pi_1\pi_{1,s}, d, b^R), d - b^E(\pi_1\pi_{1,s}, d, b^R), b^R). \tag{89}$$

Similar to $\underline{d}^R$ in proposition 7, define $\underline{d}^{R,*}(b^R)$ as $F(\underline{d}^{R,*}(b^R), b^R) = 0$. The crisis region now becomes $[\max\{\alpha, \underline{d}^{R,*}(b^R)\}, \tau\underline{A}]$. It can be verified that $\underline{d}^{R,*}(0) = \underline{d}$. It suffices to show that $\underline{d}^{R,*}(b^R)$ is decreasing in b^R. By implicit function theorem,

$$\frac{d\underline{d}^{R,2}\left(b^R\right)}{db^R} = \frac{-\dfrac{\partial F\left(d, b^R\right)}{\partial b^R}}{\dfrac{\partial F\left(d, b^R\right)}{\partial d}}. \tag{90}$$

Taking the partial derivative of both sides of equation (84) and rearranging the terms[18], we have

$$\frac{\partial F\left(d, b^R\right)}{\partial b^R} = \frac{1 - \pi_1 \pi_{1,s} \pi_2 h^R}{\pi_1 \pi_{1,s} \pi_2 b^E} \frac{\partial b^E}{\partial b^R} = \frac{1}{\pi_1 \pi_{1,s} \pi_2 b^E} \frac{\partial b^E}{\partial b^R},$$

$$\frac{\partial F\left(d, b^R\right)}{\partial d} = \frac{1}{\pi_1 \pi_{1,s} \pi_2 b^E} \frac{\partial b^E}{\partial d}.$$

Notice that

$$\frac{\partial F\left(d, b^R\right)}{\partial b^R} = \frac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^E} \frac{\partial b^E}{\partial b^R} + \frac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^R}.$$

We can solve $\dfrac{\partial b^E}{\partial b^R}$ as

$$\frac{\partial b^E}{\partial b^R} = \frac{\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^R}}{\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^E} - \dfrac{1}{\pi_1 \pi_{1,s} \pi_2 b^E}}.$$

From lemma 1 and $h^R = 0$, we know $\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^R} > 0$ and $\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^E} < 0$.

18. Since $h^R = 0$, we take a one-sided derivative due to the max operator.

As a result,

$$\frac{\partial b^E}{\partial b^R} > 0 \Rightarrow \frac{\partial F\left(d, b^R\right)}{\partial b^R} > 0$$

Similarly,

$$\frac{\partial F\left(d, b^R\right)}{\partial d} = \frac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^E}\frac{\partial b^E}{\partial d} + \frac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial d}.$$

And it follows that

$$\frac{\partial b^E}{\partial d} = -\frac{\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial d}}{\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial b^E} - \dfrac{1}{\pi_1 \pi_{1,s} \pi_2 b^E}}.$$

We know $\dfrac{\partial h^R\left(b^E, d - b^E, b^R\right)}{\partial d} > 0$. Therefore

$$\frac{\partial b^E}{\partial d} > 0 \Rightarrow \frac{\partial F\left(d, b^R\right)}{\partial d} > 0.$$

Combine the above two comparative statics and equation (90). The first claim is proved.

Now we move on to the second claim. For convenience, we omit the argument for endogenous function $b^E(\pi_1 \pi_{1,s}, d, b^R)$ whenever there is no ambiguity. From equation (32), S^R is

$$S^R\left(d, b^R\right) = 1 - \frac{K_{1,s}^E}{K_0} = 1 - \frac{\beta^* \eta \mathbb{E}_1\left[A\right] + \beta^*\left(1 - \pi_2 h^R\left(b^E, d - b^E, b^R\right)\right)b^E}{\beta^* \eta \mathbb{E}_1\left[A\right] + \alpha\beta}.$$

And $S^R(\pi_1 \pi_{1,s}, d, 0) = S^B(\pi_1 \pi_{1,s}, d)$. Define function $G(d, b^R) = (1 - \pi_2 h^R(b^E, d - b^E, b^R))b^E$. It suffices to show that

$$G\left(d, b^R\right) \leq G\left(d, 0\right) \Leftrightarrow h\left(b^E\left(\pi_1 \pi_{1,s}, d, 0\right), d - b^E\left(\pi_1 \pi_{1,s}, d, 0\right)\right) \geq 1 - \left(\beta R^{\$}\right)^2.$$

We prove the sufficient condition

$$\frac{\partial G\left(d,b^R\right)}{\partial b^R} > 0 \Leftrightarrow h\left(b^E\left(\pi_1\pi_{1,s},d,0\right),d-b^E\left(\pi_1\pi_{1,s},d,0\right)\right) \geq 1-(\beta R\$)^2 .$$

Taking the partial derivative of equation (84) again, we have

$$\frac{\partial G\left(d,b^R\right)}{\partial b^R} = \frac{1-\pi_1\pi_{1,s}}{\pi_1\pi_{1,s}}\frac{\partial b^E}{\partial b^R},$$

which implies

$$\frac{\partial G\left(d,b^R\right)}{\partial b^R} > 0 \Leftrightarrow \frac{\partial b^E}{\partial b^R} > 0.$$

Note earlier that we proved the following result in proving the first claim:

$$\frac{\partial F\left(d,b^R\right)}{\partial b^R} > 0 \Leftrightarrow \frac{\partial b^E}{\partial b^R} > 0 \Leftrightarrow \frac{\partial h^R\left(b^E,d-b^E,b^R\right)}{\partial b^R} > 0.$$

Also from lemma 1,

$$\frac{\partial h^R\left(b^E,d-b^E,b^R\right)}{\partial b^R} > 0 \Leftrightarrow F\left(d,b^R\right) = h^R\left(b^E,d-b^E,b^R\right) < 1-(\beta R\$)^2 .$$

From the above two inequalities, we have
$\frac{\partial F\left(d,b^R\right)}{\partial b^R} > 0 \Leftrightarrow F\left(d,b^R\right) < 1-(\beta R\$)^2$. We guess this equivalence implies

$$\frac{\partial F\left(d,b^R\right)}{\partial b^R} > 0 \Leftrightarrow F\left(d,0\right) = h\left(b^E\left(\pi_1\pi_{1,s},d,0\right),d-b^E\left(\pi_1\pi_{1,s},d,0\right)\right) < 1-(\beta R\$)^2.$$

If the guess is correct, it immediately follows that

$$G\left(d,b^R\right) \leq G\left(d,0\right) \Leftrightarrow h\left(b^E\left(\pi_1\pi_{1,s},d,0\right),d-b^E\left(\pi_1\pi_{1,s},d,0\right)\right) < 1-\left(\beta R^{\$}\right)^2, \quad (91)$$

which is the second claim.

It remains to show that our guess is correct. We prove by contradiction. Suppose $\frac{\partial F\left(d,b^R\right)}{\partial b^R}$ and $F(d,0) \geq 1-(\beta R^{\$})^2$. By mean value theorem, there exists $b_0 \in [0,b^R]$ such that

$$\frac{\partial F\left(d,b^R\right)}{\partial b^R}\left(d,b_0\right) = \frac{F\left(d,b^R\right)-F\left(d,0\right)}{b^R} < 0 \Leftarrow F\left(d,b_0\right) > 1-(\beta R\$)^2 .$$

We can construct a sequence $\{b_n\}_{n=1}^{\infty}$ by repeating mean the value theorem between points b_n and b^R. Since $b_n \in [b_{n-1}, b^R]$, the sequence is non-decreasing. It has limit b^*. By continuity of $F(d,b^R)$, $F(d,b^*) \geq 1-(\beta R^{\$})^2$. If $b^* \neq b^R$, we can construct $< b^*$ by applying mean value theorem once more, which contradicts b^* being the lower bound of the sequence. If $b^* = b^R$, it contradicts $F(d,b^R) < 1-(\beta R^{\$})^2$. Together, the only possibility is that the assumption is not true.

A.3.3 Tranching

Similar to lemmas A.3 and A.5, lemma A.7 characterizes the bond holdings and pricing in $t=0$ in the case with tranching.

Lemma A.7. *At $t=0$, the domestic senior bond price p_0^S and junior bond price p_0^J are*

$$p_0^S = \beta^2\left(1-\pi_1\pi_{1,s}\pi_2 \ \max\{0,h^S(b^{S,E},s-b^{S,E})\}\right),$$

$$p_0^J = \beta^2\left(1-\pi_1\pi_{1,s}\pi_2\right).$$

Entrepreneurs have senior bond positions

$$b^{S,E} = \frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2 \ \max\{0,h(b^{S,E},s-b^{S,E})\}}, \tag{94}$$

and junior bond positions

$$b^{J,E} = 0, \tag{95}$$

where $h^S = h(b^{S,E}, b^{S,H})$ is the haircut for senior bonds in the flight-to-safety equilibrium.

Proof. For bond prices, the same argument in the proof of lemma A.3 can be applied to senior bonds and junior bonds separately. For their bond positions at $t=0$, entrepreneurs strictly prefer to hold senior bonds over junior bonds to fulfill their safe-asset constraints. The reason is that, compared to households, entrepreneurs have higher marginal utility of wealth in a crisis state due to their ability to manage capital. While households are indifferent between the two types of bonds on the margin, entrepreneurs would strictly prefer the one offering the higher return in a crisis state. Formally, households' indifference condition is

$$1 = \beta\mathbb{E}\left(\xi_1^H \frac{p_1^S}{p_0^S}\right) = \beta\mathbb{E}\left(\xi_1^H \frac{p_1^J}{p_0^J}\right).$$

Comparing the marginal utility of wealth between entrepreneurs and households, we have $\xi^E \geq \xi^H$ with strict inequality in a crisis state (A.3.1). Also notice that junior bonds get wiped out in a crisis, $p_1^S > p_1^J = 0$. Combining both inequalities, we have entrepreneurs' valuation of both types of bonds at equilibrium price,

$$\beta\mathbb{E}\left(\xi_1^H \frac{p_1^S}{p_0^S}\right) = 1 + \pi_1\pi_{1,s}\left(\xi_{1,s}^E - \xi_{1,s}^H\right)\frac{p_{1,s}^S}{p_0^S} > 1 + \pi_1\pi_{1,s}\left(\xi_{1,s}^E - \xi_{1,s}^H\right)\frac{p_{1,s}^J}{p_0^J} = \beta\mathbb{E}\left(\xi_1^E \frac{p_1^J}{p_0^J}\right).$$

Consequently, entrepreneurs hold no junior bonds as safe assets at $t = 0$, $b^{J,E} = 0$.

The position in senior bonds can be derived similarly as in the proof of lemma A.3.

Equation (94) implicitly defines entrepreneurs' endogenous bond positions at $t = 0$ as a function of the likelihood of crisis and the tranching policy: $b^{S,E}(\pi_1\pi_{1,s}, d, s)$. Note that the total debt-to-capital ratio d is irrelevant here, just like in the model with an unanticipated crisis (equation (42)). Similar to lemma A.4, the following lemma establishes the existence of solution $b^{S,E}$ in equation (94).

Lemma A.8. *For each* $\alpha \leq s \leq d \leq \tau A$, there exists a threshold for the probability of flight to safety $\pi^*(s)$. *For* $\pi_1\pi_{1,s} \in [0, \pi^*(s)]$, *there exists a solution* $b^{S,E}(\pi_1\pi_{1,s}, s) \in [\alpha, s]$ *to equation (*94*).*

Proof. Apply lemma A.4 with $s = d$.

Lemma A.8 is the same as lemma A.4 except that the total debt ratio d is replaced by total senior debt ratio s. This is consistent with the results in section 3 of the main text. It is the amount of senior debt s instead of the amount of total domestic bonds d that matters. Moreover, we have a proposition corresponding to proposition A.3.

Proposition A.7. *We obtain the following results regarding the model with anticipated flight to safety and tranching policy.*
1. For sufficiently small $\pi_1\pi_{1,s}$, *the flight-to-safety equilibrium exists (crisis vulnerability region) if and only if* $h(b^{S,E}, s-b^{S,E})>0$. *The characterization of equilibria in propositions 8, 9, and A.2 hold as long as* $b^{S,E}$ *and* $b^{S,H}$ *are replaced with a unique pair of solutions from equations*

$$b^{S,E} = \frac{\alpha}{1-\pi_1\pi_{1,s}\pi_2 \ \max\{0, h(b^{S,E}, d-b^{S,E})\}}, \tag{96}$$

$$b^{S,H} = s-b^{S,E}, \tag{97}$$

and the bond price at $t=0$ *is replaced with the one in lemma A.7.*
2. The result is continuous at $\pi_1\pi_{1,s}=0$ *provided* $\pi_1>0$.

Proof. We point out that proposition 9 holds in the anticipated crisis case, since the proposition is about $t=1$. The rest of the proof is the same as the proof for proposition A.3 but replaces d with s. Again, we need to verify all optimality of asset positions held by entrepreneurs and households. These conditions hold as long as $\pi_1\pi_{1,s}$ is sufficiently small.

Proposition A.7 shows that our main results in tranching still hold in the neighborhood of unanticipated flight to safety as long as the *ex-ante* likelihood of flight to safety is sufficiently small. Proposition A.8 characterizes the policy implication of tranching. It shows that the results in proposition 10 are robust.

Proposition A.8. *Given a feasible tranching policy s, consider the equilibria characterized in proposition A.7. One of the following cases holds:*
1. The flight-to-safety equilibrium does not exist.
2. The flight-to-safety equilibrium exists. In the flight-to-safety equilibrium, the share of fire-sold capital $S^T(d,s,\pi_1\pi_{1,s})$ *will be the same as that in the baseline model with total debt level s,*

$$S^T(d,s,\pi_1\pi_{1,s}) = S^B(s,\pi_1\pi_{1,s}) \le S^B(d,\pi_1\pi_{1,s}). \tag{98}$$

Proof. Suppose the first case does not hold. From proposition A.7, we know $h(b^{S,E}, s-b^{S,E})>0$. Similar to the argument for proposition 10, we link the share of fire-sold capital S^T to the haircut of senior bonds $h^S = h(b^{S,E}, s-b^{S,E})$. Specifically, equation (40) gives

$$\left(1-h^S\right)s = \tau\underline{A}\frac{K_{1,s}^E}{K_0} = \tau\underline{A}\left(1-S^T\right),$$

which still holds in our case. We obtain

$$S^T\left(d,s,\pi_1\pi_{1,s}\right)=S^T\left(s,\pi_1\pi_{1,s}\right)=1-\frac{\left(1-h^s\right)s}{\tau\underline{A}}=1-\frac{\left(1-h\left(b^{S,E},s-b^{S,E}\right)\right)s}{\tau\underline{A}},$$

where the first equality follows from the irrelevance of d. A similar equation holds for the baseline case,

$$S^B\left(d,\pi_1\pi_{1,s}\right)=1-\frac{\left(1-h\left(b^E,d-b^E\right)\right)d}{\tau\underline{A}},$$

where b^E is implicitly defined by equation (71). Comparing the expression of the share of fire-sold capital in both cases, we know that

$$S^T\left(s,\pi_1\pi_{1,s}\right)=S^B\left(s,\pi_1\pi_{1,s}\right).$$

It remains to show that $S^B(d,\pi_1\pi_{1,s})$ is increasing in argument d. Thereafter the inequality in the claim would follow. We note that the result is nontrivial as b^E endogenously depends on d. For convenience, in the following discussion we omit the argument $(\pi_1\pi_{1,s},d)$ in function $b^E(\pi_1\pi_{1,s},d)$ whenever there is no ambiguity. From equation (21),

$$S^B\left(d,\pi_1\pi_{1,s}\right)=1-\frac{K_{1,s}^E}{K_0}=1-\frac{\beta^*\eta\mathbb{E}_1\left[A\right]+\beta^*\left(1-\pi_2 h\left(b^E,d-b^E\right)\right)b^E}{\beta^*\eta\mathbb{E}_1\left[A\right]+\alpha\beta}.$$

It thus is equivalent to show $(1-\pi_2 h(b^E,d-b^E))b^E$ is decreasing in d. To do that, we note $b^E(\pi_1\pi_{1,s},d)$ is strictly increasing in d when $h(b^E,d-b^E)>0$, which we mentioned in the proof of proposition A.4. From equation (71), we have

$$(1-\pi_1\pi_{1,s})b^E+\pi_1\pi_{1,s}(1-\pi_2 h(b^E,d-b^E))b^E=\alpha,$$

provided $h(b^E,d-b^E)>0$. Now suppose $h(b^E,d-b^E)>0$. Notice the first term in the left-hand side is increasing in d and the right-hand side is a constant. It must be that the second term $\pi_1\pi_{1,s}(1-\pi_2 h(b^E,d-b^E))$ b^E is decreasing in d. Or $(1-\pi_2 h(b^E,d-b^E))b^E$ is decreasing in d. It also follows that $h(b^E,d-b^E)$ is increasing in d.

Notice that for the second case we have $h(b^{S,E},s-b^{S,E})$ $=h(b^E(\pi_1\pi_{1,s},s),s-b^E(\pi_1\pi_{1,s},s))>0$, since $t\in[s,d]$, $h(b^E(\pi_1\pi_{1,s},t),t-b^E(\pi_1\pi_{1,s},t))\geq h(b^E(\pi_1\pi_{1,s},s),s-b^E(\pi_1\pi_{1,s},s))>0$. Our assumption therefore holds for all $t\in[s,d]$. Consequently, $(1-\pi_2 h(b^E(\pi_1\pi_{1,s},t),t-b^E(\pi_1\pi_{1,s},t)))$ $b^E(\pi_1\pi_{1,s},t)$ is increasing in t for $t\in[s,d]$. The second claim follows.

Proposition A.8 shows tranching is still effective as long as the *ex-ante* likelihood of flight to safety is sufficiently small.

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Capital Flow Management with Multiple Instruments

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Emerging markets (EMs) are affected by a global financial cycle originating in developed economies (Rey, 2013). An increase in risk appetite of developed economies, perhaps spurred by easy monetary policy, leads to a surge in capital flows to EMs. These foreign capital flows, especially foreign portfolio investments (FPI) in debt and equity markets (as against foreign direct equity investments or FDI), can reverse quickly, thus leading to a sudden stop and a sharp macroeconomic slowdown. Managing this capital flow cycle is a central concern for EM governments (as discussed by De Gregorio, 2010; and Ostry and others, 2010) and is the focus of this paper.

These points are evident in events of the last 10 years. Figure 1 plots, as an example, FDI and FPI flows into India over the period 2004 to 2017. FPI flows (in dashed grey) drop sharply in the global financial crisis before rising in the post-crisis period, when developed economy interest rates are low. They reverse again in the taper tantrum of 2013,

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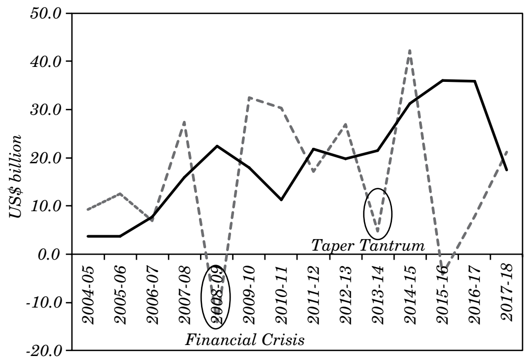
when investors feared that the Federal Reserve may tighten monetary policy (see Krishnamurthy and Vissing-Jorgensen, 2013). When these fears ease in 2014, capital flows resume before falling again in late 2015 as the Fed indeed raises rates. The figure also plots FDI flows, which are far more stable (black line).

The capital flow reversal in the taper tantrum episode led to a sharp depreciation of the Indian rupee (INR). Figure 2 plots the exchange rate (black line) from 2004 to 2017, with the shaded region indicating the taper tantrum period. The rupee depreciated by over 30 percent against the U.S. dollar in the summer of 2013, more so than other EMs on average (grey line in graph).

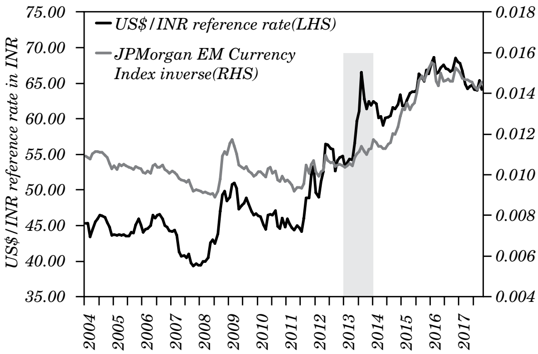
In response to such capital flow volatility and attendant consequences on exchange rates, EMs have adopted two main strategies: hoard foreign reserves and impose capital controls. Reserves can act as a buffer against a sudden stop. See Obstfeld and others (2010)'s discussion of the intellectual history and underpinnings of the role of foreign reserves as a buffer against sudden stops. Capital controls that reduce external debt limit the vulnerability of an EM to sudden stops. The IMF study by Ostry and others (2010) provides a comprehensive examination of the motivation behind capital controls as well as the effectiveness of such controls in practice.

Figure 1. Volatility of FPI and FDI Flows



Source: Reserve Bank of India (RBI). Data for 2017-18 updated until October 2017.
Note: Net Foreign Direct Investment (FDI) in black and Net Foreign Portfolio Investment (FPI) in dash grey.

Figure 2. Exchange Rate and 2013 Taper Tantrum



Sources: Bloomberg, DBIE, and RBI.

This paper revisits the topic of capital flow management, and particularly the interaction between two commonly deployed instruments to achieve it, *viz.*, foreign reserves policies and capital controls. In practice as well as in much of the literature on capital flow management, capital controls and reserves management are cast as *alternative* instruments which can both reduce sudden-stop vulnerability. Our principal theoretical result is that these policies interact and should be seen by central banks as *complementary* instruments. Better capital controls enable more effective reserve management. Likewise, a higher level of foreign reserves dictates stronger capital controls.

Jeanne (2016) is another study that examines the complementarity between these instruments in a somewhat different setting than ours.

The intuition for our key result is simply stated. One way of interpreting the sudden stop is as a state of the world in which foreign creditors refuse to rollover both external (foreign currency) short-term debt and domestic (local currency) short-term debt. This can trigger both a currency crisis and a rollover/banking crisis. Borrowers with external debt will fire-sale domestic assets to convert to foreign currency to repay foreign creditors. Foreign holders of domestic debt will convert repayments from this debt into foreign currency. The liquidation of domestic assets for foreign currency triggers a currency crisis. The rollover problem triggers defaults and a banking crisis. Consequently, our model embeds the twin-crisis nature of sudden stops in EMs (Kaminsky and Reinhart, 1999). The crisis is worsened if the aggregate amount of external and domestic short-term debt is higher, as this results in more fire-sales. On the other side, in the *extremis*, central bank reserves can be used to reduce currency depreciation as well as borrower defaults. Therefore, reserves reduce the magnitude of the fire-sale discount in prices. But *ex ante*, they induce greater undertaking of short-term liabilities by borrowers, a form of moral hazard from the insurance effect of reserves in case of sudden stops: the greater the reserves, the lower the anticipated fire-sale discount in prices, and in turn, the greater the undertaking of short-term liabilities. Hence, unless the build-up of reserves is coincident with capital controls on the growth of short-term liabilities, the insurance effect of reserves is undone by the private choice of short-term liabilities. In other words, reserves and capital controls are complementary measures in the regulatory toolkit.

With capital flows into both foreign-currency and domestic-currency-denominated assets, there arises a further complementarity result. If capital controls can only be introduced on one margin, say foreign-currency debt, then they cannot be too tight. Otherwise, there is the prospect of arbitrage of capital controls between the two markets: borrowing short-term will switch to domestic-currency assets, even if domestic borrowing is costlier in a spread sense as it enjoys weaker capital controls. We show that with an additional instrument, say capital controls on domestic-currency debt, capital controls as a whole can be more effective, which then makes reserve polices also more effective. We show that the design of capital controls in such a setting where the emerging-market currency is internationalized to some extent requires careful weighing of the gains from attracting capital flows, typically in the form of lower cost of borrowing abroad relative to domestically, against the cost of sudden stops and the cross-market regulatory arbitrage of capital controls. Moreover, our main finding continues to hold in this case: Central banks should make reserve management and capital control policy choices understanding that they are complements rather than substitutes.

Our paper contributes to the large literature on the role of reserves and capital controls in managing sudden stops. Ostry and others (2010) provide a comprehensive examination of the motivation behind capital controls, as well as the effectiveness of such controls in practice. Obstfeld and others (2010) discuss the intellectual history and underpinnings of the role of foreign reserves as a buffer against sudden stops. Aizenman and Marion (2003) rationalize the build-up of reserves in Asia as a response to precautionary motives. Jeanne and Ranciere (2011) provide a quantitative analysis regarding how much reserves a central bank should hold, shedding light on the well-known Greenspan-Guidotti rule (Greenspan, 1999). In this literature, typically both reserves and capital controls are viewed as precautionary tools to buffer against sudden stops (for example, Aizenman, 2011). Thus, the literature typically takes the perspective that these tools are substitutes, whereas our main result is that they are complements. Our paper is also related to the classic analysis of Poole (1970) studying the optimal choice of instruments. The principal difference between our analysis and Poole's is that in his model the instruments are substitutes, while in our case they are complements. We discuss this further in the conclusion.

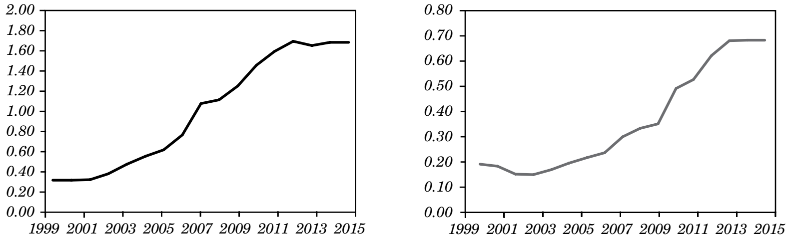
Section 1 presents empirical evidence suggestive of the complementarity perspective. Section 2 builds a model to analyze reserves and capital controls jointly. Finally, as a case study for the analysis, in section 3 we discuss how capital controls have been used in India and how they map into the model's economic forces and implications.

1. EM Liquidity: Empirical Evidence

The left panel of figure 3 plots the total foreign reserves held by central banks in a sample of EMs over the period 1999 to 2015.[1] There is a dramatic increase in foreign reserves after the global financial crisis. From 2006 to 2015, reserves increase from \$0.78 trillion to just over \$1.7 trillion. Indeed, many policy-makers and academics have described the reserve accumulation as a proactive capital flow management strategy. Carstens (2016) documents the dramatic increase in the volatility of capital flows after 2006 (chart 3 of his paper). He notes that the accumulation of international reserves is the primary policy tool EMs have used to manage this capital flow volatility.

1. The countries are: Argentina, Brazil, Colombia, Egypt, Hungary, India, Indonesia, Malaysia, Mexico, Pakistan, Peru, Philippines, Sri Lanka, Thailand, Turkey, and Venezuela. Note that we exclude China in this calculation, primarily because the movement in China's reserve holdings are so large relative to the rest of the EMs. China's foreign reserves rise by about \$2.4 trillion from 2006 to 2015.

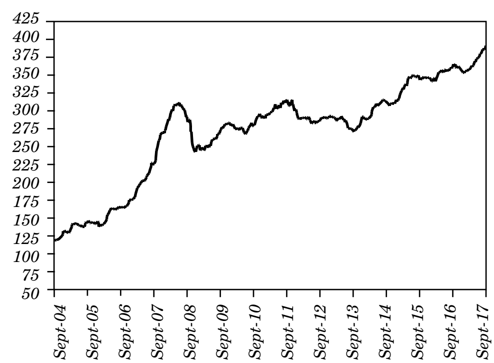
Figure 3. The Left Panel Graphs the Aggregate Foreign Reserves, in Trillions of USD, Across a Sample of Emerging Markets, from 1999 to 2015. The Right Panel Graphs the Aggregate External Short-Term Debt (<1 Year) of These Countries.



Source: International Monetary Fund.

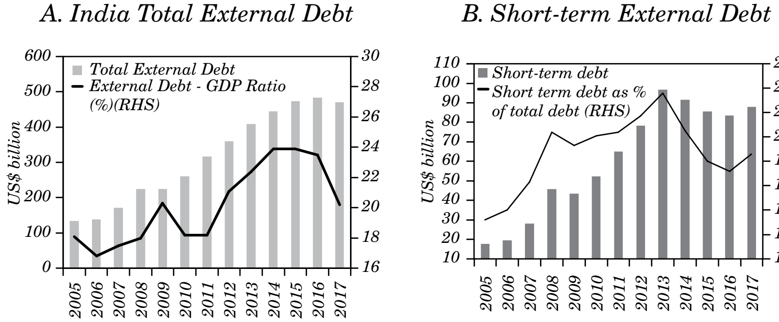
The right panel of figure 3 graphs the aggregate external short-term debt of these EMs. As is well understood in the literature, reserves can act as a buffer against withdrawals of these flows in the event of a sudden stop. External creditors may choose not to rollover their short-term debt, which indicates a liquidity need for the country that is partially covered with foreign reserves. The Greenspan-Guidotti rule, already mentioned above, is a prescription that EMs hold reserves equal to external debt less than one year in maturity. It is apparent that, as foreign reserves have grown, short-term debt has also grown.

Figure 4. Foreign Exchange Reserves for India (US$ billion)



Source: RBI.

Figure 5. India Total and Short-Term External Debt



Source: India's External Debt, a Status Report, 2016-17 by Government of India.

Figure 4 below graphs India's forex reserves, showing that they rose steadily after the global financial crisis and until 2011, dipping slightly by 2012 and then remaining relatively flat until the taper tantrum. In an absolute sense, India's reserves had accumulated by the 2013 taper tantrum to exceed the level in the crisis of 2008 levels, thus suggesting greater external sector resilience. However, the net capital outflow after the Federal Reserve's taper announcement led to a sharp depreciation in the exchange rate, as evident from figure 2. The culprit is short-term debt: the diagnosis of resilience is reversed if one accounts for the build-up of external debt in India.

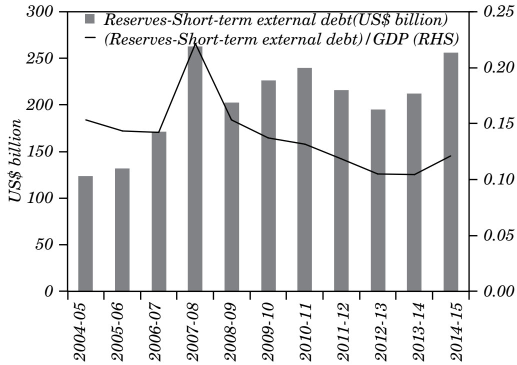
Figure 5, panel A, plots the time series of India's external debt, which rose steadily and was at close to 25 percent relative to GDP around the taper tantrum. Equally important, the short-term component of this debt (with residual maturity less than one year) is seen in figure 5, panel B, to have also risen steadily (to around 20 percent short-term debt) by the 2013 taper tantrum.

Let us define liquidity (or external-sector resilience) metric at the country level:

$$\text{Liquidity}_{i,t} = \frac{\text{Reserves}_{i,t}\text{-ST Debt}_{i,t}}{\text{GDP}_{i.t}}. \tag{1}$$

Figure 6 shows that the liquidity measure had been steadily declining for India from a peak of above 20 percent prior to the global financial crisis to a low of below 10 percent by the taper tantrum, thus more accurately capturing the loss of resilience as witnessed during the period from May to August of 2013.

Figure 6. Country Liquidity = $\dfrac{\textbf{Reserves-Short-term External Debt}}{\textbf{GDP}}$



Source: World Bank, RBI, Ministry of Statistics & Program implementation.

To summarize, the case of India in the build-up to the taper tantrum suggests that forex reserves, *per se*, were not adequate in measuring external sector resilience against sudden stops. The model we develop in this paper studies the linkage between reserves and short-term debt. We will argue theoretically that reserve adequacy is contingent upon the quantity and quality of debt and, in particular, the extent of short-term external debt. Our theoretical analysis also points to the mechanism whereby the increase in reserves in part likely drove the rise in short-term external debt, although it is difficult to causally identify this economic force from the data we have presented.

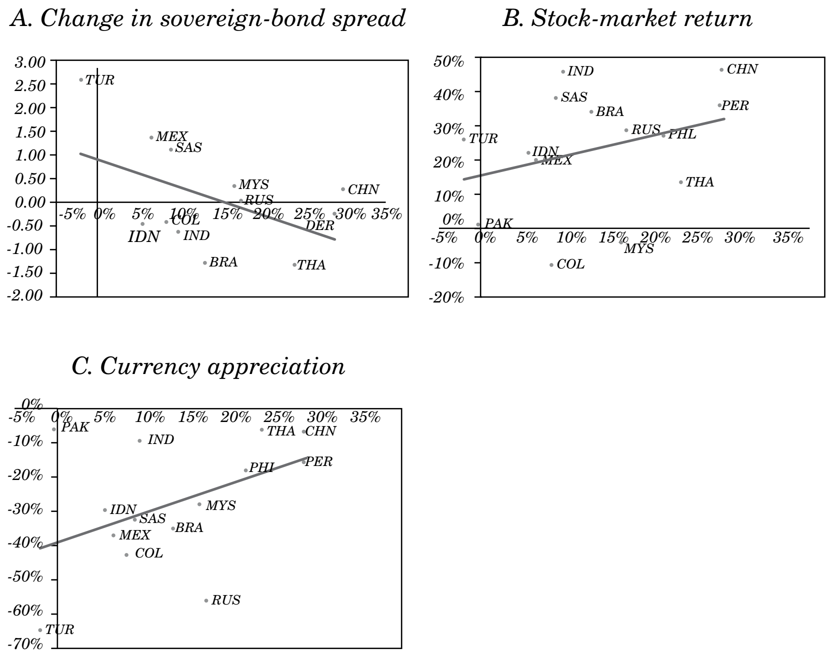
We next investigate the linkage between reserves and short-term debt more broadly across EMs, asking how well the liquidity metric in (1) discriminates among countries in their exposure to the global financial cycle.

Figure 7 plots country liquidity as of 2013, as in (1 with $t = 2013$), against asset price changes, for a group of EMs. We consider asset price changes from June 2013 to October 2017. We begin in June 2013 to include the start of the taper tantrum. Over this period, the global financial cycle turns back towards developed economies, so that, on average, EM currencies depreciate (panel C). The figure reveals that the liquidity metric discriminates between the EMs that are more and less sensitive to the financial cycle. From panel C we see that countries that are more liquid see their currencies depreciate less. Likewise, more liquid countries see sovereign-bond yield spreads rise less (panel A) and experience higher domestic stock-market returns (panel B).

That is, in all cases, higher liquidity is associated with a more favorable EM asset price outcome.

We next turn to high frequency data. The relation in figure 7 reflects a correlation over a long time window, where the global shock is negative for EMs. At a high frequency, we can hope to uncover more shifts in the global cycle and hence better document a relation between liquidity and EM performance. Our approach builds on the literature and particularly Rey (2013), who notes the importance of the VIX for the global cycle. We proxy for the global factor using the VIX multiplied by -1 (i.e., the negative of the VIX). Our normalization is that when the global factor is high we say that capital flows are favorable to EMs. Using the AR(1) innovations to the global factor, we estimate the heterogeneous effect of the global financial cycle on countries with different degrees of liquidity.

Figure 7. Country Liquidity as of 2013 Against Asset Price Changes, for a Group of Emerging Markets



Source: Author's elaboration.
Panel (a) plots liquidity on the x-axis against the change in sovereign-bond yield spreads from June 2013 to October 2017, on the y-axis. Panel (b) plots a similar relation for the country stock-market return. Panel (c) is for the EM currency appreciation against the USD. In all cases, higher liquidity is associated with a more favorable EM asset price outcome.

Table 1 reports the results of panel data regressions. In panel A, the dependent variable is the daily change in the sovereign-bond spread of a given country. The independent variables are the global factor innovations in columns (1) and (2), and the global factor innovations interacted with liquidity, as well as liquidity by itself, in columns (3) and (4). We include country and year fixed effects in all regressions. Columns (2) and (4) restrict the data to observations with large global shocks, defined as those in the 5 percent tails of the distribution of daily global innovations to check for non-linearities. The independent variables have been normalized by dividing by their standard deviation, so that the coefficients can be interpreted as the effect of a one-sigma change.

We see that the global factor innovation comes in with a negative coefficient in all four columns. There is no discernible difference between the cases where we restrict the observations to large shocks, indicating no evidence of non-linearities. The negative coefficients are to be expected as the global factor is defined in terms of good news for EMs (hence, for instance, sovereign-bond spreads fall). The more relevant covariate for our analysis is the second row, which is the global factor innovation interacted with liquidity. Higher liquidity dampens the impact of innovations in the global factor on changes in sovereign-bond spreads. The regression results are consistent with the pattern evident in figure 7.

Panel B reports results for the domestic stock-market return. Stock returns load positively on the global factor. The interaction term has a negative sign, indicating dampening, but the coefficient is not statistically different from zero.

Panel C is for the EM currency appreciation. As expected, the coefficient on the global factor innovation is positive. Again we see evidence of the dampening effect as the coefficient on the interaction is negative and significant.[2]

2. We have experimented with specifications where we include reserves and short-term debt separately in these regressions for Panels A-C. We would expect that the coefficients on these measures will have opposite signs, when interacted with the global factor. However, there is not enough variation in the data to detect this pattern.

Table 1. Liquidity and Shocks to Global Factor

	(1)	*(2)*	*(3)*	*(4)*
	(a) Change in sovereign-bond spread			
	-0.0788	-0.0620	-0.1326	-0.1163
	(3.88)***	(3.47)***		
Liquidity			0.0812	0.0770
Country FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Restrict to large shock	N	Y	N	Y
R^2	0.01	0.04	0.01	0.05
N	21,340	2,047	13,741	1,419
	(b) Stock market return			
Global factor	0.2878	0.2669	0.2775	0.2788
	(6.87)***	(7.07)***	(4.14)***	(4.63)***
Global factor × liquidity			-0.0026	-0.0350
			(0.03)	(0.47)
Liquidity			-0.0029	0.0514
			(0.12)	(0.72)
Country FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Restrict to large shock	N	Y	N	Y
R^2	0.07	0.23	0.07	0.22
N	25,545	2,535	17,549	1,892
	(c) Currency appreciation			
Global factor	0.1496	0.1314	0.2101	0.1860
	(5.08)***	(5.15)***	(3.87)***	(3.91)***
Global factor × liquidity			-0.0937	-0.0860
			(2.27)**	(2.43)**
Liquidity			-0.0020	0.0364
			(0.09)	(0.97)
Country FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Restrict to large shock	N	Y	N	Y
R^2	0.07	0.21	0.08	0.24
N	27,631	2,756	17,837	1,935

Source: Author's elaboration.
** $p < 0.05$; *** $p < 0.01$.

These results from our data analysis indicate that asset price changes in EMs depend on the global shocks, consistent with a number of papers in the literature (Calvo and others, 1996; and Rey, 2013). We also see that the impact of the global factor depends on the liquidity of the EM, which in turn depends on the foreign reserves of the central bank and the external short-term debt of the EM, as we may expect from the literature on international reserves as a buffer against sudden stops. The next section builds on these observations to construct a model to study the management of capital flows when there are multiple policy instruments, *viz.*, reserves management and capital controls.

2. Model of Macroprudential Management of Capital Flows

This section lays out a model of EM firms, more generally, banks or governments, which borrow from foreign investors to fund high return investments. The model is closest to Caballero and Krishnamurthy (2001), and Caballero and Simsek (2016). Foreign investors are "fickle" in the sense of Caballero and Simsek (2016): they may receive a shock that requires them to withdraw funding from the EM. The loss of funding leads to a fire-sale, which depreciates the exchange rate, and creates an external effect for all borrowers as in Caballero and Krishnamurthy (2001). The central bank has foreign reserves that it can use to reduce the fire-sale and stabilize the exchange rate. We study the connections between the central bank's actions and private sector borrowing decisions. We first lay out a model where all borrowing is via an external debt market, i.e., dollar debt. We then introduce foreign lending in domestic-currency debt.

2.1 Model with External Debt Market

The model has three classes of agents: domestic borrowers (B), foreign lenders (FL), and a central bank (CB). There are three dates: $t = 0, 1, 2$. Date 0 is a borrowing and investment date, at date 1 there are shocks, and at date 2 there are final payoffs.

There is a continuum of borrowers with unit mass. Each B has a project that requires capital and own labor. B's utility is:

$$U^B = E[c_2 - l_0 - l_1] \qquad c_2, l_0, l_1 \geq 0, \tag{2}$$

where c_2 is date 2 investment and l_0 and l_1 are disutility from labor at date 0 and date 1.

The borrower has an investment project at date 0. B can create K units of capital by borrowing,

$$L^F = K \tag{3}$$

goods from foreign lenders, and providing labor of $l_0(K)$, with $l_0(\cdot)$ increasing and convex. The project pays $(1+2R)K$ at date 2 and cannot be liquidated early.

FL are the only lenders at date 0. They have a large endowment of goods and are risk neutral. FL's required return in lending to the EM is $1+r$. A period in which developed market interest rates are low corresponds to a period when r is low. Additionally, if risk appetite for EM bonds is high, we can think of r as being low.

Our key assumption is that lenders are fickle. With probability ϕ they may receive a retrenchment shock at date 1, in which case they need to withdraw their funding. We assume that it is not possible to write contracts contingent on this shock. Consequently, the foreign lenders lend via one-period loans that may or may not be rolled over. It is clearest to think of these loans as in units of "dollars."

If a loan is not rolled over, borrowers owe foreign lenders $L^F(1+r)$ dollars. Loans must be repaid; bankruptcy costs are infinite. To repay a loan, the borrower turns to domestic lenders to borrow funds against collateral of K units of the project. We assume these lenders are present at date 1 and are willing to lend against collateral of K at interest rate of r. The borrower raises $(1+r)K$ domestic currency ("rupees"), with promised repayment of $(1+2r)K$, converts this to $e(1+r)K$ dollars, so that the borrower raises a total of $e(1+r)K$. Here e is the exchange rate in units of dollars per rupee. A depreciated rupee corresponds to a low value of e. The shortfall to the borrower, i.e., owed dollar debt minus funds raised from the domestic loan, is $K(1+r)(1-e)$. The borrower makes up this shortfall by working hard and suffering disutility,

$$l_1 = \beta(K(1 + r)(1 - e)), \tag{4}$$

with $\beta(\cdot)$ increasing and convex. By doing so, and with funds from the domestic loan, the borrower repays $(1+r)K$ in full. $\beta(\cdot)$ is modeled as disutility of labor to keep the model concise rather than to reflect realism. We think of $\beta(\cdot)$ as the deadweight cost of bankruptcy. More generally, it can reflect costly adjustments that must be made in order to meet debt payments.

The central bank has total foreign exchange reserves of X^F which it can use to stabilize the exchange rate. We assume that the exchange rate at all dates other than the retrenchment state is one, and can fall to $e<1$ in the retrenchment state. Henceforth, when discussing the exchange rate e, this e refers to the exchange rate in the retrenchment state at date 1.

Given e we can write the borrower's problem. The utility from choosing $K=L^F$ is,

$$U^B = 2(R-r)L^F - l_0(L^F) - \phi\times\beta(L^F(1+r)(1-e)). \tag{5}$$

Define $\Delta \equiv R - r$. The first order condition (FOC) is:

$$l_0'(L^F) = 2\Delta - \phi\times(1-e)(1-r)\beta'(L^F(1+r)(1-e)). \tag{6}$$

Note that Δ matters in the model, more so than the level of R or r. We henceforth set

$$r = 0 \tag{7}$$

to simplify some expressions. The term Δ can be thought of as the carry offered by the EM.

