Bailouts, Bail-ins, and Banking Industry Dynamics

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February 13, 2022

Abstract

In response to the controversy surrounding large bank bailouts during the financial crisis of 2008, the European Union has adopted a new framework for the resolution of systemically important banks, called the Banking Recovery and Resolution Directive. An essential part of this framework is the bail-in tool, which allows distressed, systemically important banks to restructure their liabilities and continue operating while imposing the losses of the bank upon the managers, shareholders, and creditors of the bank. This policy change will influence the exit decisions of banks, their risk-taking, the value of their shares, and the price and repayment of their debt. To measure and understand these effects, I build a quantitative model of heterogeneous bank exit and entry, including the possibility of Global Financial Crisis-style bailouts for the largest banks. I then perform a counterfactual exercise in which the probability of bailout is replaced with that of bail-in. Under the counterfactual, fewer large banks are bailed-in and the overall exit rate is reduced due to lower payoffs to shareholders and creditors in the event of a bail-in. The "too big to fail" subsidy on the debt prices of large banks is smaller, and thus, banks borrow less. Aggregate lending decreases by 4.2%.

The author thanks Dean Corbae, Rishabh Kirpalani, Erwan Quintin, Kim Ruhl, Vivian Hwa, Roni Kisin, Jon Pogach, and Lynn Shibut for helpful comments and insights.

1 Introduction

During the Global Financial Crisis, the failure of "too big to fail" (TBTF) banks posed an immense threat to European economies and the global financial system. To preserve financial stability, governments bailed out these banks by injecting equity and/or guaranteeing the debt of the big banks. These bailouts were controversial due to the use of public funds to pay for the fallout of bank managers' excessive risk-taking. In response, the EU adopted a new framework for the resolution of large banks, the Banking Recovery and Resolution Directive (BRRD), in 2014, and continued to amend these regulations until 2019. A key part of BRRD is the bail-in tool. A bail-in restructures the bank's liabilities by apportioning the losses of the bank onto the claims of the shareholders and debtholders, in that order, and converting leftover debt claims into equity in order to recapitalize the bank until it can safely continue operating. This new policy seeks to accomplish two goals: maintaining financial stability and promoting market discipline.

In this paper, I will answer how the equilibrium decisions of heterogeneous banks differ under a bail-in regime compared to a bailout regime by building a quantitative model of the EU banking industry. My paper is the first to evaluate the effect of bail-in policies on the exit decisions of banks as well as the resulting consequences for debt prices, risk-taking, lending, and dividend issuance. With the new policy in place, the exit rate is reduced substantially and there are fewer bail-ins in equilibrium than there were bailouts. The repayment to creditor in a bail-in is less than that in a bailout, and shareholders receive nothing in a bail-in. Therefore, the prices of uninsured debt rise and banks borrow significantly less. However, less borrowing translates to less funding for loans, and aggregate lending declines.

In the benchmark model, banks use equity, insured deposits, and uninsured debt to invest in risky loans with stochastic returns. Upon realizing their return on lending and the fraction of loan defaults, undercapitalized banks will be sent into resolution and all other banks will choose between entering resolution or continuing to operate. If continuing, the bank must repay the full deposit and debt claims and then choose its dividend issuance and next period debt and loan values. If a bank goes into resolution, there is a size-dependent probability that it will be bailed out, in which equity is injected into the bank by the government to allow it to continue. On the other hand, if the bank is not bailed out, it is liquidated — a discounted value of assets is used to repay first insured deposits and then as much uninsured debt as possible. Shareholders are paid last, but have limited liability, and are therefore protected from covering the remaining debt claims. A representative household owns the shares of the banks and lends insured deposits and uninsured debt. The price of the uninsured debt is pinned down via a zero profit condition based on the expected repayment of the debt and will be able to capture any endogenous TBTF subsidy. The model generates a steady state distribution of banks based on their lending and funding mixes.

I find that banks exit when they have the lowest return realization and are either very small or very levered. Small banks exit due to the relatively high costs of operating, but the very levered banks are large banks who gamble for bailout. These banks benefit from a "too big to fail" (TBTF) subsidy on their uninsured debt, resulting in a large mass of banks with very high debt to loans ratios. Under liquidation, the discounted value of a banks' loans are never enough to fully repay the creditors and shareholders receive nothing. This is not true when banks are bailed out. By construction, the creditors are fully repaid and shareholders retain the value of their shares.

