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To Bail-in or to Bailout: that's the (Macro) Question

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"To Bail-in or to Bailout: that's the (Macro) Question"*

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Abstract

In this paper we construct a dynamic general equilibrium model with limited liability banks to compare financial stability and macroeconomic outcomes under a regime in which banks are bailed out by the government with outcomes under a regime in which bank creditors are bailed in. We find that long-run investment, capital, output, and consumption are higher under the bailout regime. Bailouts also mitigate the impact of financial crises with respect to the bail-in regime, as lower funding costs increase banks' profitability. Bailouts, however, introduce moral hazard, which substantially increases the fraction of banks that need to be recapitalized from 0.24% per quarter under the bail-in regime to 3.12% per quarter under the bailout regime. The frequency of financial crises, however, hardly increases. Finally, we find that welfare is highest under the bailout regime.

Keywords: Bail-ins, Bailouts, Financial Intermediation, Macrofinancial Fragility

JEL Classification: E32, E44, E50

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1 Introduction

Bailouts of the financial sector substantially mitigated the macroeconomic impact of the Great Financial Crisis of 2007-2009 (Homar and van Wijnbergen, 2017). However, bailing out bank creditors also introduces moral hazard (Cordella and Yeyati, 2003; Gorton and Huang, 2004; Dam and Koetter, 2012; Keister, 2015): the knowledge that creditors will always be repaid, either by the bank when it is sufficiently profitable, or by the government when the bank is insolvent, implies that creditors no longer price in the probability of bank failure. This allows banks to lever up and take more risk with their balance sheet, thereby making financial crises more likely.

Among other reasons, bail-ins were introduced to mitigate this moral hazard problem: under a bail-in, failing banks are recapitalized by (partially) writing off or converting into equity the claims of bank creditors. Therefore, it is argued, creditors will correctly price in the probability of bank failure as they will lose funds when banks become insolvent.[1] By doing so, they prevent banks from leveraging up, as it becomes less profitable to do so. As a result, the financial system becomes safer, and financial crises less likely.

In this paper we investigate quantitatively whether bail-ins indeed enhance long-run financial stability by making bank failures and financial crises less likely with respect to a bailout regime. In addition, we intend to look beyond the financial stability perspective, and simultaneously look at the broader macroeconomic impact of these policies. To do so, we construct a unified dynamic general equilibrium model that encompasses both recapitalization policies, after which we simulate our economy for many periods and calculate the frequency with which financial crises occur and the average number of banks that fail under both policies. We also investigate which of these two policies is better in mitigating the macroeconomic impact of financial crises, as well as long-run macroeconomic outcomes and welfare. Finally, we compare both recapitalization policies with a policy in which insolvent banks are liquidated to see whether banks should be recapitalized at all.

To do so, we employ a small open economy real business cycle model that features banks that are subject to limited liability as in Gete and Melkadze (2020). Banks are financed through net worth and bank debt that is provided by risk-averse foreign creditors. These funds are used to acquire corporate securities that are issued by goods producers to acquire physical capital. The return on these securities is subject to an idiosyncratic risk shock of which the distribution is known (Bernanke et al., 1999; Christiano et al., 2014). We consider two types of economies: the liquidation economy and the recapitalization economy. In the first, banks are liquidated when they become insolvent. However, creditors recouping the bank's assets are subject to state verification costs that give rise to deadweight losses as in Gete and Melkadze (2020). In the second economy, insolvent banks are recapitalized. The required transfer is equal to the difference between the debt that has to be repaid and the realized return on corporate securities. In addition, extra net worth equal to

[1] The Cyprus crisis in 2013 was the first time a bail-in was employed to deal with a failing banking system. On March 25, 2013, Eurogroup chairman Jeroen Dijsselbloem motivated the bail-in decision in an interview with the Financial Times and Reuters in the following way: "If I finance a bank and I know if the bank will get in trouble I will be hit and I will lose money, I will put a price on that." (Spiegel, 2013).

an exogenous fraction of previous period assets is provided to ensure that the recapitalized banks continue to operate with positive net worth. The total transfer is divided between bank creditors that take a haircut on their claims (bail-in), and taxpayers that provide new funds (bailout). We solve the model using a global solution method to accurately capture the nonlinearities that arise from limited liability, moral hazard, and bank risk-taking. We then simulate the model for many periods, which allows us to investigate the long-run properties of both economies, as well as the dynamics around financial crises.

To the best of our knowledge, we are the first to explicitly model bank bail-ins within a dynamic general equilibrium model that features limited liability at the bank level. By constructing a macroeconomic model that encompasses both bail-ins and bailouts, our model is the first that is capable of not only comparing these policies from a financial stability perspective, but also from a macroeconomic perspective. Doing so sharply contrasts with the literature, in which bail-ins are almost exclusively investigated within stylized two- or three-period models within the corporate finance literature (Keister, 2015; Mendicino et al., 2017; Mitkov and Keister, 2021; Walther and White, 2020), or long-run simulations in dynamic partial equilibrium models with a microprudential perspective (Berger et al., 2018; Gross et al., 2018; Lambrecht and Tse, 2019).

Our first contribution is to show that the long-run average (ergodic mean) of macroeconomic variables such as investment, capital, output, and consumption are at least 20% higher under the bailout regime with respect to the bail-in regime. While both policies feature the same rule for determining the size of the transfer in net worth, banks' funding costs are always lower under the bailout regime because creditors do not price in the probability of bank insolvency. Therefore, banks' profitability and net worth are higher, everything else equal, which allows banks to provide more credit to the real economy than under the bail-in regime. As a result, investment and the physical capital stock increase, which leads to higher long-run output and consumption.

The absence of a link between the probability of insolvency and banks' funding costs sharply contrasts with the bail-in regime, which features a procyclicality between the probability of insolvency and banks' funding costs in financial crisis times: a higher probability of insolvency leads to higher funding costs, which in turn increase the probability of insolvency further etc. The absence of this procyclicality under the bailout regime substantially mitigates the credit contraction that takes place in a crisis, causing the drop in investment, capital, and output to be only half the respective drop under the bail-in regime. Therefore, bailouts are more effective in mitigating the macroeconomic impact of financial crises than bail-ins. However, consumption falls by more under the bailout regime, as households have to finance these bailouts, whereas bail-ins are financed by foreign creditors.

Our second contribution is to show that the impact of moral hazard on financial stability is mixed. On the one hand, the frequency of financial crises, defined as a drop in lending by bank creditors of more than two standard deviations (Bianchi, 2016; Gete and Melkadze, 2020), hardly increases for the bailout regime. The reason is that creditors are willing to finance the banks in times of crisis because they are also repaid in case of insolvency. On the other hand, the absence of a link between the probability of insolvency and banks' funding costs makes it profitable for banks to expand their balance sheet. As a result, long-run leverage increases by almost 40%, which causes the average fraction of banks that need to be recapitalized to increase from 0.24% per quarter under the bail-in regime to 3.12% per quarter under the bailout regime. From this point of view, moral hazard provides a substantial contribution to financial instability.

Our third contribution is to show that the level of welfare is highest under the bailout regime. This is perhaps a surprising conclusion, as bailouts are financed by domestic households who therefore see their incomes reduced, whereas bail-ins are financed by foreign creditors. This result is driven by the fact that long-run consumption increases nonlinearly with the fraction of the recapitalization that is financed by taxpayers. This positive effect trumps the negative effect on consumption from households having to finance not only a larger fraction of the recapitalization but also more bailouts, as the number of insolvencies increases with the fraction of the recapitalization that is financed through a bailout. Interestingly, the welfare cost of business cycles is the highest for the bailout regime, as consumption varies most with the state of the business cycle as a result of households financing the bailouts.

Finally, we confirm that both recapitalization policies improve macroeconomic outcomes and welfare with respect to the liquidation economy, both in the short- and long-run: recapitalizations provide insolvent banks with new net worth, which allows the aggregate banking sector to expand credit provision to the real economy with respect to the liquidation economy, especially in financial crisis times. As a result, investment, the capital stock and output increase. Financial stability as measured by the number of insolvencies and the frequency of crises, improves under the bail-in regime, as bail-ins increase aggregate net worth, which allows banks to operate with lower leverage ratios than under the liquidation regime. Interestingly, financial stability deteriorates under the bailout regime because moral hazard increases leverage, and therefore leads to more insolvencies than under the liquidation regime.

Literature review

This paper builds upon the literature that incorporates financial frictions and default in macroeconomic models, specifically Gete and Melkadze (2020).[2] Our paper extends their model by including the possibility of bank recapitalizations through bail-ins and bailouts, in which case state verification costs are absent.

Macroeconomic papers which feature bank bail-ins or other forms of debt write-downs are scarce. Breuss et al. (2015) investigate the macroeconomic effects of a one-off unanticipated lump sum contribution by depositors to banks, while Hollander (2017) looks at the effectiveness of converting contingent convertible capital (CoCos) into equity. Both papers look at a one-off recapitalization

[2] Other important papers in the literature on financial frictions and business cycles are Bernanke et al. (1999), Gertler and Kiyotaki (2010),Gertler and Karadi (2011), and Christiano et al. (2014).

that is unanticipated, whether our bail-ins (as well as the bailouts) are anticipated by bank creditors. Another difference is that the models of Breuss et al. (2015) and Hollander (2017) are solved using a first order approximation around the steady state, whereas we employ a global solution method. As such, we can also investigate the long-run financial stability effects of the different recapitalization policies.

In contrast to bail-ins, the financial stability effects from bailouts have been studied within macroeconomic general equilibrium models. Bianchi (2016) shows that whether or not moral hazard increases risk-taking by banks depends on whether bailouts are conditional on aggregate conditions (systemic bailout) or on idiosyncratic banks' decisions, in which case the negative effects from moral hazard are most pronounced. A key contribution is that Bianchi (2016) finds that welfare increases ex ante for systemic bailouts, despite the presence of moral hazard. The main difference with our paper is the way in which moral hazard arises within the model. In Bianchi (2016) the debt issued by banks is already risk-free in the absence of a bailout. Moral hazard then arises because bank managers are not ousted after a bailout, and therefore take the anticipated government funds into account when deciding how much debt to issue. Unlike Bianchi (2016), we find that bank-specific bailouts improve ex ante welfare with respect to welfare under the bail-in regime and the liquidation regime. The reason is that bailouts reduce banks' funding costs with respect to the other regimes (in which debt is risky), an effect that is absent in Bianchi (2016) where banks already borrow at the risk-free rate in the absence of a bailout.

In our paper, bailouts negatively affect financial stability ex ante because of moral hazard, but positively ex post because additional net worth allows banks to expand credit to the real economy. Van der Kwaak and Van Wijnbergen (2014), Van der Kwaak and Van Wijnbergen (2017), Farhi and Tirole (2018), and Abad (2019), however, show that bailouts can have a negative effect on financial stability ex post in the presence of the diabolic loop between weak banks and weak sovereigns. This happens when additional government borrowing (to finance the recap) leads to capital losses on banks' existing holdings of government bonds that are large enough to offset the gains in net worth from the bailout.

Since we investigate how long-run financial stability is affected by the two recapitalization policies, our paper is also connected to the literature on macroprudential policies within dynamic general equilibrium models. Bianchi (2011) and Bianchi and Mendoza (2018) study how taxes affect borrowing decisions, and to what extent such taxes reduce the incidence and severity of financial crises in open economies that are subject to borrowing constraints. A survey of this literature can be found in Bianchi and Mendoza (2020). Higher capital requirements also enhance financial stability, but create a tradeoff with credit provision to the real economy (Mendicino et al., 2018, 2020a,b; Gertler et al., 2020a,b).

Although the above-mentioned papers feature macroeconomic general equilibrium models, most papers that study financial stability issues are found in the corporate finance literature (Farhi and Tirole, 2012; Keister, 2015; Mitkov and Keister, 2021). Farhi and Tirole (2012) study how bailouts affect financial stability and banks' incentives to take risk. They find that the anticipation of a bailout induces banks to correlate risks, which results in excessive financial fragility. Whereas Farhi and Tirole (2012) focus on how ex ante regulation might rule out bailouts in equilibrium, we investigate an alternative recapitalization policy that is not discussed in Farhi and Tirole (2012), namely bail-ins, which also eliminate the moral hazard problems that arise from bailouts. A second distinction is that welfare under a bailout regime decreases in Farhi and Tirole (2012), because they model deadweight costs that are absent under our bailout policy.

Similar to our paper, Keister (2015) studies the trade-off between the negative effects that bailouts have on risk-taking by banks, and the positive ex post benefits in the form of preventing (self-fulfilling) bank runs within an extension of the famous Diamond and Dybvig (1983) model. Interestingly, he finds that a no bailout policy can actually *increase* financial fragility by raising each individual's incentive to withdraw early. In contrast to Keister (2015), we find that financial fragility, as measured by the fraction of banks that become insolvent, deteriorates substantially under the bailout policy. Keister (2015) also studies a policy mix in which the positive ex post effects of bailouts are preserved while eliminating the negative ex ante effects on risk-taking by taxing intermediaries' short-term liabilities, as this reduces intermediaries' incentive to lever up. This policy is similar in spirit to our bail-in policy in the sense that debt financing under the bail-in policy becomes more expensive with respect to the bailout regime. This reduces the incentive for banks to lever up, while insolvent banks are recapitalized ex post. We also find that financial stability is best served under such a policy.

Papers that compare the three different regimes (bail-ins, bailouts, and liquidation) can be found in dynamic, continuous-time partial equilibrium asset pricing models (Lambrecht and Tse, 2019; Correia et al., 2017; Berger et al., 2018; Gross et al., 2018). These models have a microprudential focus, as they focus on the lending behavior and net value created by an individual bank, and therefore cannot study the impact of these policies on the macroeconomy.

Unlike our paper, Lambrecht and Tse (2019) allows for banks to endogenously choose the quality of the loans they extend to the real economy. As in our paper, the probability of insolvency is highest under the bailout regime. Unlike our paper, managers retain skin in the game in case of bailouts and bail-ins. Despite this difference, Lambrecht and Tse (2019) also find that leverage and the probability of insolvency is lowest under the bail-in regime, while leverage and lending activity are highest under the bailout regime. However, they find that the probability of insolvency is lowest under the liquidation regime, whereas this probability is lowest under the bail-in regime in our model (although the difference with the liquidation economy is small). This is driven by the fact that banks in Lambrecht and Tse (2019) endogenously choose the payout rate, whereas our payout rate is exogenous and constant across time. Banks in Berger et al. (2018) take investment, the payout rate and the riskiness of assets as given, and compare how the different regimes affect the initial capitalization decision, the size of the subordinated debt, the future recapitalization strategy, and the bank's net market value.

This paper is structured as follows. Section 2 presents the model, and section 3 discusses the global solution method we use and the calibration of the model. Section 4 analyzes the effects of bail-ins on long-run financial stability and the response to shocks in the short run. Finally, Section 5 concludes.

2 Model

We construct a small open economy RBC model featuring households, banks, productions firms, and foreign lenders, which is inspired by Gete and Melkadze (2020). Bankers are financed by accumulated net worth and risky debt that is financed by risk-averse foreign investors. Bankers use these funds to acquire corporate securities issued by production firms. These securities are hit by a bank-specific shock when repayment is due, the distribution of which is the same across banks and time. Banks with low realizations of the shock become insolvent, in which case they are liquidated. In an alternative setup we deviate from Gete and Melkadze (2020) by allowing banks to be recapitalized. Such recaps can be financed in two ways. First, creditor claims can be (partially) written down in a bail-in. Second, the government can bail out the bank by injecting new net worth, which is financed by raising lump sum taxes on households. Importantly, a recapitalization prevents a liquidation of bank assets, and thus avoids the deadweight losses from liquidation (Bernanke et al., 1999).

The rest of the economy is relatively standard: households supply labor to the production sector and use all income after lump sum taxes for consumption. Final goods are produced by combining labor and physical capital, the last of which is financed by selling corporate securities to banks.

2.1 Banks

2.1.1 Liquidation economy

A continuum of banks $j \in [0, 1]$ acts as intermediary between savers and borrowers. Bank j enters period t with net worth $n_{j,t}$. It first pays out a fraction $1 - \vartheta$ in dividends to the owners of the bank, where ϑ is exogenous and constant across time (Gertler and Karadi, 2011). Next, bank j purchases corporate securities $s^k_{j,t+1}$ issued by final goods producers at a price q^k_t. These securities are financed by retained net worth $\vartheta n_{j,t}$ and short-term debt $q_t d_{j,t+1}$, which promises to pay $d_{j,t+1}$ units of the final good in period $t + 1$ and is purchased by foreign investors at price q_t. Hence, bank j's balance sheet is given by:

$$q^k_t s^k_{j,t+1} = \vartheta n_{j,t} + q_t d_{j,t+1}. \tag{1}$$

After the realizaton of aggregate shocks, corporate securities pay a gross return R^k_{t+1} in period $t + 1$. However, bank j 's effective return on securities is $\omega_{t+1} R^k_{t+1} q^k_t s^k_{j,t+1}$, as bank j is subject to an idiosyncratic shock ω_{t+1} that follows a log normal distribution with mean 1 (Bernanke et al., 1999; Christiano et al., 2014; Gete and Melkadze, 2020). Thus, there exists a threshold level $\bar{\omega}_{j,t}$ below which bank j becomes insolvent, and is forced to default:

$$\bar{\omega}_{j,t} \equiv \frac{d_{j,t}}{R_t^k q_{t-1}^k s_{j,t}^k} = \frac{d_{j,t}^k}{R_t^k q_{t-1}^k}, \tag{2}$$

where $d_{j,t}^k \equiv d_{j,t}/s_{j,t}^k$ denotes the debt-to-assets ratio. Hence we immediately see that the threshold level $\bar{\omega}_{j,t}$, and therefore the probability of insolvency, increases with $d_{j,t}^k$. Creditors, however, can only recoup a fraction $1-\mu$ of bank j's assets in case of insolvency, as a fraction μ is lost because of deadweight losses from bankruptcy (Bernanke et al., 1999). The recouped funds are paid pro-rata among the bank's creditors. When $\omega_t > \bar{\omega}_{j,t}$, bank j repays its creditors, and realizes a pre-dividend net worth $n_{j,t}$ that is equal to:

$$n_{j,t} = \omega_t R_t^k q_{t-1}^k s_{j,t}^k - d_{j,t}. \tag{3}$$

Foreign investors' holdings of debt are perfectly diversified across domestic banks. The price of one unit of debt q_t is such that it is in expectation equal to the (discounted) expected cash flows next period, which equal one unit of final goods from banks with $\omega_{t+1} > \bar{\omega}_{j,t+1}$, and $(1-\mu)\,\omega_{t+1} R_{t+1}^k q_t^k s_{j,t+1}^k / d_{j,t+1}$ units of final goods from banks that are insolvent ($\omega_{t+1} < \bar{\omega}_{j,t+1}$).