In equilibrium in the retrenchment state, borrowers pledge K units of collateral to raise L^F rupees and exchanges these domestic funds for X^F units of dollar. The exchange rate is then,

$$e = \frac{X^F}{L^F} \tag{8}$$

Throughout out analysis we will assume that parameters are such that $e<1$. The exchange rate expression reflects the fire-sale externality in our model. When a borrower increases date 0 borrowing and investment, he pushes up K, which then implies that the date 1 retrenchment exchange rate is more depreciated, thus increasing the debt burden $(L^F(1-e))$ to all borrowers. Substituting from (8) into (5) above we can write the aggregate borrower utility as

$$2\Delta L^F - l_0(L^F) - \phi\times\beta(L^F - X^F).$$

This aggregate corresponds to a welfare function for borrowers who account for the effect of their borrowing (L^F) on the exchange rate and hence the repayment ability of other borrowers. The FOC for the aggregate is,

$$l_0'(K) = 2\Delta - \phi\times\beta'(L^F - X^F) \tag{9}$$

We compare (6) to (9) and see that,

Proposition 1. *(Overborrowing)*

1. *Let $L^{F,priv}$ be the solution to the first order condition in (6), and $L^{F,agg}$ be the solution to (9). Since $1 > 1 - e$, the private solution features overborrowing:*
$L^{F,priv} > L^{F,agg}$.
The private choices of K and L^F are larger than the coordinated choices.
2. *Take the case where β is linear, or not too convex.*[3] *Then, since e is increasing in X^F, the private sector overborrowing (gap between private and coordinated solution) increases in X^F. Central bank reserves are a form of bailout fund. The larger the bailout fund, the greater the private sector borrowing.*[4]

How can borrowers implement the coordinated optimum? In our model there are at least two solutions. A planner can set a borrowing limit on L^F which directly implements the optimum. Or, the planner can set a tax rate on external borrowing, τ^F, so that a borrower who raises L^F pays $\tau^F L^F$ to the planner, who then rebates the funds to the borrowers. With this tax, the borrower would maximize:

$$2\Delta L^F - l_0(L^F) - \phi\times\beta(L^F(1-e)) - \tau^F L^F + T. \tag{10}$$

where $\tau^F L^F$ is the borrowing tax and T is the lump sum rebated to the borrower. The optimal tax is set so that the private FOC is equal to the social FOC. It is straightforward to see that,

$$\tau^F = \phi\times\beta'(L^F(1-e)). \tag{11}$$

3. The caveat is necessary because if reserves are large enough that e approaches one, then the cost of bankruptcy goes to zero.

4. If we do not assume $r=0$, which we have for simplicity, then it can be shown that as r falls and hence Δ rises, K and L^F rise. Since $\beta(\cdot)$ is convex, the term $\beta'(L^F - X^F)$ is increasing in K (and L^F). Thus a lower world interest rate, or increase in foreign investors' risk appetite, exacerbates the overborrowing problem. If bankruptcies create spillovers to un-modeled sectors, via bank losses for example, that are increasing in the amount of bankruptcy, then β is increasing in K, and the problem is reinforced.

The tax is increasing in the probability of the foreign run state, ϕ. It is also increasing in the expected marginal deadweight cost of the retrenchment state, $e \times \beta'(L^F(1-e))$, which we note is itself increasing in L^F. Our result that capital flow taxes on EM borrowers can beneficially correct an overborrowing problem is similar to Caballero and Krishnamurthy (2004), and Jeanne and Korinek (2010).

2.2 Optimal Reserve Holdings and Taxes

We next study the central bank's holdings of reserves and consider how reserve holdings affect welfare. Suppose that holding reserves for the central bank comes at a cost $\kappa(X^F)$, where κ is an increasing and convex function of X^F. We take this cost in reduced form. We can think there are other forms of capital flows, say FDI or equity, which the central bank uses to accumulate foreign reserves. In this case, κ is the opportunity cost of the alternative activity. Then, consider the following welfare function:

$$W(L^F, X^F) \equiv 2\Delta L^F - l_0(L^F) - \phi \times \beta(L^F - X^F) - \kappa(X^F) \tag{12}$$

How much X^F would a central bank choose knowing that the choice of X^F affects L^F? We optimize over X^F given that $L^F(X^F)$. The FOC is,

$$L^{F'}(X^F)\,\{2\Delta - l_0'(L^F) - \phi \times \beta'(L^F - X^F)\} + \phi\beta'(L^F - X^F) - \kappa'(X^F) = 0.$$

The term in brackets $\{\cdot\}$ can be simplified using the private FOC, (6). We find:

$$-L^{F'}(X^F) \times \phi \times e\beta'(L^F - X^F) + \phi \times \beta'(L^F - X^F) - \kappa'(X^F) = 0$$

so that,

$$\phi\beta'\left(L^F - X^F\right) = \frac{\kappa'(X^F)}{\left(1 - eL^{F'}(X^F)\right)}. \tag{13}$$

It is instructive to compare this expression to the case where the central bank can directly choose L^F. In that case, the term in the brackets {} goes to zero so that the FOC is

$$\phi\beta'(L^F - X^F) = \kappa'(X^F). \tag{14}$$

In this latter case, the intuition for the choice of X^F is clear. The marginal cost of reserves is increasing in κ' and the marginal benefit of holding reserves is the reduction in expected default cost $\phi\beta'(L^F - X^F)$. The optimal holding of reserves equates these two margins.

In the former case, when the private sector chooses L^F, the cost of reserves is higher. Algebraically we can see it is higher since $1 - eL^{F'}(X^F) < 1$ as $e > 0$ and $L^{F'}(X^F) > 0$. Intuitively, the private sector chooses a higher L^F in response to a higher X^F. Therefore, the effective cost of reserves is increased from κ' to $\frac{\kappa'}{1 - eL^{F'}(X^F)}$. The central bank recognizes that increasing X^F provides beneficial insurance, but that the private sector will undo some of this beneficial insurance by overborrowing and increasing L^F. The central bank cuts back on its optimal reserve holdings as a result.

To summarize:

Proposition 2. *(Complementarity between policy instruments I)*

• *If the central bank can directly choose L^F via a borrowing limit or external-borrowing tax, then it chooses X^F to solve (14). Call this maximized value X^F_{**}.*

• *If the central bank does not have instruments to directly affect L^F, then it chooses X^F to solve (13). Call this maximized value X^F_*. We then have that,*

$X^F_{**} > X^F_*$.

• *With two instruments, taxes and reserves, the central bank can do strictly better than with only one instrument. The two instruments are complements in the sense that taxing ability allows for more reserve holdings; likewise, more reserve holdings dictate higher taxes.*[5]

2.3 Heterogeneity among Borrowers

We extend the model to allow for heterogeneity. Suppose that in a retrenchment shock some firms are more exposed than others. In particular suppose that the probability a given firm will suffer loss of funding in the retrenchment shock is p_i where i indices borrowers. We can think of p_i as capturing the relative safety of a firm. We may expect that larger, more stable, or more export-oriented firms will be less exposed to the retrenchment shock.

5. This complementarity result is derived in a somewhat different setting by Jeanne (2016).

Borrower-i's problem is to maximize,

$$U^{B,i} = 2\Delta L^{F,i} - l_0(L^{F,i}) - \phi p_i \times \beta(L^{F,i}(1-e)) - \tau^{F,i} L^{F,i} + T \tag{15}$$

where we have allowed the tax rate to be borrower-specific, $\tau^{F,i}$. The FOC is,

$$l'_0(L^{F,i}) = 2\Delta - \phi p_i \times (1-e)\,\beta'(L^{F,i}(1-e)) - \tau^{F,i}$$

Aggregating across all borrowers, accounting for the likelihood of retrenchment for borrower i given loan amount $L^{F,i}$, the equilibrium exchange rate is,

$$e = \frac{X^F}{\overline{L}^F} \text{ where } \overline{L}^F = \int_i p_i L^{F,i}\, di. \tag{16}$$

Next, consider the coordinated solution where we use an equal-weighting welfare function:

$$\overline{U}^B = \int_i U^{B,i} di. \tag{17}$$

By differentiating with respect to an increase in borrower-i's loan amount, accounting for the effect on all other j through the exchange rate, we have that:

$$\begin{aligned}\frac{\partial \overline{U}^B}{\partial L^{F,i}} = &\left(2\Delta - l'_0\left(L^{F,i}\right) - \phi pi \times (1-e)\beta'\left(L^{F,i}(1-e)\right)\right) \\ &-\phi p_i \int_j \left(p_j e \beta'(L^{F,j}(1-e)) \frac{L^{F,j}}{\overline{L}^F}\right) dj.\end{aligned} \tag{18}$$

The second term on the right-hand side is the externality term. Increased borrowing by i puts pressure on the exchange rate in proportion to the borrower's retrenchment exposure p_i.

The optimal tax rate is chosen to equate the social and private margins. It is straightforward to derive that:

Proposition 3. *(Borrowing taxes)*

The optimal tax on borrower-i is,

$$\tau^{F,i} = \phi p^i \int_j \left(p_j e \beta'(L^{F,j}(1-e)) \frac{L^{F,j}}{\overline{L}^F}\right) dj. \tag{19}$$

Note that the term in the integral (19) is common across all borrowers. So if we compare the optimal tax rate for two borrowers, i and i', we find

$$\frac{\tau^{F,i}}{\tau^{F,i'}} = \frac{p^i}{p^{i'}}.$$

Finally, the tax rate expression (19) simplifies substantially for the special case of the model where the bankruptcy cost is linear, $\beta(z) = B \times z$. In this case,

$$\int_j \left(p_j e \beta' (L^{F,j} \ (1-e)) \frac{L^{F,j}}{\overline{L}^F} \right) dj = \overline{p} e B$$

so that,

$$\tau^{F,i} = \phi p^i \times \overline{p} e B$$

which can be readily compared to (11) for the homogeneous borrower case. The optimal tax is proportional to the pressure caused by borrower-i times the increase in expected bankruptcy cost caused by the additional borrowing.

The central implication of this analysis is that, in general, capital flow taxes should be borrower-specific and depend on the fire-sale externality imposed by a given borrower. In many cases, such contingency is hard to implement. But it is nevertheless the implication of the theory. Indeed, our analysis implies that, if taxes are set positive but uncontingent on borrower type, an across-firm distortion rises. High p^i borrowers will over-borrow, while low p^i borrowers will underborrow, all relative to the social optimum.

2.4 Domestic Loan Market

We return to the homogeneous borrower case but extend the model to introduce a domestic (rupee) loan/bond market at date 0. The market is for borrowing in local currency from either domestic or foreign lenders. Given our focus on foreign lending, we suppress domestic lenders, or alternatively can think of our modeling as net of the loans from domestic lenders. The date 0 cost of borrowing on domestic loans is $r^D > r$. The higher rate stems from the possibility of a currency depreciation, weaker legal protection in the domestic market, higher information requirements to ensure sound collateral, and so on. As noted earlier, we fix the currency to be worth one at date 0 and in the non-retrenchment state. It may depreciate to $e < 1$ in the retrenchment state. Additionally, the cost for a foreign lender to participate in the local market is s, covering the collateral issues mentioned. Thus, the return to an external lender in the domestic bond market is,

$$(1 - \phi)\,(1 + r^D) + \phi(1 + r^D)e - s.$$

Since foreign lenders can either buy domestic bonds or foreign bonds by paying r, the domestic interest rate must satisfy:

$$r^D - r \approx s + \phi\,(1 - e). \tag{20}$$

The domestic spread reflects the cost of lending in the local market, s, and the loss to foreign lenders due to the exchange rate depreciation in the sudden-stop state. As noted, we set $r = 0$ so that the required return on domestic borrowing simplifies to, $r^D = s + \phi\,(1 - e)$. A borrower who agrees to repay L^D at date 1 raises $\dfrac{L^D}{1 + s + \phi(1 - e)}$ at date 0.

We have described the rate r^D on borrowing at date 0. Next, consider date 1. We assume that in the rollover market at date 1, the cost of domestic borrowing is r rather than r^D. Although asymmetric, this latter assumption serves to simplify some algebraic expressions.

Foreign lenders can lend domestically or externally, and run at date 1 against either type of debt with probability ϕ. Define total borrowing as

$$K = L^F + \frac{L^D}{(1 + s + \phi(1 - e))} \tag{21}$$

where L^F is external loans from foreign lenders and L^D is domestic loans from foreign lenders.

At date 1, if there is retrenchment shock, borrowers have to come up with L^F dollars to repay external debt. They raise $L^F(1 - e)$ via domestic loans, and pay for the shortfall via the bankruptcy/adjustment costs of $\beta(\cdot)$.

In the domestic loan market, the retrenchment shock also leads to a need for funding. We assume (symmetrically with the case of external debt) that other domestic lenders are able to step in and rollover the borrower's debts. However, the foreign lenders receive their local funds of L^D and convert them into dollars since they need to retrench into dollars. This potentially depreciates the exchange rate:

$$e = \frac{X^F}{L^F + L^F} \text{ for } e < 1. \tag{22}$$

A larger outflow triggers a greater depreciation; and, the central bank can intervene to reduce the depreciation by using foreign reserves of X^F. Note our symmetric treatment of foreign and domestic loans. Our model captures a sudden stop as a "twin crisis" in the sense of Kaminsky and Reinhart (1999), and Chang and Velasco (2001). A domestic debt crisis triggers an outflow of capital which adds to a currency crisis.

Given e, the borrowers choose their investment and funding at date 0. They maximize,

$$U^B = 2\Delta L^F + \left(2\Delta - r^D\right)\frac{L^D}{(1+r^D)} - l_0(K) - \phi \times \beta\left(L^F(1-e)\right).$$

The second term here reflects that when $r^D > 0$ domestic borrowing results in less profits than foreign borrowing.

For the analysis of this section we assume that that the bankruptcy cost is linear in its argument, that is, $\beta(x) = Bx$. Then,

$$U^B\left(L^F, L^D, e\right) = 2\Delta\left(L^F + \frac{L^D}{(1+r^D)}\right) - l_0\left(L^F + \frac{L^D}{(1+r^D)}\right)$$
$$-\phi \times B \times L^F(1-e) - (s + \phi(1-e))\frac{L^D}{(1+r^D)}.$$

This expression highlights the key difference between domestic and foreign borrowing. External borrowing brings a potential bankruptcy cost of $B \times L^F(1-e)$. The *borrower* bears the retrenchment cost ex-post and accounts for it when making the ex-ante borrowing decision. Domestic borrowing avoids this cost but requires the higher ex-ante spread of $r^D = s + \phi(1-e)$. The *lender* bears the retrenchment cost ex-post, and charges for it ex-ante by increasing the domestic spread. Next consider the central bank's objective.

$$W\left(L^F, L^D, X^F\right) = 2\Delta\left(L^F + \frac{L^D}{1+r^D}\right) - l_0\left(L^F + \frac{L^D}{1+r^D}\right) - \tag{23}$$
$$\phi \times \mathrm{B} \times L^F(1-e) - (s + \phi(1-e)) - \kappa(X^F).$$

We simplify this expression and the following algebra by assuming that r^D is relatively small so that we can take $\frac{1}{1+r^D} \approx 1$. In this case, we rewrite the objective as

$$W(L^F, L^D, X^F) \approx 2\Delta(L^F + L^D) - l_0(L^F + L^D) \\ -\phi \times B \times L^F(1-e) - (s + \phi(1-e))L^D - \kappa(X^F) \tag{24}$$

The central bank chooses (L^F, L^D, X^F) to maximize $W(\cdot)$. Differentiating, we have that,

$$\frac{\partial W}{\partial L^F} = 2\Delta - l_0'(K) - \phi(1-e)B + \phi(L^D + BL^F)\frac{\partial e}{\partial L^F}$$

and,

$$\frac{\partial W}{\partial L^D} = 2\Delta - l_0'(K) - (s + \phi(1-e)) + \phi(L^D + BL^F)\frac{\partial e}{\partial L^D}.$$

These two expressions give the marginal value of more domestic loans and foreign loans. Notice from (22) that $\frac{\partial e}{\partial L^D} = \frac{\partial e}{\partial L^F}$. That is, an extra unit of either domestic or foreign loans results in the same pressure on the exchange rate and hence has the same fire-sale externality. This is because in the case of an extra unit of foreign loans, the borrower worsens the fire-sale with the extra unit of loans. In the case of domestic loans, the lender worsens the fire-sale with the extra unit of domestic loans. But the marginal fire-sale impact does not depend on the denomination of the loan.[6] Then, the difference in these marginal values is,

$$\frac{\partial W}{\partial L^F} - \frac{\partial W}{\partial L^D} = s + \phi(1-e) - \phi(1-e)B.$$

Foreign borrowing is socially preferable if the domestic spread s is high and the bankruptcy costs B are low, otherwise domestic borrowing is preferred.

6. In our formulation L^F and L^D appear symmetrically in equation (22). But it is also plausible that a unit of external borrowing applies more pressure on the exchange rate in the sudden-stop state. In this case, the external borrowing carries a higher externality than the domestic borrowing, analogous to our study of heterogeneity among borrowers. We set this effect aside because it is not central to our conclusions. For an analysis of the issue, see Caballero and Krishnamurthy (2003).

Next consider implementation of the optimum. Suppose that the spread s is high so that foreign borrowing is preferred to domestic borrowing. How can the central bank implement the optimum via taxes? This case superficially appears similar to our early analysis. However, there is a key difference. Increasing taxes on foreign borrowing decreases aggregate borrowing, but also *shifts borrowing to domestic markets*. To see this, let us write the borrower's objective with the foreign debt tax:

$$U^B(L^F, L^D, e) = 2\Delta(L^F + L^D) - l_0(L^F + L^D) \\ - \phi \times B \times L^F(1 - e) - (\mathrm{s} + \phi\,(1 - \mathrm{e}))L^D - \tau^F L^F. \tag{25}$$

The derivative of U^B with respect to the two forms of borrowing are:

$$\frac{\partial U^B}{\partial L^F} = 2\Delta - l_0'(K) - \phi(1-e)B - \tau^F$$

and,

$$\frac{\partial U^B}{\partial L^D} = 2\Delta - l_0'(K) - (s + \phi(1-e)).$$

As taxes, τ^F, increase, the borrower optimally chooses lower foreign borrowings L^F. However, if

$$\phi(1 - e)B + \tau^F > s + \phi(1 - e)$$

the borrower takes no external loans and shifts fully to domestic borrowing. At this point, the tax policy is completely ineffective.

We account for this substitution effect by placing an additional constraint on the central bank. The central bank maximizes (24) subject to a constraint on taxes:

$$\tau^F \leq s + \phi(1 - e) - \phi(1 - e)B. \tag{26}$$

The final result of the analysis is that the tax constraint can be relaxed. Suppose that the central bank can also tax domestic borrowing. Then, the tax constraint becomes

$$\tau^F \leq \tau^D + s + \phi(1 - e) - \phi(1 - e)B. \tag{27}$$

We highlight this result as:

Proposition 4. *(Complementarity between policy instruments II) Domestic-borrowing taxes, external-borrowing taxes, and holdings of foreign reserves are complimentary policy tools. With the ability to level a tax on domestic borrowing, the central bank can decrease aggregate borrowing without distorting the balance between foreign and domestic borrowing, which results in a higher welfare for the economy.*

3. Macroprudential Measures Deployed in India

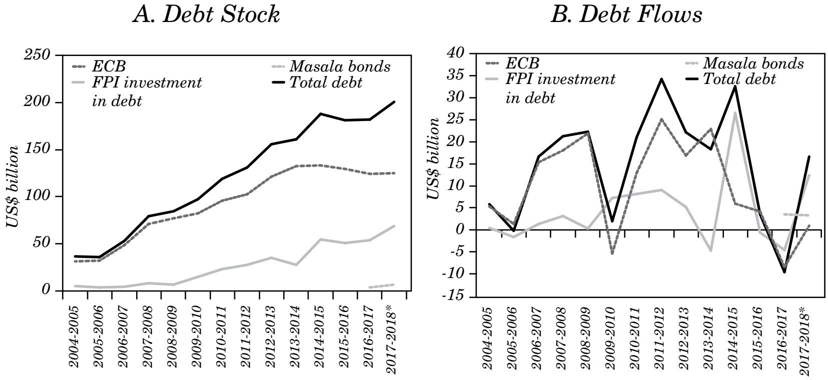
India has deployed a range of macroprudential measures to contain the impact of sudden stops and reversals of foreign capital flows, and the concomitant shocks to the financial and real sector. Many of these measures had been in place prior to the taper tantrum; however, the taper tantrum led to a further revision of their nature, as explained below. In this section, we discuss these measures through the lens of our theoretical model of optimal capital controls.

India has three principal kinds of external debt once various forms of government debt from multilateral agencies, as well as non-resident Indian deposits, are excluded (the latter have usually been a source of stability for India during stress episodes): FPI in domestic debt (in both Government of India securities at center and state level, as well as corporate bonds); external commercial borrowings (ECB), which are typically loans to Indian corporations, quasi-government entities or private firms, denominated in foreign currency; and, introduced most recently, the rupee-denominated bonds (RDB) or "Masala bonds" issued overseas, again by quasi-government entities or private firms, typically listed on the London Stock Exchange.

Net investments (stock in panel A, flow in panel B) in these various segments of external debt are plotted over time in figure 8. The ECB contributed to the bulk of such external debt flows until the taper tantrum, after which time the FPI debt flows have overtaken as the most significant component. It is also worth pointing out the growth in the Masala Bond in 2017 as ECB borrowings fall. This switch in the nature of external debt is also reflected in table 2 which shows that the foreign-currency-denominated external debt has steadily declined since 2014 while the INR-denominated component has grown. We will discuss this substitution pattern in terms of proposition 4.

Macroprudential capital controls with regard to these different forms of external debt are briefly explained below, placing the various controls into broad categories so as to interpret them in terms of our model's normative implications:

Figure 8. Debt Stocks and Flows



Sources: RBI, NSDL, and SEBI.

Table 2. Currency Composition of External Debt (%), End-of-March

Currency	Year						
	2011	2012	2013	2014	2015	2016 (PR)	2017 (QE)
1 U.S. dollar	55.3	56.9	59.1	61.1	58.3	57.1	52.1
2 Indian rupee	18.8	20.5	22.9	21.8	27.8	28.9	33.6
3 SDR	9.4	8.3	7.2	6.8	5.8	5.8	5.8
4 Japanese yen	10.9	8.7	6.1	5.0	4.0	4.4	4.6
5 Euro	3.6	3.7	3.4	3.3	2.3	2.5	2.9
6 Pound sterling	1.6	0.9	0.7	1.1	0.9	0.8	0.6
7 Others	0.4	1.0	0.6	0.9	0.9	0.5	0.4
Total (1 to 7)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Based on data from RBI, CAAA, SEBI, and Ministry of Defence.
PR: Partially revised. QE: Quick Estimate.

3.1 Caps on Exposure to Global Shocks

These are presently in the form of absolute size limits on (i) total FPI in domestic securities by asset class, with separate limits for Government of India securities (G-secs), State Development Loans (SDL), and corporate bonds, amounting to around US$39 billion, US$6 billion, and US$36 billion, respectively, or a total of about US$80 billion across the three asset categories; and on (ii) ECBs and Masala bonds together, amounting to a total of about US$130 billion.

From the standpoint of our model, the aggregate short-term external liability that cannot be rolled over relative to the forex reserves of the country is what matters for macroeconomic outcomes in the sudden-stop state. Moreover, the complementarity perspective of our model indicates that borrowing limits should be closely tied to the central bank's holdings of foreign reserves.

In practice, the limits discussed have either been set as a percentage of the underlying market size (as in the case of the G-sec and SDL limits), or set as an absolute number (as in the case of corporate debt limits). In both cases, roll-out of the limits has been calibrated over quarters, i.e., gradually, presumably based on considerations outside of our model such as implications of capital inflows on the exchange rate. Our analysis suggests that optimal limits should depend on *stocks* of debt rather than *flows*. They should also be contingent on central bank reserve holdings.

That being said, there are several aspects to these limits which conform to the model's implications. In particular, there are limits by investor and by borrower- or issuer-type, as well as restrictions on nature of the debt. These aspects have evolved over time given India's experience with external sector vulnerability. We discuss these aspects next.

Table 3. FPI Limits (US$ billion)

	Central government securities			*State development loans*			*Corporate bonds*		
Effective for quarter	*General*	*Long term*	*Total*	*General*	*Long term*	*Total*	*General*	*Long term FPIs Inf.*	*Total*
2017-18 Q3	29.29	9.31	38.60	4.63	1.44	6.07	33.64	1.47	35.10

Sources: RBI, and DBIE.

3.2 Restrictions on Investors by their Horizon of Investment

Within FPI limits for G-sec, SDLs and corporate bonds, there are sub-limits by investor type as shown in table 3, in particular, for *Long Term* versus *General* investors, where long term includes insurance firms, endowments and pension funds, sovereign wealth funds, central banks, and multilateral agencies; whereas general covers all other qualified institutional investors. The long term category has been added to the corporate bonds limit only since October 2017. Prior to July 2017, the unutilized portion of the long term category was transferred to the general category, a feature that has since been removed.

These investor-specific investment restrictions can be understood in terms of proposition 3. We showed that limits should be type-dependent, where type referred to borrower. By extension, it follows that limits should optimally depend on investor horizon to the extent that the immediacy demanded by short-term investors (typically carry traders) creates a fire-sale externality in the sudden-stop state. There is no obvious rationale within our model, however, for the transfer of unutilized long-term limits to short-term investors, as this would over time increase the short-term investor limit towards the overall limit, as indeed has been the case for India.

Interestingly, FPI restrictions in the past also included sub-limits for 100 percent debt funds as against minimum 70:30 equity-debt investment ratio funds. In addition, there were minimum lock-in periods of up to three years on investors once they purchased Indian debt securities. While such restrictions would also find support under our model as ways to limit the type of short-term external debt, these have over time been replaced entirely by investor categories based on horizon (long term vs general) and minimum maturity restrictions (which we explain below).

Counter to our theoretical analysis, long-term investors such as pension funds, insurance companies and sovereign wealth funds were not allowed by India to be eligible lenders in ECBs until 2015. There is, however, an indirect policy attempt to ensure that the sudden-stop risk does not directly affect the domestic banks (who have significant deposit liabilities), a feature that our model would support. This is achieved by disallowing the refinancing of ECBs by Indian banks as well as preventing the underlying ECB exposure to be guaranteed by Indian banks, financial institutions, or non-bank financial companies (NBFCs).[7]

3.3 Restrictions on Maturity of the Underlying Investment

Presently, FPIs are disallowed altogether from investing in liquid short-term money-market debt instruments such as Treasury bills or commercial paper (CP). Prior to the taper tantrum however (November 2013 to be precise), there was a carve-out for FPI investments in Treasury bills and CP, as shown in table 4. Since the taper tantrum, India has introduced even tighter restrictions in the form of residual maturity restrictions of investments by FPIs in debt holdings to be of minimum three years of maturity at origination or purchase. If one assumes that the arrival of the sudden-stop state is exogenous, as in our model, then these restrictions are potentially effective ways of limiting short-term external debt in case such a state materializes.[8]

Table 4. Debt Investment Restrictions

Type of securities	*April-2013 US$ bn*	*Jun-2013 US$ bn*	*Nov-2013 US$ bn*
1. Government debt	25	30	30
a. T-bills within overall limit	5.5	5.5	5.5
b. Carved out limit for SWFs & other LT FIIs	-	5	5
2. Corporate bond	51	51	51
a. CPs within overall limit	3.5	3.5	3.5
b. Credit enhancement bonds within overall limit	-	-	5
3. Total limit (1+2)	76	81	81

Sources: DBIE, and RBI.

7. These restrictions on domestic financial institutions were in part also to avoid the ever-greening of non-performing loans.

8. Another possible rationale for requiring FPIs to hold longer-dated instruments is that it exposes them to greater interest-rate risk, which could deter excessive presence of short-term investors looking for “carry” by arbitraging interest-rate differentials with an early exit.

A similar rationale for limiting the maturity of underlying external debt also exists for ECBs. Following the taper tantrum, policies were revised in November 2015 to require that a borrower could undertake an ECB of up to US$50 million (foreign-currency-denominated under the so-called Track-I of ECB, or INR-denominated under Track-III of ECB) with minimum average maturity of 3 years; or up to US$50 million if the maturity is 5 years. In contrast, no borrowing limit within the overall ECB limit is imposed for borrowings meeting a minimum average maturity of 10 years (for foreign-currency-denominated borrowing under Track-II of ECB). These maturity restrictions were not as onerous prior to the taper tantrum.

3.4 Restricting High Liquidity Demanders

Our model suggests a Pigouvian form of taxation, wherein borrowers who contribute more to the fire-sale externality in the sudden-stop state are charged a greater tax for taking on short-term external debt (proposition 3). Indian capital controls ensure that only relatively high credit quality borrowers tap into ECBs by (i) imposing coupon ceilings by debt issue, (ii) carving out sub-limits on investments in risky instruments such as unlisted corporate bonds and security receipts (a form of distressed asset resolution instrument), and (iii) ruling out excessive correlated liquidations by having investment sub-limits by sector. These restrictions limit ECBs to high-rated borrowers, as suggested by our model. However, this form of differential taxation does not exist for domestic debt issuances purchased by the FPIs, except to the extent that the current market-practice in the domestic corporate debt market is to fund only relatively high-rated investment-grade borrowers.

Closest to the model are the all-in-cost (AIC) issuance cost ceilings for ECBs, which prescribe that borrowers in the 3- to 5-year range cannot issue ECBs at a coupon of 6-month Libor + ceiling as indicated in table 5. A higher ceiling applies for issuances greater than 5-year maturity. These ceilings have evolved over time in a somewhat countercyclical manner relative to the evolution of 6-month Libor (figure 9): as global interest rates eased post the global financial crisis, the coupon ceilings were raised, and with global rates tightening since 2015, the ceilings were lowered.

Table 5. Evolution of AIC spread (in bp) over Libor-6 month/ Swap

Minimum average maturity	*3 year to 5 year*	*More than 5 year*
2004-05	200 bps	350
2007-08	150	250
2008-09	200	350
2009-10	300	500
2011-12	350	500
2015-16	300	450

Sources: DBIE, and RBI.

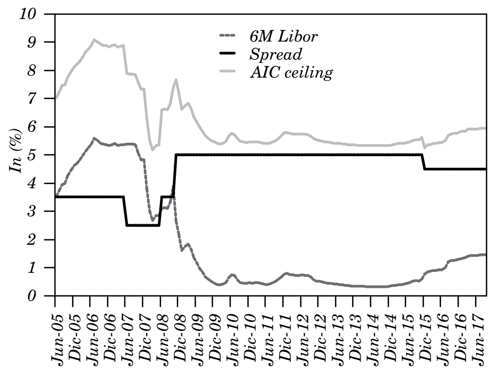
3.5 Regulatory arbitrage between domestic and overseas external debt

India permitted ECB borrowings denominated in rupees (Track III) in September 2014. For macroprudential reasons and as ECBs were envisioned as bilateral loan arrangements, they faced various tenor and all-in-cost constraints, end-use requirements, eligibility requirements on borrowers and lenders, and the like, as explained above. Borrowings under Track III were, however, not subject to cost caps that applied to other ECBs, as the borrowing was considered as not subject to exchange rate risk. It is unclear as per our model if this is necessarily the correct distinction since there is still the sudden-stop risk on rollover of rupee-denominated ECBs. Nevertheless, the scope of eligible borrowers and lenders remained similarly restrictive as for U.S. dollar ECBs.

To widen the international investor base for corporates, an additional route of RDB, or Masala bonds, was introduced in September 2015. Since these were intended to be bonds issued under market discipline, they were subject to a more relaxed regulatory regime. Most important of these is the much wider scope of eligible borrowers (any corporate or body corporate including real estate investment trusts, or REITs, and infrastructure investment trusts, or InvITs), eligible investors (any investor from FATF-compliant jurisdictions), and end-use (no restrictions except for a small negative list). Masala bonds also had an advantage *vis-à-vis* the FPI route in domestic bonds insofar as investors in Masala bonds did not have to register in India and the bonds were issued in international finance centers such as London with well-established financial and legal infrastructure. Further, there was no listing requirement for Masala bonds. FPI investments were subsequently allowed in unlisted instruments, but were subjected to a cap.

As noted, at the inception of this market, Masala bonds were viewed by regulators as bond-market borrowings similar to other FPI investments. They received a liberal regulatory treatment under the presumption that these bonds would have transparent pricing and other forms of market discipline. In actual practice, many Masala bond issuances were essentially bilateral loans issued as bonds, often to related entities. Coupon rates in many instances had no linkage with market-borrowing rates and varied from extremely low rates (related party transactions to circumvent ECB and FDI restrictions) to high rates (to circumvent the all-in-cost ceilings under the ECB route). Complicated structures using Masala bonds were also used to by-pass ECB cost caps. The overall evidence from issuances suggested that many entities were exploiting the relaxed regulatory treatment of Masala bonds to bypass ECB norms on bilateral funding arrangements.

Figure 9. All-in-Cost for ECBs with 5-year Minimum Maturity



Source: RBI.

Recognizing this regulatory arbitrage between ECB and Masala bonds, and recognizing that both were vulnerable to sudden stops because the source of capital was foreign creditors, India chose to harmonize their regulations. In June 2017, the RBI prescribed cost caps (Treasury yield + 300 bp) as well as minimum maturity period for Masala bonds (3 or 5 years, depending on the issue size). The minimum maturity period also harmonized the Masala bond investments by foreign creditors to the restrictions on FPI in domestically issued debt. Masala bonds were also not allowed to be issued to related entities. Such harmonization, and the observed regulatory arbitrage by issuers and investors in the pre-harmonization period, reinforces the importance of setting capital flow management policy based on the entirety of an EM's tools.

4. Conclusion

We have analyzed the macroprudential use of reserves and capital controls to manage sudden stops in EMs. Our principal conclusion is that these tools are complements. Hoarding reserves is beneficial against sudden stops, but creates incentives for the private sector to undo the insurance offered by reserve holdings. In this context, limits on borrowing increase the efficacy of reserve holdings. Our complementarity perspective also implies that the optimal holding of reserves depends on the set of policy instruments available to affect private borrowings. Optimal reserve holdings are increasing in the efficacy of such instruments.

In his classic analysis of policy instruments, Poole (1970) studies the use of the money supply and interest rate as instruments to stabilize output. In his baseline, both money supply and interest rate are equally effective instruments: they are substitutes. This leads to the result that either can be used as instrument. He then considers the case where there is some slippage in the transmission mechanism that varies across the instruments. In this case, he shows that the low-slippage instrument should be used more, while the high-slippage instrument should be used less, to stabilize output.

The complementarity logic for managing capital flows turns this result around. We show that the efficacy of one instrument (reserves) depends on the use of the other (capital flow taxes). Then, as the slippage in one instrument falls, both instruments should be used more, rather than just the low-slippage instrument.

Where does this end? We have studied three instruments, but what if there were 50 instruments available to the central bank, some of which were more effective than others? Should the central bank use all 50 of these instruments? Should it use some more than others? Suppose that the central bank is only able to use three out of the 50 instruments; either implementation challenges or slippage issues in the other instruments render them unusable. Our perspective implies that it should use less of the three instruments than in the case where all instruments are used. Complementarity implies that the marginal effectiveness of an instrument is increasing in the use of others. This is the main lesson from our analysis.

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Foreign-Exchange Intervention Redux

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Arguably, no issue in International Macroeconomics exhibits more dissonance between academic research and policy practice than foreign-exchange intervention. The dominant view from academia is that sterilized foreign-exchange (FX) intervention has a tiny, if any, impact on real variables, which makes it virtually useless as an independent macroeconomic policy tool. Indeed, a large body of empirical literature has struggled to find a consistent link between FX intervention and macroeconomic aggregates, including exchange rates.[1] From a theory perspective, this is hardly surprising, especially since modern dynamic macroeconomic models often predict that FX intervention should be irrelevant (Backus and Kehoe, 1989).

Policymakers, on the other hand, have ignored the prescriptions from research and have intervened, frequently and intensely, in the foreign-exchange market. FX intervention has become prominent and noticeable following the global financial crisis in advanced economies, while in emerging ones, FX intervention was the norm already before the crisis, even in countries committed to inflation targeting. Interestingly, central bankers reportedly believe that FX intervention is effective as a policy tool, and that it has been used successfully.[2]

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1. For instance, citing Obstfeld (1982) and Sarno and Taylor (2001), Feenstra and Taylor (2014, p. 369) write: “the evidence is often weak and a source of ongoing controversy”. A more recent survey of the empirical literature is Menkhoff (2013).

2. See Chutasripanish and Yetman (2015). Also, Adler and Tovar (2011).

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The purpose of this paper is to develop a recent perspective on FX intervention which, among other advantages, can help reconcile the contrasting views of academics and policy makers. Following Céspedes, Chang, and Velasco (2017), I adopt the view that FX intervention can and should be seen as a specific instance of the so-called "unconventional" central bank policies reviewed, for example, in Gertler and Kiyotaki (2010). This view strongly indicates that a useful analysis of FX intervention requires a framework that allows for financial frictions and institutions, for otherwise unconventional policies turn out to be irrelevant (as in Wallace, 1981 or, as already mentioned, Backus and Kehoe, 1989).

Accordingly, I analyze FX intervention in an extension of Chang and Velasco's (2017) model of a small open economy. In that economy, financial intermediaries or banks borrow from the world market and, in turn, extend credit to domestic households or the government, subject to an external debt limit. The model is intended to be standard and as simple as possible to help exposition, so as to isolate two features that turn out to be central. The first one is the specification of sterilized intervention. Sterilized FX interventions are operations in which the central bank buys (or sells) official reserves of foreign exchange and, at the same time, it sells (or buys) an offsetting amount of securities, such as "sterilization bonds". This implies that the central bank issues sterilization bonds—or, more generally, reduces its net credit position—when it purchases reserves, and cancels such bonds when it sells reserves.

The second aspect of our model is that domestic banks face an external debt limit that may or may not bind in equilibrium. This is key because, as I show, FX intervention has no impact on macroeconomic aggregates if it occurs when that limit does not bind. Conversely, as I also show, FX intervention does affect equilibrium real outcomes if it takes place at times of binding financial constraints.

More precisely, sterilized FX intervention can affect equilibrium because the associated sterilization operations relax or tighten financial constraints. When the central bank sells foreign exchange, sterilization means that the central bank retires sterilization bonds (or, more generally, increases its net credit position *vis*-à-*vis* domestic banks). If financial constraints do not bind, domestic banks accommodate this change by simply borrowing less from the world market, and equilibrium is left undisrupted. But when financial constraints do bind, the fall in the central bank's demand for credit associated with sterilization frees resources for banks, thus allowing them to increase the supply of loans to the domestic private sector. The result is that loan interest rates fall and aggregate demand expands.

This view of the mechanism through which sterilized FX intervention works differs sharply from alternative ones and, in particular, from those of currently dominant portfolio balance models. Such models assume that domestic- and foreign-currency bonds are imperfect substitutes and, as a result, uncovered interest parity holds up to a risk premium that depends on the ratio of domestic- to foreign-currency bonds in the hands of the public. Sterilized FX intervention affects this ratio and hence the risk premium, which in turn requires macroeconomic adjustments. In contrast, the mechanism proposed in this paper does not rely on imperfect asset substitutability nor on differences in currency denomination. In fact, and in order to stress the point, I show that FX intervention can be an effective policy tool (when financial constraints bind) under perfect asset substitutability and even if the economy is "financially dollarized".

As a significant additional payoff, our exploration of the model highlights a close link between sterilized intervention and the cost-benefit analysis of official reserves accumulation. Under the natural assumption that the central bank cannot issue foreign currency, maintaining a large stock of foreign exchange enhances the ability of the central bank to stimulate the economy, by selling reserves, when financial constraints become binding. This is obviously beneficial and intuitive. But in this model there is also a cost of holding reserves, namely, that larger reserves also imply larger outstanding quantities of sterilization bonds, the financing of which may place banks closer to their credit limits, thus making them more vulnerable to adverse exogenous shocks. A main trade-off then emerges: large amounts of official reserves allow the central bank to respond more effectively, via FX intervention, when financial constraints are hit, at the cost of those constraints being hit more frequently.

Our analysis yields several lessons for FX intervention rules and their relation to conventional monetary policy. Notably, a policy of selling reserves when the exchange rate is weak and buying them when the exchange rate is strong can relax financial constraints when they bind, but also leads to intervention when the constraints do not bind, which can be counterproductive. A policy of intervention based on credit spreads is superior, as it is only activated when financial constraints bind. Also, the question of whether sterilized FX intervention can be an independent policy tool and complement conventional monetary policy has an affirmative answer in our model.

But the fact that financial constraints bind only occasionally is crucial and means, in particular, that one must go beyond the analysis of linear models or linear approximations around the steady state.

Finally, our approach yields several other appealing insights. Specifically, it is consistent with the empirical difficulty to find significant macroeconomic effects of FX intervention in the data, since intervention has real impact only at times of binding constraints, which may be infrequent. It also indicates how intervention can be welfare improving and it sheds light on the role of the so-called quasi-fiscal deficits that central banks derive from intervention.

This paper builds on and contributes to a large literature on FX intervention. For useful surveys, see Sarno and Taylor (2001), Menkhoff (2013), Adler and Tovar (2011), and Ostry and others (2016). Until the powerful critique by Backus and Kehoe (1989), the literature was dominated by models derived from the optimal portfolio choices of investors that viewed domestic- and foreign-currency assets as imperfect substitutes. Recently the portfolio balance approach has experienced a revival, led by Benes and others (2015), and followed by Vargas and others (2013); Montoro and Ortiz (2016); and Cavallino (2017).

The newer portfolio balance models are similar to ours in that FX intervention can have real effects because of the interaction of sterilization operations with financial frictions. They differ substantially along some important details, however. For example, Benes and others (2015) and Vargas and others (2013) impose that banks pay portfolio management costs similar to those in Edwards and Vegh (1997). They make assumptions about those costs that make domestic- and foreign-currency bonds imperfect substitutes for the banks, and this leads to the same kind of uncovered interest parity condition *cum* risk premium that was the hallmark of the older portfolio balance approach. This indicates that, while the newer models have been successful in providing satisfactory theoretical underpinnings to the portfolio balance approach, they still have to be reconciled with the same evidence as older models. In comparison, in the model of this paper, financial frictions only bite sometimes and not others, which makes a significant difference in the results. For one thing, under the assumption that financial constraints are not binding in the steady state, our model implies that FX intervention is irrelevant for shocks that are not large enough to drive the economy to the financially constrained region. As already noted, this aspect of the model is consistent with the scarcity of empirical evidence of nontrivial effects of sterilized intervention on macro variables.

Section 1 of this paper presents the model that serves as the basis for our discussion. A baseline version of the model assumes complete price flexibility and financial dollarization. In that baseline version, section 2 discusses FX intervention and reserves accumulation. Nominal price rigidities and, hence, a nontrivial role for monetary policy are introduced in section 3, which examines the interaction between monetary policy and FX intervention. Section 4 shows how the assumption of financial dollarization can be relaxed with only minor changes in our arguments. Section 5 concludes. An appendix collects some peripheral technical derivations.

1. A Model of FX Intervention and Reserves Accumulation

To convey our ideas regarding intervention policy, I extend the model of Chang and Velasco (2017) to a stochastic setting, emphasizing the mechanics of sterilized intervention and how intervention policy interacts with financial constraints that bind only occasionally. This section develops a baseline version of the model that, in order to focus on the essentials, imposes very restrictive assumptions: it assumes perfectly flexible prices (implying that conventional monetary policy has no bite) and complete *financial dollarization* (i.e. that all financial assets are denominated in foreign currency). These assumptions not only simplify the analysis but also underscore that the mechanism by which FX intervention works does not depend on the currency denomination of assets or the interaction with other monetary policy tools. Of course, realistic models might require allowing for nominal price rigidities, powerful monetary policy, and differences in the currency denomination of assets. But these can be added at relatively little extra cost later, as shown in sections 3 and 4.

1.1 Commodities and Production

We consider an infinitely lived, small open economy. In each period there are two internationally traded goods, home and foreign. The price of the foreign good in terms of a world currency (called *"dollar"*) is fixed at one.

The home good is the usual Dixit-Stiglitz aggregate of varieties, with elasticity of substitution ϵ. Each variety is produced by one of a continuum of monopolistically competitive firms indexed by i in $[0,1]$. In period t, firm i produces variety i via $y_{it} = An_{it}$, where n_{it} denotes labor input, and A a productivity term kept constant for ease of exposition. Firms take wages as given, and hence nominal marginal cost in period t is common to all, given by:

$$MC_t = W_t / A \tag{1}$$

where W_t is the nominal wage, that is, the wage expressed in terms of a domestic currency ("*peso*" hereon).

For now, we assume flexible prices, meaning that in every period all firms set the peso price for their produce after observing that period's exogenous shocks. All varieties then carry the same price in equilibrium, given by the usual markup rule:

$$P_{ht} = \left(1 - \frac{1}{\epsilon}\right) MC_t \tag{2}$$

P_{ht} is also the price of the domestic home aggregate good. That aggregate is sold at home and abroad. The foreign part of demand is given simply by a function xe_t^x of its relative price, the *real exchange rate:*

$$e_t \equiv E_t / P_t$$

with E_t denoting the nominal exchange rate (pesos per dollar), and x and χ positive parameters.

Home demand for the domestic aggregate good is derived from the demand for final consumption. The latter is denoted by c_t and assumed to be a Cobb Douglas function of the domestic composite good and foreign goods. The Law of One Price is assumed, implying that the peso price of foreign goods is given by E_t: Then the price of final consumption (the CPI) is

$$P_t = P_{h,t}^{\alpha} E_t^{1-\alpha}$$

where α is a parameter between zero and one.

