Bailouts, Bail-ins, and Banking Industry Dynamics[1]

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Abstract

Following bailouts of large banks during the Global Financial Crisis (GFC), policymakers adopted a new way to resolve bank failures called the "bail-in". Bail-in policies stabilize distressed banks using the banks' internal funds rather than external government money. This policy change alters the payoffs to banks' creditors and shareholders and in response, banks re-optimize their balance sheets. To quantify and decompose the impact of these changes on the aggregate banking industry, I build a quantitative model of heterogeneous bank entry and exit with bailouts for large banks and calibrate it to the pre-GFC U.S. banking industry. In a counterfactual in which bail-in replaces bailout, uninsured debt prices are higher, and the benefits to becoming a big bank are lessened. Ex-ante riskier banks experience the largest change in debt prices and fewer grow to be big banks. Therefore, the failure rate of big banks drops by 77%. The bank size distribution shifts towards smaller banks but more banks enter to meet loan demand. The share of loans made by safer banks increases, improving the efficiency of the banking sector.

Keywords: *bail-ins, bailouts, bank failure, loan supply, macroprudential policy*

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1 Introduction

During the Global Financial Crisis, the potential failure of "too big to fail" (TBTF) banks posed an immense threat to the U.S. economy and the global financial system. To prevent their failure and preserve financial stability, the U.S. government injected equity into the banks. These bailouts were controversial as the public largely opposed the use of taxpayer dollars to pay for the fallout of banks' risk-taking. In response, the U.S. passed the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (Dodd-Frank Act) that included a new way to resolve large and distressed banks without the use of government funding — the bail-in. During a bail-in, the bank's losses are absorbed first by its shareholders and then its unsecured creditors. New bank capital is created by converting the remaining debt claims into equity claims, which repays the creditors with equity shares in the new bank and stabilizes the bank so it can continue operating. Bailouts and bail-ins similarly reduce threats to financial markets by preventing the exit of big banks, but bail-ins could mitigate moral hazard and increase market discipline compared to bailouts, resulting in less risky banks. Critics of the bail-in policy, however, argue that it will lower aggregate lending and bank entry due to increased funding costs for banks.

If a creditor of a big bank anticipates the bank receiving a bailout, the creditors' expected repayment increases and therefore they can charge the bank a lower interest rate. This decreases the price and risk-sensitivity of the uninsured debt for bigger banks, reducing the market discipline that can be imposed when riskier banks are charged higher interest rates. Additionally, if shareholders retain shares after a bailout, as they did during the Troubled Asset Relief Program, bailouts induce moral hazard, encouraging further risk-taking by banks. While these effects clearly apply to banks that are already large, the impact on smaller banks is less apparent. The higher payoffs for shareholders and creditors when the bank fails could influence the optimal size of banks, increasing the number of big banks.

In order to evaluate the effects of bailout and bail-in policies on the banking industry, it is important to understand how the expectation of these resolution policies impacts individual banks' decisions. To do so, I build a quantitative model of heterogeneous bank lending, borrowing, risk-taking, dividend issuance, and size decisions. I solve for a steady state industry equilibrium with endogenous exit and entry, calibrated to the pre-GFC period. Bank resolution policies in this benchmark model include the standard bankruptcy procedure as dictated by the FDIC Improvement Act of 1991 and an implicit bailout option for banks above a size threshold. In a counterfactual exercise, the bailout policy is replaced with the new bail-in policy. Bank debt and equity prices adjust in equilibrium, and banks re-optimize their balance sheets and desired size. Solving for the counterfactual steady state equilibrium, I study the implications of the bail-in policy on aggregate industry statistics, such as the frequency of big bank failure, the bank size distribution, and aggregate lending.

In the model, banks invest in a portfolio of risky loans and safe assets, funded via equity, insured deposits, and uninsured debt. Risky loans earn a higher return than that of the safe assets, but banks are heterogeneous in their expected stochastic default rate of these loans. Upon realization of this default rate, banks choose between entering resolution or continuing to operate. When continuing, the bank must repay both the insured deposits and uninsured debt in full. In the benchmark model, banks that enter resolution are bailed out with a positive probability if they are above an exogenous size threshold. A bailed-out bank receives a cash injection from the government large enough to allow it to repay its debts and continue operating. However, if the bank is not bailed out, it is liquidated, where a discounted value of its assets is first used to repay insured deposits, and then as much uninsured debt as possible. Shareholders receive any remaining funds, but they have limited liability and are therefore protected from covering unpaid debt claims. The price of the uninsured debt is pinned down via a zero profit condition based on the expected repayment, including the probability of full repayment due to the bank receiving a bailout. This resolution method creates a TBTF subsidy, in which banks above the size threshold pay lower interest rates, controlling for the risk of entering resolution. New banks can enter by paying a fixed cost, and the return on risky lending is pinned down by satisfying the free entry condition. Exogenous firm demand for risky loans is decreasing in this return, and the mass of banks is solved for by clearing the market. The model generates a distribution of banks based on their asset size.

The counterfactual introduces a bail-in policy by replacing the banks' probability of bailout with that of bail-in, using the same size threshold. A bailed-in bank does not repay its uninsured debt, and the bank continues with more equity and less debt. The creditors instead receive equity shares in this new bank, up to the value of their debt claim. The original shareholders only receive shares in excess of the creditors' claim, if any. I solve for a new steady state equilibrium under this policy, holding constant the parameters from the benchmark model.

To quantify the changes from the benchmark to the counterfactual equilibrium, I estimate the benchmark model parameters via simulated method of moments (SMM). I use data from the Federal Reserve's Consolidated Report of Condition and Income, also known as Call Reports, from 1992-2006 to compute moments describing bank behavior, such as average leverage, aggregate lending, and asset growth. I target analogous moments in the model to inform model parameters.

In the counterfactual, the bail-ins that occur in equilibrium are always ones in which the creditors are never fully repaid. This partial repayment to creditors decreases the average "subsidy"[2] on large banks' debt from 254 to 40 bps. The subsidy is not fully driven to zero because the repayment to creditors under bail-in is still higher than under the alternative liquidation process. 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 lend less, 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 the bailout. This is because the subsidy to creditors under bailout decreased the debt prices for riskier banks by a greater percentage than safer banks. Therefore, these banks had greater incentive to grow larger under the benchmark, but no longer do so in the counterfactual. The failure rate of big banks decreases by 77% 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 3.4%. The bank size distribution shifts left from the decline in big banks. Therefore, the bail-in both increases financial stability and market discipline but decreases aggregate lending. The quantitative trade-off between the reduction in failure rates and the decrease in aggregate lending can be used by regulators to decide on an optimal policy.

To understand the impact of bail-in policies on efficiency, I compare the counterfactual results to two alternative benchmarks. The first features a non-targeted bail-in policy, in which banks of any size can be bailed-in if they enter resolution. This policy lowers the cost of uninsured debt for small banks as the repayment to creditors under bail-in is greater than that under liquidation, which is the only option for small banks under the benchmark and counterfactual. Therefore, small banks increase their lending, but with-

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

out the size threshold for access to bail-ins, the share of big banks actually decreases in equilibrium. Aggregate lending increases as banks do not need to earn as high of returns on their lending to decide to enter. The second alternative benchmark is a "frictionless" one, designed to resemble the environment of Hopenhayn (1992). I remove all external financing frictions, allowing banks to raise equity and borrow at the risk-free rate. In this equilibrium, only the banks with the lowest expected default rate on lending engage in risky lending. With risk-free external funding, the required return on lending for banks to choose to enter decreases further, and aggregate lending increases. Further, I define a measure 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. Because only the banks with the lowest default rates lend in the frictionless benchmark, the default rate allocative efficiency is 100%. I find that this measure is only 58.9% in the benchmark equilibrium. The bail-in policy in the counterfactual drastically improves efficiency, with an allocative efficiency measure of 88.5% due to the reduction in lending by banks with higher expected default rates investing in large quantities of risky lending in order to quickly grow above the size threshold. However, the non-targeted bail-in policy can further improve the allocative efficiency to 95.4%. This change is driven by the increase in lending by small banks with low expected defaults that now have access to cheaper uninsured debt.

My paper builds on the existing literature regarding resolution policies by introducing heterogeneity and dynamics to understand the overall impact on the banking industry. Other models, such as that of Berger et. al. (2018), focus on the decisions of a representative big bank. By studying heterogeneous banks, I can draw conclusions on the behavior of all types of banks, including those not eligible for a bailout/bail-in. The choices of these banks, including entrants, affect the aggregate amount of lending and the number of big banks in the steady state economy, important factors for understanding the safety and effectiveness of the banking industry. Further, under both bailout and bail-in, big banks are able to remain operating even after adverse shocks. The behavior of big banks following each type of resolution will also have consequences for the overall industry.

The rest of the paper is structured as follows. Section 2 explores previous literature on bailouts, bail-ins and similar industry models while Section 3 goes into more detail about each resolution policy. The model and the estimation approach are described in Sections 4 and 5, respectively. Section 6 summarizes the results, including those from the counterfactual exercise. A discussion of efficiency properties is included in Section 7 and further quantitative exercises are described in Section 8. Section 9 concludes.

2 Related Literature

The study of bail-in policies is still relatively new and most papers focus on their effect on the price of bank debt and whether the adoption of these policies has ended the "too big to fail" subsidy (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. However, Beck et. al. (2017) performs a reduced-form analysis of credit supply in Portugal following the bail-in of Banco Espirito Santo. They find that other Portuguese banks reduced their credit supply following the resolution, with those banks more exposed to Banco Espirito Santo reducing by a greater amount. This corresponds well to my finding that individual banks reduce their lending in the bail-in regime.

Berger et. al. (2018) uses a dynamic banking model to determine the optimal regulatory design, under the policy regimes of bail-outs, bail-ins, and no government intervention in the resolution of banks. They focus on the decisions of a representative big bank in which the bank chooses its optimal capital structure 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 desire to be larger depending on the resolution policy in place.

Bank bailouts have been studied more extensively, such as in Nguyen (2023) and Shukayev and Ueberfeldt (2021). These papers solve for the 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 and banks do not make an optimal size decision. The bailout is provided directly to the banks' creditors and banks do not continue after receiving a bailout. In the Nguyen (2023) paper, entrants replace banks that exit and in the Shukayev and Ueberfeldt (2021) paper, 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. By estimating the demand function for uninsured deposits, they find that such demand 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), 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 stabilization policies for banks such as bailout and bail-in policies. Failed banks in these models are handled in processes similar to the liquidation process in my paper. 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.

The U.S. bail-in policy is very 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). In this paper, firms make default, exit, and entry decisions as functions of the firms' capital investment and debt. 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 industries.

3 Background on Resolution Policies

3.1 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 such a classification 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 sale of failed banks between 2007 and 2013 cost the FDIC on average 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. (2018)).

3.2 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 then 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. (2018)). 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)).

3.3 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 bank. If the risks associated with this bank's failure are determined to not be too great, 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 the 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 who 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.

3.4 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 4. 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 on 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.