The counterfactual introduces a simplified bail-in policy by replacing the probability of bailout for the largest banks with that of bail-in. A bailed-in bank will not repay its uninsured debt. Instead, creditors will receive shares in the new, restructured bank, up to the value of their original claim. The original shareholders will only receive shares in excess of the creditors' claims. The bank is restricted from issuing dividends in the period of the bail-in, but will issue new risky loans, borrow new insured deposits and uninsured debt, and continue operating.

In the counterfactual, shareholders lose their entire claims and creditors receive an average haircut of 7% in the event of a bail-in. Compared to the benchmark model where creditors are guaranteed full repayment in a bailout, uninsured debt prices rise. The higher cost of debt induces banks to borrow significantly less. Being less levered, these banks are better equipped to absorb losses on lending and therefore, the exit rate decreases significantly. Further, the rate of bail-in is substantially lower than the rate of bailout. The value of bailout to the original shareholders is no different than that of liquidation, so banks no longer have an incentive to grow large. As a result, aggregate lending decreases by 4.22%. Nonetheless, banks issue greater dividends at the median. The introduction of bail-ins creates a less levered, safer banking industry with a decreased threat of big bank failure.

My paper fits into the literature on bankruptcy and reorganization, specifically that of bank bail-in policies. While this is the first paper I am aware of to study the exit and entry decisions of banks under the bail-in tool of BRRD, it corresponds well to the findings of a dynamic model of the US's equivalent policy, Berger et. al. (2018). Their model focuses on the optimal capital trigger ratios under various policies and they find that banks increase their capital levels at a higher rate under the bail-in policy. My paper draws further conclusions about the effects of this policy on banks' exit, risk-taking, and debt-to-equity financing decisions. In this way, my paper is similar to that of Corbae and D'Erasmo (2020), which evaluates an exit and entry model of non-financial firms with a counterfactual proposal for reorganization very similar to a bank bail-in. I contribute to this literature of reorganization policies by analyzing it within the banking industry and comparing it to other resolution policies for large banks, such as bailouts.

The rest of the paper is structured as follows. Section 2 explores previous literature on 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 Section 4. Section 5 summarizes the results, including those from the counterfactual exercise. Section 6 concludes.

2 Literature Review

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” (TBTF) subsidy (Schaefer et. al. (2016), Giuliana (2017), Berndt et. al. (2019)). However, Beck et. al. (2017) performs a reduced-form analysis of credit supply in Portugal following the partial 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 solve for the optimal capital trigger ratios needed to maximize bank value minus the expected external social costs of default under each regime. The model is calibrated to the pre-crisis period for the bailout regime and the post-DFA period for the bail-in regime. In terms of welfare, the relative benefit of bail-in to bailout depends on how the costs of a bailout are distributed onto taxpayers. Additionally, they focus on the incentives provided by each regime for banks to rebuild capital during distress and find that only the bail-in regime can provide such incentives. My paper differs as I allow for the entry and exit of banks and study the impact on bank lending, repayment of debt, and choice of debt-to-equity financing. Additionally, my bail-in period will be calibrated to the pre-crisis and crisis periods in the EU rather than the period of time after the policy was enacted. In the future, I hope to capture the change to consumer welfare during the crisis if the EU was in a “bail-in” regime rather an implicit “bailout” regime.

Prior quantitative models of banking industry dynamics include Corbae and D’Erasmo (2019). This paper highlights the differences between small regional banks and large national banks in the US and how the entry and exit of these types of banks differ in response to aggregate and regional shocks. The focus of the paper is on a nontrivial endogenous bank size distribution and its implications for bank competition. In this model, the only form of bank debt is insured deposits. Banks therefore only make their exit decision based on their endogenous state and the size distribution of other banks. My model also includes uninsured debt which banks can therefore default upon. My paper then builds more off 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. While Egan et. al. (2017) studies standard bankruptcy and bailout policies, I contribute by evaluating a counterfactual of a bail-in.

