Bailouts, Bail-ins, and Banking Industry Dynamics

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Abstract

This paper analyzes the effects of bail-in policies on banks of different sizes and risk profiles, comparing them to traditional bailouts. I develop a structural model of banks' balance sheet decisions with endogenous exit and entry, estimated to U.S. banking data. Banks differ in loan risk and can influence their own size, two key factors shaping the likelihood and desirability of bailouts and bail-ins. When bail-ins replace bailouts, large banks face higher funding costs, eroding the benefits of being big. Riskier banks respond by slowing their growth, leading to a 42% reduction in the share of large banks and a 65% decline in their failure rate. Despite this shift, aggregate lending falls by only 3.3%, as entry increases to meet demand for loans. Welfare rises as the benefits from improved bank stability outweigh the costs associated with a decline in lending.

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

JEL Classification Numbers: E44, G21, G28.

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1 Introduction

To avoid financial instability stemming from a big bank's failure, governments often provide support to stabilize banks or wind them down in a way with minimal spillovers. Banks adjust their balance sheets in response to this expectation of support, 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 also limiting moral hazard.

Bail-ins recapitalize distressed banks by converting uninsured 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[2], 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 through the limiting of shareholder payoff under 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 bailouts and bail-ins has focused on a representative big bank (Berger et. al. (2022), Nguyen (2023), Shukayev and Ueberfeldt (2021)). 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 they can mitigate this loss

[2]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.

through 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" subsidy. By estimating the model to the pre-GFC period, I uncover deep parameters governing banks' decisions. In a counterfactual, the bailout policy is replaced with one of bail-in and a new equilibrium is found, which includes the updating of endogenous uninsured debt prices and entry and exit decisions. Using the parameters estimated from the benchmark model, I make quantitative statements regarding the equilibrium impacts of a fully-enforced bail-in policy.

I find that creditors are never fully repaid in the bail-ins that occur in the steady state equilibrium. This partial repayment to creditors decreases the average "subsidy" on large banks' debt from 254 to 40 bps[3]. Banks borrow less, relative to their size, and with lower leverage, they can better weather large defaults on their loans without having to enter resolution. Due to paying higher interest rates, individual banks decrease lending, and fewer banks grow to be big banks — the share of big banks decreases from 18% to 10%. Importantly, the banks that still grow large are ex-ante safer compared to those who grew large under bailout: the subsidy to creditors under bailout increased the debt prices for banks with higher expected defaults on their loans by a greater percentage than for banks with lower expected defaults. Therefore, these riskier banks were strongly incentivized to grow large in the benchmark equilibrium, but less so in the counterfactual. The failure rate of big banks decreases by 65% due to lowered riskiness of the big banks. 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 benchmark, 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 equilibria 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. This measure captures that a more efficient economy is one in which banks with lower expected default rates have the highest loan shares. I find that the value of this measure in the benchmark equilibrium is only 48% of a baseline value, but the value in the counterfactual is 92% of the same baseline. 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

[3]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.

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 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, the two equilibria are tested for resiliency 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 and its equilibrium properties. Data and the estimation approach are described in Section 4. Section 5 introduces the bail-in and the resulting counterfactual equilibrium when this policy is introduced. Section 6 summarizes the results of each model and highlights the key mechanisms and takeaways. Section 7 concludes.

Related Literature My paper relates to the literature on bail-ins, bailouts, and the reorganization of distressed firms. Most papers on bail-ins focus on the price impacts for bank debt (Schaefer et. al. (2016), Giuliana (2017), Berndt et. al. (2019)). 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. (2017) 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 with bailouts and bail-ins is Berger et. al. (2022). They focus on the capital structure decisions of a representative big bank in depending on the resolution policy in place. 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 Nguyen (2023) and Shukayev and Ueberfeldt (2021). These papers 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 nor do they 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 (2024), 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 can better capture the heterogeneity 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. As I wish to study the long run consequences of a permanent change to resolution policies, I focus on 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 be defaulted on, and banks earn R^ℓ on nondefaulted loans. Return to lending for bank j is then

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

where $\lambda_{jt} \in \Lambda \equiv \{\lambda^1, ..., \lambda^n\}$ 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 pay a monitoring cost on the quadratic value of their lending, $c_{Mjt}\ell_{jt}^2$.

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 costs to investing in these assets, and all banks earn an exogenous return of R, making the total return Rs_{jt+1}. Banks pay a fixed cost of operating c_O each period.

Investments by the bank 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 $\delta_{jt+1} \in \Delta \equiv \{\delta^1, ..., \delta^n\}$ at discounted price q^δ. A bank's level of insured deposits δ_{jt+1} arrives as an idiosyncratic shock, i.i.d. across banks, and follows a first-order Markov process with transition matrix $H(\delta_{jt+1}|\delta_{jt})$.

Banks are restricted in their portfolio choices by capital requirements

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

where ω_r and ω_s are risk-weights on the "risky" and "safe" types of assets, respectively, to replicate risk-weighted capital requirements used in practice. 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.[4] 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. Once the bank makes these choices, the after-tax net cash flow value to shareholders is given by:

$$\psi(d_{jt}) = \begin{cases} d_{jt}^{\sigma} & \text{if} \quad d_{jt} \geq 0 \\ 1 - e^{-d_{jt}} & \text{if} \quad d_{jt} < 0. \end{cases} \tag{6}$$

where

$$d_{jt} = n_{jt} - c_O - \ell_{jt+1} - c_{Mjt}\ell_{jt+1}^2 - s_{jt+1} + q^{\delta}\delta_{jt+1} + q_{jt}b_{jt+1}. \tag{7}$$

Specifically, a bank pays dividends when $d_{jt} \geq 0$. Shareholders have a preference for smooth dividends, as denoted by the function $\psi(d_{jt})$ when $d_{jt} \geq 0$. The parameter $\sigma \in (0, 1]$ can provide curvature to the dividend payment to capture this preference. If $d_{jt} < 0$, funds must be injected into the bank as seasoned equity. Raising \$x of equity costs the bank $\$1 - e^x$.

Banks can enter the industry by paying a cost c_e. After paying this cost, banks observe their initial level of default rate λ_{j0} from the stationary distribution of $\bar{F}(\lambda)$ and receive their initial level of insured deposits δ_{j0}, which is equal to the smallest value in $\Delta \equiv \{\delta^0, ..., \delta^n\}$ for all banks. Banks choose their initial levels of loans, safe assets, and uninsured debt. The mass of new entrants is denoted as M_t.

[4] 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 Financial Markets

Banks finance their lending and safe asset purchases through equity, insured deposits, and uninsured debt. Equity issuance is costly for the bank, such that the overall cost of raising \$x dollars of equity is $\$1 - e^x$. I normalize the number of shares per bank to 1 such that a share is a divisible claim on the dividends of the bank.

Bank j is endowed in period t with an amount of insured deposits $q^\delta \delta_{jt+1}$ where q^δ is the discounted price and $\delta_{jt+1} \in \Delta \equiv \{\delta^1, ..., \delta^n\}$. The bank must repay δ_{jt+1} in period $t+1$.

Competitive investors have access to one-period discount bonds issued by banks. Banks can default on this debt, and therefore, the price q_{jt} of debt lent to bank j in period t depends on the uninsured debt b_{jt+1} the bank borrows, the bank's insured deposits, the risky loans the bank lends, the safe assets it invests in, and the bank's current default rate λ_{jt}. The price will also depend on the resolution policy used if the bank fails and defaults on the debt as this will determine the amount the investors are paid back.

Banks charge a return R^ℓ on loans they make to firms. A higher R^ℓ implies a higher borrowing cost for firms. Therefore, firm demand for risky lending is decreasing in R^ℓ according to the function

$$L^D(R^\ell) = \zeta(R^\ell)^\epsilon. \tag{8}$$

Banks take R^ℓ as given and risky loan supply by banks is equal to the risky lending ℓ_{jt} supplied 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).

2.3 Resolution

Instead of repaying all insured deposits and uninsured debt to continue to operate, banks can enter resolution. In the benchmark model, there are two possible resolution methods:

1. **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 $\min\{b, \max\{c_L(R^\ell(1-\lambda_{jt})\ell_{jt} + Rs_{jt}) - c_F - \delta_{jt}, 0\}\}$.

2. **Bailout**: The bank receives an equity injection such that it now meets the capital requirement. With these funds, the bank fully repays 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, $d_{jt} \leq 0$.

2.4 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:

$$\begin{gathered}\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t) \\ \text{s.t.} \\ C_t + \int q^\delta \delta_{jt+1} dj + \int p_{jt} S_{jt+1} dj + \int q_{jt} b_{jt+1} dj \\ = \int \delta_{jt} dj + \int (p_{jt} + d_{jt}) S_{jt} dj + \int f^R(b_{jt}) dj + \int \tau_{jt} dj - \int \theta_{jt} dj - \int f^I(\delta_{jt}) dj\end{gathered} \tag{9}$$

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 $f^I(\delta_{jt})$. Finally, θ_{jt} is the equity injection in a bailout.

As a preference for smoothness has already been incorporated into the value function of the bank, the utility function for households $U(C_t)$ will be linear in C_t.

2.5 Timing

The timing for the benchmark model is as follows:

1. Banks with insured deposits δ_{jt}, loan default rate λ_{jt} and net cash n_{jt} choose risky lending ℓ_{jt+1}, safe assets s_{jt+1}, and uninsured debt b_{jt+1}. This pins down dividend/equity issuance d_{jt}, which is paid to/collected from shareholders.

2. Banks realize loan default rate λ_{jt+1} and earn R^{ℓ} on non-defaulted loans and R on safe assets. Banks choose between continuing or entering resolution.

   - **Bank enters resolution:** The bank is either bailed out or liquidated, based on a predetermined size-dependent probability.
     - **Liquidation:** The bank's assets are sold off at the firesale discount. Insured depositors and investors receive their payments, if any. Shareholders are paid a "final dividend", if any. The bank exits.
     - **Bailout:** The bank receives an equity injection from the government. The bank repays its insured deposits and uninsured debt. It receives its new insured deposits and continues, but is restricted from issuing dividends this period.
   - **Bank decides to continue:** The bank repays insured deposits and uninsured debt and pays applicable taxes. It realizes its new insured deposits and continues as a bank with δ_{jt+1}, λ_{jt+1}, and $n_{jt+1} = R^{\ell}(1 - \lambda_{jt+1})\ell_{jt+1} + \alpha R s_{jt+1} - \delta_{jt+1} - b_{jt+1} - \tau_{jt+1}$.

3. New banks pay the entry cost and receive both their insured deposits δ_{jt+1} and initial return realization λ_{jt+1}. Their net cash n_{jt+1} is equal to 0.

4. Households choose how much to consume, insured deposits and uninsured debt to lend, and bank stock to purchase.

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 decisions along with the net cash n will 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'. Tomorrow's gross return on the bank's assets is

$$G(\lambda', \ell', s') = R^{\ell}(1 - \lambda')\ell' + Rs'. \tag{10}$$

Once the bank knows this gross return on its assets, it must decide to continue operating or enter resolution. Only after this decision is made 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

$$V(\delta,\lambda,n)=\max_{\ell',s',b'}\quad \psi(d)+\beta\mathop{\mathbb{E}}_{\lambda'|\lambda}\big(\max\{V_R(\delta,\lambda',\ell',s',b'),\mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta',\lambda',n'(\delta,\lambda',\ell',s',b'))\}\big)$$
$$\text{s.t.}$$
$$d=n+q^{\delta}\delta+q(\delta,\lambda,\ell',s',b')b'-\ell'-s'-c_M(\delta)\ell'^2-c_O$$
$$\frac{\ell'+s'-\delta-b'}{\omega_r\ell'+\omega_s s'}\geq\alpha$$
$$n'(\delta,\lambda',\ell',s',b')=G(\lambda',\ell',s')-\delta-b'-\tau(\delta,\lambda',\ell',s',b')$$
$$\tau(\delta,\lambda',\ell',s',b')=\tau_C\max\{0,(R^{\ell}-1)(1-\lambda')\ell'+(R-1)s'-(\frac{1}{1+r_F}-1)b'-(\frac{1}{q^{\delta}}-1)\delta\}$$
$$\ell'\geq 0,\quad s'\geq 0,\quad b'\geq 0. \tag{11}$$

3.2 Resolution

In the benchmark model, 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[5]. If the bank is liquidated, the bank's realized assets, $G(\lambda',\ell',s')$, are devalued at a discount price, c_L, and used first to pay the fixed cost of liquidation c_F. Next, the leftover funds are used to repay insured depositors.[6] Leftover funds after this step, $\max\{0,c_LG(\lambda',\ell',s')-c_F-\delta\}$, are given to creditors to repay them for the uninsured debt. 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

$$V_L(\delta,\lambda',\ell',s',b')=\tau_c\max\{0,c_LG(\lambda',\ell',s')-c_F-\delta-b'\}. \tag{12}$$

[5]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)).

[6]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 in 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).