The implied demand for the home aggregate is $c_{ht} = \alpha e_t^{1-\alpha} c_t$ and therefore the market home output clears if

$$y_t = \alpha e_t^{1-\alpha} c_t + x e_t^{\chi}, \tag{3}$$

1.2 Banks

There is a large number of domestic financial intermediaries, or banks, which borrow from the rest of the world and lend to either households or the government, subject to financial frictions. A representative bank starts a period t with an amount of capital or net worth of k_t dollars. This amount is, as we will see, raised from domestic households in exchange for a share of the bank's next period profits. Given k_t; the bank borrows d_t dollars from foreigners, at a gross interest rate of $R_t^* \geq 0$; which the bank takes as given.

Because of financial frictions, external borrowing is restricted by a collateral constraint

$$d_t \leq \theta k_t$$

where θ is a constant. As noted in the literature, this kind of constraint can be rationalized in various ways. [3]

The resources raised by the bank finance loans to the domestic private sector, l_t, or the purchase of bonds issued from the central bank, b_t. Private loans and central bank bonds are perfect substitutes and carry the same interest rate, ϱ_t, between periods t and $t + 1$.

Observe that, for now, loans and bonds, and the interest rate, are all assumed to be denominated in dollars. This case of financial dollarization may be realistic for some countries and not for others; however, it is the simplest assumption to start with. More importantly, it emphasizes that the basic mechanism by which FX intervention works in our setting does not rely on differences in currency denomination. Once that mechanism is laid out, section 4 turns to its interaction with peso-denominated loans and bonds.

The typical bank's balance sheet therefore requires that:

$$b_t + l_t = k_t + d_t$$

3. For example, one may assume that, after raising d_t, the banker can "abscond" with the funds at a cost of θ times equity. Knowing this, lenders will not extend more credit than θk_t.

This being said, the exact form of the collateral constraint may or may not have significant impact on the analysis. For example, one might consider an alternative specification such as $d_t \leq (k_t + b_t)$, on the basis that domestic banks government bonds could be pledge government bonds as collateral to foreigners. It is not hard to see that our analysis below remains qualitatively the same if $\theta < 1$. But there may be important quantitative differences. (Thanks to José De Gregorio for this observation.)

and the bank's profits are given by

$$\pi_{t+1} = (1 + \varrho_t)(l_t + b_t) - R_t^* d_t,$$

Under our maintained assumptions, profits are realized in period $t + 1$ but they are known as of period t. The bank's problem, therefore, is simply to choose b_t, d_t, and l_t to maximize π_{t+1} subject to the collateral constraint.

The solution is simple. Combining the preceding two equations, profits can be written as

$$\pi_{t+1} = R_t^* k_t (1 + \varrho_t - R_t^*)(l_t + b_t),$$

i.e. profits are a sum of a "normal" return on equity plus an excess return on domestic credit. Hence, if $1 + \varrho_t = R_t^*$, there are no supranormal returns, and the bank's optimal policy is indeterminate as long as $b_t + l_t = k_t + d_t$ and $d_t \leq \theta k_t$. If $1 + \varrho_t > R_t^*$, on the other hand, the bank lends as much as it can. The collateral constraint then binds, so that $d_t = \theta k_t$, and $b_t + l_t = (1 + \theta)k_t$.

Finally, the return to equity is denoted by $(1 + \omega_t)R_t^* \equiv \pi_{t+1}/k_t$, and given by:

$$\frac{\pi_{t+1}}{k_t} = R_t^* + \left(1 + \varrho_t - R_t^*\right)\left(1 + \theta\right) \equiv \left(1 + \omega_t\right) R_t^*$$

1.3 Central Bank, Intervention, and Reserves Accumulation

The essence of sterilized FX intervention is that, whenever a central bank sells or buys foreign exchange, it also buys or sells a matching amount of securities. This can be implemented in many different ways, and the menu of alternatives depends in practice on institutional aspects of each economy, such as the kind of securities that are involved in sterilization. But again, and as emphasized in the literature, the defining aspect of sterilized intervention is that it involves a simultaneous change in official reserves and the net credit position of the central bank.

Accordingly, in what follows we assume that sterilized FX intervention means that the central bank buys or sells official reserves (dollars) and, at the same time, issues or retires a corresponding quantity of its own bonds (which therefore might be referred to as *sterilization bonds*). While highly stylized, this assumption is the same as in the recent papers of Benes and others (2015) and Vargas and others (2013). It also corresponds closely to actual practice in some countries. For example, Vargas and others (2013) discuss the Colombian experience in some detail, and how the practice of FX intervention led Colombia's government to issue sterilization bonds. The same specification is incorporated into modern textbooks such as Feenstra and Taylor (2014).

In our model, as will become apparent, FX intervention can affect equilibria when and only when the matching sterilizing operation relaxes or tightens the external credit constraint. This argument, stressed in Céspedes and others (2017), differs from older ones, in particular from the traditional portfolio balance view. This view started from the assumption that sterilization operations involved securities denominated in domestic currency, and therefore FX intervention must change the ratio of foreign- to domestic-currency assets in private hands. If, in addition, securities denominated in different currencies were imperfect substitutes, restoring equilibrium required a change in relative rates of return. Such an argument is obviously not applicable to our model, as we have assumed that all securities are denominated in dollars and are perfect substitutes. But this is only to emphasize that the mechanism by which FX intervention works is not a portfolio balance one.

Note that we assume that sterilization bonds are held solely by domestic agents, banks in this case. This assumption is natural and realistic, and no different from what is usually imposed in the literature. But it is a crucial part of our argument. If the central bank could freely sell sterilization bonds to the rest of the world, then the economy as a whole would effectively face no external collateral constraint. The key aspect of our assumptions is that sterilization bonds add to the economy's overall external debt, which has a limit. One can presumably adapt our analysis to alternative scenarios as long as they imply that sterilization bonds interact with financial frictions.

As mentioned, central bank bonds are assumed to yield the same interest rate as private loans, ϱ_t. Reserves, on the other hand, are assumed to be invested abroad, at the external interest rate R_t^*. In this setup, the central bank makes operational losses (the so-called quasi-fiscal deficit) if $1+\varrho_t > R_t^*$. For the time being we assume that such losses, if any, are financed via a lump sum tax on households; one implication is that the net worth of the central bank is constant, and normalized here to zero for convenience. These assumptions are prevalent in the literature, but it should be noted that they are trivial neither for the theory nor in practice. Further research is clearly warranted on this issue; I offer further thoughts in the closing section.

Our maintained assumptions now ensure that, if f_t denotes the central bank's international reserves, the central bank's balance sheet is simply given by $f_t = b_t$; and that the central bank's quasi-fiscal deficit in period t is given by

$$T_t = (1 + \varrho_{t-1} - R^*_{t-1})b_{t-1}.$$

Hence there is a tight link between foreign-exchange intervention and the amount of central bank bonds: selling foreign-exchange reserves is a fall in f_t; which then amounts to a reduction in b_t; conversely, accumulating reserves leads to an increase in b_t.

Finally, it seems natural to assume that the central bank cannot issue international currency. In this setting, this requires imposing that official central bank reserves have a lower bound, which we assume to be zero: $f_t = b_t \geq 0$.

1.4 Households

The economy has a representative household with preferences that depend on consumption and labor effort, and given by the expected value of $\sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$, with

$$U(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \frac{\eta}{1+\phi} n^{1+\phi}$$

where η, σ and ϕ are positive parameters.[4]

In each period t, the household decides how much to consume and to work, how much to borrow from domestic banks, and how much equity to send to the banks. The period's budget constraint, expressed in dollars, is:

$$e_t^{-\alpha} c_t + k_t - l_t = (1 + \omega_{t-1}) R^*_{t-1} k_{t-1} - (1 + \varrho_{t-1}) l_{t-1} + e_t^{-\alpha} w_t n_t + \upsilon_t + z_t - T_t,$$

where $w_t = W_t/P_t$ is the real wage, υ_t denotes (dollar) profits from domestic firms and banks, and T_t denotes to the lump sum taxes

4. And as usual, $\sigma = 1$, $u(c) = \log(c)$.

needed to finance the central bank's quasi-fiscal deficit. Finally, z_t is an exogenous endowment of foreign goods (dollars), which can be thought of as income earned from the ownership of a natural resource, as oil or commodities. The left hand side of the constraint gathers the value of the household's expenditure in consumption and new equity purchases, minus new bank loans. The right hand side includes the return on equity, minus the repayment of bank loans, plus income net of taxes.

Finally, we follow Chang and Velasco (2017) in assuming that there is an exogenous limit, referred to as the domestic *equity constraint,* to how much bank equity the household can hold:

$$k_t \leq \tilde{k}$$

where $\tilde{k} > 0$ 0 is some constant. The *equity constraint* reflects, presumably, some domestic distortions that we do not model here.

The household's optimal plan is straightforward. Optimal labor supply is given by

$$w_t c_t^{-\sigma} = \eta n_t^{\phi}. \tag{4}$$

Assuming that the household borrows a positive amount, which will be the case in equilibrium, the usual Euler condition must hold:

$$c_t^{-\sigma} = \beta E_t c_{t+1}^{-\sigma} R_{t+1},$$

where we have defined the consumption interest rate by

$$R_{t+1} = (1 + \varrho_t)\left(\frac{e_{t+1}}{e_t}\right)^{\alpha}. \tag{5}$$

Finally, the equity constraint binds in period t if and only if the return on equity, $(1+\omega_t)R_t^*$, exceeds the cost of domestic loans, $1 + \varrho_t$. As the reader can check, in equilibrium this will be the case if and only if $1 + \varrho_t > R_t^*$. But this means that the equity constraint and the bank's external debt constraint must bind under exactly the same circumstances. This simplifies the analysis considerably, since it allows us to impose, without loss of generality, that $k_t = \tilde{k}$ always, and that the constraint $d_t \leq \theta\tilde{k}$ binds if $1 + \varrho_t > R_t^*$ and is slack if $1 + \varrho_t = R_t^*$.

1.5 Equilibrium

We assume that parameter values are such that financial frictions do not bind in the non-stochastic steady state. As is well known, in order to be able to apply approximation techniques around that steady state, some additional assumptions must be imposed to ensure stationarity (Schmitt-Grohe and Uribe, 2017). Here we assume that the external cost of credit, R_t^*, is given by the world interest rate, denoted $\bar{R}^*$ by and taken as exogenous and constant (for simplicity), plus a spread term that depends on the amount of bank credit $l_t = k_t + d_t - b_t$:

$$R_t^* = \bar{R}^* + \tilde{\Psi}\left(e^{l_t - \bar{l}} - 1\right),$$

where $\bar{l}$, $\bar{d}$ and $\bar{b}$ are the steady-state values of domestic loans, external, debt and reserves, respectively, and $\tilde{\Psi}$ is an elasticity coefficient.

Two brief comments on the above specification are warranted. First, because the $R_t^* - \bar{R}^*$ spread increases with domestic loans, it increases with the economy's external debt net of reserves. This seems defensible: in fact, the (negative of the) quantity $d_t - b_t$ corresponds to measures of international liquidity emphasized in Chang and Velasco (2000) and elsewhere. Second, we assume that $\bar{l}$ is given exogenously. This differs somewhat from the literature, which usually imposes an exogenous $\bar{d}$. This is because we want to allow for FX intervention policies for the management of reserves and central bank debt, with implications for the steady-state value of reserves $\bar{b}$. It will become apparent that the assumption of an exogenously given $\bar{l}$ yields a cleaner analysis than an exogenous $\bar{d}$. Since whether taking $\bar{l}$ or $\bar{d}$ as exogenous is arbitrary and only needed for technical reasons, we stick with exogenous $\bar{l}$.

Under flexible prices, one can combine the optimal markup rule (2) and the labor supply condition (4) to arrive at the equilibrium aggregate supply condition:

$$e_t^{-(1-\alpha)} c_t^{-\sigma} = \left(1 - \frac{1}{\in}\right) \eta y_t^{\phi} / A^{1+\phi}.$$

In turn, the external resource constraint can be written as

$$(1-\alpha) e_t^{-\alpha} c_t - \left[z_t + \varkappa e_t^{x-1} \right] = d_t - b_t - R_t^* \left(d_{t-1} - b_{t-1} \right) \tag{6}$$

which says that the trade deficit in period t must be financed by increasing external debt or reducing central bank debt, i.e., selling international reserves. As emphasized by Chang and Velasco (2017), this constraint is a key aspect of the model, given that the collateral constraints require

$$\begin{aligned} d_t &= \theta_k \text{ if } 1 + \varrho_t > R_t^* \\ &\leq \theta_k \text{ if } 1 + \varrho_t = R_t^* . \end{aligned}$$

It may aid intuition to express the external resource constraint (6) as

$$TD_t + r_t^* (d_{t-1} - b_{t-1}) = (d_t - d_{t-1}) + \Delta_t$$

where we have defined the trade deficit TD_t as the LHS of (6), $r_t^* = R_t^* - 1$ as the net rate of interest on the external debt, and $\Delta_t = (b_t - b_{t-1}) = f_{t-1} - f_t$ as the size of foreign-exchange sales of the central bank in period t. Thus written, the LHS is the current-account deficit, the sum of the trade deficit and the service of the net foreign debt. The preceding equation then emphasizes that a current-account deficit is financed either via additional foreign debt or via sales of official reserves; the latter imply a fall in the quantity of sterilization bonds. It also stresses that, if reserves cannot be negative, $\Delta_t \leq f_{t-1}$; i.e. foreign-exchange operations in each period are limited by the inherited level of reserves.

Finally, if the collateral constraints bind so that $d_t = d_t = \theta\tilde{k}$, we have that $TD_t = \Delta_t - r_t^* (d_{t-1} - b_{t-1})$. This says that, in the absence of foreign-exchange intervention, the trade deficit is predetermined. One implication, noted in Chang and Velasco (2017), is that adverse shocks must be fully offset within the period by a fall in absorption (consumption) or real exchange depreciation. In particular, if there is a temporary fall in exogenous exports z_t, consumption smoothing would require an increase in external borrowing, which is not feasible. Some consumption smoothing, on the other hand, can be achieved by an increase in Δ_t; that is, a sale of reserves. In this sense, foreign-exchange intervention can relax binding financial constraints, as we will explore.

Equilibrium is pinned down once we specify a rule for the evolution of b_t, that is, a foreign-exchange intervention policy. An analysis of alternative policies is provided next.

2. Reserves Accumulation and Intervention

The first subsection discusses a crucial property of the model: that sterilized intervention can have real effects if and only if it relaxes binding financial constraints. A second subsection examines the implications of various intervention rules in a calibrated version of the model. In addition to illustrating how the model works under frequently observed policy rules, the exercise helps identify additional aspects of the model and policy implications.[5]

2.1 General Considerations

As in Céspedes and others (2017), sterilized intervention is irrelevant in our model unless it occurs at times of binding collateral constraints (or makes financial frictions bind if, in its absence, they would have not). For a more precise statement, fix any equilibrium, which we will denote with carets. As the interested reader can check, the equilibrium conditions[6] can be written so that $\hat{d}_t$ and $\hat{b}_t$ appear only in three of them. The first one is the collateral constraint, which can be rewritten as:

$$\hat{l}_t = (1+\theta)\tilde{k} - \hat{b}_t \quad \text{if} \quad 1+\hat{\varrho}_t > R_t^*$$
$$\hat{l}_t \le (1+\theta)\tilde{k} - \hat{b}_t \quad \text{if} \quad 1+\hat{\varrho}_t = R_t^*.$$

The second one is the bank's balance sheet, which requires:

$$\hat{d}_t = \hat{b}_t + \hat{l}_t - \tilde{k}.$$

The third one is the FX intervention rule. We allow the central bank to set b_t as any function of past, present, or future expected

5. For a more analytically oriented discussion of the transmission mechanisms in this kind of model, the interested reader is referred to Chang and Velasco (2017).

6. For notational simplicity, this paper follows the convention that the "t" subscripts index date event pairs, that is, c_t denotes consumption at t conditional on the whole history of exogenous shocks up to that point. With that understanding, our discussion, particularly in this section, applies without change to stochastic models. An alternative notation would have been to write something like $c_t = c(s^t)$ and so on for each variable, where s^t is the history of shocks up to t. I see little gain here, however, in using the more precise but also more cumbersome notation.

values of any variables in the model, as long as the rule pins down an equilibrium implying a well-defined process for official reserves, $\left\{\hat{b}_0, \hat{b}_1, \ldots\right\}$.[7]

Now consider any different policy rule that (possibly in conjunction with the original equilibrium) implies an alternative process for reserves, $\{b'_0, b'_1, \ldots\}$ that coincides with $\left\{\hat{b}_0, \hat{b}_1, \ldots\right\}$ at all times except at some given date t. If the collateral constraint did not bind at t in the original equilibrium, and does not bind under the new policy $\left(\text{i.e. } \hat{l}_t \leq (1+\theta)\tilde{k} - b'_t\right)$, then the policy leaves the original equilibrium unchanged, except that $d'_t = b'_t + l'_t - \tilde{k}$, i.e. that there is a change in external debt that exactly offsets the change in reserves. This is of course feasible, since the collateral constraint does not bind in equilibrium, and it is also intuitive: if the central bank sells reserves, the supply of stabilization bonds increases by the amount of the sale. Domestic banks can finance the increased holdings of bonds by borrowing abroad, without disrupting the domestic supply of loans, as long as their credit limit is slack.

Conversely, to affect equilibria, a change in intervention policy must involve a change in b_t at some t in which either the collateral constraint binds or a nonbinding constraint becomes binding under the new policy. It also becomes apparent that, when collateral constraints bind, the central bank can stimulate the economy by selling foreign exchange. By doing so, it redeems central bank bonds, making room for domestic banks to increase credit to households. In this sense, and as emphasized by Céspedes and others (2017), sterilized intervention "works" because the sterilizing operation relaxes the external collateral constraint.[8]

The alert reader might recognize that the propositions just stated are extensions of those in Backus and Kehoe (1989). For a large class of models, Backus and Kehoe identified conditions under which sterilized

7. More precisely, the policy rule together with the rest of the model implies an equilibrium in which the stochastic process for reserves is $\left\{\hat{b}_0, \hat{b}_1, \ldots\right\}$.

8. The mechanism through which intervention works is similar to that in Benes and others (2015) and Vargas and others (2013). Those papers assume a financial transaction technology that implies that a reduction of the supply of sterilization bonds, associated with a sale of official reserves, must induce domestic banks to also decrease the supply of loans to households, thus resulting in an increase in the interest cost of domestic loans. Note that one consequence is that central-bank FX sales must always be contractionary in those models. In the model here, in contrast, central bank FX sales either leave the supply of loans unchanged (if financial constraints do not bind) or increase it (if they do). And, crucially, the circumstances under which FX purchases stimulate domestic credit are exactly those in which the economy is credit-constrained.

intervention would not affect equilibria. But they also allowed for the possibility that sterilized intervention might not be irrelevant if those conditions were not met. Our analysis proceeds further, by asking what the implications of intervention are when they can matter.[9]

Intuitively, the economy benefits if the central bank sells foreign-exchange reserves when financial constraints bind. This provides a rationale for the accumulation of official reserves if, as we have assumed, foreign-exchange reserves cannot be negative. In other words, our analysis of intervention has implications for the discussion of observed reserves accumulation in emerging economies and elsewhere.

One such implication relates to the costs of accumulating reserves. Why would the central bank not accumulate a very large amount of foreign exchange in normal times, so as to be ready to act if financial constraints suddenly bind? In our model, reserves accumulation involves two kinds of costs. The first one has been recognized in the literature: to finance the accumulation of reserves, the central bank borrows from domestic banks with an interest cost that adds to the quasi-fiscal deficit. In our model, however, in normal times (i.e. when financial constraints do not bind), the interest cost is fully offset by the interest earned on reserves. A second source of costs is new, to my knowledge, and potentially more significant: the accumulation of central bank reserves induces domestic banks to increase their own external debt and, hence, place themselves nearer to their foreign-credit limit. It then becomes more likely that, in response to adverse shocks, the limit becomes binding.

So our model features a novel trade-off in reserves accumulation: larger official FX reserves are necessary for the central bank to be ready to stimulate the economy at times of binding financial constraints; but the financing of those reserves induces domestic banks to increase international borrowing, thus making the economy less resilient to shocks. Exploring the implications of such a trade-off is beyond the scope of the present paper, but should be a fruitful avenue for future research.

9. In contrast, Backus and Kehoe stopped their analysis after stating that, when intervention can matter, its real effects depend on accompanying assumptions about fiscal policy. Here we make progress by making specific assumptions on the quasi-fiscal deficit.

2.2 Numerical Illustrations

To illustrate our main ideas, this subsection develops a calibrated version of the model. I stress that the objective of this subsection is to expand and clarify our discussion, rather than empirical realism. Hence we choose some parameter values on the basis of just simplicity and convenience.

Details of the calibration are given in the appendix; here we only mention salient aspects. A period is a quarter. In steady state, the world interest rate is four percent per year. The steady-state values of y, e, and c are all one, and the trade surplus to GDP ratio is one percent. In the absence of foreign-exchange intervention, an implication is a steady-state debt to (annual) GDP ratio of twenty-five percent, which accords well with usual values in the literature (e.g. Schmitt-Grohe and Uribe, 2017).

The final important aspect of the calibration is the debt limit $\theta\tilde{k}$. For our discussion, I set it at a very stringent value, so that in steady state the economy is not financially constrained, but close to being so. This is because my purpose is to illustrate the workings of the model, with emphasis on the role of financial constraints.

Having calibrated the model, finding numerical solutions requires nonlinear procedures. For the experiments reported here, I solved the model via the remarkably useful OccBin procedures developed by Guerrieri and Iacovello (2015). OccBin adapts Dynare to approximate our model regarded as having different regimes, given by times of binding and nonbinding constraints. In response to exogenous shocks, the transition between regimes is endogenous and part of the computation. See Guerrieri and Iacovello (2015) for details, as well as commentary on the accuracy of the resulting approximations.

To obtain a feel for the model in the absence of foreign-exchange intervention, figure 1 displays impulse responses to a purely temporary fall in the exogenous endowment z; one can think of this shock as a fall in the world price of an export commodity. The broken lines give the impulse responses in the absence of financial constraints. In that case, as clear from the figure, a purely temporary fall in z would be accommodated primarily by borrowing from the rest of the world. This would allow the economy to spread the cost over time, smoothing the response of consumption. The exchange rate would depreciate, reflecting the fall in the derived demand for nontradables, but only by a small amount. Finally, the interest rate on loans (ϱ_t) would essentially remain the same (it increases minimally only because the increase in the debt raises the spread $R_t^* - \bar{R}^*$ through the debt elastic mechanism, which is negligible).

With occasionally binding financial constraints, the impulse responses are given by solid lines. External debt increases to the credit limit, which binds for thirteen periods. The binding constraint implies that, in response to the fall in z, consumption contracts substantially more than without the constraint. As households would like to borrow more, the consumption-based interest rate R_{t+1} must increase. For this to happen, there is a large increase in the loan interest rate ϱ_t, as shown in the figure. Note that the size of this increase is enhanced by the behavior of the exchange rate, since there is a real depreciation on impact (reflecting the fall in the demand for nontradables), and a subsequent appreciation that reduces the consumption-based interest rate (equation (5)).

Hence the model implies that binding financial constraints amplify the real impact of adverse external shocks. It bears stressing that the assumption in figure 1 is that the fall in z is large enough for the debt constraint to become binding. If it does not, the impulse responses just coincide with the ones without financial constraints (in the figure, the solid and dashed lines would have coincided if the fall in z had been small enough).

Figure 2 shows the first one thousand periods of a typical simulation. The figure illustrates two aspects of the calibration. First, the value of the debt limit, given by $\theta\tilde{k}$, combines with the stochastic process for exogenous shocks to give the frequency with which financial constraints bind. For the figure, I assume i.i.d. shocks with standard deviation of one percent. Then $\theta\tilde{k}$ is set so that the collateral constraint binds about one fourth of the time. This may be too frequent for realism, but again my purpose here is to illustrate the workings of the model.

Second, the figure emphasizes that times of binding constraints are also times of high volatility in consumption, real exchange rate, and interest spreads.

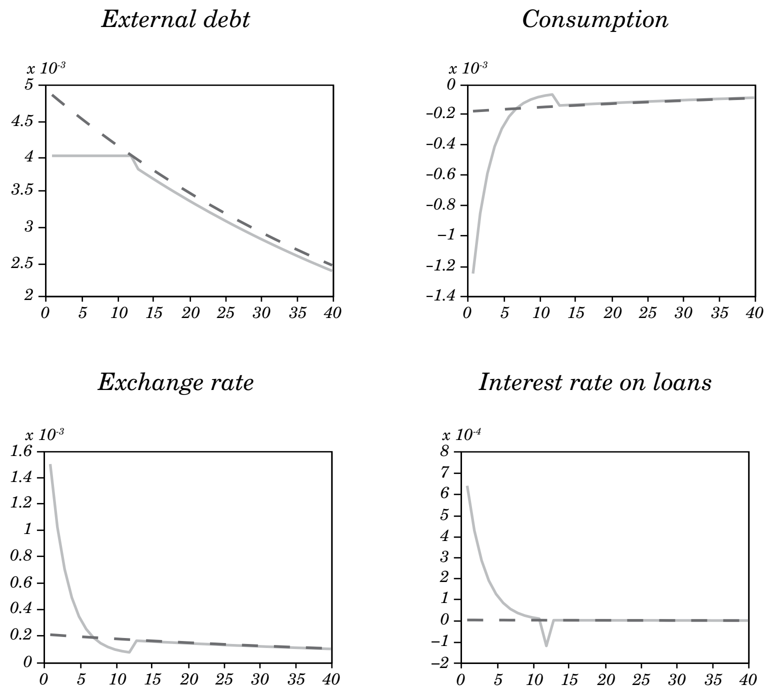
We turn to the impact of intervention policy. To start, assume that intervention is simply given by an exogenous autorregresive process with a zero lower bound:

$$b_t = Max\left\{0, (1-\rho_b)\bar{b} + \rho_b b_{t-1} + \varepsilon_{bt}\right\}$$

where ε_{bt} is an i.i.d. process, which could be interpreted as an unanticipated central bank purchase of reserves. Here, $\bar{b}$ is the steady-state stock of reserves. For ease of exposition, we assume that $0 < \bar{b} < (1+\theta)\tilde{k} - \bar{l}$; that is, that in the steady-state foreign reserves are strictly positive and the external constraint does not bind. (Note that we have not provided any rationale for this policy rule. Instead, we study its implications in hoping to obtain insight about the way intervention may or may not work.)

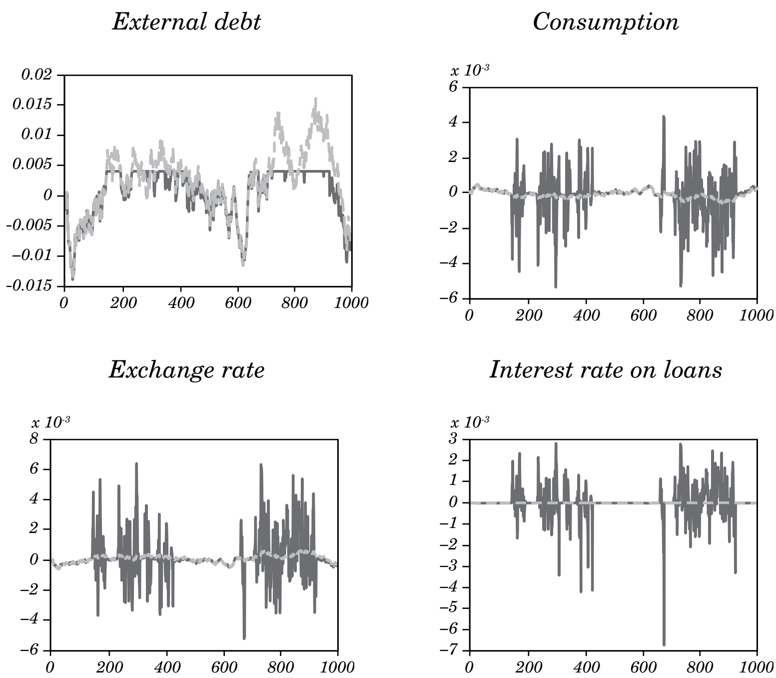
Under the above assumption on $\bar{b}$, and intuitively, small FX operations (i.e. values of ε_{bt} of small absolute value) do not affect real equilibria, and they are matched one for one by changes in d_t. To preserve space we omit the (boring) impulse responses.

Figure 1. A Temporary Fall in Endowment



Source: Author's elaboration.

Figure 2. A Typical Simulation

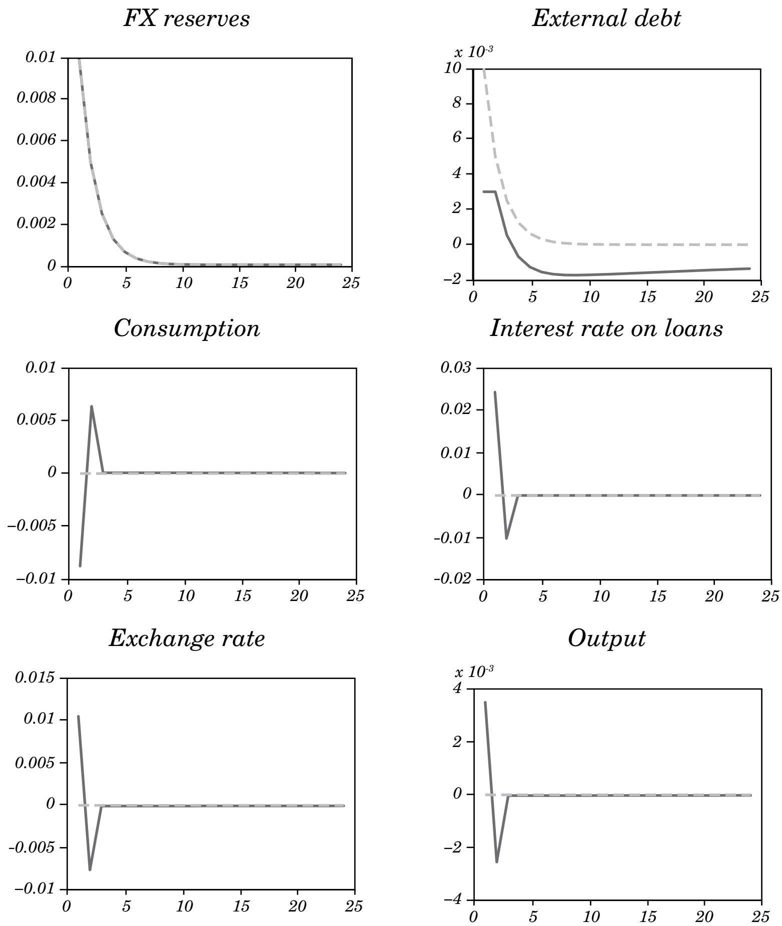


Source: Author's elaboration.

With sufficiently large ε_{bt}, the implications are asymmetric. A large negative ε_{bt} amounts to a large sale of official reserves. But reserves are bounded below by zero, so the central bank runs out of reserves. This is the only real consequence in the model; however: the fall of reserves is completely offset by a decrease in external debt, leaving domestic credit untouched.

In contrast, a sufficiently large unanticipated purchase of reserves (positive ε_{bt}) brings the economy to the financially constrained region. Figure 3 depicts the implications. As in the previous figures, the dashed lines depict impulse responses to a positive ε_{bt} in the absence of financial constraints. In this case, as shown in the figure, the accumulation of reserves would be exactly matched by an increase in the external debt of the banks, with no other real effect. In contrast, the solid lines are the responses taking into account financial constraints. The central bank intervention requires an increase in the amount of stabilization bonds, and this leads domestic banks to borrow abroad up to the credit limit. In this case, the economy remains financially constrained for two periods. Because of the credit limit, loans to domestic households must fall, which explains the fall in consumption, the increase in the loan interest rate, and the real exchange rate depreciation. Finally, the real depreciation is responsible for the output increase on impact. In short, the large purchase of FX reserves leads to the exhaustion of external credit and a domestic credit crunch.

Figure 3. A Large Purchase of Reserves

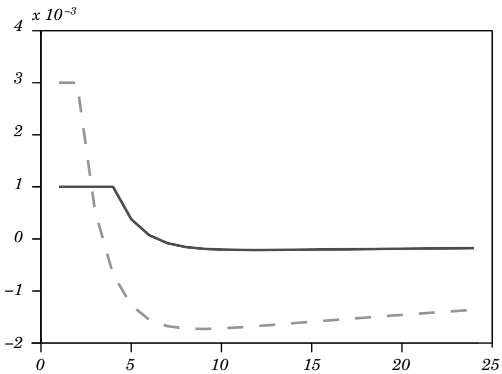


Source: Author's elaboration.

This discussion illustrates the main trade-off associated with the average level of reserves $\overline{b}$. A low $\overline{b}$ raises the possibility that the central bank may run out of reserves. A high $\overline{b}$, on the other hand, requires external credit and uses up some of the country's credit limit, thus making the economy more likely to fall into the financially constrained region in response to exogenous shocks.[10]

To illustrate further, figure 4 shows how the response of external debt to an unanticipated purchase of reserves depends on the average value of reserves $\overline{b}$. The dashed line corresponds to a lower average level of reserves (lower $\overline{b}$) than the solid line. In each case, the figure shows the response of debt relative to its steady-state value, which depends on $\overline{b}$ (since $\overline{d} = \overline{l} - \overline{b}$). The purchase of reserves is of the same magnitude and results in the external constraint binding in both cases. However, as shown, with lower $\overline{b}$, external debt can expand by more before hitting the credit limit. In addition, the economy exits the constrained region faster than with higher $\overline{b}$.

Figure 4. The Role of the Average Level of Reserves



Source: Author's elaboration.

10. This argument is reminiscent of that of Alfaro and Kanczuk (2009) in the context of sovereign debt. In their model, increased official reserve levels may reduce the amount of sovereign debt that is sustainable. The mechanisms in that paper, however, are quite different to ours, and they do not bear on the issue of FX intervention.

The above considerations help understand the implications of intervention rules that respond to endogenous variables, such as exchange rates. Consider, for instance, an intervention rule of the form:

$$b_t = Max\left\{0,(1-\rho_b)\bar{b} + \rho_b b_{t-1} - \upsilon_e\left(e_t - \bar{e}\right)\right\} \tag{7}$$

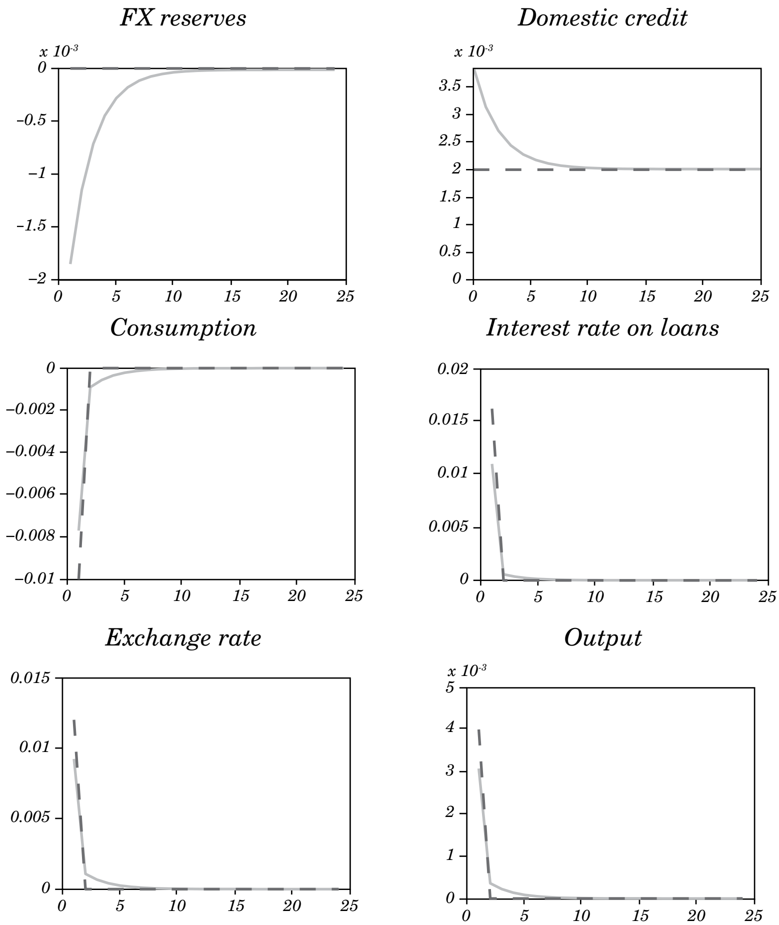
Assuming $v_e \geq 0$; the rule has the central bank buying foreign exchange when the exchange rate is stronger than its steady-state value, and selling it when the exchange rate is abnormally weak. The size of the response is given by the coefficient v_e.

By now, it should be apparent how the policy can aid stabilization in the face of adverse shocks that make financial constraints bind, for the policy prescribes that, in such events, the central bank sells reserves in response to the real depreciation. The resulting fall in the quantity of stabilization bonds frees domestic banks to extend additional credit to households, which helps them smooth consumption. This is depicted in figure 5. In the figure, the dashed lines are impulse responses to a fall in z assuming that the FX intervention rule does not respond to the exchange rate ($v_e = 0$). In fact, there is no FX intervention at all in that case, even if the shock is assumed to be large enough for the economy to hit the credit constraint, as in the figure. Domestic credit increases, but not enough to satisfy the increased demand for credit. Consumption then falls, the exchange rate depreciates, and the interest rate on loans goes up.

The solid lines assume that $v_e > 0$. Now the policy rule prescribes a sale of reserves, since the fall in z leads to real depreciation. As it does so, the central bank retires stabilization bonds, freeing resources for domestic banks to increase loans to households. The figure shows that the fall in consumption is then less acute, as are the adjustments in the real exchange rate and interest rates.

We see, therefore, that an FX intervention rule of the form (7) can stimulate the economy when financial constraints become binding. This is beneficial insofar as domestic residents would be willing, at those times, to borrow more than they can, at the external rate of interest. Rules of this kind, however, also have pitfalls. In particular, they prescribe intervention in response to exchange rate movements even when financial constraints do *not* bind. In our model, as we have seen, this is at best ineffective and, at worst, detrimental.

Figure 5. FX Intervention Rules and the Exchange Rate



Source: Author's elaboration.

To see this, suppose that financial constraints do *not* bind, and the economy is hit by an unanticipated increase in z. The economy can then afford more consumption, which could be beneficial, at least in principle. The intervention rule introduces a concern, however: since the exchange rate must appreciate, the central bank will accumulate reserves, according to the rule.[11] If the accumulation of reserves is small, the economy remains financially unconstrained, although sterilization brings the economy closer to its credit limit, making it more vulnerable to subsequent adverse shocks, as we have seen. More damagingly, if the increase in reserves is large enough, the financial constraint becomes binding. In order to accommodate the sterilization bonds of the central bank, domestic banks must then reduce loans to households. In other words, foreign-exchange purchases in response to real appreciation can end up crowding private credit out.

This is depicted in figure 6. As before, dashed lines are impulse responses when there are no financial constraints. An unanticipated increase in z induces the representative household to consume more and borrow less. Given the increase in consumption demand, the exchange rate appreciates. Following the intervention rule (7), the central bank then buys foreign exchange. In the figure, the increase in the quantity of sterilization bonds more than compensates for the fall in the private demand for credit, and external debt increases. In the absence of financial constraints, increased external borrowing does not affect the cost of domestic loans.

In the presence of financial constraints, however, the FX intervention rule makes the economy hit the external constraint, which remains binding for several periods. To finance the increased supply central bank sterilization bonds, domestic credit falls by more than in the absence of financial constraints. This means that domestic consumption must fall relative to the financially unconstrained case; this is accomplished via an increase in the interest rate on domestic loans, as shown in the figure (solid lines). The weaker response of consumption also explains why the exchange rate appreciates by less than in the unconstrained case. Hence the FX intervention policy looks like it succeeds at stabilizing the exchange rate. But this is the case only because it generates a credit crunch.

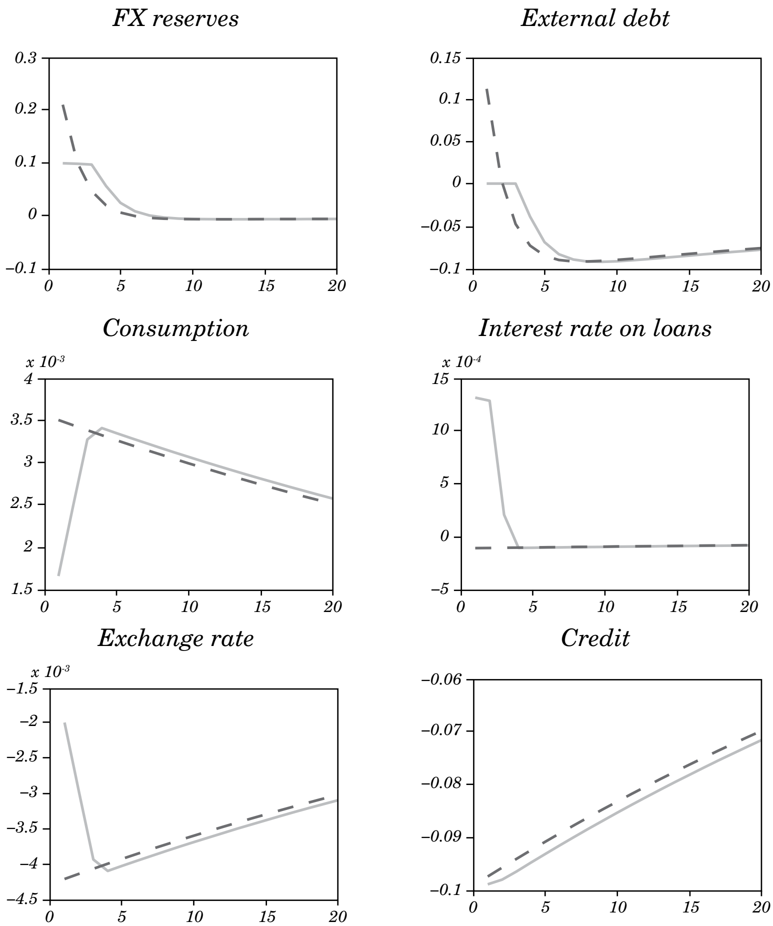
The disadvantage of an FX intervention rule that responds to the exchange rate is, therefore, that it prescribes intervention even when not justified by binding financial constraints. This suggests a superior strategy: intervention should occur in response to interest rate spreads. A suitable rule might be:

$$b_t = Max\left\{0, (1-\rho_b)\overline{b} + \rho_b b_{t-1} - \upsilon_\varrho\left(1+\varrho_t - R_t^*\right)\right\} \tag{8}$$

11. Note that this aspect of the model is consistent with evidence (e.g. Chinn, 2017) that reserves accumulation is associated with a larger current-account balance.

with $v_\varrho \geq 0$ giving the elasticity of central bank sales to widening spreads. Under this rule, the central bank sells foreign exchange, relaxing financial constraints, when the loan interest rate increases above the cost of international credit. This means that FX sales occur when financial constraints bind. When financial constraints do not bind, however, the spread is zero in our model, so that no intervention is called for (over and above what is required to bring the level of reserves back to its steady-state value $\bar{b}$).

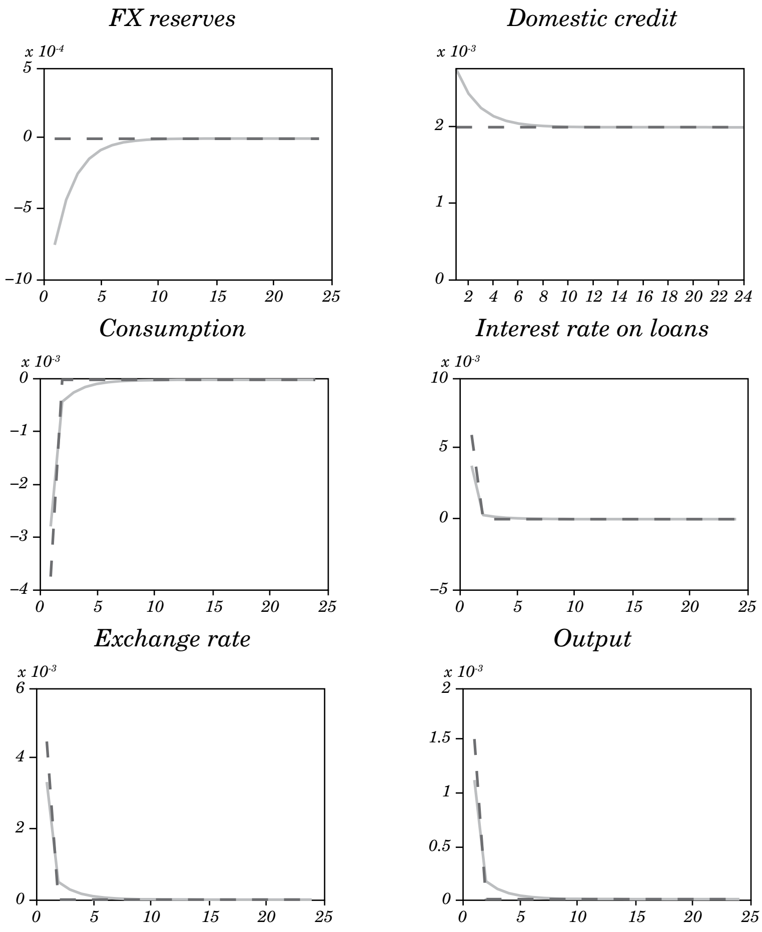
Figure 6. Intervention When Financial Constraints Bind



Source: Author's elaboration.