Foreign investors, however, are risk averse.[3] Therefore, they value the future cash flows with the following stochastic discount factor $m_{t,t+1}^*$ (Vasicek, 1977; Arellano and Ramanarayanan, 2012; Bianchi and Sosa-Padilla, 2020; Johri et al., 2020):

$$m_{t,t+1}^* = \exp\left[-r_t^* - \kappa\left(\varepsilon_{a,t+1} + \frac{1}{2}\kappa\sigma_a^2\right)\right],$$

where r_t^* is the stochastic world risk-free rate, κ the degree of risk aversion, and $\varepsilon_{a,t}$ and σ_a^2 are a shock to and the variance of domestic total factor productivity, respectively. As a result, domestic productivity shocks will affect banks' funding costs, and will therefore influence the amount of debt issued in equilibrium. In addition, an increase in the world risk-free rate reduces foreign investors' incentive to save, everything else equal, and will therefore increase the interest rate on bank debt beyond the increase in the world risk-free rate.

[3] We need some degree of risk aversion in the bailout economy that is to be introduced in the next subsection. Without it, the interest rate on bank debt would be equal to the exogenous world interest rate and would not change in response to productivity shocks. This would render the model with bailouts to be non-stationary, in which case we would not be able to solve this model version.

By using the stochastic discount factor $m^*_{t,t+1}$, we obtain the following pricing equation for bank debt:

$$q_t = \mathbb{E}_t \left\{ m^*_{t,t+1} \left[\underbrace{\int_{\bar{\omega}_{j,t+1}}^{\infty} 1 \cdot f(\omega_{t+1}) \, d\omega_{t+1}}_{\substack{\text{Debt repaid by} \\ \text{solvent banks.}}} + \underbrace{(1-\mu) \int_0^{\bar{\omega}_{j,t+1}} \left(\frac{\omega_{t+1} R^k_{t+1} q^k_t s^k_{j,t+1}}{d_{j,t+1}} \right) f(\omega_{t+1}) \, d\omega_{t+1}}_{\substack{\text{Recovered funds from insolvent banks} \\ \text{per unit of bank debt, net of recovery cost } \mu.}} \right] \right\}. \tag{4}$$

Bank j maximizes the sum of today's dividend payment $(1-\vartheta) n_{j,t}$ and the expected continuation value $\max(V_{j,t+1}, 0)$, which is discounted by households' stochastic discount factor $\beta \Lambda_{t,t+1}$, as households are the ultimate owners of the banks. Bank j's optimization problem is therefore given by:

$$V_{j,t} = \max_{\left\{s^k_{j,t+1}, d_{j,t+1}\right\}} (1-\vartheta) n_{j,t} + \mathbb{E}_t \left[\beta \Lambda_{t,t+1} \max(V_{j,t+1}, 0) \right], \tag{5}$$

subject to bank j's balance sheet constraint (1), the insolvency threshold (2), the law of motion for net worth (3), and foreign investors' demand for bank debt (4). Therefore, banks explicitly take into account how higher insolvency risk impacts their funding costs (Gete and Melkadze, 2020).

Bankers from insolvent banks exit the financial industry and are replaced by a new banker from the same household, thereby keeping the number of banks equal across time (Gertler and Karadi, 2011). New bankers receive a transfer from their respective household, the aggregate size of which equals χ_b (Gete and Melkadze, 2020). We show in Appendix A.3 that all banks choose the same cut-off value $\bar{\omega}_{j,t} = \bar{\omega}_t$ in equilibrium. Therefore, the aggregate law of motion of pre-dividend net worth is given by:

$$n_t = \int_{\bar{\omega}_t}^{\infty} \left(\omega_t R^k_t q^k_{t-1} s^k_t - d_t \right) f(\omega_t) \, d\omega_t + \chi_b. \tag{6}$$

At the beginning of each period, banks (including the newly started banks) pay out a fraction $1-\vartheta$ of net worth $n_{j,t}$ to their respective households.[4] Therefore, aggregate dividends Ω_t to households are given by:

$$\Omega_t = (1-\vartheta) n_t. \tag{7}$$

[4] Newly started banks immediately pay dividends before issuing new debt to acquire corporate securities. Not doing so would force us to write down a separate optimization problem for newly started banks which features the balance sheet constraint $q^k_t s^k_{j,t+1} = n_{j,t} + q_t d_{j,t+1}$. That would contrast with the optimization problem of existing banks, which features equation (1). Therefore, allowing newly starting banks to not pay dividends in the initial period would severely complicate aggregation across all banks.

Finally, aggregate losses n_t^d for foreign creditors are given by:

$$n_t^d = \int_0^{\bar{\omega}_t} \left[d_t - (1-\mu)\,\omega_t R_t^k q_{t-1}^k s_t^k\right] f(\omega_t)\, d\omega_t$$
$$= \int_0^{\bar{\omega}_t} (\bar{\omega}_t - \omega_t)\, R_t^k q_{t-1}^k s_t^k f(\omega_t)\, d\omega_t + \int_0^{\bar{\omega}_t} \mu\omega_t R_t^k q_{t-1}^k s_t^k f(\omega_t)\, d\omega_t, \quad (8)$$

where we employed equation (2).

2.1.2 Recapitalization economy

Instead of liquidating insolvent banks, the government might decide to have these banks recapitalized, as happened in the Great Financial Crisis of 2007-2009 and afterwards. The resulting transfer $n_{j,t}^\tau$ to an insolvent bank j consists of two components. First, bank j is provided with the difference between the funds owed to its creditors and the gross return on its corporate securities: $d_{j,t} - \omega_t R_t^k q_{t-1}^k s_{j,t}^k = (\bar{\omega}_{j,t} - \omega_t)\, R_t^k q_{t-1}^k s_{j,t}^k$. The second component is provided to ensure bank j continues to operate with positive net worth, and is equal to a fraction ζ of previous period assets, valued at today's price of corporate securities: $\zeta q_t^k s_{j,t}^k$.[5] Therefore, the total transfer $n_{j,t}^\tau(\omega_t)$ to insolvent bank j, which is a function of the idiosyncratic shock ω_t, is equal to:

$$n_{j,t}^\tau(\omega_t) = (\bar{\omega}_{j,t} - \omega_t)\, R_t^k q_{t-1}^k s_{j,t}^k + \zeta q_t^k s_{j,t}^k, \quad \omega_t < \bar{\omega}_{j,t}. \quad (9)$$

There are three ways in which this transfer can be financed. First, the government can impose losses on the private sector by writing down creditors' claims by an amount $n_{j,t}^\tau(\omega_t)$, a so-called bail-in (European Commission, 2014; Gross et al., 2018; Hüser et al., 2018). Second, the government can employ public funds to inject new net worth, a so-called bailout. Third, the government can employ a combination of a bail-in and a bailout: in that case, it imposes losses equal to a fraction $1-\xi$ of the total transfer on bank j's creditors, while injecting a fraction ξ of the transfer through public funds. The last case encompasses both the first and second case by setting $\xi = 0$ and $\xi = 1$, respectively.[6]

Just as in the liquidation economy, foreign investors are perfectly diversified across domestic banks. Therefore, the price of debt q_t is again determined by discounting the expected cash flows next period by the stochastic discount factor $m_{t,t+1}^*$. However, for banks that are insolvent $(\omega_{t+1} < \bar{\omega}_{j,t+1})$, the cash flow per unit of debt will now be equal to $1 - (1-\xi)\, n_{j,t+1}^\tau(\omega_{t+1})\,/d_{j,t+1}$,

5 We value last period's corporate securities at today's price because otherwise an additional state variable q_{t-1}^k would be introduced. Since we solve the model using global solution methods, see Section 3, we try to minimize the number of state variables.

6 Typically, equity holders are entirely wiped out or heavily diluted in case of a bail-in or bailout. We could model this by (temporarily) suspending dividend payments by setting $\vartheta = 1$ for banks with $\omega_t < \bar{\omega}_{j,t}$. Doing so, however, would prevent us from solving the value function for bankers. Therefore, even insolvent banks pay a fraction $1-\vartheta$ of net worth (ex post recapitalization) to its owners. Observe that doing so will not tilt our comparison between bail-ins and bailouts in one direction or the other, as the rule for dividend payments is the same in both economies, and dividend payments continue in both economies.

instead of $(1-\mu)\,\omega_{t+1}R^k_{t+1}q^k_t s^k_{j,t+1}/d_{j,t+1}$ in the liquidation economy. As a result, the pricing equation for bank debt is now given by:

$$q_t = \mathbb{E}_t\left\{ m^*_{t,t+1}\left[\left[\underbrace{\int_0^{\infty} 1\cdot f\left(\omega_{t+1}\right) d\omega_{t+1}}_{\text{Debt repaid by banks.}} - \underbrace{(1-\xi)}_{\substack{\text{Share financed}\\ \text{by creditors.}}}\underbrace{\int_0^{\bar{\omega}_{j,t+1}}\left(\frac{n^{\tau}_{j,t+1}\left(\omega_{t+1}\right)}{d_{j,t+1}}\right) f\left(\omega_{t+1}\right) d\omega_{t+1}}_{\substack{\text{Transfer per unit of bank debt}\\ \text{in case of insolvency.}}}\right]\right]\right\}, \tag{10}$$

We assume that the manager operating bank j is replaced by a member of the same household when the bank becomes insolvent, irrespective of whether bank j is liquidated or recapitalized. As a consequence, the banker does not take into account that bank j will continue to operate after the recapitalization, as he or she still has to exit when $\omega_t < \bar{\omega}_{j,t}$. Therefore, the maximization objective (5) remains the same as in the case where bank j is liquidiated. As a result, the only difference with the optimization problem in the liquidation economy is that foreign investors' demand for bank debt (4) is replaced by equation (10).

Again, we show in Appendix A.3 that all banks choose the same cut-off value $\bar{\omega}_{j,t} = \bar{\omega}_t$ in equilibrium. Therefore, the aggregate law of motion for net worth in an economy where insolvent banks are recapitalized is given by:

$$n_t = \int_{\bar{\omega}_t}^{\infty}\left(\omega_t R^k_t q^k_{t-1} s^k_t - d_t\right) f\left(\omega_t\right) d\omega_t + \Xi^b_t, \tag{11}$$

with Ξ^b_t the transfer received by insolvent banks:

$$\Xi^b_t = \int_0^{\bar{\omega}_t}\left[\left(\bar{\omega}_t - \omega_t\right) R^k_t q^k_{t-1} s^k_t + \zeta q^k_t s^k_t\right] f\left(\omega_t\right) d\omega_t. \tag{12}$$

Hence, a recapitalization leads to an increase in aggregate net worth n_t with respect to the liquidation economy, everything else equal.

2.2 Households

Households are infinitely lived and have identical preferences. A fraction f of household members are workers and a fraction $1-f$ bankers, with perfect consumption insurance among all members (Gertler and Karadi, 2011). Households receive wages $w_t h_t$ from providing labor h_t, profits $\mathcal{P}^k_t$ from production firms, and dividends $\Omega_t = (1-\vartheta)\,n_t$ from banks. Households are hand-to-mouth and spend their income on consumption c_t, transfers to new bankers $\mathbb{1}_L \cdot \chi_b$, and lump sum taxes $\tau_t = (1-\mathbb{1}_L)\,\xi\Xi^b_t$, where $\mathbb{1}_L$ denotes an indicator function. This indicator function is equal to one in the liquidation economy, and zero in the recapitalization economy. The household's optimization problem is to maximize expected discounted lifetime utility:

$$\max_{\{c_{t+s},h_{t+s}\}_{s=0}^{\infty}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[\frac{\left(c_{t+s} - \frac{\chi}{1+\varphi} h_{t+s}^{1+\varphi}\right)^{1-\sigma} - 1}{1-\sigma} \right] \right\}, \tag{13}$$

$$\beta \in (0,1), \varphi \geq 0, \tag{14}$$

subject to the household's budget constraint:

$$c_t + \tau_t + \mathbb{1}_L \cdot \chi_b = w_t h_t + \mathcal{P}_t^k + \Omega_t.$$

We use Greenwood et al. (1988) (GHH) preferences to eliminate the wealth effect in labor supply. The first order conditions are standard and can be found in Appendix A.1.

2.3 Non-financial firms

A continuum of perfectly competitive final goods producers $i \in [0,1]$ raises funds in period $t-1$ by issuing securities $s_{i,t}^k$ at a price q_{t-1}^k to banks. Final goods producers use these funds to buy physical capital $k_{i,t} = s_{i,t}^k$ from capital goods producers at a price q_{t-1}^k, while credibly pledging next period's after-wage profits to the banks that purchase their securities (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011). After realization of a productivity shock a_t at the beginning of period t, final goods producers hire labor $h_{i,t}$ in a perfectly competitive labor market. Next, they produce output $y_{i,t}$ using a production function that is constant returns to scale in capital $k_{i,t}$ and labor $h_{i,t}$. After production, the depreciated capital stock $(1-\delta) k_{i,t}$ is sold to capital goods producers at a price q_t^k. The gross return on corporate securities is derived in Appendix A.2.1, and is given by:

$$R_t^k = \frac{\alpha a_t k_t^{\alpha-1} h_t^{1-\alpha} + (1-\delta) q_t^k}{q_{t-1}^k}, \tag{15}$$

Capital goods producers acquire final goods i_t, and convert these into capital goods subject to Jermann (1998)-style adjustment costs, while the old capital stock is converted one-for-one into new capital goods. Capital therefore evolves according to:

$$k_{t+1} = (1-\delta) k_t + \left[a_k + \frac{b_k}{1 - 1/\kappa_k} \left(\frac{i_t}{k_t} \right)^{1-1/\kappa_k} \right] k_t. \tag{16}$$

The entire stock of newly produced capital is then sold to final goods producers at a price q_t^k. Capital goods producers maximize the sum of current and expected discounted future profits. A more elaborate description of the production sector can be found in Appendix A.2.

2.4 Market clearing

In equilibrium, the number of corporate securities issued by final goods producers has to be equal to the physical capital stock:

$$s_{t+1}^k = k_{t+1}. \tag{17}$$

Aggregate demand is given by the sum of consumption, investment, and net exports x_t^j and must equal aggregate supply:

$$y_t = c_t + i_t + x_t^j, \tag{18}$$

where $j = \{L, R\}$ to denote the liquidation economy L and the recapitalization economy R, respectively. We show in Appendix A.4 that net exports x_t^j are given by:

$$x_t^j = \int_0^{\bar{\omega}_t} \omega_t R_t^k q_{t-1}^k k_t f(\omega_t)\, d\omega_t + \int_{\bar{\omega}_t}^{\infty} d_t f(\omega_t)\, d\omega_t - q_t d_{t+1} - (1 - \mathbb{1}_L)(1 - \xi)\, \Xi_t^b,$$

where $\mathbb{1}_L$ denotes the earlier defined indicator function. Finally, we define bank leverage l_t as total assets over net worth:

$$l_t = \frac{q_t^k k_{t+1}}{n_t}, \tag{19}$$

and the interest rate on bank debt R_t^d as the inverse of the price of short-term debt q_t:

$$R_t^d = \frac{1}{q_t} \tag{20}$$

3 Solution method and calibration

3.1 Numerical solution method

We solve the model using a global solution method. We do so to accurately capture the models' nonlinearities. As we want to analyze how bail-ins and bailouts affect macrofinancial stability, we must have a solution method that is accurate in regions of the state space that are far away from the deterministic steady state. Furthermore, precautionary behavior is central to analyzing the model's financial stability properties as creditors will price in bank insolvencies in anticipation of negative future shocks. The extent to which banks' funding costs are affected by the expected number of insolvencies crucially depends on whether the economy is about to enter a financial crisis or not. This nonlinear effect cannot properly be captured by a linear approximation around the deterministic steady state. Therefore, we employ global solution methods.

Specifically, we employ a policy function iteration method based on Coleman (1990) in combination with linear interpolation to solve for future variables as advocated by Richter et al. (2014). We have two exogenous state variables, a, r^*, and two endogenous state variables k, d^k with $d^k \equiv d/k$. We create a discrete grid of size $k \times d^k \times a \times r^*$, and discretize the exogenous shocks using the Rouwenhorst (1995) method. An elaborate description of the numerical procedure can be found in Appendix E.

3.2 Calibration

We calibrate the model on a quarterly frequency using a relatively standard calibration to keep the model close to the existing literature on financial frictions. The resulting parameter values can be found in Table 1. We set the subjective discount factor β equal to 0.985 following Gete and Melkadze (2020). Next, we set risk aversion σ to 2, the capital share α to 1/3, and the capital depreciation rate δ to 0.025, which are standard values in the business cycle literature. We set the inverse Frisch elasticity φ to 1, after which we adjust the disutility of labor supply coefficient χ to ensure that households approximately work one third of their time endowment in the liquidation economy. The investment adjustment cost parameter κ_k targets a standard deviation of investment that is about four times that of output in the ergodic distribution. The other two parameters of the capital adjustment cost function, a_k and b_k are set such that $q^k = 1$ and $i = \delta k$ in the steady state.