4 Benchmark Model

4.1 Banks

The model is in discrete time with an infinite horizon and heterogeneous banks. As I am only considering stationary equilibria of the model, I use the notation $x_t = x$ and $x_{t+1} = x'$. A given bank will be represented by its place in a cross-sectional distribution of banks, $\Gamma(\delta, \lambda, n)$, because every bank with insured deposits δ, loan default rate realization λ, and retained earnings n will behave identically. The level of insured deposits δ follows an exogenous, Markov process. Banks with more insured deposits will have a cost advantage over smaller banks (Corbae and D'Erasmo (2021a)). The loan default rate λ follows an exogenous, Markov process while n evolves based on the earnings and dividend payments of the bank each period. The bank problem is represented in recursive format.

Incumbent banks begin the period with their previous loan default rate realization λ and retained earnings n and receive their insured deposits δ. As insured deposits are priced as a discount bond, the bank receive $q^{\delta}\delta$ today with the promise to repay δ tomorrow. The bank then makes its risky lending ℓ', safe asset s', and uninsured borrowing b' choices. The uninsured borrowing is also priced as a discount bond, so the bank receives $q(\delta, \lambda, \ell', s', b')b'$ today and must repay b' tomorrow. Risky lending is subject to convex monitoring costs of the form $c_M(\delta)\ell'^2$, where the cost parameter c_M differs by δ. The bank must also pay a fixed operating cost, c_O, which can be thought of as charter fees or other fixed expenses. These decisions along with the retained earnings n will pin down the bank's dividend/equity issuance

$$d = n + q^{\delta}\delta + q(\delta, \lambda, \ell', s', b')b' - \ell' - s' - c_M(\delta)\ell'^2 - c_O. \tag{1}$$

Dividends are equal to the difference between the funds of the bank $n+q^{\delta}\delta+q(\delta, \lambda, \ell', s', b')b'$ and the total cost of operating $\ell' + s' + c_M(\delta)\ell'^2 + c_O$. If $d \geq 0$, then the bank had enough funds to lend ℓ' and purchase s' and the excess is paid as a dividend. However, the value to shareholders of this dividend is $(d + \underline{d})^{\sigma} - \underline{d}^{\sigma}$, to capture a preference from shareholders for smoothing of dividends. If $d < 0$, the bank needed to raise additional funds by issuing equity. Equity issuance is costly to the bank, so it is valued to the shareholders as $1 - e^{d}$.

$$\psi(d) = \begin{cases} (d + \underline{d})^{\sigma} - \underline{d}^{\sigma} & \text{if} \quad d \geq 0 \\ 1 - e^{-d} & \text{if} \quad d < 0. \end{cases} \tag{2}$$

The bank maximizes this function of dividends and its continuation value, subject to Equation 1 and restrictions that $\ell' \geq 0, s' \geq 0$, and $b' \geq 0$. Additionally, the bank is subject to a capital requirement of the form

$$\frac{\ell' + s' - \delta - b'}{\omega_r \ell' + \omega_s s'} \geq \alpha, \tag{3}$$

where ω_r and ω_s are risk-weights on the "risky" and "safe" types of assets, to replicate risk-weighted capital requirements used in practice.

After issuing the dividend or more equity, the bank then realizes its returns on its assets. The safe assets, s', always earn a return of R. The risky loans, ℓ', earn a return of R^ℓ, where R^ℓ could be greater than R to reflect an excess return banks charge on the risky lending due to non-diversifiable default risk. Banks take this R^ℓ as given and it will be solved for in equilibrium to clear the market for risky lending, discussed in Section 4.5. However, fraction λ' of the bank's risky loans will be defaulted upon and the return to the bank from these loans will be 0. Therefore, the gross return on the bank's assets is

$$G(\lambda', \ell', s') = R^\ell(1-\lambda')\ell' + Rs'. \tag{4}$$

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

$$\begin{aligned} V(\delta,\lambda,n) = \max_{\ell',s',b'} \quad & \psi(d) + \beta \mathop{\mathbb{E}}_{\lambda'|\lambda}\Big(\max\{V_R(\delta,\lambda',\ell',s',b'), \mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta',\lambda',n'(\lambda'))\}\Big) \\ & \text{s.t.} \\ d &= n + q^\delta\delta + q(\delta,\lambda,\ell',s',b')b' - \ell' - s' - c_M(\delta){\ell'}^2 - c_O \\ & \frac{\ell'+s'-\delta-b'}{\omega_r\ell'+\omega_s s'} \geq \alpha \\ n'(\lambda') &= G(\lambda',\ell',s') - \delta - b' - \tau(\lambda') \\ \tau(\lambda') &= \tau_C \max\{0, (R^\ell-1)(1-\lambda')\ell' + (R-1)s' - (\frac{1}{1+r_F}-1)b' - (\frac{1}{q^\delta}-1)\delta\} \\ & \ell' \geq 0, \quad s' \geq 0, \quad b' \geq 0. \end{aligned} \tag{5}$$

A continuing bank must repay both types of debt b' and δ' as well as pay corporate income taxes on its interest income, but can deduct the interest expense paid on the uninsured debt and insured deposits.[3]

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. The value of a liquidated bank is modeled off of the Deposit Payoff process as mandated in PCA. First, the bank's realized assets, $G(\lambda', \ell', s')$,

[3]The true interest paid on uninsured debt is $\frac{1}{q(\delta,\lambda,\ell',s',b')} - 1$. However, I simply the uninsured interest expense to be $\frac{1}{1+r_F} - 1 \leq \frac{1}{q(\delta,\lambda,\ell',s',b')} - 1$ in order to reduce computational burden when solving for the bank's resolution decisions.

are devalued at a discount price, c_L. When the FDIC resolves banks, their Least Cost Mandate dictates them to sell the assets off right away rather than hold them to see if they will increase in value. Because they must sell so quickly, they are willing to accept below value prices for the loans. The bank uses these funds to repay its stakeholders, following the order dictated in PCA. First, the funds are used to pay administrative costs of the bank, such as salaries, and then the expenses of the FDIC to run the receivership and resolve the bank. I model this cost as a fixed cost c_F. Next, the leftover funds are used to repay insured depositors. 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. As uninsured deposits are grouped with insured deposits in my model (see Section 5), leftover funds after this step are equal to $\max\{0, c_L G(\lambda', \ell', s') - c_F - \delta\}$. These funds, if any, 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

$$V_L(\delta, \lambda', \ell', s', b') = \max\{0, c_L G(\lambda', \ell', s') - c_F - \delta - b'\}. \tag{6}$$

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 for government support (Acharya et. al. (2016)). Therefore, I model the probability to be a function of both the bank's two types of assets. The value of being bailed out, V_O, depends on the new level of insured deposits, and is therefore 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

$$\begin{gathered}\frac{G(\lambda', \ell', s') - \delta - b' + \theta(\delta, \lambda', \ell', s', b')}{\omega_r R^\ell (1-\lambda')\ell' + \omega_s R s'} = \alpha \\ \theta(\delta, \lambda', \ell', s', b') = \delta + b' - (1 - \alpha\omega_R) R^\ell (1-\lambda')\ell' - (1 - \alpha\omega_s) R s'\end{gathered} \tag{7}$$

After receiving the equity injection, the value of the bailed out bank is $\underset{\delta'|\delta}{\mathbb{E}}(V(\delta', \lambda', \tilde{n}'(\lambda')))$, where

$$\begin{aligned} \tilde{n}'(\lambda') &= G(\lambda', \ell', s') - \delta - b' + \theta(\delta, \lambda', \ell', s', b') \\ \tilde{n}'(\lambda') &= \alpha\omega_R R^{\ell}(1-\lambda')\ell' + \alpha\omega_s R s'. \end{aligned} \tag{8}$$

Each period, new banks can enter by paying an entry cost, c_E. New banks will enter with the smallest value of insured deposits in the Markov state vector, δ_S. Only after paying this cost do new banks receive their initial loan default rate realization, which will be distributed according to the distribution $\bar{F}(\lambda)$. This bank has no retained earnings and is therefore the same as a bank $V(\delta_S, \lambda, 0)$. As described in Section 4.5, the mass of entrants will be pinned down to satisfy the free entry condition.

4.2 Timing

The timing for the benchmark model is as follows:

1. Banks with insured deposits δ, loan default rate λ and retained earnings n choose risky lending ℓ', safe assets s', and uninsured debt b'. This pins down dividends/equity issuance,which are paid to/collected from shareholders.

2. Banks realize λ' and 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 uses the proceeds from the sale of assets to repay the fixed resolution cost, the insured deposits, and the uninsured debt, in that order. If there is any remaining value, it is paid to the shareholders as a "final dividend."
     - **Bailout:** The bank receives an equity injection from the government. The bank repays its insured deposits and uninsured debt and realizes its new insured deposits. It continues as a bank with δ, λ', and $n' = \alpha\omega_r R^{\ell}(1-\lambda')\ell' + \alpha\omega_s R s'$. It 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 δ' and continues as a bank with δ', λ', and $n' = G(\lambda', \ell', s') - \delta' - b' - \tau(\lambda')$.

3. New banks pay the entry cost and receive their insured deposits and initial return realization.

4.3 Uninsured Debt Prices

Uninsured debt for banks generally is lent by large intermediaries, such as mutual funds. These intermediaries 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 perfectly competitive and make zero profits on each of their lending contracts. However, because I assume the intermediaries diversify their lending to the banks, they are risk-free and will not fail.

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, $\Omega(\delta, \ell', s', b')$ is the set of λ' for which $X(\delta, \lambda', \ell', s', b') = 1$. Further, define $F(\lambda'|\lambda)$ as the probability that a bank with current loan default rate λ draws λ' tomorrow. The profit an intermediary makes on a loan contract to a bank with current default rate λ, and choices of risky loans ℓ', safe assets s', debt b', and insured deposits δ is then

$$\begin{aligned}\pi(\delta, \lambda, \ell', s', b') = \underbrace{-q(\delta, \lambda, \ell', s', b')b'}_{\text{debt lent}} + \frac{1}{1+r_f}\Big[&\underbrace{\Big(1 - \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)\Big)b'}_{\text{expected repayment - no resolution}} \\ &\underbrace{+ (1 - \rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} \min\{b', \max\{c_L G(\lambda', \ell', s') - c_F - \delta, 0\}\} F(\lambda'|\lambda)}_{\text{expected repayment - liquidation}} \\ &+ \rho(\ell', s') \underbrace{\sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)b'}_{\text{expected repayment - bailout}} \Big].\end{aligned} \tag{9}$$

The intermediary discounts its expected repayment by its discount factor $\frac{1}{1+r_F}$. The first term after the discount represents the expected repayment to the creditor from liquidation. This occurs with probability $1 - \sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)$, where $\sum_{\lambda' \in \Omega(\delta, \ell', s', b')} F(\lambda'|\lambda)$ is the probability of the bank receiving any λ' such that it will enter resolution. Therefore, if the bank does not draw one of these λ's, the bank will continue and then must fully repay the creditor the entire uninsured debt claim b'. The second line of Equation 9 represents the expected repayment to the creditor if the bank is liquidation. This occurs with probability