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

$$\begin{gathered}\frac{G(\lambda', \ell', s') - \delta - b' + \theta(\delta, \lambda', \ell', s', b')}{\omega_r R^\ell (1-\lambda')\ell' + \omega_s R s'} = \alpha \\ \theta(\delta, \lambda', \ell', s', b') = \delta + b' - (1-\alpha\omega_R)R^\ell(1-\lambda')\ell' - (1-\alpha\omega_s)Rs'\end{gathered} \tag{13}$$

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

$$\begin{gathered}\tilde{n}'(\delta, \lambda', \ell', s', b') = G(\lambda', \ell', s') - \delta - b' + \theta(\delta, \lambda', \ell', s', b') \\ \tilde{n}'(\delta, \lambda', \ell', s', b') = \alpha\omega_R R^\ell(1-\lambda')\ell' + \alpha\omega_s R s'.\end{gathered} \tag{14}$$

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 is not the same as that of the incumbent bank in Equation 11. This is because the equity injection comes with the restriction that banks cannot issue dividends in the period after receiving the equity injection. I designate this problem with the superscript $d \leq 0$ and write the problem as

$$\begin{gathered}V^{d\leq 0}(\delta, \lambda, n) = \max_{\ell', s', b'} \quad \psi(d) + \beta \mathop{\mathbb{E}}_{\lambda'|\lambda}\Big(\max\{V_R(\delta, \lambda', \ell', s', b'), \mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta', \lambda', n'(\delta, \lambda', \ell', s', b'))\}\Big) \\ \text{s.t.} \\ d = n + q^\delta \delta + q(\delta, \lambda, \ell', s', b')b' - \ell' - s' - c_M(\delta)\ell'^2 - c_O \\ \frac{\ell' + s' - \delta - b'}{\omega_r \ell' + \omega_s s'} \geq \alpha \\ n'(\delta, \lambda', \ell', s', b') = G(\lambda', \ell', s') - \delta - b' - \tau(\lambda', \ell', s', b') \\ \tau(\lambda', \ell', s', b') = \tau_C \max\{0, (R^\ell - 1)(1-\lambda')\ell' + (R-1)s' - (\frac{1}{1+r_F} - 1)b' - (\frac{1}{q^\delta} - 1)\delta\} \\ \ell' \geq 0, \quad s' \geq 0, \quad b' \geq 0, \quad d \leq 0.\end{gathered} \tag{15}$$

The value of entering resolution can then be written as

$$\begin{aligned} V_R(\delta, \lambda', \ell', s', b') &= (1-\rho(\ell', s'))V_L(\delta, \lambda', \ell', s', b') \\ &+\rho(\ell', s') \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \tilde{n'}(\delta, \lambda', \ell', s', b'))) \end{aligned} \tag{16}$$

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 $\bar{F}(\lambda)$. It also receives the lowest value of insured deposits. The bank has no net cash, and therefore its problem is equivalent to that of a bank $V(\delta^0, \lambda, 0)$.

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

$$(-c_e + \mathop{\mathbb{E}}_{\lambda}(V(\delta^0, \lambda, 0)))M = 0,\ M \geq 0 \tag{17}$$

3.4 Investor's Problem

Uninsured debt for banks generally is 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. A bank's resolution choice is a function of $(\delta, \lambda', \ell', s', b')$. 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,

$$\Omega(\delta, \ell', s', b') = \{\lambda' \in \Lambda : X(\delta, \lambda', \ell', s', b') = 1\}. \tag{18}$$

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 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

$$\pi(\delta,\lambda,\ell',s',b') = \underbrace{-q(\delta,\lambda,\ell',s',b')b'}_{\text{debt lent}} + \frac{1}{1+r_F}\Big[\underbrace{\big(1-\sum_{\lambda'\in\Omega(\delta,\ell',s',b')}F(\lambda'|\lambda)\big)b'}_{\text{expected repayment - no resolution}}$$
$$\underbrace{+(1-\rho(\ell',s'))\sum_{\lambda'\in\Omega(\delta,\ell',s',b')}\min\{b',\max\{c_L G(\lambda',\ell',s')-c_F-\delta,0\}\}F(\lambda'|\lambda)}_{\text{expected repayment - liquidation}} \tag{19}$$
$$+\rho(\ell',s')\underbrace{\sum_{\lambda'\in\Omega(\delta,\ell',s',b')}F(\lambda'|\lambda)b'}_{\text{expected repayment - bailout}}\Big].$$

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

$$q(\delta,\lambda,\ell',s',b') = \frac{1}{1+r_F}\Big[\big(1-\sum_{\lambda'\in\Omega(\delta,\ell',s',b')}F(\lambda'|\lambda)\big)$$
$$+(1-\rho(\ell',s'))\sum_{\lambda'\in\Omega(\delta,\ell',s',b')}\min\{1,\max\{\frac{c_L G(\lambda',\ell',s')-c_F-\delta}{b'},0\}\}F(\lambda'|\lambda) \tag{20}$$
$$+\rho(\ell',s'))\sum_{\lambda'\in\Omega(\delta,\ell',s',b')}F(\lambda'|\lambda)\Big].$$

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 in Equation 9 are then

$$
\begin{aligned}
\delta_{jt+1}, \forall\, j : q^{\delta} U'(C_t) &= \beta \mathbb{E}_t[U'(C_{t+1})] \\
b_{jt+1}, \forall\, j : (q_{jt} + q'_{jt} b_{jt+1}) U'(C_t) &= \beta \mathbb{E}_t[f^{R'}(b_{jt+1}) U'(C_{t+1})] \\
S_{jt+1}, \forall\, j : p_{jt} U'(C_t) &= \beta \mathbb{E}_t[(p_{jt+1} + d_{jt+1}) U'(C_{t+1})]
\end{aligned}
\tag{21}
$$

In a steady state, this implies

$$
\begin{aligned}
q^{\delta} &= \beta \\
(q_{jt} + q'_{jt} b_{jt+1}) &= \beta \mathbb{E}_t[f^{R'}(b_{jt+1})] \\
p_{jt} &= \beta \mathbb{E}_t(p_{jt+1} + d_{jt+1})
\end{aligned}
\tag{22}
$$

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). Then it is straightforward to show that Equation 22 is equivalent to Equation 11 or

$$
\begin{aligned}
p(\delta, \lambda, n) &= \beta \mathop{\mathbb{E}}_{\lambda'|\lambda} \mathop{\mathbb{E}}_{\delta'|\delta} [p(\delta', \lambda', n'(\delta, \lambda', \ell', s', b')) + d(\delta, \lambda', n'(\delta, \lambda', \ell', s', b'))] \\
V(\delta, \lambda, n) - d(\delta, \lambda, n) &= \beta \mathop{\mathbb{E}}_{\lambda'|\lambda} \mathop{\mathbb{E}}_{\delta'|\delta} (V(\delta', \lambda', n'(\delta, \lambda', \ell', s', b')]
\end{aligned}
\tag{23}
$$

In the case of purchasing a stock of an entrant, $S_E = S = S'$, in which case $p_j S_{jt+1}$ and $p_j S_{jt}$ cancel and the initial equity injection is accounted for in the household's budget set in Equation 9.

With regards to the equilibrium statement for the uninsured debt b_{jt+1}, this is equivalent to Equation 20 as long as $\beta = \frac{1}{1+r_F}$. This is because $q_{jt} b_{jt+1}$ is by definition set to $\frac{1}{1+r_F} \mathbb{E}_t(\text{Repayment of} \, b_{jt+1})$.

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 $n'(\delta, \lambda, n, \lambda') = G(\lambda', \ell'(\delta, \lambda, n), s'(\delta, \lambda, n)) - b'(\delta, \lambda, n) - \delta - \tau(\delta, \lambda, n, \lambda')$. Additionally, we can define the net cash of a bank after a bailout as $\tilde{n}(\delta, \lambda, n, \lambda') = \alpha \omega_r R^{\ell} (1 - \lambda') \ell'(\delta, \lambda, n) + \alpha \omega_s R s'(\delta, \lambda, n)$. 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:

$$\Gamma'(\bar{\Delta}, \bar{\Lambda}, \bar{N}; M) = \int_{\bar{N}} \sum_{\bar{\Lambda}} \sum_{\bar{\Delta}} \Big\{ \int_N \sum_{\Lambda} \sum_{\Delta} H(\delta'|\delta) F(\lambda'|\lambda) \Gamma(\delta, \lambda, dn)$$
$$\big[(1 - X(\delta, \lambda, n, \lambda'))1_{n'=n'(\delta,\lambda,n,\lambda')} + X(\delta, \lambda, n, \lambda')\rho(\delta, \lambda, n)1_{n'=\tilde{n}'(\delta,\lambda,n,\lambda')}\big] \Big\} \tag{24}$$
$$+M \sum_{\bar{\Lambda}} 1_{n'=n'(\delta_S,\lambda,0,\lambda')} H(\delta'|\delta_S) F(\lambda'|\lambda) \bar{F}(\lambda).$$

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 11.

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 17 is satisfied.

6. Given R^{ℓ^*} and the stationary distribution Γ^*, the risky lending market clears at M^* or
$$\int_N \sum_{\Lambda} \sum_{\Delta} \ell'(\delta, \lambda, n) \Gamma^*(\delta, \lambda, dn) + \sum_{\Lambda} M^* \ell'(\delta_S, \lambda, 0) \bar{F}(\lambda) = L^D(R^{\ell^*}) \tag{25}$$

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

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 match 14 model moments to the 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 for estimating the benchmark model. This time period starts with the passage of the FDIC Improvement Act, solidifying the PCA requirements regarding liquidation of banks. Additionally, it corresponds to 8 years after the bailout of Continental Illinois Bank and the beginning of the common phrase "too big to fail"[7].

4.1 Data Sources

Parameters in the model 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 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

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

not commercial banking. To do so, I define a "commercial" bank as one whose loan share out of all assets is greater than 25%, as in Corbae and D'Erasmo (2021a). The sample of banks and their asset values as of 2006Q4 can be found in Appendix Table 10.

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 dividend smoothness parameter σ is set to 0.9932, as estimated in Ríos-Rull et. al. (2023), while 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 set to match that from Bassett et. al. (2014). The probability of bailout function $\rho(\ell', s')$ will be a piece-wise function

$$\rho(\ell', s') = \begin{cases} 0 & \ell' + s' < \bar{a} \\ \bar{\rho} & \ell' + s' \geq \bar{a}. \end{cases} \tag{26}$$

$\bar{\rho}$ 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.

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
σ	Dividend Curvature	0.9932	Ríos-Rull et al. (2023)
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 divide 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 $\bar{F}(\lambda_L)$ 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. I calculate this average in 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

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

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, $\delta_S = \$10B$.

Figure 1: Deposit Distribution of Bank Sample 2006Q4

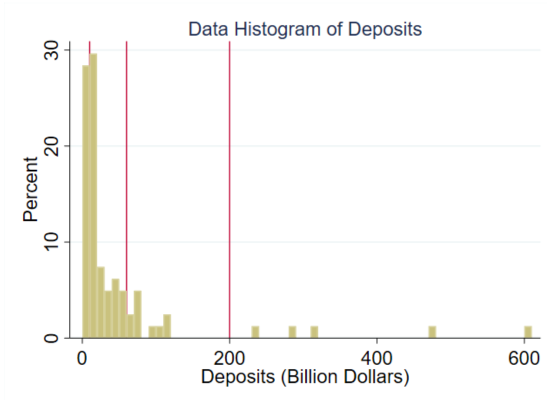


Table 3: Transition Matrix $H(\delta'|\delta)$

	δ_L = \$10B	δ_M = \$60B	δ_H = \$200B
δ_L = \$10B	0.990	0.010	0.000
δ_M = \$60B	0.005	0.990	0.005
δ_H = \$200B	0.000	0.025	0.975

Internal Calibration Internal calibration is used to minimize 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. For the moments, leverage is defined as the ratio of debt over assets. 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. Data and model moments are further defined in Appendix Section E.

