Bailouts, Bail-ins, and Banking Industry Dynamics*

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Abstract

I analyze how bail-in policies affect banks of different sizes and risk profiles using a structural model of balance sheet decisions with endogenous exit and entry estimated to U.S. data. Banks differ in loan risk and can influence their size, key factors shaping the likelihood of bailouts and bail-ins. When bail-ins replace bailouts, large banks face higher funding costs, eroding the benefits of size. Riskier banks slow their growth, reducing the share of big banks by 42% and their failure rate by 65%. Aggregate lending falls only 3.3%, while welfare rises 0.66% as improved bank stability outweighs reduced credit availability.

Keywords: *bail-ins, bailouts, bank failure, capital structure, financial stability*

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1 Introduction

To avoid potential financial instability from a big bank's failure, governments often provide support to stabilize banks or wind them down in a way with minimal spillovers. In response to expectations of this support, banks adjust their balance sheets, and some methods, such as bailouts, have been found to exacerbate moral hazard and increase the riskiness of banks (Bianchi (2016), Chari and Kehoe (2016), Farhi and Tirole (2012), Gale and Vives (2002)). Since the global financial crisis (GFC), governments have adopted new bail-in policies to stabilize failing big banks while limiting moral hazard.

Bail-ins recapitalize distressed banks by converting unsecured debt into new equity. Creditors are repaid in shares of the newly restructured bank while equity holders may be wiped out. Compared to their repayment in equity-injection bailouts,[1] creditors and shareholders are likely to be repaid less under bail-in. Therefore, bail-ins can both improve market discipline by increasing the cost of borrowing for riskier banks as well as reduce moral hazard by limiting shareholder payoffs in times of distress.

To evaluate the impacts of bail-in policies on the overall banking industry, I build a quantitative dynamic model of bank decisions in which banks are heterogeneous in size and risk. Prior literature on bail-ins has focused on a representative big bank (Berger et. al. (2022)). However, banks' eligibility for these resolution methods is often determined by asset size, a dimension banks optimally adjust (Brewer and Jagtiani (2013), Morgan and Yang (2016)). Further, bailout expectations increase with the probability of failure, benefiting riskier banks more than safer ones. While bail-ins may also be more likely for riskier banks, repayment to creditors is based on the equity value of the bank and may decrease with its risk. In this paper, I evaluate the distributional and aggregate changes in the banking industry under the expectation of bail-ins versus bailouts and the implications for financial stability, welfare, and efficiency.

The benchmark model consists of a steady state industry equilibrium with endogenous exit and entry, in which failing banks have a probability of bailout depending on their size. Banks in the model have rich balance sheets: they invest in a portfolio of risky loans and safe assets, funded via equity, insured deposits, and uninsured debt. Banks differ in the rate at which their borrowers default on their loans, but can mitigate this loss by investing in safe assets. The price of the uninsured debt is a function of a bank's bailout probability, creating a "too big to fail" (TBTF) subsidy. Using data from U.S. banks in the pre-Global Financial Crisis (GFC) period, I define key moments describing the aggregate state and dynamics

[1] Distressed banks in the U.S. received equity injections from the government under the Troubled Asset Relief Program. Banks were generally able to repay creditors and shareholders retained shares in the bank.

of banks under a bailout policy. By matching corresponding moments generated from the model to these data moments, I uncover deep parameters governing banks' decisions that are independent of policy parameters.

I solve for the equilibrium consequences of a new policy regime with bail-ins by replacing the bailout policy with one of bail-in. Like the bailout probability, the bail-in probability is a function of the bank's size. Under the new policy, endogenous unsecured debt prices, return on lending, and entry and exit decisions are updated. Using the parameters estimated from the benchmark model, I quantitatively assess the equilibrium consequences of the bail-in policy.

The introduction of bail-ins decreases the failure rate of big banks from 2.9% to 1.0%. Creditors are never fully repaid in the equilibrium bail-ins and this partial repayment decreases the average "subsidy" on large banks' debt from 254 to 40 bps.[2] The subsidy decreases more for banks with larger expected defaults from borrowers, resulting in these banks choosing to grow at a slower rate. The share of big banks thus decreases from 18% to 10%. Therefore, the big banks in this equilibrium have lower expected defaults and consequently are less likely to fail.

With fewer large banks, aggregate demand for bank loans must be met through the entrance of new banks. Average lending is \$21.8B compared to \$26.4B under the bailout policy, a 17.4% decrease, but the entrance of new banks leads to a decrease in aggregate lending of only 3.3%. A calculation of household consumption in each equilibrium finds a significant increase in welfare in the bail-in regime compared to the bailout regime.

As a measure of financial stability, I define a new variation of allocative efficiency in spirit of Olley and Pakes (1996) based on banks' expected loan default rates. The intuition for this measure is that, in a more efficient economy, banks with lower expected default rates lend a greater share of aggregate lending. Therefore, a lower value of the measure represents a more efficient economy. In a frictionless economy, default rate allocative efficiency is -.0078. I find that the value of this measure in the benchmark equilibrium is -.0038, but the value in the bail-in regime is -.0072. The increase in efficiency is driven by the reduction in banks with higher expected default rates that invest in large amounts of risky lending to grow quickly above the size threshold.

The change from the bailout to bail-in policy affects payoffs to both the shareholders and creditors of the bank. Using my model, I can decompose the effects of each of these channels on the resulting steady state equilibrium. I find that the importance of each channel for an

[2] Because government funding is not used to repay creditors in the event of a bail-in, there is no true subsidy in the bail-in. By subsidy, I refer to the difference in repayment from the bail-in compared to the repayment from the alternative liquidation process.

individual bank depends on its expected loan default rate. For banks with lower expected default rates, both channels matter, but for those with higher expected default rates, the repricing of their uninsured debt dominates. The latter banks constitute a larger percentage of banks and therefore, the debt channel is the dominant force. This decomposition emphasizes the importance of market discipline in reducing the failure of big banks.

Finally, I test for the resilience of the two equilibria in the face of an unanticipated large shock to loan default rates. I track the recovery of aggregate lending over time following the shock and find that aggregate lending recovers in half the time under bail-in compared to bailout. Banks in the bail-in equilibrium are less leveraged and have lower risky-to-safe asset ratios, stabilizing them against the shock. Further, the bail-in better recapitalizes failed banks than the bailout, allowing resolved banks to resume lending at a quicker pace.

The remainder of this section describes the related literature. Then, Sections 2 and 3 describe the model, its equilibrium properties, and the bail-in version of the model. Data and the estimation approach are described in Section 4. Section 5 summarizes the results of each model and highlights key mechanisms and takeaways. Section 6 concludes.

Related Literature My paper relates to the literature on bail-ins, bailouts, and the reorganization of distressed firms. Most articles on bail-ins focus on the price impacts of bank debt (Schaefer et. al. (2016), Berndt et. al. (2025)). Bernard et. al. (2022) studies the strategic game between a regulator and the creditors of banks and the characteristics of networks in which bail-ins can enhance welfare. Beck et. al. (2021) performs a reduced-form analysis of credit supply in Portugal following the bail-in of Banco Espirito Santo and find a reduction in lending by banks exposed to Banco Espirito Santo. This corresponds well to my finding that individual banks reduce their lending in the bail-in regime.

A closely related paper with a dynamic banking model of bailouts and bail-ins is Berger et. al. (2022). They focus on the capital structure decisions of a representative big bank under various resolution policies. The bank will be bailed out or in when its capital falls below a pre-set trigger point. I build upon this framework by introducing heterogeneity into the banking industry and allowing smaller banks to adjust their size based on the resolution policy in place. Further, the addition of entrants and the continuation of bailed out/in banks in my model play important roles in the amount of aggregate lending and the size distribution of banks.

Bank bailouts have been studied more extensively, such as in Davila and Walther (2020), Nguyen (2023), and Shukayev and Ueberfeldt (2021). Davila and Walther (2020) study the leverage decisions of small and big banks under a system-wide bailout policy and find that show that bigger banks take on more leverage due to internalizing their impact on the size of the bailout. Despite featuring banks of various sizes, they do not examine the size choice of banks under bailout as in this paper. Their findings on the welfare improvements of size-dependent regulations are aligned with those that I find of imposing higher funding costs via bail-ins for big banks.

Nguyen (2023) and Shukayev and Ueberfeldt (2021) solve for welfare under a bailout policy and various levels of capital requirements for banks. In both of these papers, the bailout probability does not depend on the bank's size, banks do not make an optimal size decision, and banks do not continue after receiving a bailout. In Nguyen (2023), entrants replace banks that exit and in Shukayev and Ueberfeldt (2021), all agents exit and are replaced with new agents. Therefore, my paper builds upon these by endogenizing the entry choice of banks and modeling the behavior of a continuing bank upon receiving a bailout. Another related study is that of Egan et. al. (2017) which focuses on the relationship between uninsured deposits and bank financial distress. They find that demand for uninsured deposits increases with the financial health of the bank. My findings are in line with this as my model shows that creditors demand higher prices to lend to banks that are more at risk of non-repayment.

Other quantitative models of banking industry dynamics include Corbae and D'Erasmo (2021a), Dempsey (2025), Pandolfo (2021), Ríos-Rull et. al. (2023), Van den Heuvel (2008), and Wang et. al. (2022). As in this paper, these papers microfound the balance sheet decisions of banks. However, they do not explicitly model resolution policies for big banks. My paper therefore adds another layer to banks' considerations when choosing their asset and liability structures regarding how these decisions affect their probability of receiving a bailout or bail-in and the payoffs in each.

This paper is one of the first to solve for uninsured debt price schedules in a dynamic banking model. Other papers focus purely on insured deposits for banks' sources of borrowing despite 25% of the average big bank's debt stemming from sources besides deposits. For papers that do consider uninsured debt, the same price is charged to all banks or a representative bank and is therefore unable to capture the difference in interest rates paid by heterogeneous banks and the impact this has on their decisions. The one exception is Ríos-Rull et. al. (2023), which focuses on market discipline from capital requirements and also solves for price schedules on wholesale funding. However, the model in my paper better captures variation in the TBTF subsidy due to heterogeneity in a bank's probability of bailout (or bail-in).

Finally, this paper contributes to a larger literature on the reorganization of distressed firms. The U.S. bail-in policy is similar to a proposed policy for the reorganization of failing non-financial firms by the American Bankruptcy Institute, as studied by Corbae and

D'Erasmo (2021b). The bankruptcy proposal they study allows the firm to become a new "all-equity" firm, forgiving the previous debt in a similar manner to my own counterfactual. My model borrows from many aspects of this model, but adapts them to match the unique features of the banking industry, such as deposit insurance and risk-shifting. Additionally, my paper also compares this new policy to one of bailouts, a policy that bears more importance in the financial than non-financial sector.

2 Model

The model is in discrete time with an infinite horizon and heterogeneous banks. Banks invest in risky loans and safe assets, funded via costly equity, insured deposits, and defaultable debt. Since banks can fail, competitive investors price the defaultable debt based on the expectation of repayment, including the probability that the bank is bailed out or bailed in instead of liquidated. Banks face idiosyncratic risk on the returns of their lending that contribute to their chance of failure. There is a representative household that maximizes lifetime utility through its lending to banks and returns from holding stock in the banks. Given the focus on long-run consequences of these policies, I solve for a stationary equilibrium characterized by a measure of banks endogenously distributed across loan returns, cash, and insured deposits.

2.1 Banks and Technology

Banks take deposits from households and lend to firms. Bank j maximizes the expected discounted value of dividends:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t d_{jt}, \tag{1}$$

where β^t is the discount rate of the bank and d_{jt} denotes dividends in period t. Banks lend one-period loans ℓ_{jt+1} to firms. A fraction λ_{jt+1} of the loans will default and pay zero, and banks earn an endogenous return R^ℓ on the nondefaulted fraction of loans. The final return from period t lending in period $t+1$ for bank j is then

$$\text{Return on Lending}_{jt+1} = R^\ell(1-\lambda_{jt+1})\ell_{jt+1} \tag{2}$$

where $\lambda_{jt+1} \in \Lambda \equiv \{\lambda^1, ..., \lambda^n\}$ is an idiosyncratic default rate, i.i.d. across banks, that follows a first-order Markov process with transition matrix $F(\lambda_{jt+1}|\lambda_{jt})$; and $\ell_{jt} \in \mathbb{R}_+$ is the loan volume. The gross interest rate R^ℓ is the same for all banks and is pinned down in equilibrium to satisfy the free-entry condition of banks, to be discussed later in this section. Banks face costs of monitoring their loans, and these costs are convex in the size of their balance sheet. For tractability, we model these costs as $c_{Mjt}\ell_{jt}^2$.

While banks cannot reduce the risk of default on their loans, they can invest in safe assets $s_{jt+1} \in \mathbb{R}_+$ to smooth their expected returns. There are no monitoring costs associated with these assets, and all banks earn an exogenous return of R, making the total return Rs_{jt+1}. The difference in cost of issuance for risky loans and safe assets helps create an interior solution to the portfolio choice problem. Otherwise, risk neutral banks would choose to fully invest in whichever asset has the highest expected return. Banks also pay a fixed cost of operating c_O each period, representing salaries, utilities, insurance, and other fees. The fixed cost introduces the concept of scale: while a bank may have to pay more monitoring costs as it lends more, its fixed cost of operating to expected return decreases.

The bank's investments are financed from four sources: *(i)* current net cash, n_{jt} *(ii)* external equity injection $d_{jt} < 0$, *(iii)* one-period non-contingent debt $b_{jt+1} \in \mathbb{R}_+$ at discounted price q_{jt}, and *(iv)* insured deposits δ_{jt+1} at discounted price q^δ. Banks' access to insured deposits vary over time according to a first-order Markov process with transition matrix $H(\delta_{jt+1}|\delta_{jt})$, which is i.i.d. across banks. While the price of insured deposits is not affected by bailout or bail-in probabilities, insured deposits are still a primary source of big bank funding and are thus important to include to quantitatively match the data. I simplify the choice of deposits into an exogenous Markov process as this choice is not a main focus of the bailout versus bail-in question and to keep the model tractable.