$(1-\rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta,\ell',s',b')} F(\lambda'|\lambda)$. In the liquidation, the creditor will be repaid via the discounted value of the bank's assets, $c_L G(\lambda', \ell', s')$, but only after the fixed cost of liquidation c_F and insured deposits δ are paid first. The creditor will not receive more than their claim b', but very well could receive less. The repayment to the creditor depends on the actual loan default rate λ' that the bank receives as it determines the value of the assets to be liquidated. The final line represents the creditor's expected repayment if the bank is bailed out, which occurs with probability $\rho(\ell', s') \sum_{\lambda' \in \Omega(\delta,\ell',s',b')} F(\lambda'|\lambda)$. In this case, the creditor will be repaid their full b'. Therefore, the intermediary only risks partial repayment of the debt claim b' in liquidation. In equilibrium, intermediaries earn zero profit on each loan contract. The price of a given contract can then be solved as

$$
\begin{aligned}
q(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_f}\big[\big(1 - \sum_{\lambda' \in \Omega(\delta,\ell',s',b')} F(\lambda'|\lambda)\big) \\
+(1-\rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \\
+\rho(\ell', s')) \sum_{\lambda' \in \Omega(\delta,\ell',s',b')} F(\lambda'|\lambda)\big].
\end{aligned} \tag{10}
$$

4.4 Too Big To Fail Subsidy

The TBTF subsidy on banks' debt prices documented in the literature can be replicated using Equation 10. First, define the discount that the creditors demand on the debt to account for risk as

$$
\text{Discount}(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_F} - q(\delta, \lambda, \ell', s', b'). \tag{11}
$$

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

$$
\begin{aligned}
q^{\rho=0}(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_f}\big[\big(1 - \sum_{\lambda' \in \Omega^{\rho=0}(\delta,\ell',s',b')} F(\lambda'|\lambda)\big) \\
+ \sum_{\lambda' \in \Omega^{\rho=0}(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda)\big].
\end{aligned} \tag{12}
$$

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 $\rho = 0 \ \forall \ (\delta, \ell', s', b')$. The TBTF subsidy can be thought of as the decrease in the discount due to the possibility of bailout, or

$$
\begin{aligned}
\text{TBTF subsidy}(\delta,\lambda,\ell',s',b') &= \text{Discount}^{\rho=0}(\delta,\lambda,\ell',s',b') - \text{Discount}(\delta,\lambda,\ell',s',b') \\
&= -q^{\rho=0}(\delta,\lambda,\ell',s',b') + q(\delta,\lambda,\ell',s',b') \\
&= \frac{1}{1+r_f}\Big[\sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')} F(\lambda'|\lambda) - \sum_{\lambda'\in\Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) \\
&\quad + \rho(\ell',s') \sum_{\lambda'\in\Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) \\
&\quad - \sum_{\lambda'\in\Omega^{\rho=0}(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda) \\
&\quad + (1-\rho(\ell',s')) \sum_{\lambda'\in\Omega(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda)\Big].
\end{aligned}
\tag{13}
$$

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

$$
\begin{aligned}
&= \frac{\rho(\ell',s')}{1+r_f}\Big[\sum_{\lambda'\in\Omega(\delta,\ell',s',b')} F(\lambda'|\lambda) \\
&\quad - \sum_{\lambda'\in\Omega(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'}, 0\}\} F(\lambda'|\lambda)\Big].
\end{aligned}
\tag{14}
$$

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.

4.5 Risky Lending Market Clearing

Banks charge R^ℓ on the risky loans they make to firms. The difference between this return and that of the safe assets, R, can be thought of as an excess return the banks charge over this safe return in order to compensate them for monitoring costs and non-diversifiable default risk. All banks take this return as given. The return on risky lending can then be used to satisfy the free entry condition

$$(-c_E + \mathop{\mathbb{E}}_{\lambda}(V(\delta_S, \lambda, 0)))M = 0. \tag{15}$$

Entrants enter with the smallest value of insured deposits δ_S, zero retaining earnings, and a draw of λ from $\bar{F}$. A higher return on risky lending can increase $\mathop{\mathbb{E}}_{\lambda}(V(\delta_S, \lambda, 0))$ both directly and indirectly. Directly, it increases the return that the entrant expects tomorrow on its risky lending today, incentivizing the bank to enter. However, even if the entrant chose no risky lending today, a higher R^ℓ can still increase the value of entering through the continuation value. If the bank expects to lend in the future, a higher return on lending increases the value of entering and operating.

A higher R^ℓ implies higher costs to firms for borrowing from banks. Therefore, firm demand for risky lending is decreasing in R^ℓ. I set this exogenous demand function to be

$$L^D(R^\ell) = \zeta(R^\ell)^\epsilon. \tag{16}$$

Risky loan supply by banks is equal to the amount of risky lending by continuing incumbents, bailed out incumbents, and entrants. As this is a steady state, the mass of entrants M pins down the steady state distribution and total mass of banks. Therefore, R^ℓ and M can be used to jointly satisfy the free entry condition and clear the risky lending market.

4.6 Equilibrium

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 retained earnings 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 retained earnings, 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 retained earnings n is $\Gamma(\delta, \lambda, n)$. Defining $H(\delta'|\delta)$ as the probability of a bank with insured deposits δ receives insured deposits δ' tomorrow, the law of motion for the cross-sectional distribution of banks is then given by:

$$
\begin{aligned}
\Gamma'(\bar{\Delta}, \bar{\Lambda}, \bar{N}; M) = \int_{\bar{N}} \sum_{\bar{\Lambda}} \sum_{\bar{\Delta}} \Big\{ \int_N \sum_{\Lambda} \sum_{\Delta} H(\delta'|\delta) F(\lambda'|\lambda) \Gamma(\delta, \lambda, dn) \\
\big[(1 - X(\delta, \lambda, n, \lambda'))1_{n'=n'(\delta,\lambda,n,\lambda')} + X(\delta, \lambda, n, \lambda')\rho(\delta, \lambda, n)1_{n'=\tilde{n}'(\delta,\lambda,n,\lambda')}\big] \Big\} \\
+ M \sum_{\bar{\Lambda}} 1_{n'=n'(\delta_S,\lambda,0,\lambda')} H(\delta'|\delta_S) F(\lambda'|\lambda) \bar{F}(\lambda)
\end{aligned} \tag{17}
$$

where $\bar{F}(\lambda)$ is distribution of initial loan default rates for entrants. A stationary equilibrium is a list $\{V^*, q^*, X^*, \Gamma^*, \Omega^*, \pi^*, R^{\ell^*}, M^*\}$ such that:

1. Given q and R^ℓ, the value function V^* and resolution decisions X^* are consistent with the firm's optimization problem in Equation 5.

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

3. The equilibrium uninsured debt price is such that intermediaries 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 15 is satisfied.

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

$$
\int_N \sum_{\Lambda} \sum_{\Delta} \ell'(\delta, \lambda, n)\Gamma^*(\delta, \lambda, dn) + \sum_{\Lambda} M^* \ell'(\delta_S, \lambda, 0)\bar{F}(\lambda) = L^D(R^{\ell^*}) \tag{18}
$$

5 Mapping the Model to Data

In order to discuss the quantitative impact of a change in resolution policies, I match the benchmark model with key moments of the banking industry. Matching these 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 is 8 years following the bailout of Continental Illinois Bank and the beginning of the common phrase "too big to fail"[4].

5.1 Data Sources

Parameters in the model are informed from data and policy. The main data is from 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 due to entering the sample from a de novo creation of a bank or because a smaller bank has grown 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 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 Table 9.

5.2 Estimation Strategy

The model period is one year. The estimation of the model consists of both external and internal calibration. In the external calibration, a subset of the parameters are chosen from outside the model. These are described in Table 1. In the internal calibration, the remaining parameters are chosen to match a set of data moments via simulated method of

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

moments (SMM). Table 2 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, I normalize the bank's discount factor β to be 0.9827 and set the uninsured creditor's risk-free rate, r_F, equal to $\frac{1}{\beta} - 1$, keeping the discount factors of all agents (modeled or unmodeled) equivalent.

Parameters related to banking regulation, such as the capital requirements α and the risk-weights ω_r and ω_s are taken from the FDIC Improvement Act of 1992. The liquidation cost on assets c_L is set at 72% to match results from Granja et. al. (2017) which finds that the cost to the FDIC to resolve banks during the GFC was on average 28% of the banks' assets. The parameter for loan demand elasticity on behalf of firms, ϵ, is set to match that from Basset et al. (2014). The probability of bailout will be a function of the bank's assets, $\rho(\ell', s')$. This is to capture that banks with large amounts of assets are costlier to liquidate due to the financial stability implications of selling off so many assets at discount prices. The function will be a piece-wise function

$$\rho(\ell', s') = \begin{cases} 0 & \ell' + s' < \bar{a} \\ \bar{\rho} & \ell' + s' \geq \bar{a}. \end{cases} \tag{19}$$

$\bar{\rho}$ is set to .9 to match results from Koetter and Noth (2016) who estimate the bailout expectations in the U.S. to be 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.

The loan default process is estimated using the Tauchen (1986) method of discretizing an AR(1) process. In the data, I define a bank's loan default rate as

$$\text{Loan Default Rate} = \frac{\text{Loans Past Due 30 Days} + \text{Charge-offs} + \text{Non-Accruals} - \text{Recoveries}}{\text{Total Loans}}. \tag{20}$$

I then estimate the following autoregressive process for loan default rates for bank i at time t:

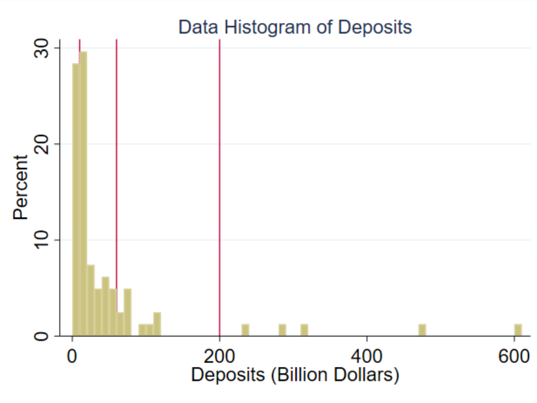
$$\lambda_t^i = (1 - \rho^{\lambda})k^0 + \rho^{\lambda}\lambda_{t-1}^i + u_t^i \tag{21}$$

where u_t^i is iid and distributed $N(0, \sigma_u^2)$. I use the method proposed by Arellano and Bond (1991) as this is a dynamic model and find the estimated values $\rho^\lambda = 0.569$, $\sigma_u = 0.0078$, and $k^0 = 0.013$. Using the Tauchen method, I solve for a 2-state vector and transition matrix from the estimated parameters. However, this does not make up the entire process for λ. 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 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 last quarter end default rates before the bailout truly represent the extent of defaults at the time the bailout was needed. Therefore, the third state λ_H will be estimated internally in SMM, not from the discretization of this AR(1) process. In addition to λ_H, the probabilities of entering the crisis state, $F(\lambda_H|\lambda)$ will also be estimated via SMM. I set that the probability a bank can transition from the crisis state to the state with the lowest default rate, λ_L, to 0, thus pinning down $F(\lambda_M|\lambda_H) = 1 - F(\lambda_H|\lambda_H)$. I use the estimated state vector from the Tauchen method for the other two values of loan default, λ_L and λ_M. 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 highest default rate, $\bar{F}(\lambda_H) = 0$. Then, by definition, $\bar{F}(\lambda_M) = 1 - \bar{F}(\lambda_L)$. I find $\bar{F}(\lambda_L)$ 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%. Therefore, $\bar{F}(\lambda_M)$ can be pinned down by solving

$$2.47 = \bar{F}(\lambda_L)\mathbb{E}(\lambda'|\lambda_L) + (1 - \bar{F}(\lambda_L))\mathbb{E}(\lambda'|\lambda_M). \tag{22}$$

The state vector for insured deposits is chosen to match the distribution of insured deposits in the data. I use the histogram of insured deposits as of 2006Q4, seen in Figure 1. From the figure, I use the general mass points of \$10B, \$60B, and \$200B as the three values of the state vector. The transition matrix H for the insured deposits is pinned down via internal calibration with the following assumptions: 1) banks cannot transition from the smallest value of deposits to the largest value in one period ($H(\delta_L|\delta_S) = 0$), 2) banks cannot transition from the largest value to the smallest in one period ($H(\delta_S|\delta_L) = 0$), and

Figure 1: Deposit Distribution of Bank Sample 2006Q4



3) 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. The rest of the transition matrix is solved via SMM, described under Internal Calibration.