Model Fit The model does well at replicating the data moments with a few small difficulties. First, the model overestimates the average assets of banks. This is primarily

Table 4: Internal Calibration

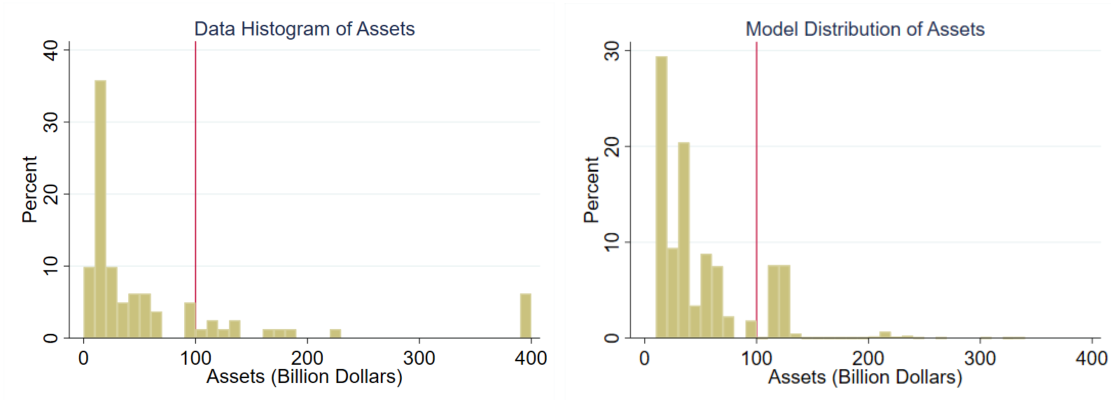
Parameter	Description	Value	Moment	Data	Model
c_e	Entry Cost	10.1	Avg. Leverage of Entrants	0.91	0.95
c_O	Fixed Operating Cost	0.2	Agg. Lending ($T)	4.51	4.61
$c_M(\delta_S)$	Loan Monitoring Cost δ_S	2.5 x 10^{-4}	Avg. Assets ($B)	22.5	34.3
$c_M(\delta_M)$	Loan Monitoring Cost δ_M	1.3 x 10^{-5}	Avg. 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. Leverage	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 Leverage	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
			Gini Coefficient of Bank Assets	0.75	0.43
			Avg. Loans to Deposits	1.1	1.2

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. This also causes the underestimation of the Gini coefficient (defined in Appendix Section E) for assets. In the data, a significantly large fraction of assets are held by these very big banks, drastically increasing the Gini coefficient. Without accurately modeling these few banks, I am understating this.

The calibration also underestimates the risky asset fraction and overestimates the uninsured leverage ratio. The 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

Figure 2: Asset Distribution of Bank Sample 2006Q4



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

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 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 Bail-in Counterfactual

I will now adapt the model to 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, I would need to include all of these other policy changes into the model to isolate the sole effect of the bail-in policy. Instead, I use the estimated parameters from the benchmark model to study how the equilibrium would change if the bail-in policy was 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 keep consistency with the benchmark model and for easier comparison to 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

$$\hat{n}'(\delta, \lambda', \ell', s', b') = R^{\ell}(1-\lambda')\ell' + Rs' - \delta. \tag{27}$$

This restructured bank is then valued at $\mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b'))$ 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 that in Equation 15.

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 $\min\{b', \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b'))\}$. 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 $\max\{0, \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b')) - b'\}$.

The bank problem can be written as in Equation 11, except that now

$$\begin{aligned} V_R(\delta, \lambda', \ell', s', b') = (1-\rho(\ell', s'))V_L(\delta, \lambda', \ell', s', b') \\ +\rho(\ell', s') \max\{0, \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b')) - b'\}. \end{aligned} \tag{28}$$

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 value to the shareholders depended only on the remaining asset values as the injection from the government would cover all of b'. This change could be instrumental to driving bank's decisions under bail-in compare to bailout.

To price the uninsured debt in the counterfactual model, we must update the resolution decisions of banks as $X_C(\delta, \lambda', \ell', s', b')$. The set of loan default rate realizations such that a bank would choose to enter resolution is

$$\Omega_C(\delta, \ell', s', b') = \{\lambda' \in \Lambda : X_C(\delta, \lambda', \ell', s', b') = 1\}. \tag{29}$$

The profit an intermediary makes on a loan contract to a bank with insured deposits δ, current realization λ, lending choice ℓ', safe assets choice s', and borrowing choice b' is then

$$\begin{aligned}
\pi_C(\delta, \lambda, \ell', s', b') = & \underbrace{-q_C(\delta, \lambda, \ell', s', b')b'}_{\text{debt lent}} + \frac{1}{1+r_F}\Big[\underbrace{\big(1 - \sum_{\lambda' \in \Omega_C(\delta, \ell', s', b')} F(\lambda'|\lambda)\big)b'}_{\text{expected repayment - no resolution}} \\
& \underbrace{+ (1-\rho(\ell', s')) \sum_{\lambda' \in \Omega_C(\delta, \ell', s', b')} \min\{b', \max\{c_L G(\lambda', \ell', s') - c_F - \delta, 0\}\}F(\lambda'|\lambda)}_{\text{expected repayment - liquidation}} \\
& +\rho(\ell', s') \underbrace{\sum_{\lambda' \in \Omega_C(\delta, \ell', s', b')} F(\lambda'|\lambda) \min\{b', \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d \leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b'))\}}_{\text{expected repayment - bail-in}} \Big].
\end{aligned} \tag{30}$$

The first two lines of this equation are identical to those in Equation 19 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. Using the fact that intermediaries make zero profit on each contract in equilibrium, the price can be solved as

$$\begin{aligned}
q_C(\delta, \lambda, \ell', s', b') = & \frac{1}{1+r_F}\Big[\big(1 - \sum_{\lambda' \in \Omega_C(\delta, \ell', s', b')} F(\lambda'|\lambda)\big) \\
& +(1-\rho(\ell', s')) \sum_{\lambda' \in \Omega_C(\delta, \ell', s', b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\}F(\lambda'|\lambda) \\
& +\rho(\ell', s')) \sum_{\lambda' \in \Omega_C(\delta, \ell', s', b')} \min\{1, \frac{\mathop{\mathbb{E}}_{\delta'|\delta}(V^{d \leq 0}(\delta', \lambda', \hat{n}'(\delta, \lambda', \ell', s', b'))}{b'}\}F(\lambda'|\lambda)\Big].
\end{aligned} \tag{31}$$

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 counterfactual equivalent to Equation 24, or the mass and law of motion equations, respectively, is then

$$\Gamma^{C'}(\bar{\Delta}, \bar{\Lambda}, \bar{N}; M^C) = \int_{\bar{N}} \sum_{\bar{\Lambda}} \sum_{\bar{\Delta}} \Big\{ \int_N \sum_{\Lambda} \sum_{\Delta} H(\delta'|\delta) F(\lambda'|\lambda) \Gamma^C(\delta, \lambda, dn)$$
$$\big[(1 - X^C(\delta, \lambda, n, \lambda'))1_{n'=n'(\delta,\lambda,n,\lambda')} + X^C(\delta, \lambda, n, \lambda')\rho(\delta, \lambda, n)1_{n'=\hat{n}'(\delta,\lambda,n,\lambda')}\big]\Big\} \tag{32}$$
$$+M^C \sum_{\bar{\Lambda}} 1_{n'=n'(\delta_S,\lambda,0,\lambda')} H(\delta'|\delta_S) F(\lambda'|\lambda) \bar{F}(\lambda)$$

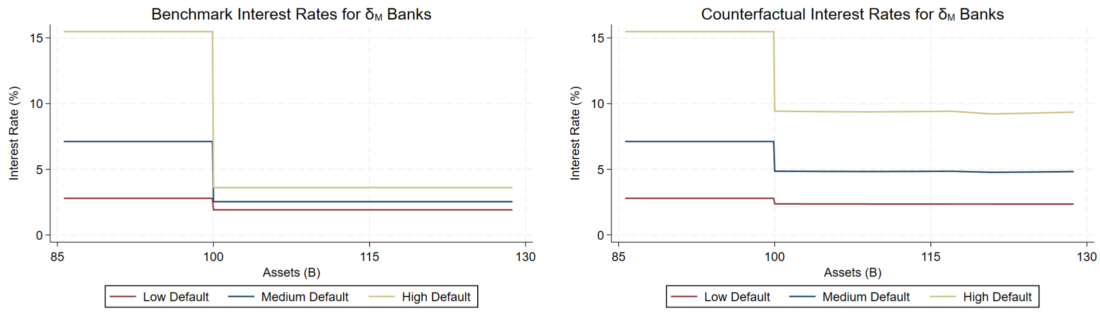
where $\hat{n}'$ now represents the net cash of a bailed-in bank. This is equivalent to $\hat{n}' = G(\lambda', \ell', s') - \delta$.

6 Results

To highlight the main mechanism, Figure 3 plots price schedules $q(\delta, \lambda, \ell', s', b')$ from the solution to the benchmark (left) and counterfactual (right) models. The q's are expressed as interest rates, which is 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.

Figure 3 demonstrates not only that interest rates fall less for banks above the \$100B threshold under bail-in compared to bailout, but also that the difference in interest rates between riskier and safer banks is larger under bail-in. 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 3 for a bank with less than \$100B in assets. At this size, banks can only be liquidated if they fail and creditors expect partial repayments. However, when a bank has assets greater than \$100 B, it now has a 90% chance of being bailed out (left)

Figure 3: Uninsured Debt Price Schedules



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

or bailed in (right) if it fails. The 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 counterfactual 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 big banks, they still drop 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 the low interest rates available under the bailout, they may still be incentivized to jump over the threshold.

Figure 4 compares the asset and uninsured leverage policy functions 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 λ_M to further highlight the impact of the differential change in interest rates above and below the TBTF threshold of \$100B.

The top left figure 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 top right panel). Banks with lower default rates can increase assets faster due to paying lower interest rates on uninsured debt, as seen by comparing to the bottom left 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. This discontinuous behavior of banks results in a clumping in the distribution around \$100B, as seen in the left-hand graph of Figure 5.

Focusing on the choices of the λ_L banks under bail-in in the top row of Figure 4, 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, needing to raise more net cash before making the jump above the \$100B 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 due to the shareholders always being wiped out. These two channels are decomposed in Section 6.3. 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.

Figure 5 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.

Table 5 compares moments between the benchmark and counterfactual equilibria. Due to the decreased repayment to creditors in the event of a bail-in, the return on risky lending R^ℓ that satisfies the free entry condition increased from 1.067 to 1.069. 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

Figure 4: Comparison of Policy Functions

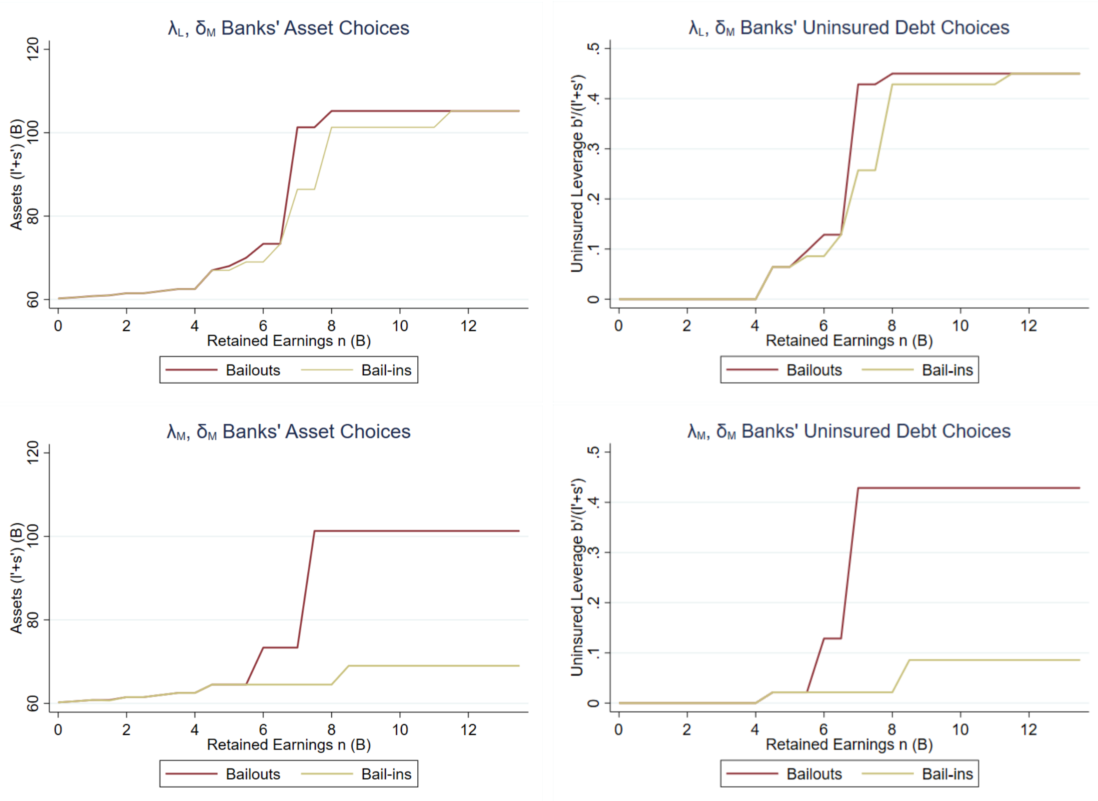


Figure 5: Comparison of Size Distributions

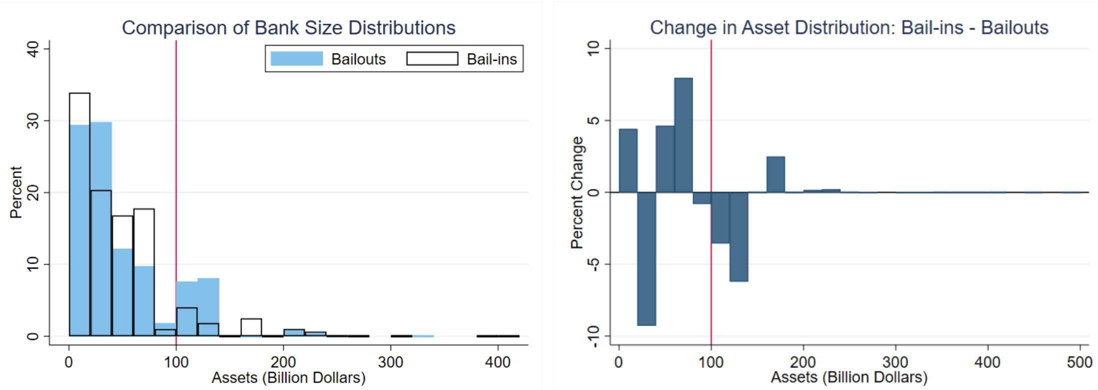


Table 5: Comparison of Results Across Resolution Policies

	Bailouts	Bail-ins
R^ℓ	1.067	1.069
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
Gini Coefficient of Bank Assets	0.43	0.46
Avg. Change in Assets (%)	9.5	9.7
Avg. Change in Assets over Threshold (%)	69.2	63.9
Avg. Risky Assets Fraction (%)	47.4	42.5
Avg. Leverage of Entrants	0.95	0.95
Avg. Leverage	0.96	0.94
Avg. Uninsured Leverage	0.45	0.36
Avg. Net Interest Margin	1.37	1.36
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
Failure Rate (%)	0.82	0.45
Bailout/Bail-in Rate (%)	0.41	0.03
Big Bank Failure Rate (%)	2.88	1.00
Resolution Costs ($B)	44.8	8.3
Avg. Dividend to Assets (%)	0.27	0.67
Share of Dividend Issuers (%)	53.2	60.6
Aggregate Consumption ($B)	61.7	102.5

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 4, banks do not jump over 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.

