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Macroprudential regulation of investment funds

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Macroprudential regulation of investment funds

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Abstract

The investment fund sector, the largest component of the non-bank financial system, is growing rapidly and the economy is becoming more reliant on investment fund financial intermediation. This paper builds a dynamic stochastic general equilibrium model with banks and investment funds. Banks grant loans and issue liquid deposits, which are valuable to households. Funds invest in corporate bonds and may hold liquidity in the form of bank deposits to meet investor redemption requests. Without regulation, funds hold insufficient deposits and must sell bonds when hit by large redemptions. Bond liquidation is costly and eventually reduces investment funds' intermediation capacity. Even when accounting for side effects due to a reduction of deposits held by households, a macroprudential liquidity requirement improves welfare by reducing bond liquidation and by increasing the economy's resilience to financial shocks akin to March 2020.

Keywords: Non-Bank Financial Intermediation, Macroprudential Policy, Liquidity Regulation

JEL Classification: E44, G18, G23

Non-Technical Summary

The investment fund sector grew significantly over the last years, both in the euro area and at a global level. Funds are very active in less liquid market segments, such as high-yield corporate bonds, but usually hold low liquidity buffers even though their shares are often redeemable at a very short notice. The combination of these factors creates a liquidity mismatch that makes funds vulnerable to sudden large-scale outflows, such as those registered in March 2020 during the Covid-19 market event. Against this backdrop, policymakers are discussing ways to address these risks, including a regulatory liquidity buffer for funds.

This paper develops a dynamic stochastic general equilibrium (DSGE) model to study the macroeconomic effects of liquidity risk in the investment fund sector and a regulation that can address this risk. In our model, non-financial firms issue bonds and receive bank loans to finance investment. Households invest in fund shares and bank deposits. Banks raise deposits to grant loans to firms. Investment funds issue shares, purchase corporate bonds and can hold a liquidity buffer in the form of bank deposits.

Investment funds are exposed to periodic redemptions. When a fund's outflows exceed its liquidity buffer, the fund must sell bonds to households who, as second-best users, purchase the assets at a discounted price. Individual fund managers do not internalise the aggregate impact of their liquidation of corporate bonds on market prices and, as a result, hold inefficiently low liquidity buffers. Hence, there is a pecuniary externality. Bond liquidation is socially costly, as it implies resource losses and depresses financial intermediation through investment funds.

We calibrate the model to the euro area economy in the late 2010s. Without fund regulation, the liquidity buffer held by funds is 2% of funds' assets under management, in line with euro area data. We show that the introduction of a higher regulatory minimum liquidity buffer improves upon the unregulated economy. The welfare-maximising optimal buffer amounts to 8% of assets under management. Regulation has benefits and costs. On the one hand, the liquidity buffer reduces assets in liquidation and the associated resource losses, which ultimately depress consumption. On the other hand, by forcing funds to hold a larger fraction of their assets in bank deposits, the regulation is associated with lower bond intermediation, which at a certain point implies a drop in output. In addition, having funds demanding more deposits crowds out households' deposits, who extract liquidity benefits from holding deposits though.

We also consider the response of our economy to a sudden change in household saving preferences for liquid assets in form of bank deposits, with the aim to capture some of the dynamics observed during March 2020. This shock leads to a shift of households' asset allocation towards bank deposits and away from investment fund shares. As a response, investment funds reduce deposits relatively more than their bond holdings, because deposits pay a lower return. Smaller liquidity buffers lead to higher bond sales and resource losses, thereby compressing the

return on fund shares. This reduces households' savings in investment funds further and, thus, the ability of the latter to invest in corporate bonds. While the change in preference implies more funding for banks, the loss in bond financing cannot be replaced in full. The overall effect is an amplification of the initial shock that leads to a drop in output and consumption. We show that the optimal regulatory liquidity buffer substantially reduces these effects: redemptions lead to smaller bond sales and resource losses, while output drops by less and consumption is stabilised.

1 Introduction

The investment fund sector grew significantly over the last years. In the euro area, assets held by investment funds increased almost fourfold, from around 3.6 EUR trillion in 2002 to more than 14 EUR trillion in 2020 (Figure 1, top left panel). Investment funds' assets now amount to 35% of those of the banking sector.[1] About a third of euro area non-financial corporate bonds is held by the fund sector (Figure 1, top right panel).

These developments make the euro area financial system – traditionally heavily bank-based – more diverse and possibly more resilient. But vulnerabilities associated to investment funds' activities are on the rise as well. Although fund shares are often redeemable at a very short notice, funds have progressively intensified their search for yield and became more active in less liquid market segments, such as high-yield corporate bonds. At the same time, funds' liquidity buffers, i.e., the share of cash and cash-like instruments in total assets, markedly declined (Figure 1, bottom left panel). Small liquidity buffers in combination with large-scale redemption requests, such as those registered in March 2020 during the Covid-19 market event (Figure 1, bottom right panel), can force funds to sell relatively illiquid assets.[2] This can amplify asset price deterioration, leading to broader adverse effects on the financing of the economy (see Falato et al., 2021b, Morris et al., 2017 and Chernenko and Sunderam, 2016). The Covid-19 event gave additional momentum to the policy debate on macroprudential regulatory options that address vulnerabilities in funds, including minimum liquidity buffers.[3] Such a regulation could contribute to containing adverse spill-overs from the investment fund sector to wider financial markets and the real economy.

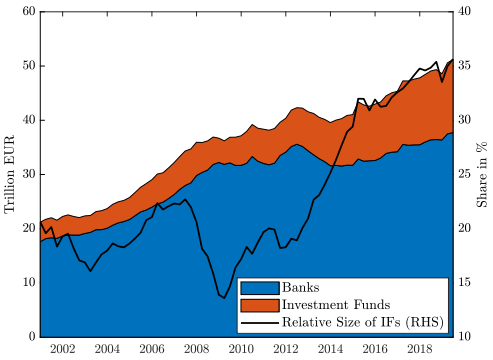
In this paper, we develop a dynamic stochastic general equilibrium model (DSGE) to study the macroeconomic effects of liquidity risk in the investment fund sector. Moreover, we analyse the macroeconomic and welfare effects of a macroprudential liquidity buffer of funds. We also discuss the different mechanisms through which the regulation affects our economy. To the best of our knowledge, this is the first paper that studies these issues in a macroeconomic model setting.

In our model, non-financial firms issue bonds and receive bank loans, which are imperfectly substitutable, to finance investment. Households invest in fund shares and bank deposits. We assume that the latter also provide liquidity benefits to households in terms of utility, as in Begenau and Landvoigt (2021). Banks issue deposits and use the proceeds to invest into loans directly. Investment funds issue shares, purchase corporate bonds, and can hold liquidity in the form of bank deposits. We capture liquidity risk in investment funds by assuming that funds

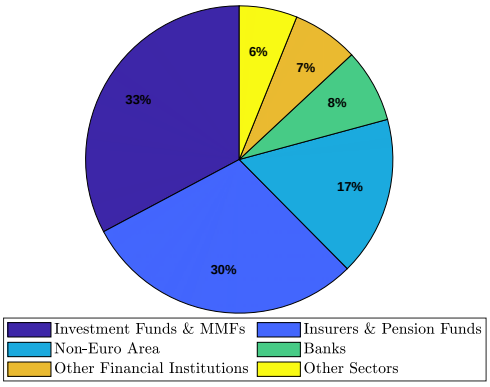
[1] Similar trends are visible at the global level (see, e.g., FSB, 2020a). Investment funds, also abbreviated as "funds" when ambiguity can be ruled out, are the largest component of the non-bank financial intermediation sector, formerly known as "shadow banking system".

[2] Market tensions ceased and outflows reversed only when central banks intervened in financial markets, for example, by means of the ECB's Pandemic Emergency Purchase Programme (PEPP) (see Breckenfelder et al., 2021). For an overview of the US case and the interventions of the Federal Reserve, see Falato et al. (2021a).

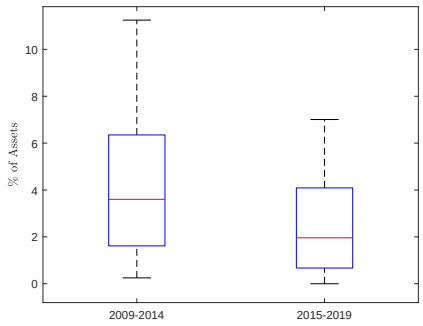
[3] See, for example, IMF (2021), FSB (2017, 2020b), and Cominetta et al. (2018).



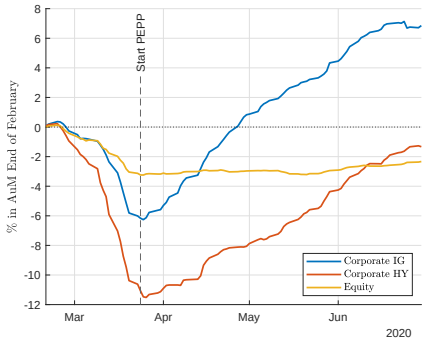
(A) Balance Sheet Size



(B) Corporate Bond Holding Sectors



(C) Cash of Corporate Bond Funds



(D) Cumulative Weekly Fund Flows

FIGURE 1: Stylised Facts on Euro Area Investment Funds

Top left (A): areas show the balance sheet size of banks and investment funds. Black line shows size of the investment fund relative to the banking sector in %. Top right (B): holdings of euro area non-financial corporate bonds in 2019 (all maturities) by holding sectors. Bottom left (C): boxplots show the distribution of cash holdings in % of total assets across funds for two periods, 2009 – 2014 and 2015 – 2019. Cash includes bank deposits, call accounts, call money, and repos. Bottom right (D): fund flows shown as cumulative changes in assets under management of different investment fund types in the euro area. Changes are expressed as relative deviation from assets as of 19 February 2020, the start of the market turmoil episode. Sources: ECB Investment Fund Statistics, ECB Quarterly Sectoral Accounts, Refinitiv Lipper, EPFR Global.

periodically face stochastic investor redemptions. When outflows exceed the liquidity buffer in terms of deposit holdings, the fund must sell bonds to households who, as second-best users, incur management cost and purchase the assets at a discount, leading to resource losses as in Gertler and Kiyotaki (2015).

Our model includes a pecuniary externality: individual fund managers do not internalise the aggregate price impact of their bond sales. Instead, they only consider how their sales reduce their own profits via a liquidity cost. As a result, funds hold inefficiently low liquidity buffers, which generate bond liquidation.[4] Bond liquidation implies resource losses and depresses investment fund intermediation. We calibrate the model to the euro area economy in the late

[4]For empirical evidence on the relevance of this externality, see Chernenko and Sunderam (2016, 2020) and Falato et al. (2021b).

2010s.

Our main results can be summarised as follows. In the unregulated economy, investment funds hold inefficiently low liquidity buffers because of the pecuniary externality. We calibrate the model such that investment funds voluntarily hold a liquidity buffer of 2% of their assets under management, in line with euro area data (see Figure 1, bottom left panel). A higher regulatory liquidity buffer helps to meet periodic redemptions and improves upon the unregulated economy. The optimal regulatory liquidity buffer is four times higher than in the unregulated economy, amounting to 8% of funds' assets under management.

We study both benefits and costs of this regulation. On the one hand, the liquidity buffer improves welfare by reducing periodic bond liquidation and the associated resource losses, which ultimately depress consumption. On the other hand, the regulation comes with welfare costs as well. By forcing investment funds to hold a larger fraction of their assets in bank deposits, the regulation is associated with lower bond intermediation. Already for intermediate values of the liquidity buffer, this implies a drop in output due to a change in the financing mix. In addition, if funds hold more deposits, less deposits are held by households, who extract utility benefits from them. Tighter regulation induces investment funds to demand deposits at lower interest rates, thereby increasing households' opportunity cost to hold them. Altogether, fund liquidity regulation trades off the resource gains from lower bond sales against a reduction in (i) bond intermediation and (ii) households' utility from holding deposits. The welfare-decreasing effect of lower bond intermediation is found to be of second-order importance, whereas the reduction of household deposits is the main welfare cost associated with the liquidity regulation.[5] We show that, in absence of this latter mechanism, e.g., in an economy where an alternative storage of liquidity is available to investment funds, the optimal liquidity buffer is much higher, at around 12% of assets under management.

We also consider the response of our economy to a sudden change in household saving preferences for liquid assets (similarly to Fisher, 2015). The exercise aims to capture certain dynamics observed during March 2020. This shock leads to a shift of households' asset allocation towards bank deposits and away from investment fund shares. Investment funds respond to the resulting loss of funding by reducing both, deposit and bond holdings. In the absence of the regulation, funds reduce deposits relatively more than bonds given deposits' lower return. This exposes funds to the periodic redemptions by more, ultimately magnifying resource losses from bond sales and reducing fund share dividends. As a consequence, investment funds attract less savings from households and must scale down their bond portfolios as well. At the same time, households' higher preference for bank deposits implies more funding for banks and a lower loan rate. This beneficial effect on production is dampened by the imperfect substitutability of loans and bonds.

The overall effect is an amplification of the initial shock, which leads to a drop in output

[5]This result is similar to findings by Begenau (2020) in the context of optimal bank regulation.

and consumption. The optimal regulatory liquidity buffer substantially limits this amplification, as investment funds cannot reduce deposits as much as they would want to in absence of the regulation. Redemptions then lead to smaller bond sales and resource losses. As a result, the regulation stabilises output and consumption, which improves welfare compared to the unregulated economy.

The negative effect of the loss in investment fund financing on output in our simulations is also consistent with empirical evidence that we provide to showcase the macroeconomic relevance of the investment fund sector. Based on a vector-autoregression (VAR) model, we show that fund outflows, which reduce the amount of financial intermediation investment funds can conduct on corporate bond markets, lead to persistent adverse effects on real economic activity in a sample of euro area data starting in 2007.

Related Literature – Closest to our paper is the work by Begenau and Landvoigt (2021). In their model, non-banks face runs that force them to sell capital to households, who are less productive users of capital such that output contracts. Non-banks can default, in which case additional resource losses in terms of capital depreciation and default cost occur. Non-bank leverage is an important aspect to generate default and model dynamics. To reduce the magnitude of sales of capital, the authors propose a tax on non-bank borrowing.

Our analysis, instead, focuses on the liquidity risk of investment funds, the largest and fastest-growing sector in the non-bank universe. For these entities, and in line with the recent policy discussion, liquidity mismatch rather than leverage is the key vulnerability. In fact, most types of investment funds are legally prohibited from using leverage at a significant scale. Our paper is the first contribution that explicitly analyses investment fund liquidity risks and the effects of macroprudential liquidity regulation of investment funds in a macroeconomic model.

Leverage or insufficient risk-controls have been used extensively in other studies to model non-banks in the context of the 2007-2009 crises, where both features played a prominent role. Verona et al. (2013) show that the presence of shadow banks that differ from banks by the markets they serve and their propensity to underestimate risk leads to a boom-bust cycle in financial markets. Gertler and Kiyotaki (2015) and Gertler et al. (2016) highlight that non-banks are more efficient in financial intermediation at the cost of higher risk, since they are prone to funding shocks. They show that caps on non-bank leverage can reduce such roll-over risk. Based on Gertler et al. (2016), several papers extend the analysis of shadow banks and potential regulatory responses. Rottner (2021) proposes a leverage tax on shadow banks to limit their risk-taking, similar to Begenau and Landvoigt (2021). Poeschl (2020) considers an intervention of central banks on the wholesale funding market after shadow bank runs that are induced by excessive leverage. However, neither paper discusses optimal responses.