The bail-in tool is very similar to a proposed US policy for the reorganization of failing non-financial firms by the American Bankruptcy Institute, as studied by Corbae and D’Erasmo (2020). In this paper, firms make exit and entry decisions as functions of the firms’ capital investment and debt. The bankruptcy law they study allows the firm to become a new "all-equity" firm, forgiving the previous debt in a similar manner to my own counterfactual. This change had significant effects on the borrowing costs and capital structure of the firms and therefore increased total factor productivity by 0.5%. Welfare increased by 0.9%, closer to an equilibrium without financial frictions. My model borrows from many aspects of this model, but adapts them to match the unique features of the banking industry. 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 Bailouts

During the Global Financial Crisis, European nations used a variety of measures to save banks from failing. From 2007 to 2009, 84 banks in the EU received government aid in the form of either recapitalization, liabilities guarantees, other liquidity support, or troubled asset relief. Recapitalization was the most common of these measures, used for 35 banks in Austria, Belgium, Germany, Italy, Ireland, Luxembourg, Netherlands, and Portugal. The mean percentage of total assets that was injected into these banks was 2.19% (Acharya et. al. (2021)).

While government support for banks is prohibited under the Treaty on the Functioning of the European Union, it can be allowed in exceptional cases, such as "a serious disturbance in the economy of a Member State". (TFEU Article 107(3.b)). Despite this explicit policy, there was an implicit belief that big banks in Europe would receive assistance from the government in the case of distress. There is a substantial literature documenting a TBTF subsidy on the debt of large banks leading up to the crisis, stemming from this belief. Included in this literature is estimation of the TBTF subsidy for European banks. Carbo-Valverde et. al. (2013) finds that banks on average benefited 10-22 bps from public guarantees from 2003-2008 and that European banks benefitted more than US banks. Li et. al. (2011) complements by finding that the value of TBTF support for the top 20 European banks was 293 billion €. These findings support the modeling of the pre-GFC banking industry as a "bailout" regime.

3.2 Bail-ins

BRRD is enacted when the bank is failing or likely to fail, a resolution action is in the public interest, and there are no private-sector alternatives. A bank is failing or likely to fail if its assets are, or there is belief they will be, less than its liabilities or that the bank will be unable to pay its debt. There are four different resolution tools included in BRRD: 1) sale of business, 2) bridge bank, 3) asset separation, and 4) bail-in. The bail-in tool was added in 2016, is the most novel for European banks, and is considered to be the cornerstone of BRRD. The purpose of the bail-in tool is to either recapitalize the bank, if it is possible to restore the bank, or to convert to equity or reduce the claims and debt instruments that are transferred to bridge institutions or under the sale of business or asset separation tools.

The claims that will be written down or converted into equity fall into a hierarcy with four levels. The first level is equity. Common Equity will be written down starting with Tier 1, moving onto Tier 2 once Tier 1 is depleted, and then onto Tier 3. The second level is subordinated debt. The third level consists of senior debt, promissory notes, commercial paper, certificates of deposits, uncovered corporate deposits, and derivatives. The final level includes uncovered SME and retail deposits. If these are not sufficient, covered deposits by Deposit Guarantee Scheme can be bailed in. Some liabililities are always excluded from bail-in, including covered bonds, deposits by the central bank or other public organizations, collateralized financing, such as repos, and employee wages.

Once a minimum of 8% of the bank's total liabilities have been imposed on the shareholders and creditors of the bank as losses, the bank can receive funds from a resolution fund. This fund can be used to make loans to the bank under resolution, guarantee assets or liabilities, to purchase assets, or to make a contribution to the bank which would have been achieved via the write down of certain claims that the resolution authority decided to exclude from the bail-in. The total amount received from the resolution fund cannot exceed 5% of the banks' total liabilities, except for in the instance of a systemic crisis. The fund will be financed by ex-ante contributions by all banks (Fernandez de Lis et. al. (2014), World Bank Group (2017)).

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 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 in the US since the passage of its 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 equilibria under each policy.

While a few bail-ins have occured in the EU so far, these resolutions were before the finalization of BRRD. There was not a unified policy to follow in executing these bail-ins and many of them were only partial bail-ins, incorporating aspects of bailout as well. Additionally, it is unclear if banks and their creditors were expecting bail-ins yet. Therefore, it is not practical to use EU banking data following the crisis and before the finalization of BRRD to infer how banks' decisions would change in a "bail-in regime".