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 benchmark, 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 invest in high risky assets in order to grow their returns. Under the counterfactual though, these banks never end up greatly increasing 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 average uninsured leverage from 0.45 under the benchmark to 0.36 under the counterfactual.

The rate at which a bailout or bail-in occurs drops significantly from 0.41% to 0.03%, due to both 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 benchmark and 1.0% under the counterfactual. This drastic change is due to selection: under the benchmark, banks with either (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 counterfactual. 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 benchmark. Instead, in the counterfactual, these banks are now classified as small banks. However, the small bank exit rate $(\frac{\text{Failure Rate}-\text{Share of Big Banks}^*\text{Big Bank Failure Rate}}{1-\text{Share of Big Banks}})$ has not increased significantly, increasing only from 0.380 to 0.388. 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 are now better able to weather the adverse shocks to their risky loans and continue operating.

With fewer bank failures, resolution costs are significantly reduced. In Table 5, I define the resolution costs of a liquidated bank as

$$\text{Liquidation Resolution Costs} = (1 - c_L)(R^\ell(1 - \lambda')\ell' + Rs') + c_F \tag{33}$$

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

$$\text{Bailout Resolution Costs} = b' + \delta - (1 - \alpha\omega_r)R^{\ell}(1 - \lambda')\ell' - (1 - \alpha\omega_s)Rs'. \tag{34}$$

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

In the benchmark model, resolution costs include the liquidation costs of the small banks entering resolution and the $(1 - \rho)$ fraction of big banks entering resolution as well as the transfers for the bailouts of the remaining big banks, amounting to an average cost of \$44.8B a period, \$29.7B of which is due to the bailout transfers. Under the counterfactual, however, this cost includes only the liquidation costs of the small banks and the $(1 - \rho)$ fraction of big banks entering resolution, totaling only \$8.3B.

Finally, the average dividend payment increases when switching to the bail-in policy. In the benchmark model, 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.

6.1 Welfare Implications

The last line of Table 5 reports aggregate consumption of households in each equilibrium. Consumption increases 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.

The increase in consumption is quite large and may be contributed to two factors: *(i)* the change in lending to firms only enters consumption through the stock value of banks, and *(ii)* the return on risk-free securities and corporate tax rate do not adjust to the demand for such securities or the collections needed to cover the deposit insurance fund or equity injections. The incorporation of these two factors is currently in progress. Allowing households to benefit directly from lending to firms could have a drastic difference on the welfare implications. Total lending changes by \$150B while the difference in consumption is currently only \$41B. If a decrease of \$150B in lending to firms translates to more than a \$41B increase in consumption for households, the welfare implication would be negative.

6.2 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 $\hat{\lambda}'$ into

$$\hat{\lambda}' = \sum_{\lambda} \sum_{\delta} \int \underset{\lambda}{\mathbb{E}}(\lambda') \omega(\ell'(\lambda)) \Gamma(\delta, \lambda, dn) = \bar{\lambda}' + cov(\underset{\lambda}{\mathbb{E}}(\lambda'), \omega(\ell'(\lambda))) \tag{35}$$

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. $\bar{\lambda}'$ is the unweighted average expected default rate $(\sum_{\lambda} \sum_{\delta} \int \underset{\lambda}{\mathbb{E}}(\lambda') \Gamma(\delta, \lambda, dn))$. 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, where 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 benchmark and counterfactual equilibria are -0.0038 and -0.0072, respectively. As lower covariance represents higher efficiency, bail-ins generate greater efficiency than bailouts. This improvement comes from 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 benchmark, 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 counterfactual, 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, in Appendix Section C, I solve for a frictionless version of the benchmark model in which banks face the same underlying loan generating technology, but financial frictions are removed. 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 benchmark to counterfactual equilbrium.[8] 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%.

6.3 Decomposition of Debt and Equity Channels

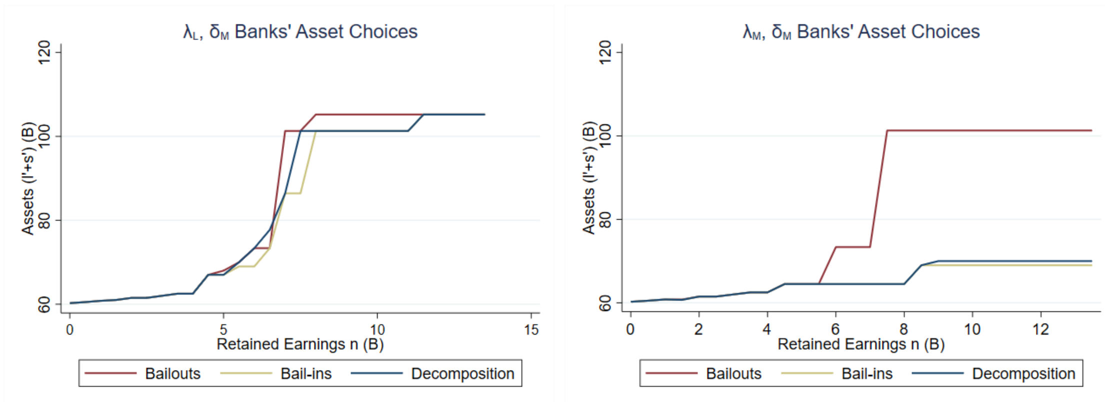
Bail-in policies change the payoffs to both creditors and shareholders relative to bailouts. Therefore, it is difficult to determine if banks are changing their behavior because the debt is more expensive or because shareholders receive less from a bail-in than a bailout. With my model, I can decompose 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 14 and the value of the bank will be retained by the shareholders; however, the creditors will only be repaid the repayment they receive in the counterfactual and the price equation will be the same as in Equation 31.

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 counterfactual equilibrium, then the debt channel dominates, as 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 counterfactual, and therefore the debt channel dominates. However, the effects vary based on the banks' default rates λ. Figure 6 plots the asset decisions of banks with the medium value of insured deposits δ_M under the benchmark, counterfactual, and this decomposition exercise. While the λ_L banks need greater 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 the

[8] 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. As this distribution is part of the technology and could only be adjusted through large scale exits of banks, this serves as a strong benchmark for evaluating the increase in allocative efficiency from the benchmark to counterfactual equilibrium.

Figure 6: Policy Functions under Decomposition Exercise



counterfactual banks. This implies that both channels matter for these banks.[9] However, the banks with the medium default rate λ_M behave almost exactly the same as they do under the counterfactual. 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 benchmark to the counterfactual.

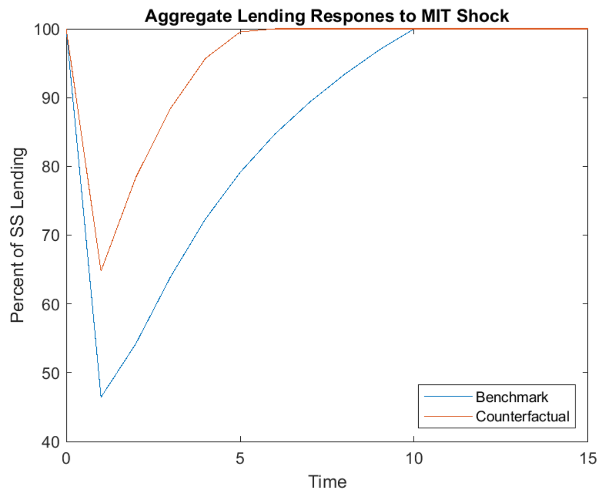
Under the decomposition exercise in 6.3, default rate allocative efficiency is -0.0073, representing greater efficiency than the counterfactual equilibrium. In the exercise, the (δ_M, λ_L) banks actually lend more than they did under the counterfactual due to the higher equity payoff if they were to be bailed out. As these are the banks with the lowest default rate, the increased loan share increases allocative efficiency.

6.4 Resilience following Aggregate Shocks

The model assumes bank failure is driven by idiosyncratic shocks to the asset value of individual banks. However, big bank failures may occur simultaneously due to aggregate shocks. As a simple framework to capture the resiliency of the banking system under

[9]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 of the bailout policy. This is not true under the counterfactual with the true bail-in. Here, 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.

Figure 7: Aggregate Lending Response to Shock



bailout and bail-in to aggregate shocks, I introduce a one-time, unanticipated shock to the loan default rates of all banks in the benchmark and counterfactual 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 banks' risky loans to total assets $(\frac{\ell'}{\ell' + s'})$ as returns to the safe asset will not change. The same mass of banks enters[10], so changes to aggregate lending and the bank size distribution are due to the increase in liquidations as well as the change in net cash for continuing and bailed out/in banks.

Figure 7 plots the aggregate lending responses to this unanticipated shock to the benchmark and counterfactual equilibria. The benchmark equilibrium experiences both a larger decline in aggregate lending and a slower recovery. Banks in the benchmark are more leveraged and have higher risky asset fractions. Therefore, they are more susceptible to additional failures due to increased defaults.

Aggregate lending recovers to its steady state value after a little more than five years. However, the benchmark takes approximately ten years to recover due to the large fail-

[10] 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.

ure of banks and the low values of net cash of the surviving banks. Further, the steady state aggregate lending under the counterfactual is approximately 97% of that under the benchmark. It still takes the benchmark 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.

6.5 Other Policy Counterfactuals

Since the financial crisis, other macroprudential policies that have been adopted to reduce bank failure rates are the increase in capital requirements and the introduction of size-dependent capital requirements. A comparison of the benchmark and counterfactual results to equilibria with these policies can be found in Appendix Sections D.2, D.3, and D.4.

7 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 aggregate consumption by households increases.

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A Background on Resolution Policies

A.1 Bankruptcy

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. Despite the resolution process needing to be completed in the least-cost manner possible, the average cost to the FDIC from the sale of failed banks between 2007 and 2013 was 28% of the value of each of the failed bank's assets (Granja et. al. (2017)). Deposit Insurance Fund costs at this time were approximately $90 billion, leaving the FDIC with a negative balance (Davison and Carreon (2010)). Additionally, the selling of failed banks can be costly to the customers of the bank in more indirect ways. P&A often leads to more concentrated markets, resulting in higher rates on small business loans and lower rates on retail deposits. Large institutions created by acquisitions may also use their new size to provide wholesale services for larger market participants, reducing or eliminating their more retail-oriented services for smaller customers. These financial institutions are also more likely to cut services to customers who rely on relationships, such as lower income and elderly customers (Berger et. al. (1999)). Despite the sixteen years in which this resolution system was used prior to the crisis, large commercial banks were never closed, most likely due to concerns over the systemic risk involved (Berger et. al. (2022)).

A.2 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 went 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)).

A.3 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 will 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 of the 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)).

The two goals of the bail-in policy are to maintain financial stability and to promote market discipline. The bail-in policy supports financial stability by allowing distressed banks whose failure threatens the safety of other banks to reorganize its liabilities and to continue to operate as a safer bank. In addition to reducing the threat of systemic risk, bail-ins can also promote financial stability through the preservation of banking services. As mentioned above, the rise in market concentration from acquisitions of failing banks can increase the cost of banking for small customers. The closure of a bank can also result in lost soft information, a valuable component of the relationship lending many small business and customers rely on (Berger et. al. (1999)). Allowing the bank to reorganize and continue operating independently avoids these possible rising costs of banking, and thus ensures the availability of financial services for the American taxpayers.