Fève et al. (2019) and Meeks et al. (2017) study the role of non-banks in asset securitisation, which relaxes funding constraints of banks.[6] Meeks et al. (2017) introduce central bank asset

[6]While non-bank securitisation vehicles played a large role in the global financial crisis, especially in the United

purchases to address asset price deterioration and the propagation of losses. Ferrante (2018) assumes that non-banks have a superior ability in risk diversification; yet, since they are highly leveraged and subject to runs, their presence adds fragility to financial markets. Ferrante (2018) finds that central bank asset purchases can prevent negative price spirals during runs. As a policy tool, our paper instead considers the macroprudential regulation of non-banks, rather than central bank support interventions. While a fully-fledged comparison between these different policy options is beyond the scope of our paper, regulation can have several advantages, e.g., in terms of moral hazard that is usually associated with ex-post central bank support.

In Gebauer (2021) and Gebauer and Mazelis (2020) tighter capital regulation of banks leads to leakages of financial intermediation to the non-bank sector. Consistent with this result, we find that fund intermediation falls and bank intermediation rises, when a macroprudential liquidity regulation for funds is introduced.

There is also considerable work on non-banks in microeconomic models. For example, based on the work by Stein (2012), Hanson et al. (2015) assume that traditional banking and shadow banking are different ways to create safe claims. In their setting, shadow bank liabilities are subject to fire sales that give rise to a pecuniary externality. Di Iasio and Kryczka (2021) build a model with banks, investment funds, and insurance companies. Similarly to our model, investment funds suffer from a pecuniary externality and hold inefficiently low amounts of liquidity. Asset fire sales increase the overall cost of meeting redemptions and depress risk-adjusted returns delivered by funds. In line with our results, the liquidity regulation of funds improves upon competitive equilibrium allocations.

Outline – The rest of the paper is structured as follows. In Section 2, we provide empirical evidence on the macroeconomic relevance of the investment fund sector. Section 3 describes our model. The calibration of the model, all results, and robustness checks are discussed in Section 4. Finally, Section 5 concludes.

2 The Macroeconomic Effect of Fund Outflows

Before presenting our DSGE model analysis, we empirically assess the impact of outflows from investment funds on macroeconomic outcomes in euro area data. As outflows reduce the amount of financial intermediation investment funds can conduct on corporate bond markets, we think of this measure as a proxy for a non-bank credit supply shock. This exercise showcases the macroeconomic relevance of the investment fund sector and represents a useful empirical benchmark for the subsequent model analysis.

We use a VAR to estimate the effects of fund outflows on macro variables in monthly data between April 2007 and June 2019. We consider a VAR with seven variables in the following ordering: the annual inflation in the harmonized index of consumer prices, the log of industrial

States, their importance has receded afterwards. In European markets, securitisation vehicles only make up a small share of the non-bank financial sector, so that we abstract from this feature.

production, the annual growth in lending of euro area banks, cumulative flows to European corporate bond funds, the spread between BBB-rated euro non-financial corporate bond yields and the 5-year German government bond yield, the yield of the 5-year German Bund itself, and

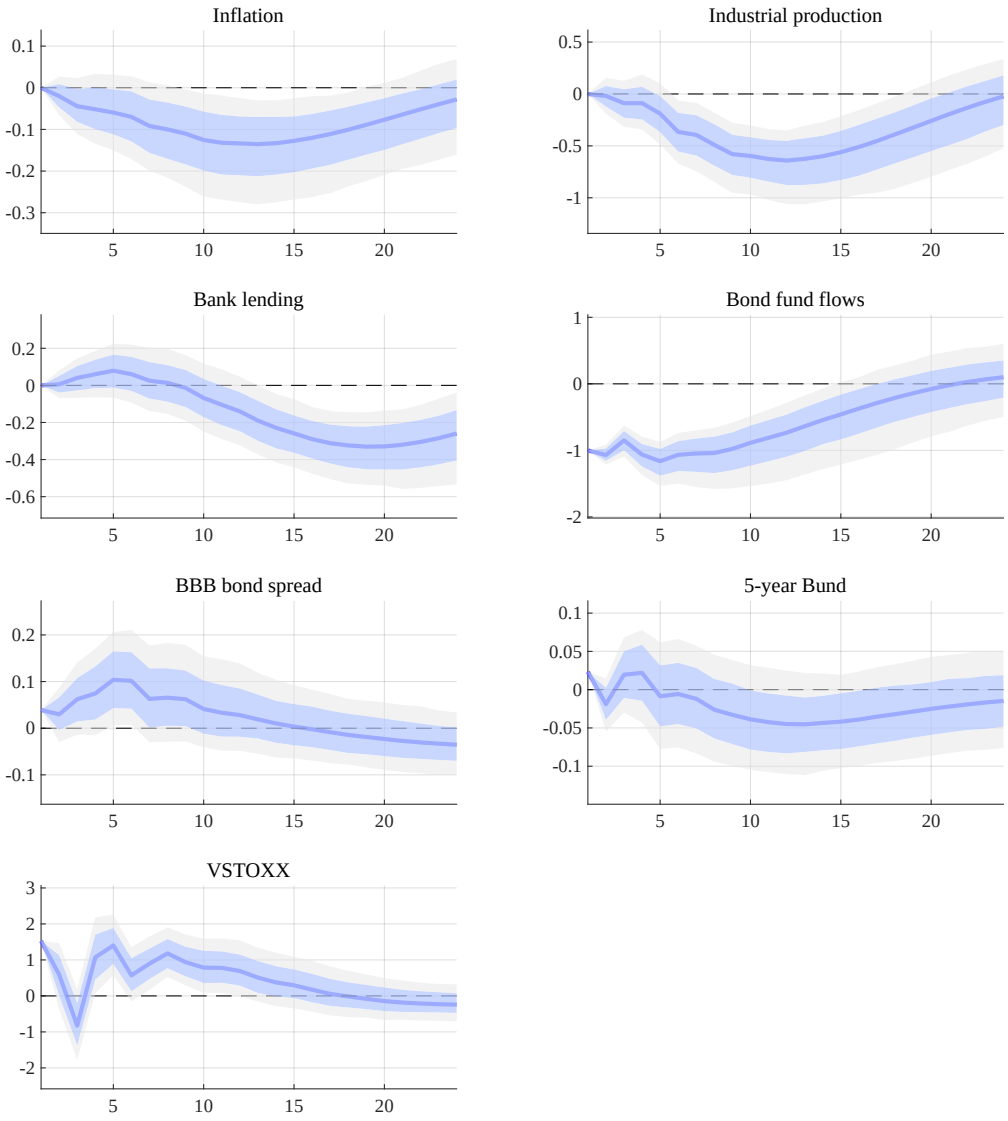


FIGURE 2: Impulse Responses to a Fund Outflow Shock

Impulse response functions to a 1 percentage point shock to bond fund flows obtained from a structural VAR model identified via Cholesky ordering. The blue (grey) areas show 68% (90%) confidence intervals. The y-axes are given in percent for the first four variables, in percentage points for the bond spread and the 5-year yield, and in index points for the VSTOXX. The x-axis shows months after the shock. Data is taken from EPFR Global (Investment fund flows), Markit (bond spread), Datastream (VSTOXX) and various ECB datasets (industrial production, inflation, bank lending, Bund yield).

Our analysis focuses on funds domiciled in the euro area that have an investment focus on European corporate bond markets. Cumulative flows are measured in percent of lagged assets under management. The corporate bond spread serves as a measure for the severity of financial

frictions that has been shown to be a relevant ingredient for deriving sensible macro responses in VAR analyses (see, e.g., Gertler and Karadi, 2015 and Jarociński and Karadi, 2020). The 5-year German Bund is used to capture monetary policy in the model.[7] Corporate bond spreads and German Bunds are measured in percent. The VSTOXX – the 30-day implied volatility of the EURO STOXX 50 – captures investor risk sentiment, widely acknowledged as a major determinant of fund flows.

We choose a lag length of four based on comparing Akaike and Bayesian information criteria. The VAR is conventionally estimated with ordinary least squares. We use the estimated VAR to compute impulse responses for a shock to cumulative fund flows. The shock is identified via Cholesky ordering. The ordering of variables reflects the assumption that industrial production, inflation, and bank lending can respond to changes in the fund flows only with a lag, while financial variables can react immediately.[8]

Figure 2 shows the impulse responses to a 1%-shock on cumulative bond fund flows. The shock implies higher financing costs for firms on corporate bond markets, as visible from the increase in the bond spread. The positive response of the VSTOXX indicates increased uncertainty and a reduction of risk appetite in financial markets. Bank lending does not respond significantly to the shock in the first 11 months, after which it starts falling. Banks may, accordingly, not be able to fully compensate for the reduction in non-bank financial intermediation. The macroeconomic variables react significantly to the shock, from both an economic and statistical perspective. The decrease in fund flows reduces real economic activity, as measured by industrial production, by about 0.4 percentage points after six months before reaching a trough of -0.6 after one year. Inflation also falls by up to 0.15 percentage points one year after the shock.

In sum, we find that a decrease in fund financing leads to persistent adverse macroeconomic effects. The related literature, while being still relatively small, arrives at similar conclusions. For example, Ben-Rephael et al. (2021) find that flows towards high-yield bond mutual funds are a highly informative lead indicator for the business cycle. Kaufmann (2020) shows that investment fund flows, triggered by changes in US monetary policy, affect global financial conditions as well as real economic activity in both the United States and the euro area. Barauskaite et al. (2021) estimate the effects of bank and market-based (non-bank) credit supply shocks on euro area GDP in a VAR model. They find that both types of shocks are important drivers of the business cycle and have a similar explanatory power for output.

[7] By including a yield with a long maturity, we also capture the effects of unconventional monetary policy when short-term interest rates are close to their effective lower bound.

[8] All findings are highly robust to a change in the ordering of the variables, e.g., with fund flows ordered first, and to the inclusion of less and more lags.

3 The Model

The model consists of households, a financial sector with banks and investment funds, a firm sector that is made up of entrepreneurs, intermediate, capital and final goods producers, and a macroprudential regulator (see Figure 3 for an overview). All derivations are provided in Appendix A. Unless stated differently, all variables are formulated in real terms.

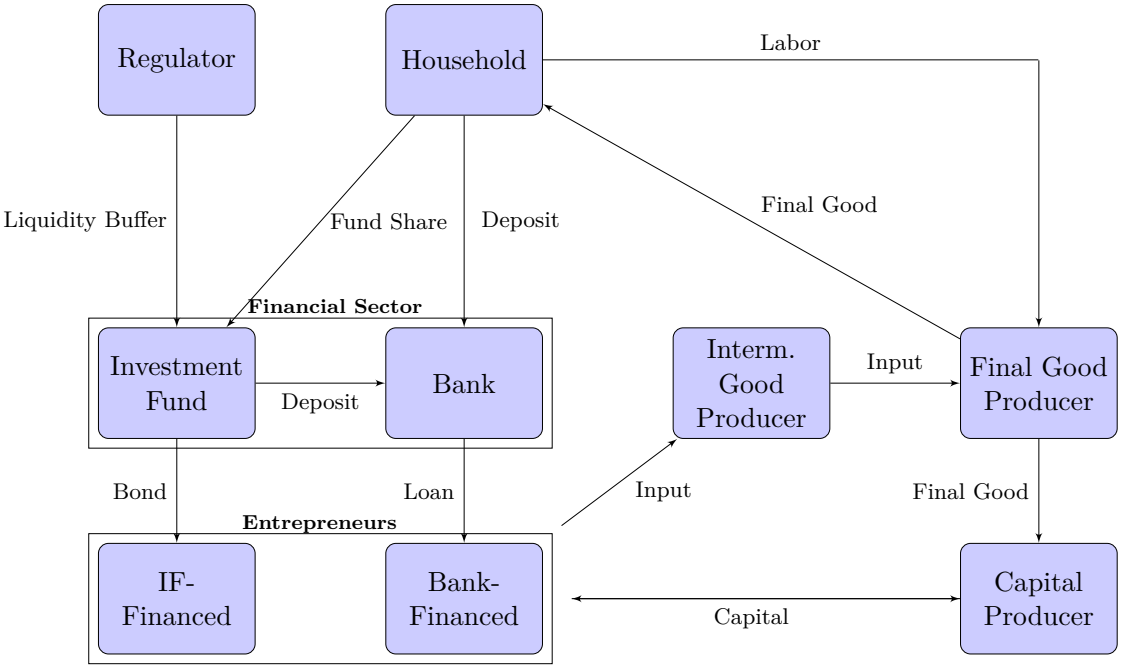


FIGURE 3: Model Overview

3.1 Households

The representative household derives utility from consumption c_t and from holding bank deposits d_t^{hh}, which provide liquidity services for transactions. The household has dis-utility from labour n_t, which is supplied to the final good producer. Period-t utility is given by

$$U(c_t, d_t^{hh}, n_t) = \frac{c_t^{1-\sigma}}{1-\sigma} + \delta_t^d \frac{\left(d_t^{hh}\right)^{1-\sigma_d}}{1-\sigma_d} - \psi_n \frac{n_t^{1+\sigma_n}}{1+\sigma_n} ,$$

where $\sigma, \sigma_n, \sigma_d \geq 0$ denote the relative risk aversion, the inverse Frisch elasticity, and a liquidity preference parameter, respectively. Utility weights for labour and liquidity are given by ψ_n and δ_t^d. We assume that the latter can be stochastic to capture a shock to household's preferences for liquid assets in the spirit of Fisher (2015) and Smets and Wouters (2007). Besides holding bank deposits, households can save in investment fund shares s_t, which pay dividends div_t^{if} but

carry no liquidity benefit.[9] The price of shares is q_t^s.

The period-t real budget constraint is

$$c_t + d_t^{hh} + q_t^s s_t + f\left(\tilde{b}_t\right) = w_t n_t + (1 + i_{t-1}^d) d_{t-1}^{hh} + (q_t^s + div_t^{if}) s_{t-1} + \Pi_t \ , \tag{1}$$

where w_t is the real wage, Π_t are total profits of the financial and non-financial sectors, and i_{t-1}^d is the deposit rate, which is agreed in period $t-1$ and paid in period t. The term $f\left(\tilde{b}_t\right) = (\kappa_{hh}/2) \cdot \tilde{b}_t^2$ captures costs that are associated with intra-period bond sales $\tilde{b}_t$. We assume that households are second-best users of bonds and face convex management costs when holding corporate bonds sold by investment funds. These costs represent a resource loss as in Gertler and Kiyotaki (2015).[10] Section 3.2.2 describes the mechanism behind bond sales in details.

Households maximise the discounted sum of life-time utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t, d_t^{hh}, n_t) \ , \tag{2}$$

subject to the sequence of period budget constraints (1), where β is the discount factor. The first-order conditions (FOCs) of the household for deposits, fund shares, and labour are given by

$$c_t^{-\sigma} = \delta_t^d (d_t^{hh})^{-\sigma_d} + \mathbb{E}_t \left[\beta c_{t+1}^{-\sigma} (1 + i_t^d)\right] \ , \tag{3}$$

$$c_t^{-\sigma} = \mathbb{E}_t \left[\beta c_{t+1}^{-\sigma} \frac{q_{t+1}^s + div_{t+1}^{if}}{q_t^s}\right] \ , \tag{4}$$

$$\psi_n (c_t)^{\sigma} n_t^{\sigma_n} = w_t \ . \tag{5}$$

Equation (3) is the Euler equation related to deposits. The left-hand side represents the opportunity cost of investing in deposits in terms of forgone marginal utility. The right-hand side denotes the marginal utility benefit from holding deposits plus the expected marginal utility of repayment. Equation (4) is the corresponding asset-pricing equation for investment fund shares. Equation (5) describes the labour supply decision. We define $\Lambda_{t,t+s} \equiv \beta^s \left(c_{t+s}/c_t\right)^{-\sigma}$ as the stochastic discount factor of households.

3.2 Financial Sector

There are two types of financial intermediaries, banks and investment funds. Besides their specialisation on different types of financial intermediation (loans and bonds, respectively), they

[9] This assumption can be relaxed without changing our results, as long as deposits grant a sufficiently higher liquidity benefit than fund shares.