Internal Calibration

Internal calibration is used to minimize the weighted difference between data and model moments. These internally calibrated parameters are generally unobservable cost parameters of banks or the remaining parts of underlying transition matrices. These costs are very influential for banks' balance sheet, resolution, and entry decisions. To capture these parameters, I focus on moments regarding banks' lending and borrowing decisions and aggregates of the industry. 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 an adjustment cost for banks' portfolios. Data and model moments are further defined in Section A.

The model does a good job capturing the data moments with small difficulties in some spots. First, the model overestimates the average assets of banks. This is primarily due to the presence of extremely large banks, such as JP Morgan & Co., in the data. These banks make up a significant portion of bank assets in the data. Without an even larger state of deposits in the model, I cannot 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 Section A) for assets. In the data, a significantly large fraction of assets are held by these largest banks, drastically

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 Lending	1.0	FDICIA (1992)
ω_s	Risk-Weight Safe Assets	0.0	FDICIA (1992)
τ_C	Corporate Income Tax	0.35	US Tax Code
c_L	Asset Liquidation Cost	0.72	Granja et. al. (2017)
ϵ	Elasticity of Loan Demand	-1.1	Basset et al. (2014)
$\bar{\rho}$	Bailout Probability	0.9	Koetter and Noth (2016)
$\bar{a}$	Asset Size Threshold	\$100B	Brewer and Jagtiani (2013)
$\bar{d}$	Dividend Curvature Scale	1.0	Normalization
σ	Dividend Curvature	0.9932	Ríos-Rull et al. (2023)
λ_L	Lowest Default Rate	0.0043	Call Reports
λ_M	Medium Default Rate	0.0226	Call Reports
$F(\lambda_L\|\lambda_L)$	$P(\lambda' = \lambda_L\|\lambda = \lambda_L)$	$\frac{0.82667}{1+F(\lambda_H\|\lambda_L)}$	Call Reports
$F(\lambda_M\|\lambda_L)$	$P(\lambda' = \lambda_M\|\lambda = \lambda_L)$	$\frac{0.17333}{1+F(\lambda_H\|\lambda_L)}$	Call Reports
$F(\lambda_L\|\lambda_M)$	$P(\lambda' = \lambda_L\|\lambda = \lambda_M)$	$\frac{0.17333}{1+F(\lambda_H\|\lambda_M)}$	Call Reports
$F(\lambda_M\|\lambda_M)$	$P(\lambda' = \lambda_M\|\lambda = \lambda_M)$	$\frac{0.82667}{1+F(\lambda_H\|\lambda_M)}$	Call Reports
$F(\lambda_L\|\lambda_H)$	$P(\lambda' = \lambda_L\|\lambda = \lambda_H)$	0.0	-
$\bar{F}(\lambda_L)$	Prob. of Entering with λ_L	$\frac{.0247-\mathbb{E}(\lambda'\|\lambda_M)}{\mathbb{E}(\lambda'\|\lambda_L)-\mathbb{E}(\lambda'\|\lambda_M)}$	Call Reports
$\bar{F}(\lambda_M)$	Prob. of Entering with λ_M	$1 - \bar{F}(\lambda_L)$	-
$\bar{F}(\lambda_H)$	Prob. of Entering with λ_H	0	-
$H(\delta_M\|\delta_S)$	$P(\delta' = \delta_M\|\delta = \delta_S)$	$1 - H(\delta_M\|\delta_S)$	-
$H(\delta_L\|\delta_S)$	$P(\delta' = \delta_L\|\delta = \delta_S)$	0	-
$H(\delta_S\|\delta_M)$	$P(\delta' = \delta_S\|\delta = \delta_M)$	$\frac{1-H(\delta_M\|\delta_M)}{2}$	-
$H(\delta_L\|\delta_M)$	$P(\delta' = \delta_L\|\delta = \delta_M)$	$\frac{1-H(\delta_M\|\delta_M)}{2}$	-
$H(\delta_S\|\delta_L)$	$P(\delta' = \delta_S\|\delta = \delta_L)$	0	-
$H(\delta_M\|\delta_L)$	$P(\delta' = \delta_M\|\delta = \delta_L)$	$1 - H(\delta_L\|\delta_L)$	-

increasing the Gini coefficient. Without being able to accurately model these few banks, I am understating this.

The calibration also underestimates the risky asset fraction and overestimates the uninsured leverage ratio. The overestimation of uninsured leverage ratio is partly 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 cannot invest in as many risky loans. Therefore, banks reduce their risky asset fraction, thus leading to an underestimate of risky assets and an overestimate of uninsured leverage. The underestimate of the risky asset fraction also leads to the underestimate 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.

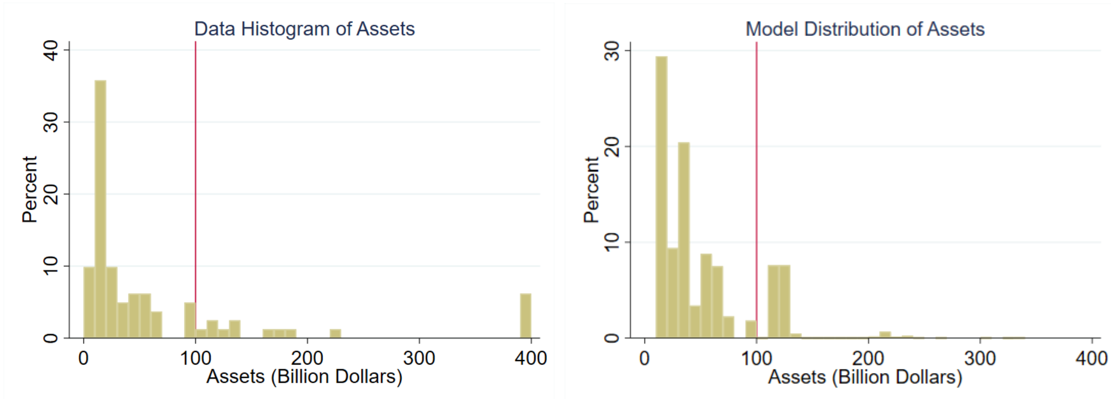
A comparison of the data and model distributions of bank assets can be seen in Figure

Table 2: Internal Calibration

Parameter	Description	Value	Moment	Data	Model
c_e	Entry Cost	10.0	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 (%)	58	69
λ_H	High Default Rate	0.5	Avg. Dividend to Assets (%)	0.23	0.27
$F(\lambda_L\|\lambda_H)$	$P(\lambda' = \lambda_L \| \lambda = \lambda_H)$	0.025	Avg. Leverage	0.91	0.96
$F(\lambda_M\|\lambda_H)$	$P(\lambda' = \lambda_M \| \lambda = \lambda_H)$	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 (%)	65	47
ζ	Loan Demand Scale	190	Share of Big Banks (%)	18	18
$H(\delta_S\|\delta_S)$	$P(\delta' = \delta_S \| \delta = \delta_S)$	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

2. The left-hand panel plots the data distribution of assets in 2006Q4 while the right-hand panel plots the model distribution of banks' assets after the realization of the 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 clumping 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.

Figure 2: Asset Distribution of Bank Sample 2006Q4



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

This is due to the fact that the threshold is 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 ($R^{\ell}(1-\lambda')$ and R) 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.

The final transition matrices for the loan default rate λ and insured deposits δ can be found in Tables 3 and 4, respectively.

Table 3: Transition Matrix $F(\lambda'|\lambda)$

	λ_L	λ_M	λ_H
λ_L	.8065	.1685	.025
λ_M	.1595	.778	.0625
λ_H	0	.8812	.1188

Table 4: Transition Matrix $H(\delta'|\delta)$

	δ_L	δ_M	δ_H
δ_L	0.99	0.01	0
δ_M	0.005	0.99	0.005
δ_H	0	0.025	0.975

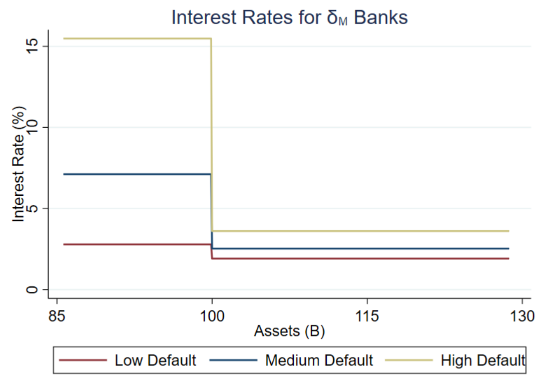
6 Results

6.1 Benchmark Model

Figure 3 plots an example price schedule $q(\delta, \lambda, \ell', s', b')$ from the solution to the benchmark model. 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 $\frac{b'}{\ell'+s'} = .9$, safe assets s' to $\frac{\ell'}{\ell'+s'} = .9$, and only vary total assets $\ell' + s'$ and the loan default rate λ. In the model, banks generally only enter resolution when they draw $\lambda' = \lambda_H$. Banks that start with the higher default rates, such as λ_M or λ_H, have a higher probability of receiving $\lambda' = \lambda_H$, and therefore are priced with higher interest rates than banks with λ_L. When banks choose assets $\ell' + s' < \$100$ B, they can only be liquidated if they fail. Therefore, the interest rates are higher when banks choose assets $\ell' + s' \geq \$100$ B, as they now have a 90% probability of being bailed out and the creditors being fully repaid. Interest rates charged to banks with each λ drop when these banks cross this threshold, but the largest drops come from the banks with the higher λ's and therefore the higher probabilities of drawing $\lambda' = \lambda_H$. The bailout policy therefore has a differential effect on the pricing of uninsured debt by the banks' default rate λ.