Banks are restricted in their portfolio choices by risk-weighted capital requirements, such that book equity over risk-weighted assets must be greater than a threshold α. As book equity is equal to the difference between assets and debt, the capital requirement is

$$\frac{\ell_{jt+1} + s_{jt+1} - \delta_{jt+1} - b_{jt+1}}{\omega_r \ell_{jt+1} + \omega_s s_{jt+1}} \geq \alpha, \tag{3}$$

where ω_r and ω_s are risk-weights on the "risky" and "safe" types of assets, respectively. To match the regulatory environment in the United States before the GFC, the capital requirement parameters $(\omega_r, \omega_s, \alpha)$ are the same for all banks.

Corporate taxes paid by banks are equivalent to

$$\tau_{jt} = \tau_C \max\{0, (R^\ell - 1)(1 - \lambda_{jt})\ell_{jt} + (R - 1)s_{jt} - (\frac{1}{1 + r_F} - 1)b_{jt} - (\frac{1}{q^\delta} - 1)\delta_{jt}\}, \tag{4}$$

or interest income less interest expense.[3] Since interest expenses are deductible, there is a tax-advantage to both insured deposits and uninsured debt.

I denote the "net cash" of a bank after it realizes its returns on assets and repays debt and taxes as

$$n_{jt} = R^{\ell}(1 - \lambda_{jt})\ell_{jt} + Rs_{jt} - \delta_{jt} - b_{jt} - \tau_{jt}. \tag{5}$$

This is the available cash to the bank before it decides the quantity of dividends/equity injections, the volume of new lending, the quantity of new safe asset investments, and the quantity of new uninsured borrowing as well as before it realizes its new level of insured deposits and pays the fixed cost of operating and variable monitoring cost on lending. Equity issuance is costly, captured by a weakly convex function (ψ), which is zero when a bank issues dividends instead of equity. The flow budget constraint

$$\psi(d_{jt}) - s_{jt+1} - \ell_{jt+1} - c_{Mjt}\ell_{jt+1}^2 - c_O \leq n_{jt} + q^{\delta}\delta_{jt+1} + q_{jt}b_{jt+1} \tag{6}$$

states that dividends ($d_{jt} \geq 0$), safe asset purchases (s_{jt+1}), lending (ℓ_{jt+1}), and operating and variable costs ($c_O + c_{Mjt}\ell_{jt+1}^2$) must be financed by net cash n_{jt}, insured deposits ($q^{\delta}\delta_{jt+1}$), uninsured borrowing ($q_{jt}b_{jt+1}$), and equity issuance net of issuance costs ($\psi(d_{jt}) < 0$).

Banks enter the industry by paying a cost c_e. After paying this cost, banks observe their initial level of default rate λ_{jt} from the stationary distribution of $\bar{F}(\lambda)$ and receive their initial level of insured deposits δ_{jt}. Banks choose their initial levels of loans, safe assets, and uninsured debt. The mass of new entrants is denoted as M_t.

Banks charge firms a return R^{ℓ} on lending. A higher R^{ℓ} implies a higher borrowing cost for firms. I follow the literature in assuming an isoelastic demand for loans by firms with elasticity ϵ and a scale parameter ζ. Firm demand for risky lending is decreasing in R^{ℓ} according to the function

$$L^D(R^{\ell}) = \zeta(R^{\ell})^{-\epsilon}. \tag{7}$$

Banks take R^{ℓ} as given, and banks' supply of risky lending equals risky lending ℓ_{jt} by continuing incumbents, bailed out incumbents, and entrants. The return R^{ℓ} and mass of entrants M_t are jointly pinned down in equilibrium to satisfy *(i)* the free entry condition and *(ii)* the market clearing for loans to firms (loan supply equals loan demand).

[3] The true interest paid on uninsured debt is $\frac{1}{q_{jt-1}} - 1$. However, I simplify the uninsured interest expense to be $\frac{1}{1+r_F} - 1 \leq \frac{1}{q_{jt-1}} - 1$ in order to reduce the computational burden when solving for the bank's decisions.

2.2 Resolution

Instead of repaying all insured deposits and uninsured debt to continue to operate, banks can enter resolution. Resolution policies in the model are modeled after explicit and implicit resolution policies in the U.S., as described in detail in Appendix A. In the benchmark model, there are two possible resolution methods:

Liquidation Modeled after the FDIC's Deposit Payoff Process, bank j's assets are liquidated at firesale discount $c_L < 1$. Additionally, the bank incurs a fixed cost of resolution, c_F, to represent salaries and administrative costs paid to the FDIC for handling bank resolution. Remaining proceeds are used first to repay insured deposits δ_{jt}, then uninsured debt b_{jt}. The bank exits and shareholders obtain $\tau_c \max\{c_L(R^\ell(1-\lambda_{jt})\ell_{jt} + Rs_{jt}) - c_F - \delta_{jt} - b_{jt}, 0\}$. Investors obtain $\min\{b, \max\{c_L(R^\ell(1-\lambda_{jt})\ell_{jt} + Rs_{jt}) - c_F - \delta_{jt}, 0\}\}$.

Bailout The bank receives an equity injection θ_{jt} such that it now meets the capital requirement

$$\frac{R^\ell(1-\lambda_{jt})\ell_{jt} + Rs_{jt} - \delta_{jt} - b_{jt} + \theta_{jt}}{\omega_r R^\ell(1-\lambda_{jt})\ell_{jt} + \omega_s Rs_{jt}} = \alpha. \tag{8}$$

With these funds, the bank fully repays its insured deposits and uninsured debt. It receives its new insured deposits δ_{jt+1} and continues as a bank with δ_{jt+1}, λ_{jt}, and $n_{jt} = \alpha\omega_r R^\ell(1-\lambda_{jt})\ell_{jt} + \alpha\omega_s Rs_{jt}$. It is restricted from issuing dividends this period, $d_{jt} \leq 0$.

2.3 Households

In any period t, households choose a stream of consumption C_t, insured deposits $\{\delta_{jt+1}\}_j$, uninsured debt $\{b_{jt+1}\}_j$, and shares $\{S_{jt+1}\}_j$ of incumbent and entrant banks to maximize the expected present discounted value of utility given by:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t) \tag{9}$$

subject to

$$C_t + \int q^\delta \delta_{jt+1}\,\mathrm{d}j + \int p_{jt}S_{jt+1}\,\mathrm{d}j + \int q_{jt}b_{jt+1}\,\mathrm{d}j$$
$$= \int \delta_{jt}\,\mathrm{d}j + \int (p_{jt} + d_{jt})S_{jt}\,\mathrm{d}j + \int f^R(b_{jt})\,\mathrm{d}j + \int \tau_{jt}\,\mathrm{d}j - \int \theta_{jt}\,\mathrm{d}j - \int f^I(\delta_{jt})\,\mathrm{d}j + W_t^{rest} \tag{10}$$

where p_{jt} is the after-dividend stock price of bank j. The function $f^R(b_{jt})$ represents the repayment of the uninsured debt by the bank. If the bank does not enter resolution or is bailed out, then this is equal to b_{jt}. If the bank is liquidated, the repayment could be less than b_{jt} and will be determined by the liquidation process outlined above. Even in a liquidation, insured deposits will be fully repaid due to deposit insurance. However, if the remaining assets after the firesale cost are not enough to cover insured deposits, then the difference will be imposed onto households through a tax, represented by $f^I(\delta_{jt})$. Equity injections in bailouts are captured by θ_{jt}. Finally, the model is of an industry equilibrium. Therefore, the households have net wealth that comes from other sources, such as stock holdings of firms and wages from labor. This is captured by the term W_t^{rest}.

3 Equilibrium

I study equilibria that do not depend on the name of bank j, but only on relevant state variables. As I use recursive methods to solve the bank's decision problem, I denote any variable x_t as x and x_{t+1} as x'. Further, I refer to banks by their place in the cross-sectional distribution of banks $\Gamma(\delta, \lambda, n)$ where the relevant state variables are a bank's insured deposits δ, current realization of the loan default rate λ, and net cash n.

3.1 Incumbent Bank's Problem

An incumbent bank begins the period with their current loan default rate realization λ and net cash n and receives their insured deposits $q^\delta \delta$. The bank then makes its choices of risky lending ℓ', safe assets s', and uninsured borrowing b'. As the repayment to the uninsured investor depends on the bank's realization of the loan default rate, its quantities of lending and safe assets, and the insured deposits it must first repay, the price on the uninsured debt is therefore a function of the variables $(\delta, \lambda, \ell', s', b')$. The bank receives $q(\delta, \lambda, \ell', s', b')b'$ today and must repay b' tomorrow. The monitoring cost parameter c_{Mjt} will be implemented such that banks with the same level of insured deposits will be subject to the same monitoring cost parameter, $c_{Mjt} = c_M(\delta)$. This parameter will be decreasing in δ, aligned with the finding of Corbae and D'Erasmo (2021a) that larger banks have a cost advantage over smaller banks. These decisionsm, along with the bank's net cash n, pin down the bank's dividend/equity issuance d.

After issuing the dividend or raising equity, the bank then realizes its returns on its assets, including the realization of the loan default rate λ', for a gross return on lending of

$$G(\lambda', \ell', s') = R^{\ell}(1-\lambda')\ell' + Rs'. \tag{11}$$

Once the bank realizes this gross return on its assets, it must decide to continue operating or enter resolution. Only after making this decision does the bank realize its new level of insured deposits δ'. Letting $V_R(\delta, \lambda', \ell', s', b')$ denote the value of resolution and $V(\delta', \lambda', n')$ the value of a continuing bank, the bank's decision problem can be written as

$$V(\delta, \lambda, n) = \max_{\ell', s', b'} \quad d + \beta \mathop{\mathbb{E}}_{\lambda'|\lambda}\Big(\max\{V_R(\delta, \lambda', \ell', s', b'), \mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta', \lambda', n'(\delta, \lambda', \ell', s', b'))\}\Big) \tag{12}$$

subject to

$$\psi(d) + s' - \ell' - c_M(\delta)\ell'^2 - c_O = n + q^{\delta}\delta + q(\delta, \lambda, \ell', s', b')b' \tag{13}$$

$$\frac{\ell' + s' - \delta - b'}{\omega_r \ell' + \omega_s s'} \geq \alpha \tag{14}$$

$$n'(\delta, \lambda', \ell', s', b') = G(\lambda', \ell', s') - \delta - b' - \tau(\delta, \lambda', \ell', s', b') \tag{15}$$

$$\tau(\delta, \lambda', \ell', s', b') = \tau_C \max\{0, (R^{\ell}-1)(1-\lambda')\ell' + (R-1)s' - (\frac{1}{1+r_F} - 1)b' - (\frac{1}{q^{\delta}} - 1)\delta\} \tag{16}$$

$$\ell' \geq 0, \quad s' \geq 0, \quad b' \geq 0. \tag{17}$$

3.2 Resolution

In the benchmark model, the resolution options include liquidation and bailout. If the bank is sent to resolution, it is bailed out with probability $\rho(\ell', s')$ and liquidated with probability $1 - \rho(\ell', s')$. ρ is a function of the bank's assets to capture the "too big to fail" aspect of the bailout policy[4]. If the bank is liquidated, the bank's realized assets, $G(\lambda', \ell', s')$, are devalued at a discount price, c_L, and are used first to pay the fixed cost of liquidation c_F. The leftover funds are then used to repay insured depositors.[5] Leftover funds after this step, $\max\{0, c_L G(\lambda', \ell', s') - c_F - \delta\}$, are given to creditors to repay them for the uninsured debt.

[4]In reality, the probability of a bailout is due to the systemic importance of the bank. However, systemic importance is highly correlated with size, as it was the largest banks that were discovered to receive subsidies for their debt and equity leading up to the crisis due to implicit guarantees of government support (Acharya et. al. (2016)).

[5]In Deposit Payoffs, the FDIC uses the Deposit Insurance Funds to make insured depositors completely whole. The FDIC itself then takes the place of the insured depositors in the payout order to reimburse the Deposit Insurance Fund. At this step, the funds are used to pay the FDIC and uninsured depositors equally. Each dollar is split between the FDIC and uninsured depositors rather than paying one then the other. Uninsured deposits are grouped with insured deposits in my model (see Section 4).

Shareholders are only repaid if all creditors are fully repaid. However, they have limited liability, so their "final dividend" cannot be negative. The value of liquidation to the shareholders is then

$$V_L(\delta, \lambda', \ell', s', b') = \tau_c \max\{0, c_L G(\lambda', \ell', s') - c_F - \delta - b'\}. \tag{18}$$

The value of being bailed out, V_O, depends on the new level of insured deposits, and is thus a conditional expectation over δ'. A bank that is bailed out receives an equity injection $\theta(\delta, \lambda', \ell', s', b')$ from the government equal to the amount of equity needed to make the bank once again well-capitalized, or that

$$\frac{G(\lambda', \ell', s') - \delta - b' + \theta(\delta, \lambda', \ell', s', b')}{\omega_r R^\ell (1-\lambda')\ell' + \omega_s R s'} = \alpha \tag{19}$$

$$\theta(\delta, \lambda', \ell', s', b') = \delta + b' - (1 - \alpha\omega_R) R^\ell (1-\lambda')\ell' - (1 - \alpha\omega_s) R s' \tag{20}$$

Bailed out banks do not pay taxes in this period as imposed taxes would only lead to a higher level of necessary injection. After receiving the equity injection and repaying its debt, the bank's net cash is

$$\tilde{n}'(\delta, \lambda', \ell', s', b') = G(\lambda', \ell', s') - \delta - b' + \theta(\delta, \lambda', \ell', s', b') \tag{21}$$

$$\tilde{n}'(\delta, \lambda', \ell', s', b') = \alpha\omega_R R^\ell (1-\lambda')\ell' + \alpha\omega_s R s'. \tag{22}$$

The fact that the net cash of the bank post-injection does not depend on the level of insured deposits or uninsured debt will play a key role in the leverage decisions of banks under the bailout policy.