On the financial side of the economy we set r^* such that the annual risk free rate is equal to 4%. Foreign investors' risk aversion coefficient κ is set to 2.5 following Johri et al. (2020). We set the fraction of retained net worth ϑ, the recovery cost μ, and the dispersion of the idiosyncratic return shock σ_ω to target the following moments in the stochastic steady state of the liquidation economy: a leverage ratio $l = q^k s^k / n$ of around 5, a bank funding spread $R^d - (1 + r^*)$ of approximately 40 basis points per year, and a credit spread $R^k - R^d$ of around 300 basis points per year (Gilchrist and Mojon, 2018).[7] We hit these targets by setting the fraction of retained net worth ϑ to 0.95, the liquidation cost μ to 0.30, and the dispersion of the idiosyncratic return shock σ_ω to 0.075. Our calibration of the fraction of retained net worth is close to the values used in the financial frictions literature for the expected survival rate when bankers are finitely lived (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011, 2013). We set the aggregate startup transfer to new bankers χ_b to 0.0001 in the liquidation economy following Gete and Melkadze (2020). χ_b is zero in the recapitalization economy, as banks are recapitalized rather than liquidated upon insolvency. We set the parameter ζ, which determines the amount of net worth with which an insolvent bank will operate after the recapitalization, equal to the recovery cost μ in the liquidation economy.[8]

We set the parameters of the autoregressive processes for a_t and r_t^* such that the unconditional probability that the economy experiences a financial crisis is about 3% and the standard deviation of output growth σ_g is around 0.6% (Mendicino et al., 2020a; Schularick and Taylor, 2012).

[7] Average leverage ratios in the Euro Area are around 10 (Gerali et al., 2010). However, corporate securities in our model are essentially equity claims. Therefore, a leverage ratio of 10.7 would overstate the risk from fluctuations in asset prices to banks' net worth. Therefore, we reduce the leverage ratio to 5, see Gertler and Karadi (2013) for a more elaborate explanation on this point.

[8] We check in our simulations that creditors' losses under a full bail-in (expression (12) with $\xi = 0$) are always smaller than their losses in the liquidation economy (expression (8)), as a key requirement of a bail-in is that creditors are better off than under a bankruptcy (European Commission, 2014).

Table 1 Model calibration

Parameter	Value	Definition	Target/Source
β	0.985	Subjective discount factor	Literature
σ	2	Risk aversion	Literature
φ	1	Inverse Frisch elasticity	Literature
χ	5.446	Disutility of labor	Hours $h \approx 1/3$ in liq. economy
α	0.33	Capital share in output	Literature
δ	0.025	Depreciation rate	Literature
κ_k	4	Capital adjustment cost parameter	$\sigma_i/\sigma_y = 4$
a_k	-0.0083	Constant in capital adjustment cost function	$i = \delta k$
b_k	0.3976	Constant in capital adjustment cost function	$q^k = 1$
ϑ	0.95	Dividend payout rate of bankers	$l = 5$
χ_b	0.0001, 0	Endowment for new bankers	Gete and Melkadze (2020)
μ	0.30	Bank default cost in no-bail-in economy	Bank asset spread
ζ	0.30	Size of write-down in bail-in economy	Equal to μ
σ_ω	0.075	Dispersion of i.i.d. idiosyncratic return shock	Bank funding spread
κ	2.5	Foreign investors' risk aversion	Johri et al. (2020)
r^*	0.0101	Steady state net foreign interest rate	Annual risk free rate of 4%
a	1	Steady state productivity	Normalization
ρ_r	0.9	AR(1) parameter of foreign interest rate shock	Frequency and severity of crises
σ_r	0.0005	Std. dev. of foreign interest rate shock	Frequency and severity of crises
ρ_a	0.875	AR(1) parameter of productivity shock	σ_g approx. 0.6%
σ_a	0.00375	Std. dev. of productivity shock	σ_g approx. 0.6%

4 Quantitative results

In this section we present our numerical results. First, we will investigate impulse response functions from a productivity and a world interest rate shock to get familiar with the dynamics of the model. Afterwards, we will simulate the model for many periods, and investigate the dynamics of the different economies in financial crisis times to learn how well each policy is capable of mitigating the impact of financial crises. Then we will look at the unconditional average of the ergodic distribution, which we will refer to as the long-run average, for several financial and macroeconomic variables. This allows us to investigate how each policy affects (long-run) financial stability and macroeconomic outcomes. Finally, we compare welfare in both the liquidation economy as well as the recapitalization economies.

4.1 Impulse response functions

To investigate the short-run response of our economies, we look at impulse response functions from a productivity shock and a world interest rate shock. First, we compare an economy where insolvent banks are liquidated with an economy where banks are recapitalized through a bail-in. We compare these two economies first, as their impulse response functions turn out to be qualitatively similar. Afterwards, we compare a recapitalization through a bail-in with a recapitalization that is financed through a bailout.

4.1.1 Liquidation vs. bail-in

In Figure 1 the economy is initially in the stochastic steady state, and then experiences a negative productivity shock of 0.75%. The blue solid line represents the impulse response functions of an economy where banks are liquidated when they become insolvent. The red dashed line represents the case where they are recapitalized through a bail-in ($\xi = 0$), while the black slotted line represents the case where they are recapitalized through a bailout ($\xi = 1$). As mentioned above, we first compare the liquidation economy with the bail-in economy. We immediately observe that the impulse response functions are qualitatively very similar. Therefore, we will first discuss the mechanisms that are common in both economies, and only afterwards discuss the differences.

We see in Figure 1 that a negative productivity shock reduces the unconditional return on corporate securities on impact, which directly decreases banks' net worth. Lower aggregate productivity decreases the marginal product of capital, and therefore the (expected) return on corporate securities, which in turn reduces the profitability of credit intermediation. A second effect through which banks' profitability decreases is an increase in banks' funding costs. This occurs because foreign investors price in the higher probability of bank insolvency, which increases because of two mechanisms. First, the decrease in banks' expected profitability makes it more likely that banks will become insolvent, everything else equal. Second, a larger fraction of banks' balance sheets has to be financed with debt since there is fewer net worth in the banking system. This, in turn, leads to a more leveraged banking system, which further increases the probability of insolvency.

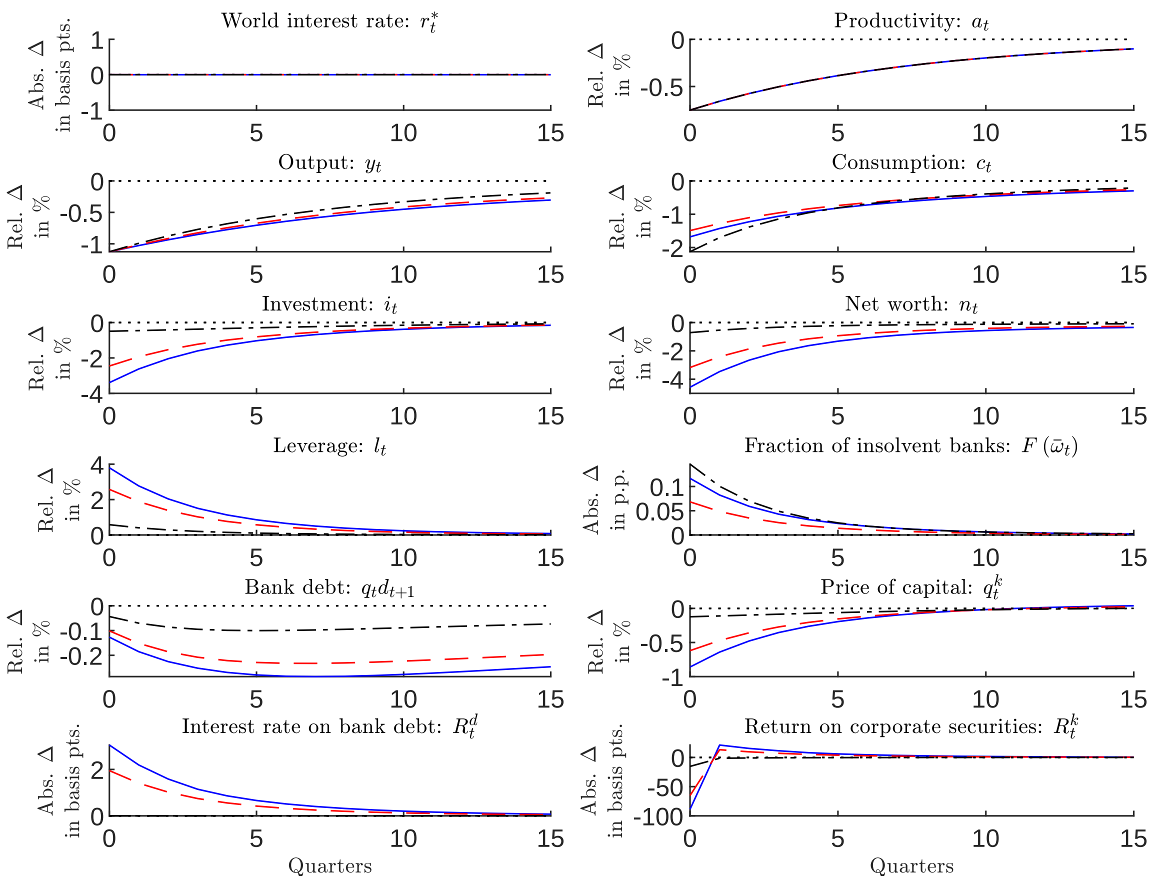


Figure 1. Impulse response functions following a negative productivity shock of 0.75% for the liquidation economy (blue, solid), the bail-in economy (red, dashed), and the bailout economy (black, slotted). All economies are initially in the stochastic steady state.

The resulting decrease in net worth causes a contraction in the credit supply. As a result, the demand for physical capital falls, which causes a drop in the price of capital. These capital losses further decrease the unconditional return on corporate securities, see the second term of expression (15). As a result net worth decreases further, giving rise to a financial accelerator effect (Bernanke et al., 1999; Gete and Melkadze, 2020).

These financial sector dynamics amplify the effects that the negative productivity shock has on the real economy: a lower credit supply leads to lower investment, and therefore a lower capital stock. The productivity shock also causes the marginal product of labor to decrease, which reduces households' labor supply. In addition to lower labor income, households' income also decreases because bank dividends $\Omega_t = (1 - \vartheta)\, n_t$ decrease. Consumption decreases immediately as a result, since households consume their entire income.

Although the qualitative response in both economies is the same, financial conditions improve in the bail-in economy relative to the liquidation economy. This is caused by the fact that bail-ins increase aggregate net worth, which reduces the fraction of their balance sheet that is financed by bank debt, see panel "Leverage". As a result, the probability of insolvency decreases (relative to the liquidation economy), which leads to a lower interest rate on bank debt. Lower funding costs, in turn, increase banks' profitability, which causes the credit supply and the *level* of bank debt to increase, and consequently investment (relative to the liquidation economy).

Note, however, that the increase in investment hardly increases output. Although bail-ins improve financial conditions, the origins of the recession are in the real economy, and are not addressed by the bail-ins. With output approximately the same in the two economies, the (small) increase in consumption and investment is offset by a decrease in net exports (not shown). This decrease is driven by a capital inflow, as Figure 1 shows that bank debt increases with respect to the liquidation economy.

Next, we investigate in Figure 2 the impulse response functions to a shock that increases the world interest rate r_t^* by 10 basis points, again starting from the stochastic steady state.

This shock directly increases banks' funding costs, which decrease their profitability and net worth. As a result, a larger fraction of the balance sheet has to be financed through bank debt (see panel " Leverage"), which in turn increases the probability of insolvency. Foreign investors respond by demanding an even higher interest rate on bank debt, which is in equilibrium almost 10 basis points above the world interest rate, which is the risk-free rate in this model. Therefore, the increase in the interest rate on bank debt is almost double the increase in the world interest rate.

Just as in the case of the productivity shock, we see that lower net worth forces banks to reduce the credit supply. A lower credit supply reduces the demand for physical capital, and leads to a lower price of capital, which in turn reduces net worth even further. Therefore, a financial accelerator channel emerges again, because lower net worth causes leverage to increase further, which leads to a second round of interest rate increases on bank debt, etc.

The effect on output, however, is different under a world interest rate shock: in the absence of a productivity shock, output only starts to fall when the capital stock decreases. As the capital

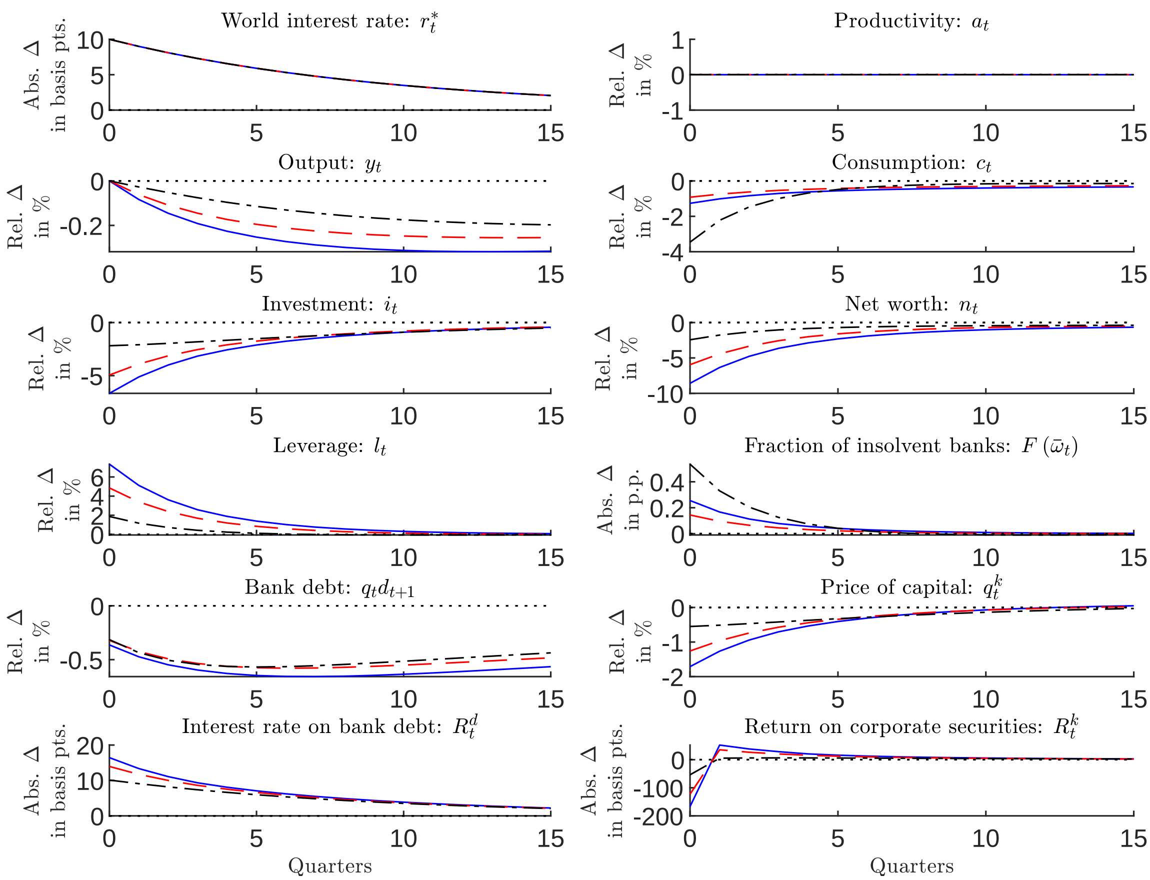


FIGURE 2. Impulse response functions following a world interest rate shock of 10 basis points for the liquidation economy (blue, solid), the bail-in economy (red, dashed), and the bailout economy (black, slotted). All economies are initially in the stochastic steady state.

stock decreases, the marginal product of labor and the wage rate fall which leads to a lower labor supply by households. Consumption, however, decreases on impact rather than with the gradual decline of the capital stock, which is driven by an immediate drop in bank dividends $\Omega_t = (1-\vartheta)\, n_t$. After the initial impact of the shock, consumption immediately starts to revert back to steady state following the recovery of net worth.

The same mechanism through which a bail-in caused credit supply and investment to increase for a productivity shock (with respect to the liquidation economy), is also operative for a world interest rate shock: imposing losses upon foreign creditors increases the aggregate net worth of the banking sector, which decreases leverage with respect to the liquidation economy. As a result, the probability of bank insolvency decreases, leading to lower funding costs. Lower funding costs increase banks' profitability from credit provision to the real economy. Therefore, banks increase lending, with an expansion of investment as a consequence.

However, bail-ins become much more effective under a world interest rate shock (compared with a productivity shock), as the initial macroeconomic contraction is now caused by a deterioration of financial conditions, which bail-ins directly counter, rather than by shocks originating in the real economy, which bail-ins cannot directly offset.

4.1.2 Bail-in vs. bailout

Next, we compare the two recapitalization policies. Remember that the red dashed line in Figures 1 and 2 represents the bail-in regime, whereas the black slotted line the bailout regime.

In both figures we see that a bailout is much more effective in improving financial conditions than a bail-in: the drop in net worth, credit provision, and investment is less than half the respective drop under the bail-in regime. Output also increases for a world interest rate shock, but hardly does so for a productivity shock: since the capital stock does not drop by more than 0.5% (even under a bail-in), the drop in output is primarily driven by the productivity shock itself, which is the same for both a bailout and a bail-in. Consumption, on the other hand, substantially decreases with respect to a bail-in: by 33% for a productivity shock, and by 200% for a world interest rate shock. This drop in consumption is driven by the fact that bailouts are financed by domestic households and directly decrease their income, unlike bail-ins which are financed by foreign creditors. Since households have no savings to tap into, consumption must fall as a result.

The key mechanism why bailouts are more effective in improving macroeconomic and financial conditions (except consumption) is that bank creditors are shielded from any losses in case a bank becomes insolvent. As a result, the probability of bank insolvency is no longer priced in, which becomes clear from looking at the interest rate on bank debt: Figures 1 and 2 show that the interest rate on bank debt is exactly equal to the risk-free world interest rate under the bailout regime. As a result, banks' profitability increases with respect to a bail-in, which induces them to expand credit provision to the real economy. This raises investment, the capital stock and output in turn.

Just as in Section 4.1.1, the impact of the bailout regime on the real economy depends on the type of shock: the impact is relatively small for a productivity shock whose origins are in the real economy. This is different for a world interest rate shock, in which case the recapitalization can (partially) offset the negative impact that this shock has on financial conitions, and through that channel positively affect the real economy (with respect to the liquidation and bail-in economies).