Responses to a fall in z with the above rule are given in figure 7. The fall in z raises the households' demand for credit, which banks attempt to meet by borrowing abroad. As the credit limit is hit, the spread of the domestic loan rate over the foreign interest rate widens. The intervention rule then implies that the central bank sells reserves. The associated reduction in stabilization bonds then allows banks to expand domestically further. This helps stabilizing credit spreads, consumption, output, and the exchange rate.

Figure 7. Intervention and Credit Spreads



Source: Author's elaboration.

The responses in figure 7 are similar in shape to the ones in figure 5, and the intuition is also very close. The main difference is the variable to which FX intervention reacts to (the exchange rate in figure 5, credit spreads in figure 7). But this difference is crucial: when financial constraints do not bind, there is active FX intervention with the exchange-rate-based policy, but none with the spread-based policy.

This subsection indicates that the analysis of sterilized intervention should pay close attention to the interplay between intervention, official reserves, and occasionally binding financial constraints. Such a focus promises to deliver useful insights and potentially valuable lessons for policy. We have seen, for example, that an intervention rule that responds to the exchange rate can be improved upon by a rule that reacts to credit spreads. Further study of the properties and consequences of intervention rules should prove fruitful for future research.

3. Nominal Rigidities and Monetary Policy

As claimed earlier, our analysis of sterilized intervention is easily amended to study its interaction with conventional monetary policy. To show how, in this section I drop the assumption of nominal price flexibility, and instead adopt the well-known Calvo pricing protocol. Because this specification is well known, I only give a brief description here, and refer interested readers to Galí (2015) for details.

In any given period, an individual producer can set a new price for his product only with some probability $(1-\theta) < 1$. Because producers cannot set prices every period, they do not set the static optimal markup when they can, and equation (2) is dropped. Instead, producers able to change prices choose them so that the markup over marginal cost is optimal, on average, for the random interval of time until they can change prices again. As shown in Galí (2015), to a first order approximation, domestic inflation, denoted by $\pi_{ht} = \log P_{ht} - \log P_{ht-1}$, is then given by

$$\pi_{ht} = \beta E_t \pi_{h,t+1} + \lambda(\log mc_t - \mu) \tag{9}$$

where $mc_t = MC_t / P_{ht}$ denotes marginal cost in terms of domestic goods, $\mu = \log\left(1 - \frac{1}{\epsilon}\right)$ is its steady-state value (in logs), and the coefficient is given by

$$\lambda = \frac{(1-\theta)}{\theta}(1-\beta\theta).$$

Domestic inflation now depends on current and future real marginal costs. In turn, real marginal costs in our model are determined by technology, as given by (1), and optimal labor supply (4):

$$mc_t = \frac{(W_t / A)}{P_{ht}} = \eta e_t^{1-\alpha} c_t^{\sigma} y_t^{\phi} / A^{1+\phi}. \tag{10}$$

Solving the model now requires one more equation, which is given by a monetary policy rule. Our model is cashless but, as discussed by Woodford (2003), this is not an issue if monetary policy is given by an appropriate interest rate rule of the Taylor type. As advocated by Romer (2000), here we assume that the central bank sets policy in order to steer the expected real interest rate:

$$i_t \equiv E_t R_{t+1} = E_t (1 + \varrho_t) \left(\frac{e_{t+1}}{e_t} \right)^{\alpha}.$$

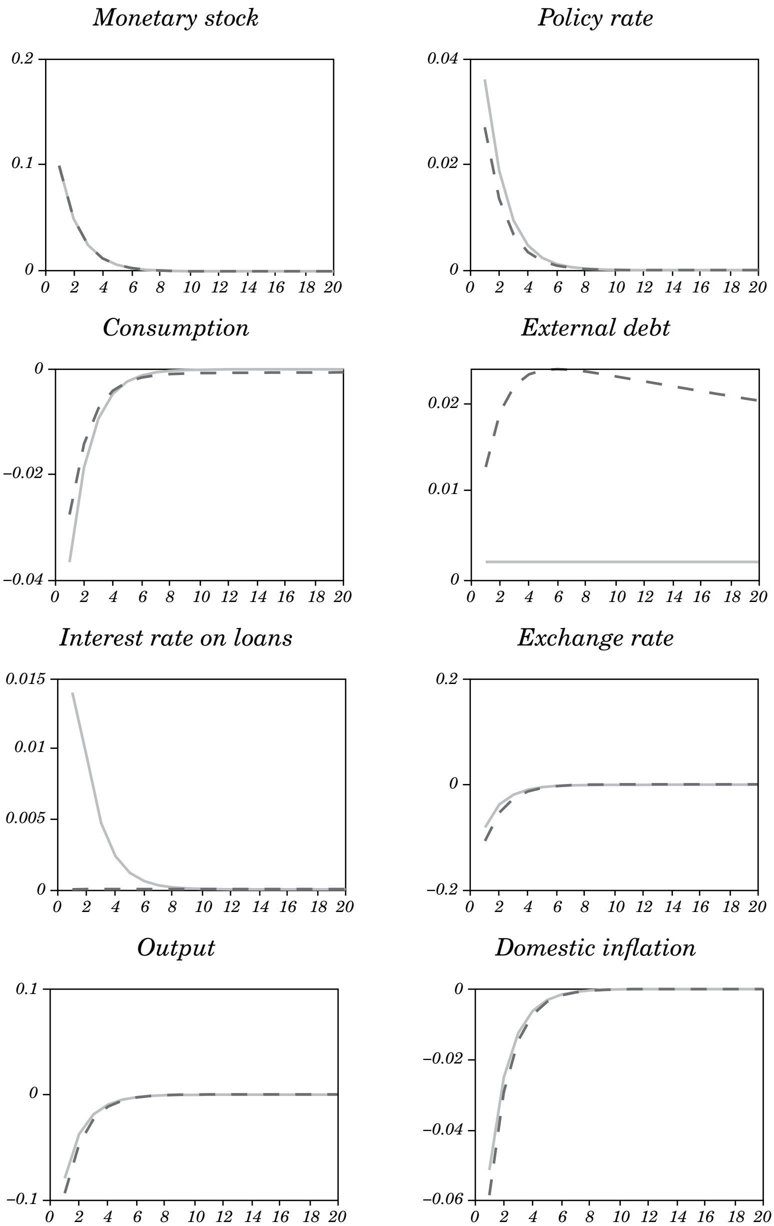
Then we posit a rule of the Taylor type, such as:

$$i_t = \log R_t^* + \phi_\pi \pi_t + u_{mt}. \tag{11}$$

To get a sense of the implications, figure 8 displays impulse responses to a contractionary monetary shock (a positive u_{mt}), assumed to be large enough to place the economy in the financially constrained region. The dashed lines assume no financial constraints, while the solid lines take binding constraints into account. In both cases, the shock directly raises the expected consumption-based interest rate (by assumption) and, therefore, consumption growth. In response, consumption must fall on impact.[12] Households attempt to cushion the blow by borrowing from domestic banks. Domestic loans (not shown) then increase in both cases; but this mechanism is limited if there are financial constraints. As the figure shows, the external credit constraint is reached on impact: if there were no constraints (dashed lines), consumption would fall less and external debt would increase more than in the presence of constraints (solid lines). To ration credit in the case of binding constraints, the interest rate on domestic loans, $1 + \varrho_t$, rises above and over the world interest rate.

12. Note that, for this experiment I assumed that the coefficient of risk aversion is 2. This is because, under log utility, there is no impact on the level of debt.

Figure 8. A Contractionary Monetary Shock



Source: Author's elaboration.

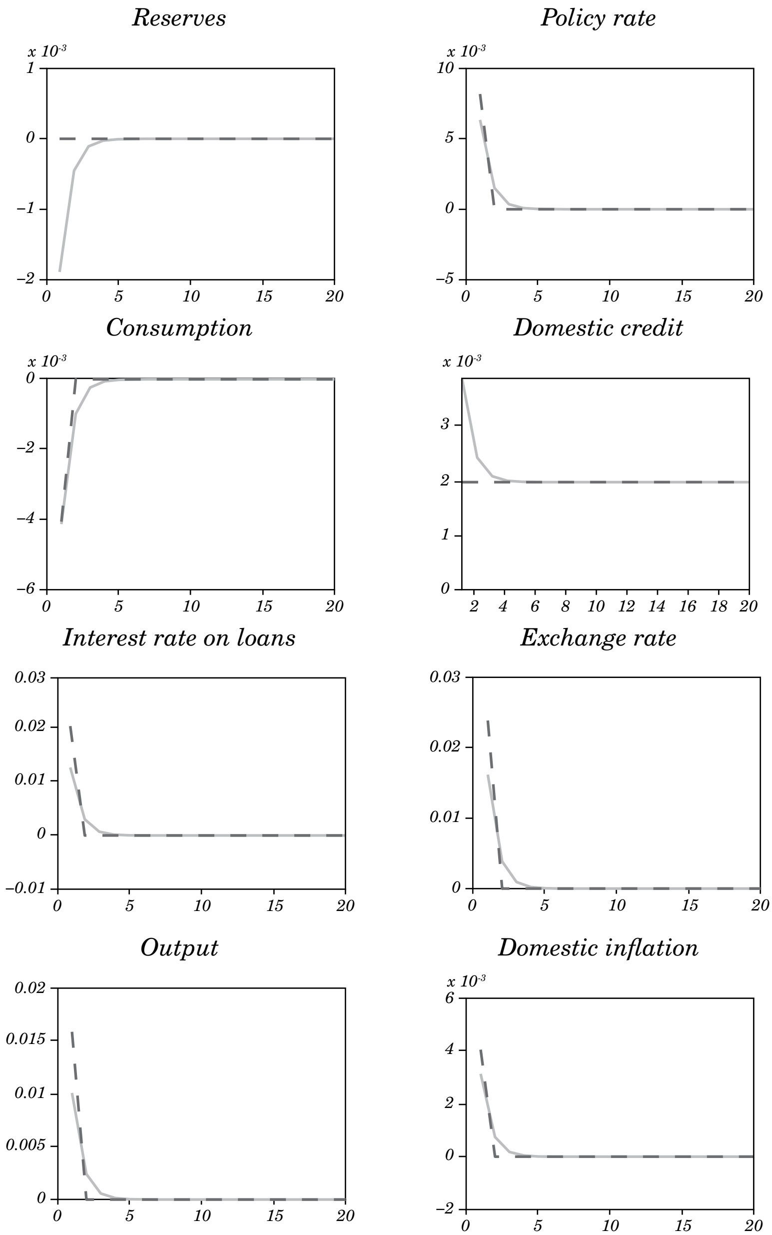
This exercise emphasizes not only that monetary policy is powerful in this model, but also that binding financial constraints can exacerbate the impact of monetary shocks on domestic demand. One may note, on the other hand, that the exchange rate appreciates, but binding financial constraints reduce the extent of the appreciation. As a consequence, domestic inflation and output fall by less and the policy rate increases more than in the absence of financial constraints. The intuition is that, when there are no financial constraints, the loan rate ϱ_t is pinned down by the external rate , so that a given rise in the expected rate i_t is accomplished solely via an increase in the expected depreciation rate. In contrast, when financial constraints bind, the raise in i_t is accomplished partly via an increase in the interest rate spread, thus requiring a comparatively smaller increase in expected depreciation, and consequently a smaller appreciation on impact.

We might now ask about the role of sterilized foreign-exchange intervention. Our first observation is that, as in the model with flexible prices, intervention does not have real effects if it occurs at times of nonbinding constraints. The argument is virtually the same as in subsection 2.1, except that the relevant system of equilibrium equations excludes (2) and includes (9), (10), and (11). The intuition is unaltered: if the collateral constraint does not bind at *t,* any change in b_t (which leaves the constraint still not binding) is offset one for one by a change in d_t, without any impact on equilibrium.

A notable implication is that, independently of monetary policy, intervention policy does not affect real allocations for shocks that are small enough so as not to make financial constraints bind. This is clear under intervention rules such as (7) or (8). If intervention is triggered by abnormally high credit spreads, as with (8), there is no intervention at all as long as constraints do not bind. With an intervention rule that responds to the exchange rate, as with (7), shocks that do not result in binding financial constraints do trigger sales or purchases of reserves, but ones that are fully accommodated by changes in external debt d_t, with no other real impact.

For large enough shocks, financial constraints bind and, as we have stressed, FX intervention does have real effects. In this kind of situation, intervention can complement conventional monetary policy. To illustrate, figure 9 displays responses to a fall in z, assuming a Taylor rule like (11). In the figure, the dashed lines depict responses when there is no active intervention, while the solid lines give responses when intervention responds to spreads. The figure also assumes that, whether there is active intervention or not, financial constraints are present and become binding under the shock.

Figure 9. Monetary Policy and FX Intervention



Source: Author's elaboration.

The figure shows that, without an active intervention response, the shock would raise the domestic demand for private loans. Banks would then borrow abroad up to the credit limit, and the loan interest rate would increase to ration credit. Consumption demand would fall, leading to a real exchange rate depreciation. The depreciation would imply an increase in the foreign demand for domestic output and an overall output increase. As a consequence, domestic inflation would increase. Then the Taylor rule would prescribe an increase in the policy interest rate.

With an intervention rule as (8), the increase in spreads prompts the central bank to sell reserves. As discussed, the corresponding fall in sterilization bonds allows for domestic loans to increase by more than in the absence of intervention. For this calibration, the intervention rule has negligible effects on the impact response of consumption, although it implies a smoother transition back to the steady state. More notably, the active intervention rule moderates the exchange rate depreciation, and hence the increases in output and domestic inflation.

Clearly, one could expand further on the specifics of this analysis and the consequences of different combinations of monetary rules and intervention policy. This is outside my main purpose here, however, which is to emphasize that our perspective on sterilized intervention can straightforwardly be combined with standard monetary policy analysis.

This being said, one notable and general lesson from our discussion is that, in the presence of financial frictions, the question of whether sterilized intervention can be an independent policy instrument has an unambiguously positive answer. But the answer differs substantially from others offered in the recent literature. Sterilized intervention is ineffective locally: it cannot help in case of shocks small enough that financial constraints do not bind. On the other hand, intervention can help when the constraints do bind and, in that case, it works by alleviating the external credit limit.

In short, nonlinearities are essential, and a proper analysis of intervention requires going beyond current approaches that restrict attention to local approximations around the steady state.

4. The Role of Financial Dollarization

To this point we have assumed that the economy is "financially dollarized", in that all financial instruments are denominated in dollars. This is partly because some real-world economies are financially dollarized, and partly to emphasize that our basic arguments do not depend on currency mismatches or debt denomination. Often, however, some securities are denominated in domestic currency (pesos) along with others that are denominated in foreign currency (dollar). In this section I show how to modify our model to allow for peso securities and argue that, while some additional effects are introduced, our line of reasoning remains largely untouched.

Assume now that domestic loans and central bank bonds are denominated in pesos, paying a gross interest rate R_t^n between periods t and t+1. What is crucial is that R_t^n is determined in period t: the arguments of previous sections obviously apply if returns on peso securities were indexed to, say, the dollar. Under our new assumption, the *dollar* return on loans and bonds between t and t + 1 depends on the realized rate of depreciation, and is given by

$$R_{t+1}^d = R_t^n \frac{E_t}{E_{t+1}} \cdot$$

Observe the notation: the subscript on R_{t+1}^d emphasizes that it is a random variable that becomes known only at t + 1.

Because the dollar rate of return on domestic loans is unknown as of period t, we need to amend our analysis of the decision problems of domestic agents. To simplify things, we just assume from now on that domestic banks belong to households, which provide banks with equity $\tilde{k}$. Then the typical bank's problem is to maximize the discounted expected value of dollar profits:

$$E_t M_{t+1} \pi_{t+1}$$

where

$$\pi_{t+1} = R_{t+1}^d (l_t + b_t) - R_t^* d_t$$

subject to $b_t + l_t = \tilde{k} + d_t$ and the collateral constraint $d_t \leq \theta\tilde{k}$, where M_{t+1} is the household's discount factor for *dollar* payoffs, which we derive shortly.

The first order conditions to this problem imply that the collateral constraints now can be written as:

$$\begin{aligned} d_t &= \theta\tilde{k} \quad \text{if} \quad E_t M_{t+1}\left(R_{t+1}^d - R_t^*\right) > 0 \\ &\leq \theta\tilde{k} \quad \text{if} \quad E_t M_{t+1}\left(R_{t+1}^d - R_t^*\right) = 0. \end{aligned}$$

Note that these conditions are very similar to the ones we derived earlier, in the case of financial dollarization.

The analysis of the central bank is the same as before, observing only that the quasi-fiscal deficit in period t is now given by

$$T_t = \left(R_t^d - R_{t-1}^*\right) b_{t-1}$$

and hence it depends on the realized rate of depreciation.

Lastly, the household's problem is solved just as before, but now we need to take into account that the dollar interest rate on loans taken at t is R_{t+1}^d instead of $1 + \varrho_t$, and hence it is uncertain as of period t. The Euler condition for loans then becomes:

$$c_t^{-\sigma} = \beta E_t c_{t+1}^{-\sigma} R_{t+1}^d \left(\frac{e_{t+1}}{e_t}\right)^{\alpha}$$

or

$$1 = E_t M_{t+1} R_{t+1}^d$$

which identifies the dollar discount factor as:

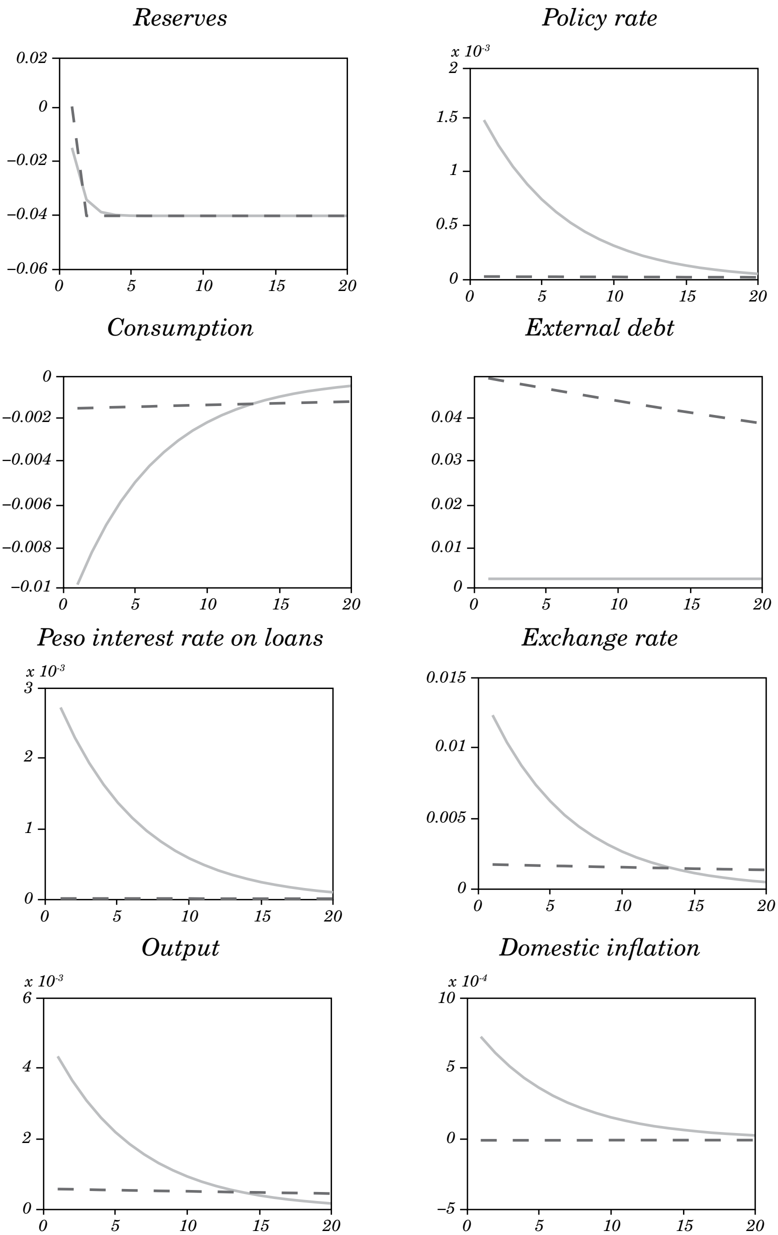
$$M_{t+1} = \beta \left(\frac{c_{t+1}}{c_t}\right)^{-\sigma} \left(\frac{e_{t+1}}{e_t}\right)^{\alpha}.$$

The expected consumption-based real rate is $E_t R_{t+1}^d \left(\frac{e_{t+1}}{e_t}\right)^{\alpha}$. With these modifications, we can retrace the analysis above, without significant change.

To illustrate, figure 10 presents impulse responses to a fall in z. The figure assumes a Taylor rule of the form (11), and an intervention rule similar to (8) but with $E_t R_{t+1}^d - R_t^*$ as the relevant spread. In the absence of financial constraints (dashed lines), the shock would be accommodated by increased household borrowing, and an increase in the banks external debt, without noticeable impact on real variables or inflation. Given the policy rules, the central bank neither changes the policy interest rate nor intervenes in the foreign-exchange market.

The shock is assumed to be large enough for external debt to hit the credit limit, however. As discussed before, adjustment then entails a larger fall in consumption, which requires an increase in the real interest rate. This is accomplished via a relatively large devaluation and, in this model, an increase in the nominal peso interest rate on loans. The monetary policy rate increases in response to rising inflation, and reserves fall because the intervention rule prescribes foreign-exchange sales as credit spreads widen.

Figure 10. The Role of Currency Denomination



Source: Author’s elaboration.

No major differences emerge between this case and the one of the previous section. In other words, assuming that domestic securities are denominated in pesos or dollars does not appear to have but a minor effect. In this model, the denomination of domestic securities only results in some unanticipated transfers between households and banks, which have little impact on equilibrium.

This being said, it must be noted also that the presence of peso securities might result in currency *mismatches* interacting with credit constraints, thus resulting in potentially much more significant balance sheet effects. Such effects could presumably be added to our model. For instance, one might assume that the equity constraint is denominated in pesos, which implies that $e_t^{\alpha} k_t \leq \tilde{k}$ rather than $k_t \leq \tilde{k}$. Then a real depreciation would cause a reduction in bank equity, and this would tighten the debt limit. A plausible conjecture is that sterilized intervention might have a larger role in this context, but exploring this issue is outside the scope of the present paper.

5. Final Remarks

This paper has proposed an alternative perspective on the way sterilized foreign-exchange intervention works, and developed several implications for theory and policy. As stressed in the introduction, this perspective can help reconcile theory and practice in compelling, intuitive ways.

As for the theory, we have seen that occasionally binding financial constraints imply that sterilized intervention can have real effects, but only at some specific times, if it relaxes the financial constraints when they bind. This result is quite consistent with standard theory, but it implies that sterilized intervention is not always irrelevant. And in fact, our analysis suggests that intervention can be powerful when it matters the most.

Our analysis also suggests that sterilized intervention may be irrelevant much, or even most, of the time. In this sense, it is no surprise that empirical evidence for significant effects of intervention has been elusive. Future empirical research should examine whether the impact of intervention depends on the incidence of financial constraints.

More generally, our analysis stresses that the impact of sterilized intervention may depend on the degree of financial frictions as well as on the nature of financial institutions. This suggests that, empirically, the effectiveness of intervention should differ across countries, according to their degree of financial development.

As stressed in Céspedes and others (2017), the model in this paper suggests that it may be beneficial to sell reserves in response to an excessive depreciation, if "excessive depreciation" is to be understood as depreciation at times of binding constraints. On the other hand, there is no gain in fighting exchange rate *appreciation* over and beyond replenishing official reserves for the central bank to be ready to deal with future adverse shocks. In this sense, our analysis does not offer a justification of observed episodes of reserves accumulation that appear to be motivated by competitiveness reasons. Presumably one could extend our model in such a direction, but that extension is outside the scope of this paper.

For exposition, we made some very specific assumptions. One of them was that the central bank used its own sterilization bonds in sterilization operations. A little thought should convince the reader that this assumption is much less restrictive than it appears. For instance, suppose that, to sterilize purchases of official reserves, the central bank sells government debt instead of its own debt. The impact of this operation would be exactly the same as the one in this paper, assuming that government debt has to be absorbed by domestic banks. In fact, a useful way to look at this alternative may be to think of the "central bank" of our model as a consolidated entity encompassing the central bank plus the fiscal authority.

A second assumption worthy of additional comment is that sterilization bonds are held exclusively by domestic banks. This implies that intervention can have real effects by relaxing or tightening the external credit limit of the banks. But the assumption may appear unrealistic, especially in cases where central bank can sell debt to foreigners. It should not be too hard, however, to relax the assumption in realistic ways while preserving the essence of our analysis. For example, as in Gabaix and Maggiori (2015), Montoro and Ortiz (2016) or Cavallino (2017), one might posit foreign investors that specialize in trading domestic securities, including stabilization bonds.

If those investors are themselves constrained by some kind of market segmentation, financial imperfection, or credit limit, their presence and intermediation activities may not suffice for domestic agents to have unrestricted access to international credit. Assuming that the financial frictions are such that access is interrupted occasionally, sterilized intervention is likely to have real effects similar to the ones we have discussed, and for essentially the same reasons.

Finally, we had to commit to particular assumptions on the central bank quasi-fiscal deficit. If those assumptions were to be dropped, one would have to supply further detail about how the quasi-fiscal deficit is financed and, further, what determines the evolution and management of the central bank's net worth. These are not trivial issues, but best left for future research. Let us only remark that this question is related to the more general claim that unconventional policy may matter if there are frictions in the links between the central bank and fiscal authorities. See, for example, Benigno and Nisticò (2015).

This paper focused on the transmission mechanism behind intervention, and suggested ways in which intervention may be beneficial in terms of welfare. But it did not attempt to characterize welfare maximizing policy, which is a promising avenue for future study.

A related question is that of optimal reserves management. Our discussion has identified a novel trade-off in accumulating reserves: larger reserves place the central bank in a better position to deal with suddenly binding financial constraints, but financing the stock of reserves may imply that the constraints bind more often. This indicates that the analysis of optimal reserves may involve this trade-off and combine insights from the recent macroprudential policy literature with the perspective on intervention discussed here.

APPENDIX

Here we provide details on the calibration used for the examples and illustrations. I assume that there is a steady state in which the external constraint does not bind. (It should be noted that this assumes that FX intervention policy is consistent with such a steady state.)

We denote steady-state values with overbars. Then, $1+\overline{\varrho}=\overline{R}^*$ (which here denotes the steady-state value of both $\overline{R}_t^*$ and R_t^*) because financial constraints do not bind. The Euler condition then requires that $\beta\overline{R}^*= 1$, as usual.

The steady-state values of y, c, and e must satisfy:

$$\overline{y} = \alpha\overline{e}^{(1-\alpha)}\overline{c} + x\overline{e}^{x}$$

$$(1-\alpha)\overline{e}^{-\alpha}\overline{c} - \left[\overline{z} + x\overline{e}^{x-1}\right] = -\overline{r}^*\left(\overline{d}-\overline{b}\right)$$

$$1/\eta(1-1/) = \overline{e}^{(1-\alpha)}\overline{y}^{\phi}\overline{c}^{\sigma} / A^{1+\phi}$$

where $\overline{r}^* = \overline{R}^* - 1$.

For calibration, I impose that the steady value of e be one, and that the trade balance surplus be one percent of output (it is common to impose balanced trade in the steady state, but Schmitt-Grohe and Uribe (2017) argue in favor or a surplus of two percent of GDP; as a compromise, I impose one percent). Now, from the definition of trade surplus, this requires:

$$[\overline{z}+\varkappa]-(1-\alpha)\overline{c}$$
$$=\overline{z}+\overline{y}-\overline{c}$$
$$=0.01y$$

the second equality following from market clearing ($\overline{y} = \alpha\overline{c} + \varkappa$).

Optimal labor supply reduces to

$$\Theta = \overline{c}^{\sigma}\overline{y}^{\phi} / A^{1+\phi}$$

where

$$\Theta = 1/\left(1-\frac{1}{\in}\right)\eta.$$

I choose parameters so that $\overline{y} = \overline{c} = 1$ as well. For the market clearing condition to be satisfied, this will require $\varkappa = 1-\alpha$. Also, for optimal output,

$$A = \Theta^{-(1/1+\phi)} = \left(\left(1-\frac{1}{\epsilon}\right)\eta\right)^{1/1+\phi}$$

and

$$\bar{z} = 0.01.$$

Finally, for the country budget constraint to hold, we need that

$$0.01 = \bar{z} = \bar{r}^*\left(\bar{d} - \bar{b}\right).$$

This restricts $\left(\bar{d} - \bar{b}\right)$. The usual assumption is that $\bar{b} = 0$; if so, $\bar{d} = \bar{z} / \bar{r}^*$. If we assume $\bar{r}^* = 0.01$, then $\bar{d} = 1$. (Note that this is the ratio of debt to *quarterly* output. So, it corresponds to 0.25 in terms of the usual debt/annual GDP ratio, and so it is in the ballpark).

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Interest-Rate Policies, Banking and the Macroeconomy

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The debate over the effectiveness of monetary policy often centers around the benefits of low interest rates as a stimulus for the real economy. The idea is that low interest rates encourage spending, either in the form of consumption or investment, and this promotes employment and production. The potential cost of low interest rates is the possibility of inflation, not only in commodity prices but also in the price of assets (for example, real estate). Therefore, the debate about the desirability of low interest rates centers around the trade-off between economic stimulus and higher inflation.

However, low interest rates have two additional implications that have received less attention in the monetary policy debate. The first implication is that low interest rates reduce the incentive of savers to hold liquid financial assets. The second implication is that low interest rates increase the incentive of financial intermediaries to leverage. In this paper I show that the first implication (lower liquid assets held by savers) discourages economic activity while the second (higher leverage in financial intermediation) increases macroeconomic fragility.

I show these results by extending the theoretical framework developed in Quadrini (2017) to include a monetary/fiscal authority that controls interest rates. In addition to the monetary/fiscal authority, the model consists of three sectors: a production sector, a household sector, and a financial intermediation sector. The equilibrium structure of the model is somewhat special as compared to other macroeconomic

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models with financial intermediation: In equilibrium, producers (firms) are net savers, while households are net borrowers. By working with this theoretical framework, I am able to capture the fact that U.S. corporations hold high volumes of financial assets (cash) which, in aggregate, are in excess of their financial liabilities. Thus, the corporate sector is no longer a net borrower. On the other hand, household debt has grown over time and reached a very high level when compared to household income.

If firms hold large volumes of financial assets, it must be because they provide some value on top of the earned interest. In the model proposed in this paper firms hold low-interest-bearing assets because they provide insurance against production risks. Because of the insurance service, when firms hold more financial assets they are willing to take more production risks, which translate in higher demand for labor and higher economic activity. But when the interest rate is low, firms will hold less financial assets. This implies that they are less insured and, as a result, they are willing to take less production risk. This is the mechanism through which lower interest rates have a negative impact on economic activity.

In the model, financial intermediaries issue liabilities that are sold to the market. When the interest rate is low, financial intermediaries have a higher incentive to finance investments with more liabilities and less equity, that is, they increase leverage. But higher leverage also implies that the macroeconomic consequences of a crisis are larger. In particular, it generates a bigger redistribution of financial wealth from savers (which in the model are producers) to borrowers (which in the model are households). But larger redistribution of financial wealth away from savers-producers implies that they will cut more heavily the demand of labor, thus generating a stronger macroeconomic contraction. So, ultimately, a policy of low interest rates generates a contraction in economic activity and increases macroeconomic volatility.[1]

The organization of the paper is as follows: Section 1 describes the model, starting with the monetary authority, and characterizes the equilibrium. Section 2 uses the model to study how the action

1. There are recent contributions that also propose mechanisms for which low interest rates are associated with lower economic activity. They include Brunnermeier and Koby (2017)—low interest rates impair the profitability of banks—, Bullard (2015) and Cochrane (2016)—neo-Fisherian view where low interest rates eventually lead to low inflation—, Eggertsson and others (2017)—secular stagnation—.

of the monetary authority/fiscal authority affects interest rates and real equilibrium allocations. The final section 3 provides some concluding remarks.

1. Model

The economy is composed of three sectors: the entrepreneurial sector, the household sector, and the financial intermediation sector. The role of financial intermediaries is to facilitate the transfer of resources between entrepreneurs and households. There is also a monetary/fiscal authority that purchases bank liabilities with funds raised by taxing households. In strict sense, the funds used by the monetary/fiscal authority to purchase bank liabilities are not fiat money. However, they play a similar role as fiat money since they increase the funds that banks can use to make loans. I will then refer to the holding of bank liabilities by the monetary/fiscal authority as 'money' and denote it by M_t.

All variables are in real terms and I abstract from nominal prices. Of course, by doing so, I will not be able to study the implication of monetary policy for inflation. However, this has the advantage of simplifying the presentation of the central mechanism emphasized in the paper.

Bank liabilities pay the gross interest R_t^l and the monetary/fiscal authority faces the following budget constraint

$$M_t = \frac{M_{t+1}}{R_t^l} + T_t \ ,$$

where T_t are lump-sum transfers to households (or taxes if negative).

The purchase of bank liabilities by the monetary/fiscal authority is similar to open-market operations. In fact, I could assume that there is a stock of government bonds in circulation that pay the gross interest rate R_t^l. Monetary policy interventions would then consist in the purchase of these bonds from banks. By holding government bonds, the monetary authority earns the gross interest rate R_t^l. The difference, however, is that the purchase of government bonds is not made with fiat money, but they are fully funded with taxes. As observed above, even if there is no fiat money, the transmission mechanism is similar: purchases of government bonds generate an injection of funds in the banking system which will then be used by banks to make loans. I now describe each of the three sectors, starting with the financial intermediation sector.

1.1 Financial Intermediation Sector

There is a continuum of infinitely-lived financial intermediaries. Financial intermediaries are profit-maximizing firms owned by households. Although I will often refer to a financial intermediary as "bank", the financial intermediation sector should be interpreted broadly as including all financial firms, not just commercial banks.

A bank starts the period with investments i_t and liabilities l_t. The difference between investments and liabilities is bank equity $e_t = i_t - l_t$. As we will see later, in equilibrium, the investments of banks are loans made to households and the liabilities are held in part by entrepreneurs and in part by the monetary/fiscal authority. However, this is an equilibrium property and, at this stage, I do not need to specify which sector holds the liabilities of banks and which sector receives the investments.

Given the beginning-of-period balance-sheet position, the bank could default on its liabilities. In case of default creditors have the right to liquidate the bank investments i_t. However, they may not be able to recover the full value of the investments. In particular, with probability λ creditors recover a fraction $\xi < 1$, while with probability $1-\lambda$ they recover the full value of the investments. Denoting by $\xi_t \in \{\xi, 1\}$ the fraction of the bank investments recovered by creditors, the recovery value is $\xi_t i_t$.

The stochastic variable ξ_t is the same for all banks (aggregate shock) and its value is unknown when the bank issues liabilities l_t and make investments i_t. In this paper ξ_t follows an exogenous stochastic process. However, this variable can be made endogenous if we interpret ξ_t as the market price of bank investments which depends on the liquidity of the whole banking system (Quadrini, 2017).

The choice of l_t and i_t are made at the end of period $t - 1$. The realization of ξ_t, instead, arises at the beginning of period t. Thus, the bank enters period t with l_t and i_t and, knowing ξ_t, it could use the threat of default to renegotiate its liabilities. Assuming that the bank has the whole bargaining power, the liabilities can be renegotiated to $\xi_t i_t$, that is, to the value that the creditors would recover in case of liquidation. Therefore, after renegotiation, the residual liabilities of the bank are

$$\tilde{l}_t(l_t, i_t) = \begin{cases} l_t & \text{if } l_t \leq \xi_t i_t \\ \xi_t i_t & \text{if } l_t > \xi_t i_t \end{cases}. \tag{1}$$

Financial intermediation implies an operation cost that depends on the leverage chosen by the bank. Denoting the leverage by $\omega_{t+1} = l_{t+1}/i_{t+1}$, the operation cost takes the form

$$\varphi(\omega_t+1)q_t\, l_{t+1},$$

where q_t is the price of the newly issued liabilities and $q_t\, l_{t+1}$ are the funds raised by the bank.

Assumption 1 *The function* $\varphi(\omega_{t+1})$ *is twice continuously differentiable. For* $\omega_{t+1} \leq \xi$ *it is constant at* τ. *For* $\omega_{t+1} > \underline{\xi}$, *it is strictly increasing and convex, that is,* $\varphi'(\omega_{t+1}) > 0$ *and* $\varphi''(\omega_{t+1}) > 0$.

The unit cost function is constant and equal to τ if the leverage ω_{t+1} is smaller than $\underline{\xi}$ but it becomes increasing and convex for $\omega_{t+1} > \underline{\xi}$. This assumption captures, in reduced form, the potential agency frictions which increase in leverage. From a technical point of view, it insures that the optimal leverage is an interior solution to the bank problem specified below. Being an interior solution, banks would optimally change the leverage when market conditions change.

Denote by $\bar{R}_t^l$ the expected gross return on the market portfolio of bank liabilities issued in period t and repaid in period $t + 1$. This is the expected return on the liabilities of the whole banking sector. Since banks are atomistic and competitive, the expected return on the liabilities issued by an individual bank must be equal to the aggregate expected return $\bar{R}_t^l$. Therefore, the price for the liabilities issued by an individual bank at t must satisfy

$$q_t\left(l_{t+1}, i_{t+1}\right) l_{t+1} = \frac{1}{R_t^l} \mathbb{E}_t \tilde{l}_{t+1}\left(l_{t+1}, i_{t+1}\right). \tag{2}$$

The left-hand-side is the payment made by investors (entrepreneurs) to purchase l_{t+1} at price $q_t(b_{t+1}, l_{t+1})$. The right-hand-side is the expected repayment in the next period, discounted by $\bar{R}_t^l$ (the expected market return). The expected repayment and, therefore, the price of the bank liabilities depend on the financial structure chosen by the bank, that is, l_{t+1} and i_{t+1}. Condition (2) guarantees that, whatever the policy chosen by the bank, the holders of its liabilities receive the same expected return $\bar{R}_t^l$.

The budget constraint of the bank, after the renegotiation of its liabilities can be written as

$$\tilde{l}_t\left(l_t, i_t\right) + \frac{i_{t+1}}{R_t^i} + div_t = i_t + q_t\left(l_{t+1}, i_{t+1}\right) l_{t+1}\left[1 - \varphi\left(\frac{l_{t+1}}{i_{t+1}}\right)\right]. \tag{3}$$

The left-hand-side contains the residual liabilities after renegotiation, the funds needed to make new investments, and the dividends paid to shareholders (households). The right-hand-side contains the repayment of the loans made to households and the funds raised by issuing new liabilities, net of the operation cost. Using condition (2), the funds raised with new liabilities are $\mathbb{E}_t \tilde{l}_{t+1}\left(l_{t+1}, i_{t+1}\right) / \bar{R}_t^l$.

The optimization problem solved by the bank is

$$V_t\left(l_t, i_t\right) = \max_{div_t, l_{t+1}, i_{t+1}} \left\{ div_t + \beta \mathbb{E}_t V_{t+1}\left(l_{t+1}, i_{t+1}\right) \right\} \tag{4}$$

subject to (1), (2), (3).

Notice that the problem takes into account the renegotiation of the debt through the function $\tilde{l}(l_t, i_t)$ in the budget constraint. Leverage cannot exceed 1 since, in this case, the bank would renegotiate with certainty. Therefore, problem (4) is also subject to the constraint $l_{t+1} \leq i_{t+1}$.

The first order conditions with respect to l_{t+1} and i_{t+1}, derived in appendix A, are

$$\frac{1}{\bar{R}_t^l} \geq \beta\left[1 + \Phi\left(\omega_{t+1}\right)\right] \tag{5}$$

$$\frac{1}{\bar{R}_t^l} \geq \beta\left[1 + \Psi\left(\omega_{t+1}\right)\right], \tag{6}$$

with $\Phi(\omega_{t+1})$ and $\Psi(\omega_{t+1})$ increasing in leverage $\omega_{t+1} = l_{t+1} / i_{t+1}$. These conditions are satisfied with equality if $\omega_{t+1} < 1$ and inequality if $\omega_{t+1} = 1$.

From condition (5) we can see that leverage $\omega_{t+1} = l_{t+1} / i_{t+1}$ is the relevant variable, not the scale of operation l_{t+1} or i_{t+1}. This follows from the linearity of the intermediation technology and the risk neutrality of banks. Bank leverage matters because it affects the operation cost. These properties imply that, in equilibrium, all banks choose the same leverage ω_{t+1} (although they could chose different scales of operation).

Because the first order conditions (5) and (6) depend only on ω_{t+1}, there is no guarantee that these conditions are both satisfied for arbitrary values of $\bar{R}_t^l$ and R_t^i. However, in the general equilibrium, these rates adjust to clear the markets for bank liabilities and investments, so both conditions will be satisfied.

Lemma 1 *If* $\omega_{t+1} > \underline{\xi}$, *then* $\overline{R}_t^l < R_t^i < \frac{1}{\beta}$ *and* $R_t^i / \overline{R}_t^l$ *increases with* ω_{t+1}.

Proof 1 *Appendix B.*

Since leverage increases the operation cost, the bank chooses to do so only if there is a differential between the cost of funds and the return on investments. As the spread increases, banks are willing to pay the higher cost induced by higher leverage. When the leverage exceeds $\underline{\xi}$, banks could default with positive probability. Default implies losses for the holders of bank liabilities.

In the next section we will see that the bank liabilities are held by entrepreneurs and, therefore, bank default implies wealth losses for entrepreneurs. These losses affect adversely the willingness of entrepreneurs to undertake risky production with negative macroeconomic consequences.

1.2 Production Sector

Production is carried out by a unit mass of entrepreneurs with lifetime utility $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \ln(c_t)$. Entrepreneurs are individual owners of firms, each operating the production function $y_t = z_t h_t$, where h_t is the input of labor supplied by households at the wage rate w_t, and z_t is an idiosyncratic productivity shock. The productivity shock is independently and identically distributed among firms and over time, with probability distribution $\Gamma(z)$.

A key assumption is that the input of labor h_t is chosen before observing the idiosyncratic productivity z_t. Since entrepreneurs are risk-averse, this implies that labor is risky.

To facilitate consumption smoothing, entrepreneurs can hold bank liabilities, which I denote by b_t. However, since banks could default on their liabilities, what matters for entrepreneurs is the value after renegotiation which I denote by $\tilde{b}_t$. The budget constraint faced by an entrepreneur in period i is

$$ct + q_t b_{t+1} = (z_t - w_t)h_t + \tilde{b}_t. \tag{7}$$

An entrepreneur enters the period with financial wealth b_t (in the form of bank liabilities). After banks renegotiate, the residual wealth is $\tilde{b}_t$. Given $\tilde{b}_t$, the entrepreneur chooses the labor input h_t and, after the realization of the idiosyncratic shock z_t, s/he chooses consumption c_t and next period financial assets b_{t+1}.

Because labor h_t is chosen before the realization of z_t, while the saving decision is made after the observation of z_t, it will be convenient to define $n_t = \tilde{b}_t + (z_t - w_t)h_t$ the entrepreneur's net worth after production. Given the timing structure, the input of labor h_t depends on $\tilde{b}_t$ while the saving decision $q_t b_{t+1}$ depends on n_t.

Lemma 2 *Let ϕ_t satisfy $\mathbb{E}_z \left\{ \frac{z - w_t}{1 + (z - w_t)\phi_t} \right\} = 0$. The optimal entrepreneur's policies are*

$h_t = \phi_t \tilde{b}_t,$

$c_t = (1 - \beta_t)\, n_t,$

$q_t b_{t+1} = \beta\, n_t$

Proof 2 *Appendix C.*

The demand for labor is linear in the financial wealth of the entrepreneur $\tilde{b}_t$. The term of proportionality ϕ_t is defined by the condition $\mathbb{E}_z \left\{ \frac{z - w_t}{1 + (z - w_t)\phi_t} \right\} = 0$, where the expectation is over the idiosyncratic productivity z. Since the only endogenous variable that affects ϕ_t is the wage rate, I denote this term by $\phi(w_t)$. It is easy to verify that this function is strictly decreasing in w_t.