The problem of the bailed out bank post-injection almost exactly the same as that of the incumbent bank in Equation 12. The one difference is that the equity injection comes with the restriction that banks cannot issue dividends ($d \leq 0$) in the period after receiving the equity injection. I designate the value function that solves this problem as $V^{d \leq 0}(\delta, , n)$.

The value of entering resolution can then be written as

$$V_R(\delta, \lambda', \ell', s', b') = (1 - \rho(\ell', s')) V_L(\delta, \lambda', \ell', s', b') + \rho(\ell', s') \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d \leq 0}(\delta', \lambda', \tilde{n'}(\delta, \lambda', \ell', s', b'))) \tag{23}$$

3.3 Entrant's Problem

After paying a fixed cost c_E, a new bank realizes its current loan default rate λ drawn from the distribution $\bar{F}(\lambda)$. For simplicity, I assume it also receives the lowest value of insured deposits and has no net cash. The entrant's problem is then equivalent to that of a bank $V(\delta^0, \lambda, 0)$.

The free entry condition dictates that entering banks make zero profits in expectation. This condition is therefore

$$(-c_e + \underset{\lambda}{\mathbb{E}}(V(\delta^0, \lambda, 0)))M = 0,\ M \geq 0 \tag{24}$$

3.4 Investor's Problem

Uninsured debt for banks is generally lent by large intermediaries, such as mutual funds. These investors have access to unlimited external funding at the risk-free rate, r_F, and complete information about the default risk of individual banks. There are many of these intermediaries in the world and they compete among themselves to lend to banks. Therefore, they are modeled as perfectly competitive and earn zero profits on each of their lending contracts. However, because I assume the investors diversify their lending to the banks, they are risk-free and will not fail.

The first component to the expected profit from an investor's loan to a bank is the probability of default by the bank, which can only occur if the bank enters resolution. Define $X(\delta, \lambda', \ell', s', b') = 1$ if a bank with $(\delta, \lambda', \ell', s', b')$ enters resolution and $X(\delta, \lambda', \ell', s', b') = 0$ if not. Then, the set of λ's such that the bank enters resolution is

$$\Omega(\delta, \ell', s', b') = \{\lambda' \in \Lambda : X(\delta, \lambda', \ell', s', b') = 1\}. \tag{25}$$

At the time the loan is made, λ' is unknown but can be estimated based on the bank's current default rate realization λ and the Markov process $F(\lambda'|\lambda)$. The expected profit an investor makes on a loan contract to a bank with insured deposits δ, current default rate λ, and choices of risky loans ℓ', safe assets s', and debt b' is then

$$\begin{aligned}\pi(\delta, \lambda, \ell', s', b') = \underbrace{-q(\delta, \lambda, \ell', s', b')b'}_{\text{debt lent}} + \frac{1}{1+r_F}\Big[& \underbrace{\Big(1 - \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)\Big)b'}_{\text{expected repayment - no resolution}} \\ + (1-\rho(\ell', s')) & \underbrace{\sum_{\lambda' \in \Omega(\delta, \ell', s', b')} \min\{b', \max\{c_L G(\lambda', \ell', s') - c_F - \delta, 0\}\}F(\lambda'|\lambda)}_{\text{expected repayment - liquidation}} \\ + \rho(\ell', s') & \underbrace{\sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)b'}_{\text{expected repayment - bailout}} \Big].\end{aligned} \tag{26}$$

In expectation, investors earn zero profit on each loan contract. The price of a given contract can then be solved as

$$q(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_F}\big[\big(1 - \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)\big)$$
$$+(1-\rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \tag{27}$$
$$+\rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)\big].$$

Given that investors are not guaranteed a full repayment in liquidation but they are in bailout, the price q is increasing in the probability of bailout ρ. An increase in q represents a decrease in the borrowing costs of banks. Since ρ is a function of the size of the bank's assets, this creates a "too big to fail" subsidy on the borrowing costs of bigger banks. A more detailed explanation of this subsidy can be found in Appendix Section B.

3.5 Household's Problem

Households do not internalize that their insured deposit choices can affect the repayment of the deposits by the bank itself and the taxes needed to make up the difference. The first-order conditions for the household problem are described in Appendix Section C[6]. In a steady state, these first-order conditions imply the equilibrium conditions

$$q^{\delta} = \beta \tag{28}$$

$$\frac{1}{1+r_f} = \beta \tag{29}$$

$$p_{jt} = \beta \mathbb{E}_t(p_{jt+1} + d_{jt+1}) \tag{30}$$

To characterize stock prices, consider the case of an incumbent bank and let $p(\delta, \lambda, n) = V(\delta, \lambda, n) - d(\delta, \lambda, n)$ (i.e. the ex-dividend stock price is given by bank value). Plugging this in, we see that

$$p(\delta, \lambda, n) = \beta \mathop{\mathbb{E}}_{\lambda'|\lambda} \mathop{\mathbb{E}}_{\delta'|\delta}(p(\delta', \lambda', n'(\delta, \lambda', \ell', s', b')) + d(\delta', \lambda', n'(\delta, \lambda', \ell', s', b'))) \tag{31}$$

$$V(\delta, \lambda, n) - d(\delta, \lambda, n) = \beta \mathop{\mathbb{E}}_{\lambda'|\lambda} \mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta', \lambda', n'(\delta, \lambda', \ell', s', b')) \tag{32}$$

[6] Appendix Section C also provides an explanation of Equation 29

However, the continuing value of the bank in the next period depends on the resolution decision, so we can substitute the expected value as

$$
\begin{aligned}
V(\delta,\lambda,n) - d(\delta,\lambda,n) = \beta \mathop{\mathbb{E}}_{\lambda'|\lambda}(\max\{&V_R(\delta,\lambda',\ell'(\delta,\lambda,n),s'(\delta,\lambda,n),b'(\delta,\lambda,n)),\\
&\mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta',\lambda',n'(\delta,\lambda',\ell',s',b')\})
\end{aligned} \tag{33}
$$

Then it is straightforward to show that Equation 30 is equivalent to Equation 12.

In the case of purchasing a stock of an entrant, $S_E = S = S'$ due to the normalization. Once the stock is purchased, the price can be accounted for on both sides of the budget constraint. Then, only the initial equity injection d_E is included in the household budget set in Equation 9.

3.6 Cross-Sectional Distribution

Given that all banks with the same (δ, λ, n) will make the same (ℓ', s', b') decisions, we can define

$$
n'(\delta,\lambda,n,\lambda') = G(\lambda',\ell'(\delta,\lambda,n),s'(\delta,\lambda,n)) - b'(\delta,\lambda,n) - \delta - \tau(\delta,\lambda,n,\lambda'). \tag{34}
$$

Additionally, we can define the net cash of a bank after a bailout as

$$
\tilde{n}(\delta,\lambda,n,\lambda') = \alpha\omega_r R^{\ell}(1-\lambda')\ell'(\delta,\lambda,n) + \alpha\omega_s R s'(\delta,\lambda,n). \tag{35}
$$

In the same way, we can describe the resolution decision, X, based on $(\delta, \lambda, n, \lambda')$. Entrants can also use this notation, where $n = 0$ for all entrants. Let Δ, Λ, and N be the sets of insured deposits, loan default rates, and net cash, respectively and $\bar{\Delta} \subset \Delta$, $\bar{\Lambda} \subset \Lambda$, and $\bar{N} \subset N$. The mass of incumbent banks with insured deposits δ, loan default rate λ, and net cash n is $\Gamma(\delta, \lambda, n)$. The law of motion for the cross-sectional distribution of banks is then given by:

$$
\begin{aligned}
\Gamma'(\bar{\Delta},\bar{\Lambda},\bar{N};M) = \int_{\bar{N}} \sum_{\bar{\Lambda}} \sum_{\bar{\Delta}} \Big\{ \int_N \sum_{\Lambda} \sum_{\Delta} H(\delta'|\delta)F(\lambda'|\lambda)\Gamma(\delta,\lambda,dn)\\
\big[(1-X(\delta,\lambda,n,\lambda'))1_{n'=n'(\delta,\lambda,n,\lambda')} + X(\delta,\lambda,n,\lambda')\rho(\delta,\lambda,n)1_{n'=\tilde{n}'(\delta,\lambda,n,\lambda')}\big]\Big\}\\
+M\sum_{\bar{\Lambda}} 1_{n'=n'(\delta_S,\lambda,0,\lambda')}H(\delta'|\delta_S)F(\lambda'|\lambda)\bar{F}(\lambda).
\end{aligned} \tag{36}
$$

3.7 Definition of Equilibrium

A stationary equilibrium is a list $\{V^*, q^*, X^*, \Gamma^*, \Omega^*, \pi^*, R^{\ell^*}, M^*, q^{\delta^*}, p^*\}$ such that:

1. Given q and R^ℓ, the value function V^* and resolution decisions X^* are consistent with the bank's optimization problem in Equation 12.

2. The set Ω^* is consistent with bank decision rules.

3. The equilibrium uninsured debt price is such that investors earn zero profits in expected value on each contract, or that at $q^*(\delta, \lambda, \ell', s', b')$, $\pi^*(\delta, \lambda, \ell', s', b') = 0$.

4. Γ^* is a stationary measure consistent with bank decision rules, the law of motion for stochastic variables, and M^*.

5. The free entry condition in Equation 24 is satisfied.

6. Given R^{ℓ^*} and the stationary distribution Γ^*, the risky lending market clears at M^* or

$$\int_N \sum_\Lambda \sum_\Delta \ell'(\delta, \lambda, n)\Gamma^*(\delta, \lambda, dn) + \sum_\Lambda M^* \ell'(\delta_S, \lambda, 0)\bar{F}(\lambda) = L^D(R^{\ell^*}) \tag{37}$$

7. Stock, insured deposits, and uninsured debt markets clear at p^*, q^{δ^*}, and q^*.

3.8 Bail-in

In this section, I introduce changes to the model when I replace the bailout policy with a modified version of the bail-in policy described in the Dodd-Frank Act. While the U.S. has had a bail-in policy in place since 2010, no bail-in has occurred. Further, it is not clear that we have reached a new steady state equilibrium after the adoption of the bail-in policy. Additionally, at the time that the bail-in policy was adopted, many other banking reforms were enacted, such as size-dependent capital requirements. In order to properly calibrate the model to the true bail-in regime, one would need to include all of these other policy changes into the model to isolate the sole effect of the bail-in policy. Instead, we used the estimated parameters from the benchmark model to study how the equilibrium would change if the bail-in policy were in place from 1992-2006 instead of the implicit bailout policy.

In this counterfactual model, if a bank enters resolution, it is bailed in with the same probability function $\rho(\ell', s')$ and liquidated with the complementary probability of $1 - \rho(\ell', s')$. These probabilities are chosen to be consistent with the benchmark model and for easier comparison with those results. In a bail-in, all of the uninsured debt will be converted into equity, and the bank will only need to repay insured deposits. Therefore, the new net cash of the bank is equal to

$$\hat{n}'(\delta, \lambda', \ell', s', b') = R^{\ell}(1 - \lambda')\ell' + Rs' - \delta. \tag{38}$$

This restructured bank is then valued at $\mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b'))$ as the bail-in occurs before the realization of the new deposit base and the bailed-in bank is restricted from issuing dividends in that period. After the realization of the new insured deposit base, the problem of the bailed in bank is the same as Equation 12 but with the restriction that $d \leq 0$.

In exchange for the forgiveness of their debt claims, the creditors receive shares in the new bank, up to the value of their claim, or $\min\{b', \mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b'))\}$. The original shareholders only retain shares in the bank if the value of the bank exceeds that of the original debt claim. They still have limited liability, so the value to the *original* shareholders of a bailed-in bank is $\max\{0, \mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b')) - b'\}$.

The bank problem can be written as in Equation 12, except that now

$$\begin{aligned} V_R(\delta, \lambda', \ell', s', b') &= (1 - \rho(\ell', s'))V_L(\delta, \lambda', \ell', s', b') \\ &+ \rho(\ell', s') \max\{0, \mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b')) - b'\}. \end{aligned} \tag{39}$$

Comparing the value of resolution under bail-in to that under bailout, we see that the value to the original shareholders now depends on both δ and b'. Net cash after the bail-in is a function of δ, unlike the post-bailout injection net cash. Further, shareholders will only have positive value from the bail-in if the value of the new shares exceeds b'. Under bailout, the shareholders' value depended only on the remaining assets as the injection from the government would repay all of b'. This change could be instrumental to driving bank's decisions under bail-in compared to bailout.