[10] This can reflect costly information acquisition, which gets ever more expensive due to the rising complexity of managing a large portfolio. In comparison, we assume that bond purchases via investment funds are costless, since they are specialised professional investors. A related approach that assumes that households are less productive users of capital is used in Brunnermeier and Sannikov (2014) and Begenau and Landvoigt (2021).

differ across important dimensions.

First, by issuing deposits, banks engage in liquidity creation, which provides a utility benefit to households and, as a result, gives banks access to a cheap form of funding.

Second, we assume that households never redeem bank deposits before maturity. This can be motivated by an implicit assumption that bank liabilities are backed by some form of government guarantee, such as a deposit insurance. Investment funds, in turn, are subject to liquidity risk in the form of early redemptions, which can only be settled with liquid assets in the form of deposits or by selling bonds on secondary markets.

3.2.1 Banks

Since the focus of the paper is on investment funds, we consider a very stylised banking sector. Appendix E proposes a version of the model where banks have more structure, but we show that this affects our results only marginally.

The banking sector finances loans with deposits d_t. Households' non-pecuniary benefit from deposits drives down the deposit rate i_t^d and, thus, banks' cost of funding. Banks grant loans l_t to entrepreneurs at the loan rate i_t^l. Table 1 depicts the bank balance sheet.

TABLE 1: Bank Balance Sheet

Assets	Liabilities
Loans l_t	Deposits d_t

Banks are owned by households to whom they transfer their profits as dividends. They maximise the discounted sum of cash-flows div_t^b,

$$\max_{d_t, l_t} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[d_{t+1} - \left(1 + i_t^d\right) d_t + (1 + i_t^l) l_t - l_{t+1} \right] ,$$

subject to a balance sheet constraint $d_t = l_t$. After repeated substitutions, this leads to the static bank problem

$$\max_{d_t, l_t} \quad i_t^l l_t - i_t^d d_t ,$$

where $i_t^l l_t$ denotes revenues from lending and $i_t^d d_t$ are the interest payments to depositors. FOCs imply that the deposit rate equals the loan rate,

$$i_t^l = i_t^d . \tag{6}$$

3.2.2 Investment Funds

Investment fund j issues shares to households and invests in bonds $b_{j,t}$ and bank deposits $d_{j,t}^{if}$. Fund shares are subject to redemption risk that we capture with a two sub-period setup, similarly

to Kara and Ozsoy (2020).

Sub-Period I – In the first sub-period, the only market that opens is the secondary market for bonds, where investment funds can sell bonds to households. Fund j enters the sub-period I of period t with its end-of-$t-1$ period positions. In the spirit of Bianchi and Bigio (2022), a stochastic fraction $\phi_{j,t}$ of the fund's shares is redeemed by households.[11] When faced with redemptions, the fund either uses its deposit holdings or sells a fraction $1-\vartheta_{j,t}$ of its bonds,

$$\phi_{j,t} q^s_{j,t-1} s_{j,t-1} \leq d^{if}_{j,t-1} + (1-\vartheta_{j,t}) \tilde{q}^b_t b_{j,t-1} \ . \tag{7}$$

Investment funds sell bonds to households that value the bonds at the secondary market price $\tilde{q}^b_t$. As selling bonds is costly, investment funds only do so when deposits are insufficient to cover the liquidity need. Investment funds with insufficient deposits choose to retain the maximum share of bonds $\vartheta_{j,t}$. For these investment funds the redemption constraint (7) holds with equality,

$$1-\vartheta_{j,t} = \frac{\phi_{j,t} q^s_{j,t-1} s_{j,t-1} - d^{if}_{j,t-1}}{\tilde{q}^b_t b_{j,t-1}} \ .$$

The fraction of bonds sold to households rises in the size of the draw and in the value of fund shares issued. Larger deposits or a higher secondary market bond price imply that a smaller fraction of bonds needs to be sold. Bond sales by fund j are given by

$$\tilde{b}_{j,t} \equiv (1-\vartheta_{j,t}) b_{j,t-1} = \frac{\phi_{j,t} q^s_{j,t-1} s_{j,t-1} - d^{if}_{j,t-1}}{\tilde{q}^b_t} \ .$$

Let $\tilde{\phi}_t \equiv d^{if}_{t-1}/(q^s_{t-1} s_{t-1})$ denote the redemption threshold above which investment funds must sell bonds. Since all investment funds hold equal positions at the start of a period, the threshold is not fund-specific. The aggregate bond sales are given by the sum of sales by individual funds with a redemption draw above $\tilde{\phi}_t$

$$\tilde{b}_t(q^s_{t-1} s_{t-1}, d^{if}_{t-1}) = \int_{\tilde{\phi}_t}^{1} \tilde{b}_{j,t} g(\phi_{j,t}) d\phi_{j,t} \ ,$$

where $g(\phi_j)$ denotes the probability density function of the stochastic redemptions ϕ_j.

When purchasing bonds, households face convex costs $f(\tilde{b}_t)$. These can be seen as management costs that reflect households' lack of expertise that increase with bond holdings. As the value of a bond just before maturity is one, we derive the bond price schedule on the secondary

[11] As pointed out by De Fiore et al. (2019), one may think of (not modelled) random idiosyncratic consumption needs of households. Intuitively, households would not use deposits to cater to the consumption needs as they would lose the utility benefit.

TABLE 2: Investment Fund Balance Sheet

Assets	Liabilities
Bonds $q_t^b b_t$	Shares $q_t^s s_t$
Deposits d_t^{if}	

market as

$$\tilde{q}_t^b = 1 - f'\left(\tilde{b}_t\right) \ .$$

Since households have convex costs from accepting bonds, the secondary market price is decreasing in the amount of sales. We assume households sell their bond holdings back to investment funds at the end of sub-period I. Hence, the liquidity need of investment funds is only temporary and positions are equal again across investment funds at the end of the sub-period.[12]

Sub-Period II – In the second sub-period, all markets open and investment funds make their portfolio choice. Investment funds are all identical again at this stage and maximise the discounted sum of dividends

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} div_t^{if} \ , \tag{8}$$

where real dividends are

$$div_t^{if} = b_{t-1} - q_t^b b_t - d_t^{if} + (1 + i_{t-1}^d) d_{t-1}^{if} - L\left(\tilde{b}_t\right) \ . \tag{9}$$

In each period, investment funds invest in bank deposits and purchase bonds in the primary market at the price q_t^b. The last term $L(\tilde{b}_t) = (\kappa_{if}/2) \cdot \tilde{b}_t^2$ represents a convex function that captures costs from trading bonds with households on an illiquid secondary market in sub-period I.[13] Ultimately, costs L create a motive for investment funds to voluntarily hold deposits. Investment funds maximise (8) subject to the balance sheet constraint

$$q_t^s s_t = q_t^b b_t + d_t^{if} \ , \tag{10}$$

[12] This assumption follows De Fiore et al. (2019), who assume that a reverse redemption shock hits financial intermediaries at the end of the sub-period, such that households re-invest the redemptions. This assumption greatly reduces the model's complexity. We also built a more structural version of the model that did not rely on the assumption of full redemption reversion. While it allows to track financial flows more rigorously, it yields little additional insights.

[13] This can be motivated along different dimensions. The literature models bilateral or over-the-counter trading using opportunity costs, transaction costs, or search and matching frameworks. These imply rising price discounts induced by agents' bargaining power or market tightness (see, e.g., Duffie et al., 2005, Geromichalos and Herrenbrueck, 2016, or Bianchi and Bigio, 2022). Instead of taking this structural route, we capture such frictions parsimoniously by assuming the convex costs L that increase in the amount of trading similar to Chernenko and Sunderam (2020).

which is also depicted in Table 2. This leads to the following FOCs for deposits and bonds:

$$1+\lambda_t^{if} = \mathbb{E}_t \Lambda_{t,t+1} \left[(1+i_t^d) - \frac{dL}{d\tilde{b}_{t+1}} \frac{d\tilde{b}_{t+1}}{dd_t^{if}} \right] , \tag{11}$$

$$1+\lambda_t^{if} = \mathbb{E}_t \Lambda_{t,t+1} \frac{1}{q_t^b} . \tag{12}$$

Equation (11) captures investment funds' deposit investment trade-off. Investing today reduces available resources and tightens the balance sheet constraint (10), whose Lagrange multiplier is given by λ_t^{if}. Next period, the deposits yield interest income i_t^d. The second term of the right-hand side is the reduction in liquidity costs. These costs fall because bond sales in sub-period I are reduced for any additional unit of deposits. Equation (12) is the FOC related to bond investment. Taking both FOCs together, the deposit choice of investment funds follows a trade-off between the lower relative return on deposits and the expected cost from selling bonds similar to Chernenko and Sunderam (2020).

3.3 Non-Financial Sector

Entrepreneurs produce inputs for the final good producer. The latter combines labour with the entrepreneur inputs into the final good that is sold to households and capital producers. The capital producers provide capital and face investment adjustment cost.

3.3.1 Entrepreneurs

In each period, there is a unit mass of entrepreneurs who raise funding from banks or investment funds to purchase capital from capital producers at real price $q_t^{k,\tau}$ with $\tau = l, b$. We assume that financing is obtained from one type of financial intermediary only. Accordingly, we distinguish between bond- and loan-financed entrepreneurs. To retain the notion of an endogenous financing choice while limiting model complexity, we assume both entrepreneur types sell their good to a firm that aggregates their output into an intermediate good sold to the final good producer.

Bond-users – Bond-using entrepreneurs buy new capital K^b from and sell old depreciated capital to specialised capital producers at the end of a period. They finance the acquisition of new capital by issuing one-period bonds. Entrepreneurs sell their product at price p_t^b to the intermediate good producer. Their profits are

$$div_t^b = p_t^b \left(K_{t-1}^b\right)^{\gamma} - b_{t-1} + q_t^b b_t + (1-\delta) q_t^{k,b} K_{t-1}^b - q_t^{k,b} K_t^b$$
$$\text{with } q_t^b b_t = q_t^{k,b} K_t^b ,$$

where δ denotes the rate of capital deprecation. The FOCs yield

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\frac{1}{q_t^b}\right] = \mathbb{E}_t\left[\Lambda_{t,t+1}\frac{\gamma p_t^b (K_t^b)^{\gamma-1} + (1-\delta)q_{t+1}^{k,b}}{q_t^{k,b}}\right] . \tag{13}$$

The marginal value from investing into capital, including its marginal product and the re-sale value, is equated with the capital financing cost on bond markets.

Loan-users – These entrepreneurs operate the same technology but finance their capital with loans. Profits are given by

$$\begin{aligned} div_t^l &= p_t^l \left(K_{t-1}^l\right)^{\gamma} - (1+i_{t-1}^l)l_{t-1} + l_t + (1-\delta)q_t^{k,l}K_{t-1}^l - q_t^{k,l}K_t^l \\ &\text{with } l_t = q_t^{k,l}K_t^l \, , \end{aligned}$$

where K_t^l and p_t^l denote loan-user capital and the price of their output, respectively. The FOCs imply

$$\mathbb{E}_t\left[\Lambda_{t,t+1}(1+i_t^l)\right] = \mathbb{E}_t\left[\Lambda_{t,t+1}\frac{\gamma p_t^l (K_t^l)^{\gamma-1} + (1-\delta)q_{t+1}^{k,l}}{q_t^{k,l}}\right] .$$

Intermediate good producer – Both types of entrepreneurs sell to an intermediate good producer that aggregates these inputs using a CES-technology

$$z_t = \left(\upsilon (z_t^l)^{\tilde{\epsilon}} + (1-\upsilon)(z_t^b)^{\tilde{\epsilon}}\right)^{\frac{1}{\tilde{\epsilon}}} , \tag{14}$$

where υ denotes a production weight and $\tilde{\epsilon}$ guides the elasticity of substitution. Input demand follows as

$$\begin{aligned} z_t^l &= (\upsilon)^{\frac{1}{1-\tilde{\epsilon}}}\left(\frac{p_t^z}{p_t^l}\right)^{\frac{1}{1-\tilde{\epsilon}}} z_t \, , \\ z_t^b &= (1-\upsilon)^{\frac{1}{1-\tilde{\epsilon}}}\left(\frac{p_t^z}{p_t^b}\right)^{\frac{1}{1-\tilde{\epsilon}}} z_t \, . \end{aligned}$$

Since both entrepreneur types operate the same technology but use different sources of funding, one can think of the optimal input mix chosen by the intermediate firm as an endogenous financing choice. The technology parameters υ and $\tilde{\epsilon}$ play an important role to determine the relative sizes of bond and loan finance as well as the ability to switch between financing choices. The two financing choices are not perfect substitutes but, according to the calibrated parameter $\tilde{\epsilon}$, they are still good substitutes. The idea underpinning this imperfect substitutability is that entrepreneurs could face frictions to switch without costs across financing options, including the time and costs needed to arrange a bond issuance or effort and time to build a bank-relationship.

3.3.2 Capital Good Producers

At the end of each period, capital producers purchase depreciated capital from bond- and loan-financed entrepreneurs and refurbish it into new capital. They purchase the final good to invest into new capital. Their technology only allows them to do so subject to quadratic adjustment cost $\Phi(\frac{I_t^\tau}{I_{t-1}^\tau}) = \frac{\kappa^I}{2}\left(\frac{I_t^\tau}{I_{t-1}^\tau} - 1\right)^2$ with $\tau = l, b$. Capital evolves as follows:

$$K_t^\tau = (1-\delta) K_{t-1}^\tau + I_t^\tau \left(1 - \Phi\left(\frac{I_t^\tau}{I_{t-1}^\tau}\right)\right) .$$

New capital is sold to entrepreneurs at real price $q^{k,\tau}$. Given that the marginal rate of transformation between depreciated and new capital is one, old capital is also valued at this price. The FOC for investment is

$$q_t^{k,\tau}\left[1 - \Phi\left(\frac{I_t^\tau}{I_{t-1}^\tau}\right) - \frac{I_t^\tau}{I_{t-1}^\tau}\Phi'\left(\frac{I_t^\tau}{I_{t-1}^\tau}\right)\right] - \mathbb{E}_t \Lambda_{t,t+1} q_{t+1}^{k,\tau}\left(\frac{I_{t+1}^\tau}{I_t^\tau}\right)^2 \Phi'\left(\frac{I_{t+1}^\tau}{I_t^\tau}\right) = 1 .$$

3.3.3 Final Good Producer

There is a final good producer owned by households that produces the good Y_t. It is produced using the intermediate good z_t and labour of households n_t. The production technology reads

$$Y_t = A_t \left(n_t\right)^\alpha \left(z_t\right)^{1-\alpha} , \tag{15}$$

where $\alpha \in (0,1)$ is the labour share and A_t is the total factor productivity that evolves according to an AR(1) process. The final good producer pays p_t^z for intermediate inputs z_t and the real wage w_t per unit of labor. Profits in period t are

$$\Gamma_t = Y_t - w_t n_t - p_t^z z_t .$$

FOCs equalise marginal products with marginal cost,

$$\alpha \frac{Y_t}{n_t} = w_t , \tag{16}$$

$$(1-\alpha)\frac{Y_t}{z_t} = p_t^z . \tag{17}$$

3.4 Resource Constraint and Market Clearing

The aggregate resource constraint is given by

$$Y_t = c_t + \sum_{\tau=l,b} I_t^\tau + f(\tilde{b}_t) + L(\tilde{b}_t) . \tag{18}$$

We define net output, i.e., the usage of production aside from cost terms, as

$$Y_t^{net} = c_t + \sum_{\tau=l,b} I_t^{\tau} \ . \tag{19}$$

Market clearing for deposits implies

$$d_t = d_t^{hh} + d_t^{if} \ . \tag{20}$$

The equilibrium conditions of the model as well as the derivation of the steady state are given in Appendix B.