Because $\phi(w_t)$ is the same for all entrepreneurs, the aggregate demand for labor is

$$H_t = \phi(\omega_t) \int b_t = \phi(\omega_t) \tilde{B}_t,$$

where I have used capital letters to denote average (per-capita) variables.

We can see from the above expression that the demand for labor depends negatively on the wage rate and positively on the financial wealth of entrepreneurs $\tilde{B}_t$. When banks default, the renegotiated wealth of entrepreneurs $\tilde{B}_t$ drops and this generates a reduction in the demand for labor.

Although the dependence of the production scale on the wealth of entrepreneurs is a feature of many models with financial market frictions, the mechanism that generates this property is different. It does not derive from the need to finance working capital or investments with binding borrowing constraints. Instead, it derives from the assumption that production is risky and entrepreneurs are willing to hire more labor only if they hold a larger wealth buffer that allows for smoother consumption. Thanks to this feature, financial market frictions play an important role for the real sector of the economy even if producers are not borrowing constrained.

1.3 Household Sector

There is a unit mass of households with utility $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(c_t - \alpha \frac{h_t^{1+\frac{1}{v}}}{1+\frac{1}{v}} \right)$, where c_t is consumption and h_t is labor. Households do not face idiosyncratic risks and the assumption of risk neutrality is not important for the key properties of the model. Each household holds a non-reproducible asset available in fixed supply $\overline{K}$, each producing χ units of consumption goods. I think of the non-reproducible asset as housing and χ as housing services. Houses are divisible and can be traded at market price p_t. Households can borrow from banks at the gross interest rate R_t^i and face the budget constraint

$$c_t + d_t + \left(k_{t+1} - k_t\right) p_t = \frac{d_{t+1}}{R_t^i} + w_t h_t + \chi k_t + T_t,$$

where d_t is the loan (household debt) contracted in period $t-1$ (due in period t), and d_{t+1} is the new loan that will be repaid in the next period $t+1$. The variable T_t denotes the transfers received from the monetary/fiscal authority. Household debt is constrained by the following borrowing limit

$$d_{t+1} \leq \kappa + \eta_t \mathbb{E}_t p_{t+1} k_{t+1}, \tag{8}$$

where κ and η are constant parameters.

I will consider two specifications of the borrowing constraint. I will first consider the case with $\eta = 0$ so that the borrowing limit is constant. This allows me to derive analytical intuitions; then, in the quantitative section, I will consider the more general case with $\eta > 0$.

The first order conditions can be written as

$$\alpha h_t^{\frac{1}{v}} = \omega_t, \tag{9}$$

$$1 = \beta R_t^i \left(1 + \mu_t\right), \tag{10}$$

$$p_t = \beta \mathbb{E}_t \left[\chi + \left(1 + \eta \mu_t\right) p_{t+1}\right]. \tag{11}$$

The term $\beta\mu_t$ is the Lagrange multiplier for the borrowing constraint. From the third equation we can see that, if $\eta = 0$, the real estate price p_t must be constant. Instead, when $\eta > 0$, p_t depends on the tightness of the borrowing constraint captured by the multiplier μ_t.

1.4 Equilibrium with Direct Borrowing and Lending

Before characterizing the equilibrium for the general model, it would be convenient to focus on a simplified version of the model without financial intermediaries. In this case, the loans taken by households, D_t, are equal to the financial wealth of entrepreneurs plus the financial assets held by the monetary authority, that is, $B_t + M_t$. In this economy the monetary/fiscal authority lends directly to households and there is no default. This implies that $\tilde{B}_t = B_t$. The equilibrium prices satisfy $1/q_t = R_t^l = R_t^i = R_t$. I also assume that $\eta = 0$ in the borrowing constraint (8) so that the borrowing capacity of households is fixed.

Proposition 1 *In absence of aggregate shocks, the economy converges to a steady state in which households borrow from entrepreneurs and monetary/fiscal authority, and* $\beta R < 1$.

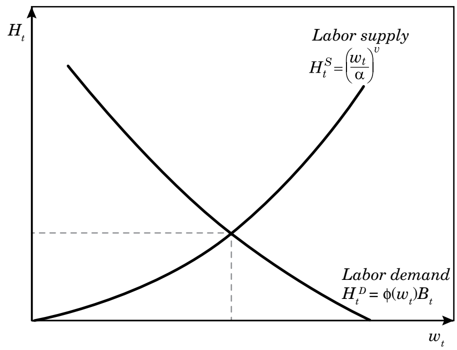
Proof 1 *Appendix D.*

The fact that the steady-state interest rate is lower than the intertemporal discount rate is a consequence of the uninsurable risk faced by entrepreneurs. If $\beta R = 1$, entrepreneurs would continue to accumulate wealth without limit in order to insure against the idiosyncratic risk. The supply of liabilities from households, however, is limited by the borrowing constraint. To ensure that the demand of liabilities from entrepreneurs equals the supply, the interest rate has to fall below the intertemporal discount rate.

The equilibrium in the labor market can be characterized as the intersection of aggregate demand and supply as depicted in figure 1. The aggregate demand was derived in the previous subsection and takes the form $H_t^D = \phi(w_t)B_t$ (remember that without default $\tilde{B}_t = B_t$). The supply is derived from the households' first order condition (9) and takes the form $H_t^S = \left(\frac{w_t}{\alpha}\right)^{\upsilon}$.

The dependence of the demand of labor on the financial wealth of entrepreneurs is a key property of this model. When entrepreneurs hold a lower value of B_t, the demand for labor declines and in equilibrium there is lower employment and production.

Figure 1. Labor Market Equilibrium



Source: Author's elaboration.

It is easy to see the effect of an increase in liquidity. Since $B_t + M_t = D_t$, but $D_t = \kappa$, an increase in M_t has to be followed by a reduction in B_t. In other words, the financial wealth held by entrepreneurs is crowded out by the financial assets held by the monetary authority. Of course, to induce entrepreneurs to hold less financial assets, the interest rate R_t has to fall.

But when the interest rate is low, entrepreneurs hold less financial wealth, which in turn reduces the demand for labor. This is the channel through which lower interest rates could have negative macroeconomic effects.

This channel is also present in the general model with financial intermediaries. The intermediation of banks also introduces an additional mechanism, in which the fall in the financial wealth of entrepreneurs could be the result of a banking crisis. I will then be able to show that the lower the interest rate, the bigger the macroeconomic consequences of a banking crisis.

1.5 General Equilibrium

To characterize the general equilibrium with financial intermediation, I first derive the aggregate demand for bank liabilities from the optimal savings of entrepreneurs, B_{t+1}, and the demand from the monetary authority M_{t+1}. I then derive the supply by consolidating the demand of loans from households with the optimal investment of banks. I continue to assume that $\eta = 0$ so that the borrowing limit specified in equation (8) reduces to $d_{t+1} \leq \kappa$.

Demand for bank liabilities. As shown in lemma 2, entrepreneurs' savings take the form $q_t b_{t+1} = \beta n_t$, where n_t is the end-of-period wealth $nt = \tilde{b}_t + (z_t - w_t)h_t$.

Since $h_t = \phi(w_t)\,\tilde{b}_t$ (lemma 2), the end-of-period net worth can be rewritten as $n_t = [1+(z_t - w_t)\phi(w_t)]\tilde{b}_t$. Substituting into the optimal saving and aggregating over all entrepreneurs we obtain

$$B_{t+1} = \beta\left[1 + \left(\bar{z} - \omega_t\right)\phi\left(\omega_t\right)\right]\frac{\tilde{B}_t}{q_t}. \tag{12}$$

This equation defines the aggregate demand for bank liabilities from entrepreneurs as a function of its price q_t, the wage rate w_t, and the aggregate wealth $\tilde{B}_t$. Remember that the tilde sign denotes the financial wealth of entrepreneurs after renegotiation from banks. Also notice that $1/q_t$ is not the 'expected' return from bank liabilities which we previously denoted by $\bar{R}_t^l$ since banks will repay B_{t+1} in full only with some probability.

Using the equilibrium condition in the labor market, we can express the wage rate as a function of $\tilde{B}_t$. In particular, equalizing the demand for labor, $H_t^D = \phi\,(w_t)\tilde{B}_t$, to the supply from households, $H_t^S = (w_t/\alpha)^\nu$, the wage w_t becomes a function of only $\tilde{B}_t$. We can then use this function to replace w_t in (12) and express the demand for bank liabilities as a function of only $\tilde{B}_t$ and q_t. This takes the form

$$B_{t+1} = \frac{s\left(\tilde{B}_t\right)}{q_t}, \tag{13}$$

where $s(\tilde{B}_t)$ is strictly increasing in the financial wealth of entrepreneurs $\tilde{B}_t$.

The total demand of bank liabilities is the sum of the demand coming from entrepreneurs, B_{t+1}, and the demand coming from the monetary authority M_{t+1}. Figure 2 plots the total demand for a given value of $\tilde{B}_t$. As we change $\tilde{B}_t$, the slope of the demand function changes. More specifically, keeping the price q_t constant, higher initial wealth $\tilde{B}_t$ implies higher demand coming from entrepreneurs and, therefore, higher total demand $B_{t+1} + M_{t+1}$.

Supply of bank liabilities. The supply of bank liabilities is derived from consolidating the borrowing decisions of households with the investment and funding decisions of banks.

According to lemma 1, when banks are highly leveraged, that is, $\omega_{t+1} > \underline{\xi}$, the interest rate on bank investments must be smaller than the intertemporal discount rate ($R_t^i < 1/\beta$). From the households' first order condition (10) we can see that $\mu_t > 0$ if $R_t^i < 1/\beta$. Therefore, the borrowing constraint for households is binding, that is, $D_{t+1} = \kappa$. Since $L_{t+1} = \omega_{t+1} I_{t+1}$, and $I_{t+1} = D_{t+1}$, the supply of bank liabilities is $L_{t+1} = \kappa\omega_{t+1}$.

When the lending rate is equal to the intertemporal discount rate, instead, the demand of loans from households is undetermined, which in turn implies indeterminacy in the supply of bank liabilities. In this case, the equilibrium liabilities are only determined by the demand. In summary, the supply of bank liabilities is

$$L(\omega_{t+1}) = \begin{cases} \text{Undertermined}, & if \quad \omega_{t+1} < \underline{\xi} \\ k\omega_{t+1} & if \quad \omega_{t+1} \geq \underline{\xi} \end{cases}. \tag{14}$$

So far I have derived the supply of bank liabilities as a function of bank leverage ω_{t+1}. However, leverage also depends on the cost of borrowing $\bar{R}_t^i$ through condition (5). The expected return on bank liabilities for the holder of these liabilities, $\bar{R}_t^i$, is in turn related to the price q_t by the condition

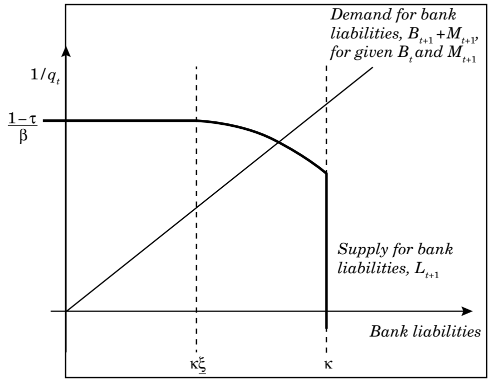
$$\bar{R}_t^i = \left[1 - \theta(\omega_{t+1}) + \theta(\omega_{t+1})\left(\frac{\underline{\xi}}{\omega_{t+1}}\right)\right]\frac{1}{q_t}. \tag{15}$$

With probability $1 - \theta(\omega_{t+1})$ banks do not renegotiate and the *ex-post* return is $1/q_t$. With probability $\theta(\omega_{t+1})$ banks renegotiate and investors recover only a fraction $\underline{\xi}/\omega_{t+1}$ of the initial investment. Therefore, when banks renegotiate, the *ex-post* return is $(\underline{\xi}/\omega_{t+1})/q_t$.

Using (15) to replace $\bar{R}_t^i$ in equation (5) I obtain a function that relates the price q_t to the leverage ω_{t+1}. Finally, I combine this function with $L_{t+1} = \kappa\omega_{t+1}$ to obtain the supply of bank liabilities as a function of q_t. This is plotted in figure 2.

The figure shows that the supply is undetermined when the price q_t is equal to $\beta/(1 - \tau)$ and strictly increasing for higher values of q_t until the supply reaches κ. Remember that, according to assumption 1, $\tau \geq 0$ is the unitary operation cost when $\omega_{t+1} \leq \underline{\omega}$.

Figure 2. Demand and Supply of Bank Liabilities



Source: Author's elaboration.

Equilibrium. The intersection of demand and supply of bank liabilities plotted in figure 2 defines the general equilibrium. The supply (from banks) is increasing in the price q_t while the demand is decreasing in q_t. The demand is plotted for a particular value of outstanding post-renegotiation liabilities held by entrepreneurs, $\tilde{B}_t$, and demand from the monetary authority, M_{t+1}. By changing the outstanding post-renegotiation liabilities, the slope of the demand function changes.

The figure indicates three regions. When the price is $q_t = \beta/(1-\tau)$, banks are indifferent in the choice of leverage $\omega_{t+1} \leq \underline{\xi}$. If the equilibrium is in this region (that is, the intersection of demand and supply arises at $B_{t+1}+M_{t+1} = L_{t+1} = D_{t+1} \leq \underline{\xi}\kappa$), a realization of $\xi_{t+1} = \underline{\xi}$ is inconsequential, since banks always repay their liabilities in full. When $q_t > \beta/(1-\tau)$, however, the optimal leverage starts to increase above $\underline{\xi}$. In this region banks repay only a fraction of their liabilities after a realization of $\xi_{t+1} = \underline{\xi}$. Once $\omega_{t+1} = 1$, a further increase in the price q_t does not lead to higher leverages since the choice of $\omega_{t+1} > 1$ would cause renegotiation with probability 1.

The equilibrium illustrated in figure 2 is for a particular value of financial wealth held by entrepreneurs, $\tilde{B}_t$, and a given demand from the monetary authority, M_{t+1}. Given the equilibrium value of L_{t+1} and the random draw of ξ_{t+1}, we determine the next period financial wealth of entrepreneurs $\tilde{B}_{t+1}$. The new $\tilde{B}_{t+1}$ will determine a new slope for the demand of bank liabilities which, together with M_{t+2}, will determine the new equilibrium value of L_{t+2}. Depending on parameters, the economy may or may not reach a steady state. It would reach a steady state if, starting with $L_t < \underline{\xi}\kappa$, bank liabilities never increase above $\underline{\xi}\kappa$. An important factor is the operation cost $\varphi(\omega_t)$.

According to assumption 1, the unit operation cost is constant and equal to τ for values of $\omega_t \leq \underline{\xi}$. This parameter plays an important role in determining the existence of a steady state as stated in the following proposition.

Proposition 2 *Suppose that M_{t+1} is constant and equal to $\overline{M}$. There exists $\hat{\tau} > 0$ such that: If $\tau \geq \hat{\tau}$, the economy converges to a steady state without renegotiation. If $\tau < \hat{\tau}$, the economy never converges to a steady state but switches stochastically between equilibria with and without renegotiation depending on the realization of ξ_t.*

Proof 2 *Appendix E.*

In a steady state, the price at which banks sell their liabilities must be equal to $q_t = \beta/(1-\tau)$. At this price, banks do not have incentive to leverage because the funding cost is equal to the return on loans. In order to have $q_t = \beta/(1-\tau)$, the demand for bank liabilities must be sufficiently low. This cannot be the case when $\tau = 0$. With $\tau = 0$, in fact, the steady-state price of bank liabilities must be equal to $q = \beta$. But then, because of precautionary savings, entrepreneurs continue to accumulate bank liabilities without a bound. The demand for bank liabilities will eventually become bigger than the supply (which is bounded by the borrowing constraint of households), thus driving the price q_t above $\beta/(1-\tau)$. As the interest rate falls, equilibria with renegotiation become possible. But then the economy fluctuates stochastically and a steady state is never reached.

The above proposition is stated for a constant value of $M_{t+1} = \overline{M}$. But how does an increase in $\overline{M}$ affect the properties of the equilibrium?

Proposition 3 *Suppose that $M_{t+1} = \overline{M}$ and $\tau \geq \hat{\tau}$ so that the economy converges to a steady state without renegotiation. Then a sufficiently high increase in $\overline{M}$ induces a transition away from the steady state and the economy becomes stochastic.*

Proof 3 *Appendix F.*

The proposition has a simple intuition. A higher value of $\overline{M}$ induces a decrease in the interest rate on bank liabilities, that is, an increase in q_t. The lower interest rate then increases the incentive of banks to leverage. But a higher leverage implies that banks renegotiate their liabilities when $\xi_t = \underline{\xi}$. More specifically, bank liabilities are renegotiated to $\kappa\overline{\xi}$. Therefore, the bigger the liabilities issued by banks, the larger the losses incurred by the entrepreneurs holding these liabilities. Larger financial losses incurred by entrepreneurs then imply bigger declines in the demand for labor, which in turn cause bigger macroeconomic contractions.

Proposition 3 thus shows that low interest rates could lead to greater macroeconomic instability, which is one of the key messages of this paper. In the next section I will show this property numerically.

2. Quantitative analysis

In this section, I study the impact of interest-rate policies by using a calibrated version of the model. In the baseline calibration I set $M_t = 0$ for all t. I will then consider an increase M_t (leading to lower interest rates) and show how the economy responds to this change.

The period in the model is a quarter. I set the discount factor to $\beta = 1/1.07^{\frac{1}{4}}$, so that the expected return on equity for banks is 7% annually.

The parameter ν in the utility function of households is the elasticity of labor supply. To mimic an environment with rigid wages while keeping the model simple, I set $\nu = 50$. With this elasticity, wages are almost constant while equilibrium labor is mostly demand-determined. The parameter α in the dis-utility from working is chosen to have an average labor supply is 0.3.

The average productivity is normalized to $\bar{z}=1$. Since the average input of labor is 0.3, the average production in the entrepreneurial sector is also 0.3. The supply of houses is normalized to $\bar{k}=1$ and housing services are set to $\chi = 0.05$. Total production is the sum of entrepreneurial production (0.3) plus housing services (0.05). Therefore, total output is 0.35 per quarter (about 1.4 per year).

The borrowing constraint (8) has two parameters: κ and η. The parameter κ is the constant limit which I set to zero. The parameter η determines the fraction of the value of houses that can be used as collateral. I calibrate η to 0.6 so that the leverage of the household sector is similar to the data. The productivity shock follows a truncated normal distribution with standard deviation of 0.3. The truncation is necessary because the idiosyncratic shock has to be bounded. This implies that the standard deviation of entrepreneurial wealth is about 7%. This is within the range of estimates for rich households reported by Fagereng, Guiso, Malacrino, and Pistaferri (2016) in Norway.

The last set of parameters pertains to the banking sector. The quarterly probability that the liquidation value of bank assets is ξ (which could lead to a bank crisis) is set to 1 percent ($\lambda = 0.01$). Therefore, provided that banks choose sufficiently high leverage, a crisis is a low-probability event that arises, on average, every 25 years.

This number is close to calibrations of crisis probabilities used in the literature. See for example Bianchi and Mendoza (2013).

I do not have direct evidence to calibrate parameter $\underline{\xi}$. I set it to 0.75 which implies that, if a crisis arises, creditors recover at least 75 percent of the bank investment. A loss of 25% for the investments of the whole banking sector (excluding safe financial investments like government bonds) seems plausible. Notice that the actual losses for the creditors of banks are lower than 25% since they depend on bank leverage. For example, if the leverage of banks is 80%, creditors would lose 5% of their assets (held in bank liabilities).

The operation cost takes the quadratic form $\varphi(\omega) = \tau + \overline{\varphi} \cdot \max\{\omega - \underline{\xi}, 0\}^2$. The convex part of the cost is scaled by the parameter $\overline{\varphi}$. This parameter determines the response sensitivity of bank leverage and interest rates to a change in market conditions. The higher the value of $\overline{\varphi}$, the higher the sensitivity of interest rates to shocks, but the lower the response of bank leverage. I set $\overline{\varphi} = 0.05$ which allows for reasonable responses of the interest rate and leverage.

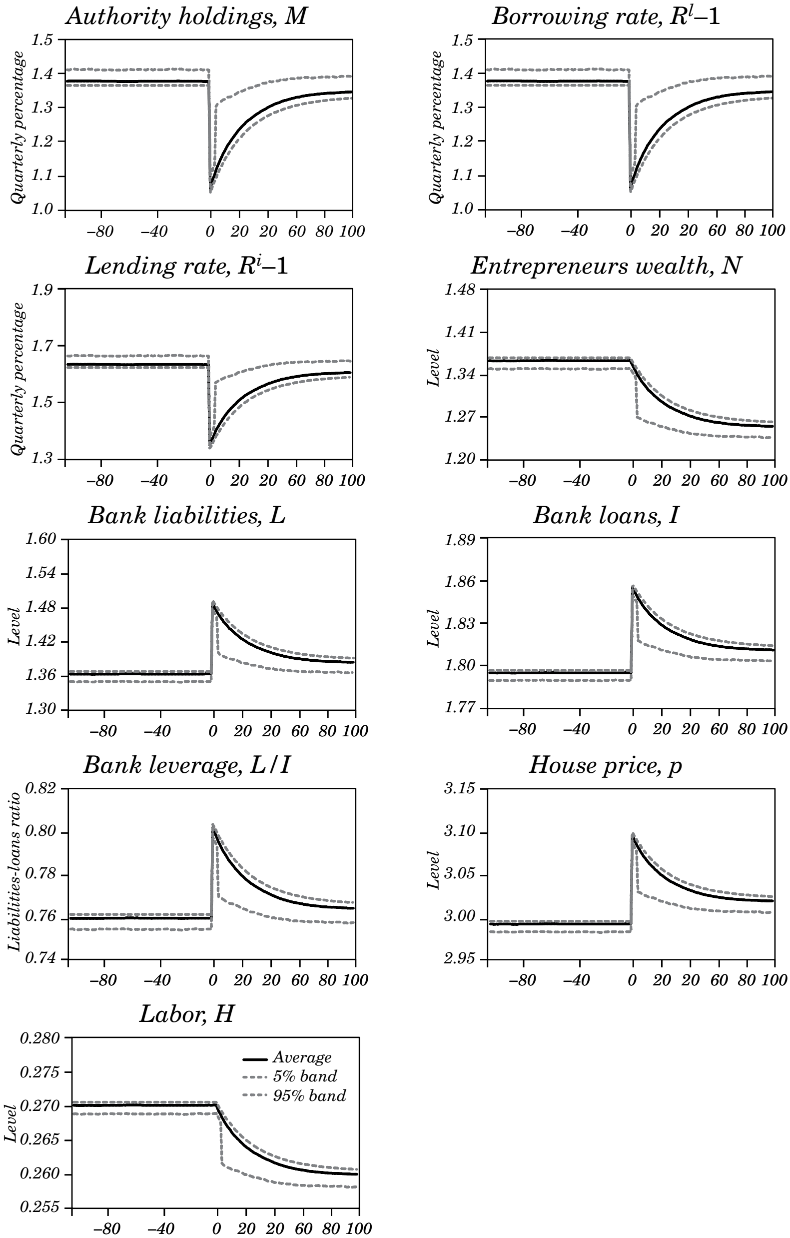
The linear component of the operation cost, τ, is chosen so that the long-run leverage in absence of crises is higher than $\underline{\xi} = 0.75$. This guarantees that the economy experiences stochastic dynamics in response to realizations of ξ_t. The calibrated value is $\tau = 0.0025$, which implies an average leverage of 0.76. Therefore, abstracting from the convex component of the cost, the operation cost is 0.25% per quarter or about 1% per year. Since the calibration of $\underline{\xi}$, τ and $\overline{\varphi}$ are not based on direct empirical targets, the quantitative results should be interpreted with caution.

2.1 Interest-Rate Policies and Macroeconomic Stability

The only aggregate shock in the model is ξ_t, that is, the liquidation value of bank investments. The distribution of this variable is iid: In each quarter, with 1% probability $\xi_t = \underline{\xi}$ and with 99% probability $\xi_t = 1$. If, in equilibrium, banks choose to be sufficiently leveraged (which is the case for the parameter values chosen above), the economy displays stochastic dynamics.

To illustrate the stochastic properties of the economy and the importance of asset purchases by the monetary/fiscal authority (leading to changes in interest rates), I simulate the model with a random sequence of ξ_t over a period of 2,200 quarters. During the first 2,100 quarters $M_{t+1} = 0$ (baseline calibration). In the remaining 100 quarters, I set $M_{t+1} = 0.129$, which is about 10% the average value of bank liabilities before the policy change.

Figure 3. The Effects of Asset Purchases by the Monetary/ Fiscal Authority, M_{t+1}
Mean and Percentiles for 1,000 Repeated Simulations



The simulation is repeated 1,000 times (with each simulation performed over 2,200 periods based of new random draws of ξ_t). I use only the last 200 quarters of each simulation to illustrate the stochastic properties of the economy. By discarding the first 2,000 quarters I eliminate the impact of initial conditions. The numerical procedure used to solve the model is described in appendix G.

Figure 3 plots the average as well as the 5$^{\text{th}}$ and 95$^{\text{th}}$ percentiles of the 1,000 repeated simulations for each of the last 200 quarters (the first 100 quarters with $M_{t+1} = 0$ and the subsequent 100 quarters with $M_{t+1} = 0.129$). The range of variation between the 5$^{\text{th}}$ and 95$^{\text{th}}$ percentiles captures the volatility of the economy at any point in time.

The first panel plots the bank liabilities held by the monetary/fiscal authority, M_{t+1} (asset purchases). This variable is exogenous in the model and the permanent change that takes place in quarter one is what drives the changes in key statistics for the endogenous variables plotted in the other panels.

Let's focus first on the mean of the endogenous variables (continuous line). This is the average, for each quarter, calculated over the 1,000 repeated simulations. Following the increase in M_{t+1}, we observe a decline in the average interest rates (both the rate paid by banks on their liabilities, 'borrowing rate', and the rate charged to loans made to households, 'lending rate'). Notice that, even if these rates recover somewhat over the transition periods, they remain lower than the pre-intervention values also in the long run. Thus, the second part of the simulation is characterized by lower interest rates induced by the higher supply of funds (asset purchases) from the monetary/fiscal authority.

The panels in the middle and bottom rows illustrate the impact of lower interest rates. First, since banks pay lower interest on their liabilities, they increase leverage and supply more loans. This induces a fall in the lending rate paid by households which in turn induces, on average, an increase in the price of houses. Even though there is more liquidity in the economy and the interest rates fall, the input of labor (and therefore production) falls on average.

The mechanism that generates the macroeconomic contraction (lower employment and production) can be described as follows. The lower interest rate on bank liabilities implies that savers (entrepreneurs in the model) have less incentive to hold financial assets. We can then see from the first panel in the middle of figure 3 that the financial wealth of entrepreneurs falls. Even if bank liabilities L_{t+1} rise, the increase is smaller than the increase in M_{t+1}

and, therefore, entrepreneurs' wealth B_{t+1} has to decline. Remember that in equilibrium $L_{t+1} = B_{t+1} + M_{t+1}$. Thus, if L_{t+1} rises less than M_{t+1}, B_{t+1} has to decline. Effectively, the asset purchases by the monetary/fiscal authority crowd out the purchases from savers (entrepreneurs). But lower financial wealth held by savers implies that savers are less willing to hire labor. Thus, the unintended consequences of asset purchase policies are the reduction in the demand for labor.

Let's now look at the percentiles of the repeated simulations. The dashed lines in figure 3 show the 5^{th} and 95^{th} percentiles for the 1,000 repeated simulations.[2] The intervals between the two percentiles widen after the policy intervention. This shows that the asset purchases from the monetary/fiscal authority increase financial and macroeconomic volatility. The probability of a bank crisis is always positive, even before the structural break associated with the higher M_t. However, after the structural break, the consequence of a crisis could be much bigger since banks become more leveraged. Because they are more leveraged, when the economy experiences a negative shock, entrepreneurs face higher losses due to larger renegotiation from banks.

Counter-cyclical asset purchases. Suppose that the monetary/fiscal authority increases M_{t+1} in response to a crisis. To make the analysis simple, suppose that M_{t+1} becomes positive when a financial crisis arrives (that is, $\xi_t = \underline{\xi}$) and stays at this high level for N periods (unless another crisis hits).
Formally,

$$M_{t+1} = \begin{cases} \bar{M}, \; if \; \xi_{t-j} = \underline{\xi} \text{ for any } j = 0,\ldots,N-1; \\ 0, \quad \text{otherwise.} \end{cases} \tag{16}$$

With this policy rule, I simulate the model for a particular sequence of shocks in which a crisis arrives in only one quarter. More specifically, I simulate the economy for the same number of periods as before, 2,200 quarters. The exogenous variable ξ_t takes the value of 1 in all simulation periods with the exception of quarter 2101. I then discard the first 2,000 quarters and show the statistics for the remaining 200.

2. The percentiles are calculated as follows. For each quarter, the values of each variable in the 1,000 repeated simulations are sorted from the lowest to the highest values. The 5th percentile is then the value that is located in position 950 of the 1,000 sorted realizations in the particular quarter (and, therefore, only 5% of all realizations have higher values). The 95th percentile is the value that is located in position 51 (and, therefore, only 5% of all realizations have lower values).

Thus, the negative shock arises in the middle of the last 200 quarters. Since the simulation is for a particular sequence of shocks, I do not need to repeat the simulation as I did before.

Figure 4 plots the simulated variables with two policy regimes. In the first regime the monetary authority behaves passively and keeps $M_t = 0$ in all periods, and therefore, it does not respond to the negative shock. In the second regime the monetary authority follows the rule described in (16), with $N = 8$. Thus, in response to a crisis, the monetary authority increases liquidity for 8 quarters.

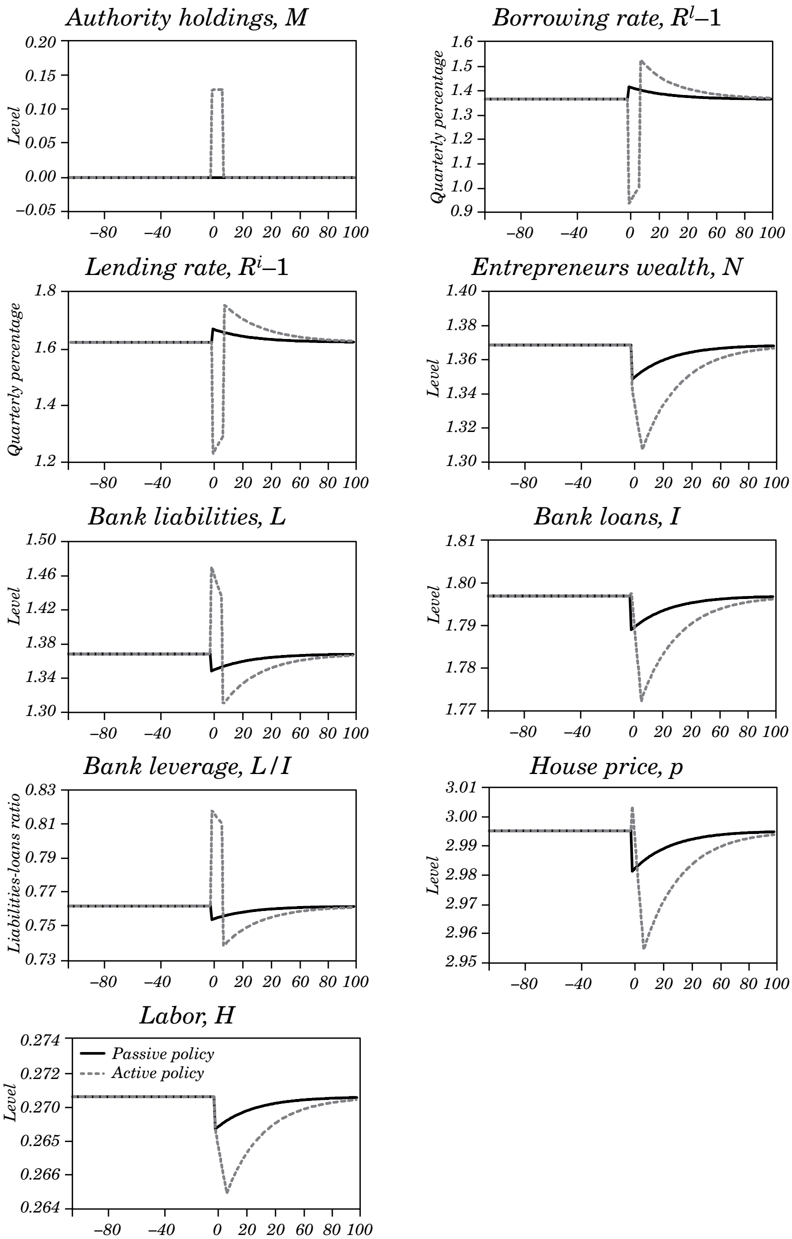
Let's look first at the case in which the monetary/fiscal authority does not respond to the crisis. The realization of $\xi_t = \underline{\xi}$ generates a wealth loss for entrepreneurs (due to the renegotiation from banks) which in turn reduces the demand of labor (macroeconomic contraction). Even if the negative shock is only for one period and there are no crises afterwards, the recovery in the labor market is very slow. This is because it takes a while for employers to rebuild the lost wealth with savings.

When the monetary/fiscal authority reacts to the crisis with asset purchases, the negative macroeconomic impact of the shock gets amplified. The intervention has the effect of reducing the interest rate on bank liabilities which in turn discourages savings. As a result, entrepreneurs take longer to rebuild their financial wealth. The lower interest rates have an immediate positive effect on house prices. But the positive effect is only temporary. This is because the reversal of the policy after 8 quarters is anticipated by the market and, therefore, there is the anticipation of higher future interest rates. The positive effect of the policy on asset prices would be long-lasting if the policy intervention was permanent (as in the simulations shown in figure 3). But a permanent policy intervention would also make the negative impact on employment permanent.

The simulation exercise presented in figure 4 shows that asset purchases from the monetary/fiscal authority do reduce interest rates. However, lower interest rates do not necessarily help the real sector of the economy. On the contrary, it may amplify the macroeconomic impact of the negative shock.

Of course, there are other channels through which asset purchases and interest policies could affect the real sector of the economy that have not been modeled in this paper. So, ultimately, what is shown here does not lead to the conclusion that reducing the interest rate may be counterproductive if the goal is to alleviate the negative macroeconomic consequences of an adverse shock. However, the channel emphasized in this paper should be taken into account when discussing the desirability of monetary policy interventions in response to negative aggregate shocks and, in particular, financial crises.

Figure 4. Countercyclical Asset Purchases by the Monetary/ Fiscal Authority. Increase in M_t for 2 Years in Response to a Financial Crisis Hits ($\xi_t = \underline{\xi}$) at Quarter 1



3. Conclusion

Monetary policy interventions that reduce interest rates encourage spending, either in the form of consumption or in the form of investment, and stimulate the real sector of the economy. In this paper I show that low interest rates could also have a negative macroeconomic impact if they discourage savings. I illustrated the idea in a model in which the financial wealth of producers has a positive impact on production. Since low interest rates reduce the incentive of producers to hold financial wealth, they have negative consequences on production. Low interest rates may also increase macroeconomic volatility if they encourage financial intermediaries to become more leveraged.

The goal of this paper is not to prove that low interest rates are necessarily counter-productive for the performance of the economy, both in level and volatility. To show that policy induced low interest rates could be associated with low economic activity and greater macroeconomic volatility, I have used a model where the positive channels of low interest rates are absent. For example, even if low interest rates increase the market price of houses in the model, it does not increase the production of new houses (since houses are in zero net supply in the model).

The purpose of the paper is only to emphasize that there could be an alternative channel that has not been fully explored by academic researchers and practitioners. This is especially important considering that there is weak evidence that low interest rates are associated with economic growth and macroeconomic stability. Although in emerging countries the correlation between interest rates and macroeconomic indicators is negative, this is not the case for developed countries (Neumeyer and Perri, 2005; and Fernández and Gulan, 2015). Of course, correlations do not reveal the forces that generate these correlations and an empirical exploration of the importance of the channel illustrated here requires deeper empirical analysis which is beyond the scope of this paper.

APPENDIX

A. First Order Conditions for Problem (4)

The probability of renegotiation, denoted by θ_{t+1}, is defined as

$$\theta_{t+1} = \begin{cases} 0, & if\ \omega_{t+1} < \underline{\xi} \\ \overline{\lambda}, & if\ \underline{\xi} \leq \omega_{t+1} \leq 1 \\ 1, & if\ \omega_{t+1} > 1 \end{cases} .$$

Define $\beta(1-\theta_{t+1})\gamma_t$ the Lagrange multiplier associated to the constraint $l_{t+1} \leq i_{t+1}$. The first order conditions for problem (4) with respect to l_{t+1} and i_{t+1} are

$$\frac{1-\varphi_t}{\overline{R}_t^l}\mathbb{E}_t\frac{\partial\tilde{l}_{t+1}}{\partial l_{t+1}} - \frac{\partial\varphi_t}{\partial l_{t+1}}\frac{\mathbb{E}_t\tilde{l}_{t+1}}{\overline{R}_t^l} - \beta\mathbb{E}_t\frac{\partial\tilde{l}_{t+1}}{\partial l_{t+1}} - \beta\left(1-\theta_{t+1}\right)\gamma_t = 0, \tag{17}$$

$$-\frac{1}{R_t^i} + \frac{1-\varphi_t}{\overline{R}_t^l}\mathbb{E}_t\frac{\partial\tilde{l}_{t+1}}{\partial i_{t+1}} - \frac{\partial\varphi_t}{\partial i_{t+1}}\frac{\mathbb{E}_t\tilde{l}_{t+1}}{\overline{R}_t^l} + \beta\mathbb{E}_t\left(1-\frac{\partial\tilde{l}_{t+1}}{\partial i_{t+1}}\right) + \beta\left(1-\theta_{t+1}\right)\gamma_t = 0. \tag{18}$$

I now use $\tilde{b}_{t+1}$ the definition provided in (1) to derive the following terms

$$\frac{\partial\varphi_t}{\partial l_{t+1}} = \varphi'_{t+1}\frac{1}{i_{t+1}},$$

$$\frac{\partial\varphi_t}{\partial i_{t+1}} = -\varphi'_{t+1}\omega_{t+1}\frac{1}{i_{t+1}},$$

$$\mathbb{E}_t\frac{\partial\tilde{l}_{t+1}}{\partial l_{t+1}} = 1-\theta_{t+1},$$

$$\mathbb{E}_t\frac{\partial\tilde{l}_{t+1}}{\partial i_{t+1}} = \theta_{t+1}\underline{\xi},$$

$$\mathbb{E}_t\tilde{l}_{t+1} = \left(1-\theta_{t+1}\right)l_{t+1} + \theta_{t+1}\underline{\xi}i_{t+1}.$$

Substituting in (17) and (18) and re-arranging we obtain

$$\frac{1}{\overline{R}_t^l} = \beta\left[1 + \frac{\varphi_{t+1} + \varphi'_{t+1}\hat{\omega}_{t+1} + \gamma_t}{1-\varphi_{t+1} - \varphi'_{t+1}\hat{\omega}_{t+1}}\right], \tag{19}$$

$$\frac{1}{\bar{R}_t^l} = \beta\left[1 + \frac{\varphi'_{t+1}\hat{\omega}^2_{t+1}\left(1-\theta_{t+1}\right)\left(1+\gamma_t\right)}{1-\varphi_{t+1}-\varphi'_{t+1}\hat{\omega}_{t+1}} + \left(1-\theta_{t+1}+\theta_{t+1}\underline{\xi}\right)\gamma_t\right], \tag{20}$$

where $\hat{\omega}_{t+1} = \omega_{t+1} + \dfrac{\theta_{t+1}\underline{\xi}}{1-\theta_{t+1}}$.

The multiplier γ_t is zero if $\omega_{t+1} < 1$ and positive if $\omega_{t+1} = 1$. Therefore, the first order conditions can be written as

$$\frac{1}{\bar{R}_t^l} \geq \beta\left[1 + \frac{\varphi_{t+1}+\varphi'_{t+1}\hat{\omega}_{t+1}}{1-\varphi_{t+1}-\varphi'_{t+1}\hat{\omega}_{t+1}}\right],$$

$$\geq \beta\left[1 + \frac{\varphi'_{t+1}\hat{\omega}^2_{t+1}\left(1-\theta_{t+1}\right)}{1-\varphi_{t+1}-\varphi'_{t+1}\hat{\omega}_{t+1}}\right],$$

which are satisfied with the inequality sign if $\gamma_t > 0$. Since they are all functions of ω_{t+1}, the first order conditions can be written as in (5) and (6).

B. Proof of Lemma 1

Let's consider the first order conditions (19) and (20) when $\omega_{t+1} < 1$. In this case the Lagrange multiplier γ_t is zero. Provided that $\varphi_{t+1} + \varphi'_{t+1}\hat{\omega}_{t+1} < 1$—which will be satisfied for plausible calibrations—, conditions (19) and (20) imply that $\bar{R}_t^l$ and R_t^i are smaller than $1/\beta$.

The return spread can be computed from (19) and (20) as

$$\frac{R_t^i}{\bar{R}_t^l} = \frac{1}{1-\varphi_{t+1}-\varphi'_{t+1}\hat{\omega}_{t+1}\left[1-\left(1-\theta_{t+1}\right)\hat{\omega}_{t+1}\right]}. \tag{21}$$

Given the properties of the cost function (assumption 1), to show that the spread is bigger than 1, I only need to show that $\left(1-\theta_{t+1}\right)\hat{\omega}_{t+1} < 1$. Using $\hat{\omega}_{t+1} = \omega_{t+1} + \dfrac{\theta_{t+1}\underline{\xi}}{1-\theta_{t+1}}$ and taking into account that $\omega_{t+1} < 1$ and $\theta_{t+1} < 1$, we can verify that $\left(1-\theta_{t+1}\right)\hat{\omega}_{t+1} < 1$. Therefore, the spread is bigger than 1.

To show that the spread is increasing in the leverage, I differentiate (21) with respect to ω_{t+1} to obtain

$$\frac{R_t^i}{\bar{R}_t^l} = \frac{\left(\varphi''_{t+1}\hat{\omega}_{t+1}+2\varphi'_{t+1}\right)\left[1-\left(1-\theta_{t+1}\right)\hat{\omega}_{t+1}\right]}{\left[1-\varphi_{t+1}-\varphi'_{t+1}\hat{\omega}_{t+1}\left(1-\left(1-\theta_{t+1}\right)\hat{\omega}_{t+1}\right)\right]^2}.$$

Given the properties of the cost function (Assumption 1), the derivative is zero for $\omega_{t+1} \leq \underline{\xi}$. To prove that the derivative is positive for $\omega_{t+1} > \underline{\xi}$, I only need to show that $(1 - \theta_{t+1})\,\hat{\omega}_{t+1} < 1$, which has already been shown above. Therefore, the return spread is strictly increasing for $\omega_{t+1} > \underline{\xi}$. *Q.E.D.*

C. Proof of Lemma 2

The optimization problem of an entrepreneur can be written recursively as

$$V_t\left(\tilde{b}_t\right) = \max_{h_t} \mathbb{E}_t \tilde{V}_t\left(n_t\right) \tag{22}$$

subject to

$$n_t = \tilde{b}_t + (z_t - w_t)h_t$$

$$V_t\left(n_t\right) = \max_{b_{t+1}} \left\{ \ln\left(c_t\right) + \beta \mathbb{E}_t V_{t+1}\left(\tilde{b}_{t+1}\right) \right\} \tag{23}$$

subject to

$$c_t = n_t - q_t b_{t+1}.$$

Since the information set changes from the beginning of the period to the end of the period, the optimization problem has been separated according to available information. In sub-problem (22), the entrepreneur chooses the input of labor without knowing the productivity z_t. In sub-problem (23), the entrepreneur allocates the end-of-period wealth to consumption and savings after observing z_t. Notice that the expectation in sub-problem (23) takes into account the dependence of $\tilde{b}_{t+1}$—the renegotiated value of bank liabilities—on pre-renegotiated value b_{t+1}. The first order condition for sub-problem (22) is

$$\mathbb{E}_t \frac{\partial \tilde{V}_t}{\partial n_t}\left(z_t - w_t\right) = 0.$$

The envelope condition from sub-problem (23) gives

$$\frac{\partial \tilde{V}_t}{\partial n_t} = \frac{1}{c_t}.$$

Substituting in the first order condition we obtain

$$\mathbb{E}_t\left(\frac{z_t - w_t}{c_t}\right) = 0. \tag{24}$$

At this point we proceed by guessing and verifying the optimal policies for employment and savings. The guessed policies take the form:

$$h_t = \varphi_t \tilde{b}_t \tag{25}$$

$$c_t = (1-\beta) n_t \tag{26}$$

Since $n_t = \tilde{b}_t + (z_t - w_t)h_t$ and the employment policy is $h_t = \varphi_t \tilde{b}_t$, the end-of-period wealth can be written as $n_t = [1 + (z_t - w_t)\varphi_t]\tilde{b}_t$. Substituting in the guessed consumption policy we obtain

$$c_t = (1-\beta)\left[1 + (z_t - \omega_t)\phi_t\right]\tilde{b}_t. \tag{27}$$

This expression is used to replace c_t in the first order condition (24) to obtain

$$\mathbb{E}_t\left(\frac{z_t - w_t}{1 + (z_t - \omega_t)\phi_t}\right) = 0, \tag{28}$$

which is the condition stated in lemma 2.