4.2 Macro-dynamics around financial crises

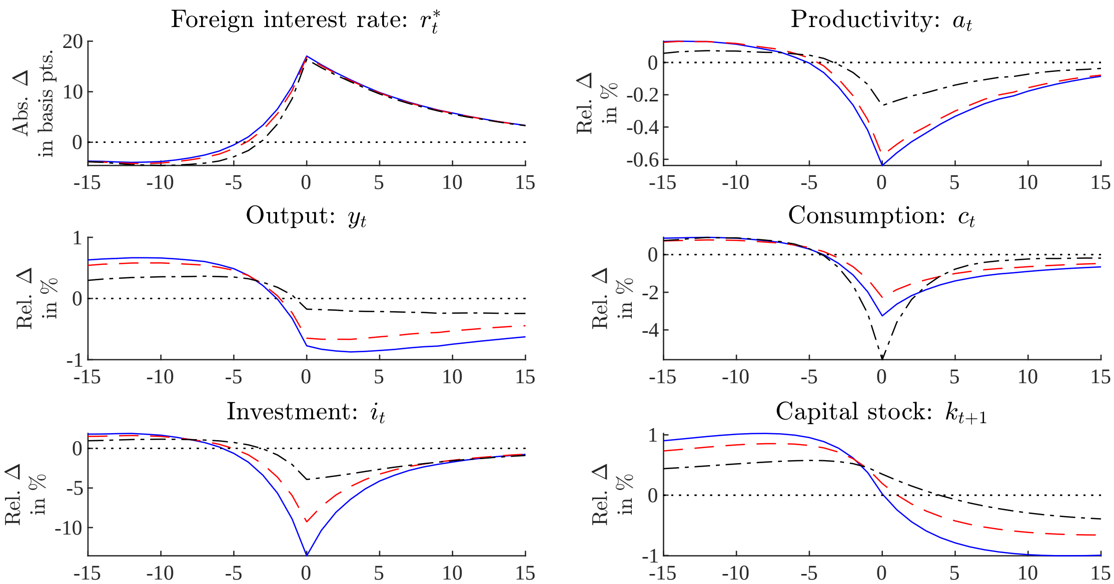
In the previous section we investigated how bank recapitalizations affect the economy in response to two isolated exogenous shocks. However, bank recapitalizations are instruments to deal with failing banks, the number of which especially increases in times of financial crises. Therefore, it is important to know how recapitalizations affect the economy in financial crisis times, and to what extent they can mitigate their negative impact.

To do so, we first simulate the different economies for 511,000 periods and discard the first 11,000 periods as burn-in. This leaves us with 500,000 quarters (125,000 years) of simulated data. Next, we construct event windows around financial crises of 15 periods before and after a crisis hits the economy. We define financial crises as periods in which the change in lending to banks, $\Delta_t^d = -(d_{t+1} - d_t)$, falls by at least two standard deviations (Bianchi, 2016; Gete and Melkadze, 2020). The results can be found in Figure 3, which displays unweighted averages across identified financial crises for each respective variable. We plot the macroeconomic variables in deviation from their respective unconditional mean. Again, the blue solid line depicts the liquidation economy, the red dashed line the bail-in economy, and the black slotted line the bailout economy. Just as in the previous section we will first discuss and compare the liquidation economy and the bail-in economy, after which we compare the bail-in economy with the bailout economy.

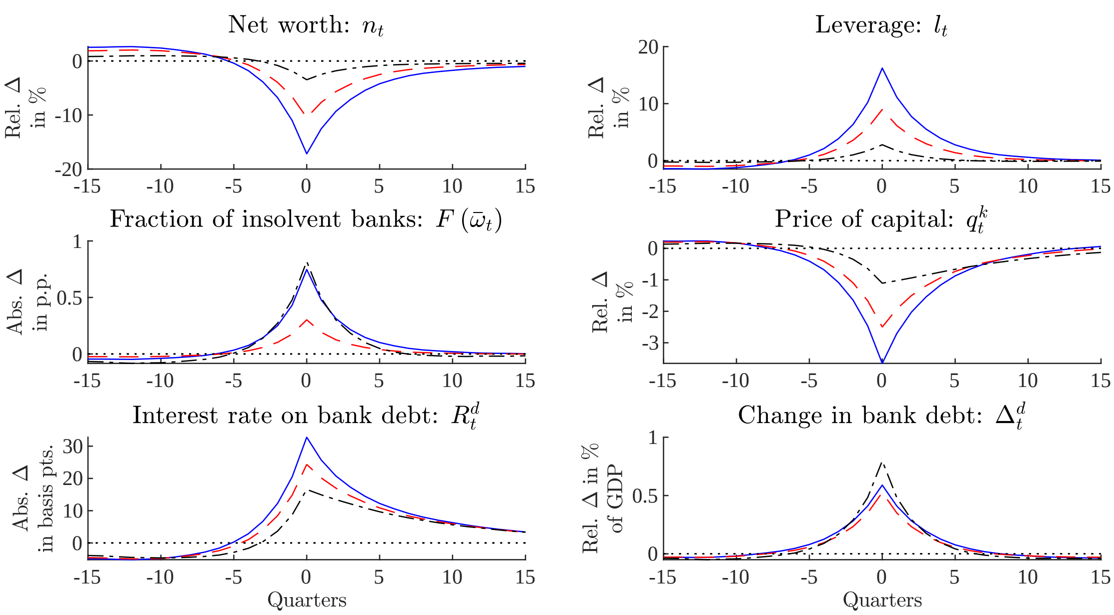
4.2.1 Liquidation vs. bail-in

We start by comparing the liquidation economy with the bail-in economy. Just as for the impulse response functions, we observe that the impact of financial crises is qualitatively very similar in the two economies: financial crises are triggered by negative shocks to productivity a_t and positive shocks to foreign interest rates r_t^*. This is unsurprising given the impulse response functions from the previous section, where both shocks negatively affected macroeconomic and financial conditions: lower producitivity causes the marginal product of capital to decrease (and therefore the return on corporate securities), whereas a higher world interest rate leads to higher funding costs. Both shocks therefore reduce banks' profitability and net worth, which forces banks to rely more on debt financing. Leverage increases as a conseuqence, which in turn raises the probability of insolvency. As a result, funding costs increase further as creditors correctly price in the higher probability of insolvency in both economies. In equilibrium, the fraction of banks that actually become insolvent indeed increases: by 0.25 percentage points in the bail-in economy, and by 0.7 percentage points in the liquidation economy.

As a result, net worth falls by at least 10% in both economies, forcing banks to reduce credit provision to the real economy. Fewer credit provision causes investment to fall by at least 10%



(A)



(B)

FIGURE 3. Dynamics around typical financial crises in liquidation (blue, solid), bail-in (red, dashed), and bailout (black, slotted) economies.

from its unconditional mean in both economies. Finally, a lower capital stock reduces output and consumption, by at least 0.5% and 2%, respectively.

Observe, however, that consumption, output, and the capital stock are all above their long-run average in the run-up to a financial crisis. In addition, we see that the financial sector immediately starts to recover after the crisis hits in period $t = 0$, as the price of capital and banks' aggregate net worth immediately start to increase after period $t = 0$, while leverage, the fraction of insolvent banks, and banks' funding costs immediately decrease. This is driven by a simultaneous increase in productivity (with respect to the trough) and a decrease in the world interest rate (with respect to its zenith), both of which improve banks' profitability and net worth immediately with positive knock-on effects on credit provision to the real economy.

In contrast, the capital stock and output remain below their long-run average for several periods after the start of the financial crisis: although investment immediately starts to recover after period $t = 0$, it remains below its long-run average for at least 15 quarters. As a result, the newly created capital (from investments) is not enough to offset the depreciation of the existing capital stock. As a result, the capital stock continues to fall after the financial crisis has hit the economy, which implies that output remains below its long-run average. Note, however, that consumption immediately starts to recover, as the recovery in net worth implies that bank dividends increase with respect to the period that the crisis hits.

Next, we focus on the differences between the liquidation economy and the bail-in economy. It turns out that the mechanisms that drive the quantitative differences in financial crisis times are similar to those in Section 4.1: by not liquidating insolvent banks but recapitalizing them, the drop in aggregate net worth is mitigated. As a result, leverage does not increase as much as in the liquidation economy. This leads to a smaller increase in the probability of insolvency ex ante and a smaller fraction of insolvent banks ex post, which amounts to only half the increase in the liquidation economy. Therefore, funding costs decrease with respect to the liquidation economy, while a smaller drop in the price of capital mitigates the hit to the return on corporate securities (not shown). As a result of the recap and the larger credit spread, the drop in net worth is only two-thirds of that in the liquidation economy, which allow banks to expand their balance sheets, with beneficial consequences on investment, capital, output and consumption. Therefore, bail-ins mitigate the macroeconomic impact from financial crises.

Also observe that bail-ins smooth the impact of financial crises by providing banks with additional net worth at the exact moment when it would drop otherwise as a result of more banks being liquidated. Therefore, bail-ins reduce the volatiltiy of net worth, and as a result the volatility of credit provision to the real economy. The reduction of volatility in the financial sector carries over to the real economy: the drop in investment, the capital stock and output is mitigated in the bail-in economy. Moreover, the reduction of macrofinancial volatility in financial crises times carries over to the periods in the run-up to crises, as the extent to which the economy operates above its long-run average is also reduced. As such, bail-ins help to reduce macroeconomic and financial volatility both before and after financial crises.

4.2.2 Bail-in vs. bailout

Now that we have compared the liquidation economy and the bail-in economy, we turn to a comparison between the bail-in economy and the bailout economy. One of the reasons for doing so is that it is important for policymakers to know which of these two recapitalization policies is most effective in mitigating the impact of financial crises. Just as in the previous section, the red, dashed line depicts the case of a bail-in ($\xi = 0$), whereas the black slotted line depicts a bailout ($\xi = 1$).

We see that bailouts substantially mitigate the impact of financial crises with respect to bail-ins. The drop in net worth is halved with respect to the bail-in economy, as a result of which the increase in leverage is more than halved. Therefore, banks do not have to shrink the balance sheet as much, which results in a higher capital stock and investment with respect to the bail-in economy. This substantially mitigates the drop in output, which is less than one-third the drop in the bail-in economy. However, the drop in consumption is more than doubled with respect to the bail-in economy, as domestic households finance the bailouts, whereas foreign creditors finance the bail-ins.

The reason why bailouts are better capable of mitigating the impact of financial crises is the absence of a link between banks' funding costs and the probability of insolvency. This sharply contrasts with the bail-in regime, in which such a procyclicality arises in financial crises times: a higher probability of insolvency leads to higher funding costs, which in turn increase the probability of insolvency further leading to even higher interest rates etc. The bailout economy does not feature this procyclicality. As a result, funding costs are always lower in the bailout economy. This explains why the drop in net worth is so much smaller, which in turn mitigates the credit contraction that takes place in a crisis. Therefore, bailouts are more effective in mitigating the macroeconomic impact of financial crises than bail-ins.

Finally, observe that productivity needs to fall by less for the economy to land in a financial crisis when banks are recapitalized through a bailout. We will see in the next section that this is driven by the fact that the bailout economy features a banking sector that on average operates with higher leverage ratios in the ergodic distribution. As a result, the probability of insolvency is higher, and therefore smaller negative shocks suffice to generate a financial crisis.

4.3 Long-run macrofinancial stability

In the previous sections we saw that recapitalizing the financial sector through a bailout is more effective in improving macrofinancial conditions than through a bail-in, except for consumption, whose drop doubled with respect to a bail-in. The reason why the other macroeconomic and financial variables increase with respect to a bail-in is that the financial sector does not only receive new net worth (which is also the case for a bail-in), but in addition benefits from the fact that funding costs do not increase with respect to the world interest rate, despite the probability that banks might become insolvent ex post.

Whereas the absence of a link between funding costs and the probability of insolvency is beneficial in dealing with financial crisis ex post, bailouts also have the potential to make financial crises more likely ex ante because of moral hazard (Cordella and Yeyati, 2003; Gorton and Huang, 2004; Dam and Koetter, 2012; Keister, 2015; Gete and Melkadze, 2020): by not pricing in the probability of insolvency, it becomes more profitable for banks to expand their balance sheets and lever up. This increases the probability of insolvency, everything else equal, and thereby increases the probability of new financial crises.

The problem of moral hazard is thought to be mitigated by bail-ins: as creditors have to finance bank recapitalizations, they will price in the probability with which banks become insolvent. This should reduce the incentive for banks to lever up, and thereby reduce the probability of new financial crises ex ante (Spiegel, 2013). Therefore, bail-ins might be the better recapitalization policy from a financial stability perspective.

Hence, there seems to be a tradeoff between mitigating the impact of financial crises ex post, which is best served by the bailout policy, and enhancing financial stability ex ante, which might be better served by the bail-in policy. In this section we will quantitatively investigate to what extent this tradeoff exists by looking at a number of moments of the ergodic distribution of several macroeconomic and financial variables. In particular, we will first investigate how long-run macroeconomic outcomes are affected by the two recapitalization policies. Afterwards we will look at the long-run probability of insolvency under both recapitalization regimes, as well as the frequency with which financial crises occur.

Specifically, we calculate the unconditional means of several variables from the same simulated data that were used in Section 4.2 to study the macro-dynamics around financial crises. In addition, we calculate the unconditional probability of a financial crisis by looking at the frequency with which financial crises occur within our sample of simulated data. The results can be found in Tables 2 and 3.

First, we see that all macroeconomic variables are higher in the bailout economy. Long-run output increases by more than 40%, consumption increases by more than 20%, and physical capital increases by more than 100%. Finally, labor supply increases by almost 20%. Therefore, macroeconomic variables substantially increase with respect to the bail-in economy. Again, this result is driven by the fact that funding costs are always lower in the bailout economy, as the probability of insolvency is not priced in by bank creditors. This increases banks' profitability and net worth, everything else equal, and subsequently credit provision to the real economy. Higher credit provision, in turn, allows for a larger capital stock, which leads to higher output and consumption. This mechanism not only operates in financial crises times, but in every period. Therefore, long-run macroeconomic variables are (substantially) above their respective counterpart in the bail-in economy.

Table 3 shows that the volatility of output decreases in the bailout economy with respect to that in the bail-in economy. This is driven by the fact that banks' funding costs are not only lower than in the bail-in economy, but also less volatile as they do not depend on the probability of insolvency. This decreases the volatility in net worth, which in turn leads to less volatility in credit provision to the real economy with respect to the bail-in economy. The volatility of consumption, however, is higher in the bailout economy, which is driven by the fact that households finance the bailouts, the

Table 2 Ergodic means of selected variables in the liquidation economy, the bail-in economy, and the bailout economy.

Variable	Liquidation	Bail-in	Bailout
Output: y	0.9007	0.9132	1.3021
Consumption: c	0.6691	0.6813	0.8312
Physical capital: k	6.7955	6.9865	14.2797
Hours worked: h	0.3329	0.3352	0.4002
Leverage: l	5.1973	5.0407	6.9161
Fraction of insolvent banks: $F(\bar{\omega})$	0.3278%	0.2398%	3.1172%
Gross bank funding cost: R^d	1.0112	1.0111	1.0102
Probability of financial crisis:	2.8588%	2.7050%	2.8630%

size of which depends on the state of the economy. Since households consume their entire after-tax income, the volatility of consumption increases as a result. This is different in the bail-in economy, in which foreign creditors finance the recapitalizations, and household incomes are unaffected by the recapitalizations.

Table 3 Simulated standard deviations in the liquidation economy, the bail-in economy, and the bailout economy.

Variable	Liquidation	Bail-in	Bailout
Output: y	1.6795%	1.5398%	1.3459%
Consumption: c	2.2368%	1.9099%	2.9624%

However, as mentioned above, bailouts also introduce moral hazard, as a result of which it is thought that financial instability increases and financial crises become more likely. This is most clearly visible from the fraction of banks that become insolvent, which increases from 0.2398% per quarter in the bail-in economy to 3.1172% per quarter in the bailout economy. As such, the number of bank insolvencies in the bailout economy is more than 10 times larger than in the bail-in economy!

We can see from Figure 4 that this substantial increase in insolvencies is driven by bankers taking more risks with their balance sheets: there is a substantial shift in the ergodic distribution of bank leverage, whose unconditional long-run average increases by almost 40% from 5.0407 in the bail-in economy to 6.9161 in the bailout economy. Again we see that it is profitable for banks to do so, as the probability of insolvency is not incorporated in the interest rate at which they can borrow: the gross interest rate on bank debt decreases from 1.0111 in the bail-in economy to 1.0101 in the bailout economy, despite a substantially larger probability of bank insolvency. From this point of view, moral hazard substantially deteriorates financial stability.

Interestingly, the frequency with which financial crises occur hardly increases: from 2.7050% in the bail-in economy to 2.8630% in the bailout economy. Therefore, the large increase in the number of insolvencies does not lead to substantially more financial crises.

So how are we to square these observations? Remember that a financial crisis is defined as a period in which the change in lending to banks, $\Delta_t^d = -(d_{t+1} - d_t)$, falls by at least two standard deviations (Bianchi, 2016; Gete and Melkadze, 2020). Therefore, the crucial decision whether or not the economy will land in a financial crisis is whether or not bank creditors start to withdraw their funds when banks' balance sheets deteriorate. But because creditors are guaranteed to be repaid in the bailout economy, they will continue to finance the banks even when many banks are expected to fail. Therefore, an increase in bank insolvencies does not necessarily lead to financial crises in the bailout economy. In addition, observe that the macroeconomic impact of bank insolvencies is substantially mitigated because insolvent banks are recapitalized, and therefore continue to provide credit to the real economy.

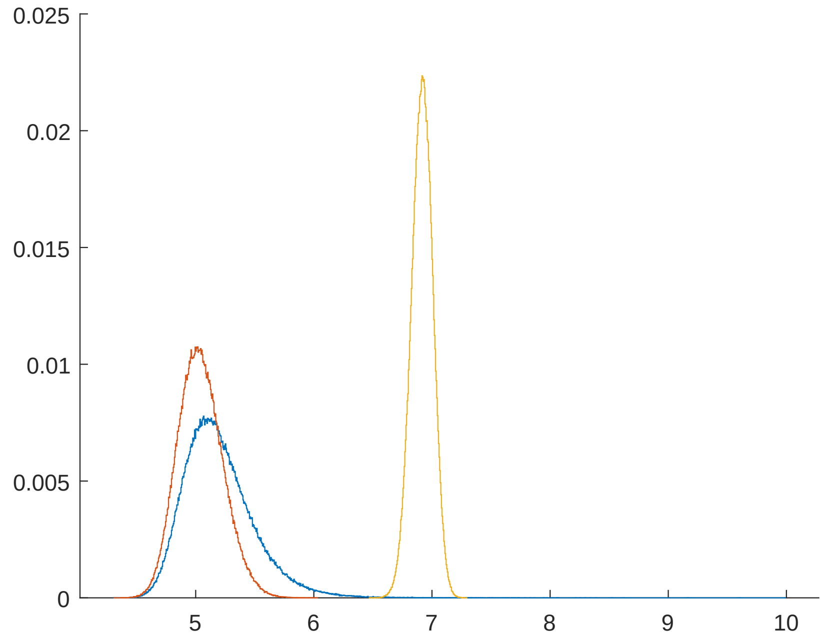


Figure 4. Ergodic distribution of bank leverage in liquidation economy (blue), bail-in economy (orange), and bailout economy (yellow).