To price the uninsured debt in the bail-in model, I update the resolution decisions of banks, denoted $X_{IN}(\delta, \lambda', \ell', s', b')$. The set of loan default rate realizations such that a bank would choose to enter resolution is

$$\Omega_{IN}(\delta, \ell', s', b') = \{\lambda' \in \Lambda : X_{IN}(\delta, \lambda', \ell', s', b') = 1\}. \tag{40}$$

The price of a loan an intermediary makes to a bank with insured deposits δ, current realization λ, lending choice ℓ', safe assets s', and uninsured borrowing b' is

$$\begin{aligned} q_{IN}(\delta,\lambda,\ell',s',b') = \frac{1}{1+r_F}\Big[\big(1 - \sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')} F(\lambda'|\lambda)\big) \\ +(1-\rho(\ell',s')) \sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \\ +\rho(\ell',s')) \sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')} \min\{1, \frac{\mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta',\lambda',\hat{n}'(\delta,\lambda',\ell',s',b'))}{b'}\} F(\lambda'|\lambda)\Big]. \end{aligned} \tag{41}$$

The first two lines of this equation are identical to those in Equation 27 except for potential differences in the sets of λ' at which the bank enters resolution. The final line, the expected repayment in bail-in, is where this equation could differ drastically from that of the bailout equilibrium. Unlike under the benchmark model, the intermediary is now at risk for not being fully repaid under both bail-in and liquidation.

A TBTF subsidy is not as clear here. Varying ρ simply changes the weight placed on two types of potentially partial repayment — one from liquidation and one from bail-in. If the repayment under bail-in is always full repayment, then bail-in is no different for creditors than bailout, aside from possible differences in resolution decisions. However, if not, then large banks will have to pay more expensive prices to the creditors to compensate them for extra losses compared to the equilibrium with bailouts. A further derivation of the TBTF subsidy can be found in Appendix Section B.

The bail-in equivalent to Equation 36, or the mass and law of motion equations, respectively, is then

$$\begin{aligned} \Gamma^{IN\prime}(\bar{\Delta},\bar{\Lambda},\bar{N};M^{IN}) = \int_{\bar{N}} \sum_{\bar{\Lambda}} \sum_{\bar{\Delta}} \Big\{ \int_N \sum_{\Lambda} \sum_{\Delta} H(\delta'|\delta) F(\lambda'|\lambda) \Gamma^{IN}(\delta,\lambda,dn) \\ \big[(1 - X^{IN}(\delta,\lambda,n,\lambda')) 1_{n'=n'(\delta,\lambda,n,\lambda')} + X^{IN}(\delta,\lambda,n,\lambda') \rho(\delta,\lambda,n) 1_{n'=\hat{n}'(\delta,\lambda,n,\lambda')}\big] \Big\} \\ + M^{IN} \sum_{\bar{\Lambda}} 1_{n'=n'(\delta_S,\lambda,0,\lambda')} H(\delta'|\delta_S) F(\lambda'|\lambda) \bar{F}(\lambda) \end{aligned} \tag{42}$$

where $\hat{n}'$ now represents the net cash of a bailed-in bank. This is equivalent to $\hat{n}' = G(\lambda',\ell',s') - \delta$.

Other Policy Counterfactuals Since the financial crisis, other macroprudential policies that have been adopted to reduce bank failure rates include an increase in capital requirements and the introduction of size-dependent capital requirements. A comparison of the results under bailout and bail-in to equilibria with these policies can be found in an Online Appendix on the author's website.

4 Estimation

In order to discuss the quantitative impact of a change in resolution policies, I estimate the model parameters to match data from the U.S. banking industry. There are 42 parameters in the benchmark model that I estimate using a mix of internal and external calibration. Thirteen of the parameters are estimated via Simulated Method of Moments by matching 14 model moments to corresponding data moments. The remaining parameters are externally calibrated using values from regulation, previous literature, and other empirical relationships in the data.

Matching moments ensures that the balance sheets and distribution of banks are similar to those observed in the data when a bailout policy for big banks was in place. By estimating deep parameters outside of those governing the bailout policy, I can calculate the quantitative impact of switching to a bail-in policy, with bank decisions governed by the same parameters. I use data from the time period of 1992-2006 to estimate the benchmark model. This time period starts with the passage of the FDIC Improvement Act, solidifying the PCA requirements for the liquidation of undercapitalized banks.[7] Additionally, it corresponds to 8 years after the bailout of Continental Illinois Bank in 1984 and the beginning of the common phrase "too big to fail"[8].

4.1 Data Sources

Model parameters are informed from data and policy. The main dataset is the Federal Reserve's Consolidated Report of Condition and Income (Call Reports), which consists of commercial bank regulatory filings, including both independent commercial banks and those belonging to a bank holding company. I consolidate the data to the bank holding company level. I focus on larger banks, defined as those with \$10B in assets in 1990 dollars. In the data, banks are defined as entrants when they enter the sample from a de novo creation of a bank or through a smaller bank growing above the \$10B in 1990 dollars threshold. Once a bank has crossed the \$10B threshold, it is not removed from the sample nor counted as an

[7] More details can be found in Appendix A

[8] See https://www.federalreservehistory.org/essays/continental-illinois.

exit if its assets drop below the threshold. Banks are only defined as exits if designated as a closure or failure on the National Information Center website. As I do not model acquisitions, these are not counted as exits in the data. My focus in this paper is on commercial banks, so I have dropped banks whose primary business activity is not commercial banking: one whose loan share out of all assets is less than 25%, as in Corbae and D'Erasmo (2021a).

4.2 Estimation Strategy

The model period is one year. In the external calibration, a subset of the parameters are chosen from outside the model. These are primarily described in Table 1. Externally calibrated parameters relating to the Markov processes for the loan default rate and insured deposits are described in Tables 2 and 3, respectively. In the internal calibration, the remaining parameters are chosen to match a set of data moments via simulated method of moments (SMM). Table 4 summarizes these parameters and the matching of moments.

External Calibration The median interest earned by banks on their deposits during the time period was 1.76%. I therefore set the price of insured deposits $q^{\delta} = \frac{1}{1.0176} = 0.9827$. Additionally, equilibrium relationships dictate the bank's discount factor β equals q^{δ} and the uninsured creditor's risk-free rate, r_F, equals $\frac{1}{\beta} - 1$.

Parameters related to banking regulation, such as the capital requirements α and the risk-weights ω_r and ω_s, are taken from the FDIC Improvement Act of 1992. The liquidation cost on assets c_L is set at 72% to match results from Granja et. al. (2017), which finds that the average cost to the FDIC to resolve banks during the GFC was 28% of the banks' assets. The parameter for loan demand elasticity on behalf of firms, ϵ, is 1.1 to match that from Bassett et. al. (2014). The probability of bailout function $\rho(\ell', s')$ will be a piece-wise function

$$\rho(\ell', s') = \begin{cases} 0 & \ell' < \bar{a} \\ \bar{\rho} & \ell' \geq \bar{a}. \end{cases} \tag{43}$$

$\bar{\rho}$ is set to 0.9 to match results from Koetter and Noth (2016) who estimated the bailout expectations in the U.S. as between 90 and 93 percent. The asset threshold $\bar{a}$ is set to \$100B based on the finding of Brewer and Jagtiani (2013) that during this time period, banks paid significant merger premiums for mergers that would increase their size above \$100B. They do not find a significant premium at any other threshold size[9].

[9]The bailout probability is a function of only risky assets due to the connection between risky assets and systemic importance. The failure of a bank using deposits to only invest in cash and safe assets would not

Table 1: Externally Calibrated Parameters

Parameter	Description	Value	Source
q^δ	Insured Deposits Price	0.9827	Call Reports
β	Bank Discount Factor	0.9827	Normalization to q^δ
r_F	Uninsured Creditors' Discount Rate	0.0176	Normalize to $\frac{1}{\beta} - 1$
α	Capital Requirement	0.04	FDICIA (1992)
ω_r	Risk-Weight on Lending	1.0	FDICIA (1992)
ω_s	Risk-Weight on Safe Assets	0.0	FDICIA (1992)
τ_C	Corporate Income Tax	0.35	US Tax Code
c_L	Asset Liquidation Cost	0.72	Granja et. al. (2017)
ϵ	Elasticity of Loan Demand	-1.1	Basset et al. (2014)
$\bar{\rho}$	Bailout Probability	0.9	Koetter and Noth (2016)
$\bar{a}$	Asset Size Threshold	\$100B	Brewer and Jagtiani (2013)

Loan Default Rate Markov Process The Markov process for the loan default rate λ is estimated using both internal and external calibration. I first estimate an AR(1) process for loan default rates of banks in the data and use the Tauchen (1986) discretization method to solve for a 2-state vector and transition matrix. The values from the 2-state vector correspond to λ_L and λ_M. However, in the model, the λ vector is a 3-state vector, where the third state is a very high/crisis default rate. This third state represents a severe event that drives most big bank failure. It is not directly estimated from the data as the data represents bank data at quarter end. If a bank in the data failed, the last available quarter end data may not reflect the state of defaults the bank faced at the time of its own default. Even if the bank was given a bailout and continued in the data sample, it is not clear that the previous quarter end's default rate truly represents the extent of defaults at the time the bailout was needed. Therefore, the third state λ_H is estimated internally through SMM (as seen in Table 4), not from the discretization of this AR(1) process.

In addition to λ_H, the probabilities of entering the crisis state, $F(\lambda_H|\lambda)$ are also estimated via SMM. I set that a bank cannot transition from the crisis state λ_H to the lowest default rate state λ_L in one period, or that $F(\lambda_L|\lambda_H) = 0$. Estimating $F(\lambda_H|\lambda_H)$ via SMM is then sufficient to solving for $F(\lambda_M|\lambda_H)$ as well. For the transition probabilities $F(\lambda_L|\lambda_L)$ and $F(\lambda_M|\lambda_L)$, I use the estimated values from the Tauchen method, but multiply each by $(1 - F(\lambda_H|\lambda_L))$ to ensure that the three probabilities add to 1. I repeat the procedure to obtain the transition probabilities $F(\lambda_L|\lambda_M)$ and $F(\lambda_M|\lambda_M)$.

For the distribution of default rates for the entrant, $\bar{F}$, I set that a bank cannot enter with the crisis default rate, $\bar{F}(\lambda_H) = 0$. Then, by definition, $\bar{F}(\lambda_M) = 1 - \bar{F}(\lambda_L)$. I estimate

cause substantial spillover to other financial markets.

$\bar{F}(\lambda_L)$ by requiring that the average expected loan default rate of entrants match the average loan default rate of entrants in the data in the period after they enter, which I calculate from the data to be 2.47%. The final state vector and transition matrix for λ can be found in Table 2. Also included is the distribution of λ for entrants, $\bar{F}(\lambda)$.

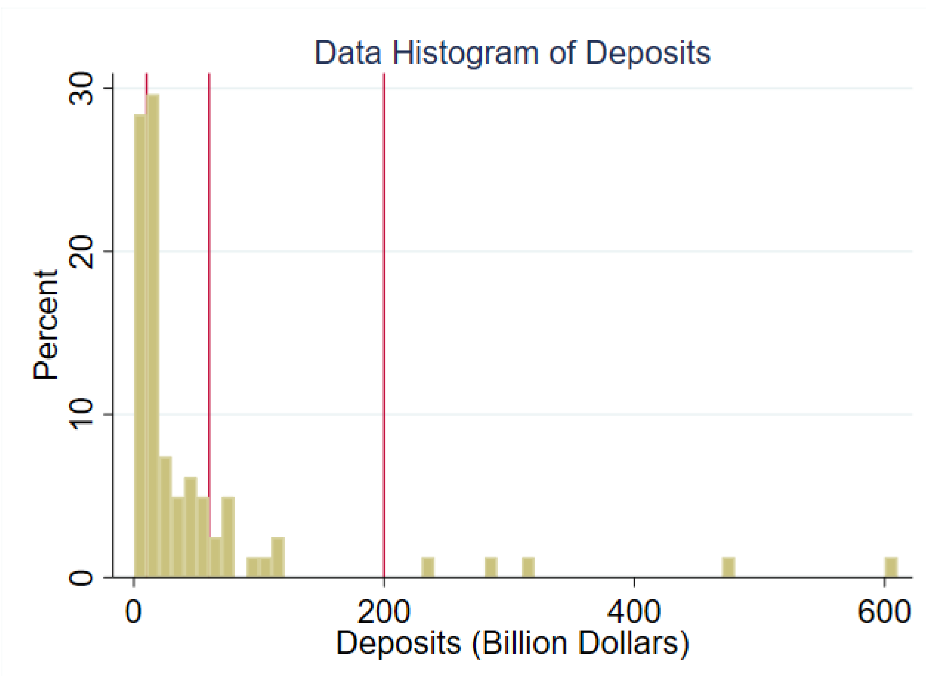
Table 2: State and Transition Values for λ

	$F(\lambda'\|\lambda)$		
	$\lambda_L = 0.0043$	$\lambda_M = 0.0226$	$\lambda_H = 0.500$
$\lambda_L = 0.0043$	0.8065	0.1685	0.0250
$\lambda_M = 0.0226$	0.1595	0.7780	0.0625
$\lambda_H = 0.500$	0.0000	0.8812	0.1188

[H]

	$\bar{F}(\lambda)$	
$\lambda_L = 0.0043$	$\lambda_M = 0.0226$	$\lambda_H = 0.500$
0.834	0.166	0.000

Figure 1: Deposit Distribution of Bank Sample 2006Q4



Insured Deposits Markov Process The state vector for insured deposits is chosen to match the distribution of deposits in the data. Figure 1 plots a histogram of deposits as of 2006Q4. The histogram demonstrates that there are three general mass points of \$10B, \$60B, and \$200B, and I use these values for the state vector. The transition matrix H for the insured deposits is pinned down via internal calibration with the following assumptions: *(i)* banks cannot transition between the smallest and largest value of deposits in one period ($H(\delta_L|\delta_S) = 0$), $H(\delta_S|\delta_L) = 0$)), and *(ii)* banks have equal probability of switching to the smallest value or largest value from the middle value ($H(\delta_S|\delta_M) = H(\delta_L|\delta_M)$). These assumptions reduce the number of parameters needed to pin down the transition matrix to 3, which are estimated internally via SMM. The resulting state vector and transition matrix can be found in Table 3. Finally, all entrants enter with the lowest value of insured deposits, $\delta_S = \$10$B.