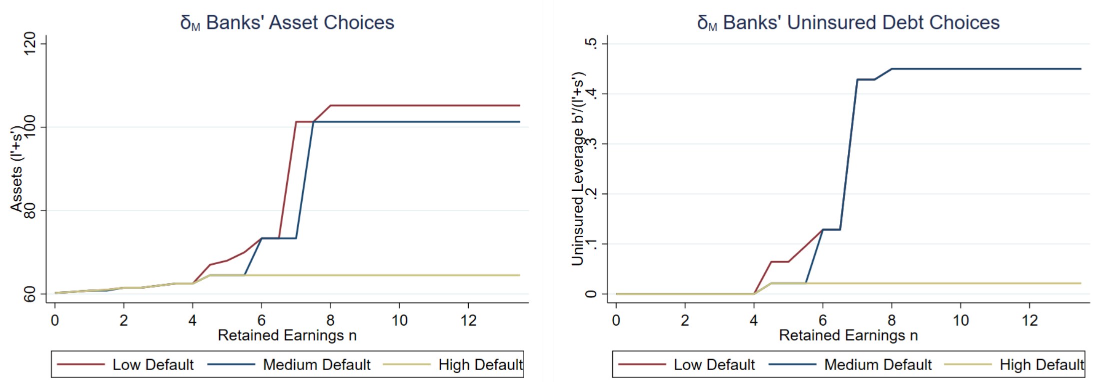
The differential effect of the bailout policy on interest rates by λ can also be seen in the policy functions. Figure 4 plots the asset decisions (left panel) and uninsured leverage decisions (right panel) of banks with δ_M by their initial default rate λ and retained earnings n. When banks have low retained earnings 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. They generally choose assets in an increasing (with n) amount over the insured deposit level. However, as n increases further, these constraints are less binding, and we see that banks start to increase assets at a faster pace and fund these assets with uninsured debt (right panel). Banks with lower default rates can increase assets quicker because the interest rates they are charged on uninsured debt are lower.

Figure 3: Uninsured Debt Price Schedules



Risky asset fractions are held constant at .9. Total leverage ratios are held constant at .9.

Figure 4: Policy Decisions



Then, banks will discontinuously choose asset levels over the $100 B threshold, in order to take advantage of the bailout policy. Again, this increase occurs at lower levels of retained earnings for banks with lower default rates, and is in fact never chosen by banks with the highest default rate. These asset choices are once again funded primarily through increasing uninsured borrowing. The discontinuous behavior of banks leads to a clumping in the distribution around $100B, as seen in the right-hand plot of Figure 2.

6.2 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 yet. 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 also need to include all of these other policy changes into the model, so I could isolate the sole effect of the bail-in policy. Instead, I will 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 retained earnings of the bank is equal to

$$\hat{n}'(\lambda') = R^{\ell}(1 - \lambda')\ell' + Rs' - \delta. \tag{23}$$

This new restructured bank is then valued at $\mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda'))$ 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. 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 $\min\{b', \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda'))\}$. 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, however, so the value to the *original* shareholders of a bailed-in bank is $\max\{0, \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda')) - b'\}$. The bank problem can be written as in Equation 5, except that

$$\begin{aligned} V_R(\delta, \lambda', \ell', s', b') = (1 - \rho(\ell', s'))V_L(\delta, \lambda', \ell', s', b') \\ +\rho(\ell', s') \max\{0, \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda')) - b'\}. \end{aligned} \tag{24}$$

To price the uninsured debt in the counterfactual model, define $X_C(\delta, \lambda', \ell', s', b')$ as the resolution decision for a bank with insured deposits δ, loan default rate realization λ', loans ℓ', safe assets s', and uninsured debt b'. The set of loan default rate realizations such that a bank would choose to enter resolution is

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

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

$$\begin{aligned}
\pi_C(\delta,\lambda,\ell',s',b') = &\underbrace{-q_C(\delta,\lambda,\ell',s',b')b'}_{\text{debt lent}} + \frac{1}{1+r_f}\Big[\underbrace{\Big(1 - \sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} F(\lambda'|\lambda)\Big)b'}_{\text{expected repayment - no resolution}} \\
&\underbrace{+(1-\rho(\ell',s'))\sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{b', \max\{c_L G(\lambda',\ell',s') - c_F - \delta, 0\}\}F(\lambda'|\lambda)}_{\text{expected repayment - liquidation}} \\
&+\rho(\ell',s')\underbrace{\sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} F(\lambda'|\lambda)\min\{b', \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\le 0}(\delta',\lambda',\hat{n}'(\lambda'))\}}_{\text{expected repayment - bail-in}}\Big].
\end{aligned} \tag{26}$$

The first two lines of this equation are identical to those in Equation 9 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

$$\begin{aligned}
q_C(\delta,\lambda,\ell',s',b') = &\frac{1}{1+r_f}\Big[\Big(1 - \sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} F(\lambda'|\lambda)\Big) \\
&+(1-\rho(\ell',s'))\sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{1, \max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'}, 0\}\}F(\lambda'|\lambda) \\
&+\rho(\ell',s'))\sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{1, \frac{\mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\le 0}(\delta',\lambda',\hat{n}'(\lambda'))}{b'}\}F(\lambda'|\lambda)\Big].
\end{aligned} \tag{27}$$

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 bail-out, 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.

$$
\begin{aligned}
&\text{TBTF subsidy}_C(\delta,\lambda,\ell',s',b') = \frac{1}{1+r_f} \\
&[-\sum_{\lambda'\in\Omega_C^{\rho=0}(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda) \\
&+(1-\rho(\ell',s')) \sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda) \\
&+\rho(\ell',s') \sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{1, \frac{\mathbb{E}_{\delta'|\delta}(V(\delta',\lambda',\hat{n}'(\lambda')))}{b'}\}F(\lambda'|\lambda)].
\end{aligned}
\tag{28}
$$

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

$$
\begin{aligned}
&= \frac{\rho(\ell',s')}{1+r_f}[\sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{1, \frac{\mathbb{E}_{\delta'|\delta}(V^{d\leq 0}(\delta',\lambda',\hat{n}'(\lambda'))))}{b'}\}F(\lambda'|\lambda) \\
&- \sum_{\lambda'\in\Omega_C(\delta,\ell',s',b')} \min\{1,\max\{\frac{c_L G(\lambda',\ell',s') - c_F - \delta}{b'},0\}\}F(\lambda'|\lambda)].
\end{aligned}
\tag{29}
$$

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

The counterfactual equivalent to Equation 17, or the mass and law of motion equations, respectively, is then

$$
\begin{aligned}
\Gamma^{C'}(\bar{\Delta},\bar{\Lambda},\bar{N};M^C) = &\int_{\bar{N}} \sum_{\bar{\Lambda}} \sum_{\bar{\Delta}} \{ \int_N \sum_{\Lambda} \sum_{\Delta} H(\delta'|\delta)F(\lambda'|\lambda)\Gamma^C(\delta,\lambda,dn) \\
&\big[(1-X^C(\delta,\lambda,n,\lambda'))1_{n'=n'(\delta,\lambda,n,\lambda')} + X^C(\delta,\lambda,n,\lambda')\rho(\delta,\lambda,n)1_{n'=\hat{n}'(\delta,\lambda,n,\lambda')}\big]\} \\
&+M^C \sum_{\bar{\Lambda}} 1_{n'=n'(\delta_S,\lambda,0,\lambda')} H(\delta'|\delta_S)F(\lambda'|\lambda)\bar{F}(\lambda)
\end{aligned}
\tag{30}
$$

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

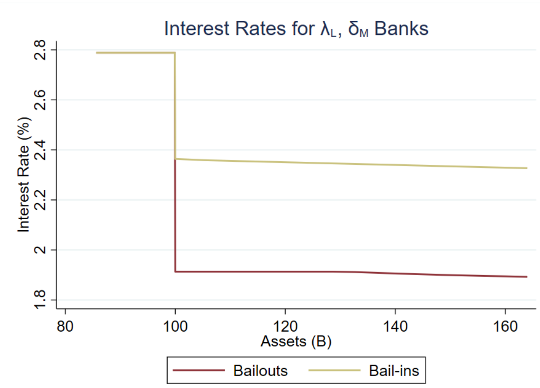
6.3 Counterfactual Results

As in the benchmark equilibrium, banks enter resolution when they receive the highest default rate λ_H and are very leveraged. However, in the counterfactual equilibrium, creditors are repaid on average 55.8% and a maximum of 64.5% of their uninsured debt claim b' in a bail-in. This is significantly less than the 100% repayment that creditors were guaranteed from the bailout. Therefore, the equilibrium interest rate schedules are higher under the counterfactual, as illustrated in Figure 5. This figure plots interest rates charged to the same $(\delta, \lambda, \ell', s', b')$ banks under the benchmark and counterfactual equilibria. When the banks are choosing assets less than the \$100B threshold, the interest rates are virtually the same. This is because in either equilibria, the bank will be liquidated and the parameters governing this liquidation value have been held constant. However, when the bank chooses assets greater than or equal to \$100B, then the bank will be bailed out with probability ρ in the benchmark and bailed-in with the same probability in the counterfactual. Due to the significantly lower repayment under bail-in compared to bailout, the drop in interest rates is not as severe. However, there is still a drop as the repayment under bail-in is higher than that of liquidation. This implies that while the banks can no longer access the low interest rates available under the bailout, there may still be an incentive for the banks to jump over the threshold as the interest rates will still be cheaper compared to when they are below the threshold.

As the creditors are never being fully repaid in a bail-in in equilibrium, the original shareholders are always losing their shares and receiving a value of zero from the bail-in. Due to the higher funding costs and the reduced value to shareholders from a bail-in, banks need to earn more profit on their risky lending in order for the free entry condition to be satisfied. The equilibrium R^ℓ is now 1.069, compared to 1.067 under the benchmark. However, an increase in the interest rate on risky lending decreases firm demand for loans. Using the formula in Equation 16, the aggregate amount of lending must be \$4.45 T, a 3.4% decrease from the benchmark aggregate lending.

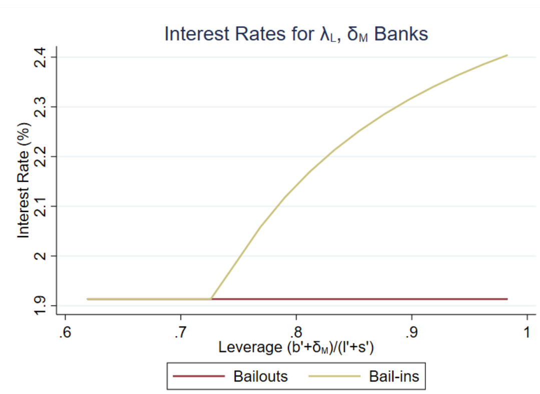
Although in equilibrium, creditors are never fully repaid in a bail-in, this does not imply that there do not exist debt contracts in which the creditor could be fully repaid. As an illustration, I plot the interest rate charged to a bank with (δ_M, λ_L) as a function of total leverage $\frac{b+\delta_M}{\ell'+s'}$, holding $\ell' + s' = 100$ and $\frac{\ell'}{\ell'+s'} = .9$, in Figure 6. These banks enter resolution when they receive $\lambda' = \lambda_H$. Because the value of the shares from a bail-in are based on the retained earnings $R^\ell(1-\lambda')\ell' + Rs' - \delta$, all of which are held constant in this figure, then the value of the shares is constant. What does vary is the total amount of

Figure 5: Comparison of Uninsured Debt Price Schedules



Risky asset fractions are held constant at .9. Total leverage ratios are held constant at .9.