Finally, we look at Table 2 again, and observe that both recapitalization policies unequivocally increase macroeconomic variables, although the increase is less than 3% in the bail-in economy. Things are less straightforward from a financial stability perspective. First, observe that the probability of financial crises and the fraction of insolvent banks are the lowest in the bail-in economy. From a financial stability perspective, this policy has the best of both worlds: on the one hand there is no moral hazard, which keeps leverage and the number of insolvencies low. On the other hand, insolvent banks are recapitalized. This increases credit provision to the real economy with respect to the liquidation economy, in which insolvent banks are liquidated.

More interestingly, we see that the liquidation economy does better on these financial stability measures than the bailout economy: both the probability of financial crises and the fraction of insolvent banks are lower in the liquidation economy, although the difference in the financial crisis probability is only 0.01 percentage points. The reason is that moral hazard is absent in the liquidation economy, which prevents banks from leveraging up. However, when looking at the volume of credit provision to the real economy, we see that the bailout economy substantially outperforms the other two economies.

4.4 Welfare analysis

In the previous section we looked at long-run macroeconomic and financial outcomes, and saw that the bailout economy features the highest level of long-run capital and output. However, from households' perspective it might be more important in which economy welfare is maximized. Ex ante it is not directly clear for which policy this will be the case. On the one hand we saw in previous sections that long-run consumption is highest under the bailout regime, suggesting that welfare might be highest for this regime. On the other hand, we know that consumption substantially decreases in financial crisis times as a result of higher lump sum taxes that finance the bailouts. This contrasts with the bail-in regime, where the recapitalization is financed by foreign creditors rather than domestic households. Everything else equal, this would imply that welfare is higher under the bail-in regime. In this section we will investigate which of these two effects dominates.

Specifically, we look at two welfare measures in Figure 5, in which ξ, the fraction of the recapitalization that is financed through a bailout, is plotted on the horizontal axis. Remember that the corner case $\xi = 1$ denotes a recapitalization that is entirely financed through a bailout, while $\xi = 0$ denotes a full bail-in. Finally, the recapitalization is financed through a combination of a bail-in and bailout when $0 < \xi < 1$. The left subfigure displays the welfare cost of business cycles λ, which is defined as the percentage drop in steady state consumption that would make households indifferent between staying in the stochastic steady state and living in an economy where shocks arrive each period, similar to Bianchi (2016); Bernstein et al. (2020); Gete and Melkadze (2020):

$$\mathbb{E}_t\left[\sum_{s=0}^{T}\beta^s u\left(c_{t+s}, h_{t+s}\right)\right] = \mathbb{E}_t\left[\sum_{s=0}^{T}\beta^s u\left(c\left(1-\lambda\right), h\right)\right], \tag{21}$$

where $T = 1,000,000$, and c, h are consumption and hours worked in the stochastic steady state. The right subfigure in Figure 5 displays the absolute level of the discounted sum of period utility (13) over the entire sample.

Let us first consider the welfare cost of business cycles in the left subfigure. We see that it is approximately 0.22% for values of ξ between 0 and 0.5, after which the welfare cost of business cycles sharply increases when we move to a full bailout. This result can be explained in the following way. The larger ξ, the larger the fraction of the recapitalization that is financed by domestic households, as a result of which their consumption decreases, everything else equal. On top of that, the fraction of banks that need to be recapitalized in the stochastic steady state increases nonlinearly with ξ: from 0.24% per quarter under the bail-in regime ($\xi = 0$), to 0.49% for $\xi = 0.5$, to 3.12% under the bailout regime ($\xi = 1$). The fact that more banks need to be recapitalized in the stochastic steady state for larger values of ξ also implies that more banks will have to be recapitalized when the economy is hit by shocks. Therefore, not only do households finance a larger *fraction* of a single recapitalization for larger values of ξ, also the *number* of recapitalizations increases, which explains the nonlinear increase in the welfare cost of business cycles.

Next, we study the absolute level of welfare in the right subfigure of Figure 5. Interestingly, we see that welfare unequivocally increases with ξ. Apparently, the increase in the long-run average level of consumption more than offsets the higher welfare cost from business cycles for the full bailout regime. This can be seen from long-run average consumption, which increases nonlinearly from 0.9132 under the full bail-in regime ($\xi = 0$), to 0.9442 for $\xi = 0.5$, to 1.3021 for the full bailout regime ($\xi = 1$). This more than offsets the fact that a larger fraction of banks has to be recapitalized under the full bailout-regime, even in the stochastic steady state. Therefore, we conclude that fully recapitalizing the banking system through bailouts is the best policy when looking at the absolute level of welfare.

TABLE 4 Welfare comparisons. The first row refers to the welfare cost of business cycles, whereas the second row refers to the sum of expected discounted lifetime utility. 'Liq. econ.' refers to the liquidation economy.

Variable	Liq. econ.	$\xi = 0$	$\xi = 0.25$	$\xi = 0.5$	$\xi = 0.75$	$\xi = 1$
Cost of bus. cycles	0.4685%	0.2222%	0.2209%	0.2219%	0.2302%	0.3078%
Lifetime utility	-116.0834	-111.8223	-111.1633	-109.9992	-107.3620	-103.3123

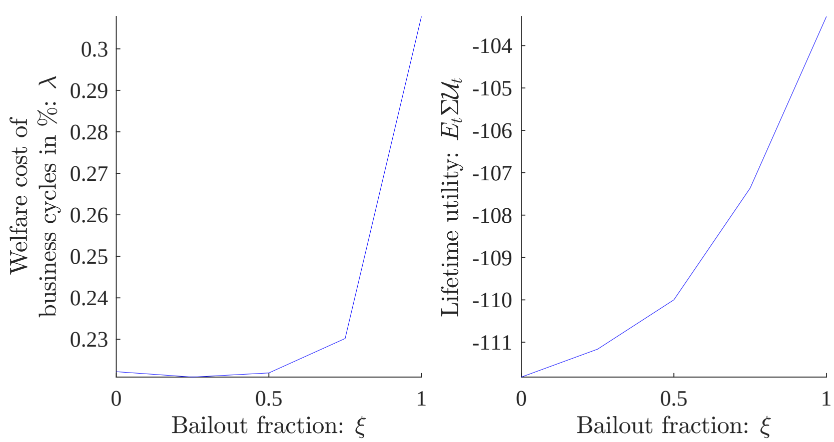


FIGURE 5. The bailout fraction ξ is on the horizontal axis of both subfigures, where $\xi = 0$ denotes the case where the recapitalization is entirely financed through a bail-in, and $\xi = 1$ the case where the recapitalization is entirely financed through a bailout, with a combination of bail-ins and bailouts for $0 < \xi < 1$. The left subfigure denotes the welfare cost from business cycles λ as defined by equaton (21). The right subfigure denotes the absolute level of welfare as defined by the expected discounted sum of period utility (13).

Finally, we see from Table 4 that the liquidation economy has the worst results for both welfare measures: the absolute level of welfare is the lowest, whereas the welfare cost of business cycles is the highest of all economies. It is unsurprising that this is the case, as the long-run level of consumption is the lowest of the three economies, whereas the relatively high welfare cost of business cycles is driven by the fact that banks are liquidated rather than recapitalized, which increases the volatility of net worth, credit provision to the real economy, and output, see Table 3.

We conclude that both recapitalization economies improve welfare with respect to the liquidation economy. These results suggest that governments are right to recapitalize insolvent banks rather than liquidate them.

5 Conclusion

In this paper we extend a dynamic general equilibrium model with limited liability banks as in Gete and Melkadze (2020) to include the possibility of recapitalizing insolvent banks through a bail-in and/or a bailout. We do so to compare the impact that these two policies have on financial stability and macroeconomic outcomes. We solve the model using global solution methods to properly capture the nonlinearities that arise from limited liability, moral hazard, and bank risk-taking.

We find that long-run investment, capital, output and consumption under the bailout regime are at least 20% higher than their counterparts under the bail-in regime. While bail-ins and bailouts feature the same rule to determine the additional net worth that is provided, banks' funding costs are always lower under the bailout regime: since bank creditors are also repaid in case of insolvency, they do not price in the probability with which this might occur. The resulting lower funding costs increase banks' net worth with respect to the bail-in regime, allowing them to expand credit provision to the real economy. As a result, an economy in which banks are bailed out features higher capital, output and consumption.

Most importantly, the fact that funding costs do not increase with the probability of insolvency under the bailout regime especially increases banks' net worth in financial crisis times with respect to the bail-in regime, for which there is a procyclicality between the probability of insolvency and banks' funding costs: a higher probability of insolvency increases banks' funding costs, which in turn further increases the probability of insolvency etc. The resulting credit contraction is substantially mitigated under the bailout regime for which this procyclicality is absent. As a result, the drop in investment, capital and output is half the respective drop under the bail-in regime. Therefore, bailouts are more effective in mitigating the macroeconomic impact of financial crises than bail-ins.

However, bailouts also introduce moral hazard: as creditors are always repaid they do not price in the probability of insolvency. This allows banks to expand their balance sheets without facing higher funding costs. As a result, long-run leverage increases by 40% with respect to the bail-in regime, causing the fraction of banks that need to be recapitalized to increase from 0.24% per quarter under the bail-in regime to 3.12% under the bailout regime. As such, moral hazard substantially increases financial instability.

Despite the presence of moral hazard, however, the frequency with which financial crises occur hardly increases with respect to the bail-in regime: as creditors will always be repaid under the bailout regime, they will not withdraw their funds when the probability of insolvency increases in financial crisis times, which sharply contrasts with the bail-in regime, where creditors increase the interest rate on bank debt and/or withdraw their funding.

We compute welfare under both recapitalization regimes, and also look at the case where banks are recapitalized through a combination of a bail-in and a bailout. We find that welfare is maximized under the bailout regime, driven by the fact that long-run consumption increases nonlinearly with the fraction of the recapitalization that is financed through a bailout. This is the case despite the negative effects in the form of higher lump sum taxes from i) households having to finance a larger fraction of the recapitalization, and ii) a larger number of banks that need to be recapitalized when the fraction of the recapitalization financed by a bailout increases.

Finally, we provide support for governments that recapitalize failing banks rather than liquidate them. Macroeconomic outcomes and welfare improve for both recapitalization policies with respect to the liquidation economy. The intuition is that aggregate net worth increases by providing insolvent banks additional net worth instead of liquidating them. This, in turn, allows aggregate credit provision to the real economy to increase, with positive knock-on effects on investment, capital, output and consumption.

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A Mathematical appendix

A.1 Household

Households gain utility from consuming final goods and disutility from supplying labor. The household's optimization problem is to maximize expected, discounted lifetime utility:

$$\max_{\{c_{t+s},h_{t+s}\}_{s=0}^{\infty}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[\frac{\left(c_{t+s} - \frac{\chi}{1+\varphi} h_{t+s}^{1+\varphi}\right)^{1-\sigma} - 1}{1-\sigma} \right] \right\},$$
$$\beta \in (0,1), \varphi \geq 0,$$

We use Greenwood et al. (1988) (GHH) preferences to both get rid of the wealth effect in labor supply and for computational reasons, as GHH preferences eliminate the need to guess the policy function for h_t in the iterative procedure. The next step in finding a solution to the household's optimization problem is to maximize the household's lifetime utility function subject to the following budget constraint:

$$c_t + \tau_t + \chi_b = w_t h_t + \mathcal{P}_t^k + \Omega_t.$$

In the model economy with bail-ins and bailouts, households have to pay lump sum taxes τ_t that depends on the share ξ of the recapitalization Ξ_t^b that is financed by households. Using the utility function and the household budget constraint, we set up the following Lagrangian:

$$\mathcal{L} = \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[\frac{\left(c_{t+s} - \frac{\chi}{1+\varphi} h_{t+s}^{1+\varphi}\right)^{1-\sigma} - 1}{1-\sigma} \right] \right\}$$
$$+ \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} \left(w_{t+s} h_{t+s} + \mathcal{P}_{t+s}^k + \Omega_{t+s} - c_{t+s} - \tau_{t+s} - \chi_b \right) \right\}$$

Solving the household's optimization problem yields the following first order conditions:

$$c_t : \lambda_t = \left(c_t - \frac{\chi}{1+\varphi} h_t^{1+\varphi} \right)^{-\sigma}, \tag{A.1}$$

$$h_t : w_t = \chi h_t^{\varphi}. \tag{A.2}$$

A.2 Production

A.2.1 Final goods producers

The constant returns to scale production technology available to final goods firms is:

$$y_{i,t} = a_t k_{i,t}^{\alpha} h_{i,t}^{1-\alpha}. \tag{A.3}$$

Taking the first order condition with respect to labor, we get that the wage rate equals:

$$w_t = (1-\alpha) \frac{y_{i,t}}{h_{i,t}}. \tag{A.4}$$

The representative final goods producing firm's profits are equal to:

$$\mathcal{P}_{i,t}^f = y_{i,t} + (1-\delta) q_t^k k_{i,t} - R_t^k q_{t-1}^k k_{i,t} - w_t h_{i,t},$$

which states that profits are equal to production plus the income gained after selling previous period's capital stock net of depreciation times the price of capital, minus the cost of capital and the wage bill. Final goods producers can credibly pledge all after-wage profits to banks since there are no monitoring frictions between banks and final goods producers (Gertler and Kiyotaki, 2010). We plug the expression for the wage rate into the final goods producing firm's profit function, set the profit function to zero, and solve for the return on capital. This equals:

$$R_t^k = \frac{r_t^k + (1-\delta) q_t^k}{q_{t-1}^k}, \tag{A.5}$$

where r^k_t is the marginal product of capital:

$$r^k_t = \alpha \frac{y_{i,t}}{k_{i,t}}. \tag{A.6}$$

A.2.2 Capital goods producers

Final goods producers sell their used capital stock to capital producers. They sell the capital stock net of depreciation, i.e. $(1-\delta)k_t$ for a price q^k_t. Capital producers use final goods i_t to refurbish the depreciated capital stock. They face Jermann (1998)-style adjustment costs, which depend on investment i_t relative to the capital stock chosen in the previous period. The law of motion for capital is then:

$$k_{t+1} = (1-\delta)\, k_t + \left[a_k + \frac{b_k}{1-1/\kappa_k} \left(\frac{i_t}{k_t} \right)^{1-1/\kappa_k} \right] k_t. \tag{A.7}$$

Profits for capital goods producers are then the revenue they make from selling refurbished capital, minus the costs they incur when purchasing used capital and final goods used in the refurbishing process:

$$\mathcal{P}^k_t = q^k_t k_{t+1} - (1-\delta) q^k_t k_t - i_t.$$

Substituting the law of motion for capital k_{t+1} into the capital goods producer's profit function and taking the derivative with respect to investment i_t yields the following expression for the price of capital q^k_t:

$$q^k_t = \frac{1}{b_k} \left(\frac{i_t}{k_t} \right)^{1/\kappa_k}. \tag{A.8}$$

A.2.3 Aggregation of non-financial firms

To find expressions for aggregate supply, we aggregate (A.3) for all firms i. Aggregation over the left hand side yields:

$$\int_0^1 y_{i,t}\, di = y_t. \tag{A.9}$$

We can calculate the right hand side by integrating (A.3) over di:

$$\int_0^1 a_t k^{\alpha}_{i,t} h^{1-\alpha}_{i,t}\, di = a_t \int_0^1 \left(\frac{k_{i,t}}{h_{i,t}} \right)^{\alpha} h_{i,t}\, di. \tag{A.10}$$

We can find the capital-labor ratio by inspecting the factor prices. Rewriting these gives us that:

$$h_{i,t} = (1-\alpha)\frac{y_{i,t}}{w_t}, \tag{A.11}$$
$$k_{i,t} = \frac{\alpha y_{i,t}}{R_t^k q_{t-1}^k - (1-\delta) q_t^k}. \tag{A.12}$$

The ratio of these two is then equal to:

$$\frac{k_{i,t}}{h_{i,t}} = \frac{\alpha}{1-\alpha}\left[\frac{w_t}{R_t^k q_{t-1}^k - (1-\delta) q_t^k}\right], \tag{A.13}$$

where we can clearly see that the individual capital-labor ratio does not depend on any individual firm characteristics. Hence, all firms choose the same capital-labor ratio, since $\frac{k_{i,t}}{h_{i,t}} = \frac{k_t}{h_t}$. As such, we can aggregate the aggregate supply function in the following way:

$$a_t \int_0^1 \left(\frac{k_{i,t}}{h_{i,t}}\right)^\alpha h_{i,t}\, di = a_t \left(\frac{k_t}{h_t}\right)^\alpha \int_0^1 h_{i,t}\, di = a_t k_t^\alpha h_t^{1-\alpha}. \tag{A.14}$$