3.5 Macroprudential Liquidity Regulation

In this section, we discuss the rationale behind a macroprudential liquidity regulation of investment funds and describe how we integrate it to the model.

Investment funds are subject to a pecuniary externality because of which they operate with an inefficiently low liquidity buffer. In each sub-period I, funds face stochastic redemptions. When the latter are sufficiently high, funds must liquidate bonds, thereby depressing bond prices. Individual funds do not internalise the aggregate price impact of their sales but only consider their own expected liquidity cost L that they face in sub-period II.

In other terms, there is a 'wedge' between the private and social valuation of holding deposits. This is because investment funds take the secondary market bond price as given and do not internalise how their individual portfolio choice of deposit holdings affects prices via the aggregate amount of sales (see Chernenko and Sunderam (2016, 2020) and Falato et al. (2021b) for empirical evidence). From a social perspective, this has two adverse effects. First, bond sales bring about resource losses that depress consumption via the cost terms f and L in the resource constraint (18). Second, bond sales decrease investment fund dividends and the value of fund shares via the cost term L . Eventually, this reduces total bond intermediation via the balance sheet constraint of investment funds (10).

The pecuniary externality can be addressed by a regulation that imposes a liquidity buffer for investment funds. This intervention is macroprudential as it considers the general equilibrium effects of the individual investment fund choices on financial markets and the economy. The regulation reduces bond sales and the associated drop in bond prices. This implies lower resource losses and higher dividends paid by investment funds, which increase the market value of shares, $q_t^s s_t$. This can lead to higher bond intermediation if $q_t^s s_t$ increases relatively more than the deposit holdings.

For our model economy, consider a macroprudential regulator who requires investment funds to hold a fraction ϱ of its fund shares in the form of bank deposits, i.e., a liquidity buffer,

$$d_t^{if} = \varrho q_t^s s_t \ . \tag{21}$$

Importantly, while the regulatory requirement (21) must be met at the end of each period, *within* periods the liquidity buffer is usable, in the sense that funds can deplete deposits to meet the periodic redemptions.

Under the regulation, investment funds attach extra value to deposit holdings, which is also reflected in first-order conditions. The equilibrium conditions for the model with regulation are given in Appendix C. In the next section, we discuss the effects of regulation in a calibrated version of the model.

4 Quantitative Analysis

Section 4.1 presents the calibration of the model. We conduct a welfare analysis and solve for the optimal regulatory liquidity buffer in Section 4.2. Section 4.3 analyses the effects of the regulation in stabilising the economy after a shock to households' liquidity preferences. This aims to capture some of the dynamics experienced in financial markets during the Covid-19 event in March 2020. Finally, Section 4.4 deepens the analysis regarding the asset used for the liquidity buffer.

4.1 Calibration

We calibrate the model to euro area data and our period length is one quarter. Some parameters are set in line with the relevant literature, while others are set to target data moments.[14]

We assume log-utility from consumption by setting the risk aversion parameter $\sigma = 1$ and set the Frisch elasticity of labour supply $\sigma_n = 3$, both within the range of common choices. Likewise, we set $n = 1/3$ in the steady state and choose the utility weight of labour ψ_n accordingly. Utility from deposits is also logarithmic, $\sigma_m = 1$, and the steady state utility weight δ^d is set to the standard value of 0.02 (see, e.g., Begenau, 2020). The labour share is set to $\alpha_n = 0.67$, in accordance with European data. Productivity A is normalised to a value of 1 in the steady state. The entrepreneur return to scale parameter is $\gamma = 0.627$, based on the estimates of Hennessy and Whited (2007).

Redemptions of investment fund shares are drawn from a distribution, which is calibrated to data on outflows from euro area corporate bond funds between 2007 and 2019. The data source for this is EPFR Global. We fit a Lomax distribution to the aggregate quarterly outflows using a methods of moments approach. We set the shape parameter of the distribution $\tilde{\alpha} = 57.02$ and the scale parameter $\tilde{\lambda} = 2.23$. This allows us to target the quarterly median redemptions of 2.48% and a standard deviation of 4.05% in the data.[15]

The discount factor is set to $\beta = 0.994$ to match an annualized investment fund share return of 2.5%, based on data for representative corporate bond indices from Markit that cover both

[14] See Appendix D for additional information on data sources and definitions.

[15] Chernenko and Sunderam (2020) use an exponential distribution to model outflow draws. Its shape is comparable to the one of the Lomax distribution.

TABLE 3: Parameter Choices and Calibrated Parameters

		Value	Source
Households			
σ	Risk aversion	1	Broader literature
σ_n	(Inverse) Frisch elasticity	3	Broader literature
ψ_n	Utility weight labour	19.79	Steady state labour 1/3
σ_d	Liquidity parameter	1	Broader literature
δ^d	Steady state utility weight on liquidity	0.02	Broader literature
Firms			
δ	Depreciation rate of physical capital	0.025	Gerali et al. (2010)
γ	DRS parameter of entrepreneurs	0.627	Hennessy and Whited (2007)
α	Labor share	0.67	Labor income share 67%
Financial Sector			
$\tilde{\lambda}$	Scale Lomax Distribution	2.23	Bond fund flow data
$\tilde{\alpha}$	Shape Lomax Distribution	57.02	Bond fund flow data
		Calibrated	**Target**
β	Household discount factor	0.994	Annual fund return 2.5%
κ_{if}	IF cost parameter	0.198	Deposit share in IFs' AuM 1.96 %
κ_{hh}	HH cost parameter	2.84	Bond share HH 2.5 %
υ	Production weight	0.678	Bond to loan finance: 29%
$\tilde{\epsilon}$	Entrepreneur Aggregator	0.499	Loans-to-GDP 1.5
ρ_δ	Persistence preference shock	0.60	Auto-correlation Deposits (HH) 0.86
σ_δ	Std. dev. preference shock	0.001	$\sigma_c/\sigma_Y = 0.59$
ρ_a	Persistence TFP shock	0.96	Auto-correlation GDP 0.85
σ_a	Std. dev. TFP shock	0.0054	$\sigma_Y = 0.72$
κ^I	Investment Adjustment Cost	0.33	$\sigma_I/\sigma_Y = 3.35$

We use the following abbreviations. DRS: decreasing returns to scale; AuM: assets under management; IF: investment fund; HH: household; TFP: total factor productivity; Std. dev.: standard deviation; $\sigma_Y, \sigma_c, \sigma_I$: standard deviations of output, consumption, investment.

the investment grade and high yield segments for the period 2010 to 2019.

The next set of parameters is derived jointly by minimizing the distance between data and model moments over a discrete grid. Investment funds and households are subject to quadratic costs. The parameter κ_{hh} in the household bond management cost f directly affects the willingness of households to pay for bonds and thereby the amount of bonds sold in the first sub-period. We calibrate κ_{hh} to match the household share in non-financial corporate bond holdings, which is equal to 2.5% in the euro area.[16] The investment fund cost parameter κ_{if} affects the willingness of investment funds to hold deposits. We calibrate the parameter by targeting the median liquidity share in the portfolio of euro area corporate bond funds between 2015 and 2019 of 1.96% (see Figure 1). The parameters κ_{if} and κ_{hh} both affect investment funds' deposits and households' bonds. We, therefore, perform sensitivity checks and verify that no other combination of parameters offers a better fit.

The production function of the intermediate good producer (14) features two parameters, υ

[16] In Begenau and Landvoigt (2021) households are four times less productive than financial intermediaries. Similar to our formulation, a resource loss occurs as soon as households hold capital.

TABLE 4: Empirical and Model-Implied Moments

Targeted Moments	**Data**	**Model**
IF return	2.50 %	2.50 %
Bond to loan finance	29 %	29.03 %
Deposits in IF assets	1.96 %	1.96 %
Loan-to-GDP	150 %	138 %
Bond share HH	2.50 %	2.65 %
σ_I/σ_Y	3.35	3.14
σ_c/σ_Y	0.59	0.59
σ_Y	0.72	0.73
Auto-correlation Y	0.85	0.75
Auto-correlation d^{hh}	0.86	0.57
Non-Targeted Moments	**Data**	**Model**
IF shares in HH saving	17.2 %	23.0 %
Bonds-to-GDP	0.44	0.40
Investment-to-GDP	0.21	0.18
Auto-correlation c	0.82	0.54
Auto-correlation b	0.71	0.60
Auto-correlation s	0.82	0.60

We calculate theoretical moments after solving and simulating the model under the productivity and the liquidity preference shock. We compare the model moments to Hodrick-Prescott-filtered data of the euro area. $\sigma_Y, \sigma_c, \sigma_I$: standard deviations of output, consumption, investment; IF: investment fund; HH: household.

and $\tilde{\epsilon}$. We set ν by targeting the relative size of firm financing via investment funds relative to banks, which is 29%. The ability to substitute bond- and loan-finance is captured by the parameter $\tilde{\epsilon}$, which we set to target a loan-to-GDP share of 1.5.

The model features two types of shocks. On the supply side, there is a shock to total factor productivity. On the demand side, we use a shock to the household preferences for liquid assets in the form of bank deposits:

$$\log(A_t) = (1-\rho_a)\log(A) + \rho_a \log(A_{t-1}) + \sigma_a \epsilon_a \ , \tag{22}$$

$$\log(\delta_t^d) = (1-\rho_\delta)\log(\delta^d) + \rho_\delta \log(\delta_{t-1}^d) + \sigma_\delta \epsilon_\delta \ . \tag{23}$$

We calibrate the standard deviations and persistence of the shocks by setting the four parameters $\sigma_a, \rho_a, \sigma_\delta, \rho_\delta$ to target the auto-correlations of output and household deposits, the standard deviation of output, and the relative standard deviation of consumption to output. Finally, we set the investment adjustment cost parameter κ^I by targeting the relative standard deviation of investment to GDP.

Table 4 provides a comparison between targeted and non-targeted moments in the model and the data. With respect to targeted parameters, first and second moments are mostly in accordance with the data.

We linearise the model around its deterministic steady state and solve it using Dynare (see

Adjemian et al., 2021).

4.2 Optimal Liquidity Regulation

In this section, we show that the macroprudential liquidity regulation expressed in (21) can improve welfare in the economy and discuss the welfare-relevant trade-offs of the regulation. To this end, we solve a second-order approximation of the model and simulate the economy under the productivity and the deposit preference shocks for different levels of the liquidity buffer.

We compute a utilitarian measure of welfare based on conditional expected utility (2) and compare welfare in the economy without the liquidity regulation, V^{woreg}, to welfare in the economy with the regulation, $V^{reg,\varrho}$. We then derive consumption equivalents (CE) for different levels of the liquidity buffer ϱ,

$$CE_{\varrho} = 100 \cdot (\exp(1-\beta)(V^{reg,\varrho} - V^{woreg}) - 1) \ ,$$

where CE_{ϱ} represents the fraction of 'no policy' consumption that the household would be willing to forego to live in an economy with liquidity regulation ϱ.

Figure 4 plots the welfare measure and long-run means of key variables for different levels of the liquidity buffer. Welfare follows a hump-shaped curve (top left panel). A liquidity buffer of 7.57% is associated with the highest welfare. This optimal buffer is about four times higher than the median value of 1.96% observed in the data (see Figure 1).[17]

The regulation increases welfare by reducing resource losses, which in turn allows higher consumption (top middle panel). Without regulation, funds hold 'too little' deposits because of the pecuniary externality and need to sell bonds. The bond sales lead to resource losses via the liquidity and management costs of investment funds and households. The sales also make fund shares less attractive by decreasing dividends (9). Instead, the liquidity regulation ϱ forces investment funds to hold a higher liquidity buffer, thereby reducing bond sales and increasing secondary market bond prices (top right panel). The regulatory buffer raises the redemption threshold $\tilde{\phi}$ above which sales occur, i.e., less funds must liquidate bonds. At the optimal buffer, only 15% of investment funds draw a shock in excess of their deposits and must sell bonds, compared to 60% in the equilibrium without regulation. This mechanism is responsible for most of the reduction in bond sales.

The regulation can have two negative effects on welfare. The first one is related to household savings. By imposing mandatory deposit holdings to investment funds, the regulation lowers the return on deposits, thereby inducing households to hold less of them (bottom left panel, blue line). Households' utility from holding deposits, therefore, falls with higher regulatory liquidity buffers.

[17] When simulating the model without regulation for a large number of periods, we find that the buffer held by funds voluntarily fluctuates between 1.84% and 2.08%, i.e., one can interpret our optimal 7.57%-buffer as a minimum regulatory buffer consistent with the policy discussion.

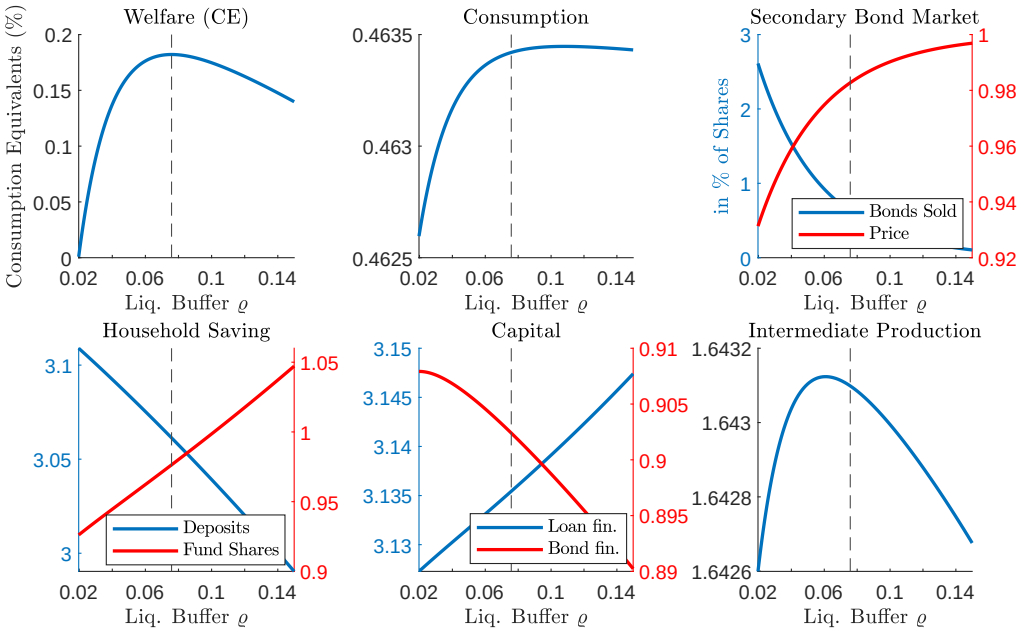


FIGURE 4: Optimal Liquidity Regulation Trade-Offs

We solve a second-order approximation of the model and simulate the economy under a productivity and a preference shock for different levels of the macroprudential liquidity buffer. We calculate conditional welfare to derive consumption equivalents (CE) in terms of the final good. The solid lines depict theoretical long-run means for each simulation. The x-axes start at 1.96%, which is the liquidity buffer voluntarily held by investment funds in absence of regulation. The vertical dashed lines denote the welfare-maximising liquidity buffer of 7.57%.

A second downside of the regulation is due to changes in the financing mix of the economy that can lead to lower net output. Although the regulatory buffer boosts fund dividends and makes fund shares more attractive (bottom left panel, red line), it eventually *reduces* bond intermediation (bottom middle panel, red line). This is because funds' deposit holdings increase relatively more than the market value of fund shares when the regulatory buffer rises. This implies a drop in bond holdings according to the balance sheet constraint (10). Overall, the regulation prompts a shift in credit intermediation from funds towards banks.[18] A higher demand for deposits from investment funds lowers the deposit rate, reducing funding costs for banks and making loans and, thus, the goods produced by loan-financed entrepreneurs cheaper. The relative increase of loan-financed goods boosts intermediate good production (bottom right panel) for lower values of the buffer, which supports the increase in consumption. But for liquidity buffers above 6.1%, and, hence, before reaching the optimal buffer, intermediate output starts falling due to the imperfect substitutability of loan- and bond-financed inputs. The increase in loan-finance is not sufficient to maintain higher production. The drop in output then weighs down on consumption and welfare.