Table 3: Transition Matrix $H(\delta'|\delta)$

	$\delta_L = \$10$B	$\delta_M = \$60$B	$\delta_H = \$200$B
$\delta_L = \$10$B	0.990	0.010	0.000
$\delta_M = \$60$B	0.005	0.990	0.005
$\delta_H = \$200$B	0.000	0.025	0.975

Internal Calibration Simulated Method of Moments minimizes the weighted difference between data moments and model moments. The internally calibrated parameters in this paper are generally unobservable cost parameters of banks or the remaining parts of underlying transition matrices. These costs and probabilities are very influential for banks' balance sheet, resolution, and entry decisions. To capture these parameters, I focus on moments regarding banks' lending and portfolio decisions. Further, I use moments about changes in banks' decisions to help pin down the transition matrices and the importance of the equity issuance costs, which can act as adjustment costs for banks' portfolios. Two key moments include the average change in assets of continuing banks from one period to the next as well as the average change in assets of banks whose assets are below the \$100B threshold one period and above the threshold in the next period. Finally, small bank refers to a bank below this asset threshold.

Model Fit The model does well in replicating the data moments with a few small difficulties. First, the model overestimates the average assets of banks. This is primarily due to the presence of extremely large banks, such as JP Morgan & Co., who make up a significant portion of bank assets in the data. Without an even larger state of deposits in the model, I do not capture this monumental volume of assets. Therefore, in order to match average assets, the model must increase the asset volume of all banks. The calibration also underestimates the risky asset fraction and overestimates the uninsured leverage ratio. The

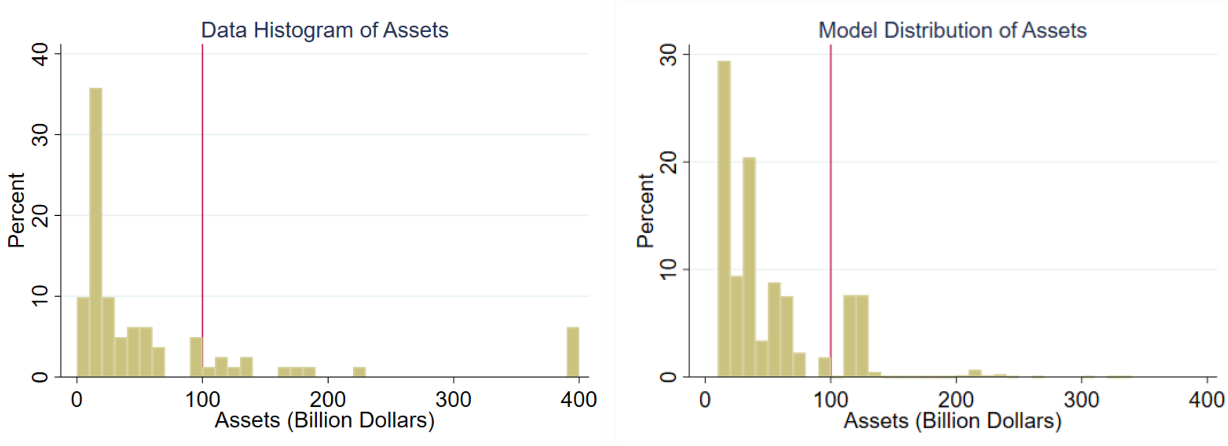
Table 4: Internal Calibration

Parameter	Description	Value	Moment	Data	Model
c_e	Entry Cost	10.1	Avg. Leverage of Entrants	0.91	0.95
c_O	Fixed Operating Cost	0.2	Agg. Lending ($T)	4.51	4.61
$c_M(\delta_S)$	Loan Monitoring Cost δ_S	2.5 x 10^{-4}	Avg. Assets ($B)	22.5	34.3
$c_M(\delta_M)$	Loan Monitoring Cost δ_M	1.3 x 10^{-5}	Avg. Change in Assets (%)	11.4	9.5
$c_M(\delta_L)$	Loan Monitoring Cost δ_L	6.3 x 10^{-6}	Avg. Change in Assets over Threshold (%)	55.2	69.2
λ_H	High Default Rate	0.5	Avg. Dividend to Assets (%)	0.23	0.27
$F(\lambda_H\|\lambda_L)$	$P(\lambda' = \lambda_H\|\lambda = \lambda_L)$	0.025	Avg. Debt/Assets	0.91	0.96
$F(\lambda_H\|\lambda_M)$	$P(\lambda' = \lambda_H\|\lambda = \lambda_M)$	0.0625	Avg. Interest Income on Loans (%)	5.5	4.8
$F(\lambda_H\|\lambda_H)$	$P(\lambda' = \lambda_H\|\lambda = \lambda_H)$	0.1188	Avg. Risky Assets Fraction (%)	63.4	47.5
ζ	Loan Demand Scale	190.2	Share of Big Banks (%)	18.5	17.6
$H(\delta_S\|\delta_S)$	$P(\delta' = \delta_S\|\delta = \delta_S)$	0.99	Avg. Uninsured Debt/Assets	0.25	0.45
$H(\delta_M\|\delta_M)$	$P(\delta' = \delta_M\|\delta = \delta_M)$	0.99	Small Bank Exit (%)	0.3	0.4
$H(\delta_L\|\delta_L)$	$P(\delta' = \delta_L\|\delta = \delta_L)$	0.975	Avg. Net Interest Margin	3.75	1.37
			Avg. Loans to Deposits	1.1	1.2

overestimation of the uninsured leverage ratio is partially due to the fixed nature of the insured deposits. When banks want to increase their assets, they cannot do so by increasing their insured deposits. Therefore, banks can only raise costly equity or borrow more uninsured debt. However, due to capital requirements, banks face a trade-off when they increase their debt: they need to reduce their risky asset fraction. This results in an underestimation of risky assets and an overestimation of uninsured leverage. The underestimation of the risky asset fraction also leads to the underestimation of the average Net Interest Margin, which is calculated using the interest income on all assets. Banks investing more in the safe asset, which generates lower interest income, and borrowing more uninsured debt, which requires higher interest expense, significantly decreases the net interest margin earned by banks in the model.

A comparison of the data and model distributions of bank assets can be seen in Figure 2. The left-hand panel plots the data distribution of assets in 2006Q4 while the right-hand panel plots the model distribution of banks' assets after the realization of the asset returns $(R^{\ell}(1-\lambda')\ell' + Rs')$. Both histograms demonstrate that majority of the mass is on the lower end of the distribution, and there exists a mass point at the $100B threshold. In the data distribution, there is a mass of banks right below $100B, representing the inability of banks to perfectly control their returns and guarantee they are exactly over the $100B threshold. The model distribution also shows this mass just to the left of the threshold due to the threshold being based on the face value of assets $(\ell' + s')$, and not the realized value $(R^{\ell}(1-\lambda')\ell' + Rs')$. Therefore, banks that have chosen $\ell' + s' = 100$ but received the high default rate $\lambda' = \lambda_H$ will end up under the threshold. Majority of the mass above the threshold is actually further to the right. This is due to the high returns earned on the assets when the banks receive a lower default rate on their risky lending. While the model distribution does demonstrate

Figure 2: Asset Distribution of Bank Sample 2006Q4



Data histogram truncates assets at \$400B. Model histogram plots the realized value of assets $(R^{\ell}(1-\lambda')\ell' + Rs')$.

a long right-tail, it underestimates this tail in the data (which is truncated in the figure at \$400B) due to the difficulty in measuring the largest few banks in the data.

5 Quantitative Results

As a result of the bail-in policy, fewer banks exceed the \$100B threshold for intervention, banks use less leverage, and banks overall invest in fewer risky assets. These results are driven by changes in funding costs. Because bail-in policies no longer guarantee repayment to creditors, interest rates on uninsured debt rise, and these changes are heterogeneous depending on bank size and ex-ante riskiness (given by the default rates on loans). Importantly, resolution rates decrease substantially, as banks now have more incentive to protect against failure. Table 5 compares moments between the equilibria under bailout and bail-in.

5.1 Bank Size, Leverage, and Asset Risk

In equilibrium, there are important changes in interest rates and equity pricing, and these have first-order effects on banks' size and investment choices. As an illustration, Figure 3 compares the asset and uninsured leverage policy functions, respectively, of banks with insured deposits δ_M based on the value of their net cash under bailout and bail-in. The functions are plotted separately for banks with the low default rate λ_L and the medium one

Table 5: Comparison of Results Across Resolution Policies

	Bailouts	Bail-ins
Bank Size, Leverage, and Asset Risk		
$R^{\ell} - 1$ (%)	6.7	6.9
Avg. Interest Income on Loans (%)	4.8	5.2
Agg. Lending ($T)	4.61	4.46
Avg. Assets ($B)	34.3	26.1
Share of Big Banks (%)	17.6	10.2
Avg. Risky Assets Fraction (%)	47.4	42.5
Avg. Net Interest Margin	1.37	1.36
Avg. Debt over Assets of Entrants	0.95	0.95
Avg. Debt over Assets	0.96	0.94
Avg. Uninsured Debt over Assets	0.45	0.36
Asset Growth		
Avg. Change in Assets (%)	9.5	9.7
Avg. Change in Assets over Threshold (%)	69.2	63.9
Resolution Rates and Costs		
Failure Rate (%)	0.82	0.45
Bailout/Bail-in Rate (%)	0.41	0.03
Big Bank Failure Rate (%)	2.88	1.00
Resolution Costs ($B)	44.8	8.3
Debt Pricing and Equity Channels		
Avg. Repayment under Bailout/Bail-in (%)	100.0	45.7
Max Repayment under Bailout/Bail-in (%)	100.0	48.0
Avg. Interest Rate (%)	2.17	2.12
Avg. TBTF Subsidy (bps)	254	40
Avg. Dividend to Assets (%)	0.27	0.67
Share of Dividend Issuers (%)	53.2	60.6
Welfare and Efficiency		
Banking Industry Contribution to Consumption ($B)	61.7	102.5

λ_M to further highlight the differential effects of bailouts and bail-ins on banks of varying ex-ante riskiness.

The top left plot of Figure 3 focuses on the total asset choices of banks with λ_L. When banks have low net cash n, they are more constrained. Due to capital requirements and costly equity issuance, banks may not be able to choose high volumes of risky loans or safe assets. Banks increase assets as net cash n increases, until these constraints are less binding. Then, banks increase assets at a faster pace, funded with uninsured debt (see bottom left plot of Figure 3). Banks with lower default rates can choose higher quantities of assets with less net cash due to paying lower interest rates on uninsured debt, as seen by comparing to the top right figure, which shows the asset decisions of banks with λ_M. However, when the bank has more cash, it will discontinuously choose asset levels over the \$100B threshold to take advantage of the bailout/bail-in policies. These asset choices are once again funded primarily through increased uninsured borrowing. The discontinuous behavior of banks results in a clumping in the distribution around \$100B, as seen in the left-hand graph of Figure 4.

Focusing on the choices of the λ_L banks under bail-in in the top plot of Figure 3, we see that they behave similarly to the same banks under the bailout policy. However, they increase assets less with an increase in net cash compared to the bailout solution, waiting until they have more net cash before jumping above the \$100 B threshold. This could be due to either the increase in interest rates relative to the benchmark model or the decline in continuation value in a bail-in because shareholders are always wiped out. These two channels are decomposed in Section 5.3.

Although banks with λ_L behave similarly under the bailout and bailout policies, banks with λ_M differ greatly in their decisions as they become less constrained. These banks no longer "jump" over the \$100B threshold and in fact remain smaller even as net cash increases. Without this jump, these banks require less uninsured debt to fund their assets, and uninsured leverage decreases compared to the benchmark solution.

Size Distribution Figure 4 compares the size distributions under the benchmark and counterfactual equilibrium. The left-hand plot overlays the two distributions, while the right-hand plot graphs the percent change from the bailout distribution to the bail-in one. The largest change occurs around the \$100B threshold: the bail-in distribution has significantly less mass in this area than the bailout distribution. In fact, this group of banks can instead be seen in the bar that represents banks with \$60-80B in assets. These banks are primarily those with (δ_M, λ_M) that no longer jump over the \$100B threshold.