Hence, aggregate supply is equal to:

$$y_t = a_t k_t^\alpha h_t^{1-\alpha}. \tag{A.15}$$

A.3 Banking sector

A.3.1 Banking sector optimization with default

Bank j faces the following optimization problem:

$$V_{j,t} = \max_{\left\{s_{j,t+1}^k, d_{j,t+1}\right\}} \left[(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{\beta \frac{\lambda_{t+1}}{\lambda_t} \max\left(V_{j,t+1}, 0\right)\right\}\right],$$

subject to

$$\begin{aligned}
q_t^k s_{j,t+1}^k &= \vartheta n_{j,t} + q_t d_{j,t+1}, \\
n_{j,t} &= \int_{\bar{\omega}_{j,t}}^{\infty} \omega_{j,t} R_t^k q_{t-1}^k s_{j,t}^k f\left(\omega_{j,t}\right) d\omega_{j,t} - \int_{\bar{\omega}_{j,t}}^{\infty} d_{j,t} f\left(\omega_{j,t}\right) d\omega_{j,t}, \\
\bar{\omega}_{j,t} &= \frac{d_{j,t}}{R_t^k q_{t-1}^k s_{j,t}^k}, \\
q_t d_{j,t+1} &= \mathbb{E}_t \left\{ m_{t,t+1}^* \left[\int_{\bar{\omega}_{j,t+1}}^{\infty} d_{j,t+1} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} + (1-\mu) \int_0^{\bar{\omega}_{j,t+1}} \omega_{j,t+1} R_{t+1}^k q_t^k s_{j,t+1}^k f\left(\omega_{j,t+1}\right) d\omega_{j,t+1}\right]\right\}.
\end{aligned}$$

Let us define the deposit to securities ratio $d^k_{j,t} \equiv d_{j,t}/s^k_{j,t}$. Using

$$\int_{\bar{\omega}_{j,t+1}}^{\infty} f(\omega_{j,t+1})\, d\omega_{j,t+1} = 1 - \int_0^{\bar{\omega}_{j,t+1}} f(\omega_{j,t+1})\, d\omega_{j,t+1} = 1 - F(\bar{\omega}_{j,t+1}),$$
$$\int_{\bar{\omega}_{j,t+1}}^{\infty} \omega_{j,t+1} f(\omega_{j,t+1})\, d\omega_{j,t+1} = 1 - \int_0^{\bar{\omega}_{j,t+1}} \omega_{j,t+1} f(\omega_{j,t+1})\, d\omega_{j,t+1} = 1 - G(\bar{\omega}_{j,t+1}),$$
$$\int_0^{\bar{\omega}_{j,t+1}} f(\omega_{j,t+1})\, d\omega_{j,t+1} = F(\bar{\omega}_{j,t+1}),$$

we can then rewrite the constraints as:

$$\begin{aligned}
\vartheta n_{j,t} &= \left(q^k_t - q_t d^k_{j,t+1}\right) s^k_{j,t+1}, \\
n_{j,t} &= \left[\left(1 - G(\bar{\omega}_{j,t})\right) R^k_t q^k_{t-1} - \left(1 - F(\bar{\omega}_{j,t})\right) d^k_{j,t}\right] s^k_{j,t}, \\
\bar{\omega}_{j,t} &= \frac{d^k_{j,t}}{R^k_t q^k_{t-1}}, \\
q_t &= \mathbb{E}_t \left\{ m^*_{t,t+1} \left[1 - F(\bar{\omega}_{j,t+1}) + (1-\mu) G(\bar{\omega}_{j,t+1}) R^k_{t+1} \frac{q^k_t}{d^k_{j,t+1}} \right] \right\}.
\end{aligned}$$

We conjecture that the bank's value function is linear in individual net worth and later check whether this is the case:

$$V_{j,t} = v_t n_{j,t}.$$

Using our conjecture, we rewrite the Bellman equation accordingly:

$$V_{j,t} = \max_{\left\{s^k_{j,t+1}, d^k_{j,t+1}\right\}} \left[(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(\left[\left(1 - G(\bar{\omega}_{j,t+1})\right) R^k_{t+1} q^k_t - \left(1 - F(\bar{\omega}_{j,t+1})\right) d^k_{j,t+1} \right] s^k_{j,t+1} \right) \right\} \right].$$

Next, we set up the following Lagrangian:

$$\begin{aligned}
\mathcal{L} = {} & (1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(\left[\left(1 - G(\bar{\omega}_{j,t+1})\right) R^k_{t+1} q^k_t - \left(1 - F(\bar{\omega}_{j,t+1})\right) d^k_{j,t+1} \right] s^k_{j,t+1} \right) \right\} \\
& + \eta_t \left[\vartheta n_{j,t} - \left(q^k_t - q_t d^k_{j,t+1}\right) s^k_{j,t+1} \right].
\end{aligned}$$

We find the following first order conditions:

$$\begin{aligned}
d^k_{j,t+1} : {} & \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left[-\left(1 - F(\bar{\omega}_{j,t+1})\right) + \frac{\partial F(\bar{\omega}_{j,t+1})}{\partial d^k_{j,t+1}} d^k_{j,t+1} - \frac{\partial G(\bar{\omega}_{j,t+1})}{\partial d^k_{j,t+1}} R^k_{t+1} q^k_t \right] s^k_{j,t+1} \right\} \\
& + \eta_t \left(q_t + \frac{\partial q_t}{\partial d^k_{j,t+1}} d^k_{j,t+1} \right) s^k_{j,t+1} = 0, \\
s^k_{j,t+1} : {} & \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left[\left(1 - G(\bar{\omega}_{j,t+1})\right) R^k_{t+1} q^k_t - \left(1 - F(\bar{\omega}_{j,t+1})\right) d^k_{j,t+1} \right] \right\} - \eta_t \left(q^k_t - q_t d^k_{j,t+1} \right) = 0.
\end{aligned}$$

Using the balance sheet constraint and the FOC for corporate securities, we can rewrite the value function as:

$$V_{j,t} = \max_{\left\{s^k_{j,t+1}, d^k_{j,t+1}\right\}} \left[(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left((1 - G(\bar{\omega}_{j,t+1})) R^k_{t+1} q^k_t - (1 - F(\bar{\omega}_{j,t+1})) d^k_{j,t+1} \right) s^k_{j,t+1} \right\} \right], \Rightarrow$$

$$V_{j,t} = (1-\vartheta) n_{j,t} + \eta_t \left(q^k_t - q_t d^k_{j,t+1} \right) s^k_{j,t+1}, \Rightarrow$$

$$V_{j,t} = (1-\vartheta) n_{j,t} + \eta_t \vartheta n_{j,t}, \Rightarrow$$

$$V_{j,t} = [(1-\vartheta) + \vartheta \eta_t] n_{j,t}.$$

Hence, we find that the value function is indeed linear in net worth:

$$v_t = (1-\vartheta) + \vartheta \eta_t.$$

As a result, banks will all choose the same quantities, face the same default threshold and the same cost of deposits. We compute the partial of the deposit pricing condition with respect to the deposits over securities ratio:

$$q_t = \mathbb{E}_t \left\{ m^*_{t,t+1} \left[1 - F(\bar{\omega}_{j,t+1}) + (1-\mu) G(\bar{\omega}_{j,t+1}) R^k_{t+1} \frac{q^k_t}{d^k_{j,t+1}} \right] \right\}.$$

Next, take the derivative with respect to $d^k_{j,t+1}$:

$$\frac{\partial q_t}{\partial d^k_{j,t+1}} = \mathbb{E}_t \left\{ m^*_{t,t+1} \left[-\frac{\partial F(\bar{\omega}_{j,t+1})}{\partial d^k_{j,t+1}} + (1-\mu) \frac{\partial G(\bar{\omega}_{j,t+1})}{\partial d^k_{j,t+1}} R^k_{t+1} \frac{q^k_t}{d^k_{j,t+1}} - (1-\mu) G(\bar{\omega}_{j,t+1}) R^k_{t+1} \frac{q^k_t}{\left(d^k_{j,t+1}\right)^2} \right] \right\},$$

where:

$$\frac{\partial F(\bar{\omega}_{j,t+1})}{\partial d^k_{j,t+1}} = \frac{\partial \bar{\omega}_{j,t+1}}{\partial d^k_{j,t+1}} F_{\bar{\omega}}(\bar{\omega}_{j,t+1}),$$

$$\frac{\partial G(\bar{\omega}_{j,t+1})}{\partial d^k_{j,t+1}} = \frac{\partial \bar{\omega}_{j,t+1}}{\partial d^k_{j,t+1}} G_{\bar{\omega}}(\bar{\omega}_{j,t+1}),$$

where $F_{\bar{\omega}}, G_{\bar{\omega}}$ denote the derivatives with respect to $\bar{\omega}_{j,t+1}$. We know that:

$$\frac{\partial \bar{\omega}_{j,t+1}}{\partial d^k_{j,t}} = \frac{1}{R^k_{t+1} q^k_t}.$$

As is standard, we know that F and G are given by:

$$F(\bar{\omega}_{j,t+1}) = \Phi \left(\frac{\ln(\bar{\omega}_{j,t+1}) + \frac{1}{2}\sigma^2_\omega}{\sigma_\omega} \right),$$

$$G(\bar{\omega}_{j,t+1}) = \int_0^{\bar{\omega}_{j,t+1}} \omega_{j,t+1} dF(\bar{\omega}_{j,t+1}),$$

where Φ is the cumulative density function of the standard normal. Hence, their derivatives are given by:

$$F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right) = \frac{1}{\bar{\omega}_{j,t+1}\sigma_\omega}\phi\left(\frac{\ln\left(\bar{\omega}_{j,t+1}\right)+\frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right),$$
$$G_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right) = \bar{\omega}_{j,t+1}F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right),$$

where ϕ is the probability density function of the standard normal. Hence, we get that:

$$\frac{\partial F\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} = \frac{1}{R^k_{t+1}q^k_t}F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right),$$
$$\frac{\partial G\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} = \frac{\bar{\omega}_{j,t+1}}{R^k_{t+1}q^k_t}F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right).$$

Plugging these back in:

$$\frac{\partial q_t}{\partial d^k_{j,t+1}} = \mathbb{E}_t\left\{m^*_{t,t+1}\left[-F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right)\frac{1}{R^k_{t+1}q^k_t} + (1-\mu)F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right)\frac{\bar{\omega}_{j,t+1}}{d^k_{j,t+1}} - (1-\mu)G\left(\bar{\omega}_{j,t+1}\right)R^k_{t+1}\frac{q^k_t}{\left(d^k_{j,t+1}\right)^2}\right]\right\},$$

Multiplying and dividing the first term in square brackets by $d^k_{j,t+1}$ and rewriting slightly yields:

$$\frac{\partial q_t}{\partial d^k_{j,t+1}} = -\mathbb{E}_t\left\{m^*_{t,t+1}\left[\mu F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right)\frac{\bar{\omega}_{j,t+1}}{d^k_{j,t+1}} + (1-\mu)G\left(\bar{\omega}_{j,t+1}\right)\frac{R^k_{t+1}q^k_t}{\left(d^k_{j,t+1}\right)^2}\right]\right\}.$$

Look at our FOC for the deposit ratio, and substituting the deposit price, the derivative of the deposit price, the derivatives with respect to the default probabilites, and the solution of the value function in:

$$\eta_t = \frac{\mathbb{E}_t\left\{\beta\frac{\lambda_{t+1}}{\lambda_t}\left[1-\vartheta+\vartheta\eta_{t+1}\right]\left[1-F\left(\bar{\omega}_{j,t+1}\right)\right]\right\}}{\mathbb{E}_t\left\{m^*_{t,t+1}\left[1-F\left(\bar{\omega}_{j,t+1}\right)-\mu F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right)\bar{\omega}_{j,t+1}\right]\right\}}.$$

From our FOC for corporate securities, we find:

$$\eta_t q^k_t = \mathbb{E}_t\left\{\beta\frac{\lambda_{t+1}}{\lambda_t}\left[1-\vartheta+\vartheta\eta_{t+1}\right]\left[\left(1-G\left(\bar{\omega}_{j,t+1}\right)\right)R^k_{t+1}q^k_t - \left(1-F\left(\bar{\omega}_{j,t+1}\right)\right)d^k_{j,t+1}\right]\right\} + \eta_t q_t d^k_{j,t+1}.$$

Since all banks choose the same quantities (since the solution of the value function does not depend on any individual bank characteristics), we can drop the j subscript to find the aggregate relationships. Aggregate pre-dividend net worth evolves according to:

$$n_t = \left[\left(1-G\left(\bar{\omega}_t\right)\right)R^k_t q^k_{t-1}s^k_t - \left(1-F\left(\bar{\omega}_t\right)\right)d_t\right] + \chi_b.$$

The aggregate bank balance sheet is given by:

$$\vartheta n_t = \left(q_t^k - q_t d_{t+1}^k\right) s_{t+1}^k.$$

A.3.2 Banking sector optimization with bail-in

Now, we assume that an individual bank does not take into account that it will receive additional funds in a bail-in from creditors or household when it defaults. Instead, we assume that the banker operating the bank is forced to exit and is replaced by a different bank manager from the same household. Bank j faces the following optimization problem:

$$V_{j,t} = \max_{\left\{s_{j,t+1}^k, d_{j,t+1}\right\}} \left[(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{\beta \frac{\lambda_{t+1}}{\lambda_t} \max\left(V_{j,t+1}, 0\right)\right\}\right],$$

subject to

$$\begin{aligned}
q_t^k s_{j,t+1}^k &= \vartheta n_{j,t} + q_t d_{j,t+1}, \\
n_{j,t} &= \int_{\bar{\omega}_{j,t}}^{\infty} \omega_{j,t} R_t^k q_{t-1}^k s_{j,t}^k f\left(\omega_{j,t}\right) d\omega_{j,t} - \int_{\bar{\omega}_{j,t}}^{\infty} d_{j,t} f\left(\omega_{j,t}\right) d\omega_{j,t}, \\
\bar{\omega}_{j,t} &= \frac{d_{j,t}}{R_t^k q_{t-1}^k s_{j,t}^k}, \\
q_t d_{j,t+1} &= \mathbb{E}_t \left\{ m_{t,t+1}^* \left[\int_0^{\infty} d_{j,t+1} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} - (1-\xi)\left(\int_0^{\bar{\omega}_{j,t+1}} \left(\bar{\omega}_{j,t+1} - \omega_{j,t+1}\right) R_{t+1}^k q_t^k s_{j,t+1}^k f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} \right.\right.\right. \\
&\quad \left.\left.\left. + \zeta \int_0^{\bar{\omega}_{j,t+1}} q_{t+1}^k s_{j,t+1}^k f\left(\omega_{j,t+1}\right) d\omega_{j,t+1}\right)\right]\right\},
\end{aligned}$$

where $m_{t,t+1}^*$ is the foreign investor's stochastic discount factor:

$$m_{t,t+1}^* = \exp\left[-r_t^* - \kappa\left(\varepsilon_{a,t+1} + \frac{1}{2}\kappa\sigma_a^2\right)\right].$$

Let us define the deposit to securities ratio $d_{j,t}^k \equiv d_{j,t}/s_{j,t}^k$. Using

$$\begin{aligned}
\int_{\bar{\omega}_{j,t+1}}^{\infty} \omega_{j,t+1} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} &= 1 - G\left(\bar{\omega}_{j,t+1}\right), \\
\int_0^{\bar{\omega}_{j,t+1}} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} &= F\left(\bar{\omega}_{j,t+1}\right), \\
\int_0^{\infty} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} &= 1, \\
\int_{\bar{\omega}_{j,t}}^{\infty} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} &= 1 - \int_0^{\bar{\omega}_{j,t+1}} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} = 1 - F\left(\bar{\omega}_{j,t+1}\right), \\
\int_0^{\bar{\omega}_{j,t+1}} \omega_{j,t+1} f\left(\omega_{j,t+1}\right) d\omega_{j,t+1} &= G\left(\bar{\omega}_{j,t+1}\right),
\end{aligned}$$

we can rewrite the constraints as:

$$
\begin{aligned}
\vartheta n_{j,t} &= \left(q_t^k - q_t d_{j,t+1}^k\right) s_{j,t+1}^k, \\
n_{j,t} &= \left(\left[1 - G\left(\bar{\omega}_{j,t}\right)\right] R_t^k q_{t-1}^k - \left[1 - F\left(\bar{\omega}_{j,t}\right)\right] d_{j,t}^k\right) s_{j,t}^k \\
\bar{\omega}_{j,t} &= \frac{d_{j,t}^k}{R_t^k q_{t-1}^k}, \\
q_t &= \mathbb{E}_t \left\{ m_{t,t+1}^* \left[1 - (1-\xi)\left(\left(\bar{\omega}_{j,t+1} F\left(\bar{\omega}_{j,t+1}\right) - G\left(\bar{\omega}_{j,t+1}\right)\right) \frac{R_{t+1}^k q_t^k}{d_{j,t+1}^k} + \zeta F\left(\bar{\omega}_{j,t+1}\right) \frac{q_{t+1}^k}{d_{j,t+1}^k}\right)\right]\right\}.
\end{aligned}
$$

We conjecture that the bank's value function is linear in individual net worth and later check whether this is the case:

$$
V_{j,t} = v_t n_{j,t}.
$$

Using our conjecture, we rewrite the Bellman equation accordingly:

$$
V_{j,t} = \max_{\left\{s_{j,t+1}^k, d_{j,t+1}^k\right\}} \left[(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(\left[1 - G\left(\bar{\omega}_{j,t+1}\right)\right] R_{t+1}^k q_t^k - \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] d_{j,t+1}^k\right) s_{j,t+1}^k \right\}\right].
$$

Next, we set up the following Lagrangian:

$$
\begin{aligned}
\mathcal{L} = &(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(\left[1 - G\left(\bar{\omega}_{j,t+1}\right)\right] R_{t+1}^k q_t^k - \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] d_{j,t+1}^k\right) s_{j,t+1}^k \right\} \\
&+ \eta_t \left[\vartheta n_{j,t} - \left(q_t^k - q_t d_{j,t+1}^k\right) s_{j,t+1}^k\right].
\end{aligned}
$$

We find the following first order conditions:

$$
\begin{aligned}
d_{j,t+1}^k : &\mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(-\frac{\partial G\left(\bar{\omega}_{j,t+1}\right)}{\partial d_{j,t+1}^k} R_{t+1}^k q_t^k - 1 + F\left(\bar{\omega}_{j,t+1}\right) + \frac{\partial F\left(\bar{\omega}_{j,t+1}\right)}{\partial d_{j,t+1}^k} d_{j,t+1}^k\right) s_{j,t+1}^k \right\} \\
&+ \eta_t \left(q_t + \frac{\partial q_t}{\partial d_{j,t+1}^k} d_{j,t+1}^k\right) s_{j,t+1}^k = 0, \\
s_{j,t+1}^k : &\mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(\left[1 - G\left(\bar{\omega}_{j,t+1}\right)\right] R_{t+1}^k q_t^k - \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] d_{j,t+1}^k\right) \right\} - \eta_t \left(q_t^k - q_t d_{j,t+1}^k\right) = 0.
\end{aligned}
$$