Bail-in policies promote market discipline by ensuring that the agents responsible for bank distress are held accountable by firing the managers of the bank and reducing the claims of the shareholders and creditors. Shareholders and creditors are considered to be responsible for monitoring the bank and preventing excessive risk-taking, primarily through the pricing of shares and debt. Prior to the crisis, the TBTF subsidy on the debt of large banks meant that market discipline was failing — more distressed banks were not required to pay higher costs to borrow. Additionally, during the crisis, the losses faced by shareholders and creditors of the bailed out banks were reduced due to the capital injections. While bail-ins would also save the bank from failure, the shareholders and creditors would be the ones to pay for the losses and the cost of the bail-in. Prices for shares and debt should adjust accordingly for these expected losses. In fact, Berndt et. al. (2019) provides evidence that the TBTF subsidy has been reduced since the passage of the U.S. bail-in policy.

Due to the change in payoffs to shareholders and creditors in the event of a bail-in, the prices of shares and debt should differ in an equilibrium under this new regime compared to those in the bailout environment. A change in prices could then alter the exit, entry, risk-taking, and debt-to-equity financing decisions of banks. For example, the higher costs to borrowing for banks after the elimination of bailouts could result in less investment and lending, which could inadvertently harm consumers. Additionally, with a possible loss of shares from a bail-in, shareholders may not find it valuable enough to invest in a new bank, reducing entry into the industry. While the bailing-in of a bank may preserve its services for some customers, decreased entry could reduce banking services overall. Therefore, the effects of this new policy on consumers is unclear and warrants a structural model to compare equilibrium under each policy.

A.4 Resolution Policies in 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 20. First, define the discount that the creditors demand on the debt to account for risk as

$$\text{Discount}(\delta, \lambda, \ell', s', b') = \frac{1}{1 + r_F} - q(\delta, \lambda, \ell', s', b'). \tag{36}$$

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

$$\begin{aligned} q^{\rho=0}(\delta, \lambda, \ell', s', b') = \frac{1}{1 + r_F} \big[\big(1 - \sum_{\lambda' \in \Omega^{\rho=0}(\delta, \ell', s', b')} F(\lambda'|\lambda)\big) \\ + \sum_{\lambda' \in \Omega^{\rho=0}(\delta, \ell', s', b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \big]. \end{aligned} \tag{37}$$

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

$$\begin{aligned} \text{TBTF subsidy}(\delta, \lambda, \ell', s', b') &= \text{Discount}^{\rho=0}(\delta, \lambda, \ell', s', b') - \text{Discount}(\delta, \lambda, \ell', s', b') \\ &= -q^{\rho=0}(\delta, \lambda, \ell', s', b') + q(\delta, \lambda, \ell', s', b') \\ &= \frac{1}{1 + r_F} \big[\sum_{\lambda' \in \Omega^{\rho=0}(\delta, \ell', s', b')} F(\lambda'|\lambda) - \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda) \\ &\quad + \rho(\ell', s') \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda) \\ &\quad - \sum_{\lambda' \in \Omega^{\rho=0}(\delta, \ell', s', b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \\ &\quad + (1 - \rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \big]. \end{aligned} \tag{38}$$

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

$$\begin{aligned} &= \frac{\rho(\ell', s')}{1+r_F}\Big[\sum_{\lambda' \in \Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) \\ &- \sum_{\lambda' \in \Omega(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda)\Big]. \end{aligned} \tag{39}$$

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.

Counterfactual

$$\begin{aligned} &\text{TBTF subsidy}_C(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_F} \\ &[-\sum_{\lambda' \in \Omega_C^{\rho=0}(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \\ &+(1-\rho(\ell', s')) \sum_{\lambda' \in \Omega_C(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \\ &+\rho(\ell', s') \sum_{\lambda' \in \Omega_C(\delta,\ell',s',b')} \min\{1, \frac{\mathbb{E}_{\delta'|\delta}(V(\delta', \lambda', \hat{n}'(\lambda')))}{b'}\} F(\lambda'|\lambda)]. \end{aligned} \tag{40}$$

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 $\Omega_C = \Omega_C^{\rho=0}$, then the subsidy is

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

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

C Frictionless Benchmark

To study the efficiency of the banking sector under each resolution policy regime, I first 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)* set the dividend issuance function to be $\psi(d) = d$ 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, 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 which to use 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[11]. 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

$$\begin{gathered} V(\delta,\lambda,n) = \max_{\ell'} \quad d + \beta \mathop{\mathbb{E}}_{\lambda'|\lambda}\Big(\max\{n'(\lambda'), \mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta',\lambda',n'(\delta,\lambda',\ell'))\}\Big) \\ \text{s.t.} \\ d = n + \beta\delta - \ell' - c_M(\delta)\ell'^2 - c_O \\ n'(\delta,\lambda',\ell') = R^{\ell}(1-\lambda')\ell' - \delta \\ \ell' \geq 0. \end{gathered} \tag{42}$$

[11] 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, and banks no longer have limited liability. The bank is only choosing the volume of risky lending ℓ' in order to maximize its value now. Further, the insured deposits are priced at the risk-free rate β[12]. Banks still must 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. 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

$$\begin{aligned} -1 - 2c_M(\delta)\ell' + \beta R^\ell(1 - \mathbb{E}(\lambda'|\lambda)) = 0 \\ \ell'^* = \max\{\frac{\beta R^\ell(1 - \mathbb{E}(\lambda'|\lambda)) - 1}{2c_M(\delta)}, 0\} \end{aligned} \tag{43}$$

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.

In equilibrium, only the banks with the lowest default rate λ_L choose to invest in risky lending. For all other banks, if $n + \beta\delta - c_O$ is positive, they will pay this value out as a dividend today and raise equity tomorrow to repay insured deposits δ. If this value is negative, they will raise the equity today as well. Further, no bank exits. Despite the operating costs c_O, the charter value of the bank is large enough that the bank is willing to continue, even if they must keep raising equity to pay the operating cost. When it comes to pinning down the risky loan return R^ℓ via the free entry condition, the lending banks already earn relatively high returns given that their default rates are so low. Additionally, they are paying much less for their funding for these loans. Therefore, R^ℓ decreases compared to the benchmark model and aggregate lending increases. However, the share of big banks decreases significantly. The optimal lending for (δ_M, λ_L) banks is only \$73B; therefore, the only banks that are large enough to be characterized as big banks are those with the highest value of insured deposits, δ_H. Without financing frictions or bankruptcy costs, consumption by households increases considerably to \$222.1B.

[12] In equilibrium, $q^\delta = \beta$ so this is not a substantial change

Table 6: Results from Frictionless Benchmark

	Bailouts	Bail-ins	Frictionless
R^ℓ	1.067	1.069	1.057
Avg. Interest Income on Loans (%)	4.8	5.2	4.6
Agg. Lending ($T)	4.61	4.46	5.91
Share of Big Banks (%)	17.6	10.2	5.4
Avg. Interest Rate (%)	2.17	2.12	1.18
Failure Rate (%)	0.82	0.45	0.0
Big Bank Failure Rate (%)	2.88	1.00	0.0
Default Rate Allocative Efficiency	-0.0038	-0.0072	-0.0078

D Policy Counterfactuals

D.1 Non-Targeted Bail-in Policy

The results from the counterfactual exercise in Section 5 are based on implementing the same size threshold as seen in the bailout policy as well as a probability function to determine whether a bank receives the bail-in or liquidation. However, this size-based policy could create inefficiencies in the banking sector. To examine further, I solve for a second counterfactual equilibrium in which any bank can receive the bail-in when they enter resolution. Further, banks will only be liquidated if the value to the creditors is greater under liquidation than it is under bail-in. The value to the creditors of liquidation can be defined as

$$VC_L = \min\{b', \max\{c_L G(\lambda', \ell', s') - c_F - \delta, 0\}\} \tag{44}$$

and the value to the creditor of bail-in as

$$VC_I = \min\{b', \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta, \lambda', \hat{n}'(\lambda'))\} \tag{45}$$

where $\hat{n}' = G(\lambda', \ell', s') - \delta$. Due to the firesale and fixed costs of liquidation, it is most likely that the value of bail-in will be higher in equilibrium. However, it is possible that the fixed cost of operating c_O as seen in Equation 11 is high enough that continuing even after a bail-in is very costly and the creditor would prefer the repayment from liquidation.

The value of resolution is then

$$
\begin{aligned}
&V_R(\delta, \lambda', \ell', s', b') = \mathbb{1}_{VC_L > VC_I} V_L(\delta, \lambda', \ell', s', b') \\
&+(1 - \mathbb{1}_{VC_L > VC_I}) \max\{0, \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda')) - b'\}.
\end{aligned} \tag{46}
$$

This implies price schedules of

$$
\begin{aligned}
&q_N(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_F}\big[\big(1 - \sum_{\lambda' \in \Omega_N(\delta, \ell', s', b')} F(\lambda'|\lambda)\big) \\
&+ \sum_{\lambda' \in \Omega_N(\delta, \ell', s', b')} \min\{1, \max\{\frac{\mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda'))}{b'}, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\}\} F(\lambda'|\lambda)\big]
\end{aligned} \tag{47}
$$

where Ω_N is the set of loan default rate realizations such that the bank will enter resolution. The last row of Equation 47 represents the repayment to the creditors in resolution, either from liquidation or bail-in. The repayment is a maximum of 100% and a minimum of 0% of the debt claim b', but the interior value of repayment depends on if the value of bail-in or liquidation is higher to the creditor.

The results of the non-targeted bail-in are summarized in the third column of Table 6. In equilibrium, the value of a bail-in is always greater than the value of liquidation due to the costly firesale and fixed costs associated with the liquidation. This policy decreases the price of uninsured debt for banks below the TBTF threshold due to their access to the bail-in. For these banks, I find that the average repayment to creditors in the event of a bail-in is 81% of their original debt claim. This is in great contrast to the average 11% repayment that the creditors would have received in liquidation in this equilibrium. With access to cheaper funding, these banks lend more compared to both the benchmark and the counterfactual, which can be seen in the bottom row of Figure 8. These figures calculate the change in the size distribution from the bailouts or bail-ins equilibria to the non-targeted bail-ins equilibrium. Compared to either solution, the non-targeted bail-in policy decreases the mass of banks with less than \$10B in assets as these small banks now have cheaper funding to invest in higher quantities of assets. However, without the size threshold of \$100B, fewer banks grow to such a level, as seen by the decrease in the mass of banks just to the right of the threshold. The share of big banks decreases to 6%, compared to 18% under the benchmark and 10% under the counterfactual.

Borrowing uninsured debt is now cheaper for entering banks, who receive the smallest value of insured deposits and are constrained from making large quantities of risky loans due to having no internal funding to start. Now, with cheaper debt, these entrants do not need to earn as high of a return on their lending to choose to enter. Therefore, the risky loan return that satisfies the free entry condition is 1.066, down from 1.067 under the benchmark. At this lower return, firm demand for bank loans increases, and the aggregate amount of lending increases from \$4.61T under the benchmark to \$4.72T.

The average risky asset fraction decreases to 39.8% under the non-targeted bail-in policy. Without the incentive to quickly surpass the \$100B threshold, banks choose to smooth their returns more by investing in more safe assets. However, average uninsured leverage and total leverage increase compared to the counterfactual. Debt prices have decreased for banks and there are greater returns to earn from borrowing to fund investment in assets rather than using internal funding. The change in assets when banks cross the \$100B threshold appears very large under the non-targeted bail-in policy. However, this is driven by a composition effect. Under the benchmark and the counterfactual, there were banks, specifically those with $\delta = \delta_M$ who would drastically increase their assets to grow over the threshold. Under this policy in which the threshold is not needed for access to the bail-in, the banks that grow over the threshold are only banks who are switching from δ_M to δ_H, creating a very large increase in assets.

The failure rate of banks is lower under the non-targeted bail-in policy than the benchmark or counterfactual. This is due to the decreased mass of banks engaging in very risky lending or over leveraging themselves in order to grow quickly above the TBTF threshold. However, the rate of bail-ins is higher under the non-targeted policy than the counterfactual because small banks, who fail at the highest rates, are bailed in now. Nonetheless, bail-ins avoid the deadweight losses from the firesale of assets that occurs in liquidation, so total resolution costs are the lowest under the non-targeted bail-in policy.

The enactment of the bail-in policy was just one example of new regulations imposed on banks in response to the financial crisis. Another includes the adjustment of capital requirements, a frequently studied and discussed way to combat bank moral hazard. In this section, I solve for two new counterfactuals related to changing capital requirements and compare the steady state distributions and statistics to those from the original bailout and bail-in equilibria.