To complete the proof, we need to show that the guessed policies (25) and (26) satisfy the optimality condition for consumption and savings. This is the first order condition in sub-problem (23), which is equal to

$$-\frac{q_t}{c_t} + \beta\mathbb{E}_t \frac{\partial V_{t+1}}{\partial \tilde{b}_{t+1}} \frac{\partial \tilde{b}_{t+1}}{\partial b_{t+1}} = 0.$$

From sub-problem (22) we derive the envelope condition $\partial V_t / \partial \tilde{b}_t = 1/c_t$ which can be used in the first order condition to obtain

$$\frac{q_t}{c_t} = \beta\mathbb{E}_t \frac{1}{c_{t+1}} \frac{\partial \tilde{b}_{t+1}}{\partial b_{t+1}}.$$

We have to verify that the guessed policies satisfy this condition. Using the guessed policy (26) and equation (27) updated one period, the first order condition can be rewritten as

$$\frac{q_t}{n_t} = \beta\mathbb{E}_t \frac{1}{\left[1 + (z_{t+1} - \omega_{t+1})\phi_{t+1}\right]\tilde{b}_{t+1}} \frac{\partial \tilde{b}_{t+1}}{\partial b_{t+1}}.$$

Multiplying both sides by b_{t+1}/β, it can be rewritten as

$$\frac{q_t b_{t+1}}{\beta n_t} = \mathbb{E}_t \frac{1}{\left[1+\left(z_{t+1}-\omega_{t+1}\right)\phi_{t+1}\right]} \frac{b_{t+1}}{\tilde{b}_{t+1}} \frac{\partial \tilde{b}_{t+1}}{\partial b_{t+1}}.$$

Notice that, since in case of bank renegotiation, the entrepreneur recovers a fraction of financial wealth ($\tilde{b}_{t+1}/b_{t+1} < 1$) and this fraction depends only on the size of the aggregate financial wealth (not the individual wealth b_{t+1}), the term $\frac{b_{t+1}}{\tilde{b}_{t+1}} \frac{\partial \tilde{b}_{t+1}}{\partial b_{t+1}} = 1$. Furthermore, using the guessed policy (26) we have that $q_t b_{t+1} = \beta n_t$. Substituting in the last expression for the first order condition and rearranging, we obtain

$$1 = \mathbb{E}_t \frac{1}{\left[1+\left(z_{t+1}-\omega_{t+1}\right)\phi_{t+1}\right]}. \tag{29}$$

The final step is to show that, if condition (28) is satisfied, then condition (29) is also satisfied. Let's start with condition (28), updated by one period. Multiplying both sides by ϕ_{t+1} and then subtracting 1 in both sides we obtain

$$\mathbb{E}_t \left[\frac{\left(z_{t+1}-\omega_{t+1}\right)\phi_{t+1}}{1+\left(z_{t+1}-\omega_{t+1}\right)\phi_{t+1}} - 1 \right] = -1.$$

Multiplying both sides by -1 and taking expectations at time t we obtain (29). *Q.E.D.*

D. Proof of Proposition 1

As shown in lemma 2, the optimal saving of entrepreneurs takes the form $q_t b_{t+1} = \beta n_t$, where n_t is the end-of-period wealth $n_t = \tilde{b}_t + (z_t - w_t)h_t$. Since $h_t = \phi(w_t)\tilde{b}_t$ (lemma 2), the end-of-period wealth can be rewritten as $n_t = [1+(z_t - w_t)\,\phi\,(w_t)]\,\tilde{b}_t$. In the environment with direct borrowing and lending there is not default and, therefore, $\tilde{b}_t = b_t$. Substituting into the optimal saving and aggregating over all entrepreneurs we obtain

$$B_{t+1} = \beta\left[1+\left(\bar{z}-\omega_t\right)\phi\left(\omega_t\right)\right]\frac{B_t}{q_t}. \tag{30}$$

This equation defines the aggregate demand for bonds as a function of the price q_t, the wage rate w_t, and the beginning-of-period aggregate wealth of entrepreneurs B_t. Notice that the term in square brackets is bigger than 1. Therefore, in a steady-state equilibrium where $B_{t+1} = B_t$, the condition $\beta < q$ must be satisfied.

Using the equilibrium condition in the labor market, I can express the wage rate as a function of B_t. In particular, equalizing the demand for labor, $H_t^D = \varphi(w_t)B_t$, to the supply from households, $H_t^S = (w_t/\alpha)^\nu$, the wage w_t can be expressed as a function of only B_t. We can then use this function to replace w_t in (30) and express the demand for bank liabilities as a function of only B_t and q_t as follows

$$B_{t+1} = \frac{s(B_t)}{q_t}. \tag{31}$$

The function $s(B_t)$ is strictly increasing in the wealth of entrepreneurs, B_t.

Consider now the supply of bonds from households. For simplicity I assume that $\eta = 0$ in the borrowing constraint (8). Therefore, the constraint takes the form $d_{t+1} \leq \kappa$. Using this limit together with the first order condition (10), we have that, either the price satisfies $q = \beta$ or households are financially constrained, that is, $d_{t+1} = \kappa$. Notice that in equilibrium $B_{t+1} = D_{t+1} - \overline{M}$. Therefore, if the borrowing constraint is binding for households, $B_{t+1} = \kappa - \overline{M}$.

When the price is equal to the inter-temporal discount factor (first case), we can see from (30) that $B_{t+1} > B_t$. So eventually, the borrowing constraint of households becomes binding and the equilibrium condition is $B_{t+1} = \kappa - \overline{M}$ (second case). When the borrowing constraint is binding, the multiplier μ_t is positive and condition (10) implies that the price is bigger than the inter-temporal discount factor. So the economy has reached a steady state. The steady-state price is determined by condition (31) after setting $B_t = B_{t+1} = \kappa - \overline{M}$. This is the only steady-state equilibrium.

When $\eta > 0$ in the borrowing constraint (8), the proof is more involved but the economy also reaches a steady state with $\beta < \mathrm{q}$. *Q.E.D.*

E. Proof of Proposition 2

Given a fixed price q, the aggregate demand for bank liabilities, equation (13), has a converging fix point $B^*(q)$. The fixed point is decreasing in q and converges to infinity as q converges to β. This implies that, if $\tau = 0$, the leverage of banks is always bigger than $\underline{\xi}$.

To show this, suppose that banks choose a leverage of $\omega < \underline{\xi}$. According to conditions (5) and (6), we have that $q = 1/R^i = \beta$. But when $q = \beta$, the demand for bank liabilities is unbounded in the limit. This implies that, to reach a stable equilibrium without renegotiation (that is, $\omega < \underline{\xi}$), q must be bigger than β. This requires τ to be sufficiently large. In fact, when $\tau > 0$ and $\omega < \underline{\xi}$, we have $(1 - \tau)q = 1/R^i = \beta$. Since the demand for bank liabilities is decreasing in q, there must be some $\hat{\tau} > 0$ such that, for $\tau > \hat{\tau}$, the equilibrium is characterized by $\omega < \underline{\xi}$. This implies that the economy is not subject to crises and converges to a steady state.

For $\tau < \hat{\tau}$, instead, the equilibrium is characterized by $\omega > \underline{\xi}$. In this case, the economy displays stochastic dynamics and never converges to a steady state.

F. Proof of Proposition 3

The proof can be illustrated by using figure 2. This figure shows the equilibrium values of q and L, as determined by the intersection of the demand and supply of bank liabilities. The demand for bank liabilities is the sum of $\overline{M}$ and entrepreneurial holdings specified in equation (13), that is,

$$L_{t+1}^d = \overline{M} + B_{t+1} \equiv \overline{M} + \frac{s(\tilde{B}_t)}{q_t},$$

where the function $s(\tilde{B}_t)$ is increasing in $\tilde{B}$. In a steady-state equilibrium $\tilde{B}_t = B_t = B_{t+1}$ and the demand function can be expressed as

$$\overline{M} + B = \overline{M} + \frac{s(B)}{q}.$$

If we are in a steady state, the equilibrium value of L must be lower than $\kappa\underline{\xi}$. An increase in $\overline{M}$ shifts the demand function to the right. As long as q does not change and B stays the same, the increased demand will be filled with an increased supply of bank liabilities. However, if the shift is sufficiently big, the intersection of demand and supply must arise at a higher value of q and a higher value of $L > \kappa\underline{\xi}$. For this value of L. the economy experiences stochastic dynamics. *Q.E.D.*

G. Numerical Solution

I describe first the numerical procedure when M_t is constant. I will then describe the computational procedure when M_t changes to a new value.

G.1 Computation of Equilibrium with Constant M_t

The states of the economy are given by the bank liabilities L_t, the bank loans I_t, and the realization of the stochastic variable ξ_t. Since M_t is constant, the financial wealth of entrepreneurs is $B_t = L_t - \bar{M}$. The three states are important in determining the renegotiated liabilities $\tilde{L}_t$. However, once we know the renegotiated liabilities, $\tilde{L}_t$ becomes the sufficient state for solving the model. Therefore, in the computation I will solve for the recursive equilibrium by using $\tilde{L}_t$ as a state variable.

The key equilibrium conditions are:

$$H_t = \phi(\omega_t)\tilde{B}_t, \tag{32}$$

$$q_t B_{t+1} = \beta N_t, \tag{33}$$

$$N_t = \tilde{B}_t + (1-\omega_t)H_t, \tag{34}$$

$$\alpha H_t^{\frac{1}{\upsilon}} = \omega_t, \tag{35}$$

$$1 = \beta R_t^i(1+\mu_t), \tag{36}$$

$$p_t = \beta\mathbb{E}_t\left[\chi + (1+\eta\mu_t)\,p_{t+1}\right], \tag{37}$$

$$I_{t+1} = \eta\mathbb{E}_t p_{t+1}, \tag{38}$$

$$\frac{1}{\bar{R}_t^l} = \beta\left[1 + \frac{\varphi_{t+1} + \varphi'_{t+1}\hat{\omega}_{t+1}}{1-\varphi_{t+1} - \varphi'_{t+1}\hat{\omega}_{t+1}}\right], \tag{39}$$

$$\frac{1}{R_t^l} = \beta\left[1 + \frac{\varphi'_{t+1}\hat{\omega}_{t+1}^2\left(1-\theta_{t+1}\right)}{1-\varphi_{t+1} - \varphi'_{t+1}\hat{\omega}_{t+1}}\right], \tag{40}$$

$$\bar{R}_t^i = \left[1 - \theta\left(\omega_{t+1}\right) + \theta\left(\omega_{t+1}\right)\left(\frac{\xi}{\omega_{t+1}}\right)\right]\frac{1}{q_t}, \tag{41}$$

$$\omega_{t+1} = \frac{I_{t+1}}{L_{t+1}}, \tag{42}$$

$$L_{t+1} = B_{t+1} + \overline{M}. \tag{43}$$

Equations (32) and (34) derive from the aggregation of the optimal policies of entrepreneurs (labor demand, savings, and end-of-period wealth). Equations (35) and (38) derive from the optimization problem of households (labor supply, optimal borrowing, optimal holding of the fixed asset, and borrowing constraint). Notice that the borrowing constraint of households, equation (38), is not always binding. However, when it is not binding and the multiplier is $\mu_t = 0$, households' borrowing is not determined. Therefore, without loss of generality, I assume that in this case households borrow up to the limit. Equations (39) and (40) are the first order conditions of banks. These conditions are satisfied with equality if $\omega_{t+1} < 1$ and with inequality if $\omega_{t+1} = 1$. Equation (41) defines the expected return on bank liabilities given their price q_t. Equation (42) defines leverage and (43) is the market clearing condition for bank liabilities.

One complication in solving the system is that the expectation for the next period price of the fixed asset, $\mathbb{E}_t p_{t+1}$, is unknown. All we know is that the price is a function of $\tilde{B}_{t+1}$, that is, $p_{t+1} = P(\tilde{B}_{t+1})$. If we knew the function $P(\tilde{B}_{t+1})$, for any given state $\tilde{B}_t$, the above conditions would be a system of 12 equations in 12 variables: H_t, N_t, μ_t, ω_t, p_t, q_t, R^i_t, $\overline{R}^l_t$, B_{t+1}, L_{t+1}, I_{t+1}, ω_{t+1}. Notice that $\tilde{B}_{t+1}$ is a known function of B_{t+1}, L_{t+1}, I_t and the realization of ξ_t. Therefore, knowing the function $P(B_{t+1})$, I can compute the expectation of the next period price p_{t+1}. We can then solve the 12 equations for the 12 variables and this would provide a solution for any given state $\tilde{B}_t$.

However, the function $P(\tilde{B}_{t+1})$ is unknown. Therefore, the numerical procedure follows by using an approximation of this function. In particular, I approximate $P(\tilde{B}_{t+1})$ with a piecewise linear function over a grid for the state variable $\tilde{B}_t$. I then solve the above system of equations at each grid point for $\tilde{B}_t$. As part of the solution, I obtain the current price p_t. I then use the solution for the current price to update the approximated function $P(\tilde{B}_{t+1})$ at the grid point. I repeat the computation until convergence, that is, the values guessed for $P(\tilde{B}_{t+1})$ at each grid point must be equal (up to a small rounding number) to the values of p_t obtained by solving the model (given the guess for $P(\tilde{B}_{t+1})$).

G.2 Computation of Equilibrium with Changing M_t

When M_t changes, the economy transitions from a stochastic equilibrium to a new stochastic equilibrium. To solve for the transition, I use the following steps:

1. I first compute the stochastic equilibrium under the regime with the initial constant M_t.
2. I then compute the stochastic equilibrium under the new and constant M_t.
3. At this point, I solve the model for the transition period in which M_t changes. I solve for the transition backward starting at the terminal period when M_t becomes constant at the new level. In each period t, I solve the system (32) and (43) by using the approximated function $P_{t+1}(\tilde{B}_{t+1})$ found at time $t + 1$. In the first backward step (last period of the transition), $P_{t+1}(\tilde{B}_{t+1})$ is the approximated price function found in the stochastic stationary equilibrium after the break (see previous computational step).

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The Relation between Monetary Policy and Financial-Stability Policy

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What is the relation between monetary policy and financial-stability policy? How can they be distinguished? How similar or different are they? Should they have the same or different goals? How should they be conducted? Should they be coordinated or conducted separately? Should they be conducted by the same or different authorities? What if monetary policy would pose a threat to financial stability? Should monetary policy ever "lean against the wind" (of asset prices and credit booms)?

The answers to these questions continue to be discussed and debated. To answer them, it is necessary to specify how different economic policies, in general, and monetary and financial-stability policies, in particular, can be distinguished; how appropriate goals and policy instruments for each economic policy can be determined; and how responsibility for achieving the goals and control of the appropriate instruments can be assigned to authorities and decision-making bodies.[1]

In the rest of the paper, how to distinguish different economic policies in general is discussed in section 1, and how to distinguish monetary and financial-stability policies in particular, in section 2.

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1. This paper extends on the discussion in Svensson (2016) and has benefited from Kohn (2015).

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Section 3 discusses whether monetary policy should have financial stability as an additional goal. Section 4 examines whether monetary policy and financial-stability policy should be conducted separately or co-ordinately. Section 5 discusses whether monetary policy and financial-stability policy should be conducted by the same or separate authorities. Section 6 examines how to handle a situation in which monetary policy would pose a threat to financial stability. Section 7 takes up the issue of monetary policy "leaning against the wind" (LAW). This includes a summary of, first, the Swedish example of a dramatic LAW and, second, a complete turnaround of policy and abandonment of LAW. It also includes a summary of the research on costs and benefits of LAW, and a demonstration that LAW implies a lower average inflation and a lower average policy rate. Section 8 presents some conclusions.

1. How can different economic policies be distinguished?

In general, when we discuss different economic policies, we distinguish them according to their goals, their instruments, and the authorities that control the instruments and are responsible for achieving the goals. For example, without going into details, it is obvious that monetary policy and fiscal policy are different economic policies, with different goals, instruments, and responsible authorities. Furthermore, it is obvious that there is considerable interaction between the policies. For example, fiscal policy has effects on inflation and employment, and these effects have to be taken into account in the conduct of monetary policy. Also, monetary policy has effects on government revenues and expenditures, including interest on government debt, and these have to be taken into account in the conduct of fiscal policy.

In spite of this interaction, normally monetary policy and fiscal policy are conducted separately, with each policy taking the conduct and effects of the other policy into account. This corresponds to the so-called Nash equilibrium in game theory, where each player chooses his instruments independently to achieve his goals, while taking into account the conduct of the policy by the other player. This is different from the so-called cooperative equilibrium, where the two players jointly choose their instruments to achieve joint goals.

Given this, an interesting and relevant question is whether the relation between monetary policy and financial-stability policy is similar to or different from the well-established and well-understood relation between monetary policy and fiscal policy.

2. How can monetary policy and financial-stability policy be distinguished?

In order to distinguish monetary policy and financial-stability policy, let us look at the goals, instruments, and responsible authorities of the two policies.

For *monetary policy*, under flexible inflation targeting, there are two goals— price stability and real stability; more precisely, to stabilise inflation around the inflation target, and resource utilisation around its estimated long-run sustainable rate. The long-run sustainable rate of resource utilisation may be measured as the maximum sustainable employment rate, the minimum sustainable unemployment rate, or the potential output level. For example, under the Federal Reserve's dual mandate, the two goals are price stability and maximum employment (what is often called full employment), that is, to stabilise inflation around the Federal Reserve's inflation target, and employment around its (estimated) maximum long-run sustainable rate.[2]

In normal times, the instruments of monetary policy are the policy rate and the communication. The latter includes publishing forecasts of the target variables, such as inflation and unemployment, and possible forward guidance, such as publishing a policy-rate path, that is, a forecast for the policy rate. In crisis times, the set of instruments of monetary policy is larger and includes balance-sheet policies, such as large-scale asset purchases (quantitative easing), fixed-rate lending at longer maturities,[3] and foreign-exchange interventions and exchange-rate floors. The authority controlling the instruments and responsible for achieving the goals of monetary policy is the central bank.

2. As is explained in Svensson (2011), I am sceptical about the usefulness of estimates of potential output as a reliable measure of full resource utilization and believe that the estimated long-run sustainable rate of unemployment normally is a more reliable measure.

3. Fixed-rate lending by the central bank can be classified as monetary policy, because it can be seen primarily as a commitment to keeping the current policy rate fixed at least until the maturity of the loan. Variable-rate lending can be seen as primarily liquidity support (credit easing) and lending of last resort. In crisis times and crisis management, classifying central-bank actions is sometimes not obvious. The same central-bank action may have aspects of fiscal, monetary, or financial-stability policy. In such cases, my preference is to classify actions according to their primary purpose.

Before discussing the goals, instruments, and responsible authorities of financial-stability policy, let me clarify that I consider financial-stability policy somewhat more broadly, including both macro- and microprudential policy as well as resolution. The discussion will nevertheless mostly concern macroprudential policy. Furthermore, it is important to distinguish between normal times and (financial) *crisis prevention* on one hand, and crisis times and *crisis management* on the other. Financial-stability policy involves both crisis prevention and crisis management. The discussion will mostly concern crisis-prevention financial-stability policy.[4]

For *financial-stability policy*, the goal is *financial stability*. The definition of financial stability is not as clear and obvious as the definition of price stability and real stability. An appropriate definition of financial stability is: the condition when *the financial system can fulfil its three main functions* (transforming saving into financing, allowing risk management, and transmitting payments) *with sufficient resilience to disturbances that threaten these functions*. The crucial part of the definition is *sufficient resilience*. In the future, there will unavoidably be disturbances and shocks to the financial system, very likely from unanticipated directions and of unanticipated kinds. The crucial thing is then that there is sufficient resilience to disturbances, so as to limit the probability and magnitude of financial crises.

The resilience of the financial system needs to be considered more broadly. Not only is it the resilience of lenders, banks and other financial intermediaries that matters, but also the resilience of borrowers, including households and firms, for example in real estate and construction.

Importantly, there may be a trade-off between financial stability and resilience on one hand, and efficiency, growth, and prosperity on the other. We clearly do not want the stability of the graveyard. Regulation has benefits to the extent that it remedies negative effects of some market failures, such as externalities, but it may also have

4. See Tucker (2015, 2016) for a thoughtful discussion of these issues. However, Tucker's definition of macroprudential policy emphasizes the dynamic adjustment of regulatory parameters to maintain a desired degree of resilience in the system. I find the emphasis on dynamic adjustment a bit too restrictive; macroprudential policy might, to a large extent, include constant policies, such as fixed capital requirements, that are not dynamically adjusted, or at least very rarely changed. To make sure that more structural and constant prudential policies are included, I prefer to use the somewhat broader term financial-stability policy (which is somewhat more restrictive than the even broader term financial policy, which might include more policies, such as consumer protection and competition policy for the financial sector).

costs in terms of less competition, less efficient resource allocation, and so on. Regulation may also have income- and wealth-distribution effects, including intergenerational effects. This means that financial-stability policy needs to have a secondary goal. For example, the Bank of England's Financial Policy Committee has a secondary objective of "supporting the economic policy of Her Majesty's Government, including its objectives for growth and employment" (Hammond, 2017).

However, in this paper I will not discuss the role of such a secondary objective any further.[5]

Under normal times, that is, under crisis prevention, the instruments of financial-stability policy are supervision, regulation, and communication. They include capital and liquidity requirements, including restrictions on maturity transformation; mortgage loan-to-value (LTV) caps; stress tests of banks, other financial firms, and households; financial-stability reports; and so on.[6]

Under crisis times, that is, under crisis management, things are very different. Then, all the relevant authorities (fiscal, monetary, and financial-stability and resolution authorities) cooperate with all available and suitable instruments to minimise the scope and magnitude of the crisis and restore financial stability.

The authority or authorities controlling the financial-stability instruments and being responsible for achieving and maintaining financial stability vary across countries and may include the financial supervisory authority, the central bank, the ministry of finance, and other regulatory and supervisory agencies.

Clearly, from the above perspective, monetary policy and financial-stability policy are quite different and distinct policies. But how closely related are they? Should they really have different goals?

5. Given a possible long-run tradeoff between resilience and prosperity, Tucker (2015) discusses the need for an explicit political decision on a standard of resilience that financial-stability policy shall maintain.

6. The instruments of micro- and macroprudential policy overlap and the boundary between them is not clear. This is particularly the case when, as in Sweden, the financial sector is dominated by a few large and systemically important banks and microprudential policy of individual financial institutions thus have systemic consequences. This is an additional reason why I prefer to consider a broader financial-stability policy that includes both micro- and macroprudential policy and has the goal of financial stability (with microprudential policy's focus on the stability of individual financial institutions seen as a part of a policy for stability of the financial system). IMF (2013) provides an extensive discussion of the goals and scope of macroprudential policy and their relation to microprudential policy and to crisis management and resolution policies.

3. Should monetary policy have financial stability as its third goal?

In particular, should monetary policy have a third goal, not only price stability and real stability, but also financial stability? First of all, we should realise that the question "should *monetary policy* have financial stability as a goal?" is different from the related question "should *central banks* have a financial-stability goal?" The answer to the latter depends on whether we are considering crisis prevention or crisis management. In crisis management, central banks have a role as lenders of last resort.[7] Therefore, it is obvious that central banks should have financial stability as an objective in crisis management. In crisis prevention, the answer depends on whether or not the central bank has control of any macroprudential instruments. If it has, the goal for the use of those instruments should of course be financial stability. Then the question still remains if the central bank's *monetary policy* should also have financial stability as a goal. If instead the central bank lacks macroprudential instruments, as is the case for the Riksbank, the Bank of Canada, and (as far as I know) the Central Bank of Chile, the question is only whether *monetary policy* should have financial stability as an additional goal.

Regarding whether monetary policy should have financial stability as a goal, I am convinced that the answer is no. Monetary policy should not have financial stability as a goal. The reason is that monetary policy cannot achieve financial stability.

An important principle for economic-policy goals is that *economic policies should only have goals that they can achieve*.[8] Monetary policy

7. However, the central bank does not have a monopoly on lending of last resort. The Ministry of Finance or the National Debt Office can also provide liquidity support at short notice. For instance, during the 2008-2009 crisis, the Swedish NDO provided immediate liquidity support to Swedish banks, by first issuing treasury bills to get cash and then lending the cash to the banks with mortgage-backed securities as collateral (Riksgälden, 2008).

8. Obviously this principle should apply to all public policies, not only economic policies. Furthermore, for economic policies, the ultimate goal for overall economic policy can be said to be to safeguard and improve the welfare of citizens. This ultimate goal is normally expressed in terms of a few more specific goals that contribute to the welfare of citizens, for example, efficient resource allocation (including an efficient financial system), high and stable growth, full and stable employment, price stability, fair distribution of living standards, regional balance, and a good environment. Each economic policy could have all these goals. But it is better to give each economic policy a specific goal that it can achieve and that contributes to the ultimate goals. This way policy can be more effective, and accountability for achieving each specific goal can be more directly assigned.

should thus have only goals that monetary policy can achieve. So what can monetary policy achieve?

Monetary policy can stabilise inflation around a given inflation target and resource utilisation around its estimated long-run sustainable rate. Because the inflation rate over the longer run is primarily determined by monetary policy, it is possible to select a fixed target for the inflation rate and for monetary policy to achieve an average inflation rate over a longer period at or close to the target. In contrast, the long-run sustainable rate of resource utilisation (measured by, for example, the maximum long-run sustainable employment rate or the minimum long-run sustainable unemployment rate) is largely determined not by monetary policy but by non-monetary factors that affect the structure and working of the economy. These factors may change over time and may not be directly observable and measurable. This means that it is not appropriate to set a fixed monetary-policy target for the long-run rate of resource utilisation. Instead, the long-run rate of resource utilisation must be estimated, and such estimates are necessarily uncertain and subject to revision (FOMC, 2017).

Thus, monetary policy can normally not increase the long-run sustainable rate of resource utilisation; for this, structural policies must be used.[9] Generally, monetary policy cannot solve structural problems.

It follows that price stability and real stability in the above sense are suitable goals for monetary policy.[10] But what about financial stability? Can monetary policy achieve financial stability?

The one thing we should have learned from the global financial crisis is that price stability does not imply financial stability. Monetary policy can achieve price stability, but it cannot achieve financial stability. Bear in mind that sufficient resilience is the crucial part of the definition of financial stability. There is no way monetary policy can systematically affect and thereby achieve sufficient resilience of the financial system; for example, there is obviously no way monetary policy can ensure that there are sufficient capital and liquidity buffers in the financial system.

9. There are exceptions. There can sometimes be hysteresis effects—or very persistent effects—of monetary policy on the labour-market participation rate or on the unemployment rate that need to be taken into account.

10. It goes without saying that fiscal instability or financial instability can make it difficult or even impossible for monetary policy to achieve its goals.

What about LAW? This involves a tighter policy for financial-stability purposes than justified by standard flexible inflation targeting and has been strongly promoted by the BIS, for instance, BIS (2014, 2016). It has been followed by Norges Bank (Olsen, 2015) and the Riksbank (but was later, in the spring of 2014, dramatically abandoned by the latter). A robust result is that the costs of LAW are higher than the benefits, by a substantial margin. Raising the policy rate simply has too small and uncertain effects on the probability or magnitude of a financial crisis to match the certain substantial costs, in terms of lower inflation and higher unemployment (Svensson, 2017a).

Stein (2013) has put forward the arguably strongest *theoretical* argument in favour of LAW for financial-stability purposes:

> …while monetary policy may not be quite the right tool for the job, it has one important advantage relative to supervision and regulation—namely, that it gets in all of the cracks [of the financial system].

But, given existing *empirical* estimates, a modest policy-rate increase would barely cover the bottom of those cracks. To fill the cracks, the policy-rate would need to be increased so much that it may kill the economy (Svensson, 2017a). Often, *qualitative* effects are not sufficient; estimates of the *quantitative* effects are necessary for a final assessment.

It is sometimes suggested that the so-called risk-taking channel would increase the effect of monetary policy on the probability or severity of crises (for instance, Borio and Zhu, 2008, and Adrian and Liang, 2018). But there is reason to doubt that any risk-taking channel is sufficiently strong to be economically significant. Dell'Ariccia and others (2017) provide a thorough examination of the risk-taking channel and the effect of the real federal funds rate on a measure of loan risk for U.S. banks, by using extensive confidential Federal Reserve data. They find that an increase in the real federal funds rate of 1 percentage point is associated with a *statistically* significant fall in the loan-risk measure of 0.052 (table IV, column 4). But the effect is *economically insignificant*. The standard deviation of the loan-risk measure is 0.85 (table I, panel B), so the effect of a 1-percentage-point higher real federal funds rate is only 0.052/0.85 = 6.1 percent of the standard deviation of the loan-risk measure. This means that the loan-risk measure is influenced mainly by factors other than the federal funds rate. This is hardly a risk-taking effect that could have any material effect on the probability or magnitude of a crisis. Furthermore, as the authors emphasize, their results are not well suited for answering whether the additional risk taking of banks facing more accommodative monetary policy is excessive from a social-welfare standpoint.

As far as I can see, if there are financial-stability problems, in order to ensure financial stability there is simply no choice but to use other policies than monetary policy, primary macro- and microprudential policy (or other policies, such as housing policy, that are appropriate for the precise problem at hand). If the existing financial-stability policy is insufficient or ineffective, there is no choice but to develop and apply a better financial-stability policy.

Furthermore, as discussed below, results of Svensson (2017a) indicate, somewhat surprisingly, that when financial-stability policy is weak or non-existent, the margin of costs over benefits of LAW is likely to be even larger. To the extent such weak financial-stability policy results in a credit boom with a higher probability of a crisis, a larger magnitude of a crisis, or a longer duration of a crisis, these changes all increase costs more than benefits. This is consistent with the statement of Williams (2015), that "monetary policy is poorly suited for dealing with financial stability, even as a last resort."

4. Should monetary and financial-stability policies be conducted separately or co-ordinately?

Given the above principle for economic-policy goals, the conclusion is that financial stability is not a suitable goal for monetary policy, because monetary policy cannot achieve financial stability. What about financial-stability policy? What can and cannot it achieve?

Financial-stability policy can, with sufficient instruments, achieve financial stability. Thus, financial stability is a suitable goal for financial-stability policy. But financial-stability policy cannot stabilise inflation around the inflation target and resource utilisation around its estimated long-run sustainable level. Thus, by the above principle for economic-policy goals, price stability is not a suitable goal for financial-stability policy.

It follows that both monetary and financial-stability policies are needed to achieve the monetary-policy goals of price stability and real stability and the financial-stability-policy goal of financial stability.

But should monetary financial-stability policies be conducted in a separate or coordinated way? By being conducted in a separate way, I mean that the two policies are conducted as in a game-theoretic Nash-equilibrium, that is, each policy is being conducted so as to achieve its goal while taking into account the conduct and effects, but not the goal achievement, of the other. By being conducted in a coordinated way, I mean that the two policies are conducted as in a game-theoretic coordinated equilibrium, that is, the policy actions of both policies are determined together so as to simultaneously achieve the goals of both policies.

Note that the question of whether the policies are best conducted separately or co-ordinately is relevant also if the same authority, the central bank, is in charge of both policies. In this case, the question is whether or not the policies work better with separate decision-making bodies within the bank for the two policies, each with its separate goals and its separate instruments.

There is certainly some interaction between the two policies. Financial-stability policy affects financial markets, spreads between different interest rates, and lending by banks. Via loan-to-value caps, it affects household borrowing, housing demand, housing prices, and construction. This way it may, depending on the situation, indirectly affect inflation and resource utilisation, but not systematically, not strongly, and not always in the same direction. For instance, some regulation may deteriorate the working of the economy, reduce activity, and reduce the sustainable rate of resource utilisation. But better regulation and more effective implementation of credit standards may allow financial deepening and more lending to suitable borrowers, thus increasing activity and the sustainable rate of resource allocation.

Monetary policy affects interest rates, output and employment, profits, credit losses, and assets prices. This way it affects debt service, balance sheets, and leverage. This way it may, depending on the situation, indirectly affect financial stability, but not systematically, not strongly, and not always in the same direction.[11]

In summary, monetary policy has a strong and systematic effect on inflation and resource utilisation but a small and unsystematic effect on financial stability. Financial-stability policy has a strong and

11. Furthermore, as emphasized by Bernanke (2015), the neutral/natural/equilibrium interest rate is determined by structural factors, not monetary policy. It follows that monetary policy can only let the policy rate deviate somewhat above or below the neutral rate, this way conducting contractionary or expansionary policy, respectively. The monetary policy stance is therefore measured by the gap between the policy rate and the neutral rate, not by the policy rate. The effect of monetary policy should therefore be measured as the effect of the gap between the policy rate and the neutral rate, not of the policy rate itself. The effect of the latter will be the effect of the sum of the monetary policy stance and the neutral rate.

systematic effect on financial stability but a small and unsystematic effect on inflation and resource utilisation. This means that monetary policy can normally adjust to and neutralise any effect of financial-stability policy on inflation and resource utilisation, and financial-stability policy can normally adjust to and neutralise any effect of monetary policy on financial stability. This means that the conditions for a Nash equilibrium to be optimal are satisfied and it implies that the policies can successfully be conducted separately, while being fully informed of and taking into account the conduct of the other. Thus, under these conditions, the goals of both monetary policy and financial-stability policy can be achieved by each policy conducted separately to achieve its goal, while taking into account the conduct and effects of the other.[12]

Conducting each policy separately furthermore has the considerable advantage that each policy, with its separate goals and instruments, becomes more distinct, more transparent, and easier to evaluate. This in turn makes it easier to hold the decision-making body for each policy accountable for achieving its goals. This creates stronger incentives for each policy to achieve its goals and makes it more likely.

As emphasized above, monetary policy and financial-stability policy are really very different policies, each with different suitable goals and different suitable instruments. In particular, they work through very different mechanisms. The mechanisms to achieve price stability and real stability, and the ones to achieve sufficient resilience of the financial system are quite different. In contrast, Borio (2017, p. 41) has suggested that monetary policy and macroprudential policy may cause a tension by being employed in opposite directions: "it is a bit like driving by pressing on the accelerator and brake simultaneously —not exactly what is normally recommended." This use of a driving metaphor presumes that monetary and financial-stability policies work through very similar mechanisms. But I find this metaphor quite misleading. Staying within driving metaphors, I would suggest that a more relevant one is that monetary policy operates the accelerator and the brake to achieve a steady optimal speed of the car. This means monetary policy presses the accelerator when the road is uphill and the brake when it is downhill. Financial-stability policy makes sure

12. Bean (2014) provides a thorough discussion of why and how monetary policy and macroprudential policy can achieve a good outcome by each policy focusing on its own goals.

that the safety belts and airbags are in good condition, that the safety belts are being used, and that the airbags are activated. The policies are more or less orthogonal.

Still, the overall policy framework is more robust if it can explicitly handle the rare occasion when there would be considerable interaction between the two policies and some explicit coordination is warranted. More precisely, I have in mind the rare situation when the monetary policy stance might provide a significant threat to financial stability that financial-stability policy could not contain with its available instruments. This issue is discussed in section 6.

The above refers to normal times and crisis prevention. In *crisis* times, when there is crisis management rather than crisis prevention, things are very different. Then full cooperation and coordinated policies by all the relevant authorities would be warranted. These authorities normally include the financial supervisory authority(ies), the central bank, the ministry of finance, and the bank-resolution authority. In particular, in a crisis, coordinated policy packages by several authorities may have a strong effect on private-sector expectations and thereby help to stabilise the situation.

The central bank has a traditional role in crisis management, through its capacity to provide liquidity support, as a lender of last resort. However, as mentioned, the central bank does not have a monopoly on liquidity support in a crisis. The ministry of finance or the national debt office (NDO) can also provide liquidity support, in a very short time. This was demonstrated by the Swedish NDO during the 2008 crisis (footnote 7).

In Sweden, the fact that central banks have a role in crisis management and can provide liquidity support has been used by the Riksbank as an argument why it should be in charge of crisis prevention and macroprudential policy. However, the argument is hardly convincing. By the same logic, because foreign policy could result in a war, the defence department should be in charge of foreign policy. Furthermore, the central bank is not the only authority with a responsibility for crisis management and, as noted, it is not even the only authority that can provide liquidity support in a crisis.

Instead, the role in crisis management implies that the central bank, like all other authorities with such a role, should make *preparations* for crisis management, including crisis-management games (tabletop exercises) together with other authorities. This is not the same as crisis prevention.

5. Should monetary and financial-stability policies be conducted by the same authority or by different authorities?

As concluded above, monetary policy and financial-stability policy are quite different economic policies and are normally best conducted separately. This means that they should have separate decision-making bodies, each with its separate goals and separate instruments, and each accountable for achieving its own goals.

The efficiency of and accountability for financial-stability policy under crisis prevention is enhanced if one authority controls all financial-stability instruments. Splitting instruments across several authorities makes it difficult to hold authorities accountable, and the different authorities may apply the different instruments at cross purposes or at least inefficiently. Under crisis management, when all relevant authorities cooperate and coordinate their policies to reduce the magnitude of the crisis and restore financial stability, holding individual authorities accountable is obviously more difficult.

There are at least two clean models that are likely to work well. One of them is that of the U.K., where the Bank of England has the responsibility for both monetary and financial-stability policy. There are two decision-making bodies—the Monetary Policy Committee (MPC) in charge of monetary policy and the Financial Policy Committee (FPC) in charge of financial-stability policy. Each committee has its goals and its instruments, and each is accountable for achieving its goals. Furthermore, each policy is conducted in an open and transparent way, and there is overlap of members in the two committees. This makes each committee fully informed about the policy of the other committee.[13]

Another model is the Swedish one. In August 2013, the Swedish government announced a new strengthened framework for financial stability in Sweden and clarified the roles and responsibilities of the different authorities. Finansinspektionen, the Swedish financial supervisory authority (FSA), was assigned the main responsibility for financial stability and received control of all macroprudential instruments, including the countercyclical capital buffer. The Riksbank thus has no financial-stability instruments (except communication) for crisis prevention, only lending of last resort for crisis management.

13. See Kohn (2015) for details on the U.K. model and the case for two committees.

This assignment of goals and instruments enhances efficiency and accountability by assigning all the financial-stability instruments to one authority. Because the FSA already had control of all the microprudential instruments, it also puts both micro- and macroprudential instruments into one institution. In general, the boundary between micro- and macroprudential instruments can be somewhat unclear, and macroprudential policy is arguably much closer to microprudential policy than to monetary policy. Furthermore, in a financial sector similar to that in Sweden, where four major banks in a cosy oligopoly dominate the financial sector, microprudential policy has macroprudential consequences and the distinction between micro- and macroprudential policy is even less clear. Altogether, there are thus arguably some additional efficiency and accountability gains in putting micro- and macroprudential policy together. Because the FSA is an authority under the government, the government has the ultimate responsibility and accountability for financial stability, including any intergenerational and other distributional consequences and tradeoffs.[14]

Monetary and financial-stability policies in Sweden are conducted in a very transparent and open way, making it easy to for the Riksbank and the FSA to be fully informed about the conduct and effects of the other authority's policy. Furthermore, the government has created a new Financial Stability Council, with the minister of financial markets from the Ministry of Finance as chair, and the director generals of the FSA and the Swedish National Debt Office (which is the national bank-resolution authority in Sweden) and the governor of the Riksbank as members. The Council meets regularly and is a forum for exchange of information and discussion of financial-stability issues, including reports commissioned by the Council from workgroups formed by staff of the authorities represented in the Council. The Council has no decision power; this power rests with the authorities represented in the Council. The Council creates a forum where the authorities can exchange information about their respective views and policies relating to financial stability. In a crisis, the Council will lead and coordinate the crisis management.

In practice, history and political-economy aspects to a large extent explain the particular institutional arrangements in each country, for example in the U.S. There, financial-stability instruments,

14. In Sweden, the Riksbank is an authority under the Swedish Parliament, not under the government.

regulation, and supervision are split across several authorities with different mandates. This, together with vested interests and extensive lobbying by the financial industry and related political influence over the authorities, makes effective financial-stability regulation quite difficult.

6. What if monetary policy would pose a threat to financial stability?

On rare occasions, unforeseen situations could arise, in which monetary policy might pose a threat to financial stability even when it is fulfilling its monetary policy goals. In principle, the financial-stability authority should be able to contain such threats with its available instruments. But how should a situation be handled when such a threat cannot easily be contained?

The August 2013 forward guidance by the Bank of England's MPC provides a good example (Bank of England, 2013). At the time, the MPC agreed its intention not to raise the policy rate until the unemployment rate had fallen to a threshold of 7 percent, subject to three "knockouts" not being breached. The third knockout is the FPC judging that the stance of monetary policy poses a significant threat to financial stability that cannot be contained by the range of mitigating policy actions available to the FPC, the Financial Conduct Authority, and the Prudential Regulation Authority in a way consistent with their goals.

Thus, according to this example, the financial-stability authority should warn the monetary policy authority if monetary policy poses a threat to financial stability that the financial-stability authority could not contain with its available policy instruments. Then the monetary policy authority may choose to adjust monetary policy, by either tightening or loosening it, depending on the situation, and thus temporarily deviate from the monetary policy goals. This clarifies the responsibility of each authority and makes it possible to hold them accountable. Effectively, the MPC is put in a "comply or explain" position. Because the final decision of adjusting monetary policy is left with the monetary-policy authority, its independence to conduct monetary policy is maintained.

In particular, it should be the financial-stability authority, not the monetary-policy authority, which decides if monetary policy poses a threat to financial stability that it cannot contain with its available instruments. The principle should be that the authority in charge of the goal decides if its goal is threatened in such a way that assistance is needed, not the other authority. The monetary-policy authority should not be the one to decide whether its policy poses a threat to the goal of the financial-stability authority. Without a warning from the financial-stability authority, the monetary-policy authority should not be allowed to deviate from the monetary policy goals.

Had such a principle been applied in Sweden in 2010, and the FSA had been the authority to judge whether monetary policy posed a threat to financial stability that could not be contained by FSA's available instruments, the much discussed and criticised aggressive LAW undertaken by the Riksbank in 2010-2011 would most likely not have occurred. This leads naturally to a discussion of whether monetary policy should ever lean against the wind in an attempt to promote financial stability.

7. Should monetary policy ever "lean against the wind"?

In the ongoing discussion about monetary policy and financial policy, there has been considerable focus on the particular issue of whether monetary policy should lean against the wind (of asset prices and credit booms)—more precisely, in order to promote financial stability raise the policy rate somewhat higher than justified by stabilizing inflation around the inflation target and resource utilisation around its long-run sustainable rate. Such a policy has been strongly advocated by the BIS, for example in BIS (2014, 2016).

7.1 The Swedish experience

The recent experience in Sweden provides, first, a dramatic example of LAW and, second, a dramatic and complete turnaround of policy.[15] In June 2010, the forecast for inflation and unemployment by the Riksbank for Sweden and by the FOMC for the U.S. looked very similar. The inflation forecast was below 2 percent and the unemployment forecast was far above each central bank's estimate of a long-run sustainable rate (Svensson, 2011). With reference to those

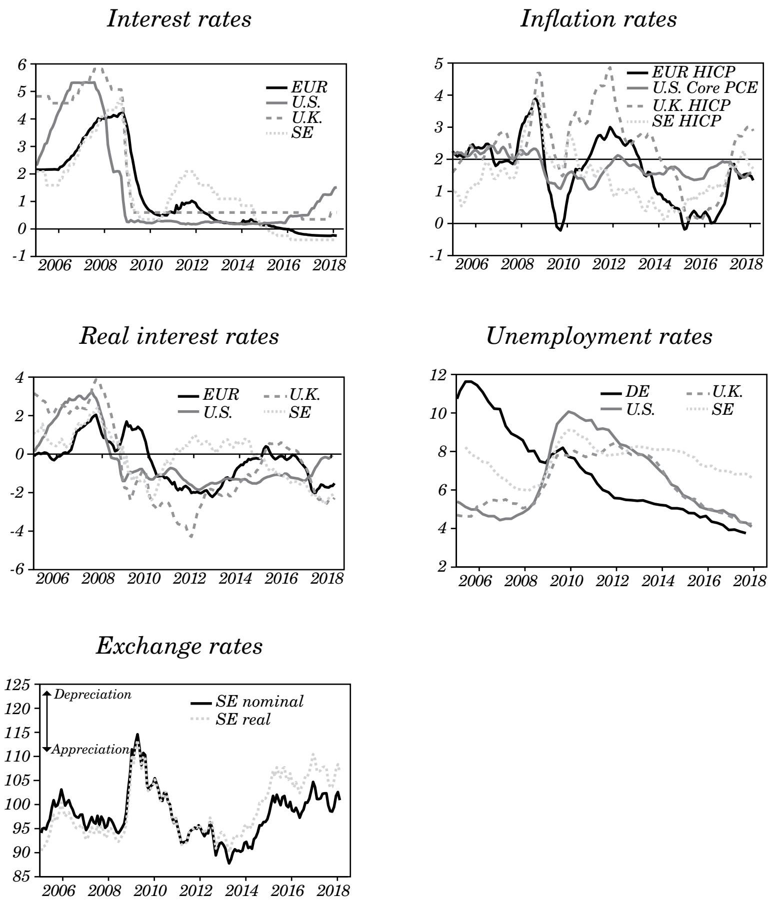
15. Turner (2017) provides a broad discussion of LAW with examples from several countries.