[18] Vice versa, studies that discuss *bank regulation* in the presence of non-bank financial intermediaries document leakages of activity from banks to non-banks (see Begenau and Landvoigt, 2021; Gebauer and Mazelis, 2020).

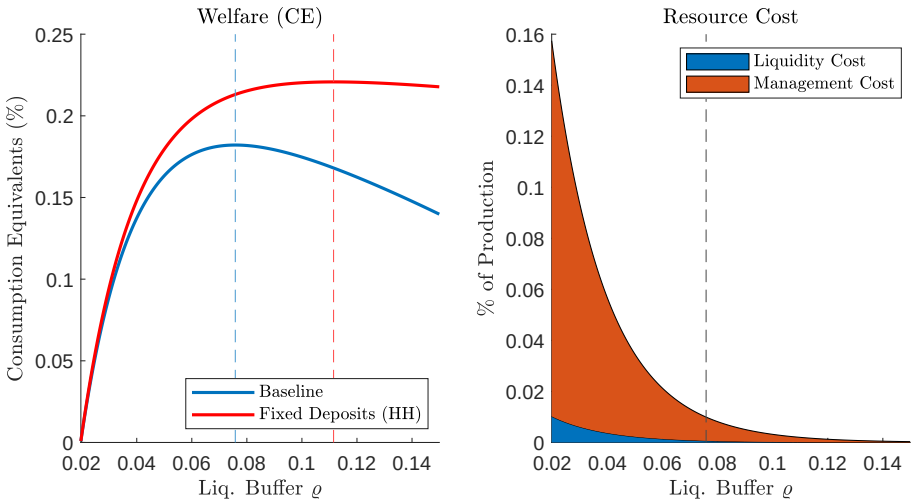


FIGURE 5: Adverse Effects of Liquidity Regulation

We solve a second-order approximation of the model and simulate the economy under a productivity and a preference shock for different levels of the macroprudential liquidity buffer. We calculate conditional welfare to derive consumption equivalents (CE) in terms of the final good. The solid lines depict theoretical long-run means for each simulation. The x-axes start at 1.96%, which is the liquidity buffer voluntarily held by investment funds in absence of regulation. The left panel compares baseline welfare (blue line) to an alternative welfare measure that keeps household deposits fixed (red line). The dashed lines depict the respective optimal buffers. The right panel shows a decomposition of the resource cost components in (18) related to household bond management cost f (red) and fund liquidity cost L (blue).

Figure 5 sheds light on the relevance of the mechanisms through which the buffer affects welfare. The left panel focuses on the welfare effects of the reduction of households' deposits. The blue line shows welfare under the regulation, as in Figure 4. Using the same model specification, the red line depicts an alternative welfare measure in which household deposits are kept constant. The vertical distance between the two curves captures the change in welfare associated with the reduction of household deposits. Ignoring the drop in household deposits, the optimal buffer is 11.15% (red dashed line), well above the 7.57% that is optimal in the baseline case. At this point it is important to put this channel into perspective. First, a key role for available liquidity in welfare analysis is also found in the analysis of bank regulation in Begenau (2020) and Begenau and Landvoigt (2021). Second, while in our model *households* suffer a direct welfare loss, this can in principle work via different agents that have a demand for safe and liquid assets. For example, banks need to hold sufficient high-quality liquid assets in compliance with bank regulation or want to hold such assets to maintain access to secured lending. Similarly, in the euro area different non-banks that are active in derivative trading need to hold liquid assets to comply with regulation. In short, different agents have a demand for those assets and raising those assets' opportunity cost might reduce the amount held, lead to substitution with less liquid assets, and tighten those actors' constraints. Thus, this effect is an important driver of the welfare trade-off associated with the regulation and we further explore it in Section 4.4.

The right panel of Figure 5 shows how the resource losses evolve when liquidity buffers rise. The reduction of resource losses leads to higher welfare, as it allows for higher consumption.

TABLE 5: Sensitivity of Optimal Liquidity Buffers

	(I) Baseline	(II) Deposit utility	(III) Household cost	(IV) Redemptions
Optimal buffer (%)	7.57	6.42	8.50	11.50
CE (%)	0.18	0.31	0.18	0.19
HH Deposits (d^{hh})	-1.44	-1.01	-1.38	-1.31
Fund shares ($q^s s$)	5.54	4.93	5.48	5.14
Capital (b)	-0.51	-0.93	-0.52	-0.10
Capital (l)	0.36	0.51	0.42	0.33
Bond price ($\tilde{q}^b$)	5.54	7.43	36.63	10.81
Intermediate output (z)	0.08	0.10	0.11	0.14

Values denote percentage deviations from the respective long-run means of the economies without regulation. Column I "Baseline": calibration as in Section 4.1; Column II "Deposit utility": $2 \cdot \delta^d$; Column III "Household Cost": $4 \cdot \kappa_{hh}$; Column IV "Redemptions": $2 \cdot \tilde{\lambda}$.

The coloured areas provide a decomposition of the resource cost components in (18). These are the household bond management cost f (red area) and the fund liquidity cost L (blue area). Most of the drop in resource costs is achieved via lower household bond management cost, while the liquidity costs of funds play a limited role.

To highlight the contribution of different channels to the welfare trade-off and as a robustness check, Table 5 shows optimal buffers, welfare values, and long-run means of relevant variables for different assumptions on a selected set of parameters. To ensure comparability, we express values in terms of the percentage deviations from the respective long-run means of the economies without regulation. Column I of the table shows results for our baseline calibration with regulation.

In Column II, utility benefits δ^d that households derive from bank deposits are doubled. As banks become more important as creators of liquidity for households, the welfare trade-off changes: the drop in deposits demanded by households induced by the regulation implies a more sizeable loss in welfare. Consequently, the optimal liquidity buffer falls to 6.42%.

In Column III, we increase the parameter of household bond management cost, κ_{hh}, by a factor of four. As a result, the optimal buffer increases to 8.50%, since any reduction in the amount sold to households has a bigger impact on the secondary market price.

Finally, in Column IV, we consider larger periodic redemptions. The parameter $\tilde{\lambda}$ governing the random draws from the Lomax distribution is changed. In this calibration, redemptions are on average twice as high as in the baseline. The amount of bonds sold by investment funds rises, implying higher resource losses. Reducing the price dislocation from bond sales, thus, becomes even more important. The optimal liquidity buffer rises to 11.50%.

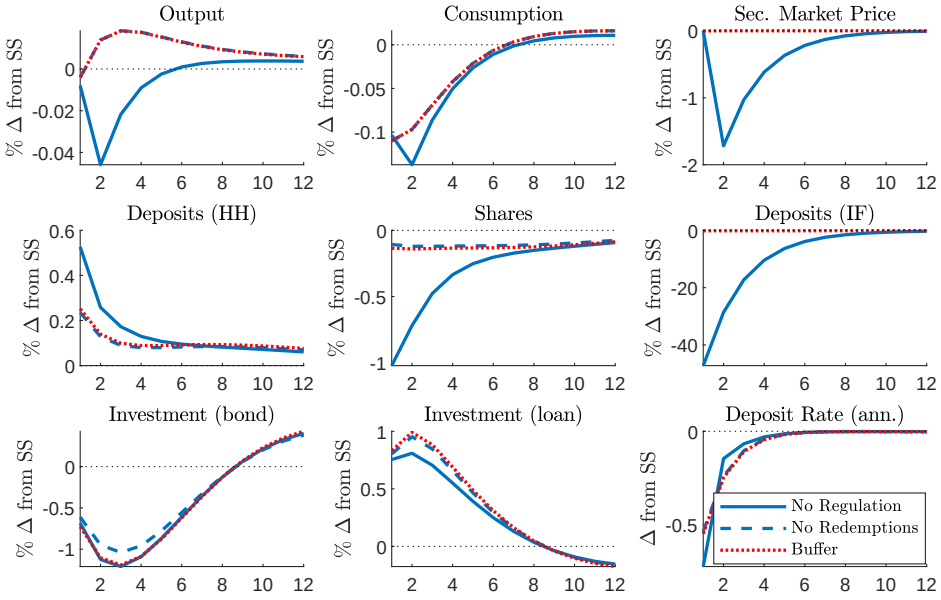


FIGURE 6: Impulse Response Functions to a Deposit Preference Shock

Impulse response functions are shown for a positive shock to δ_t^d (23) inducing an outflow from the investment fund sector of 1% on impact. Blue lines denote the economy without regulation, blue dashed lines an economy without periodic redemptions, and red lines an economy with liquidity buffer regulation. Responses of the variables are given in percentage deviations from steady state. The x-axis denotes quarters after the shock. Output is defined as in (19). IF: investment fund; HH: household.

4.3 Liquidity Regulation and Aggregate Outflow Shocks

Regulation alleviates the adverse welfare effects of periodic idiosyncratic redemptions by limiting the fraction of funds that must liquidate bonds in every period. To gain further intuition for the findings of the welfare analysis in the last section, we now turn to the analysis of an aggregate shock that triggers a shift in household savings from fund shares into bank deposits. This would test the ability of the optimal liquidity regulation to reduce adverse macroeconomic outcomes related to the investment fund sector. The analysis is motivated by the large-scale outflows from investment funds in March 2020 that can be interpreted as an abrupt change in savers' risk preferences (Figure 1, bottom right panel).

Figure 6 shows the impulse response functions of a positive shock to the liquidity weight δ_t^d in (23) that generates an outflow from the investment fund sector of 1% on impact. Blue solid lines represent the effects of the shock in the economy without regulation.

The shock leads to an overall increase of household savings, but to a reduction of those allocated to investment funds. This implies lower financial intermediation through funds, as shown by a decline in bond-financed capital investment, as well as a drop in deposits held by funds. Funds reduce their deposit holdings disproportionately more than their bond investment, given the return differential between the two assets. This increases the amount of bonds that the

investment fund must sell to cover the periodic redemptions. As a result, the secondary market price drops sharply, while bond sales and resource losses increase. This lowers consumption beyond the decline from the overall shift into savings. Dividends paid by funds fall, leading to a further reduction in the market value of fund shares and, hence, fund assets.

The increase in deposits held by households more than compensates for the drop in fund deposits. Thus, bank lending and loan-financed investment increase. Although bond and loan finance are imperfectly substitutable, the rise in loan-financed investment, driven by a falling loan rate, more than compensates the drop in bond-financed investment such that aggregate investment increases slightly. In sum, output still falls because of the drop in consumption.

Before analysing the effects of regulation, we display the amplification effect of our model's key inefficiency, i.e., the liquidity risk in the investment fund sector that generates bond liquidation. The blue dashed lines refer to an economy without periodic redemptions. In this case, investment funds do not need to sell bonds on secondary markets and they have no reason to hold deposits. The amplification effect via funds does not exist. As a result, the decline in fund shares is significantly smaller than in the corresponding solid blue line. Bond-financed investment, accordingly, falls by less. The increase in loan-financed investment after impact is in fact *higher*, since the dampening effect on loan provision from a decrease in fund deposits (implying a loss of funding for banks) in the model with redemptions is now absent.

The initial declines of output and consumption are of similar size as in case of the solid blue lines. But while in the case without redemptions both start recovering immediately after the shock, output and consumption decline significantly more persistently in presence of the redemption risk. The reason is that the amplification through bond sales becomes relevant in the period after impact, when investment funds have reduced their deposits.[19]

As compared to the economy without regulation (solid blue lines), the optimal liquidity buffer of 7.57% alleviates the shock's impact on fund shares considerably (red lines). The fall in the deposits of the investment funds is almost absent, as deposits are now a fixed fraction of the value of fund shares by regulation. As a result, less bonds need to be sold and the secondary market price hardly reacts. Accordingly, resource losses decline as well. The drop in bond-financed investment is reduced; yet bond-financed investment is lower when compared to the economy without redemptions (dashed blue lines). This is because under the regulation investment funds always need to maintain the mandatory amount of deposits so that they cannot fully invest in bonds. Again, loan-financed investment increases since banks' total deposits, and, thus, their balance sheet size, grow.

Overall, the introduction of the liquidity buffer dampens the negative effects of the shock not only in the investment fund sector but also on macroeconomic aggregates, like consumption and output. Under the optimal regulation, the response of the economy closely follows the one where redemptions do not take place at all.

[19] Empirically, Ma et al. (2022) find that mutual fund outflows in March 2020 were amplified due to a liquidity mismatch between assets and liabilities. Our findings are, thus, consistent with their results.

We follow Gertler and Karadi (2011) and compute the welfare gains from the optimal liquidity buffer compared to the unregulated economy. More specifically, based on the second-order approximation of the model, we assume the economy is hit with the single aggregate outflow shock and calculate the CE in every period afterwards, for the regulated and unregulated economies. As we are considering a one-off event – as opposed to a sequence of shocks as in the previous section – we discount and add up the single CE in every period following the shock. We are interested in any welfare gains beyond those taking place in the long-run (see Section 4.2) and, therefore, deduct the long-run CE. Our result is that, when the economy faces the aggregate outflow shock, the optimal buffer increases welfare beyond the long-run gain. A household in the unregulated economy is willing to forego an additional 0.02% of long-run consumption to switch to an economy with the optimal buffer. In other terms, the model suggests that the macroprudential liquidity regulation is an effective instrument to address the wider economic ramifications of the liquidity risks in the investment fund sector.

4.4 Alternative Storage of Liquidity

The previous sections showed that an important effect of the liquidity regulation on welfare is associated with the reduction of deposits held by households (see Figure 5). In our model, bank deposits are the only 'liquid' asset. In this section, we instead consider a case where funds have access to an alternative asset to store liquidity.[20] The key change is that investment funds do not compete with households for bank deposits.

To minimise changes to the model, we consider that the alternative asset m_t investment funds can hold is one-period government debt. Since households are now the only investor in bank deposits, aggregate deposits and household deposits coincide, $d_t = d_t^{hh}$, replacing the previous deposit market clearing condition (20). We add a public budget constraint

$$m_t + t_t = \left(1 + i_{t-1}^d\right) m_{t-1} \ , \tag{24}$$

where t_t is a lump-sum tax paid by households that clears the government budget. We assume the interest rate on government debt is equal to the deposit rate, as in Gertler and Karadi (2011), while we keep parameters unchanged.

Figure 7 shows results for the welfare analysis with government debt. The optimal liquidity buffer is at 12.08%, which is significantly higher than the level of 7.57% in the baseline case of Section 4.2. Importantly, bank deposits held by households no longer decrease, but increase instead (bottom left panel). This finances the increase in bank loans (bottom middle panel), whereas in our baseline case, the increased loan origination is financed by additional deposits held by investment funds.

This difference affects the intermediate production (bottom right panel). When compared

[20] In practice, asset managers use a variety of instruments to hold liquidity, including bank deposits, reverse repos with banks, as well as short-term government securities.