Aggregate Lending Due to the decreased repayment to creditors in the event of a bail-in, the interest rate on risky lending $R^\ell - 1$ that satisfies the free entry condition increased from

Figure 3: Comparison of Asset Policy Functions

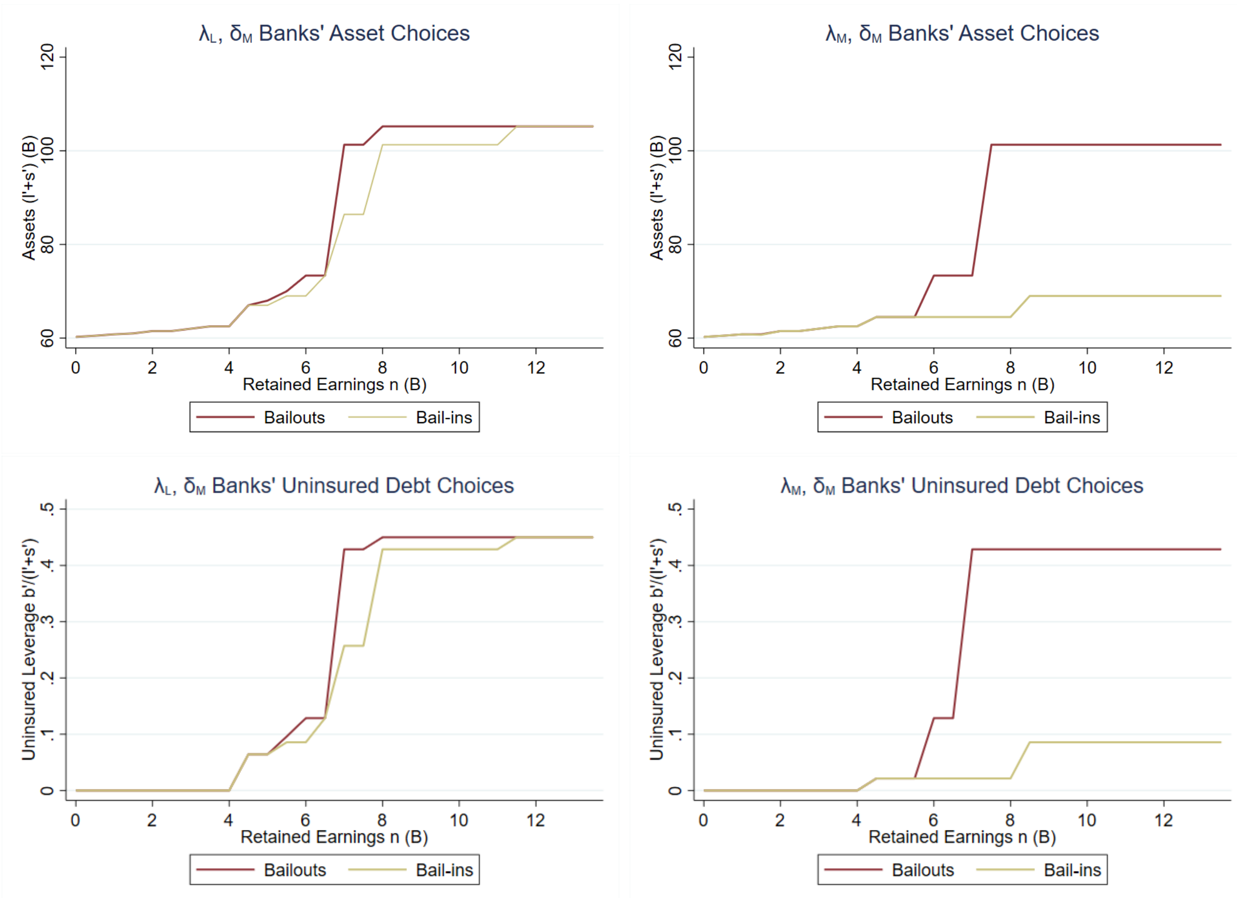
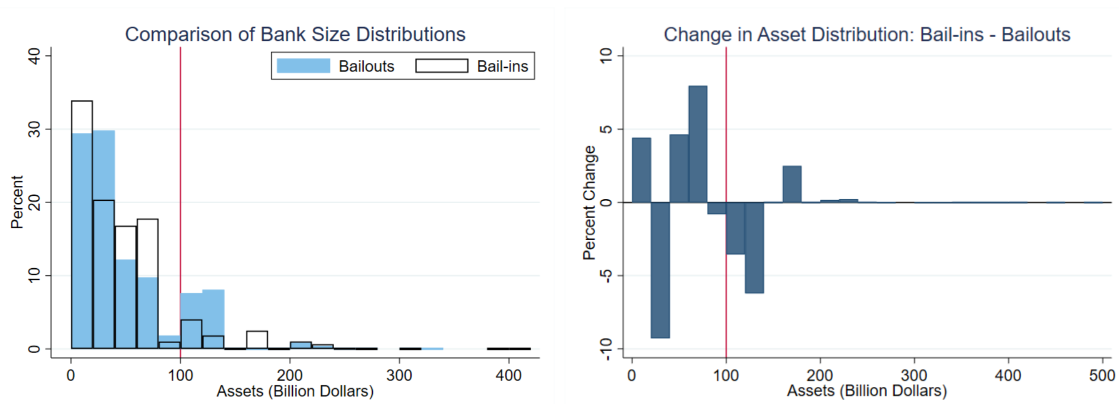


Figure 4: Comparison of Size Distributions



6.7% to 6.9%. With a higher R^{ℓ}, firms demand fewer loans, and aggregate lending decreases from \$4.61T to \$4.46T. However, there are fewer big banks. This leaves room for more banks to enter to meet the demand for firm loans. The measure of banks increases 32%. With the addition of new entrants, average lending decreases from \$34.3B to \$26.1B. The average change in assets when banks cross the threshold decreases slightly. As shown in the first plot in Figure 3, banks do not cross the threshold until they have a higher value of net cash. Net cash is typically raised from higher levels of investment in the previous period, thus decreasing the change in assets when the bank makes this jump.

Asset Risk The average risky asset fraction decreases over 10%, from 47.4% under the benchmark to 42.5% under the counterfactual. This change is primarily driven by the behavior/distribution of (δ_M, λ_M) banks. When net cash is low for these banks, they are very constrained. Under each equilibria, these banks borrow very little uninsured debt and invest primarily in safe assets. The net interest margin of such banks is very low; and therefore, they stay relatively constrained even if they receive low default rates. However, under the bailout policy, these banks end up drastically increasing their assets, borrowing a lot of uninsured debt and choosing a high risky asset fraction. If these banks receive a lower default rate, they earn high net interest margins and remain above their equity constraint. This shifts the distribution of banks with (δ_M, λ_M) further to the unconstrained part of the distribution. These banks continue to choose high risky asset fractions in order to grow their returns. Under the bail-in policy however, these banks never greatly increase their assets and instead stay in the more constrained part of the distribution. They continue to choose low risky asset fractions. This shift in the distribution has large effects on the industry averages due to the substantial portion of (δ_M, λ_M) banks in the distribution. This shift is also primarily responsible for the decrease in the average uninsured debt to assets ratio from 0.45 under the bailout policy to 0.36 under the bail-in policy.

5.2 Resolution Rates and Costs

In the benchmark model, the expected percentage of banks receiving a bailout in any given period is 0.41%. In the bail-in model, the expected percentage receiving a bail-in is only 0.03%. This significant drop is due to 1) the reduced probability of resolution of any big bank and 2) the reduction of big banks in the economy. The former can be seen in Table 5 as the Big Bank Failure Rate. Conditional on the bank being above the \$100B threshold, the average probability that the bank will enter resolution is 2.88% under the bailout policy and 1.0% under the bail-in policy. This drastic change is due to selection: Under the bailout policy, banks with (δ_M, λ_L) or (δ_M, λ_M) grow to be big banks, but only banks with (δ_M, λ_L) become big banks under the bail-in model. Due to the higher probability that a bank with λ_M will receive the high default rate λ_H next period, these banks have a higher probability of failure than banks with λ_L, thus increasing the average probability of failure of big banks under the bailout policy. Instead, under bail-in, these banks are now classified as small banks. However, the small bank exit rate has not increased significantly, only increasing from 0.380 to 0.388.[10] The (δ_M, λ_M) banks choose fewer risky assets and borrow less uninsured debt now that they are not trying to grow above the \$100B threshold. They can now better weather adverse shocks to their risky assets and continue operating.

Resolution Costs With fewer bank failures, resolution costs are significantly reduced. In both models, resolution costs include the liquidation costs of the small banks entering resolution and the $(1-\rho)$ fraction of big banks entering resolution who are not bailed out/in. The resolution costs of a liquidated bank are

$$\text{Liquidation Resolution Costs} = (1 - c_L)(R^\ell(1 - \lambda')\ell' + Rs') + c_F, \tag{44}$$

which is equivalent to the discounted portion of the liquidated assets and the fixed cost of liquidation. The resolution cost of a bailed-out bank is the value of the cash transfer

$$\text{Bailout Resolution Costs} = b' + \delta - (1 - \alpha\omega_r)R^\ell(1 - \lambda')\ell' - (1 - \alpha\omega_s)Rs'. \tag{45}$$

Given that the bail-in policy uses only the banks' internal funds, there are no resolution costs associated with a bail-in.

As seen in Table 5, resolution costs under the bailout policy amount to \$44.8B, \$29.7B of which is due to the bailout transfers. Under bail-in, however, this cost totals only \$8.3B due to fewer liquidations stemming from big banks.

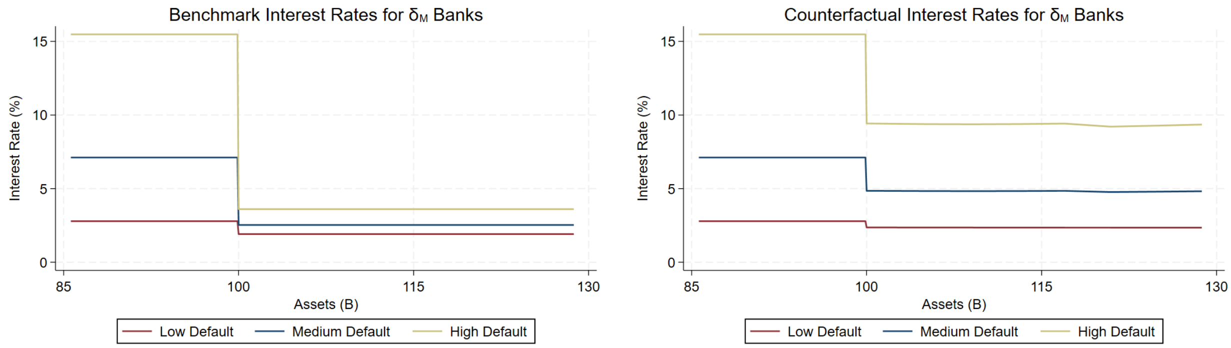
5.3 Debt Pricing and Equity Channels

The results described above regarding bank balance sheets, resolution decisions, and industry aggregates are all driven by the equilibrium changes in debt and equity prices associated with the switch from bailouts to bail-ins.

Debt Pricing Figure 5 plots price schedules $q(\delta, \lambda, \ell', s', b')$ from the solution under the bailout (top) and bail-in (bottom) policies. The q's are expressed as interest rates, which is

[10]The small bank exit rate is defined as $\frac{\text{Failure Rate} - \text{Share of Big Banks}^{*}\text{Big Bank Failure Rate}}{1 - \text{Share of Big Banks}}$

Figure 5: Uninsured Debt Price Schedules



Risky asset fractions are held constant at 0.9. Total leverage ratios are held constant at 0.9.

equivalent to $\frac{1}{q(\delta,\lambda,\ell',s',b')} - 1$. To simplify the plotting of the five-dimensional schedule, I fix the level of insured deposits δ to δ_M, the level of uninsured debt b' to $\frac{b'}{\ell'+s'} = 0.9$, risky loans ℓ' to $\frac{\ell'}{\ell'+s'} = 0.9$, and only vary the total assets $\ell' + s'$ and the loan default rate λ.

Two key results can be seen in Figure 5. First, interest rates fall less under the bail-in model than the bailout model when banks cross the \$100B threshold. Second, the difference in interest rates between riskier and safer banks is larger under bail-in than under bailout. In both models, banks generally enter resolution only when they draw $\lambda' = \lambda_H$. Banks that start with higher default rates, such as λ_M, have higher probabilities of receiving $\lambda' = \lambda_H$, and therefore are priced with higher interest rates than banks with lower default rates, such as λ_L. This is very evident in each plot in Figure 5 for a bank with less than \$100B in assets. At this size, banks entering resolution can only be liquidated; therefore, creditors expect partial repayments. However, when a bank has assets greater than \$100 B, it now has a $\rho = 90\%$ chance of being bailed out (top) or bailed in (bottom) if it fails. Guaranteed repayment under bailout leads to a drastic decrease in interest rates. This decrease is particularly large for riskier banks, those that have the higher default rates, λ_M or λ_H, and therefore have higher probabilities of receiving $\lambda' = \lambda_H$. In the bail-in equilibrium though, creditors are repaid on average 55.8% and at maximum 64.5% of their uninsured debt claim b' in a bail-in. Therefore, the interest rate decrease when the bank crosses the \$100B threshold is not as large. Particularly, ex-ante riskier banks still pay much higher interest rates than safer banks. The bail-in heterogeneously affects the interest rates paid by banks such that ex-ante riskier banks benefit less from the subsidy than they did under the bailout.

Despite interest rates increasing for the big banks under the bail-in policy, they still decrease for each λ when the bank grows above \$100B. The repayment to the creditor under bail-in is typically higher than that in liquidation due to 1) no firesale discount on the value of the assets and 2) the continuation value of the bank that comes from the value of the endowed insured deposits. Therefore, while the banks can no longer access as low of an interest rate as available under the bailout, they may still be incentivized to jump over the threshold.

Equity Channel If banks remain smaller, what do they do with the excess cash compared to the bailout equilibrium? I find that on average, dividend payments increase from 0.27% of assets to 0.67% and the share of banks issuing dividends rises from 53.2% to 60.6% when switching to the bail-in policy. Under the bailout policy, banks would often forgo larger dividend payments in order to invest in more risky assets to grow. With the reduction in the size incentive, banks pay more of their funds out as dividends to their shareholders.