June 2010 forecasts, Bernanke (2010) concluded that "[g]iven the [FOMC's] objectives, there would appear—all else being equal—to be a case for further action." meaning a case for further easing of monetary policy. Indeed, at the time, the FOMC continued to keep the policy rate close to zero and started preparing Quantitative Easing 2 (QE2).

In contrast, in spite of the similar forecasts, the majority of the Riksbank's executive board did not continue to keep the policy rate close to zero and did not prepare any QE. Instead, it raised the policy rate rapidly from 0.25 percent in July 2010 to 2 percent in July 2011, citing concerns about housing prices and household debt.[16] Figure 1, upper-left panel, shows the policy rates in Sweden, the U.S., and the U.K. and the eonia rate in the euro area. We see the dramatic rise of the Riksbank's policy rate starting in mid-2010. The upper-right panel shows the inflation rates (measured as HICP inflation—harmonised index of consumer prices—except for the U.S., as core PCE—personal consumption expenditure—inflation). Swedish inflation fell and reached zero in the beginning of 2014. The middle-left panel shows the real interest rates (measured as interest rates less inflation). The real interest rate rose dramatically in Sweden, creating a large real interest differential to the other economies. The bottom panel shows the real and nominal effective Swedish exchange rate. The krona depreciated much during the fall of 2008, which mitigated the effect of the crisis, but then appreciated as much during the tightening of 2010-2011. The middle-right panel shows that the Swedish unemployment rate, which was falling after having peaked in early 2010, stabilised at a high rate after the policy tightening, and then even rose. In Germany and the U.S., the unemployment steadily fell.

16. As a deputy governor and member of the Riksbank's executive board at the time, I dissented against every single rate increase, for reasons explained in Svensson (2010) and in more detail in the Riksbank's attributed minutes from the policy meetings, for example, the June/July meeting 2010, Sveriges Riksbank (2010) (available in English at www.larseosvensson.se or www.riksbank.se). My lessons from six years of policymaking, ending in May 2013, are summarized in Svensson (2013).

Figure 1. Interest Rates, Inflation Rates, Real Interest Rates, Unemployment Rates, and Effective Exchange Rates in Selected Economies (SE Sweden, EUR euro area, U.S., U.K., DE Germany)



Source: Thomson Reuters Datastream.

In the early spring of 2014, the majority of the executive board apparently realised that the situation was unsustainable, with unemployment very high and inflation close to zero. The Riksbank policy was dramatically reversed. The policy rate was lowered and reached zero in October. In February 2015, the policy rate was moved into the negative range. The Riksbank then also initiated a program of asset purchases. The policy rate was further lowered and eventually reached minus 0.5 percent in February 2016 (upper-left panel). Inflation rose back to close to the target of 2 percent (upper-right panel), the real interest rate fell to below minus 2 percent (middle-left panel), the krona depreciated much (bottom panel), and unemployment started to come down (middle-right panel).

Apparently, monetary policy works according to the textbook in Sweden. Tightening appreciates the krona, reduces inflation, and increases unemployment. Vice versa for easing.[17]

The 2010-2011 dramatic tightening was done without any supporting analysis of the efficacy of the policy rate as an instrument to contain the growth in household debt and housing prices and, in particular, without any explicit cost-benefit analysis. The available empirical work at the time indicated very high costs in terms of output and unemployment, and small effects on debt and housing prices.[18]

Furthermore, there was no work indicating that the level of housing prices and household debt posed any risks that the FSA could not manage on its own, for instance with its LTV cap of 85 percent for new mortgages that the FSA introduced in the fall of 2010. Also, the FSA could assess risks with considerable precision in its commendable annual mortgage market report, *The Swedish Mortgage Market*. Among other things, it included stress tests on households with new mortgages using microdata collected from the lending banks. The stress tests showed that households had substantial debt-service capacity and substantial resilience against shocks in the form of

17. A very open economy with large export and import implies a strong exchange-rate channel in the transmission mechanism of monetary policy. High household debt with adjustable mortgage rates also implies a strong cash-flow channel that affects household consumption (Flodén and others, 2016).

18. See, for example, Assenmacher-Wesche and Gerlach (2010), Bean and others (2010), and Dokko and others (2011) (working paper available in 2009). In particular, using Swedish data, Riksbank staff members Claussen and others (2011) showed that preventing housing prices from increasing above the 2004-2010 trend would have required policy-rate increases of up to 5 percentage points. Inflation would have fallen up to 6 percentage points below the inflation target, and the accumulated GDP loss would have been about 12 percent.

higher mortgage rates, falling housing prices, and income losses due to unemployment.[19]

7.2 Cost-benefit analysis of LAW

This Swedish experience certainly stimulated my own interest in a cost-benefit analysis of LAW. In Svensson (2017a), the marginal cost and benefit of LAW are assessed. LAW is specified as increasing the policy rate above what is justified by standard flexible inflation targeting that disregards the risk of a financial crisis. LAW has a first cost, in terms of a weaker economy with lower inflation and higher unemployment, *if* no crisis occurs. Importantly, LAW also has a *second* cost, which arises if a crisis occurs. This is because the cost of a crisis of any given magnitude is larger if the economy initially is weaker due to LAW. This second cost turns out to be the main cost of LAW, although it has been neglected by previous literature (including my own previous work).

LAW has possible benefits in the form of a lower probability or smaller magnitude of a crisis. However, for existing empirical estimates, the policy-rate effect on the probability and magnitude is much too small to prevent the marginal cost from exceeding the marginal benefit by a substantial margin. The result that the cost exceeds the benefit is quite robust to alternative assumptions. To get to break-even, that is, equality between the marginal cost and the marginal benefit, the policy-rate effects need to be 5–40 standard errors larger than the benchmark empirical estimates.[20, 21]

Furthermore, somewhat surprisingly, a less effective financial-stability policy, to the extent that it increases the probability, severity, or duration of a crisis, increases the marginal costs more than it

19. The 2010 report is only available in Swedish; from 2011 onwards, the mortgage market report is also available in English. The most recent is Finansinspektionen (2017).

20. As discussed in some detail in Svensson (2017a, section 5; 2017c), if the second cost of LAW is neglected, as in previous work and in recent papers by Filardo and Rungcharoenkitkul (2016) and Gourio and others (2017), then for zero LAW, the marginal cost of LAW is zero. If the marginal benefit is positive, then some positive LAW is optimal. However, the marginal cost rises rather quickly, so the optimal LAW is quite small, corresponding to a small increase in the policy rate and, as in Gourio and others (2017), a small reduction of only a few basis points of the annual probability of a crisis start. A similar result has previously been reported by Ajello and others (2016).

21. That the policy-rate effects need to be 5–40 standard errors larger than existing benchmark empirical estimates to get to break-even contradicts Adrian and Liang (2018), who have argued that reasonable alternative assumptions about the policy-rate effect on the probability or magnitude of a crisis would overturn the result (Svensson, 2017a, section 5).

increases the marginal benefits, making the case against LAW even stronger. The reason is that the expected second cost of LAW mentioned above, the larger cost of crisis due to an initially weaker economy, increases more than the benefits from an increased probability, magnitude, or duration of a crisis.

A recent IMF staff paper (IMF, 2015) presents a thorough analysis and survey of the pros and cons of LAW and finds that except in the most exceptional circumstances, costs outweigh benefits. It concludes that, "[b]ased on current knowledge, the case for leaning against the wind is limited, as in most circumstances costs outweigh benefits." Former Federal Reserve Board Chair Ben Bernanke and Bank Presidents Charles Evans and John Williams have previously reached similar conclusions.[22] More recently, the FOMC has also reached a similar conclusion.[23] The Independent Review of BIS Research (Allen and others, 2016) has noted that the BIS argument for LAW seems to have had little effect on those actually responsible for setting monetary policy, that convincing evidence that the benefits outweigh the costs is lacking, and that BIS research has been somewhat one-eyed and excessively focused on building a case for LAW (including trying to disprove my conclusion about the costs and benefits of LAW).[24]

22. Bernanke (2015): "As academics (and former academics) like to say, more research on this issue is needed. But the early returns don't favour the idea that central banks should significantly change their rate-setting policies to mitigate risks to financial stability."

Evans (2014): "Indeed, any decision to instead rely on more-restrictive interest rate policies to achieve financial stability at the expense of poorer macroeconomic outcomes must pass a cost-benefit test. And such a test would have to clearly illustrate that the adverse economic outcomes from more-restrictive interest rate policies would be better and more acceptable to society than the outcomes that can be achieved by using enhanced supervisory tools alone to address financial-stability risks. I have yet to see this argued convincingly."

Williams (2015): "[M]onetary policy is poorly suited for dealing with financial stability, even as a last resort."

23. FOMC (2016): "Most participants judged that the benefits of using monetary policy to address threats to financial stability would typically be outweighed by the costs […]; some also noted that the benefits are highly uncertain."

24. Allen and others (2016): "so far the [BIS] argument for LAW seems to have cut relatively little ice with those actually responsible for setting monetary policy. In part, that is because of the lack of convincing evidence that the expected benefits outweigh the expected costs.

"[…] in some cases the research programme appeared somewhat one-eyed. [Of 9 projects on financial stability and monetary policy] the first and (to some extent) the fifth seem motivated primarily by a desire to overturn Svensson's [2017a] conclusion on the inadvisability of LAW."

"[…] the research effort […] seems excessively focussed on building the case for LAW, rather than also investigating the scope for other policy actions to address financial-stability risks." [Reference updated.]

The Riksbank does also now seem to conclude that the costs of LAW exceed the benefits.[25]

7.3 LAW may result in lower average inflation and a lower average interest rate

In general, a LAW policy with a higher policy rate implies an equilibrium with lower average inflation and a lower average policy rate (Svensson, 2017b). To see this, take the simplest possible LAW policy rule,

$$i_t = r + \pi_t + \gamma\,(\pi_t - \pi^*) + \alpha, \tag{1}$$

where i_t denotes the policy rate, r denotes the average real interest rate, π^* denotes a fixed inflation target, and $\gamma > 0$. Furthermore, $\alpha > 0$ denotes a constant increase in the policy rate representing LAW (it could also be random and have a positive unconditional mean, without changing the result). Note that we can rewrite (1) as

$$i_t = r + \pi_t + \gamma\,(\pi_t - \pi^{**}), \tag{2}$$

where

$$\pi^{**} = \pi^* - \alpha/\gamma < \pi^*. \tag{3}$$

Writing the policy rule as (2) suggests that (1) is equivalent to having a lower inflation target given by π^{**} instead of π^* and that average inflation and the average policy rate will be lower.

To show this more rigorously, assume that the Fisher equation holds on average, so we have

$$\mathrm{E}[i_t] = r + \mathrm{E}[\pi_\mathrm{t} + 1] = r + \mathrm{E}[\pi_\mathrm{t}], \tag{4}$$

where E[ ] denotes the unconditional mean. Taking the unconditional mean of (2), we then have

25. Sveriges Riksbank (2017, p. 13): “It is not likely that small increases in the repo rate would have any tangible effects on household indebtedness. A large increase in the repo rate could certainly slow down the buildup of debts but would also lead to higher unemployment, a much stronger krona and lower inflation. Other measures more specifically aimed at reducing the risks associated with household debt have less negative effects on the economy as a whole.”

$$\mathrm{E}[i_t] = r + \mathrm{E}[\pi_t] + \gamma\,(\mathrm{E}[\pi_t] - \pi^{**}). \quad (5)$$

Combining (4) and (5) gives

$$\mathrm{E}[\pi_t] = \pi^{**} < \pi^{*}. \quad (6)$$

From (4) and (6) then follows

$$\mathrm{E}[i_t] = r + \pi^{**} < r + \pi^{*}. \quad (7)$$

It follows that $\alpha > 0$, representing LAW, implies that average inflation equals the "effective" lower inflation target π^{**} rather than the "official" inflation target π^{*} and that the average policy rate will be correspondingly lower.

If LAW thus implies lower average inflation and a lower average policy rate, it is clear that the probability that the effective lower bound on the policy rate will bind will be higher. Furthermore, with lower average inflation, the real value of any fixed nominal debt is falling more slowly over time. Together, this seems to make the economy more sensitive to shocks.

7.4 No LAW without support from a thorough and convincing cost-benefit analysis

The main policy conclusion that I draw from this work is that any LAW should only be undertaken if it is supported by a thorough and convincing cost-benefit analysis. Given the available evidence, the burden of proof should arguably be on those proposing LAW. I would personally be quite surprised to see a convincing cost-benefit analysis supporting LAW.

8. Conclusions

We should not ask too much from monetary policy. Monetary policy can really at best just stabilise inflation around a given inflation target and resource utilisation around its estimated long-run sustainable rate. This way it can keep average inflation on target and average resource utilisation equal to its long-run sustainable rate. In particular, monetary policy cannot achieve financial stability; a separate financial-stability policy is needed for that. Then, by the above principle for economic-policy goals, monetary policy should not have financial stability as a goal.

Monetary policy and financial-stability policy are different policies, with different goals, different suitable instruments and, in many countries, different responsible authorities. Still, there may be considerable interaction between the policies. In this regard, the relation between monetary and financial-stability policies is similar to that between monetary and fiscal policies. Furthermore, given that monetary policy is much more effective in achieving price stability and real stability, and financial-stability policy is much more effective in achieving financial stability, the two policies should normally be conducted independently, but with each policy fully informed about and taking into account the conduct of the other. This means that they should be conducted by separate decision-making bodies, even when the central bank is in charge of both. This allows each decision-making body to be held accountable for achieving its goals. Also in this regard are monetary and financial-stability policies similar to monetary and fiscal policies.

One cannot exclude that, on rare occasions, monetary policy might pose a threat to financial stability that cannot be contained by the instruments of the financial-stability authority. The authority judging whether such a situation has occurred should be the financial-stability authority. This authority should then warn the monetary policy authority about the threat, after which warning, the monetary policy authority may decide whether or not to adjust monetary policy. This clarifies the responsibility and makes it possible to hold each authority accountable. It also respects the independence of monetary policy.

The Swedish example of, first, a dramatic LAW and, second, a dramatic complete turnaround of policy provides a strong warning to other central banks (and to the Riksbank itself). At the current state of knowledge, there is little or no theoretical or empirical support for monetary policy leaning against the wind for financial-stability purposes, that is, a monetary policy that is somewhat tighter than justified by the monetary policy goals alone. The estimated costs are much larger than the estimated possible benefits. Given this, any leaning against the wind should be undertaken only if is supported by a thorough and convincing cost-benefit analysis. Given the currently available evidence, the burden of proof should be on the proponents of leaning against the wind.

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Monetary Policy in the Grip of a Pincer Movement

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Monetary policy has come under strain since the global financial crisis (GFC) of 2007–09. Once the GFC broke out, central banks' swift and determined response was essential to stabilise markets and to avoid a self-reinforcing downward spiral between the financial system and the real economy. But putting the economy back onto a robust, balanced and sustainable path has proved much harder than expected. This has been so despite the adoption of extraordinary measures which would have been simply unthinkable just a few years back.

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The GFC has raised some tough questions for monetary policy. The pre-crisis experience has shown that, in contrast to common belief, disruptive financial imbalances could build up even alongside low and stable, or even falling, inflation. Granted, anyone who had looked at the historical record would not have been surprised: just think of the banking crises in Japan, the Asian economies and, going further back in time, the U.S. experience in the run-up to the Great Depression. But somehow the lessons had got lost in translation during the inebriating enthusiasm of the Great Moderation. And post-crisis, the performance of inflation has brought repeated surprises. Inflation was higher than expected during the Great Recession, given the depth of the slump, and lower than expected during the recovery. And it has been puzzlingly low especially more recently, as a number of economies have been reaching or even exceeding previous estimates of full employment. Again, this is not entirely new: even well before the GFC, central banks had been voicing questions about the sensitivity of inflation to domestic slack. However, the recent experience has hammered the point home, raising nagging doubts about a key pillar of monetary policymaking.

This essay explores the implications for monetary policy of the conjunction of these two developments—the emergence of disruptive financial cycles on the one hand, and the limited sensitivity of inflation to domestic economic slack on the other. It is as if monetary policy were in the grip of a pincer movement that threatened to upend the current regime, just as many of its predecessors have been upended in the past. We largely draw on our previous work, although we also provide a preview of some research under way.

Our conclusion is that adjustments to current monetary policy frameworks may indeed be desirable, particularly in the analytical underpinnings that guide their implementation. We argue that the natural rate of interest, as traditionally conceived, is not a particularly useful guidepost. And we suggest that responding systematically to the financial cycle need not imply abandoning price-stability-oriented frameworks, but simply adopting a more flexible interpretation in their application than is often the case. In fact, this could be done within current mandates. While amending mandates to explicitly include financial stability concerns may be appropriate in some circumstances, this should be done with great caution, mainly for institutional considerations.

This paper is organised as follows: The first section briefly describes the nature of the challenge: the pincer movement and its causes and consequences. The second, draws implications for the natural rate of interest as a guidepost for policy. It explains why the pincer movement means that monetary policy may have a longer-lasting impact on real rates than commonly assumed; why it may not be helpful to think of market rates as tracking natural rates that are independent of monetary policy; and why, if the concept is used at all, it would be useful to extend it to include also a reference to financial equilibrium. The third section discusses possible adjustments to policy frameworks. Drawing on the previous analysis and based on a simple counterfactual exercise, it illustrates how policy might respond to the financial cycle and, in the process, improve macroeconomic outcomes. It then considers practical adjustments to monetary policy frameworks to allow for the necessary room for policy manoeuvre to respond to the financial cycle.

1. The Pincer Movement: The Financial Cycle and Inflation

The emergence of disruptive financial cycles and the limited sensitivity of inflation to domestic slack may at first sight seem to be unrelated. But, in fact, there may be a common thread: the behaviour of monetary policy. Consider each in turn.

1.1 The Financial Cycle

The first major development is that, since around the early 1980s, financial cycles appear to have grown in amplitude and length (Borio and Lowe, 2002; Drehmann and others, 2012; Claessens and others, 2011; Borio, 2014a).1 There is no unique definition of the financial cycle. A useful one refers to the self-reinforcing processes between funding conditions, asset prices, and risk-taking that generate expansions followed by contractions. These processes operate at different frequencies. But if one is especially interested in those that cause major macroeconomic costs and banking crises, probably the most parsimonious description is in terms of credit and property prices. Figure 1 illustrates the phenomenon for the United States by using some simple statistical filters, although the picture would not be that different for many other countries or using other techniques (e.g., peak-trough analysis). The figure shows that the amplitude and length of

1. See also Claessens and Kose (2018) for a broader review of the related literature.

the fluctuations has been increasing, that the length of the financial cycle is considerably longer than that of the traditional business cycle (black versus gray line), and that banking crises, or serious banking strains, tend to occur close to the peak of the financial cycle.

Another key feature of financial cycles is that the bust phase tends to generate deeper recessions. Indeed, if the bust coincides with a banking crisis, it causes *very long-lasting* damage to the economy.[2] There is evidence of permanent output losses, so that output may regain its pre-crisis long-term growth trend while evolving along a lower path. There is also evidence that recoveries are slower and more protracted. And even in some cases, growth itself may also be seriously damaged for a long time.

Some recent work with colleagues sheds further light on some of the possible mechanisms at work (Borio and others, 2016). Drawing on a sample of over 40 countries spanning over 40 years, we find that credit booms misallocate resources towards lower-productivity growth sectors, notably construction, and that the impact of the misallocations that occur during the boom is twice as large in the wake of a subsequent banking crisis (figure 2). The reasons are unclear, but may reflect, at least in part, the fact that overindebtedness and a broken banking system make it harder to reallocate resources away from bloated sectors during the bust. This amounts to a neglected form of hysteresis. The impact can be sizeable, equivalent cumulatively to several percentage points of GDP over a number of years.[3]

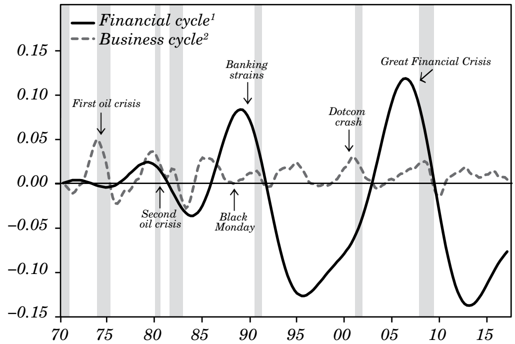
Why should financial cycles have grown in intensity and disruptiveness? Part of the answer lies in changes in financial and monetary regimes. On the one hand, financial liberalisation back in the 1980s weakened financing constraints and made funding easier and cheaper to obtain. Meanwhile, prudential safeguards lagged behind. On the other hand, the emergence of monetary policy regimes focused on near-term inflation control meant that policy would be tightened during financial booms only if inflation increased, but would then be loosened aggressively and persistently during busts. And, as we shall

2. See the BCBS (2010) survey and, in particular, Cerra and Saxena (2008) and, more recently, Ball (2014). Blanchard and others (2015) find that other recessions too may have permanent effects.

3. If taken at face value, the results suggest that, over the period 2008–2013, the effect shaved off some 0.5 percentage points per year in productivity growth for those countries that saw a financial boom-bust cycle. This is roughly equal to their actual productivity growth during the same period. The findings could help explain the faster pace in the long-term decline in productivity growth seen in recent years.

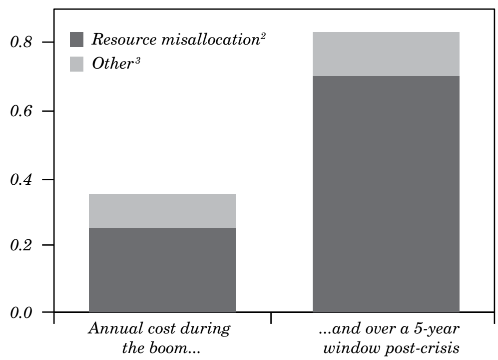
see below, inflation often remained low and stable during the booms. Moreover, downplaying the role of monetary and credit aggregates also worked in the same direction.

Figure 1. Financial and Business Cycles in the United States



Source: Drehmann and others (2012), updated.
1 The financial cycle as measured by frequency-based (bandpass) filters capturing medium-term cycles in real credit, the credit-to-GDP ratio, and real house prices.
2 The business cycle as measured by a frequency-based (bandpass) filter, capturing fluctuations in real GDP over a period of one to eight years.

Figure 2. Financial Booms Sap Productivity by Misallocating Resources[1]



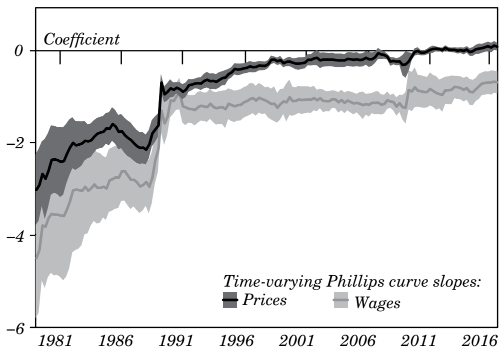
Source: Based on Borio and others (2016).
1 Estimates calculated over the period 1980–2010 for 22 advanced economies.
2 Annual impact on productivity growth of labour shifts into less productive sectors during the credit boom, as measured over the period shown.
3 Annual impact in the absence of reallocations during the boom.

1.2 Inflation

The second major development is that inflation has generally been quiescent, at times surprisingly so. Indeed, from a longer-term perspective, the response of both price and wage inflation to domestic measures of slack has been quite muted and appears to have declined over time (figure 3).[4] Why?

One possible explanation is that central banks have been very successful in bringing inflation down and keeping it there. Heightened anti-inflation credibility could also help explain why inflation has proved rather insensitive to domestic slack: This credibility means wages and prices are less likely to respond to tight conditions, as economic agents anticipate the central bank's response. Indeed, proxies of inflation expectations have tended to be generally well anchored around inflation objectives. This general narrative is the most popular, especially within the central banking community. No doubt, it is part of the answer. To that extent, it may also mean that central banks have been partly the victim of their own success: Their heightened credibility, by keeping inflation low and avoiding the need to tighten, has added fuel to the financial cycle—the "paradox of credibility" (Borio and Lowe, 2002).

Figure 3. A Flatter Phillips Curve for Prices and (less so) Wages



Source: Borio (2017a).
Note: Rolling 15-year window estimates from panel of G7 economies. See source for details.

4. See, among others, Stock and Watson (2007), Ball and Mazumder (2011), IMF (2013), Faust and Wright (2013), Faust and Leeper (2015), Kiley (2015), and Blanchard (2017). For a different view, see Gordon (2013) and Coibion and Gorodnichenko (2015).

But this explanation is probably incomplete. After all, post-GFC, central banks have toiled to push inflation back to target with disappointing results overall, and the Bank of Japan has had huge difficulties for almost two decades. If credibility was the only factor, and if inflation expectations exerted such a powerful sway over inflation, surely the mechanisms should have worked symmetrically.

Another possible explanation is that some deeper forces have been at work, acting as tailwinds pre-crisis and turning into headwinds post-crisis. A likely candidate is globalisation, particularly the entry into the trading system of former communist countries and many emerging market economies that liberalised their markets—countries that, in addition, tended to resist exchange-rate appreciation.[5] As argued and documented in more detail elsewhere (Borio, 2017a),[6] the entry and greater prominence of such producers are likely to have weakened the pricing power of firms and, above all, of labour, thus making markets more contestable. During the cost-convergence process, this would result in persistent disinflationary winds, especially in advanced economies, where wages are higher.[7] If so, on balance, developments in the real economy may have exerted persistent downward pressure on inflation, possibly outweighing the cyclical influence of aggregate demand.

1.3 Monetary Policy Challenges

Larger and more virulent financial cycles have emerged in conjunction with a subdued and less responsive inflation process; these two factors, interacting in important ways, have given rise to the pincer movement.

In particular, globalisation amounts to a string of positive supply side "shocks" that may well have added fuel to financial cycles. Not only may it have put persistent downward pressure on inflation,

5. This phenomenon has been greatly boosted by technology, which has allowed the relocation of production to lower-cost countries; see Baldwin (2016).

6. That paper contains numerous references to the literature on the impact of globalisation on inflation.

7. Technological change, quite apart from strengthening globalisation, may have similar effects to it on inflation (Borio, 2017a). Technological change can undermine labour's pricing power—through, for example, the rise of "robotisation"—as well as reduce incumbent firms' pricing power—through cheaper products, through newer products that make older ones obsolete, and through more transparent prices that make shopping around easier. Going forward, technological advance may become more important than globalisation in influencing price dynamics.

allowing monetary policy to be easier than otherwise; but also it may have fostered expectations of stronger growth and thus provided fertile ground for asset-price booms.

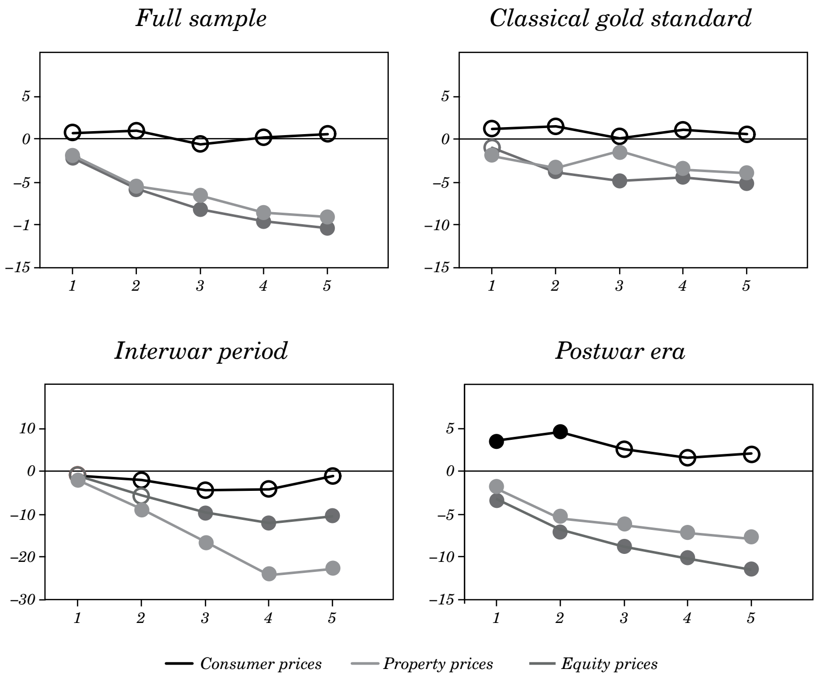
Supply-side-driven disinflation can also help explain another development that has been quite prominent since the 1990s: disinflations, and at times outright deflations, have often coincided with par or strong growth, rapid credit expansion and asset-price increases. Just looking at the more recent period, countries such as China, the Nordic economies and Switzerland, to name but a few, have been experiencing such a combination.

However, this combination is not so exceptional: historical experience tends to indicate that it may be more the rule than the exception. In recent work with colleagues, we examined deflations by using a newly constructed data set that spans more than 140 years (1870–2013), covers up to 38 economies, and includes equity and house prices as well as debt (Borio and others, 2015). We come up with three findings: First, before controlling for the behaviour of asset prices, we find only a weak association between deflation and growth; the Great Depression is the main exception. Second, we find a stronger link with asset-price declines, and controlling for them further weakens the link between deflations and growth. In fact, the link disappears even in the Great Depression (figure 4). Finally, we find no evidence of a damaging interplay between deflation and debt (Fisher's "debt deflation"; Fisher, 1932). By contrast, we do find evidence of a damaging interplay between private sector debt and property (house) prices, especially in the post-war period. These results are consistent with the prevalence of supply-induced deflations.

The conjunction of financial cycles and benign disinflationary pressures generates fundamental dilemmas for monetary policy. On the one hand, benign below-target disinflations or outright deflations put central banks under huge pressure to ease policy. On the other hand, such a response may add fuel to the build-up of financial imbalances. The risk is that a benign or good deflation may turn into a bad deflation, thus reflecting serious demand weakness, if the boom turns to bust further down the road.

All this, in turn, raises tough questions about the analytical framework that underlies policy. We next turn more specifically to the implications for a popular policy guidepost: the natural interest rate.

Figure 4. Change in *Per Capita* Output Growth after Price Peaks[1]
(percentage points[2])



Source: Borio and others (2015).
1 The figure shows the estimated difference between h-period *per capita* output growth after and before price peak.
2 The estimated regression coefficients are multiplied by 100 in order to obtain the effect in percentage points.

2. Implications for Monetary Policy: the Natural Interest Rate

In recent years, with the advent of dynamic stochastic general equilibrium (DSGE) models in the New Keynesian tradition (Woodford, 2003), economists and policymakers have rediscovered the concept of the natural interest rate, initially developed in the late 19th century by Wicksell (1898). The pincer movement from the financial cycle and inflation has significant implications for the usefulness of the concept.

We next consider, sequentially, the implications for the concept's analytics and some new empirical evidence.[8]

2.1 The Natural Rate of Interest: Analytical and Empirical Limitations[9]

The natural interest rate is defined as the real (inflation-adjusted) rate that prevails when the economy is at full employment (output at potential). In a closed economy, this amounts to equilibrating desired saving and investment at that point.

The natural rate is generally assumed to depend only on real factors. This perspective derives from the notion that money (monetary policy) is neutral in the long run, i.e., that it can only have a transitory impact on real variables. The notion of the "long run" is purely an analytical concept, the result of a thought experiment: what would occur once all the variables in the system, including prices, were allowed to adjust in the absence of shocks? In practice, when translated into calendar time—the only form of time relevant for policy—this is taken to mean something like a decade, if not considerably less.[10] Put differently, the idea is that, over time, market rates will tend to gravitate towards the natural rate.

This gravitational pull is important and non-trivial, for we all know that market rates are not determined by anonymous forces. Rather, they are determined by a combination of central banks' and *market* participants' actions. Central banks set the nominal short-term rate and they influence the nominal long-term rate through their signals of future policy rates and their asset purchases. Market participants, in turn, adjust their portfolios based on their expectations of central bank policy, their views about the other factors driving long-term rates, their attitude towards risk and various balance-sheet constraints. Given nominal interest rates, actual inflation—which is given in the short run—determines ex-post real rates, and expected inflation determines ex-ante real rates.

8. In Rungcharoenkitkul and others (2017), we propose an alternative model that might provide the basis for a different interpretation of the natural or equilibrium interest rate. The model incorporates key elements of the interaction between financial factors and a price level that is relatively unresponsive to economic slack.

9. See Borio and others (2017a) for a more detailed discussion of the issues and evidence presented in this section.

10. In fact, in his famous presidential address, Friedman (1968) notes that the effect could take some *two decades* to play itself out, underlining the difficulties in mapping analytical statements about neutrality into calendar time.

How, then, can we tell whether market rates are indeed close to the natural rate—an inherently unobservable, model-dependent concept? And which forces guide central banks and market participants to get them there?

The answer to the first question is "with great difficulty". The two main approaches used to provide evidence for the claim that the two interest rates are, on average, close to each other over long horizons rely heavily on maintained hypotheses. They allow the data to speak, but only within quite tight constraints.

The first approach simply assumes that, over the relevant sample, the market rate tracks the natural rate.[11] In the process, it abstracts entirely from the behaviour of inflation. It then proceeds to do a couple of things. The less formal variant is to tell plausible stories based on visual inspection of graphs; the more formal one is to use more articulated models and calibrate parameters to see whether they can produce results roughly consistent with the data.[12]

The second approach seeks to filter out the unobservable natural rates from market rates. Since the natural rate is defined as the real interest rate that prevails at full employment, or when output equals potential output, the behaviour of inflation provides a key signal. After all, the Phillips curve tells us that, when output is above potential (the output gap is positive), inflation rises; when it is below, inflation falls. So one infers that, whenever inflation rises, the market rate is below the natural rate, and vice versa when inflation falls. This is because the real interest rate is assumed to be the key variable influencing aggregate demand, via the investment/saving (IS) curve.

The drawbacks of the first approach are apparent. Neither of its two variants provides *independent* evidence that the market rate has actually tracked the natural rate. Moreover, upon closer reflection, neither really *tests* the underlying IS framework of interest rate determination. The less formal variant takes it as the starting point to see whether some factors might provide reasonable explanations. The more formal variant at best tells us whether the stylised model can in

11. Admittedly, the studies focus mainly on medium-term fluctuations, where, assuming that the framework is correct, it might be more reasonable to expect the rates to be close to each other, as long as on-average output is at potential. Even then, though, the variant is also used to explain post-crisis developments, for which the assumption is less compelling.

12. Examples of the narrative approach include IMF (2014), CEA (2015), Bean and others (2015), and Eichengreen (2015); examples of calibration include Rachel and Smith (2017), Gagnon and others (2016), Carvalho and others (2016), Thwaites (2015), and Marx and others (2017).

principle describe some features of the data, but not whether the model is true or not: the behaviour of the interest rate is not actually used to test it—the bar would be too low. Moreover, the numerous degrees of freedom mean that it may typically be not that hard to reproduce the behaviour of the interest rate qualitatively.[13]

The drawbacks of the second approach concern, in particular, the role of inflation and the Phillips curve. If one takes the model as true, it becomes almost a tautology to say that, since inflation is not rising and economies are close to estimates of full employment, the natural rate *must* have fallen.[14] And yet, as discussed above, the Phillips curve is precisely the relationship that has proved so elusive. Recall, for instance, how inflation has recently remained remarkably subdued even though economies seem to be close to full employment or beyond it using benchmarks *other than inflation itself*, or how inflation remained quiescent in the run-up to the crisis.

Indeed, recent research has found that information about the state of the financial cycle, excluded from the standard procedure, outperforms inflation in a straight horse race to identify potential output and output gaps in real time, i.e. as events unfold. Specifically, we have found that, while traditional approaches indicate that pre-crisis output was above potential only with the benefit of hindsight, by using financial-cycle proxies this would have been apparent in real time (Borio and others, 2014 and 2017b, and figure 5).[15]

All this has significant implications for how to think of natural or equilibrium interest rates and for the persistence of monetary policy's impact on real interest rates.

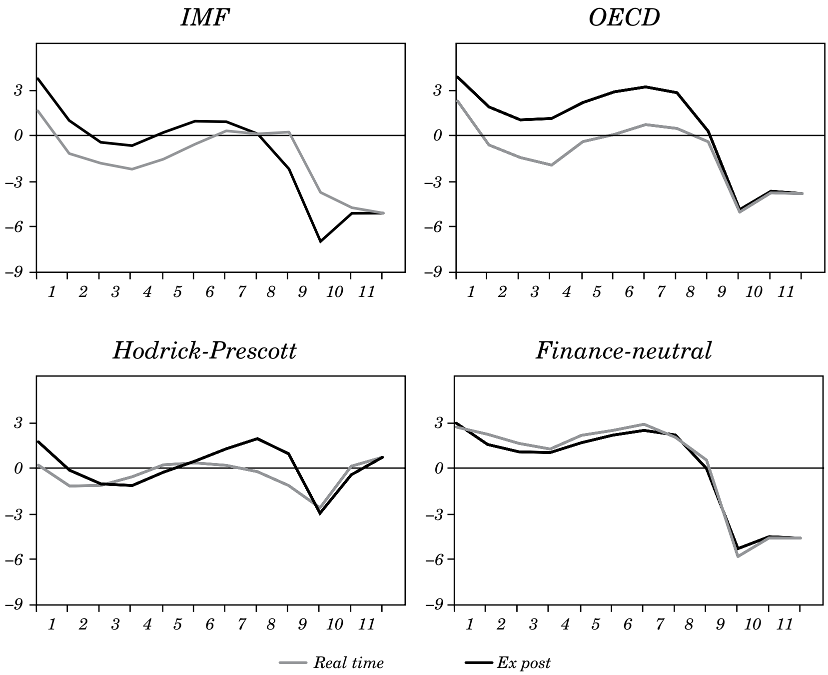
13. In calibration, the researcher chooses values for both the structural parameters and unobserved shock processes to mimic some key features of the data. These commonly include steady state ratios between variables, second moments of selected variables, and so on. Yet the key features typically constitute only a small subset of the model's full implications for the data, and there is less discipline in the remaining directions. This gives the researcher considerable degrees of freedom when fitting the features of interest at the expense of general model fit. Equally problematic is the high reliance on persistent shock processes or unobserved stochastic trends. With a sufficiently high number of such processes, the model can generate a perfect fit without an increase in predictive power—a case of "overfitting".

14. Indeed, it is not uncommon for policymakers to revise their estimates of potential output or the non-accelerating inflation rate of unemployment (NAIRU)—two other unobservable variables—assuming that the Phillips curve relationship holds, i.e., if inflation fails to rise, potential output is revised upwards and the NAIRU downwards.

15. These findings have been confirmed by subsequent research, e.g., Arseneau and Kiley (2014), Blagrave and others (2015), and Melolinna and Tóth (2016).

For one, defining an equilibrium or natural interest purely in terms of inflation is arguably too restrictive. Inflation need not be the only signal of disequilibrium; financial imbalances can also serve that purpose. If low interest rates can contribute to financial instability by encouraging booms and busts and if financial instability has long-lasting, but not permanent, effects on output and employment, then it is hard to regard a given interest rate as an equilibrium or natural rate if it generates financial instability, even if inflation is low and stable. The notion needs to be broadened to encompass some form of financial equilibrium (see below).

Figure 5. U.S. Output Gaps: Ex post and Real-Time Estimates
(percent)



Source: Borio and others (2017a).
For each time *t*, the "real-time" estimates are based only on the sample up to that point in time. The "*ex post*" estimates are based on the full sample.

Broadening the notion of equilibrium would avoid an apparent paradox. It is not uncommon to hear supporters of the "saving glut" and "secular stagnation" hypotheses say that the equilibrium or natural rate is very low, even negative, and that this very rate generates financial instability. Seen from this angle, such a statement is somewhat misleading. It is more a reflection of the incompleteness of the analytical frameworks used to define and measure the natural rate concept—frameworks that rule out financial instability—than a reflection of an inherent tension between natural rates and financial stability.

More generally, if inflation is not as responsive to economic slack as once thought, the impact of changes in nominal (policy) rates on the real rate may be correspondingly larger and longer-lasting. To fix ideas: At the limit, if inflation was *entirely* exogenous and trendless, the trend in the real interest rate would simply depend on whether inflation was below or above target. For instance, the real rate would tend to fall continuously if inflation started below target, as the central bank cut nominal interest rates repeatedly in the vain attempt to boost inflation towards target. More realistically, imagine that inflation is below target and that headwinds make it hard to generate the second-round effects whereby wages chase prices. Then, easing policy would have a permanent impact on the price *level*—say, through a currency depreciation—, but only a temporary one on *inflation*. If the central bank continued to try to push inflation up, nominal and hence real interest rates would trend downwards.

The general point is that what happens to the real interest rate depends on the reaction function of the central bank (i.e. the monetary regime in place) and the behaviour of inflation. One can get persistent effects when inflation is unresponsive and the central bank seeks to influence it. This is the unfamiliar case, not discussed much in the literature. But one can equally get persistent effects if inflation takes off and the central bank does not respond. This is a more familiar case, and often aptly used to describe the experience of the Great Inflation of the 1970s.

The two cases, however, differ substantially in terms of the role of the natural rate. In the standard framework, changes in real rates that reflect a persistent rise in inflation coupled with a passive monetary policy would be interpreted as a persistent deviation of market rates from the (Wicksellian) natural rate.[16] By contrast, changes in real

16. Lubik and Matthes (2016), for example, estimated a model of learning and argued that misperceptions about the state of the economy by the Federal Reserve led to sustained deviations from equilibrium real rates during the Great Inflation of the 1970s.

rates that reflect a limited influence of monetary policy on inflation would cast doubt on the usefulness of the very concept of a natural rate. This is because they would undermine the presumption that real interest rates have a tendency to revert to a given equilibrium level and that the resulting gap between actual rates and this equilibrium level drives inflation.

2.2 The Natural Rate of Interest: New Empirical Evidence and Interpretation

The previous analysis suggests that the impact of purely real factors on real interest rates may be overestimated, and that of monetary factors correspondingly underestimated. How can one try to break out of the grip of maintained hypotheses in current tests in order to explore this possibility further?

One option is to let the data speak a bit more. Crucially, this also requires going beyond the traditional period used to discuss the decline in real interest rates—from the early 1990s or, in some cases, early 1980s. During that period, one can indeed observe some similarity in the trends between real interest rates and the IS factors emphasised by, say, the popular "saving glut" (Bernanke, 2005, 2015) and secular stagnation (Summers, 2014) hypotheses. But these trends may simply be coincidental. Do they survive over longer periods?

This is what we have explored in some recent work (Borio and others, 2017b).[17] In it, we go back to the 1870s for 19 countries, and we examine the relationship between real interest rates and the "usual suspects": growth, productivity, demographics, income distribution, the relative price of capital, and the marginal product of capital. We do this for both real long-term interest rates and the most popular filtered estimate of the short-term natural rate, based on the behaviour of inflation. We then compare the role of these factors with that of monetary policy. The advantage of going that far back is that we cover different monetary policy regimes.

We come up with two key findings. First, while the usual suspects appear to work reasonably well over the often cited, more recent

17. For studies following a similar approach, but testing a fewer set of variables and largely on U.S. data, see Hamilton and others (2015), and Lunsford and West (2017). In line with the results reviewed below, they do not find any systematic relationship between the real interest rate and variables such as GDP and productivity growth, which theory takes for granted as the determinants of the natural interest rate.

sample, the relationships break down when going back in history: no consistent pattern emerges—a sign that the relationships may be spurious. Even a simple visual inspection of the data suggests that this is likely to be the case (figure 6). The finding is confirmed by more formal testing, when one allows the various real sector determinants to interact (see table 1, where statistically significant and correctly signed coefficients are with a grey rectangle, while statistically significant and wrongly signed ones are bold). And it appears robust to the use of different interest rates—long and short, market or traditional estimates of natural rates—as well as measures of inflation expectations.[18] Second, there are generally economically and statistically significant differences in the level of interest rates across monetary policy regimes; moreover, their trends also differ. This is so even when one controls for the usual suspects (see left-hand panel of figure 7, for an illustration).