Figure 8: Size Distribution under Non-Targeted Bail-ins

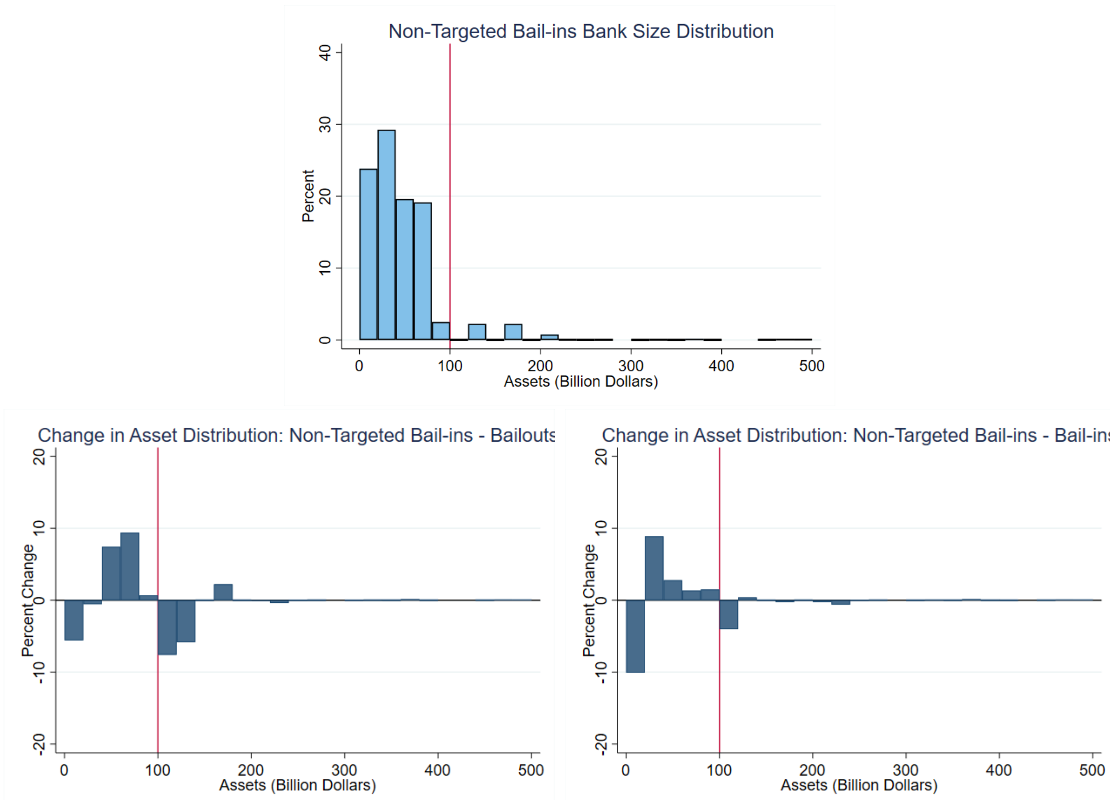


Table 7: Comparison of Results Across Resolution Policies

	Bailouts	Bail-ins	Non-Targeted Bail-ins
R^ℓ	1.067	1.069	1.066
Avg. Interest Income on Loans (%)	4.8	5.2	4.7
Agg. Lending ($T)	4.61	4.46	4.73
Avg. Assets ($B)	34.3	26.1	45.7
Share of Big Banks (%)	17.6	10.2	6.0
Gini Coefficient of Bank Assets	0.43	0.46	0.43
Avg. Change in Assets (%)	9.5	9.7	9.0
Avg. Change in Assets over Threshold (%)	69.2	63.9	112.4
Avg. Risky Assets Fraction (%)	47.4	42.5	39.8
Avg. Leverage of Entrants	0.95	0.95	0.94
Avg. Leverage	0.96	0.94	0.96
Avg. Uninsured Leverage	0.45	0.36	0.40
Avg. Net Interest Margin	1.37	1.36	1.32
Avg. Repayment under Bailout/Bail-in (%)	100.0	45.7	81.2
Max Repayment under Bailout/Bail-in (%)	100.0	48.0	100.0
Avg. Interest Rate (%)	2.17	2.12	1.92
Avg. TBTF Subsidy (bps)	254	40	33
Failure Rate (%)	0.82	0.45	0.45
Bailout/Bail-in Rate (%)	0.41	0.03	0.40
Big Bank Failure Rate (%)	2.88	1.00	0.44
Resolution Costs ($B)	44.8	8.3	7.1
Avg. Dividend to Assets (%)	0.27	0.67	0.38
Share of Dividend Issuers (%)	53.2	60.6	46.0

Table 8: Comparison of Capital Requirement Counterfactuals

	Bailouts	Bail-ins	Higher Cap. Req.	Size Dependent	Incorrect Size Dependent
R^ℓ	1.067	1.069	1.072	1.069	1.068
Agg. Lending ($T)	4.61	4.46	4.20	4.46	4.52
Avg. Assets ($B)	29.7	21.8	30.23	21.7	29.2
Share of Big Banks (%)	17.6	10.2	16.9	9.5	18.2
Avg. Risky Assets Fraction (%)	47.4	42.5	52.4	42.7	47.9
Avg. Leverage of Entrants	0.95	0.95	0.92	0.95	0.95
Avg. Leverage	0.96	0.96	0.92	0.95	0.96
Avg. Uninsured Leverage	0.44	0.36	0.37	0.32	0.30
Failure Rate (%)	0.82	0.45	0.79	0.45	0.77
Bailout/Bail-in Rate (%)	0.41	0.03	0.37	0.05	0.36
Big Bank Failure Rate (%)	2.88	1.00	2.92	1.45	2.87
Resolution Costs ($B)	44.9	6.5	31.0	15.4	33.5
Default Rate Allocative Efficiency	-.0038	-00.72	-.0036	-.0074	-.0043

This table compares statistics of the steady state equilibria of the benchmark model with higher capital requirements (Column 4), with the size-dependent capital requirements (Column 5), and with incorrect size-dependent capital requirements (Column 6) to those of the original benchmark model (Column 2) and bail-in counterfactual (Column 3).

D.2 Higher Capital Requirements

In this section, I solve for a counterfactual in which the capital requirement α is increased from the level used in the benchmark model, 4%, to the Basel II regulatory level, 8%, in the benchmark framework of bailouts. Aggregate statistics from the steady state distribution under this scenario can be found in Column 4 of Table 8.

Higher capital requirements for all banks decrease the value of entering as a bank. Therefore, the equilibrium return on lending R^ℓ must increase compared to the benchmark model. In fact, the new equilibrium R^ℓ is even higher than that of the bail-in counterfactual model. Despite big banks having a positive probability of bailout and therefore a TBTF subsidy on their debt prices, these big banks are constrained by capital requirements, lowering their value. Further, a bank has to grow large enough to take advantage of this subsidy and therefore, the entrants require a higher return on lending to choose to enter. With a higher required return on lending, aggregate lending decreases to $4.20B, compared to $4.61B under the benchmark model and $4.46 under the counterfactual bail-in model.

Asset choice policy functions of banks with the medium insured deposits (δ_M) under the higher capital requirement can be found in Figure 9. The top left figure plots the asset choices of banks with the lowest default rate λ_L under the benchmark bailout model and this higher capital requirement bailout model. Despite the higher return on lending, higher capital requirements have a substantial effect on the asset decisions when net cash is low and capital requirements are more binding. The banks still jump above the \$100B threshold, but not until they have over \$11B in net cash, compared to the only \$6.5B they need under the benchmark model. However, when the banks do choose asset values over the threshold, they actually choose a higher level of assets than chosen under the benchmark model due to their increased expected return on lending. The same result can be seen in the bottom left figure in which I plot the asset policy functions of banks with λ_M instead. The higher capital requirement banks are again more constrained and need to build more net cash before they can grow above the \$100B threshold. Further, the choice of assets once they cross the threshold is once again higher due to the higher return on lending.

The top right figure compares the policy functions of banks with the lowest default rate λ_L under the bail-in counterfactual and this counterfactual with bailouts but higher capital requirements. The higher capital requirement banks are again more constrained than the banks in the bail-in model and choose fewer assets when net cash is low. When the higher capital requirement banks do choose assets over \$100B, they once again choose an asset value higher than that chosen by the bail-in banks due to the higher return on lending and the positive value of the bailout probability. However, the largest change between the bail-in counterfactual and the higher capital requirement one can be seen in the bottom right figure, which plots the asset policy functions of λ_M banks. A key feature of the bail-in counterfactual is that these banks do not grow over the \$100B threshold and become big banks. The higher capital requirements is not enough though to offset the additional value from a positive bailout probability though, and there is a much larger share of big banks in this counterfactual. As seen in Table 8, the share of big banks in the higher capital requirements model is 15.8% compared to the 10.2% in the bail-in model.

The corresponding debt policy functions can be found in Figure 10. Given the higher capital requirements, banks borrow less uninsured debt. However, given that banks still grow above the \$100B threshold when they have the medium default rate λ_M, this corresponds to higher overall uninsured leverage than under the bail-in counterfactual.

The resulting size distributions can be found in Figure 11, in comparison to those under the bailout (left) and bail-in (right) distributions. The share of big banks under the higher capital requirements is only 0.7% lower than that under the benchmark model. However, big banks stay slightly smaller on average due to the constraints from higher