Figure 6: Uninsured Debt Price Schedules as a Function of Leverage



Risky asset fractions are held constant at .9. Total assets is held constant at $100B.

uninsured debt b' that the shares must be used to repay the creditor. When the bank has little uninsured debt, or that total leverage is low, the creditors are actually fully repaid as the value of the shares are worth enough to repay all of b'. Therefore, the interest rate is the same between the bailout and the bail-in. However, as leverage increases, the shares are no longer enough to repay the creditor and therefore, the interest rate is increased. I find that banks only borrow from this part of the state space, never from the part in which the creditor is fully repaid, and therefore, the creditors are never fully repaid from a bail-in in equilibrium.

Banks' behavior reacts to the change in debt prices and continuation values heterogeneously. Figure 7 compares the policy functions for asset and uninsured leverage choices of banks under the bailout and bail-in. The first row plots the asset and uninsured debt decisions of banks with (δ_M, λ_L) as a function of retained earnings n under the benchmark and counterfactual equilibria. These banks are not drastically affected by the change in resolution policy. Instead, they adjust dividend payouts to be lower in order to continue to increase assets at about the same rate as they did under the benchmark despite the higher interest rates. Like the banks in the benchmark, these banks also "jump" over the TBTF threshold, but they do not do so until they have a higher level of retained earnings. Because of this, the "jump" is also smaller, as banks with retained earnings slightly below the level at which banks jump are already choosing more assets than under the benchmark. As seen in the right-hand plot of this first row, the asset choices are funded primarily through uninsured debt.

The second row of Figure 7 shows a key change from the bailout to bail-in equilibria: the behavior of banks with (δ_M, λ_M). In the benchmark model, these banks jump over the $100B threshold quickly after becoming less constrained by using with a large fraction of uninsured debt. However, the same banks under the counterfactual choose much lower values of assets, borrowing very little uninsured debt, and never growing over the threshold. This change leads to the decrease in the share of big banks from 18% to 10%, as seen in the right panel of Figure 8. While the bottom left panel of Figure 7 makes it clear that the change from the bailout to bail-in reduces the incentives for these banks to be over the $100B threshold, it is unclear from the graph whether this is due to the loss of the bailout continuation value to the shareholders or due to the higher interest rates on uninsured debt. Section 8.1 investigates this further.

Figure 8 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 representing banks with $60-80B in assets. These banks are primarily those with (δ_M, λ_M) that no longer jump over the $100B threshold.

The first two columns of Table 5 compare moments between the benchmark and counterfactual equilibria. Once again, 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 declines from $4.61T to $4.45T. However, there are fewer big banks. This leaves room for

Figure 7: Comparison of Policy Functions

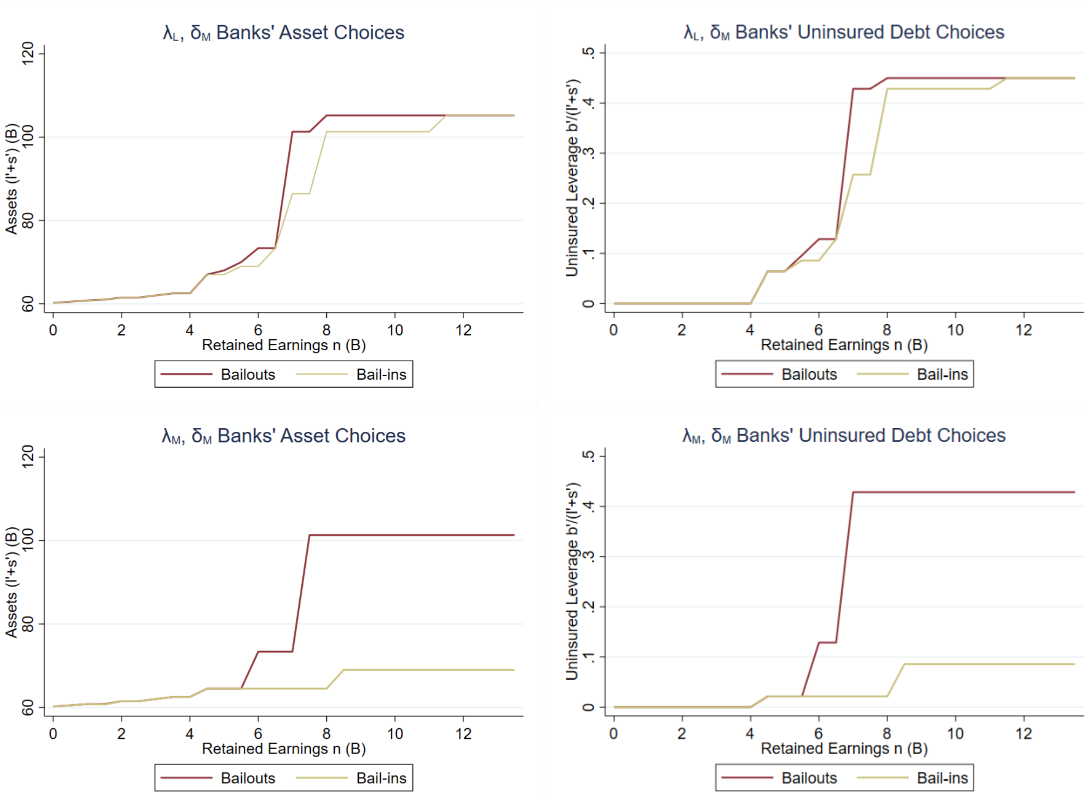
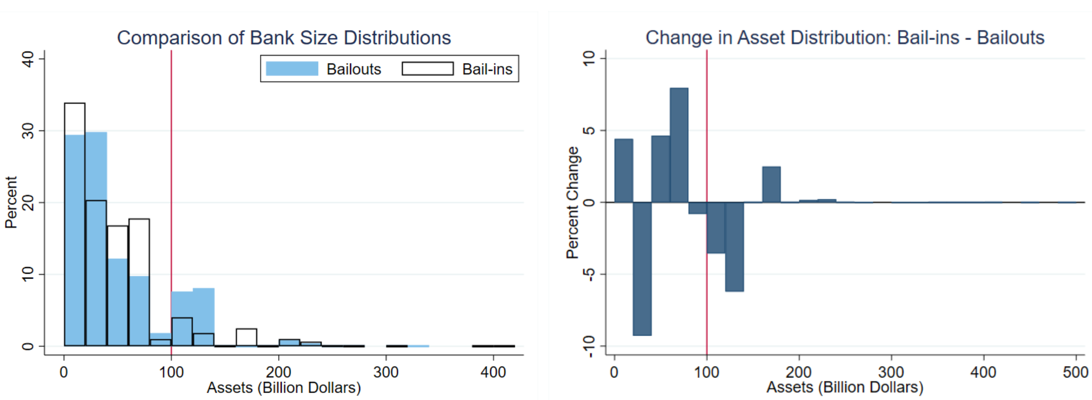


Figure 8: Comparison of Size Distributions



more banks to enter to meet the demand for firm loans. The measure of banks increases 32%. With the addition of new entrants, average lending decreases from \$34.3B to \$26.1B. The average change in assets when banks cross the threshold decreases slightly. As shown in the first plot in Figure 7, banks do not jump over the threshold until they have a higher value of retained earnings. This generally comes from having had higher values of assets last period, thus decreasing the change in assets.

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 retained earnings (n) is low for these banks, they are very constrained. Under each equilibria, these banks borrow very little uninsured debt and invest in primarily 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 0.54% to 0.07%, 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. Conditioning for the bank being above the \$100B threshold, the average probability the bank will enter resolution is 3.1% under the benchmark and 0.7% under the counterfactual. This drastic change is due to selection: fewer banks with higher default rates become big banks[5]. Under the benchmark, both banks with (δ_M, λ_L) and (δ_M, λ_M) would 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

[5] This also explains the increase in the small bank failure rate. These banks with higher default rates are staying smaller and still enter resolution if they receive the highest default rate next period.

next period, these banks have a higher probability of failure than the 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 has not increased significantly. This is because the (δ_M, λ_M) banks are choosing fewer risky assets and borrowing 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

$$\text{Liquidation Resolution Costs} = (1 - c_L)(R^\ell(1 - \lambda')\ell' + Rs') + c_X \tag{31}$$

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

$$\text{Bailout Resolution Costs} = b' + \delta - (1 - \alpha\omega_r)R^\ell(1 - \lambda')\ell' - (1 - \alpha\omega_s)Rs'. \tag{32}$$

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. This equals only \$8.3B. The difference in resolution costs of \$36.5B exceeds the reduction in lending of \$16B.

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.

6.4 Non-Targeted Bail-in Policy

The results from the counterfactual exercise in Section 6.2 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

$$VC_L = \min\{b', \max\{c_L G(\lambda', \ell', s') - c_F - \delta, 0\}\} \tag{33}$$

and the value to the creditor of bail-in as

$$VC_I = \min\{b', \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta, \lambda', \hat{n}'(\lambda'))\} \tag{34}$$

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 5 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

$$\begin{aligned} V_R(\delta, \lambda', \ell', s', b') = \mathbb{1}_{VC_L > VC_I} V_L(\delta, \lambda', \ell', s', b') \\ +(1 - \mathbb{1}_{VC_L > VC_I}) \max\{0, \mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda')) - b'\}. \end{aligned} \tag{35}$$

This implies price schedules of

$$q_N(\delta, \lambda, \ell', s', b') = \frac{1}{1+r_f}\big[\big(1 - \sum_{\lambda' \in \Omega_N(\delta, \ell', s', b')} F(\lambda'|\lambda)\big)$$

$$+ \sum_{\lambda' \in \Omega_N(\delta, \ell', s', b')} \min\{1, \max\{\frac{\mathop{\mathbb{E}}_{\delta'|\delta}(V^{d\leq 0}(\delta', \lambda', \hat{n}'(\lambda'))}{b'}, \max\{\frac{c_L G(\lambda', \ell', s') - c_F - \delta}{b'}, 0\}\}\} F(\lambda'|\lambda)\big] \tag{36}$$