Using the balance sheet constraint and the FOC for corporate securities, we can rewrite the value function as:

$$
\begin{aligned}
V_{j,t} &= \max_{\left\{s_{j,t+1}^k, d_{j,t+1}^k\right\}} \left[(1-\vartheta) n_{j,t} + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} v_{t+1} \left(\left[1 - G\left(\bar{\omega}_{j,t+1}\right)\right] R_{t+1}^k q_t^k - \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] d_{j,t+1}^k\right) s_{j,t+1}^k \right\}\right], \Rightarrow \\
V_{j,t} &= (1-\vartheta) n_{j,t} + \eta_t \left(q_t^k - q_t d_{j,t+1}^k\right) s_{j,t+1}^k, \Rightarrow \\
V_{j,t} &= \left[(1-\vartheta) + \vartheta \eta_t\right] n_{j,t}.
\end{aligned}
$$

Hence, we find that the value function is indeed linear in net worth:

$$v_t = (1-\vartheta) + \vartheta \eta_t.$$

As a result, banks will all choose the same quantities, face the same default threshold and the same cost of deposits. We compute the partial of the deposit pricing condition with respect to the deposits over securities ratio. First, plugging these definitions into the deposit price:

$$q_t = \mathbb{E}_t \left\{ m^*_{t,t+1} \left[1 - (1-\xi) \left(F\left(\bar{\omega}_{j,t+1}\right) - G\left(\bar{\omega}_{j,t+1}\right) \frac{R^k_{t+1} q^k_t}{d^k_{j,t+1}} + \zeta F\left(\bar{\omega}_{j,t+1}\right) \frac{q^k_{t+1}}{d^k_{j,t+1}} \right) \right] \right\},$$

where we have $F\left(\bar{\omega}_{j,t+1}\right)$, since $\bar{\omega}_{j,t+1} F\left(\bar{\omega}_{j,t+1}\right) \frac{R^k_{t+1} q^k_t}{d^k_{j,t+1}} = \frac{\bar{\omega}_{j,t+1} F\left(\bar{\omega}_{j,t+1}\right)}{\bar{\omega}_{j,t+1}} = F\left(\bar{\omega}_{j,t+1}\right)$. Next, take the derivative with respect to $d^k_{j,t+1}$:

$$\begin{aligned} \frac{\partial q_t}{\partial d^k_{j,t+1}} = &-(1-\xi)\, \mathbb{E}_t \left\{ m^*_{t,t+1} \left[\frac{\partial F\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} - \frac{\partial G\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} \frac{R^k_{t+1} q^k_t}{d^k_{j,t+1}} + G\left(\bar{\omega}_{j,t+1}\right) \frac{R^k_{t+1} q^k_t}{\left(d^k_{j,t+1}\right)^2} \right.\right. \\ &\left.\left. + \zeta \frac{\partial F\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} \frac{q^k_{t+1}}{d^k_{j,t+1}} - \zeta F\left(\bar{\omega}_{j,t+1}\right) \frac{q^k_{t+1}}{\left(d^k_{j,t+1}\right)^2} \right] \right\}, \end{aligned}$$

where:

$$\begin{aligned} \frac{\partial F\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} &= \frac{\partial \bar{\omega}_{j,t+1}}{\partial d^k_{j,t+1}} F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right), \\ \frac{\partial G\left(\bar{\omega}_{j,t+1}\right)}{\partial d^k_{j,t+1}} &= \frac{\partial \bar{\omega}_{j,t+1}}{\partial d^k_{j,t+1}} G_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right), \end{aligned}$$

where $F_{\bar{\omega}}, G_{\bar{\omega}}$ denote the derivatives with respect to $\bar{\omega}_{j,t+1}$. We know that:

$$\frac{\partial \bar{\omega}_{j,t+1}}{\partial d^k_{j,t+1}} = \frac{1}{R^k_{t+1} q^k_t}.$$

As is standard, we know that F is given by:

$$F\left(\bar{\omega}_{j,t+1}\right) = \Phi\left(\frac{\ln\left(\bar{\omega}_{j,t+1}\right) + \frac{1}{2}\sigma^2_\omega}{\sigma_\omega} \right),$$

where Φ is the cumulative density function of the standard normal. Hence, the derivative is given by:

$$F_{\bar{\omega}}(\bar{\omega}_{j,t+1}) = \frac{1}{\bar{\omega}_{j,t+1}\sigma_\omega}\phi\left(\frac{\ln(\bar{\omega}_{j,t+1}) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right),$$
$$G_{\bar{\omega}}(\bar{\omega}_{j,t+1}) = \bar{\omega}_{j,t+1}F_{\bar{\omega}}(\bar{\omega}_{j,t+1}),$$

where ϕ is the probability density function of the standard normal. Hence, we get that:

$$\frac{\partial F(\bar{\omega}_{j,t+1})}{\partial d_{j,t+1}^k} = \frac{1}{R_{t+1}^k q_t^k}F_{\bar{\omega}}(\bar{\omega}_{j,t+1}),$$
$$\frac{\partial G(\bar{\omega}_{j,t+1})}{\partial d_{j,t+1}^k} = \frac{\bar{\omega}_{j,t+1}}{R_{t+1}^k q_t^k}F_{\bar{\omega}}(\bar{\omega}_{j,t+1}).$$

Plugging these back in:

$$\frac{\partial q_t}{\partial d_{j,t+1}^k} = -(1-\xi)\mathbb{E}_t\left\{m_{t,t+1}^*\left[\frac{1}{R_{t+1}^k q_t^k}F_{\bar{\omega}}(\bar{\omega}_{j,t+1}) - \frac{\bar{\omega}_{j,t+1}}{R_{t+1}^k q_t^k}F_{\bar{\omega}}(\bar{\omega}_{j,t+1})\frac{R_{t+1}^k q_t^k}{d_{j,t+1}^k} + G(\bar{\omega}_{j,t+1})\frac{R_{t+1}^k q_t^k}{\left(d_{j,t+1}^k\right)^2}\right.\right.$$
$$\left.\left.+\zeta\frac{1}{R_{t+1}^k q_t^k}F_{\bar{\omega}}(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{d_{j,t+1}^k} - \zeta F(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{\left(d_{j,t+1}^k\right)^2}\right]\right\},$$

Using that $\bar{\omega}_{j,t+1}\frac{R_{t+1}^k q_t^k}{\left(d_{j,t+1}^k\right)^2} = \frac{1}{d_{j,t+1}^k}$, multiplying and dividing by $d_{j,t+1}^k$ and rewriting slightly yields:

$$\frac{\partial q_t}{\partial d_{j,t+1}^k} = -(1-\xi)\mathbb{E}_t\left\{m_{t,t+1}^*\left[\frac{G(\bar{\omega}_{j,t+1})}{\bar{\omega}_{j,t+1}}\frac{1}{d_{j,t+1}^k} + \zeta\bar{\omega}_{j,t+1}F_{\bar{\omega}}(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{\left(d_{j,t+1}^k\right)^2} - \zeta F(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{\left(d_{j,t+1}^k\right)^2}\right]\right\}.$$

Hence, we get that:

$$q_t + \frac{\partial q_t}{\partial d_{j,t+1}^k}d_{j,t+1}^k = \mathbb{E}_t\left\{m_{t,t+1}^*\left[1-(1-\xi)\left(F(\bar{\omega}_{j,t+1}) - G(\bar{\omega}_{j,t+1})\frac{R_{t+1}^k q_t^k}{d_{j,t+1}^k} + \zeta F(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{d_{j,t+1}^k}\right)\right.\right.$$
$$\left.\left.-(1-\xi)\left(\frac{G(\bar{\omega}_{j,t+1})}{\bar{\omega}_{j,t+1}} + \zeta\bar{\omega}_{j,t+1}F_{\bar{\omega}}(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{d_{j,t+1}^k} - \zeta F(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{d_{j,t+1}^k}\right)\right]\right\}, \Rightarrow$$
$$q_t + \frac{\partial q_t}{\partial d_{j,t+1}^k}d_{j,t+1}^k = \mathbb{E}_t\left\{m_{t,t+1}^*\left[1-(1-\xi)\left(F(\bar{\omega}_{j,t+1}) + \zeta\bar{\omega}_{j,t+1}F_{\bar{\omega}}(\bar{\omega}_{j,t+1})\frac{q_{t+1}^k}{d_{j,t+1}^k}\right)\right]\right\}.$$

Look at our FOC for the deposit ratio, and substituting the deposit price, the derivative of the deposit price, and the solution of the value function in:

$$\eta_t = \frac{\mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 - \vartheta + \vartheta \eta_{t+1}\right] \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] \right\}}{\mathbb{E}_t \left\{ m^*_{t,t+1} \left[1 - (1-\xi) \left(F\left(\bar{\omega}_{j,t+1}\right) + \zeta \bar{\omega}_{j,t+1} F_{\bar{\omega}}\left(\bar{\omega}_{j,t+1}\right) \frac{q^k_{t+1}}{d^k_{j,t+1}} \right) \right] \right\}}.$$

From our FOC for corporate securities, we find:

$$\eta_t q^k_t = \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 - \vartheta + \vartheta \eta_{t+1}\right] \left(\left[1 - G\left(\bar{\omega}_{j,t+1}\right)\right] R^k_{t+1} q^k_t - \left[1 + F\left(\bar{\omega}_{j,t+1}\right)\right] d^k_{j,t+1} \right) \right\} + \eta_t q_t d^k_{j,t+1}.$$

Since all banks choose the same quantities (since the solution of the value function does not depend on any individual bank characteristics), we can drop the j subscript to find the aggregate relationships. Aggregate pre-dividend net worth evolves according to:

$$n_t = \left[\left(1 - G\left(\bar{\omega}_t\right)\right) R^k_t q^k_{t-1} - \left(1 - F\left(\bar{\omega}_t\right)\right) d^k_t \right] s^k_t + \Xi^b_t + \chi_b,$$

where $\Xi^b_t = \left[F\left(\bar{\omega}_t\right) \bar{\omega}_t - G\left(\bar{\omega}_t\right)\right] R^k_t q^k_{t-1} s^k_t + \zeta F\left(\bar{\omega}_t\right) q^k_t s^k_t$ is the bail-in and bailout transfer received by defaulting bankers.

A.4 Market clearing

A.4.1 Liquidation economy

Given that households are hand to mouth, we can simply use the household budget constraint to determine consumption and be done with it. However, we can also derive exactly how output is spent, which gives us an additional term that depends on the fraction of bank assets in default $G\left(\bar{\omega}_t\right)$ and the probability of default $F\left(\bar{\omega}_t\right)$. Let's start from the household budget constraint:

$$c_t = w_t h_t + \Omega_t + \mathcal{P}^k_t - \chi_b.$$

Next, use that workers get paid their marginal product $w_t = (1-\alpha) y_t / h_t$ and the profit function for capital goods producers $\mathcal{P}^k_t = q^k_t k_{t+1} - i_t - (1-\delta) q^k_t k_t$:

$$c_t = (1-\alpha) y_t + \Omega_t + q^k_t k_{t+1} - i_t - (1-\delta) q^k_t k_t - \chi_b.$$

We can replace $q^k_t k_{t+1}$ with the balance sheet constraint of the financial sector, $q^k_t k_{t+1} = \vartheta n_t + q_t d_{t+1}$, use that $\Omega_t = (1-\vartheta) n_t$ and we can substitute in $n_t = \left[\left(1 - G\left(\bar{\omega}_t\right)\right) \left(r^k_t + (1-\delta) q^k_t \right) - \left(1 - F\left(\bar{\omega}_t\right)\right) d^k_t \right] k_t + \chi_b$:

$$\begin{aligned} c_t = {} & (1-\alpha) y_t + \left[\left(1 - G\left(\bar{\omega}_t\right)\right) \left(r^k_t + (1-\delta) q^k_t \right) - \left(1 - F\left(\bar{\omega}_t\right)\right) d^k_t \right] k_t \\ & + q_t d_{t+1} - i_t - (1-\delta) q^k_t k_t - \chi_b. \end{aligned}$$

Since we're adding and subtracting $(1-\delta) q_t^k k_t$, we can get rid of that term. Next, we use the marginal productivity condition for capital $r_t^k = \alpha y_t / k_t$, such that we get $(1-\alpha) y_t + \alpha y_t = y_t$ on the right hand side:

$$c_t = y_t - G(\bar{\omega}_t)\left(r_t^k + (1-\delta) q_t^k\right) k_t - d_t + F(\bar{\omega}_t) d_t + q_t d_{t+1} - i_t.$$

Hence, we get:

$$y_t = c_t + i_t + G(\bar{\omega}_t)\left(r_t^k + (1-\delta) q_t^k\right) k_t + (1 - F(\bar{\omega}_t)) d_t - q_t d_{t+1}.$$

Akinci (2019) thinks of the terms after investment i_t as net exports in a small open economy model with BGG-style default risk and foreign creditors. That is, $G(\bar{\omega}_t)\left(r_t^k + (1-\delta) q_t^k\right) k_t + (1 - F(\bar{\omega}_t)) d_t$ is the repayment of bank debt to foreign creditors, and $q_t d_{t+1}$ is the amount banks borrow in period t. Given we are also working in an SOE with default risk and foreign creditors, this also makes sense in our setup. Hence, we get that:

$$y_t = c_t + i_t + x_t,$$

where x_t is net exports and given by:

$$x_t = G(\bar{\omega}_t)\left(r_t^k + (1-\delta) q_t^k\right) k_t + (1 - F(\bar{\omega}_t)) d_t - q_t d_{t+1}.$$

A.4.2 Recapitalization economy

Given that the law of motion for net worth changes and households might have to pay bailout taxes when $\xi > 0$, the aggregate resource constraint also changes. Starting from the household's budget constraint:

$$c_t = w_t h_t + \Omega_t + \mathcal{P}_t^k - \xi \Xi_t^b - \chi_b.$$

Next, use that workers get paid their marginal product $w_t = (1-\alpha) y_t / h_t$ and the profit function for capital goods producers $\mathcal{P}_t^k = q_t^k k_{t+1} - i_t - (1-\delta) q_t^k k_t$:

$$c_t = (1-\alpha) y_t + \Omega_t + q_t^k k_{t+1} - i_t - (1-\delta) q_t^k k_t - \xi \Xi_t^b - \chi_b.$$

We can replace $q_t^k k_{t+1}$ with the balance sheet constraint of the financial sector, $q_t^k k_{t+1} = \vartheta n_t + q_t d_{t+1}$, use that $\Omega_t = (1-\vartheta) n_t$ and we can substitute in $n_t = \left[(1 - G(\bar{\omega}_t))\left(r_t^k + (1-\delta) q_t^k\right) - (1 - F(\bar{\omega}_t)) d_t^k\right] k_t + \Xi_t^b + \chi_b$:

$$\begin{aligned} c_t = (1-\alpha) y_t &+ \left[(1 - G(\bar{\omega}_t))\left(r_t^k + (1-\delta) q_t^k\right) - (1 - F(\bar{\omega}_t)) d_t^k\right] k_t \\ &+ q_t d_{t+1} - i_t - (1-\delta) q_t^k k_t + (1-\xi) \Xi_t^b - \chi_b. \end{aligned}$$

Since we're adding and subtracting $(1-\delta)\, q_t^k k_t$, we can get rid of that term. Next, we use the marginal productivity condition for capital $r_t^k = \alpha y_t / k_t$, such that we get $(1-\alpha)\, y_t + \alpha y_t = y_t$ on the right hand side:

$$c_t = y_t - G(\bar{\omega}_t) \left(r_t^k + (1-\delta)\, q_t^k \right) k_t - d_t + F(\bar{\omega}_t)\, d_t + q_t d_{t+1} - i_t + (1-\xi)\, \Xi_t^b.$$

Hence, we get:

$$y_t = c_t + i_t + G(\bar{\omega}_t) \left(r_t^k + (1-\delta)\, q_t^k \right) k_t + (1 - F(\bar{\omega}_t))\, d_t - q_t d_{t+1} - (1-\xi)\, \Xi_t^b.$$

Hence, we get that:

$$y_t = c_t + i_t + x_t,$$

where x_t is net exports and given by:

$$x_t = G(\bar{\omega}_t) \left(r_t^k + (1-\delta)\, q_t^k \right) k_t + (1 - F(\bar{\omega}_t))\, d_t - q_t d_{t+1} - (1-\xi)\, \Xi_t^b.$$

B Equilibrium conditions

B.1 Equilibrium conditions of macro model with bank default and foreign lenders

Households:

$$\lambda_t = \left(c_t - \frac{\chi}{1+\varphi} h_t^{1+\varphi} \right)^{-\sigma}, \tag{B.1}$$

$$w_t = \chi h_t^{\varphi}. \tag{B.2}$$

Foreign lenders:

$$q_t = \mathbb{E}_t \left\{ m_{t,t+1}^* \left[1 - F(\bar{\omega}_{t+1}) + (1-\mu)\, \frac{G(\bar{\omega}_{t+1})}{\bar{\omega}_{t+1}} \right] \right\}, \tag{B.3}$$

$$m_{t,t+1}^* = \exp\left[-r_t^* - \kappa \left(\varepsilon_{a,t+1} + \frac{1}{2} \kappa \sigma_a^2 \right) \right]. \tag{B.4}$$

Banks:

$$\vartheta n_t = \left(q_t^k - q_t d_{t+1}^k\right) k_{t+1}, \tag{B.5}$$

$$\eta_t = \frac{\mathbb{E}_t \left\{\beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 - \vartheta + \vartheta \eta_{t+1}\right] \left[1 - F\left(\bar{\omega}_{t+1}\right)\right]\right\}}{\mathbb{E}_t \left\{m_{t,t+1}^* \left[1 - F\left(\bar{\omega}_{t+1}\right) - \mu F'\left(\bar{\omega}_{t+1}\right) \bar{\omega}_{t+1}\right]\right\}}, \tag{B.6}$$

$$\begin{aligned}\eta_t q_t^k = \mathbb{E}_t \Bigg\{\beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 - \vartheta + \vartheta \eta_{t+1}\right] \Big[&\left(1 - G\left(\bar{\omega}_{t+1}\right)\right) \left(r_{t+1}^k + \left(1 - \delta\right) q_{t+1}^k\right) \\ &- \left(1 - F\left(\bar{\omega}_{t+1}\right)\right) d_{t+1}^k\Big]\Bigg\} + \eta_t q_t d_{t+1}^k,\end{aligned} \tag{B.7}$$

$$n_t = \left[\left(1 - G\left(\bar{\omega}_t\right)\right) \left(r_t^k + \left(1 - \delta\right) q_t^k\right) - \left(1 - F\left(\bar{\omega}_t\right)\right) d_t^k\right] k_t + \chi_b, \tag{B.8}$$

$$\Omega_t = \left(1 - \vartheta\right) n_t \tag{B.9}$$

Production:

$$y_t = a_t k_t^{\alpha} h_t^{1-\alpha}, \tag{B.10}$$

$$r_t^k = \alpha y_t / k_t, \tag{B.11}$$

$$w_t = \left(1 - \alpha\right) y_t / h_t, \tag{B.12}$$

$$k_{t+1} = \left(1 - \delta\right) k_t + \left[a_k + \frac{b_k}{1 - 1/\kappa_k} \left(\frac{i_t}{k_t}\right)^{1 - 1/\kappa_k}\right] k_t, \tag{B.13}$$

$$q_t^k = \frac{1}{b_k} \left(\frac{i_t}{k_t}\right)^{1/\kappa_k}. \tag{B.14}$$

Default variables:

$$\bar{\omega}_t = \frac{d_t^k}{r_t^k + \left(1 - \delta\right) q_t^k}, \tag{B.15}$$

$$F\left(\bar{\omega}_t\right) = \Phi\left(\frac{\ln\left(\bar{\omega}_t\right) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right), \tag{B.16}$$

$$F_{\bar{\omega}}\left(\bar{\omega}_t\right) = \frac{1}{\bar{\omega}_t \sigma_\omega} \phi\left(\frac{\ln\left(\bar{\omega}_t\right) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right), \tag{B.17}$$

$$G\left(\bar{\omega}_t\right) = \Phi\left(\frac{\ln\left(\bar{\omega}_t\right) - \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right). \tag{B.18}$$

Market clearing:

$$y_t = c_t + i_t + x_t, \tag{B.19}$$

$$x_t = G\left(\bar{\omega}_t\right) \left(r_t^k + \left(1 - \delta\right) q_t^k\right) k_t + \left(1 - F\left(\bar{\omega}_t\right)\right) d_t - q_t d_{t+1}. \tag{B.20}$$

Stochastic processes:

$$r_t^* - r^* = \rho_r \left(r_{t-1}^* - r^*\right) + \varepsilon_{r,t}, \tag{B.21}$$

$$a_t - a = \rho_r \left(a_{t-1} - a\right) + \varepsilon_{a,t}. \tag{B.22}$$

The model is given by 22 equations.