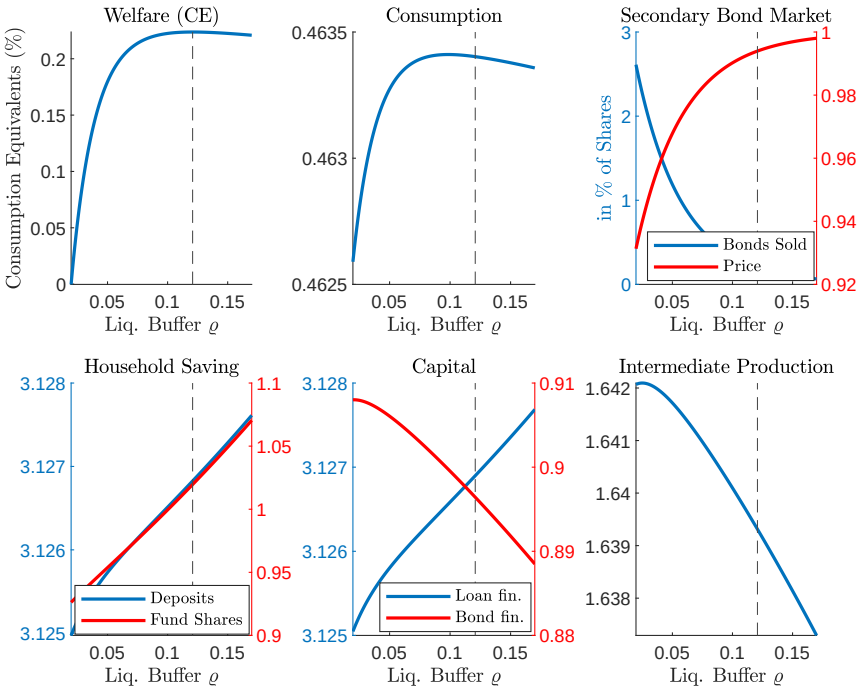


FIGURE 7: Optimal Liquidity Regulation Trade-Offs: Government Debt

We solve a second-order approximation of the model and simulate the economy under a productivity and a preference shock for different levels of the macroprudential liquidity buffer. We calculate conditional welfare to derive consumption equivalents (CE) in terms of the final good. The solid lines depict theoretical long-run means for each simulation. The x-axes start at 1.96%, which is the liquidity buffer voluntarily held by investment funds in absence of regulation. The simulations are based on a model version where government debt is used to fulfill the regulatory liquidity buffer. The vertical dashed lines denote the welfare-maximising liquidity buffer of 12.08%.

to Figure 5, intermediate production declines already for small buffers. The reason is that bank loans become more expensive when fund regulation tightens, while they get cheaper in the economy of Figure 5. Since household deposits rise, the deposit rate increases due to a falling marginal utility from deposits. As a result, loan finance is more expensive, leading to a reduction in production in equilibrium. The optimal liquidity buffer is reached as soon as the resource gain from reducing bond sales is more than offset by the reduction in output. In the baseline case, the utility loss from the decline in household's deposit holdings drives the hump-shape of the welfare curve (see Figure 5, left panel). In the model with government debt, the interior optimum for the liquidity buffer is due to the reduction in output.

In an economy with an alternative storage of investment fund liquidity, adverse welfare effects of regulation are weakened. Regulation no longer lowers deposit returns and, effectively, pushes households out of deposits. This shows that there are important interactions between the scarcity of liquid assets and the liquidity regulation of non-bank financial intermediaries. The result can also inform the debate on the possibility to grant certain non-banks access to central bank liabilities (see, for instance, Stein, 2012). Indeed, when liquid assets such as bank deposits

or short-term government debt are scarce, central banks could expand the supply of such assets to certain non-banks by establishing dedicated deposit facilities. Examples include the Reverse Repo Facility introduced by the US Federal Reserve in 2013 (see Anderson and Kandrac, 2018 for an overview).

5 Conclusion

The last two decades witnessed an extraordinary growth of the investment fund sector and of its importance in the financing of the real economy. The Covid-19 event in March 2020 showed that investment funds can contribute to amplify macroeconomic and financial shocks. Large-scale outflows put extreme pressure on funds that were forced to sell assets in increasingly illiquid markets. These developments catalysed the debate on the systemic relevance of investment funds and regulatory options to mitigate vulnerabilities in the sector.

In this paper, we analyse the role of the investment fund sector in the macroeconomy as well as its regulation from two angles. First, in a motivational empirical analysis, we document that outflows from investment funds, by reducing the sector's financial intermediation capacity, have significant and persistent adverse macroeconomic effects. Second, as the main contribution of the paper, we develop a DSGE model with two types of financial intermediaries, banks and investment funds. The latter are subject to stochastic periodic redemptions that can lead to costly bond sales. Individual funds fail to internalise the full impact of sales on the bond price and hold inefficiently low liquidity buffers. This pecuniary externality eventually results in lower bond intermediation and resource losses.

We show that a macroprudential liquidity buffer improves upon the unregulated economy by limiting bond sales. The optimal liquidity buffer is 7.57%, which is about four-times the median liquidity holdings of investment funds in the euro area, to which we calibrate our model. Our model allows us to identify different channels through which the regulation affects welfare and we disentangle benefits and costs of the regulation. Aside from reducing welfare losses stemming from the periodic redemptions, the regulation successfully contains the amplification of financial shocks and limits their adverse macroeconomic effects in a scenario reminiscent of the March 2020 episode.

Our paper constitutes the first analysis of macroprudential policies that address the liquidity risk of investment funds in a macroeconomic model. In future research, our analysis could be enriched to explore other policy measures to address liquidity mismatch in open-ended investment funds as well as interactions between monetary policy and macroprudential policies for the non-bank financial sector.

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Appendix

A Model Derivations

A.1 Household

Households maximize the discounted value of life-time utility subject to the real period budget constraints. The Lagrangian reads

$$\begin{aligned}\mathscr{L} =&\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma}}{1-\sigma} + \delta_t^d \frac{d_t^{1-\sigma_d}}{1-\sigma_d} - \psi_n \frac{n_t^{1+\sigma_n}}{1+\sigma_n} + \lambda_t \left(w_t n_t + \left(1 + i_{t-1}^d\right) d_{t-1}^{hh} \right.\right. \\ &\left.\left. + \left(q_t^s + div_t^{if}\right) s_{t-1} + \Pi_t - c_t - d_t^{hh} - q_t^s s_t - f(\tilde{b}_t) \right) \right] .\end{aligned}$$

The FOCs are

$$\begin{aligned}\frac{\partial \mathscr{L}}{\partial c_t} =& c_t^{-\sigma} - \lambda_t = 0 , \\ \frac{\partial \mathscr{L}}{\partial d_t^{hh}} =& \delta_t^d d_t^{-\sigma_d} - \lambda_t + \beta \mathbb{E}_t \left[\lambda_{t+1} (1 + i_t^d) \right] = 0 , \\ \frac{\partial \mathscr{L}}{\partial s_t} =& -\lambda_t + \beta \mathbb{E}_t \left[\lambda_{t+1} \frac{q_{t+1}^s + div_{t+1}^{if}}{q_t^s} \right] = 0 , \\ \frac{\partial \mathscr{L}}{\partial n_t} =& -\psi_n n_t^{\sigma_n} + \lambda_t w_t = 0 .\end{aligned}$$

A.2 Banks

The representative bank faces the balance sheet constraint $d_t = l_t$ in every period and maximizes the discounted sum of profits. Repeated substitution of the balance sheet renders its problem static. It maximizes the cash-flow from its portfolio in period t

$$\max_{d_t, l_t} \quad i_t^l l_t - i_t^d d_t .$$

subject to the balance sheet constraint. The FOCs are

$$\begin{aligned}\frac{\partial \mathscr{L}}{\partial d_t} =& -i_t^d + \lambda_t = 0 , \\ \frac{\partial \mathscr{L}}{\partial l_t} =& i_t^l - \lambda_t = 0 ,\end{aligned}$$

where λ_t denotes the multiplier on the period t balance sheet constraint.

A.3 Investment Funds

Investment funds maximize the discounted value of their dividend income. They issue fund shares and invest into bonds and bank deposits. In the first part of a period, they are subject to redemption risk in the sense that a fraction of their fund shares is redeemed early by households which requires an immediate settlement. Settlement of redemptions is done through deposits or selling bonds to households.

Redemptions occur for all investment funds but differ in size. The i.i.d. draws follow a Lomax distribution with parameters $\tilde{\alpha}$ and $\tilde{\lambda}$. Note that given $g(\phi_{j,t}) = \frac{\tilde{\alpha}}{\tilde{\lambda}}(1+\frac{\phi_{j,t}}{\tilde{\lambda}})^{-(\tilde{\alpha}+1)}$,

$$\int_{\tilde{\phi}_t}^{\infty} \phi_{j,t} g(\phi_{j,t}) d\phi_{j,t} = \left[-\phi_{j,t} \left(1+\frac{\phi_{j,t}}{\tilde{\lambda}}\right)^{-\tilde{\alpha}} - \frac{\tilde{\lambda}}{\tilde{\alpha}-1} \left(1+\frac{\phi_{j,t}}{\tilde{\lambda}}\right)^{-\tilde{\alpha}+1} \right]_{\tilde{\phi}_t}^{\infty},$$

$$\int_{\tilde{\phi}_t}^{\infty} g(\phi_{j,t}) d\phi_{j,t} = \left[1 - \left(1+\frac{\phi_{j,t}}{\tilde{\lambda}}\right)^{-\tilde{\alpha}} \right]_{\tilde{\phi}_t}^{\infty}.$$

Aggregating across all draws gives the aggregate redemption,

$$\int_{0}^{\infty} \phi_{j,t} g(\phi_{j,t}) d\phi_{j,t} = \frac{\tilde{\lambda}}{\tilde{\alpha}-1},$$

which is just the mean redemption. Note that we use an unbounded Lomax distribution, that is draws above one are technically possible. However, given the fitted parameters of our distribution the probability to have draws above one is $7e-8\%$ so that we stick with the general distribution instead of a bounded Pareto distribution. Investment fund j sells the fraction,

$$1-\vartheta_{j,t} = \frac{\phi_{j,t} q^s_{j,t-1} s_{j,t-1} - d^{if}_{j,t-1}}{\tilde{q}^b_t b_{j,t-1}},$$

of beginning-of-period bonds. The amount sold by investment fund j is then,

$$\tilde{b}_{j,t} \equiv (1-\vartheta_{j,t}) b_{j,t-1} = \frac{\phi_{j,t} q^s_{j,t-1} s_{j,t-1} - d^{if}_{j,t-1}}{\tilde{q}^b_t}.$$

Aggregating across i.i.d draws gives (using that all investment funds hold the same initial positions, e.g., $s_{j,t-1} = s_{t-1}$ and $q^s_{j,t-1} = q^s_{t-1}$),

$$\tilde{b}_t = \frac{1}{\tilde{q}^b_t} \left(1+\frac{\tilde{\phi}_t}{\tilde{\lambda}}\right)^{-\tilde{\alpha}} \left(\frac{\tilde{\lambda}+\tilde{\alpha}\tilde{\phi}_t}{\tilde{\alpha}-1} q^s_{t-1} s_{t-1} - d^{if}_{t-1} \right).$$

Since the probability of a draw above the threshold value is given by $1-G = \left(1+\frac{\tilde{\phi}_t}{\tilde{\lambda}}\right)^{-\tilde{\alpha}}$, the amount of bonds sold is weighted by the probability of a (sufficiently) high draw. G denotes the cumulative density function of the redemption distribution. Intuitively, cost fall in the amount of deposits and increase in the amount of fund shares issued. The latter is multiplied by a

factor that corresponds to the mean redemption plus a term that increases in the threshold draw above which investment funds start to sell bonds. Theoretically, a high threshold has an ambiguous effect. While it lowers the probability that sales occur, it also implies that, if sales occur, redemptions are higher. However, given $\tilde{\alpha} > 1$ the net effect can be shown to be negative.

The secondary market price can be expressed as

$$\tilde{q}_t^b = 1 - \kappa_{hh}\tilde{b}_t \ .$$

Investment funds further obey a balance sheet constraint $q_t^b b_t + d_t^{if} = q_t^s s_t$. At the end of a period, they transfer all income as dividends to households,

$$div_t^{if} = b_{t-1} - q_t^b b_t - d_t^{if} + (1 + i_{t-1}^d) d_{t-1}^{if} - L(\tilde{b}_t) \ ,$$

where we assume $L(\tilde{b}_t) = \frac{\kappa_{if}}{2}\left(\tilde{b}_t\right)^2$. The problem of investment funds can then be written as follows:

$$\mathscr{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[b_{t-1} - q_t^b b_t - d_t^{if} + (1 + i_{t-1}^d) d_{t-1}^{if} - \frac{\kappa_{if}}{2}\left(\tilde{b}_t\right)^2 + \lambda_t^{if}\left(q_t^s s_t - q_t^b b_t - d_t^{if}\right)\right] .$$

FOCs for bonds and bank deposits follow,

$$\begin{aligned}
\frac{\partial \mathscr{L}}{\partial b_t} &= -q_t^b + \mathbb{E}_t \Lambda_{t,t+1} - \lambda_t^{if} q_t^b = 0 \ , \\
\frac{\partial \mathscr{L}}{\partial d_t^{if}} &= \mathbb{E}_t \Lambda_{t,t+1} \left((1 + i_t^d) + \frac{1}{\tilde{q}_{t+1}^b} \left(\kappa_{if} \tilde{b}_{t+1} \left(1 + \frac{\tilde{\phi}_{t+1}}{\tilde{\lambda}} \right)^{-\tilde{\alpha}} \right) \right) - 1 - \lambda_t^{if} = 0 \ ,
\end{aligned}$$

with λ_t^{if} denoting the multiplier on the balance sheet constraint.

A.4 Entrepreneurs

The problem of loan-financed entrepreneurs reads

$$\begin{aligned}
\max_{l_t, K_t^l} \ \mathbb{E}_0 \ & \sum_{t=0}^{\infty} \Lambda_{0,t} \left(p_t^l \left(K_{t-1}^l \right)^{\gamma} - (1 + i_{t-1}^l) l_{t-1} + l_t + (1 - \delta) q_t^{k,l} K_{t-1}^l - q_t^{k,l} K_t^l \right) \\
& \text{subject to } l_t = q_t^{k,l} K_t^l \ .
\end{aligned}$$

The FOCs for capital and loans from maximizing the discounted value of dividends are

$$\begin{aligned}
1 - \lambda_t^l &= \mathbb{E}_t \left[\Lambda_{t,t+1} \frac{\gamma p_{t+1}^l (K_t^l)^{\gamma - 1} + (1 - \delta) q_{t+1}^{k,l}}{q_t^{k,l}} \right] \ , \\
1 - \lambda_t^l &= \mathbb{E}_t \left[\Lambda_{t,t+1} (1 + i_t^l) \right] \ ,
\end{aligned}$$

where λ_t^l is the multiplier on the financing constraint. Similarly, for bond-financed entrepreneurs we have,

$$\max_{b_t, K_t^b} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left(p_t^b \left(K_{t-1}^b \right)^{\gamma} - b_{t-1} + q_t^b b_t + (1-\delta) q_t^{k,b} K_{t-1}^b - q_t^{k,b} K_t^b \right)$$
$$\text{subject to } q_t^b b_t = q_t^{k,b} K_t^b \ .$$

The FOCs for capital and bonds are

$$1 - \lambda_t^b = \mathbb{E}_t \left[\Lambda_{t,t+1} \frac{\gamma p_{t+1}^b (K_t^b)^{\gamma-1} + (1-\delta) q_{t+1}^{k,b}}{q_t^{k,b}} \right] ,$$
$$1 - \lambda_t^b = \mathbb{E}_t \left[\Lambda_{t,t+1} \frac{1}{q_t^b} \right] ,$$

where λ_t^b is the multiplier on the financing constraint. The intermediate good producer buys input from both types and uses a CES-technology. It maximises

$$div_t^{entr} = p_t^z \left(\upsilon (z_t^l)^{\bar{\epsilon}} + (1-\upsilon)(z_t^b)^{\bar{\epsilon}} \right)^{\frac{1}{\bar{\epsilon}}} - p_t^l z_t^l - p_t^b z_t^b \ .$$

The FOCs yield the demand equations

$$z_t^l = (\upsilon)^{\frac{1}{1-\bar{\epsilon}}} \left(\frac{p_t^z}{p_t^l} \right)^{\frac{1}{1-\bar{\epsilon}}} z_t \ ,$$
$$z_t^b = (1-\upsilon)^{\frac{1}{1-\bar{\epsilon}}} \left(\frac{p_t^l}{p_t^b} \right)^{\frac{1}{1-\bar{\epsilon}}} z_t \ .$$