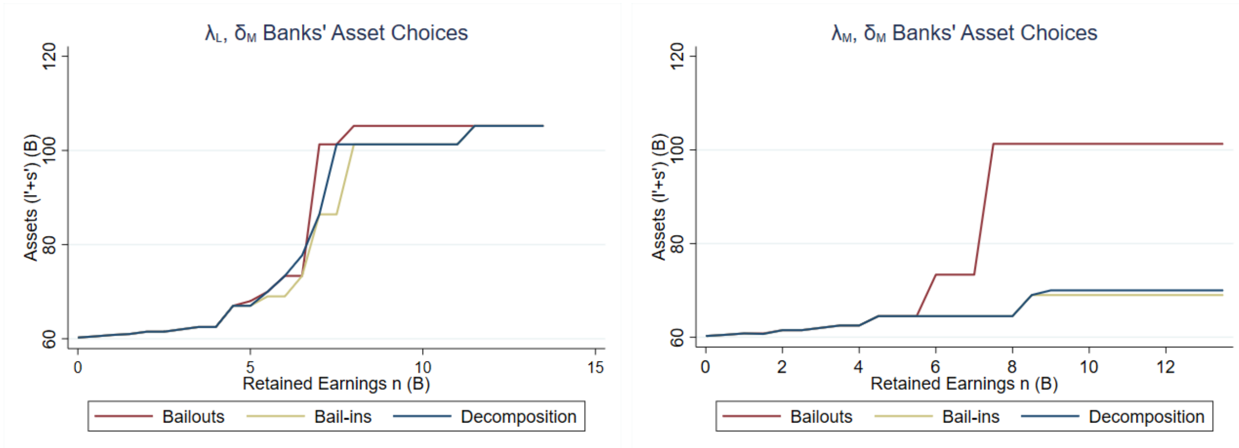
Decomposition Bail-in policies change the payoffs to both creditors and shareholders relative to bailouts. Therefore, it is difficult to determine if banks are changing their behavior because the debt is more expensive or because shareholders receive less from a bail-in than a bailout. With my model, I can decompose these two channels. I solve for a new equilibrium with an adapted "bailout" policy in which the new net cash of the bank will be as set in Equation 21 and the value of the bank will be retained by the shareholders; however, the creditors will only be repaid the repayment they would receive in the bail-in model and the price equation will be the same as in Equation 41.

If the results of this decomposition exercise resemble those of the benchmark equilibrium, then the equity channel is the dominant channel. Banks' decisions are driven more by the value to the shareholders in the bailout than by the pricing of the debt based on the bailout repayment to creditors. However, if the results are closer to those of the bail-in equilibrium, then the debt channel dominates and it is the pricing of the debt that matters more for bank decisions.

Overall, I find that the steady state equilibrium of the decomposition exercise more closely resembles that of the bail-in model, and therefore the debt channel dominates. However, the effects vary based on the bank's default rate λ. Figure 6 plots the asset decisions of banks with the medium value of insured deposits δ_M under the benchmark, bail-in model, and this decomposition exercise. While the λ_L banks need more net cash in the decomposition exercise to finance the jump over the $100B asset threshold compared to under the benchmark, they require less cash for the sudden increase than under the bail-in model. This implies that both channels matter for these banks.[11] However, the banks with the medium default rate

[11]Further, it is clear that the equity payoff to shareholders from the bailout matters for the decisions of these banks by looking at the dividend/equity issuance behavior of the banks. Under the benchmark and this decomposition exercise, banks will issue equity to finance their jump over the $100B threshold. The shareholders are actually willing to put more "skin-in-the-game" in order to grow large and take advantage

Figure 6: Policy Functions under Decomposition Exercise



λ_M behave almost exactly the same as they do in the bail-in model. Therefore, it is the debt channel that dominates here. Banks with this medium default rate λ_M make up a larger part of the distribution than the other λ's, so the debt channel is the quantitatively dominant channel driving the changes from the bailout to bail-in models.

5.4 Welfare and Efficiency

Welfare Implications The last line of Table 5 reports the consumption of households based on the banking industry-specific elements of household consumption in each equilibrium. Banking industry contributions to consumption increase significantly from \$61.7B to \$102.5B when switching from the bailout to bail-in regime. This change in welfare is driven by the reduced costs of resolution required for liquidations and bailout injections.

In the U.S., aggregate consumption in 2006 was \$9.1T in 1990 dollars. Therefore, assuming there are no impacts on the rest of the economy from the switch to bail-ins, aggregate consumption under the bail-in model is \$9.16T. I define welfare as the sum of utility from consumption as in Equation 9. As this is a steady state equilibrium, $C_t = C \; \forall \, t$, and regardless of using linear, CRRA, or log utility, we can solve for the consumption equivalence μ as

$$(1-\mu)C_{IN} = C_{OUT}. \tag{46}$$

of the bailout policy. This is not true under the bail-in model, in which banks will wait to grow over the threshold until they can completely finance it with net cash n, insured deposits δ, and uninsured debt b'. The fact that the shareholders will invest more equity for the jump in this "alternative" bailout proves that the equity channel is important for the decisions of the low expected default rate banks.

Thus, welfare increases by 0.66%.

This calculation of welfare does assume that the changes in the banking sector do not impact the household's wealth from firm stock or wages. This is a simplifying assumption; however, as firms are now paying higher interest rates on the loans they receive from banks and are borrowing less. It also assumes that the government does not adjust the return on the safe assets or the corporate tax rate to account for the demand of such assets or the collections needed to cover the deposit insurance fund or equity injections.

Allocative Efficiency One measure of efficiency in the banking sector is the allocation of loans in the economy across heterogeneous banks. The model results demonstrate that there is significant heterogeneity in the impacts of bailouts and bail-ins on individual banks' funding costs and risk choices based on their expected default rates on lending. Therefore, I focus on the allocation of loans across these default rates.

Following Olley and Pakes (1996), I define default rate allocative efficiency as the covariance between banks' expected default rate on loans and their share of lending. This can be seen by decomposing the loan-weighted average expected loan default rate into

$$\sum_{\lambda}\sum_{\delta}\int \underset{\lambda}{\mathbb{E}}(\lambda')\omega(\ell'(\lambda))\Gamma(\delta,\lambda,dn) = \sum_{\lambda}\sum_{\delta}\int \underset{\lambda}{\mathbb{E}}(\lambda')\Gamma(\delta,\lambda,dn) + cov(\underset{\lambda}{\mathbb{E}}(\lambda'),\omega(\ell'(\lambda))) \tag{47}$$

where $\underset{\lambda}{\mathbb{E}}(\lambda')$ is the expected default rate of a bank with current default rate λ and $\omega(\ell'(\lambda))$ is the loan share of banks with that λ. The second term of Equation 47 is the unweighted average expected default rate. Therefore, the loan-weighted average expected default rate can be decomposed into the unweighted average expected default rate and a covariance term between expected default rates and loan shares.

The covariance term is the key to understanding allocative efficiency. A smaller value represents a shift in loans towards banks with lower expected default rates. When banks with lower expected default rates lend majority of the loans in the economy, the total number of defaults is minimized and there are greater overall returns to the banking sector.

The default rate allocative efficiencies of the bailout and bail-in equilibria are -0.0038 and -0.0072, respectively. As lower covariance represents higher efficiency, bail-ins generate greater efficiency than bailouts. This improvement is driven by the change in behavior of the banks with the medium default rate λ_M and the medium level of insured deposits δ_M. Under the bailout policy, these banks lend a lot in order to grow above the TBTF threshold and take advantage of the positive probability of bailout. However, they lend significantly less under the bail-in policy, shifting a higher percentage of all loans to the banks with the lowest default rate.

To provide a baseline value for default rate allocative efficiency, I solve for a frictionless version of the model in which banks face the same underlying loan generating technology, but financial frictions are removed[12]. In this equilibrium, only the banks with the lowest default rate invest in risky loans. There are no exits or entries, and the distribution of banks across default rates is that of the ergodic distribution of $F(\lambda'|\lambda)$. The default rate allocative efficiency measure from this environment can be used as a baseline to compare the change in efficiency from the bailout to bail-in equilbrium.[13] In this environment, default rate allocative efficiency is -0.0078. The measure for the bail-in counterfactual is therefore 91.6% of this baseline while the bailout benchmark is only 48.7%.

Under the decomposition exercise in 5.3, default rate allocative efficiency is -0.0073, representing greater efficiency than the bail-in equilibrium. In the exercise, the (δ_M, λ_L) banks actually lend more than they did under the bail-in policy due to the higher equity payoff if they were to be bailed out. As these are the banks with the lowest default rate, their increased loan share increases allocative efficiency.

5.5 Aggregate Shocks

The model assumes bank failure is driven by idiosyncratic shocks to the asset value of individual banks. As a simple framework to capture the resiliency of the banking system under bailout and bail-in policies to aggregate shocks, I introduce a one-time, unanticipated shock to the loan default rates of all banks in the bailout and bail-in steady-state equilibria. In this exercise, I increase each loan default rate λ' by $\eta = .05$ for one period only. This shock is unanticipated and lasts for only one period; therefore, banks do not adjust their ex-ante or ex-post expectations regarding λ.

In the period of the shock, more banks may fail if the new loan default rate $\lambda' + \eta$ is high enough that more banks would prefer resolution over continuation. Even for continuing banks, this greater default rate will decrease their net cash n' at the start of next period. The impact on net cash will depend on the fraction of the bank's risky loans to total assets $(\frac{\ell'}{\ell'+s'})$ as returns to the safe asset will not change. The same mass of banks enters,[14] so changes in aggregate lending and the bank size distribution are due to the increase in liquidations and the impact of lower net cash for continuing and bailed out/in banks.

[12]The frictionless model is described in Appendix D

[13]While the efficiency measure could be further improved by changing the distribution of banks across λ, this value represents the maximum efficiency achieved when the banks are distributed across the ergodic distribution of λ. This distribution is part of the technology and can only be adjusted through large scale exits of banks. Therefore, it serves as a strong baseline for evaluating the increase in allocative efficiency from the bailout to bail-in equilibrium.

[14]As there is no change to the banks' expected returns due to the shock being only one period, the same mass of banks will choose to enter.

Figure 7: Aggregate Lending Response to Shock

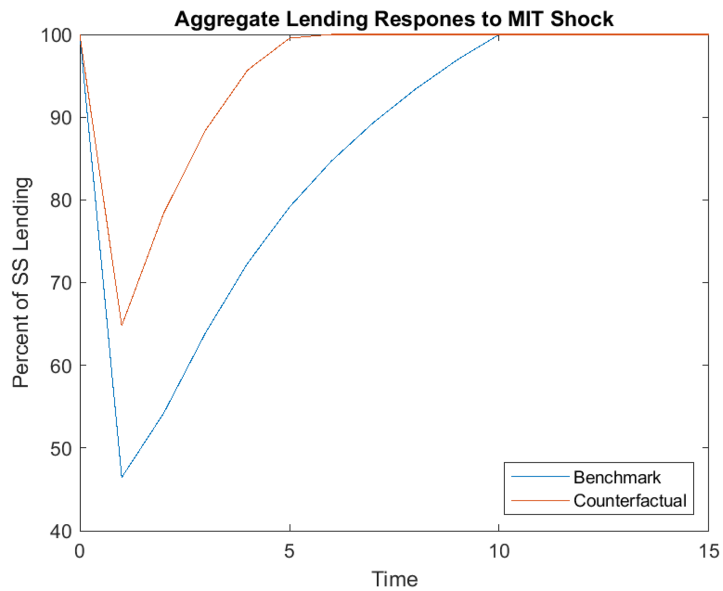


Figure 7 plots the aggregate lending responses to this unanticipated shock to the bailout and bail-in equilibria. The bailout equilibrium experiences both a larger decline in aggregate lending and a slower recovery due to banks in the bailout equilibrium being more leveraged and having higher risky asset fractions. Therefore, they are more susceptible to failing due to the increased default rate.

Under bail-in, aggregate lending recovers to its steady state value after a little more than five years. However, under bailout, it takes approximately ten years to recover due to the large failure of banks and the low net cash of the surviving banks. Further, the steady state aggregate lending under bail-in is approximately 97% of that under bailout, and it still takes the bailout equilibrium over nine years to reach this level of lending. Due to the lower leverage ratios and risky asset fractions, banks are more resilient to unexpected shocks in equilibria with bail-in policies.

6 Conclusion

In this paper, I evaluate the impact of bail-in policies on the bank size distribution, aggregate lending, and the rate of bank failure. I build a dynamic model of heterogeneous banks that I estimate to the U.S. banking industry of the pre-GFC period. Banks in the model differ in both their insured deposit bases and their expected returns on lending, both of which influence the possible size of the bank. In a benchmark model, banks over a certain size threshold can be bailed out when they fail. The subsidy provided to creditors in a bailout decreases the funding costs of banks over this threshold, and the attractiveness of this subsidy leads smaller banks to increase risky lending to quickly grow over the threshold. This subsidy is more attractive for banks that have a higher probability of large defaults on their loans and ex-ante riskier banks engage in more risky behavior. Estimation of the model generates a similar size distribution to that in the data, including discontinuous behavior around the bailout threshold.

In a counterfactual, I replace the bailout policy with one of bail-in. Creditors are now on average paid only 56% of their original claim in a bail-in, and the attractiveness of growing over the threshold declines. Specifically, banks with a larger probability of failure invest in significantly fewer risky loans and stay below the bail-in threshold. This reduces the mass of big banks in equilibrium and further, the banks that still grow large are ex-ante safer and fail less often. Households spend less on the resolution of banks. While individual banks lend less, new banks enter to meet demand for loans. Aggregate lending declines 3.3% but welfare increases by 0.66%.

Appendix

A Background on Resolution Policies

Bankrupctcy The standard bankruptcy procedure for banks in the U.S. was established in the FDIC Improvement Act of 1991. Section 38 of this Act, "Prompt Corrective Action (PCA)," created a classification system for the capitalization of banks ranging from critically undercapitalized to well capitalized. A critically undercapitalized bank is one whose tangible equity to total assets ratio has fallen below 2% and a classification of this type triggers the bankruptcy proceeding (FDIC (2019)). In this event, the FDIC would place this bank under its receivership and choose between two resolution methods — Purchase & Acquisition (P&A) or Deposit Payoff — based on which imposes the lowest cost to the organization, and inadvertently to taxpayers. Under Deposit Payoff, the FDIC pays off all insured deposits of the bank and the bank is closed. P&A, however, has been the more frequent method chosen by the FDIC since the passage of the Act. Under P&A, the FDIC sells the bank to a healthy financial institution that meets a strict list of requirements.