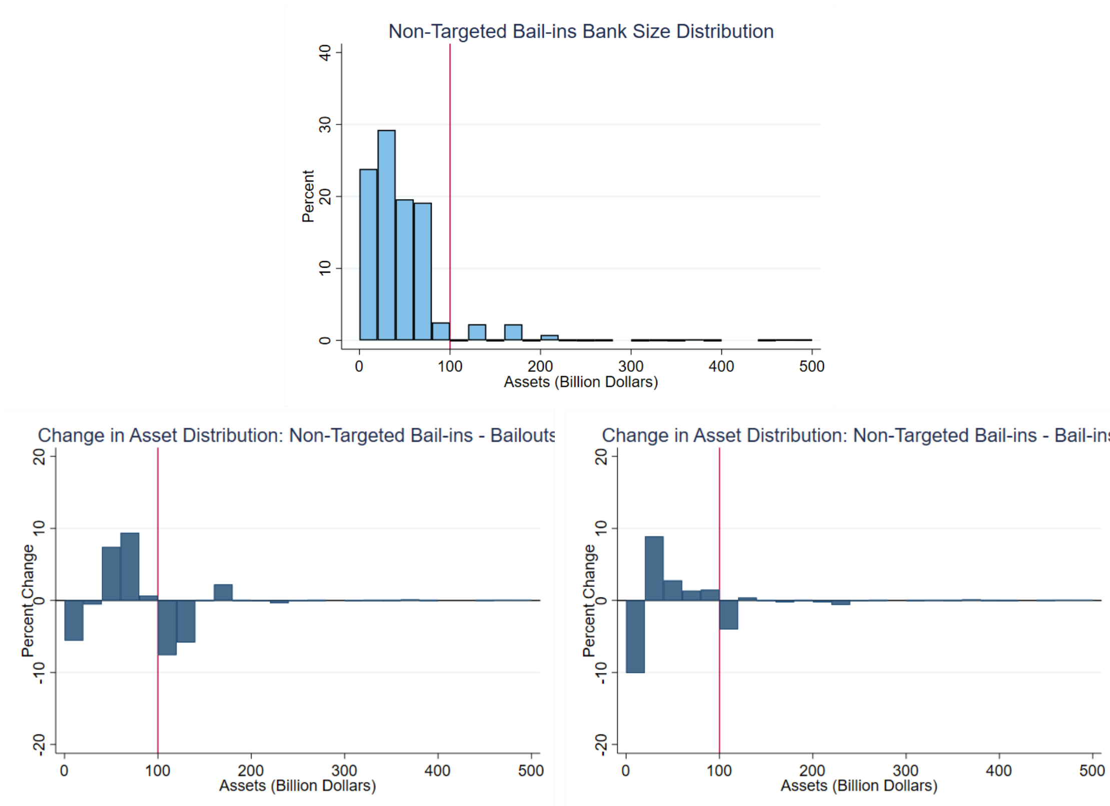
where Ω_N is the set of loan default rate realizations such that the bank will enter resolution. The last row of Equation 36 represents the repayment to the creditors in resolution, either from liquidation or bail-in. The repayment is a maximum of 100% and a minimum of 0% of the debt claim b', but the 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 9. 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 returns 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

Figure 9: Size Distribution under Non-Targeted Bail-ins



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 I find that total resolution costs are the lowest under the non-targeted bail-in policy.

Table 5: 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	5.9
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 (%)	1.6	0.9	0.4
Bailout/Bail-in Rate (%)	0.54	0.07	0.3
Big Bank Failure Rate (%)	3.1	0.7	0.2
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

7 Efficiency

I solve for a "frictionless benchmark" that removes the financing frictions but keeps the underlying technology behind bank lending and the supply of insured deposits. This is analogous to a Hopenhayn (1992) framework. Specifically, I

1. Set the costs of liquidation, c_L and c_F, to 1 and 0, respectively
2. Remove limited liability
3. Set the dividend issuance function to be $\psi(d) = d$ for the entire state space
4. Set the corporate tax rate to zero
5. Remove capital requirements
6. 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 if they do exit. Coupled with costless exit, this results in all debt being priced at the risk-free rate. With change number three on the list, the banks now have costless equity issuance. They can now raise either type of funding — equity or debt – at the risk-free rate and the bank is therefore indifferent between which to use. For this reason, the bank is also indifferent between investing excess funds in the safe asset or paying it out as a dividend today. Even if the bank does not have the funds tomorrow to repay the deposits, it can raise equity at the risk-free rate, rendering it indifferent between raising it tomorrow versus saving the money from last period to pay back the deposits[6]. 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

[6]The bank still has the same level of deposits, following the same Markov process, as this is a fundamental element of the environment.

$$
\begin{aligned}
V(\delta, \lambda, n) = \max_{\ell'} \quad & d + \beta \mathop{\mathbb{E}}_{\lambda'|\lambda} \Big(\max\{n'(\lambda'), \mathop{\mathbb{E}}_{\delta'|\delta}(V(\delta', \lambda', n'(\lambda'))\}\Big) \\
& \text{s.t.} \\
& d = n + \beta\delta - \ell' - c_M(\delta)\ell'^2 - c_O \\
& n'(\lambda') = R^\ell(1 - \lambda')\ell' - \delta \\
& \ell' \geq 0.
\end{aligned} \tag{37}
$$

We can compare this to the bank problem in Equation 5. The value of resolution $V_R(\delta, \lambda', \ell', s', b')$ is replaced with the new value of retained earnings 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. Without liquidation costs and limited liability, the pricing equation for uninsured debt is meaningless. Banks must still pay the entry cost c_E to enter and the mass of banks is still pinned down by equating bank supply of loans with firm inverse demand.

In equilibrium, I find that a bank's retained earnings 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 renders

$$
\begin{aligned}
-1 - 2c_M(\delta)\ell' + \beta R^\ell(1 - \mathbb{E}(\lambda'|\lambda)) = 0 \\
\ell'^* = \max\{\frac{\beta R^\ell(1 - \mathbb{E}(\lambda'|\lambda)) - 1}{2c_M(\delta)}, 0\}
\end{aligned} \tag{38}
$$

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 retained earnings 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 volume of loans 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.

7.1 Allocative Efficiency

Another measure of efficiency is the allocation of loans in the economy across heterogeneous banks. I focus on the allocation of loans across banks' expected loan default rates as these represent the effectiveness of banks' monitoring abilities/the diversification of their client base. Following Olley and Pakes (1996), I define the default rate allocative efficiency by decomposing the weighted average bank-level expected loan default rate

$$\hat{\lambda}' = \sum_{\lambda}\sum_{\delta}\int \underset{\lambda}{\mathbb{E}}(\lambda')\omega(\ell'(\lambda))\Gamma(\delta,\lambda,dn) = \bar{\lambda}' + cov(\underset{\lambda}{\mathbb{E}}(\lambda'),\omega(\ell'(\lambda))) \tag{39}$$

where $\hat{\lambda}'$ is the loan-weighted average expected default rate across all banks in a period. $\underset{\lambda}{\mathbb{E}}(\lambda')$ is the expected default rate of a bank with 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.

In the frictionless benchmark, all loans are made by the banks with the lowest expected default rate. Therefore, the equilibrium in this benchmark represents the highest possible value of default rate allocative efficiency (lowest covariance) given the lending technology, which is equal to -.00798. The default rate allocative efficiency of the benchmark model

Table 6: Results from Frictionless Benchmark

	Bailouts	Bail-ins	Non-Targeted Bail-ins	Frictionless
R^ℓ	1.067	1.069	1.066	1.057
Avg. Interest Income on Loans (%)	4.8	5.2	4.7	4.6
Agg. Lending ($T)	4.61	4.46	4.73	5.91
Share of Big Banks (%)	17.6	10.2	5.9	5.4
Avg. Interest Rate (%)	2.17	2.12	1.92	1.18
Failure Rate (%)	1.6	0.9	0.4	0.0
Big Bank Failure Rate (%)	3.1	0.7	0.2	0.0
Default Rate Allocative Efficiency	-0.00470	-0.00707	-0.00761	-0.00798

was -.00470, only 58.9% of the value in the frictionless benchmark. The counterfactual, however, had a measure of -.00707, or 88.5% of the frictionless benchmark's measure. This large improvement comes from the change in behavior of the banks with the medium default rate λ_M and the medium level of insured deposits λ_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. Default rate allocative efficiency improves even more under the non-targeted bail-in policy. Under this policy, smaller banks have access to cheaper funding due to the higher repayment to their creditors under bail-in than liquidation. Therefore, these banks lend more, but most importantly, small banks with the lowest default rate lend significantly more. This shifts the share of loans even further to the lowest default rate banks, achieving a default rate allocative efficiency measure equal to 95.4% of the frictionless benchmark. Given that the frictionless benchmark removes many frictions that would be difficult to alleviate in the real world, the non-targeted bail-in policy represents a more realistic resolution policy for achieving efficiency in the banking industry.

8 Quantitative Exercises

8.1 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 tell if banks are changing their behavior because the debt is more expensive or because shareholders have less value from a bail-in than a bailout. With my model, however, I can decompose these two channels. To do so, I solve for a new equilibrium with an adapted “bailout” policy. In this equilibrium, I use the bailout probability function as in the benchmark model where only banks with assets above $100B are eligible for the bailout and only 90% of those will actually receive it. Under this bailout, the retained earnings of the bank will once again be as set in Equation 8. This value is retained by the original shareholders, therefore holding the equity channel constant. 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 27, keeping the debt channel consistent with the counterfactual.

If the results of this decomposition exercise look more like 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, not by the pricing of the debt based on the bailout repayment to creditors. However, if they look more like 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 decomposition exercise more closely resembles the counterfactual exercise, and therefore, the debt channel dominates. However, looking at the heterogeneity of the banks, the decomposition results vary based on the banks’ default rates λ’. Figure 10 plots the asset and uninsured debt decisions of banks with the lowest default rate λ_L and the medium value of insured deposits δ_M. While these banks need greater retained earnings n in order to finance the jump over the $100B asset threshold compared to the benchmark banks, they increase assets and debt sooner than under the counterfactual. This implies that both the equity and debt channels matter for these banks. 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 retained earnings n, insured deposits δ, and uninsured debt b'. These shareholders will not put more “skin-in-the-game” to take advantage of the bail-in policy.