Figure 9: Asset Policy Functions under Higher Capital Requirements

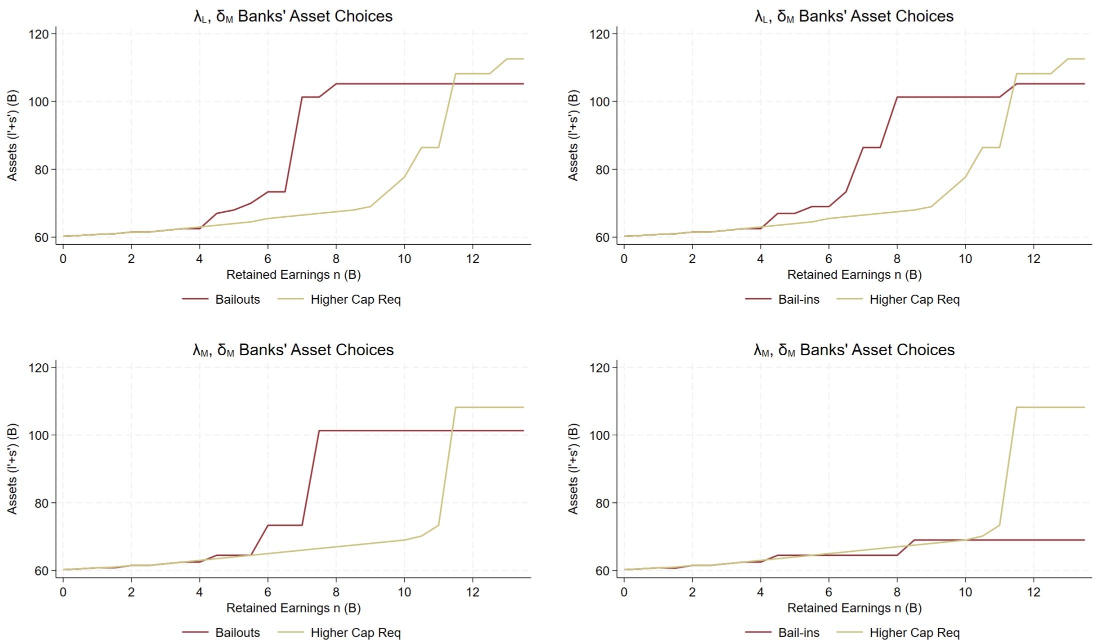


Figure 10: Uninsured Leverage Policy Functions under Higher Capital Requirements

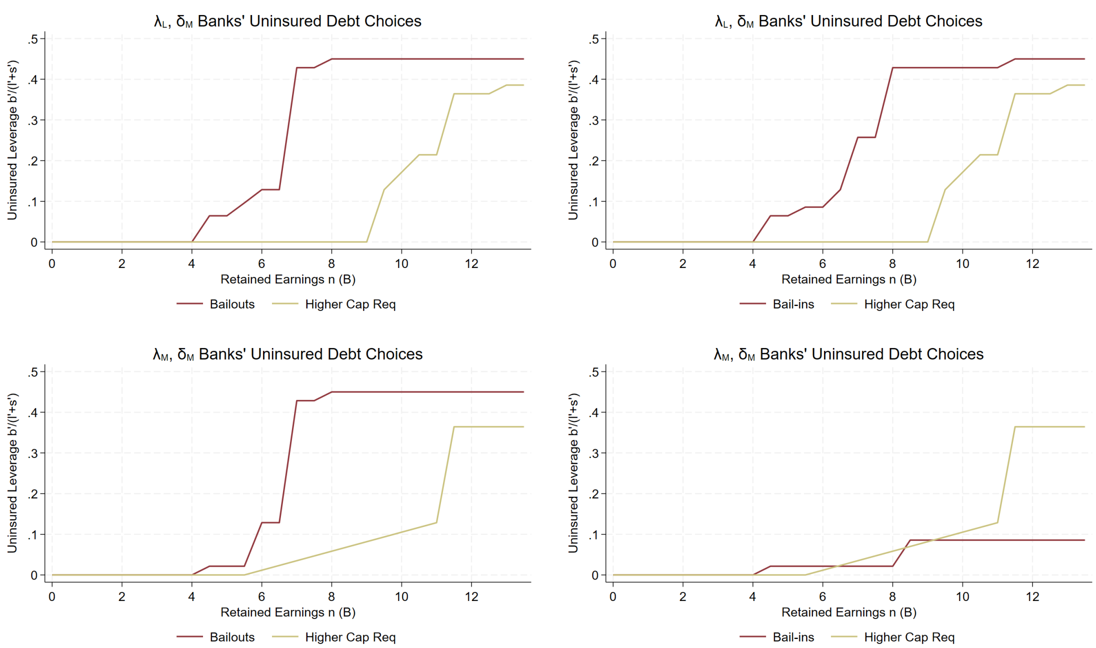
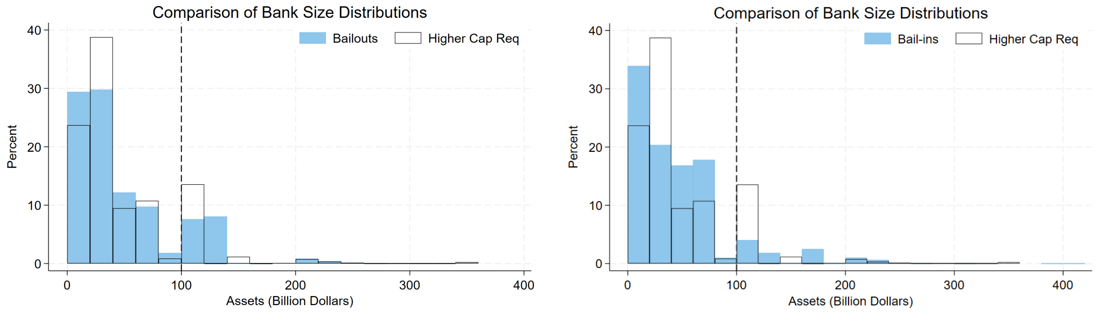


Figure 11: Comparison of Size Distributions under Higher Capital Requirements



capital requirements. There is a smaller share of banks with assets between \$0 and \$20B and a higher share between \$20-40B due to two complementary forces. First, banks earn a higher return on lending under the higher capital requirements, therefore the gross value of assets $R^\ell(1-\lambda')\ell' + Rs'$ can be higher, even for the same value of ℓ'. Second, due to the higher required return on lending R^ℓ, demand for loans from firms is significantly lower. However, there are still big banks lending a significant amount. These banks meet a large amount of the demand for loans by firms and leave less room for entrants; therefore, the mass of entrants is smaller. This same effect can be seen to an even greater extent in the right graph, which compares the size distribution under higher capital requirements to that of the bail-in model. In addition to a smaller mass of the smallest banks, the key difference between these two distributions is the missing mass between \$60 and \$100B under higher capital requirements and the increased mass point just above \$100B. Even with higher capital requirements, banks with both λ_L and λ_M will jump above the \$100B threshold, unlike under bail-in where only the λ_L banks do so. The discrete increase in asset choices results in missing mass just under the threshold and increased mass just over it. Despite the higher return on lending, capital requirements restrict banks and the average assets level is lower at \$24.7B, compared to \$34.3B. Further, a smaller share of banks grow large, only 15.8%, compared to under the benchmark model, but this is still significantly higher than the share of big banks under bail-in.

An interesting finding is that the average uninsured leverage ($\frac{b'}{\ell'+s'}$) of banks decreases under the higher capital requirements, but the average risky assets fraction ($\frac{\ell'}{\ell'+s'}$) increases. While we would expect banks to decrease this fraction, as risky assets hold a risk weight of 1, banks can more substantially decrease the capital requirement by decreasing leverage. Further, the banks now earn a greater return on risky lending. Therefore, banks appear to decrease their uninsured debt by a greater extent but increase their risky asset fractions slightly in order to raise their expected profits.

Even though banks need to hold more capital, the failure rate of big banks is actually slightly higher (2.92% compared to 2.88%). This difference stems from a greater portion of banks with λ_M in equilibrium, which have a greater probability of receiving λ_H next period, thus increasing the overall failure rate. There are more λ_M big banks due to the slower growth rate of banks with λ_L, which increases the probability that they will switch to λ_H before they raised enough net cash to weather negative shocks.

Individual big banks may have a higher probability of failing under the higher capital requirements scenario, yet the cost of these resolutions is lower. Banks are choosing lower levels of uninsured debt, which reduces the necessary transfer in a bail-in. Further, the return on lending is higher, and therefore, the bank has more funds from its loans that were not defaulted upon, further decreasing the transfer needed in a bailout.

Finally, the last row of Table 8 summarizes the default rate allocative efficiencies for each equilibria. The default rate allocative efficiency measure under these higher capital requirements is -.0036, even higher than -.0038 under the benchmark. While banks lend less under the higher capital requirements, the higher capital requirements apply to all banks, and therefore have little effect on the relationship between default rates and share of lending. The increase in the measure is driven by the choice of banks to relatively decrease their leverage more than their risky asset fraction to meet the higher capital requirements. This is particularly true of the medium default rate banks jumping over the \$100B. To qualify for the bailout, these banks need \$100B in total assets and they choose to reach this with a greater fraction of risky assets compared to the benchmark, resulting in a greater share of risky lending by banks with higher expected default rates.

While increasing capital requirements for all banks does decrease the failure rate of banks and the cost of resolution, the decrease in aggregate lending is substantial. Replacing bailouts with bail-ins dominates increasing capital requirements in regards to promoting lending and reducing big bank failure.

D.3 Size Dependent Capital Requirements

In this section, the capital requirement is increased to 8% if the bank has assets greater than \$100B, the asset threshold at which the bailout probability becomes positive. Results from this counterfactual can be found in Column 5 of Table 8. This policy counterfactual is in-line with size-dependent capital requirements enacted in the Dodd-Frank Act and can be used to compare how higher capital requirements for banks with bailout expectations can reduce big bank failure relative to replacing bailout expectations with bail-in expectations.

Figure 12 plots the asset policy functions of banks as a function of their net cash and current default rate for banks with the medium insured deposits under the bailout, bail-in, and size-dependent capital requirements models. Banks avoid crossing the $100B threshold until they have built up enough net cash to help them meet the higher capital requirements. We can see that they stay in the realm of $90-96B in assets when their net cash n varies from $7.5-11B. However, once they do choose assets above the threshold, their assets are actually higher than under bailout or bail-in, for the same value of net cash n. Despite having to hold more capital, banks are actually earning more on their risky lending than under the benchmark model. Therefore, the optimal choice of assets has increased, as long as they can use more equity to fund it to avoid violating the capital requirements. Compared to the bail-in world, banks earn approximately the same rate on their lending. However, these banks benefit from the subsidy on their debt prices and increased equity value from a bailout compared to a bail-in. This increases the optimal choice of assets relative to the bail-in counterfactual.

The corresponding uninsured leverage policy functions can be found in Figure 13. The plots in the top row demonstrate the uninsured leverage policy functions of banks with the lowest default rate λ_L. When banks are below the $100B threshold and are not subject to the higher capital requirements, they make similar uninsured leverage decisions as those by banks under both the original bailout (left) and bail-in (right) models. However, because the banks stall growing over the threshold and having to face the higher constraint, they borrow less. Even when the banks do choose assets above the threshold, they still borrow less uninsured debt. This is because more leverage binds the capital requirement, so banks are more willing to fund their assets with equity. In the plots in the bottom row, we see that the λ_M banks behave just like those in the bail-in model. Due to the higher capital requirements over the threshold, these banks choose assets significantly below it. They will always be liquidated if they fail, and therefore, their debt and equity values are very similar to those in the bail-in counterfactual.

Figure 14 plots the corresponding size distributions. Compared to the original bailout model, the distribution of banks around the $100B threshold is substantially smoother. The constraint of higher capital requirements offsets some of the benefit of having a positive probability of bailout and more λ_L banks stay below the threshold. Further, the λ_M

Figure 12: Policy Functions under Size Dependent Capital Requirements

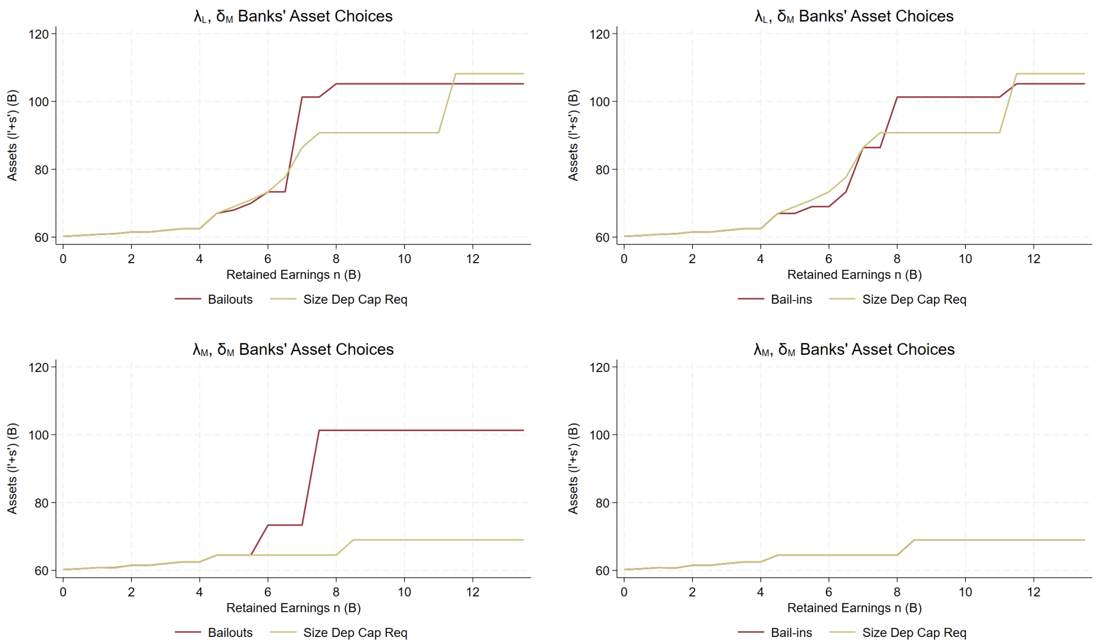


Figure 13: Uninsured Leverage Policy Functions under Size Dependent Capital Requirements

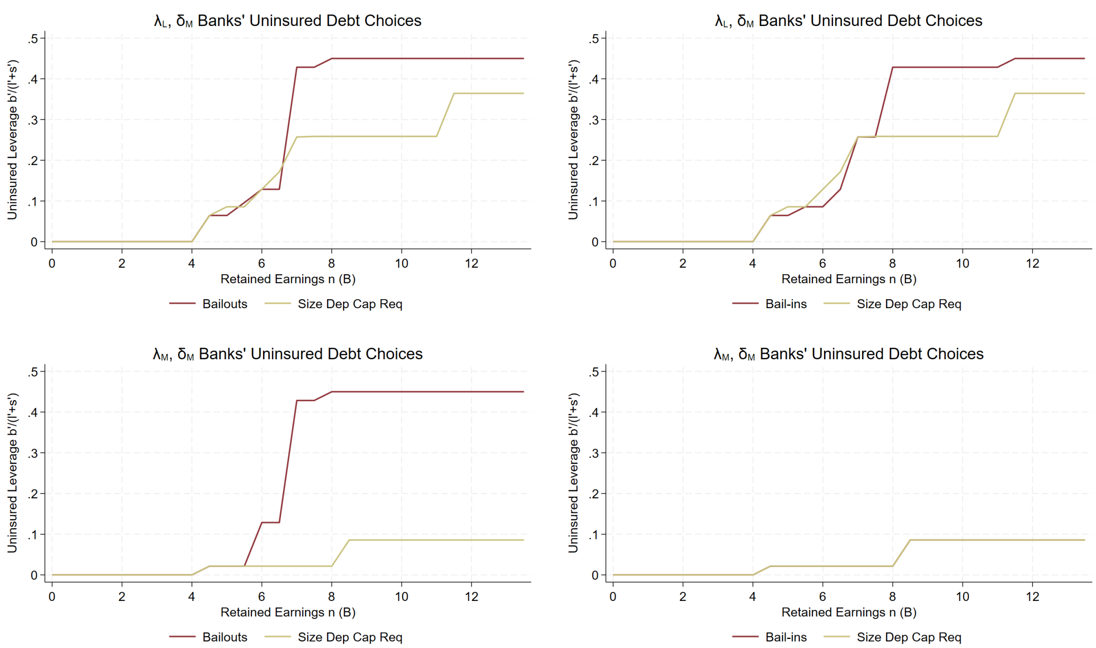
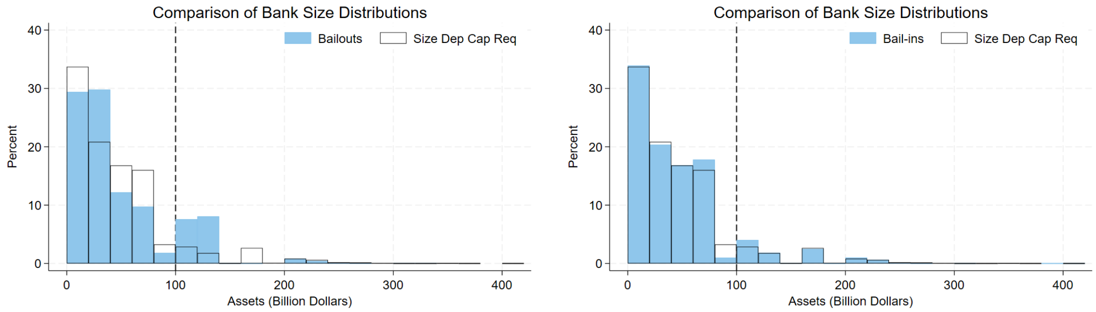