Bailouts In 2008, the risk to financial stability from large, failing banks became too great for the FDIC to follow its regular bankruptcy proceedings. The U.S. Treasury set up the

Troubled Asset Relief Program (TARP) to inject preferred equity capital into troubled banks. The amount of these injections totaled over $200 billion across 709 institutions, but most funds were allocated to the largest eight bank holding companies. Each institution received the minimum of $25 billion and 1-3% of their risk-weighted assets (Berger et. al. (2022)). While the bailouts are believed to have prevented greater widespread loss, the cost burden was placed disproportionately on the government and taxpayers rather than the shareholders and managers of the banks. In March of 2014, the Congressional Budget Office estimated the net cost of TARP to the federal government to be $27 billion (Calomiris and Khan (2015)).

Bail-ins In response to the financial crisis, the U.S. passed the Dodd-Frank Act in 2010. Title II of the Dodd-Frank Act enacts the new bail-in policy, which works as follows. If a bank is at risk of failure, the Secretary of the Treasury, the FDIC Board, and the Federal Reserve Board apply a two-part test. First, they will decide if the bank is actually in default or in danger of default. Second, they will estimate the systemic risk from the potential default of the bank. They will consider the risks to financial stability and the harm imposed on underrepresented communities, such as low income or minority communities, and on the creditors, shareholders, and counterparties. If these risks and harm are not large, the bank will be subject to the standard bankruptcy procedure. Otherwise, the bank will be placed under the receivership of the FDIC to be bailed-in.

Once the FDIC has taken control of the bank for the bail-in, the current management will be dismissed and the agency will be in charge of all managerial decisions. The FDIC will create a new bridge bank with the non-distressed assets of the bank and non-defaultable debt such as insured deposits or secured (by collateral) debt. The secured debt may take a haircut however if the value of the collateral has been reduced. Then, the FDIC will begin to build the capital base of the bridge bank. To do so, it will estimate the losses of the original bank and apportion these to the firm's equity holders, subordinated creditors, and unsecured creditors, in that order. As stated by Martin Gruenberg, the former Chairman of the FDIC, the equity claims will most likely be completely wiped out by the losses (Gruenberg (2012)). Additionally, subordinated or even senior debt claims may be written down to reflect losses the shareholders cannot cover. The surviving debt claims will be converted into new equity claims to capitalize the bridge bank. Any remaining claims after the bank is fully capitalized will become new unsecured debt. New management will then be appointed and the bank will continue operating (111th Congress (2009-2010)).

Resolution Policies in the Model Due to the complexity of the true resolution policies, some simplifications must be made in order to incorporate these policies into a tractable, quantitative model. First, when a bank exits and is not bailed out, it will be resolved following the Deposit Payoff process, not through a Purchase & Acquisition. I follow the Deposit Payoff process very closely in the model, as explained in Section 2. While the banks may not be sold, which is more common in practice, their liquidations will free up the resources of shareholders and creditors to invest in other banks, thus allowing them to grow, similar to if they were to purchase the assets and deposits of a failing bank. Further, even when P&A is used, the FDIC often agrees to share losses with the acquirer, or to sell the bank's liabilities at a discount, thus still imposing losses on the Deposit Insurance Fund. Modeling all non-bailouts as Deposit Payoffs captures these costs.

In the counterfactual model, large banks' probability of bailout is replaced with that of bail-in. For simplification, in a bail-in, the bank will not repay the uninsured debt. Instead, the original creditors will receive shares in the new, restructured bank. This translates to debt claims being completely converted to equity claims, when in reality, creditors may lose part of their claim, have another fraction converted to equity, and the rest remain as debt. The Dodd-Frank Act is not explicit about how much uninsured debt will be converted into equity until the bank is deemed "adequately capitalized". Given the importance of investors' and depositors' beliefs regarding the safety of a bank for the actual safety of a bank, it is not unreasonable to assume that the FDIC will err on the side of caution and convert more claims than less. The true losses on the assets are uncertain at the time of resolution. If the FDIC converts too little uninsured debt and investors/depositors believe the bank is not adequately capitalized, they could run, thus fulfilling the idea that the bank was not adequately capitalized.

As in the Dodd-Frank Act, the original shareholders will only keep shares that are in excess of the value of the creditors' original claims.

B Too Big To Fail Subsidy

The TBTF subsidy on banks' debt prices documented in the literature can be replicated using Equation 27. First, define the discount that the creditors demand on the debt to account for risk as

$$\text{Discount}(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_F} - q(\delta, \lambda, \ell', s', b'). \tag{48}$$

Then, if the possibility of a bailout did not exist ($\rho = 0 \ \forall \ \ell', s'$), the price of each debt contract would be

$$q^{\rho=0}(\delta,\lambda,\ell',s',b') = \frac{1}{1+r_F}\big[\big(1 - \sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')} F(\lambda'|\lambda)\big) + \sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda)\big]. \tag{49}$$

where $\Omega^{\rho=0}(\delta,\ell',s',b')$ is the set of default rate realizations λ such that a bank would choose resolution in the equilibrium where $\rho = 0 \ \forall \ (\ell', s')$. The TBTF subsidy can be thought of as the decrease in the discount due to the possibility of bailout, or

$$\begin{aligned}
\text{TBTF subsidy}(\delta,\lambda,\ell',s',b') &= \text{Discount}^{\rho=0}(\delta,\lambda,\ell',s',b') - \text{Discount}(\delta,\lambda,\ell',s',b') \\
&= -q^{\rho=0}(\delta,\lambda,\ell',s',b') + q(\delta,\lambda,\ell',s',b') \\
&= \frac{1}{1+r_F}\big[\sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')} F(\lambda'|\lambda) - \sum_{\lambda'\in\Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) \\
&+\rho(\ell',s')\sum_{\lambda'\in\Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) - \sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda) \\
&+(1-\rho(\ell',s'))\sum_{\lambda'\in\Omega(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda)\big].
\end{aligned} \tag{50}$$

If we suppose that in equilibrium, banks make the same resolution decisions in the world without bailouts and the world with bailouts, or that $\Omega = \Omega^{\rho=0}$, then the subsidy is

$$= \frac{\rho(\ell',s')}{1+r_F}\big[\sum_{\lambda'\in\Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) - \sum_{\lambda'\in\Omega(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda)\big]. \tag{51}$$

The TBTF subsidy is always greater than or equal to 0 as long as the sets of resolution decisions are the same. This is because an increase in ρ puts less weight on the potentially partial repayment from liquidation and more weight on the guaranteed full repayment from bailout. If a large bank has a positive ρ while a small bank has a smaller, or even zero, ρ, then the large bank is given a higher q (lower price) than the small bank.

Bail-in Model

$$\text{TBTF subsidy}_{IN}(\delta,\lambda,\ell',s',b') = \frac{1}{1+r_F}[-\sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')}\min\{1,\max\{\frac{c_L G(\lambda',\ell',s')-c_F-\delta}{b'},0\}\}F(\lambda'|\lambda)$$
$$+(1-\rho(\ell',s'))\sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')}\min\{1,\max\{\frac{c_L G(\lambda',\ell',s')-c_F-\delta}{b'},0\}\}F(\lambda'|\lambda)$$
$$+\rho(\ell',s')\sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')}\min\{1,\frac{\mathbb{E}_{\delta'|\delta}(V(\delta',\lambda',\hat{n}'(\lambda')))}{b'}\}F(\lambda'|\lambda)]. \tag{52}$$

Once again, if we suppose that, in equilibrium, banks make the same resolution decisions when $\rho = 0 \;\forall\; \ell', s'$ and $\rho > 0$ for at least one ℓ', s' combination, or that $\Omega_{IN} = \Omega^{\rho=0}$, then the subsidy is

$$\begin{aligned} &= \frac{\rho(\ell',s')}{1+r_F}[\sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')}\min\{1,\frac{\mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta',\lambda',\hat{n}'(\lambda'))))}{b'}\}F(\lambda'|\lambda) \\ &-\sum_{\lambda'\in\Omega_{IN}(\delta,\ell',s',b')}\min\{1,\max\{\frac{c_L G(\lambda',\ell',s')-c_F-\delta}{b'},0\}\}F(\lambda'|\lambda)]. \end{aligned} \tag{53}$$

It is no longer true that the first term in the brackets must be greater than or equal to the latter term.

C Household First Order Conditions

The first-order conditions of Equation 9 with respect to δ_{jt+1}, $\underline{j}t+1$, and S_{jt+1} are

$$\delta_{jt+1}, \forall\, j : q^{\delta}U'(C_t) = \beta\mathbb{E}_t[U'(C_{t+1})] \tag{54}$$

$$b_{jt+1}, \forall\, j : (q_{jt}b_{jt+1})'U'(C_t) = \beta\mathbb{E}_t[f^{R'}(b_{jt+1})U'(C_{t+1})] \tag{55}$$

$$S_{jt+1}, \forall\, j : p_{jt}U'(C_t) = \beta\mathbb{E}_t[(p_{jt+1}+d_{jt+1})U'(C_{t+1})]. \tag{56}$$

To see how the FOC for b_{jt+1} leads to Equation 55, we write out the expected repayment of b_{jt+1} as

$$\begin{aligned} \mathbb{E}_t(f^R(b_{jt+1})) &= \mathbb{E}_t((1-X(\delta_{jt},\lambda_{jt+1},\ell_{jt+1},s_{jt+1},b_{jt+1}))b_{jt+1} \\ &+X(\delta_{jt},\lambda_{jt+1},\ell_{jt+1},s_{jt+1},b_{jt+1}))\min\{b_{jt+1}\max\{c_L G(\lambda_{jt+1},\ell_{jt+1},s_{jt+1})-\delta_{jt},0\}\}). \end{aligned} \tag{57}$$

This is equivalent to the expression to the right of $\frac{1}{1+r_f}$ in Equation 27. Therefore, in steady state, Equation 55 implies that $\frac{1}{1+r_f} = \beta$.

D Frictionless Benchmark

To study the efficiency of the banking sector under each resolution policy regime, I solve for a "frictionless benchmark" that removes the financing frictions but keeps the underlying technology behind bank lending and the supply of insured deposits. This is analogous to a Hopenhayn (1992) framework. Specifically, I *(i)* set the costs of liquidation, c_L and c_F, to 1 and 0, respectively, *(ii)* remove limited liability, *(iii)* remove equity issuance costs such that $\psi(d) = d$ for the entire state space, *(iv)* set the corporate tax rate to zero, *(v)* remove capital requirements, and *(vi)* remove bailouts/bail-ins.

The first change implies costless exit for banks. They can now sell off their assets at face value and do not pay a fixed cost of liquidation. Without limited liability or bailouts/bail-ins, the banks must now fully repay their creditors even if they exit. Coupled with costless exit, this results in all debt being priced at the risk-free rate. The banks also have costless equity issuance and therefore can raise either type of funding — equity or debt — at the risk-free rate. This results in banks being indifferent between using equity or debt as well as being indifferent between investing excess funds in the safe asset or paying it out as a dividend today. Even if banks do not have the funds tomorrow to repay deposits, they can raise equity at the risk-free rate, rendering them indifferent between raising it tomorrow versus saving the money from last period to pay back the deposits.[15] After all of these changes, the resulting world is one in which the Modigliani-Miller theorem holds. Without loss of generality, I assume that the bank does not invest in safe assets and uses equity instead of risk-free debt for funding. The problem of the bank can then be written as

$$V(\delta, \lambda, n) = \max_{\ell'} \quad d + \beta \mathop{\mathbb{E}}_{\lambda'|\lambda} \Big(\max\{n'(\lambda'), \mathop{\mathbb{E}}_{\delta'|\delta} (V(\delta', \lambda', n'(\delta, \lambda', \ell'))\} \Big) \tag{58}$$

subject to

$$d + \ell' + c_M(\delta)\ell'^2 + c_O = n + \beta\delta \tag{59}$$

$$n'(\delta, \lambda', \ell') = R^{\ell}(1 - \lambda')\ell' - \delta \tag{60}$$

$$\ell' \geq 0. \tag{61}$$

[15] Banks still have the same level of insured deposits, following the same Markov process, as this is a fundamental element of the environment.

The value of resolution $V_R(\delta, \lambda', \ell', s', b')$ is replaced with the new value of net cash n' as there are no longer costs associated with liquidation, there are no bailouts/bail-ins, and banks no longer have limited liability. The bank is now only choosing the volume of risky lending ℓ' to maximize its value. Further, the insured deposits are priced at the risk-free rate β.[16] Banks must still pay the entry cost c_E to enter and the mass of banks is still pinned down by equating bank supply of loans with firm demand.

In equilibrium, I find that a bank's net cash n has no effect on their lending and exit decisions, as expected from the Modgliani Miller theorem. Without costly equity issuance, costly uninsured debt, capital requirements, and corporate income taxes, banks' lending decisions are pinned down solely by their expected loan default rates and monitoring costs $c_M(\delta)$. In fact, the first-order condition provides

$$\begin{aligned} -1 - 2c_M(\delta)\ell' + \beta R^\ell(1 - \mathbb{E}(\lambda'|\lambda)) = 0 \\ \ell'^* = \max\{\frac{\beta R^\ell(1 - \mathbb{E}(\lambda'|\lambda)) - 1}{2c_M(\delta)}, 0\} \end{aligned} \tag{62}$$

where the maximum operator represents the restriction that $\ell' \geq 0$.

If the optimal amount of lending for a bank with a given (δ, λ) exceeds its net cash n and insured deposits $\beta\delta$, the bank will simply raise the equity to pay for the lending. If the bank's funds exceed the optimal level of lending and the monitoring costs associated with it, then the bank will pay the extra funds out as a dividend.

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