A.5 Capital Good Producer

There are two types of capital good producers that purchase depreciated capital from loan- and bond-financed firms, invest into new capital subject to adjustment cost, and resell the new capital to entrepreneurs. Derivations hold for $\tau = l, b$. Capital evolves as

$$K_t^{\tau} = (1-\delta) K_{t-1}^{\tau} + I_t^{\tau} \left(1 - \frac{\kappa^I}{2} \left(\frac{I_t^{\tau}}{I_{t-1}^{\tau}} - 1 \right)^2 \right) \ .$$

New capital is sold at price $q_t^{k,\tau}$ to entrepreneur of type τ. The problem of the capital good producer is given by maximizing real profits

$$\max_{I_t^{\tau}} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[q_t^{k,\tau} \left((1-\delta) K_{t-1}^{\tau} + I_t^{\tau} \left(1 - \frac{\kappa^I}{2} \left(\frac{I_t^{\tau}}{I_{t-1}^{\tau}} - 1 \right)^2 \right) \right) \right.$$
$$\left. - I_t^{\tau} - q_t^{k,\tau} (1-\delta) K_{t-1}^{\tau} \right] \ .$$

The FOC with respect to investment reads

$$q_t^{k,\tau}\left[1-\frac{\kappa^I}{2}\left(\frac{I_t^\tau}{I_{t-1}^\tau}-1\right)-\frac{I_t^\tau}{I_{t-1}^\tau}\kappa^I\left(\frac{I_t^\tau}{I_{t-1}^\tau}-1\right)\right]+\mathbb{E}_t\Lambda_{t,t+1}q_{t+1}^{k,\tau}\left(\frac{I_{t+1}^\tau}{I_t^\tau}\right)^2\left(\frac{I_{t+1}^\tau}{I_t^\tau}-1\right)=1\ .$$

A.6 Final Good Firms

The final good producer uses labour and the intermediate good to produce the final good. Their profits read

$$\Gamma_t = A_t\left(n_t\right)^\alpha\left(z_t\right)_t^{1-\alpha}-w_t n_t-p_t^z z_t\ .$$

FOCs for labour and intermediate goods equate the input prices with their marginal products:

$$\alpha\frac{Y_t}{n_t} = w_t\ , \tag{25}$$

$$(1-\alpha)\frac{Y_t}{z_t} = p_t^z\ . \tag{26}$$

A.7 Derivation of Resource Constraint

When deriving the resource constraint, we take the household budget and insert profits of entrepreneurs, the intermediate good producer, the final good producer, capital producers, and banks,

$$\begin{aligned}&c_t+d_t^{hh}+q_t^s s_t+f(\tilde{b}_t)=w_t n_t+(1+i_{t-1}^d)d_{t-1}^{hh}+\left(q_t^s+div_t^{if}\right)s_{t-1}+p_t^z z_t-p_t^b z_t^b-p_t^l z_t^l\\&+p_t^b z_t^b-b_{t-1}+q_t^b b_t+(1-\delta)q_t^{k,b}K_{t-1}^b-q_t^{k,b}K_t^b+p_t^l z_t^l-(1+i_{t-1}^l)l_{t-1}+(1-\delta)q_t^{k,l}K_{t-1}^l\\&+l_t-q_t^{k,l}K_t^l+Y_t-p_t^z z_t-w_t n_t+div_t^b+\sum_{\tau=l,b}\left(q_t^{k,\tau}K_t^\tau-I_t^\tau-q_t^{k,\tau}(1-\delta)K_{t-1}^\tau\right)\ .\end{aligned}$$

Many terms cancel directly. We normalise $s_t=1$.

$$\begin{aligned}&c_t+d_t^{hh}+f(\tilde{b}_t)=(1+i_{t-1}^d)d_{t-1}^{hh}+div_t^{if}-b_{t-1}+q_t^b b_t\\&-(1+i_{t-1}^l)l_{t-1}+l_t+Y_t-\sum_{\tau=l,b}I_t^\tau+div_t^b\ .\end{aligned}$$

Next, we eliminate bank-related terms. Recall $d_t=d_t^{hh}+d_t^{if}$ and $d_t=l_t$ so $d_t^{hh}=l_t-d_t^{if}$,

$$\begin{aligned}&c_t+l_t-d_t^{if}+f(\tilde{b}_t)=(1+i_{t-1}^d)d_{t-1}^{hh}+div_t^{if}-b_{t-1}+q_t^b b_t\\&-(1+i_{t-1}^l)l_{t-1}+l_t+Y_t-\sum_{\tau=l,b}I_t^\tau+div_t^b\ .\end{aligned}$$

Using the bank balance sheet for $t-1$, $d^{hh}_{t-1} = l_{t-1} - d^{if}_{t-1}$ and that $i^l_{t-1} = i^d_{t-1}$ yields

$$\begin{aligned} c_t - d^{if}_t + f(\tilde{b}_t) = (1 + i^d_{t-1})(l_{t-1} - d^{if}_{t-1}) + div^{if}_t - b_{t-1} + q^b_t b_t \\ - (1 + i^d_{t-1})l_{t-1} + Y_t - \sum_{\tau=l,b} I^\tau_t \ . \end{aligned}$$

Next, we insert investment fund dividends

$$div^{if}_t = b_{t-1} - q^b_t b_t - d^{if}_t + (1 + i^d_{t-1})d^{if}_{t-1} - L(\tilde{b}_t) \ .$$

Inserting yields:

$$Y_t = c_t + \sum_{\tau=l,b} I^\tau_t + f(\tilde{b}_t) + L(\tilde{b}_t) \ .$$

B Equilibrium Without Regulation

Households

$$c_t^{-\sigma} = \delta^d (d^{hh}_t)^{-\sigma_d} + \mathbb{E}_t \left[\beta c_{t+1}^{-\sigma} (1 + i^d_t) \right] \ , \tag{27}$$

$$c_t^{-\sigma} = \mathbb{E}_t \left[\beta c_{t+1}^{-\sigma} \frac{q^s_{t+1} + div^{if}_{t+1}}{q^s_t} \right] \ , \tag{28}$$

$$\psi_n (c_t)^\sigma n_t^{\sigma_n} = w_t \ , \tag{29}$$

$$\Lambda_{t,t+1} = \beta (\frac{c_t}{c_{t+1}})^\sigma \ . \tag{30}$$

Banks

$$i^l_t = i^d_t \ , \tag{31}$$

$$d_t = l_t \ , \tag{32}$$

$$d_t = d^{hh}_t + d^{if}_t \ . \tag{33}$$

Investment Funds

$$div^{if}_t = b_{t-1} - q^b_t b_t + (1 + i^d_{t-1})d^{if}_{t-1} - d^{if}_t - L(\tilde{b}_t) \ , \tag{34}$$

$$1 + \lambda^{if}_t = \mathbb{E}_t \Lambda_{t,t+1} \left((1 + i^d_t) + \frac{\kappa_{if} \tilde{b}_{t+1}}{\tilde{q}^b_{t+1}} \left(1 + \frac{\tilde{\phi}_{t+1}}{\tilde{\lambda}} \right)^{-\tilde{\alpha}} \right) \ , \tag{35}$$

$$q^b_t = - q^b_t \lambda^{if}_t + \mathbb{E}_t \Lambda_{t,t+1} \ , \tag{36}$$

$$q^s_t s_t = q^b_t b_t + d^{if}_t \ , \tag{37}$$

$$\tilde{\phi}_t = \frac{d^{if}_{t-1}}{q^s_{t-1} s_{t-1}} \ . \tag{38}$$

Bond Sales

$$\tilde{b}_t = \frac{1}{\tilde{q}_t^b}\left(1+\frac{\tilde{\phi}_t}{\tilde{\lambda}}\right)^{-\tilde{\alpha}}\left(\frac{\tilde{\lambda}+\tilde{\alpha}\tilde{\phi}_t}{\tilde{\alpha}-1}q_{t-1}^s s_{t-1} - d_{t-1}^{if}\right) , \tag{39}$$

$$\tilde{q}_t^b = 1-\kappa_{hh}\tilde{b}_t . \tag{40}$$

Loan Using Entrepreneur

$$l_t = q_t^{k,l}K_t^l , \tag{41}$$

$$z_t^l = \left(K_{t-1}^l\right)^{\gamma} , \tag{42}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}(1+i_t^l)\right] = \mathbb{E}_t\left[\Lambda_{t,t+1}\frac{\gamma p_t^l (K_t^l)^{\gamma-1}+(1-\delta)q_{t+1}^{k,l}}{q_t^{k,l}}\right] . \tag{43}$$

Bond Using Entrepreneur

$$q_t^b b_t = q_t^{k,b}K_t^b , \tag{44}$$

$$z_t^b = \left(K_{t-1}^b\right)^{\gamma} , \tag{45}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\frac{1}{q_t^b}\right] = \mathbb{E}_t\left[\Lambda_{t,t+1}\frac{\gamma p_t^b (K_t^b)^{\gamma-1}+(1-\delta)q_{t+1}^{k,b}}{q_t^{k,b}}\right] . \tag{46}$$

Intermediate Good Producer

$$z_t = \left(\upsilon (z_t^l)^{\tilde{\epsilon}} + (1-\upsilon)(z_t^b)^{\tilde{\epsilon}}\right)^{\frac{1}{\tilde{\epsilon}}} , \tag{47}$$

$$z_t^l = \left(\upsilon\frac{p_t^z}{p_t^l}\right)^{\frac{1}{1-\tilde{\epsilon}}} z_t , \tag{48}$$

$$z_t^b = \left((1-\upsilon)\frac{p_t^z}{p_t^b}\right)^{\frac{1}{1-\tilde{\epsilon}}} z_t . \tag{49}$$

Capital Producer

$$K_t^l = (1-\delta)K_{t-1}^l + I_t^l\left(1-\Phi\left(\frac{I_t^l}{I_{t-1}^l}\right)\right) , \tag{50}$$

$$\begin{aligned} 1 =& q_t^{k,l}\left[1-\frac{\kappa^I}{2}\left(\frac{I_t^l}{I_{t-1}^l}-1\right)-\frac{I_t^l}{I_{t-1}^l}\kappa^I\left(\frac{I_t^l}{I_{t-1}^l}-1\right)\right] \\ &+ \mathbb{E}_t\Lambda_{t,t+1}q_{t+1}^{k,l}\left(\frac{I_{t+1}^l}{I_t^l}\right)^2\left(\frac{I_{t+1}^l}{I_t^l}-1\right) , \end{aligned} \tag{51}$$

$$K_t^b = (1-\delta)K_{t-1}^b + I_t^b\left(1-\Phi\left(\frac{I_t^b}{I_{t-1}^b}\right)\right) , \tag{52}$$

$$1 = q_t^{k,b}\left[1-\frac{\kappa^I}{2}\left(\frac{I_t^b}{I_{t-1}^b}-1\right)-\frac{I_t^b}{I_{t-1}^b}\kappa^I\left(\frac{I_t^b}{I_{t-1}^b}-1\right)\right]$$

$$+ \mathbb{E}_t \Lambda_{t,t+1} q_{t+1}^{k,b} \left(\frac{I_{t+1}^b}{I_t^b} \right)^2 \left(\frac{I_{t+1}^b}{I_t^b} - 1 \right) . \tag{53}$$

Final Good Producer

$$\alpha \frac{Y_t}{n_t} = w_t , \tag{54}$$

$$(1-\alpha) \frac{Y_t}{z_t} = p_t^z , \tag{55}$$

$$Y_t = A_t \left(n_t\right)^{\alpha_n} \left(z_t\right)^{1-\alpha_n} . \tag{56}$$

Resource Constraint

$$Y_t = c_t + \sum_{\tau=l,b} \frac{\kappa^I}{2} \left(\frac{I_t^\tau}{I_{t-1}^\tau} - 1 \right)^2 I_t^\tau + \sum_{\tau=l,b} q_t^{K,\tau} \left(K_t^\tau - (1-\delta) K_{t-1}^\tau \right) + f(\tilde{b}_t) + L(\tilde{b}_t) . \tag{57}$$

Shocks

$$\log A_{t+1} = (1-\rho^a) \log A^* + \rho^a \log A_t + \epsilon_t , \tag{58}$$

$$\log \delta_{t+1}^d = \left(1-\rho^\delta\right) \log \delta^{d,*} + \rho^\lambda \log \delta_t^d + \epsilon_\delta . \tag{59}$$

We set $s = 1$. This gives 33 equations and 33 unknowns:

- Quantities: $c, n, z, z^b, z^l, K^b, K^l, l, b, Y, q^s, d, d^{if}, d^{hh}, I^l, I^b, \tilde{b}_t, div^{if}$
- Prices & Interest Rates: $w, i^d, i^l, p^z, p^b, p^l, q^b, \tilde{q}^b, q^{k,l}, q^{k,b}$
- Shocks: δ^d, A
- Auxiliary: $\Lambda, \tilde{\phi}, \lambda^{if}$

Steady State

The capital price is $q^{k,\tau} = 1$ in the steady state. Further, $\Lambda = \beta$. Consider the final good producer. Inserting equation (55),

$$z = (1-\alpha) \frac{Y}{p^z} ,$$

into the production function (56) gives

$$Y = n \cdot A^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{p^z} \right)^{\frac{1-\alpha}{\alpha}} ,$$

where Y and p^z are unknown. Equating with the resource constraint (57) yields

$$n \cdot A^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{p^z}\right)^{\frac{1-\alpha}{\alpha}} = c + \delta(l + q^b b) + f(\tilde{b}) + L(\tilde{b}) \,, \tag{60}$$

where we use that $K^l = l$ and $K^b = q^b b$. We will use this equation at a later stage. Next, consider the equilibrium conditions of banks. Note (31)

$$i^l = i^d \,.$$

Using $K^l = l$ and $K^b = q^b b$ as well as the entrepreneur production functions, the entrepreneur and intermediate good producer equilibrium conditions yield

$$\left(\frac{i^d + \delta}{\gamma p^l}\right)^{\frac{1}{\gamma-1}} = l \tag{61}$$

$$\left(\frac{1/q^b - 1 + \delta}{\gamma p^b}\right)^{\frac{1}{\gamma-1}} = q^b b \tag{62}$$

$$(l)^\gamma = \left(\upsilon \frac{p^z}{p^l}\right)^{\frac{1}{1-\tilde{\epsilon}}} \left((1-\alpha)\frac{A}{p^z}\right)^{\frac{1}{\alpha}} n \,, \tag{63}$$

$$\left(q^b b\right)^\gamma = \left((1-\upsilon)\frac{p^z}{p^b}\right)^{\frac{1}{1-\tilde{\epsilon}}} \left((1-\alpha)\frac{A}{p^z}\right)^{\frac{1}{\alpha}} n \,, \tag{64}$$

$$\left((1-\alpha)\frac{A}{p^z}\right)^{\frac{1}{\alpha}} n = \left(\upsilon (l^\gamma)^{\tilde{\epsilon}} + (1-\upsilon)(\left(q^b b\right)^\gamma)^{\tilde{\epsilon}}\right)^{\frac{1}{\tilde{\epsilon}}} \,, \tag{65}$$

where we use $z = \left((1-\alpha)\frac{A}{p^z}\right)^{\frac{1}{\alpha}} n$ and $i^l = i^d$.