B.2 Equilibrium conditions of macro model with bank bail-ins and foreign lenders

Households:

$$\lambda_t = \left(c_t - \frac{\chi}{1+\varphi} h_t^{1+\varphi}\right)^{-\sigma}, \tag{B.23}$$

$$w_t = \chi h_t^{\varphi}. \tag{B.24}$$

Foreign lenders:

$$q_t = \mathbb{E}_t \left\{ m_{t,t+1}^* \left[1 - (1-\xi) \left(F\left(\bar{\omega}_{j,t+1}\right) - \frac{G\left(\bar{\omega}_{t+1}\right)}{\bar{\omega}_{t+1}} + \zeta F\left(\bar{\omega}_{t+1}\right) \frac{q_{t+1}^k}{d_{t+1}^k} \right) \right] \right\}, \tag{B.25}$$

$$m_{t,t+1}^* = \exp\left[-r_t^* - \kappa \left(\varepsilon_{a,t+1} + \frac{1}{2} \kappa \sigma_a^2 \right) \right]. \tag{B.26}$$

Banks:

$$\vartheta n_t = \left(q_t^k - q_t d_{t+1}^k\right) k_{t+1}, \tag{B.27}$$

$$\eta_t = \frac{\mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 - \vartheta + \vartheta \eta_{t+1}\right] \left[1 - F\left(\bar{\omega}_{t+1}\right)\right] \right\}}{\mathbb{E}_t \left\{ m_{t,t+1}^* \left[1 - (1-\xi) \left(F\left(\bar{\omega}_{t+1}\right) + \zeta \bar{\omega}_{t+1} F_{\bar{\omega}}\left(\bar{\omega}_{t+1}\right) \frac{q_{t+1}^k}{d_{t+1}^k} \right) \right] \right\}}, \tag{B.28}$$

$$\begin{aligned} \eta_t q_t^k = \mathbb{E}_t \Big\{ & \beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 - \vartheta + \vartheta \eta_{t+1}\right] \Big[\left(1 - G\left(\bar{\omega}_{t+1}\right)\right) \left(r_{t+1}^k + (1-\delta) q_{t+1}^k \right) \\ & - \left(1 - F\left(\bar{\omega}_{t+1}\right)\right) d_{t+1}^k \Big] \Big\} + \eta_t q_t d_{t+1}^k, \end{aligned} \tag{B.29}$$

$$n_t = \left[\left(1 - G\left(\bar{\omega}_t\right)\right) \left(r_t^k + (1-\delta) q_t^k \right) - \left(1 - F\left(\bar{\omega}_t\right)\right) d_t^k \right] k_t + \Xi_t^b + \chi_b, \tag{B.30}$$

$$\Xi_t^b = \left[F\left(\bar{\omega}_t\right) \bar{\omega}_t - G\left(\bar{\omega}_t\right) \right] R_t^k q_{t-1}^k s_t^k + \zeta F\left(\bar{\omega}_t\right) q_t^k s_t^k, \tag{B.31}$$

$$\Omega_t = (1-\vartheta) n_t \tag{B.32}$$

Production:

$$y_t = a_t k_t^{\alpha} h_t^{1-\alpha}, \tag{B.33}$$

$$r_t^k = \alpha y_t / k_t, \tag{B.34}$$

$$w_t = (1-\alpha) y_t / h_t, \tag{B.35}$$

$$k_{t+1} = (1-\delta) k_t + \left[a_k + \frac{b_k}{1 - 1/\kappa_k} \left(\frac{i_t}{k_t} \right)^{1-1/\kappa_k} \right] k_t, \tag{B.36}$$

$$q_t^k = \frac{1}{b_k} \left(\frac{i_t}{k_t} \right)^{1/\kappa_k}. \tag{B.37}$$

Default variables:

$$\bar{\omega}_t = \frac{d_t^k}{r_t^k + (1-\delta) q_t^k}, \tag{B.38}$$

$$F(\bar{\omega}_t) = \Phi \left(\frac{\ln(\bar{\omega}_t) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega} \right), \tag{B.39}$$

$$F_{\bar{\omega}}(\bar{\omega}_t) = \frac{1}{\bar{\omega}_t \sigma_\omega} \phi \left(\frac{\ln(\bar{\omega}_t) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega} \right), \tag{B.40}$$

$$G(\bar{\omega}_t) = \Phi \left(\frac{\ln(\bar{\omega}_t) - \frac{1}{2}\sigma_\omega^2}{\sigma_\omega} \right). \tag{B.41}$$

Market clearing:

$$y_t = c_t + i_t + x_t, \tag{B.42}$$

$$x_t = G(\bar{\omega}_t) \left(r_t^k + (1-\delta) q_t^k \right) k_t + (1 - F(\bar{\omega}_t)) d_t - q_t d_{t+1} - (1-\xi) \Xi_t^b. \tag{B.43}$$

Stochastic processes:

$$r_t^* - r^* = \rho_r (r_{t-1}^* - r^*) + \varepsilon_{r,t}, \tag{B.44}$$

$$a_t - a = \rho_r (a_{t-1} - a) + \varepsilon_{a,t}. \tag{B.45}$$

The model is given by 23 equations.

C Recursive competitive equilibrium

The model has two endogenous state variables in d^k and k, and two exogenous states in r^* and a. Let today's state vector be $\mathbb{Z}$ and tomorrow's state vector $\mathbb{Z}'$, such that:

$$\mathbb{Z} \equiv \left\{ d^k, k, r^*, a \right\},$$

$$\mathbb{Z}' \equiv \left\{ d^{k\prime} \left(d^k, k, r^*, a \right), k' \left(d^k, k, r^*, a \right), r^{*\prime}, a' \right\} = \left\{ d^{k\prime}(\mathbb{Z}), k'(\mathbb{Z}), r^{*\prime}, a' \right\}.$$

The recursive equilibrium is defined by a set of recursive functions for

- Quantities (11): $\left\{d^{k\prime}(\mathbb{Z}), k'(\mathbb{Z}), c(\mathbb{Z}), h(\mathbb{Z}), y(\mathbb{Z}), i(\mathbb{Z}), n(\mathbb{Z}), \bar{\omega}(\mathbb{Z}), \Omega(\mathbb{Z}), x(\mathbb{Z}), \Xi^b(\mathbb{Z})\right\}$.
- Prices (8): $\left\{q(\mathbb{Z}), q^k(\mathbb{Z}), w(\mathbb{Z}), r^k(\mathbb{Z}), F(\mathbb{Z}), F_{\bar{\omega}}(\mathbb{Z}), G(\mathbb{Z})\right\}$.
- Multipliers (2): $\{\eta(\mathbb{Z}), \lambda(\mathbb{Z})\}$,

that satisfy the model's equilibrium conditions.

D Calibration

Table 5 Model calibration

Parameter	Value	Definition	Target/Source
β	0.985	Subjective discount factor	Literature
σ	2	Risk aversion	Literature
φ	1	Inverse Frisch elasticity	Literature
χ	5.446	Disutility of labor	Hours $h = 1/3$ in liquidation economy
α	0.33	Capital share in output	Literature
δ	0.025	Depreciation rate	Literature
κ_k	4	Investment adjustment cost parameter	$\sigma_i/\sigma_y = 4$
ϑ	0.95	Survival rate of bankers	$l = 5$
χ_b	0.0001, 0	Endowment for new bankers	Arbitrarily small
μ	0.30	Bank default cost in no-bail-in economy	Bank asset spread
ζ	0.30	Size of write-down in bail-in economy	Equal to μ
σ_ω	0.075	Dispersion of i.i.d. idiosyncratic return shock	Bank funding spread
κ	2.5	Foreign investors' risk aversion	Johri et al. (2020)
r^*	0.0101	Steady state net foreign interest rate	Annual risk free rate of 4.4%
a	1	Steady state productivity	Normalization
ρ_r	0.9	AR(1) parameter of foreign interest rate shock	Frequency and severity of crises
σ_r	0.0005	Std. dev. of foreign interest rate shock	Frequency and severity of crises
ρ_a	0.875	AR(1) parameter of productivity shock	σ_y approx. 1.7%
σ_a	0.00375	Std. dev. of productivity shock	σ_y approx. 1.7%

E Solution method

We solve the model using a global solution method. As advocated by Richter et al. (2014), we use a time iteration algorithm with linear interpolation to calculate updated policy function values and Gauss-Hermite quadrature to compute expectations. We only calculate the variables we strictly need to characterize the equilibrium, while leaving some to be calculated when the model is solved. We show how to solve the model with bank default step-by-step. The model with bail-ins can be solved in a similar manner.

1. Create a grid for k, d^k, r^*, and a, which will create a state space of size $\left(k, d^k, r^*, a\right) \in \mathcal{D} \otimes \mathcal{K} \otimes \mathcal{S}$, where we collect the exogenous states in $\mathcal{S}$. We discretize the grids for k, d^k, r^*, and a respectively with 60, 20, 11, and 11 points points, such that the total amount of nodes in the state space is 145,200. We discretize the exogenous states using the method described in Rouwenhorst (1995).

2. Choose which policy functions to calculate. We choose $q_T^k(\mathbb{Z})$, $q_T(\mathbb{Z})$, and $\eta_T(\mathbb{Z})$, as we can calculate all static time t relationships with these values in hand. For our initial conjectures,

we compute the policy functions using first order perturbation in Dynare and map this solution to the discretized state space.

3. Set iteration $j = 1$.

4. Given conjecture for $q_T^k(\mathbb{Z})$, solve for $i_T(\mathbb{Z})$ and then for $k'(\mathbb{Z})$:

$$
\begin{aligned}
i(\mathbb{Z}) &= \left(b_k q^k(\mathbb{Z})\right)^{\kappa_k} k, \\
k'(\mathbb{Z}) &= (1-\delta) k + \left[a_k + \frac{b_k}{1-1/\kappa_k}\left(\frac{i(\mathbb{Z})}{k}\right)^{1-1/\kappa_k}\right] k.
\end{aligned}
$$

We can then solve for labor hours $h(\mathbb{Z})$ by combining the FOCs of the household and the firm, such that we get an expression where h is a function of k:

$$
h(\mathbb{Z}) = \left(\frac{(1-\alpha) a}{\chi}\right)^{\frac{1}{\varphi+\alpha}} (k)^{\frac{\alpha}{\varphi+\alpha}}.
$$

Using $h(\mathbb{Z})$ and our guess for k, we can find output $y(\mathbb{Z})$ and the marginal product of capital $r^k(\mathbb{Z})$:

$$
\begin{aligned}
y(\mathbb{Z}) &= a k^{\alpha} h(\mathbb{Z})^{1-\alpha}, \\
r^k(\mathbb{Z}) &= \alpha y(\mathbb{Z}) / k.
\end{aligned}
$$

Given our values of d^k, our conjecture for $q_T^k(\mathbb{Z})$, and our solution for $r^k(\mathbb{Z})$, we can find the default threshold $\bar{\omega}(\mathbb{Z})$, and default probabilities $F(\mathbb{Z}), G(\mathbb{Z}), F_{\bar{\omega}}(\mathbb{Z})$:

$$
\begin{aligned}
\bar{\omega}(\mathbb{Z}) &= \frac{d^k}{r^k(\mathbb{Z}) + (1-\delta) q_T^k(\mathbb{Z})}, \\
F(\mathbb{Z}) &= \Phi\left(\frac{\ln(\bar{\omega}(\mathbb{Z})) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right), \\
F_{\bar{\omega}}(\mathbb{Z}) &= \frac{1}{\bar{\omega}(\mathbb{Z})\sigma_\omega}\phi\left(\frac{\ln(\bar{\omega}(\mathbb{Z})) + \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right), \\
G(\mathbb{Z}) &= \Phi\left(\frac{\ln(\bar{\omega}(\mathbb{Z})) - \frac{1}{2}\sigma_\omega^2}{\sigma_\omega}\right).
\end{aligned}
$$

This allows us to find $\Xi^b(\mathbb{Z})$, $n(\mathbb{Z})$ and $\Omega(\mathbb{Z})$:

$$
\begin{aligned}
\Xi^b(\mathbb{Z}) &= \left[F(\mathbb{Z})\bar{\omega}\Xi^b(\mathbb{Z}) - G(\mathbb{Z})\right]\left(r^k(\mathbb{Z}) + (1-\delta) q_T^k(\mathbb{Z})\right) k + \zeta F(\mathbb{Z}) q_T^k(\mathbb{Z}) k, \\
n(\mathbb{Z}) &= \left[(1-G(\mathbb{Z}))\left(r^k(\mathbb{Z}) + (1-\delta) q^k(\mathbb{Z})\right) - (1-F(\mathbb{Z})) d^k\right] k + \Xi^b(\mathbb{Z}) + \chi_b, \\
\Omega(\mathbb{Z}) &= (1-\vartheta) n(\mathbb{Z}).
\end{aligned}
$$

Since we have $q_T(\mathbb{Z}), q_T^k(\mathbb{Z}), n(\mathbb{Z}), k'(\mathbb{Z})$, we can solve for $d^{k\prime}(\mathbb{Z})$ from the bank's balance sheet constraint:

$$d^{k\prime}(\mathbb{Z}) = \frac{q^k(\mathbb{Z})\,k'(\mathbb{Z}) - \vartheta n(\mathbb{Z})}{q(\mathbb{Z})\,k'(\mathbb{Z})}.$$

Given the default probabilities and the new choice for the debt-to-assets ratio, we can find net exports $x(\mathbb{Z})$ and consumption $c(\mathbb{Z})$:

$$\begin{aligned}
x(\mathbb{Z}) &= G(\mathbb{Z})\left(r^k(\mathbb{Z}) + (1-\delta)\,q_T^k\right)k + (1-F(\mathbb{Z}))\,d^k k - q_T d^{k\prime}(\mathbb{Z})\,k' - (1-\xi)\,\Xi^b(\mathbb{Z}),\\
c(\mathbb{Z}) &= y(\mathbb{Z}) - i(\mathbb{Z}) - x(\mathbb{Z}).
\end{aligned}$$

5. Use linear interpolation given $d^{k\prime}(\mathbb{Z}), k'(\mathbb{Z})$ and our conjectures for $q_T^k(\mathbb{Z})$, $\eta_T(\mathbb{Z})$, and $q_T(\mathbb{Z})$ to calculate the value of the policy functions in the next period for each possible realization of the exogenous states.

6. Calculate the prices and quantities in the next period that we need to evaluate time t expectations, i.e. $k'(\mathbb{Z}'), d^{k\prime}(\mathbb{Z}'), i(\mathbb{Z}'), h(\mathbb{Z}'), y(\mathbb{Z}'), r^k(\mathbb{Z}'), \bar{\omega}(\mathbb{Z}'), F(\mathbb{Z}'), G(\mathbb{Z}'), F_{\bar{\omega}}(\mathbb{Z}'), \Omega(\mathbb{Z}'), x(\mathbb{Z}'), c(\mathbb{Z}')$.

7. Evaluate expectations at time t by integrating over all possible realizations of the exogenous variables. We check our conjectures for $q_T^k(\mathbb{Z})$, $\eta_T(\mathbb{Z})$, and $q_T(\mathbb{Z})$. We then compute updated $q_{T-j}^k(\mathbb{Z})$, $\eta_{T-j}(\mathbb{Z})$, and $q_{T-j}(\mathbb{Z})$.

8. Evaluate convergence of the $T-j$ terms compared to the initial conjectures at the start of the iteration. If the difference is small enough, we have solved the model. If not, go to the next iteration, set $T-j+1$ terms equal to those in $T-j$ and repeat the algorithm until the distance is smaller than 10^{-8}.

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