The banks with the medium default rate λ_M behave completely differently, as seen in

Table 7: Results of Decomposition Exercise

	Bailouts	Bail-ins	Decomposition
Agg Lending ($T)	4.61	4.46	4.53
Bailout/Bail-in (%)	0.54	0.08	0.09
% Big Banks	17.6	10.2	10.4
Default Rate Allocative Efficiency	-0.00470	-0.00707	-0.00734

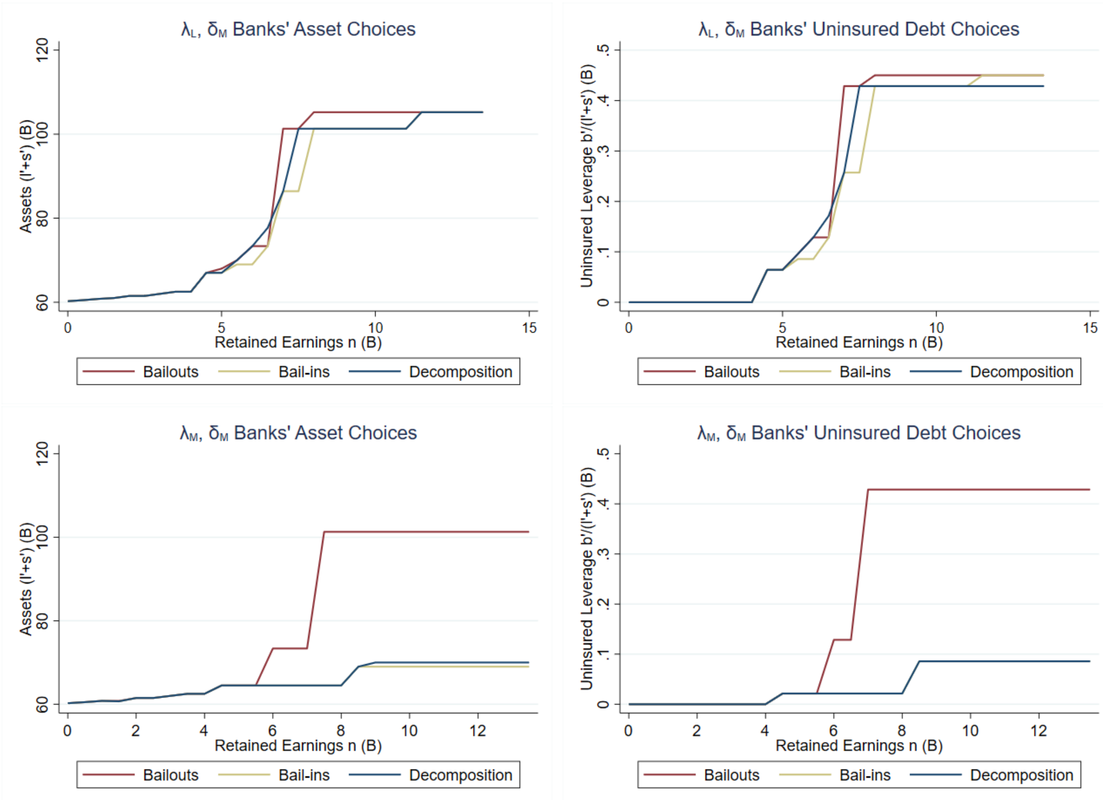
the bottom row of Figure 10. These banks behave almost exactly the same as they do under the counterfactual. Therefore, it is the debt channel that dominates here. Banks with this medium default rate λ_M make up a large part of the distribution than the other λ's, so quantitatively, the debt channel is the dominant channel driving the changes from the benchmark to the counterfactual.

Table 7 summarizes key moments comparing the equilibrium under the decomposition exercise to the benchmark and counterfactual equilibria. The last line of the table presents the default rate allocative efficiency measure for this equilibrium, which is actually lower (higher efficiency) than that of the counterfactual. The reason is that the (δ_M, λ_L) banks lend more under this decomposition than they do under the counterfactual because of 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. However, the measure is still lower than that of the non-targeted bail-in policy. The (δ_M, λ_L) banks make up a smaller portion of all banks than the (δ_L, λ_L), and therefore, lowering the cost of borrowing for the (δ_L, λ_L) banks increases the loan shares of low default rate banks more.

8.2 Fragility to Aggregate Shocks

The model assumes bank failure is driven by idiosyncratic shocks to the asset value of individual banks. In reality, many bank failures occur due to aggregate shocks. As a simple framework to capture the resiliency of the banking system 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. The shock in this one period is unanticipated and therefore banks do not ex-ante adjust their expectations of λ'. Further, the shock is for only one-period and therefore, banks do not change their expectations of future λ's either. In the period of the shock, more banks may fail if this new total loan default rate $\lambda' + \eta$

Figure 10: Policy Functions under Decomposition Exercise



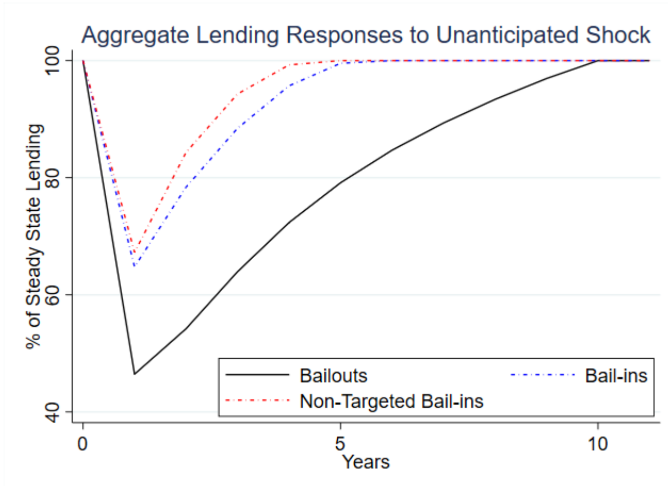
is high enough that banks would prefer resolution over continuation. Further, even for continuing banks, this will decrease the retained earnings n' with which the banks enter the next period. The extent of this effect will depend on the fraction of the bank's risky loans to total assets ($\frac{\ell'}{\ell'+s'}$) as returns to the safe asset will not change.

As this is a one-time shock, in the next period, there is no change to the banks' expected returns. Therefore, the value of entering is the same as in the steady state and the same mass of banks enter. Changes to aggregate lending and the bank size distribution then come from the increase in liquidations from the additional banks entering resolution as well as the change in n' for continuing and bailed out/in banks. The response of banks under the frictionless benchmark is not plotted. Because banks do not have limited liability but can raise new equity at the risk-free rate, the unanticipated shock does not change bank behavior and there is no effect on aggregate lending.

Figure 11 plots the aggregate lending responses to this unanticipated shock under the benchmark (Bailouts), counterfactual (Bail-ins), and Non-Targeted Bail-ins equilibria. The largest decline in aggregate lending comes from the benchmark. Banks in the benchmark are the most leveraged and have the highest risky asset fractions. Therefore, they are the most susceptible to additional failures due to the increased defaults. Aggregate lending decreases more under the counterfactual than under the non-targeted bail-in policy for two reasons. First, the average risky asset fraction is higher in the former, and banks are therefore more susceptible to this bad shock. Further, only big banks can be bailed-in in the counterfactual. The liquidation of banks is then larger under the counterfactual than the non-targeted bail-in policy, leading to greater exit of banks and fewer banks who can lend in the periods moving forward.

Aggregate lending recovers faster under the two bail-in equilibria than the bailout equilibrium. Under the non-targeted bail-in policy, aggregate lending recovers to its steady state value shortly before five years after the shock. The counterfactual takes slightly more than five years to recover. However, the benchmark takes approximately ten years to recover due to the large failure of banks and the low values of retained earnings 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.

Figure 11: Aggregate Lending Response to Shock



9 Conclusion

In this paper, I develop a model of the U.S. banking industry to evaluate the effects of bailout and bail-in policies on industry dynamics. Heterogeneous banks fund a portfolio of risky loans and safe assets via a mix of equity, insured deposits, and uninsured debt in order to maximize current and future dividends to shareholders. Upon realizing their returns on their assets, banks can choose between continuing to operate or entering resolution. In the benchmark model, big banks have a probability of being bailed out instead of the standard liquidation. The bailout is a cash injection that guarantees the repayment to current creditors. Therefore, in equilibrium, creditors price their debt to big banks lower than would be expected due to their risk, creating the TBTF subsidy that is heavily documented in the literature. I then adapt the model to replace the probability of bailout for big banks with one of a simplified version of the bail-in policy included in the Dodd-Frank Act. In a bail-in, the uninsured debt of the bank is converted to equity and the creditors receive shares in the new bank instead. Original shareholders only retain some shares if the value of the shares exceeds the creditors' original claims.

With the bail-in policy in place, the bail-in rate is 77% lower than the bailout rate in the benchmark. This is a result of the bail-in process being more costly to both creditors and shareholders as the shares given to creditors in the bail-in are always worth less than the value of their original claim. This increases the price on the uninsured debt and decreases the attraction of resolution for current shareholders as they always lose their shares in the bail-in. Banks choose to have lower uninsured leverage ratios under the counterfactual than benchmark and are thus better able to weather adverse shocks and repay their debt. The TBTF subsidy is reduced under the counterfactual to reflect decreased payouts to creditors under bail-in. These findings suggest that the bail-in policy achieves its goals of promoting market discipline and enhancing financial stability. However, due to the higher funding costs, aggregate lending decreases by 3% under the counterfactual. These results can be used by policymakers to weigh the benefits and costs of various resolution policies for banks.

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A Moment Definitions

Table 8: 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

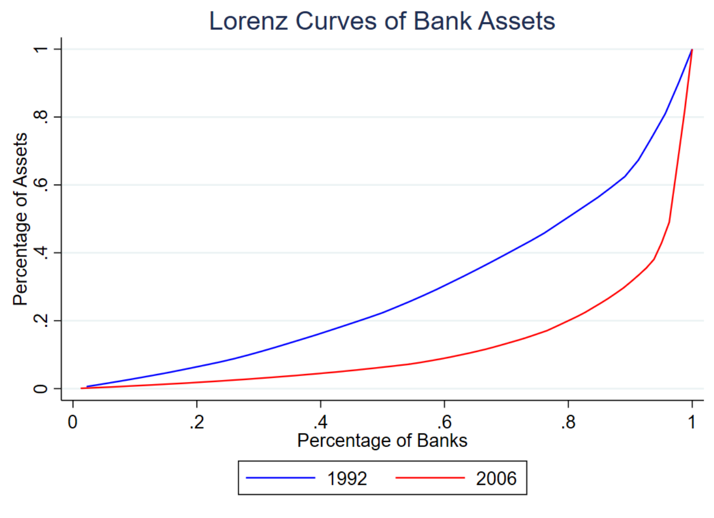
$$\text{NIM} = \frac{(R^{\ell}-1)(1-\lambda')\ell' + (R-1)s' - (\frac{1}{q(\delta,\lambda,\ell',s',b')} - 1)b' - (\frac{1}{q^{\delta}} - 1)\delta}{\ell' + s'}. \tag{40}$$

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

$$\text{Gini}_{\text{Data}} = \frac{1}{N}\Big(N + 1 - 2\frac{\sum_{i=1}^{N}(N+1-i)\text{Assets}_i}{\sum_{i=1}^{N}\text{Assets}_i}\Big) \tag{41}$$

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 12. 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

Figure 12: Lorenze Curve of Assets from Bank Sample



calculate the cumulative distribution function of banks with given $a = \ell' + s'$ values. Define

$$\Gamma^a(a) = \sum_{\Lambda} \sum_{\Delta} \int_N \mathbb{1}_{a(\delta,\lambda,n)=a} \Gamma(\delta, \lambda, dn) \tag{42}$$

We define the weighted loan distribution then as

$$\Gamma^{\omega a}(a) = \sum_{\Lambda} \sum_{\Delta} \int_N \mathbb{1}_{a(\delta,\lambda,n)=a} a(\delta, \lambda, dn) \Gamma(\delta, \lambda, dn) \tag{43}$$

I therefore use the formula

$$\text{Gini}_{\text{Model}} = 2 \int_0^{\bar{A}} \Big(\frac{\int_0^a \Gamma^a(x)dx}{\int_0^{\bar{A}} \Gamma^a(x)dx} - \frac{\int_0^a \Gamma^{\omega a}(x)dx}{\int_0^{\bar{A}} \Gamma^{\omega a}(x)dx} \Big) \Gamma^a(da) \tag{44}$$

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.

B List of Banks 2006Q4

Table 9: 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