The deposit and investment fund share demand of households read

$$1 = \delta^d \frac{(d_t^{hh})^{-\sigma_d}}{c^{-\sigma}} + \beta(1 + i^d) \,, \tag{66}$$

$$1 = \beta \frac{q^s + (1 - q^b)b + i^d d^{if} - L(\tilde{b})}{q^s} \,. \tag{67}$$

Finally, consider the equilibrium conditions of investment funds:

$$\frac{1}{\beta} = (1 + i^d) + \frac{1}{\tilde{q}^b}\left(1 + \frac{\tilde{\phi}}{\tilde{\lambda}}\right)^{-\tilde{\alpha}} \kappa_{if} \tilde{b}, \tag{68}$$

$$q^b = q^b \lambda^{if} + \beta \,, \tag{69}$$

$$q^s = q^b b + d^{if} \,, \tag{70}$$

$$\tilde{\phi} = \frac{d^{if}}{q^s} \,, \tag{71}$$

$$\tilde{b} = \frac{1}{\tilde{q}^b}\left(1+\frac{\tilde{\phi}}{\tilde{\lambda}}\right)^{-\tilde{\alpha}}\left(\frac{\tilde{\lambda}+\tilde{\alpha}\tilde{\phi}}{\tilde{\alpha}-1}q^s - d^{if}\right) , \tag{72}$$

$$\tilde{q}^b = 1-\kappa_{hh}\tilde{b} . \tag{73}$$

We use (60)-(73) and deposit market clearing

$$d = l = d^{hh} + d^{if} ,$$

to solve for the unknowns $c, p^l, l, \tilde{\phi}, p^z, b, \tilde{q}^b, i^d, p^b, q^s, d^{if}, d^{hh}, \tilde{b}, \lambda^{if}, q^b$. We use the marginal rate of substitution between consumption and labour (29) to choose ψ_n to satisfy $n = \frac{1}{3}$.

C Equilibrium with Regulation of Investment Funds

The equilibrium is the same as without investment fund regulation except for the following equations:

Investment Funds – The FOC for deposits is changed and a regulatory constraint is added:

$$1+\lambda_t^{if} = \mathbb{E}_t\Lambda_{t,t+1}\left((1+i_t^d)+\frac{1}{\tilde{q}^b_{t+1}}\left(1+\frac{\tilde{\phi}_{t+1}}{\tilde{\lambda}}\right)^{-\tilde{\alpha}}\kappa_{if}\tilde{b}_{t+1}\right)+\mu_t , \tag{74}$$

$$\varrho q_t^s s_t = d_t^{if} , \tag{75}$$

where μ_t is the multiplier on the regulatory constraint. This adds one equation and one unknown μ to the calculation of the steady state.

TABLE 6: Data Sources

Var.	Description	ID	Source
l_t	Short term loans MFIs	QSA.Q.N.I8.W2.S124.S11.N.A.LE.F4.S._Z.XDC._T.S.V.N._T	ECB
	Long term loans MFI	QSA.Q.N.I8.W2.S12K.S11.N.A.LE.F4.L._Z.XDC._T.S.V.N._T	ECB
	Listed shares MFI	QSA.Q.N.I8.W2.S12K.S11.N.A.LE.F511._Z._Z.XDC._T.S.V.N._T	ECB
b_t	Debt Sec Short Mat. IF	QSA.Q.N.I8.W2.S124.S11.N.A.LE.F3.S._Z.XDC._T.S.V.N._T	ECB
	Debt Sec. Long Mat. IF	QSA.Q.N.I8.W2.S124.S11.N.A.LE.F3.L._Z.XDC._T.S.V.N._T	ECB
	Listed shares IF	QSA.Q.N.I8.W2.S124.S11.N.A.LE.F511._Z._Z.XDC._T.S.V.N._T	ECB
d_t^{hh}	Overnight deposits, Total	BSI.M.U2.N.A.L21.A.1.U2.2250.EUR.E	ECB
	Deposits with agreed maturity, <2Y	BSI.M.U2.N.A.L22.L.1.U2.2250.EUR.E	ECB
	Deposits redeemable at notice, <3M	BSI.M.U2.N.A.L23.D.1.U2.2250.EUR.E	ECB
Y_t	GDP at market prices	MNA.Q.Y.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.V.N	ECB
c_t	Consumption Expenditure	MNA.Q.Y.I8.W0.S1M.S1.D.P31._Z._Z._T.EUR.V.N	ECB
I_t	GFCF	MNA.Q.Y.I8.W0.S1.S1.D.P51G.N11G._T._Z.EUR.V.N	ECB
π	GDP Deflator	MNA.Q.Y.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.IX.D.N	ECB
	Total Employment	ENA.Q.Y.I8.W2.S1.S1._Z.EMP._Z._T._Z.PS._Z.N	ECB
	Corp. bond fund (IG): Ann. Yield	iBoxx € Non-Financials	Markit
	Corp. bond fund (HY): Ann. Yield	iBoxx EUR High Yield core Non-Financials ex crossover LC	Markit

IF: investment fund; MFI: monetary financial institutions; GFCF: gross fixed capital formation; IG: investment grade; HY: high yield.

D Data and Calibration

Data Sources – We take most data from the Statistical Data Warehouse of the ECB. We employ a broad definition of bank-based and investment fund-based finance. We aggregate loans and listed shares vis-a-vis non-financial corporations held by monetary financial institutions (MFIs) excluding euro area central banks to obtain the measure for bank-financing. To obtain a measure of investment fund-finance, we aggregate debt securities and listed shares vis-a-vis non-financial corporations held by investment funds. Our measures encompass debt securities, loans, and equity, since in the context of our model, we do not discriminate between debt and equity funding sources for the firm sector. Our loan and bond measures are used to calculate the size of bond-to-loan finance, loans- and bonds-to-GDP as well as the autocorrelation of loans and bonds.

To obtain household deposits, we follow Gerali et al. (2010) who obtain deposits as the sum of different series of short-term deposits (all with maturity below three months). To obtain the size of the investment fund sector in our model, we proceed as follows. Using our measure of bond finance and the data on the liquidity share of corporate bond investment funds (see Figure 1), we back out the consistent amount of deposits by applying the balance sheet constraint of investment funds ($d = \text{Liq.Share} \cdot (d + b)$). This eventually yields fund shares $s = d + b$. We use the measure of household deposits and investment fund shares to calculate the fraction household save in investment fund shares. We also use fund shares to obtain their autocorrelation.

We use the GDP deflator and total employment to calculate real per capita series for output, consumption, investment, shares, loans, bonds, and deposits. Second moments are calculated based on the log of the respective series using a Hodrick-Prescott filter with smoothing parameter 1600 and discarding the first and last 1.5 years of data.

Finally, we target the return on investment fund shares using the annual yield on Markit indices that reflect the non-financial corporate bond universe in the euro area.

Redemptions – To parameterise the distribution of fund redemptions, we use weekly data on corporate bond investment fund flows from EPFR Global from 2007 to 2019. We obtain quarterly flows by aggregating across the weekly flows and dividing by assets under management of all funds at the start of a quarter. We focus on the outflow episodes to obtain a measure for the redemptions in the model. We match the histogram of the empirical outflow distribution to a Generalised Pareto distribution in Figure 8. As we obtain a location parameter of zero, we obtain a Lomax distribution, which is a special case of Generalised Pareto distributions.

Robustness of the Calibration to Parameter Changes – Table 7 shows the sensitivity of our calibration targets to changes in the calibrated parameters. All parameters are increased by one percent except for the liquidity and management cost parameters, which are increased by two percent, and for the parameters governing the preference shock. Due to their relatively small

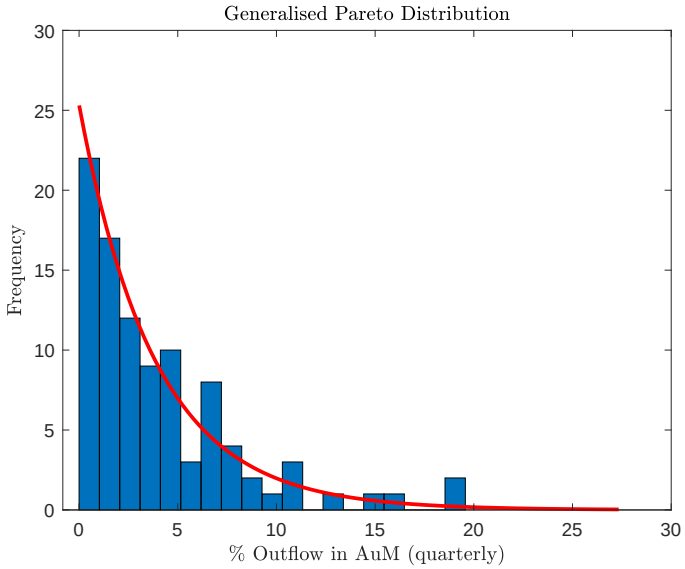

FIGURE 8: Empirical and Fitted Distribution of Corporate Bond Fund Outflows

Blue bars show empirical distribution of quarterly outflows from euro area corporate bond funds between 2007 and 2019. The red line shows the fitted Lomax (Generalised Pareto) distribution.

size, we increase the persistence by fifty percent and increase the shock standard deviation by one-half. Values denote the percentage change of the target. We highlight in bold the respective parameter targets. The responses of targets to their main parameter have the expected sign and are not unusually large.

TABLE 7: Robustness of Calibration

Target	υ	$\tilde{\epsilon}$	κ_{if}	κ_{hh}	ρ^a	σ^a	ρ^δ	σ^δ	κ^I
Bond-to-Loan Finance	**-4.286**	-0.544	-0.008	-0.001	0	0	0	0	0
Deposits in IF Assets	-2.576	-0.332	**1.851**	0.302	0	0	0	0	0
Loan-to-GDP	0.976	**0.123**	0.002	0	0	0	0	0	0
Bond Share HH	1.053	0.135	-0.931	**0.007**	0	0	0	0	0
σ_I/σ_Y	0.002	0	0.001	-0.001	-4.412	0	0	0	**-0.100**
σ_c/σ_Y	0.002	0	0.001	-0.001	4.317	0	**0.001**	0	0.175
σ_Y	-0.004	-0.001	-0.002	0.002	-0.315	**1**	0	0	-0.039
Auto-correlation Y	0.001	0	0	0	**0.040**	0	0	0	0.005
Auto-correlation d^{hh}	0.054	0.003	0.003	-0.004	1.390	0	0.002	**0.002**	-0.274

Table shows percentage change in calibration targets from their baseline in Table 4 after small changes in parameters. IF: investment fund; HH: household; $\sigma_Y, \sigma_c, \sigma_I$: standard deviations of output, consumption, investment.

E Model With Bank Frictions

As a robustness check we add more structure to the banking sector. Specifically, we assume that banks are subject to capital regulation that constrains their ability to issue loans: banks must have equity e_t to extend loans.

The banking sector finances loans with deposits d_t and equity e_t accumulated out of retained earnings. Loans l_t are granted to entrepreneurs at the loan rate i_t^l. Following Gerali et al. (2010), banks incur quadratic cost when deviating from the target capital ratio ν:[21]

$$\frac{\kappa}{2}\left(\frac{e_t}{l_t}-\nu\right)^2 e_t \ ,$$

where κ is a cost parameter. These costs are proportional to bank's equity and impose a limit to the size and the speed of adjustment of the balance sheet. Banks are owned by households to whom they pay a fraction ψ of their profits as dividends. They maximise the discounted sum of cash-flows div_t^b,

$$\max_{d_t,l_t} \quad \psi\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}\left[d_{t+1}-\left(1+i_t^d\right)d_t+(e_{t+1}-e_t)+(1+i_t^l)l_t-l_{t+1}-\frac{\kappa}{2}\left(\frac{e_t}{l_t}-\nu\right)^2 e_t\right] \ ,$$

subject to a balance sheet constraint $d_t + e_t = l_t$. After repeated substitutions, the static bank problem is

$$\max_{d_t,l_t} \quad \psi\cdot(i_t^l l_t - i_t^d d_t - \frac{\kappa}{2}\left(\frac{e_t}{l_t}-\nu\right)^2 e_t) \ ,$$

where $i_t^l l_t$ denotes revenues from lending and $i_t^d d_t$ are the interest payments to depositors. The last term captures the costs of deviations from the target capital ratio. The fraction $1-\psi$ of dividends that is retained is used to build equity capital, which evolves as:

$$e_t = (1-\delta^b)e_{t-1} + (1-\psi)div_{t-1}^b \ .$$

The parameter $0 < \delta^b < 1$ captures exogenous factors that erode bank capital in every period, such as resources used to manage the bank or equity losses due to defaulting loans. It is chosen to ensure that bank equity equals the target ν in the steady state.

From the FOCs we can derive

$$i_t^l = i_t^d - \kappa\left(\frac{e_t}{l_t}-\nu\right)\left(\frac{e_t}{l_t}\right)^2 \ . \tag{76}$$

[21] This ratio can be seen as the result of limited commitment or bank capital regulation. Intuitively, this could be the result of moral hazard on the bank's side. For example, in a model in which the borrower (bankers) can misbehave, lenders (depositors) are willing to lend only if the borrower has sufficient pledgeable income, which increases with its equity capital (see Gertler and Karadi, 2011).

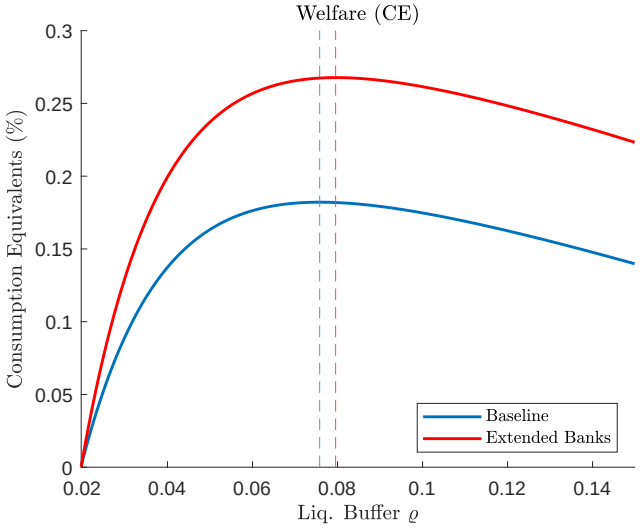

FIGURE 9: Welfare Effect of Liquidity Regulation: Relevance of Bank Frictions

We solve a second-order approximation of the model and simulate the economy under a productivity and a preference shock for different levels of the macroprudential liquidity buffer. We calculate conditional welfare to derive consumption equivalents (CE) in terms of the final good. The x-axis starts at 1.96%, which is the liquidity buffer voluntarily held by investment funds in absence of regulation. We compare the welfare in our full model (blue line) to the one in an economy with bank frictions (red line). The dashed lines depict the optimal buffers in the two economies.

Equation (76) is the loan supply schedule and defines the spread between the loan and the deposit rate. Whenever the bank increases lending, this implies a costly deviation from the capital ratio target, as equity builds up only sluggishly out of the retained earnings. This leads to a higher loan rate that, in turn, contributes to increasing dividends and lowering loan demand. These two factors support the capital ratio, which can converge back to the target. Finally, the resource constraint changes to

$$Y_t = c_t + \frac{\kappa}{2}\left(\frac{e_{t-1}}{l_{t-1}} - \nu\right)^2 e_{t-1} + \sum_{\tau=l,b} I_t^\tau + f(\tilde{b}_t) + L(\tilde{b}_t) + \delta^b e_{t-1} \ .$$

Figure 9 depicts our welfare measure for the baseline economy (blue) and an economy without bank frictions (red).[22] With the bank frictions, the optimal buffer is 7.95%, only slightly higher than our optimal buffer in the full model. These findings reveal that bank frictions are not an important driver of our results. Indeed, in the long-run mean, banks fulfill their target capital ratio because otherwise they pay cost for deviating permanently.

[22] We follow Gerali et al. (2010) and set $\kappa = 11$. We set the dividend payout ratio of banks to 0.6 to match the euro area data for 2010-2019 in Muñoz (2021). According to ECB supervisory banking statistics, the Core Equity Tier 1 ratio of euro area banks is around 15%, hence the ratio of bank equity to loans is $\nu = 0.15$. Other parameters are re-calibrated to retain a good fit of the model.

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