It is then possible to provide an interpretation of the historical evolution of real interest rates in which monetary policy regimes figure more prominently than in the prevailing narrative. Consider, in particular, two periods: the experience over the sample since the 1980s–90s, and that during the classical gold standard.

The decline in real rates over the recent standard sample could be attributed to the combination of three factors. The first factor is the gradual normalisation of interest rates after the Volcker shock that ended the Great Inflation (figure 6), which saw interest rates rising from peacetime troughs. This suggests that the starting point is rather unrepresentative and already embeds a key monetary policy imprint.

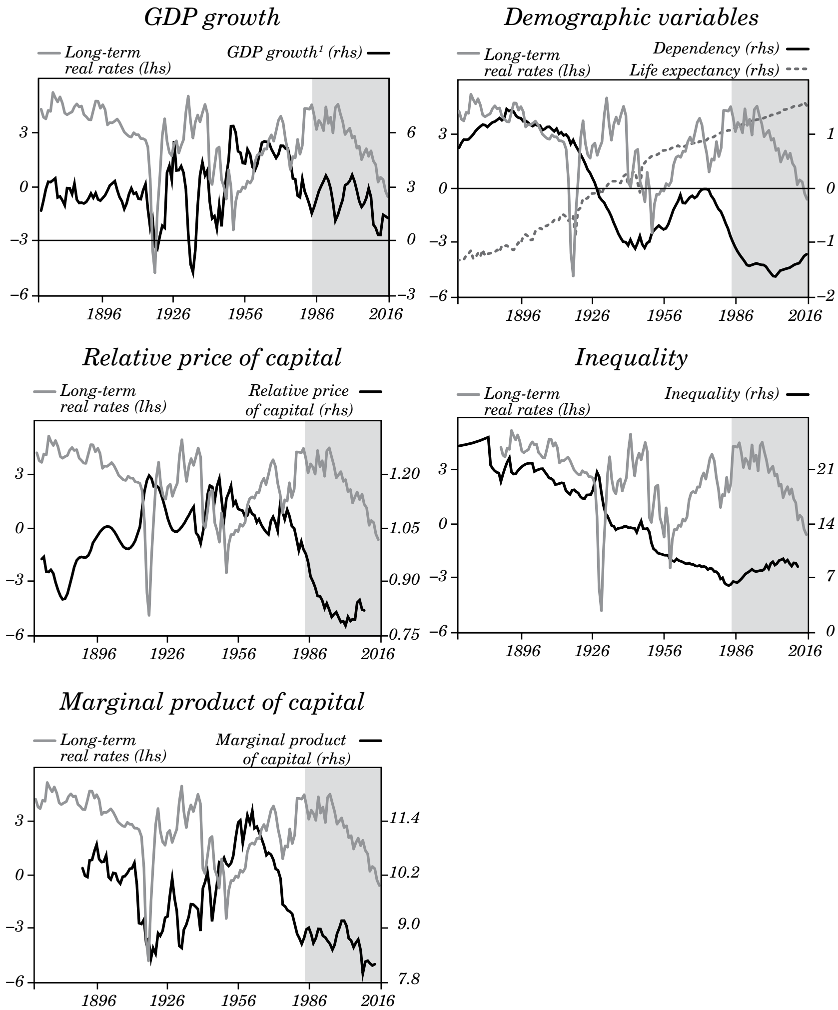
The second factor is an asymmetrical policy response to successive financial and business cycles in a context of prevailing disinflationary tailwinds linked to globalisation (e.g., Borio, 2014a, b, 2017b). In particular, asymmetrical responses were in evidence around the financial boom and bust of the 1980s–90s, and the one that surrounded the GFC.[19] As long as inflation remained low and stable, there was no incentive for central banks to tighten policy during the financial

18. Measuring expectations is notoriously hard for long-term rates. On this issue and for a review of much of the evidence, including under the gold standard, see Friedman and Schwartz (1982). See also the discussion in Borio and Filardo (2004).

19. Drehmann and others (2012) document how the asymmetrical response to equity prices in the late 1980s and early 2000s added to the downward trend in interest rates. Equity prices co-move more closely with the business than with the longer financial cycle, better captured by the joint behaviour of credit and property prices. In both cases, lowering interest rates further boosted the credit and property price boom.

booms that preceded financial strains in both cases. But there was a strong incentive to respond aggressively and persistently to fight the bust and stave off any deflation threat.

Figure 6. Real Interest Rate and Saving/Investment Drivers: Spot the Correlation
(percent)



Source: Borio and others (2017b).
1 Five-year moving average.
Shaded area indicates last 30 years.

All variables are medians of 19 advanced countries. Ten-year bond yields are used to calculate the long-term real interest rate. Dependency ratio and life expectancy are normalised.

Table 1. Real Interest Rates and the "Usual Suspects"

	(1) Full sample	*(2) Gold standard*	*(3) Interwar*	*(4) Postwar*	*(5) Pre-Volcker*	*(6) Post-Volcker*
GDP growth (+)	**–0.09****	–0.00	–0.07	0.08	0.07	0.03
	(0.04)	(0.02)	(0.05)	(0.07)	(0.07)	(0.05)
Population growth (+/–)	–0.83*	–0.50	0.25	–0.77**	–0.00	–0.68
	(0.39)	(0.50)	(0.36)	(0.28)	(0.28)	(0.71)
Dependency ratio (+)	0.02	–0.03	–0.04	0.03	0.14***	–0.03
	(0.02)	(0.02)	(0.09)	(0.02)	(0.02)	(0.07)
Life expectancy (–)	0.04	–0.20***	0.41	**0.23****	**0.47*****	–0.32***
	(0.03)	(0.05)	(0.24)	(0.09)	(0.13)	(0.09)
Relative price of capital (+)	0.01	0.11**	–0.06	–0.00	**–0.06***	0.01
	(0.02)	(0.03)	(0.05)	(0.01)	(0.03)	(0.03)
Income inequality (–)	**0.10***	–0.01	0.00	–0.26***	–0.10	–0.10
	(0.05)	(0.05)	(0.30)	(0.05)	(0.21)	(0.15)
Constant	–1.97	15.33***	–17.90	–14.27*	–42.48***	31.18***
	(2.97)	(2.61)	(21.61)	(7.79)	(11.80)	(7.95)
Adjusted R^2	0.07	0.51	0.22	0.21	0.34	0.26
N	1,102	202	205	643	303	340
Country-fixed effects	yes	yes	yes	yes	yes	yes

Source: Borio and others (2017b).
Robust standard errors in parentheses based on country clusters; ***/**/* denotes results significant at the 1/5/10% level.
Full sample, 1870–2016; gold standard, 1870–1913; interwar, 1920–1938; postwar, 1950–2016; pre-Volcker, 1950–1979; post-Volcker, 1980–2016.

The third factor, especially post-GFC, is the strenuous central bank efforts to push a stubbornly low inflation rate towards target as the disinflationary tailwinds before the crisis turned into unwelcome headwinds after it. Difficulties in generating second-round effects, with wages chasing prices, would imply that reductions in interest rates have a largely temporary effect on inflation. Thus, repeated cuts would end up reducing real interest rates further and further, even as inflation remained persistently below target.

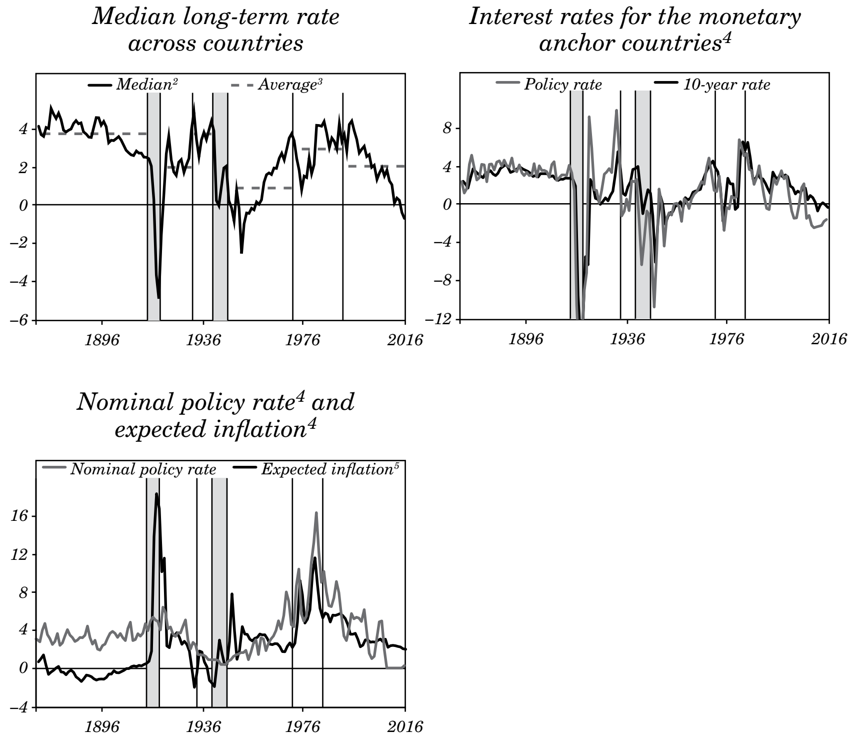
The classical gold standard is also quite revealing. During this regime, central banks did not respond systematically with changes in interest rates to output and inflation as they do now. They simply tended to keep nominal interest rates constant unless the (internal or external) convertibility-into-gold constraint came under threat (e.g., Flandreau, 2008).[20] Gold acted as a monetary anchor, but only over very long horizons.[21] Still, inflation remained very much range-bound, with the price level gradually falling or rising over long periods.[22] As a result, nominal and real interest rates were remarkably stable and did not deviate much from each other (figure 7, centre and right-hand panels). Given the behaviour of inflation, the standard approach would infer that the market rate tracked the natural rate quite closely. And yet the usual suspects tended to vary just as much as they have in the recent sample (figure 6). Another possible interpretation is that monetary policy had a persistent impact on the real interest rate without exerting a strong influence on inflation. Indeed, the classical gold-standard era coincided with a major globalisation wave, saw rapid technological change, and featured a labour force with limited pricing power. The resemblance with the experience since the 1980s–90s is striking (e.g., Obstfeld and Taylor, 2003; BIS, 2017).

20. For illuminating discussions on the gold standard and the rules of the game as applied in practice, see Bloomfield (1959) and De Cecco (1974).

21. In his political economy lectures, Wicksell (1906) recognises this and discusses the related issues in some detail. He notes, for instance, that the direct impact of increased gold supplies may be relatively small compared with the indirect influence operating through interest rates and the convertibility constraint. He then postulates an unobservable and time-varying natural rate to explain periods in which price declines coincide with falling interest rates and contractions in gold production. This contrasts with economists more firmly rooted in the monetarist tradition, who ascribe a bigger role to exogenous increases in gold in circulation in influencing the price level by boosting expenditures (e.g., Fisher, 1911, and, more recently, Bordo, 1999). For a discussion of these issues and of Wicksell's shifting views, see Laidler (1991).

22. Inflation was actually quite volatile in the short run, given the composition of the price index, in which commodities and food had a much larger weight than today. The stability mentioned in the text abstracts from this volatility, which is not relevant for our analysis.

Figure 7. The Influence of Monetary Regimes on Real Interest Rates[1]
(percent)



Source: Borio and others (2017b).
1 Monetary policy regimes, in order: (mainly) classical gold standard; post-WWI gold standard; other interwar years; Bretton Woods; post-Bretton Woods, pre-Volcker; post-Bretton Woods, post-Volcker tightening. Shaded areas indicate WWI and WWII (excluded from the empirical analysis).
2 Median interest rate for 19 countries.
3 Average of median interest rate over the periods corresponding to regimes.
4 Data for the United Kingdom up to WWI, and for the United States thereafter.
5 One-year-ahead expected inflation (year-on-year headline CPI).

3. Implications for Monetary Policy: Adjusting Frameworks

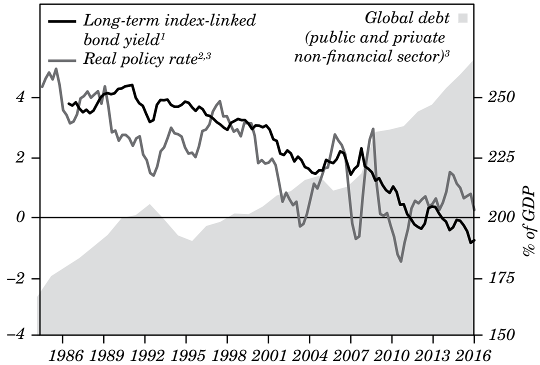
The previous analysis suggests that there is a *prima-facie* case for monetary policy to pay closer attention to the financial cycle than in the past. We may have been underestimating the influence of benign disinflationary forces and overestimating the ability of monetary policy to fine-tune inflation, especially to push it up towards targets in the face of powerful headwinds. If so, we may also have been underestimating the collateral damage that such strategies may generate in terms of financial and macroeconomic stability over longer horizons, especially by amplifying the financial cycle.

This combination of factors could even give rise to a debt trap (Borio and Disyatat, 2014, Borio, 2017b). Such a trap could result from asymmetrical policies over successive business and financial cycles, failing to tighten during expansions, but easing aggressively and, above all, persistently during contractions. Over time, policy could run out of ammunition, and it could become harder to raise interest rates without causing economic damage, owing to the large debts and distortions in the real economy that the financial cycle creates. Such a risk can be amplified by the transmission of monetary policy across countries, to the extent that the very low rates in the economies that issue international currencies tend to support the build-up of financial imbalances elsewhere.[23] And, as discussed further below, it is also amplified by the substantial impact that debt-service burdens appear to have on aggregate expenditures: if debt-to-GDP ratios continued to rise along this path, the level of interest rates an economy is able to withstand would decline. From this perspective, the continued increase in indebtedness alongside the shrinking room for manoeuvre does not bode well (figure 8).

Note also the twist that such a scenario implies for the interpretation of any natural or equilibrium interest rate. Seen through the lens of the standard approach, the contraction in aggregate demand in a debt trap would be interpreted as a sign that the natural rate has fallen, driven exclusively by some deep underlying factors. Seen through the lens of an approach that attaches importance to the financial cycle and growing indebtedness, it would be seen as a sign that the economy has been following a disequilibrium path. And what policymakers would take as given (exogenous) at that point would be, at least in part, the result of a sequence of past policy decisions. This points to a new form of time inconsistency, which is arguably more insidious than the familiar one in the context of inflation (Borio, 2014a). Policies that are too timid in leaning against financial booms, but then too aggressive and persistent in leaning against financial busts, may end up leaving the authorities with no ammunition over successive financial and business cycles.

23. For an in-depth discussion, see Borio and Disyatat (2011 and 2015), Borio (2014c), Shin (2012), Bruno and Shin (2014), Rey (2013), Rajan (2014), and Taylor (2015).

Figure 8. Interest Rates Sink as Debt Soars: A Debt Trap?
(percent)



Source: Borio and Disyatat (2014), updated.
1 From 1998, simple average of France, the United Kingdom and the United States; otherwise only the United Kingdom.
2 Nominal policy rate less consumer price inflation.
3 Aggregate based on weighted averages for G7 economies plus China based on rolling GDP and PPP exchange rates.

3.1 Why Respond to the Financial Cycle?

One possible objection to this analysis is that, rather than adjusting monetary policy frameworks, it would be better to simply enlist another instrument to target the financial cycle—prudential (and, more specifically, macroprudential) frameworks, based on solid microprudential foundations. If successful, such an approach would have additional benefits. It would allow monetary policy to continue to focus exclusively on price stability and short-term output stabilisation, thus reducing the risk of overburdening it. It would make it easier to ensure accountability wherever the objective is set in terms of an inflation target. And it would prevent monetary policy from actually damaging the economy. This is generally the conclusion reached by those who argue that "leaning" against financial imbalances is harmful (e.g., Svensson, 2014, 2017).

These objections clearly have force. However, in our view, they are not compelling enough to rule out adjustments to the frameworks.

First, it is debatable whether prudential measures alone can be sufficient to prevent the build-up of financial imbalances (Borio, 2014d). Indeed, even in countries that have used macroprudential tools aggressively, there have been signs of the emergence of such imbalances.

These are captured by standard indicators such as increases in the private credit-to-GDP ratio and property prices in excess of critical thresholds (BIS, 2017). Of course, there is little doubt that prudential measures have strengthened the resilience of the financial system. Even so, only once the expansions turn into contractions will one find out by how much. Moreover, even if the financial system is able to withstand the shock, the macroeconomic implications could be severe. For instance, the turn in the recent financial cycle in Brazil coincided with one of the deepest recessions on record, although the country avoided a full-blown crisis.[24] And, more generally, there is a tension in employing macroprudential measures and monetary policy in opposite directions, as when seeking to offset any undesired impact of a very easy monetary policy stance: this is a bit like driving by pressing on the accelerator and brake simultaneously—not exactly what is normally recommended (Borio, 2014a).

Second, it is not clear how macroprudential measures can address the risk of a debt trap following a financial bust. The measures are designed to address signs of exuberance in credit and asset markets, but that is not quite what a debt trap is about. To be sure, asset prices may appear high measured on their own terms (e.g., historical price-to-rent ratios), but valuations may not be unusual compared with bond yields. Similarly, private credit may be expanding, but its pace need not be cause for alarm, especially given the post-bust adjustment. And public sector debt is also an integral part of the picture. The debt trap is not a financial imbalance in the usual sense of the term: it is the result of a cumulative and gradual process over successive business and financial cycles. It is not synonymous with hot credit and asset markets; it is more like a cold *cul de sac*. As a result, the literature that defines the response to the financial cycle exclusively as “leaning against the wind” of financial excesses does not do full justice to the nature of the problem—and this quite apart from calibration questions (appendix 1).

Third, at issue is not so much a change in monetary policy objectives, but in the time frame over which traditional objectives are pursued and in the underlying analytical framework. This would be a framework in which financial factors have a first-order and long-lasting impact on the economy, in which monetary policy has a

24. This is not to say that the turn was the cause of the recession, although it clearly amplified it. The fact that the banking system is largely public-sector owned has also helped cushion the blow, as has the extensive use of foreign exchange reserves to insulate the corporate sector from exchange-rate risk.

sizeable impact on those factors, and in which inflation may be less responsive to monetary easing than traditionally assumed.[25] Under those conditions, over horizons that go beyond the traditional business cycle, monetary and financial stability, broadly defined, are mutually supportive; short-run trade-offs tend to vanish.

3.2 How to Respond to the Financial Cycle? An Illustration

One can illustrate these points with the results of a recent empirical study (Juselius and others, 2017).[26] The analysis uses the United States as an example and proceeds in three steps:

The first step is to decompose the financial cycle into two sets of variables that in the data are found to have very stable long-run relationships (Juselius and Drehmann, 2015). One is a proxy for the private-sector (households and firms) debt-service burden, i.e. the ratio of the sum of interest payments and amortisation-to-income (or GDP); the other is a proxy for "leverage", linking the debt-to-income ratio to property and equity prices. Deviations of these variables from their long-run (cointegrating) relationships ("gaps") interact and, when embedded in a richer econometric system, are found to have a sizeable impact on private sector expenditure and output fluctuations.[27] This is intuitive. Heavier debt-service burdens depress spending, not least as they squeeze cash flows. And higher asset prices in relation to credit can boost both spending and credit growth. There are many stories and simple models that capture these mechanisms, although none that as yet fully captures their interaction.[28]

25. Most of the recent efforts have sought to 'patch' the standard model, most prominently by adding financial frictions, which strengthen the financial channel of policy transmission, or have considered a cost-benefit analysis of deviating from traditional policy objectives. But, given the restrictiveness of the framework, often the analysis can only partly capture the highly persistent dynamics of the financial cycle and its impact on the real economy.

26. The numerical results here refer to the more elaborate, working-paper version of the published paper. Those in the published version are very similar.

27. The cointegrating relationships can be closely approximated by actual financial data, namely the actual debt-service ratio itself and the ratio of debt to real and financial wealth, which are approximately stationary.

28. See Juselius and Drehmann (2015) for references to this work. In more recent work, Drehmann and others (2017) also find that the debt-service ratio explains the delayed negative impact of credit expansion on GDP found by Mian and others (2013, 2017). On the relationship between credit booms and recessions, see also Jordà and others (2013).

The system has a couple of interesting properties that set it apart from the previous studies. For one, it can result in financial busts with permanent output losses. In fact, the interaction between the two financial gaps can help trace the Great Recession quite well out of sample, though not quite its depth—the financial crisis still appears to have an additional effect (Juselius and Drehmann, 2015). The possibility of permanent losses does not depend on the GFC; it is a more general property.[29] In addition, it does not rely on a separate crisis module (appendix 1); the financial cycle is fully integrated in the dynamics of the economy. The system gives rise to "endogenous" fluctuations in which the financial and real sectors interact, but not to crises as such.

The second step is to use the two financial gaps to derive estimates of the typical unobservable variables in any policy rule. These are economic slack (or the output gap) and the natural rate of interest. Estimates of the output gap and natural interest rate are derived by adding the two financial gaps to a very standard macroeconomic setup.[30] Thus, the natural rate now requires not just output at potential and inflation on target, but also closure of the financial gaps—the concrete definition of "financial equilibrium" in this approach.

Importantly, the financial gaps are *allowed* to have an impact on the output gap and the natural rate, but it is the *data that decide*. This richer system nests the standard model (Laubach and Williams, 2003), and the data are allowed to tell us which one is a better characterisation of the economy.

The third step is to carry out a counterfactual experiment. This is done by adding the financial gaps[31] to a traditional Taylor rule, whereby the interest rate is adjusted in response to the output gap and the deviation of inflation from target (Taylor, 1993), and then seeing how the economy would evolve under this different rule. Thus, the aim is not to respond only once the signs of an impending crisis emerge, which would be too late, but *to steer the economy throughout the financial cycle*. The financial gaps simply complement the variables traditionally included in the policy rules, which retain their role.

A number of findings emerge. First, responding systematically to the financial-cycle proxies in addition to output and inflation can result in

29. That said, Drehmann and Juselius (2014) also find that, over horizons of around one year, the debt-service ratio outperforms also the credit gap as a leading indicator of banking crises; the credit gap performs better over longer horizons.

30. The standard model follows Laubach and Williams (2003, 2015).

31. The specific rule in the study explicitly includes only by the debt-service gap.

significant output gains (figure 9). Second, there need not be much cost in terms of inflation. In fact, on average, inflation is effectively unchanged: it is a bit lower pre-crisis, reflecting the tightening phase, and higher post-crisis, as economic slack is smaller then. Third, leaning early is key, and this can gain considerable room for manoeuvre in the bust (figure 10). In the counterfactual, the policy rate is some one percentage point higher until mid-2005; it can then afford to decline earlier, starting roughly when asset prices peak (not shown) and is normalised more quickly after the recession, as output recovers faster. Finally, the source of the gains is that the policy helps to smooth out the financial cycle (figure 11) the amplitude in the cycle in asset prices, real credit and the credit-to-GDP ratio is clearly smaller in the counterfactual.[32]

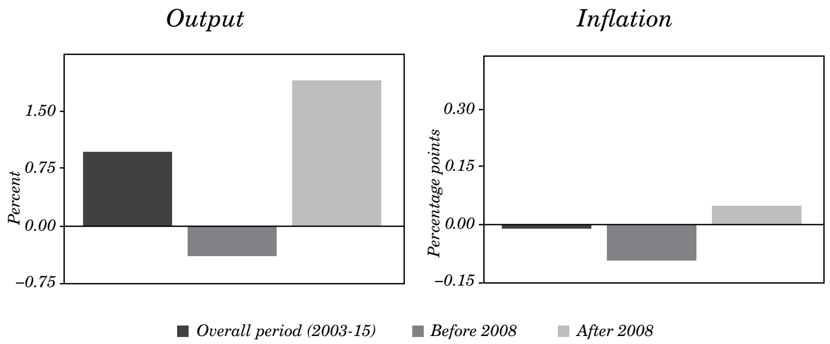
The results also shed light on the notion and usefulness of the natural rate of interest (figure 12). Even with these minimal changes in its definition, the decline in the financial-cycle-adjusted natural rate (dark grey line), which includes information about the financial cycle, is smaller than the standard estimate (solid black line) and it is even smaller in the counterfactual (dashed line). The smaller decline emerges even if the procedure *by construction* severely constrains the evolution of the natural rate to follow output growth, which, as we saw in the previous discussion, does not seem to have much explanatory power historically. In fact, once financial factors are allowed to play a bigger role, stabilising the economy sometimes requires sizeable deviations of the policy rate from the natural rate in response to the financial gaps. This is necessary so as to keep the economy close to financial equilibrium. The deviations tend to be larger than those under a standard Taylor rule. And they raise questions about the usefulness of the very concept of a natural rate for policy.[33]

There are, of course, obvious limitations in this type of analysis. It is always hazardous to make counterfactual evaluations based on historical correlations. The exercise is quite stylised, and does not address explicitly the complications that arise in small open economies, notably the exchange rate and capital flows. Moreover, it does not fully characterise the uncertainty that plagues policymaking.

32. Naturally, the performance of the economy improves further if the counterfactual experiment begins earlier (not shown). The reason is that the policy has more time to work and hence gets more traction.

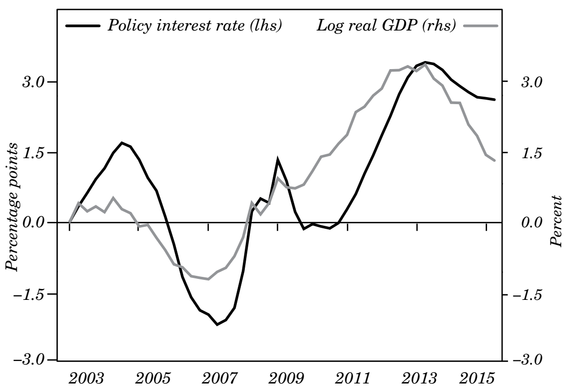
33. As is well known, the concept itself has come under attack in the past. For instance, Keynes (1936) rejected the notion, after having embraced it in his Treatise. For an in-depth discussion, see Leijonhufvud (1981) and, for a more recent sceptical view of the natural rate, see Laidler (2011) and his review.

Figure 9. An Illustrative Experiment: Higher Output and Similar Inflation



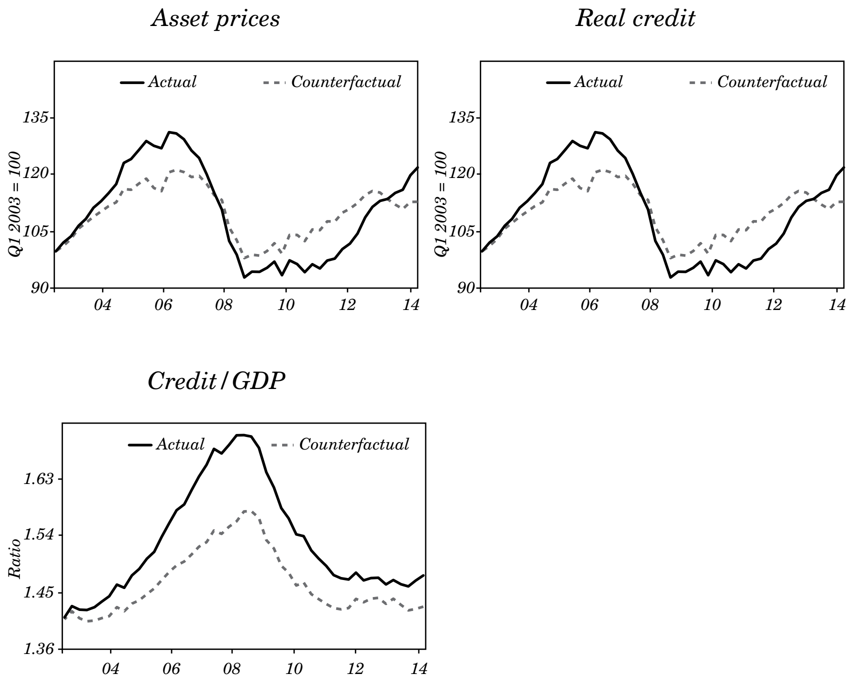
Sources: Juselius and others (2017); based on U.S. data.

Figure 10. An Illustrative Experiment: Output and Interest Rate Paths Difference between Counterfactual and Actual Outcomes



Sources: Juselius and others (2017); based on U.S. data.

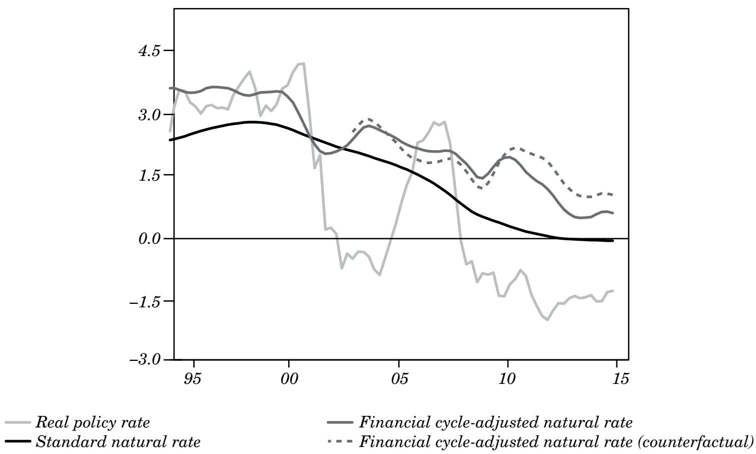
Figure 11. An Illustrative Experiment: Smoothing the Financial Cycle



Sources: Juselius and others (2017); based on U.S. data.

Even so, we would argue that the limitations are not show-stoppers. The Lucas critique can be overdone.[34] Indeed, the public becoming aware of the central bank's reaction function could even enhance the policy's effectiveness, just as anti-inflation credibility reduces the likelihood of second-round effects in wages and prices. Including explicitly the impact of the policy on the exchange rate is bound to change the balance of the policy mix in favour of macroprudential measures. At the limit, for instance, if the exchange rate was pegged, these would be the only measures *de facto* available. And a richer characterisation of the uncertainty need not overturn the conclusion. The costs of a debt trap would be very large, and current frameworks exclude this possibility altogether.

Figure 12. Comparing Interest Rates: Standard and Financial Cycle-Adjusted
(percent)



Sources: Juselius and others (2017); based on U.S. data.

34. Studies have found that the Lucas critique may be of limited relevance in practice. For instance, a common finding is that the parameters of empirical vector autoregressions (VARs) are remarkably stable despite changes in estimated policy equations in the sample (e.g., Favero and Hendry 1992; Leeper and Zha, 2003; Rudebusch, 2005. In the present context, the main parameters of the VAR model are stable over both pre- and post-crisis samples. This suggests, for instance, that the adoption of unconventional monetary policy tools post-crisis has not generated sizeable changes to the system's dynamics. To the extent that the adoption of these tools constitutes shifts in the monetary policy function, this provides indirect evidence against a strong Lucas-critique effect in our sample.

3.3 How to Adjust Current Frameworks? Practical Considerations

If this analysis is accepted, how could one adjust monetary policy frameworks? How can central banks gain the necessary room for manoeuvre to respond more systematically to the financial cycle?

The first point to note is that there is no one-size-fits-all answer. The analysis does not claim universality: some countries around the world are still struggling with the age-old problem of ensuring that inflation is brought down or does not get out of control. And initial conditions matter: the inherited regime constrains and helps shape the desirable and feasible adjustments. Even so, some general considerations are possible.

The smallest adjustment is to lengthen the horizon over which to achieve a given inflation objective. An obvious advantage of this approach is that a specific number, or narrow band, could help anchor expectations by acting as a focal point. In fact, to varying degrees, this is already how flexible inflation targeting is implemented. It has been widely recognised that the optimum horizon over which to guide inflation back to target depends on the nature of the "shocks". In principle, one could apply the same logic to the financial cycle.[35] Indeed, some central banks that take account of financial stability/financial cycle considerations have done precisely this (e.g., the Central Bank of Norway and the Reserve Bank of Australia, to mention just two).

One issue with this approach is that the tolerance for inflation deviations from target may have to be quite high. How persistent and large can the deviations be before central bank credibility comes into question? This is likely to be country-specific and depend on history and institutional arrangements. Moreover, given the history of inflation targeting, inflation shortfalls arguably raise less reputational concerns than inflation above target. For instance, in a country like Switzerland, persistent deviations in the form of actually falling prices have been tolerated quite easily: the central bank has progressively de-emphasised the target while never officially renouncing it. Similarly, in Thailand, where financial stability considerations have played an important role in the decision to leave policy unchanged despite over two years of undershooting the inflation target band, the central bank's credibility does not appear to have been affected significantly.

35. That said, it is debatable whether the shock-propagation terminology is well suited to capture the underlying process.

A second option is to move from a point target to a band, or to widen a target band. In practice, there may not be that much difference between this and the previous approach. And the room for manoeuvre would be greater if one treated the edges of the band as soft, rather than hard, bounds. The disadvantage of this option is that it could weaken the target's anchoring role. How serious a problem this turns out to be would depend on one's views about the strength of the target's gravitational pull on expectations and about their influence on wage and pricing decisions. The advantage would be to dispel the notion that monetary policy can fine-tune inflation. For instance, the Riksbank has decided to reintroduce a (softer) target band for precisely these reasons.

A third option would be to reduce the point target or shift the band downwards in order to take into account the longer-term headwinds that may be reducing inflation. This option is trickier, since it may jeopardise more directly the central bank's credibility. And it raises tougher communication issues. But it may be viable in countries that have seen persistent shortfalls in inflation alongside obvious signs of the build-up of financial imbalances and good growth. The Bank of Korea, for instance, has decided to reduce its point target from 3% to 2% based on such considerations. No doubt, reducing the target to a standard figure internationally has facilitated the move.

A fourth option is to go one step further and change the mandate to, say, include financial stability as a separate consideration. The advantage of this approach is that it would definitely give the central bank ample room for manoeuvre. The disadvantage is that it explicitly introduces the notion of a trade-off that need not be there over a sufficiently long horizon. Moreover, the political process of changing a mandate is unpredictable. While helpful under the right circumstances, the step may not be necessary. In fact, the mandates enshrined in the central bank law are typically written in very general terms and provide plenty of scope for interpretation.[36] They tend to be the product of the time when they were written. For example, the Reserve Bank of Australia actually refers also to the "welfare of the Australian people", which is clearly less constraining than

36. For instance, Section 2a of the Federal Reserve Act states: "The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates." Given the reference to monetary and credit aggregates as well as to moderate interest rates, it leaves considerable room for interpretation.

the agreement the central bank has reached with the government concerning its objectives. In order to attach greater weight to financial stability considerations, the central bank has modified that agreement and used the mandate in its communication to avoid further easing in a context of very high and rising household debt and rich property prices.[37] By contrast, the recently established independent commission in Norway has recommended explicitly adding financial stability to the central bank's mandate and setting up a joint policy committee for monetary and macroprudential policies. The objective is to strengthen the foundation for policies the Central Bank of Norway has already been following since 2012.

The key point is that, at the end of the day, mandates matter less than the analytical framework used to implement them. Many of the current arrangements already provide significant room for manoeuvre, as evidenced by the varying degree to which inflation-targeting central banks take financial stability concerns into account. And one could imagine circumstances where changes in the mandate, if interpreted the wrong way, could actually be harmful. For instance, that would be the case if a financial stability objective was interpreted as keeping interest rates low because the banking system was weak even as inflation was threatening to increase out of control. Under those circumstances, the right policy would be to tackle the banking problems head-on with other instruments. Admittedly, including financial stability in central banks' mandates could help the institution resist political pressure when taking decisions that put long-term gains above short-term ones. That said, the unpredictability of the political process means that changes in mandates should be treated with great caution.

4. Conclusion

Paradigms die hard. This is entirely understandable. The hurdle *should* be set high. New evidence cannot be interpreted in isolation. It must be evaluated against the backdrop of the body that precedes it. What is true for intellectual disciplines is equally, if not more, true

37. The agreement signed in September 2016 modifies the previous one from October 2013. It clarifies that the medium-term 2–3% inflation objective, on average, is to be pursued "over time", rather than more precisely "over the cycle"; and it now states explicitly that "the medium-term focus provides the flexibility for the Reserve Bank to set its policy so as best to achieve its broad objectives*, including financial stability*" (emphasis added).

for policymaking. Innovation is risky, both for those who carry it out and for society. The danger in all this, however, is that change may come too late, only when damaging events make it unavoidable. And then the pendulum may swing too far.

This was clearly the case of pre-crisis. The experience showed once more how some of the most serious risks do not arise from the mechanical repetition of errors in identical circumstances, but from the interaction between policy and changes in the economic environment. And they arguably reflect overconfidence in our ability to understand the economy, a sense that policy is finally on the right track. The belief in the Great Moderation in the run-up to the GFC was simply retracing an all too familiar historical pattern. In the 1960s, after having "digested" the lessons of the Great Depression, policymakers thought they had discovered the secret of how to achieve full employment at the cost of moderate inflation. In the lead-up to the Asian crisis, fiscal probity and low inflation were seen as guaranteeing the sustainability of the Asian boom. Further back in history, in the lead-up to the Great Depression, the Roaring Twenties had held out the promise of permanent prosperity.

Post-crisis, policymakers have made huge efforts to shore up the financial sector and strengthen financial regulation and supervision. As part of that, they have been implementing wholly new macroprudential frameworks, thus crystallising a concept that had been put forward a decade before and had remained largely ignored until the crisis (Crockett, 2000; Borio, 2003; Borio and Drehmann, 2011).[38] These efforts are necessary and welcome. But they have also nurtured the expectation that they are sufficient to avoid financial instability, broadly defined, and its serious macroeconomic costs—that they can, on their own, avoid the disruptive financial booms and busts of the past (Borio, 2014c). As a result, monetary policy—and fiscal policy, for that matter—have by and large continued to operate as it if it was business as usual.

This may well be the right answer. But in this paper we have argued that it may not be prudent enough. Monetary policy has been in the grip of a pincer movement, caught between growing financial cycles, on the one hand, and an inflation process that has become quite insensitive to domestic slack, on the other. With inflation stubbornly unresponsive to attempts to push it back towards target, it may be imprudent to downplay the longer-term side effects of extraordinarily

38. See Clement (2010) for a history of the term.

and persistently accommodative monetary policy for the financial side of the economy.

If so, a more balanced approach may be preferable. The approach would recognise the difficulties monetary policy has in fine-tuning inflation when the rate is already low, possibly owing to supportive real factors such as globalisation and technology. It would take into account the risks of conducting policy based on unobservables that do not consider its impact on the financial side of the economy, such as the Wicksellian or New Keynesian natural interest rate. And it would provide sufficient room for manoeuvre to respond more systematically to the financial cycle. This, too, may not be the full answer. But it may bring us closer to it.

Appendix

A.1 Recent Approaches to Evaluating Leaning Strategies

This appendix reviews recent approaches to evaluate the desirability of "leaning against the wind" (LAW) of the financial cycle (a "stability-oriented monetary policy"). It examines key assumptions underlying these approaches and highlights features that deserve greater prominence in future research to fully capture potential gains from such a strategy.

What is the standard way of evaluating empirically the costs and benefits of a financial stability-oriented monetary policy?[39] The basic idea is to trade off the output costs of leaning today against the possible output benefits that would arise tomorrow, if leaning helps reduce the likelihood and/or the costs of future banking crises.

Implementing this thought experiment involves a number of steps. First, one takes a traditional model embedding relationships between the policy rate, output, and inflation. Then one augments it with a "crisis module". The module describes the relationship between a financial variable and banking crises, links this variable to the policy rate, and assumes something about the costs of banking crises. The variable most commonly used is the growth rate of (private sector) credit, which some work has found to be a reliable leading indicator of banking crises. Finally, one estimates the resulting net benefits in terms of output and (possibly) inflation by adjusting policy, either as a one-off deviation from traditional policy rules or as the optimal response given the model.

Analyses of this type tend to find that, for typical parameter values, a LAW strategy does not generate significant net benefits and may be counterproductive.[40] Extending this basic analysis in certain directions can strengthen the case for leaning,[41] but the typical conclusion drawn from it has been that the first-order benefits are, at best, small.

39. The focus here is on the empirical work, as opposed to the theoretical studies that typically find that there may be a role for monetary policy; for two examples among many, see Woodford (2012), and Gambacorta and Signoretti (2014). See also Smets (2013), Borio (2014b), or IMF (2015) for references.

40. See, in particular, Svensson (2014, 2017), and IMF (2015).

41. For example, uncertainty about the probability and severity of a crisis could justify leaning as a robust control strategy (Ajello and others, 2015).

This type of analyses follows a clear logic, but there are a number of reasons why it may underestimate the potential net benefits of leaning. These have to do with the assumptions and with the calibration (table A1).

In most studies, crises do not result in permanent output losses, so that eventually output returns to its pre-crisis trend. But empirical evidence suggests that this is typically not the case.[42] Output may indeed regain its previous long-term growth rate, but it typically ends up following a parallel and lower path. Thus, if one postulates, plausibly, that actual and potential output eventually converge, this means that potential output is also permanently lower.

Table A1. Costs and Benefits of LAW:* Assumptions

	Permanent output losses	*Crisis cost cannot be fully offset ex post*	*LAW reduces crisis severity*	*Benefits broader than crisis prevention*	*Risks build up and endogenous to policy*	*Monetary policy experiment*
Svensson (2017)	NO	NO	YES	NO	NO	Cost-benefit of LAW
IMF (2015)	NO	YES	NO	NO	NO	Cost-benefit of LAW
Ajello and others (2015)	NO	YES	NO	NO	NO	Optimal rule
Gourio and others (2017)	YES	YES	NO	NO	NO	Optimal linear rule
Gerdrup and others (2017)	NO	NO	YES	NO	NO	Optimal rule
Adrian and Liang (2016)	NO	YES	YES	NO	NO	Cost-benefit of LAW
Juselius and others (2017)	YES	YES	YES	YES	YES	Linear rules
Filardo and Rungcharoenkitkul (2016)	NO	YES	YES	YES	YES	Optimal rule

Source: Author's elaboration.
* Leaning against the wind.

42. See the BCBS (2010) survey, Cerra and Saxena (2008) and, more recently, Ball (2014). Blanchard and others (2015) find that other recessions too may have a similar effect.

In some cases, monetary policy can even "clean up" after a crisis hits, in the sense that the central bank can cut rates and make up for any demand shortfall as it would with any other normal recession. But the GFC experience clearly suggests otherwise: monetary policy has a harder time dealing with balance sheet recessions, as agents are overindebted and balance sheets impaired (e.g., Borio. 2014a). There is indeed a consensus that this is a lesson to be drawn from the crisis.

Leaning is often assumed to affect the probability of a crisis but not its severity once it occurs. Yet one might expect that the bigger the initial imbalance is, the larger the costs will be. Indeed, the severity of a balance-sheet recession depends on the extent of bad debt previously accumulated. If policy can help restrain the build-up, it would also limit the damage of any subsequent strains. Some studies have incorporated this endogenous crisis cost and found support for leaning (e.g., Adrian and Liang, 2016; Gerdrup and others, 2017).

In most exercises, financial variables have no or limited impact on output other than through crises. And even if they do, this is not considered part of the analysis. But this means that benefits can only arise if crises are successfully averted, which is very restrictive. It couches the problem exclusively in terms of rare events rather than of the potential for financial fluctuations to damage the economy more generally.

Finally, another underappreciated key assumption concerns the evolution of financial risks. In prevailing approaches, risks are not expected to grow over time in the absence of leaning. By this we mean that if no action is taken, then any "shocks" that may occur in normal times will die away. This implies that there is little or no cost to waiting. Importantly, this encourages the view that a financial stability-oriented monetary policy is one that follows a traditional policy most of the time and then deviates from it only once the signs of financial imbalances become evident. But the risk of this strategy is obvious: it could end up doing too little too late or, worse, it could be seen as precipitating the very crisis it intends to prevent.

Some work at the BIS has relaxed most of these restrictive assumptions of the standard approach. As a result, it has found higher potential benefits from leaning (e.g., Juselius and others, 2017; Filardo and Rungcharoenkitkul, 2016). While the specifics differ, this research strand shares two elements: it allows risks to build up over time as the economy evolves—and here the notion of the financial cycle is key—and it allows monetary policy to play a bigger role in influencing both the probability and the costs of financial busts, even without crises. In other words, there is path dependence, so that once financial imbalances are allowed to build up, some losses down the road are inevitable. The benefits from leaning stem not only from averting full-blown crises, but also from tempering the financial cycle and its associated cost.

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