Figure 14: Comparison of Size Distributions under Size Dependent Capital Requirements

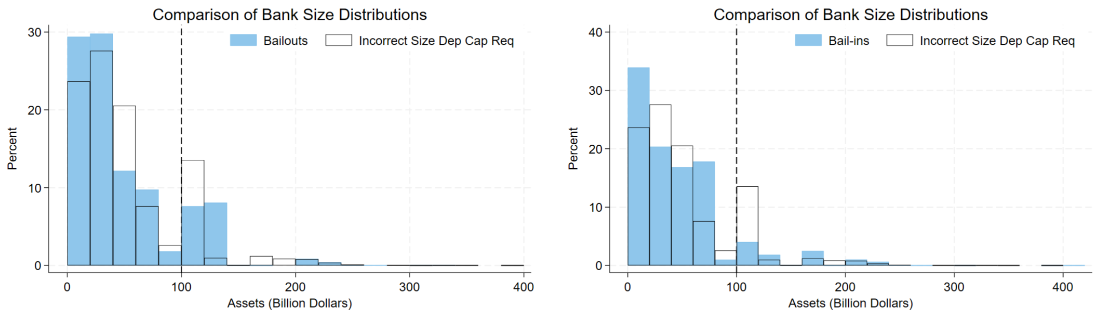


banks no longer grow above the threshold, and therefore, this size distribution is more similar to that under bail-in. The main difference between the bail-in and size dependent capital requirement distributions is that the latter has more mass between \$80-99B and less above \$100B due to the penalty of the higher capital requirements reducing the number of λ_L banks jumping over the threshold. These banks specifically benefit the most from the bail-in pricing and still jump in that counterfactual scenario. However, the higher capital requirements from the size-dependent requirement negates much of this value and banks purposely grow at a slower rate. The share of big banks in the economy is reduced from 10.2% to 9.5%.

Aggregate statistics for the size-dependent capital requirements steady state can be found in Column 5 of Table 8. In general, these statistics are very similar as those under bail-in. However, due to the higher capital requirements when over the threshold, banks choose lower uninsured debt levels and increase their risky asset fractions slightly. The largest deviation between this equilibrium and the bail-in one is in resolution costs, which are almost double for the size-dependent capital requirements scenario due to the cost of bailout transfers that are still needed. This suggests that bail-ins may be a better option to reducing big bank failure costs while promoting aggregate lending, but that size-dependent capital requirements still provide vast improvements if reducing bailout expectations to zero is not possible.

In fact, size-dependent capital requirements improve default rate allocative efficiency more than the bail-in does. Higher capital requirements lead to banks increasing their risky asset fraction slightly as they decrease leverage instead. As majority of banks subject to the higher capital requirements in this scenario are the lowest default rate banks, this results in a slight increase in the share of lending by banks with the lowest expected default rates.

Figure 15: Comparison of Size Distributions under Mismatched Size Dependent Capital Requirements



D.4 Mismatched Size Dependent Capital Requirements

Section D.3 demonstrated that size dependent capital requirements can replicate many of the benefits of bail-in expectations without the commitment to bail-ins. However, these results rely on capital requirements increasing at the same threshold at which bailout expectations increase. If these two thresholds were not aligned, the benefits of bail-ins may not be realized. In this section, I solve for an equilibrium in which banks with assets above \$100B are considered "too big to fail" and subject to a $\bar{\rho}$% probability of bailout when they fail, but higher capital requirements are only imposed on banks with at least \$110B in assets.

Figure 15 compares the size distribution of banks in this equilibrium to that of the benchmark model (left) and the bail-in counterfactual model (right). Compared to the benchmark model, the main difference in this distribution is that banks previously in the \$110-120B range now stay in the \$100-110B range. These banks will still have the positive probability of bailout if they fail, but are not subject to the higher capital requirements yet. In order to remain in this range, big banks borrow less and issue more dividends instead of borrowing more to grow slightly larger. This can be seen in Column 6 of Table 8. Average uninsured leverage decreases from 0.44 under the benchmark to only 0.30. However, these banks still borrow enough such that they will not be able to repay their debt if they receive the high default rate, and the big bank failure rate barely changes from 2.88% to 2.87%.

Failure rates and the share of big banks are much closer to those of the benchmark equilibrium than the bail-in counterfactual, thus depleting the bail-in benefits associated with size dependent capital requirements in Section D.3. Further, aggregate lending is 2.0% lower than in the benchmark model, suggesting even fewer advantages to size dependent capital requirements if they do not align with "too big to fail" beliefs.

E Moment Definitions

Table 9: Model Definitions

Leverage	$\frac{b'+\delta}{\ell'+s'}$
Uninsured Leverage	$\frac{b'}{\ell'+s'}$
Risky Lending	ℓ'
Safe Assets	s'
Risky Asset Fraction	$\frac{\ell'}{\ell'+s'}$
Assets	$\ell' + s'$
Dividend to Assets	$\frac{d}{\ell'+s'}$
Interest Income on Loans	$R^{\ell}(1-\lambda')$
Loans to Deposits	$\frac{\ell'}{\delta}$

Net Interest Margin (NIM) is defined as the difference in a bank's interest income and interest expense, divided by interest-earning assets. In the model, this corresponds to

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

The Gini coefficient is a measure of the concentration of asset by banks. For the data moment, where I have a finite number of banks, I calculate the Gini coefficient using the formula

$$\text{Gini}_{\text{Data}} = \frac{1}{N}\Big(N+1-2\frac{\sum_{i=1}^{N}(N+1-i)\text{Assets}_i}{\sum_{i=1}^{N}\text{Assets}_i}\Big) \tag{49}$$

where i represents an individual bank in a given year and N is the total number of banks in the sample in that year. The banks are first sorted in ascending order by Assets. I use the average Gini over the time period as my moment to match. The Gini coefficient is meant to capture the area between a 45 degree line and the Lorenz curve, multiplied by 2 so that it will be on the scale of [0,1]. The Lorenz curve plots the cumulative percentage of loans made by a cumulative percentage of banks. If this curve perfectly lies on the 45 degree line, it means that the assets are held equally by banks (each bank's asset share is $\frac{\sum_{i=1}^{N} Assets_i}{N}$). The Gini coefficient would then be 0. If all assets were held by one bank, then the area between the 45 degree line and the Lorenz curve would be $\frac{1}{2}$, and the Gini coefficient would be 1. The Lorenz curve for assets in 1992Q4 and in 2006Q4 is plotted in Figure 16. Given that the model solution is a continuum of banks, I must adapt this formula to solve for a continuous distribution to calculate the corresponding model moment. First, we must calculate the cumulative distribution function of banks with given $a = \ell' + s'$ values. Define

$$\Gamma^a(a) = \sum_{\Lambda} \sum_{\Delta} \int_N \mathbb{1}_{a(\delta,\lambda,n)=a} \Gamma(\delta, \lambda, dn) \tag{50}$$

We define the weighted loan distribution then as

$$\Gamma^{\omega a}(a) = \sum_{\Lambda} \sum_{\Delta} \int_N \mathbb{1}_{a(\delta,\lambda,n)=a} a(\delta, \lambda, dn) \Gamma(\delta, \lambda, dn) \tag{51}$$

I therefore use the formula

$$\text{Gini}_{\text{Model}} = 2 \int_0^{\bar{A}} \Big(\frac{\int_0^a \Gamma^a(x)dx}{\int_0^{\bar{A}} \Gamma^a(x)dx} - \frac{\int_0^a \Gamma^{\omega a}(x)dx}{\int_0^{\bar{A}} \Gamma^{\omega a}(x)dx} \Big) \Gamma^a(da) \tag{52}$$

to capture the model equivalent of the Gini coefficient. This is equivalent to the difference between the cumulative probability of banks with a given level of assets and the cumulative probability of total assets at that level, weighted by the mass of that level of assets in the distribution.

F List of Banks 2006Q4

Table 10: List of Banks

Name	Assets ($B)
JPMORGAN CHASE & CO.	1617.1
CITIGROUP INC.	1443.4
BANK OF AMERICA CORPORATION	1416.7
WACHOVIA CORPORATION	532.4
WELLS FARGO & COMPANY	428.6
U.S. BANCORP	223.6
SUNTRUST BANKS, INC.	182.6
HSBC HOLDINGS PLC	171.2
ROYAL BK OF SCOTLAND	163.2
REGIONS FINANCIAL CORPORATION	138.7
NATIONAL CITY CORPORATION	134.4
ABN AMARO HOLDINGS N.V.	122.7
CAPITAL ONE FINANCIAL CORPORATION	117.5
BB&T CORPORATION	117.3
FIFTH THIRD BANCORP	102.9
PNC FINANCIAL SERVICES GROUP, INC.	95.0
BANK OF NEW YORK COMPANY, INC.	93.0
COUNTRYWIDE FINANCIAL CORPORATION	92.8
KEYCORP	90.2
BNP PARIBAS	67.6
MERRILL LYNCH BK USA	67.2
NORTHERN TRUST CORPORATION	65.6
COMERICA INCORPORATED	58.5
ALLIED IRISH BANKS, P.L.C.	56.9
MITSUBISHI UFJ FINANCIAL GROUP, INC.	56.5
TD BK	55.0
MARSHALL & ILSLEY CORPORATION	52.2
ZIONS BANCORPORATION	47.4
COMMERCE BANCORP, INC.	45.8
BK OF MONTREAL	42.2
DEUTSCHE BK	41.9
POPULAR, INC.	40.7
FIRST HORIZON NATIONAL CORPORATION	37.6
HUNTINGTON BANCSHARES INCORPORATED	34.9
COMPASS BANCSHARES, INC.	34.2
SYNOVUS FINANCIAL CORP.	32.9
NEW YORK COMMUNITY BANCORP, INC.	29.4
ROYAL BK OF CANADA	23.1
COLONIAL BANCGROUP, INC.	22.7
CHARLES SCHWAB CORPORATION	22.1
UBS	22.0
MORGAN STANLEY BK	21.0
BOK FINANCIAL CORPORATION	20.9
ASSOCIATED BANC-CORP	20.5
GMAC BK	19.9
BANCO BILBAO VIZCAYA ARGENTARIA	19.5

Name	Assets ($B)
MERCANTILE BANKSHARES CORPORATION	18.1
NEW YORK PRIVATE BANK & TRUST CORPORATION	17.6
SKY FINANCIAL GROUP, INC.	17.5
W HOLDING COMPANY, INC.	17.0
WEBSTER FINANCIAL CORPORATION	16.8
FIRST BANCORP	16.5
FULTON FINANCIAL CORPORATION	15.7
LAURITZEN CORPORATION	15.4
COMMERCE BANCSHARES, INC.	15.2
TCF FINANCIAL CORPORATION	14.8
CITY NATIONAL CORPORATION	14.7
SOUTH FINANCIAL GROUP, INC.	14.4
CITIZENS BANKING CORPORATION	13.4
FIRST CITIZENS BANCSHARES, INC.	13.3
CULLEN/FROST BANKERS, INC.	13.3
FREMONT INV & LOAN	12.7
VALLEY NATIONAL BANCORP	12.4
FBOP CORPORATION	12.3
BANCORPSOUTH, INC.	12.0
FIRST REPUBLIC BK	11.7
WILMINGTON TRUST CORPORATION	11.2
INTERNATIONAL BANCSHARES CORPORATION	10.9
EAST WEST BANCORP, INC.	10.8
BANK OF HAWAII CORPORATION	10.6
FIRSTMERIT CORPORATION	10.2
WHITNEY HOLDING CORPORATION	10.2
FIRST BANKS, INC.	10.1
STERLING FINANCIAL CORPORATION	9.9
CORUS BANKSHARES, INC.	9.8
WINTRUST FINANCIAL CORPORATION	9.6
UMB FINANCIAL CORPORATION	9.2
TRUSTMARK CORPORATION	8.9
ARVEST BANK GROUP, INC.	8.8
OLD NATIONAL BANCORP	8.0
FIRSTBANK HOLDING COMPANY	7.9

Figure 16: Lorenze Curve of Assets from Bank Sample