4 Benchmark Model

The model will be 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, $\Gamma(z, l, b, j)$, because every bank with return realization z, loans l, uninsured debt b, and of type j will behave identically. l, and b are chosen by the bank and z is an exogenous, Markov process. Type j indicates if a bank is small or big. Big banks will have a cost advantage over small banks (Corbae and D'Erasmo (2019)) and the bank's exogenous insured deposits, δ^j, will differ by bank type. The bank problem is represented in recursive format. Additionally, there is an unmodeled household who purchases the bank stock and lends insured deposits and uninsured debt to the banks.

At the beginning of each period, an incumbent bank realizes its return, z, on last period's loans, l. Based on this realization and its current debt, b, and insured deposits, δ^j, an exit decision is made. Let $V(z, l, b, j)$ denote the value of the bank before the exit decision, $V_L(z, l, b, j)$ the value of liquidation, $V_O(z, l, b, j)$ the value of bailout, and $W(z, l, b, j)$ the value of continuing to operate. Then,

$$V(z, l, b, j) = \max\{W(z, l, b, j), \rho(j, l) \mathop{\mathbb{E}}_{j'|j}(V_O(z, l, b, j, j')) + (1 - \rho(j, l))V_L(z, l, b, j)\}. \quad (1)$$

The bank is choosing between the value of operating, $W(z, l, b, j)$, and the expected value of exiting, $\rho(j, l)\,\mathbb{E}_{j'|j}(V_O(z, l, b, j, j')) + (1-\rho(j, l))V_L(z, l, b, j)$. If the bank chooses to exit, it is bailed out with probability $\rho(j, l)$ and liquidated with probability $1 - \rho(j, l)$. In reality, the possibility 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 use a probability that first depends on the bank's type as this pins down one aspect of a bank's size. Additionally, I model the probability to be a function of the bank's loans as well becuase the systemic importance of even big banks may vary with their relative size (loans).

The value of being bailed out, V_O, depends on the new type, and is therefore a conditional expectation over j'.

The liquidation of a bank is modeled like a standard bankruptcy — remaining assets are used to repay debt. The bank's realized assets, zl, are devalued at a discount price, c_F^j, to reflect losses that may need to be accepted on the sale of loans in order to sell them off quickly. The bank uses these funds to repay their stakeholders. First, the funds are used to pay administrative costs of the bank, such as salaries, and then the expenses to run the complete the liquidation process. The latter will be a function of both fixed and variable costs where the variable costs depend on the assets of the bank. This is because the main costs of resolving a bank arise from the selling off the assets. For now, I will model this cost as only a fixed cost, which will depend on the type of the bank, c_R^j. Next, the leftover funds are used to repay depositors. While deposits are typically guaranteed through a Deposit Guarantee Scheme, this reflects the payment to the insuring body for guaranteeing these deposits. Leftover funds after this step are equal to $\max\{0, c_F^j zl - c_R^j - \delta^j\}$. Then, creditors are repaid 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 is then

$$V_L(z, l, b, j) = \max\{0, c_F^j zl - c_R^j - \delta^j - b\}. \tag{2}$$

The value of a continuing bank can be broken down into three different sub-values, depending on the value of the bank's equity, e, as it enters a period,

$$W(z, l, b, j) = \begin{cases} \mathbb{E}_{j'|j}(V_C(z, l, b, j, j')) & \text{if } \frac{e}{zl} \geq \alpha \\ \mathbb{E}_{j'|j}(V_{C,R}(z, l, b, j, j')) & \text{if } \frac{e}{zl} \in [\alpha_r, \alpha) \\ -\infty & \text{if } \frac{e}{zl} < \alpha_r \end{cases} \tag{3}$$

At the beginning of the period, e is equal to the value of the loans, zl, minus the debt obligations, $b + (1 + r_D)\delta^j$. If the equity of a bank falls below a certain percentage, α_r, of the bank's assets, it must be resolved. Therefore, the value of continuing is infinitely negative below this threshold, and the bank will automatically choose to exit. If the equity of a bank is above the threshold α_r, but below the capital requirement α, the bank may continue, but is restricted from issuing dividends in that period. If the bank's equity is already above the capital requirement α, it may continue and is free from additional restrictions on its dividends. Whether restricted or not, the value of continuing depends on the bank's new type, but this information is unknown to the bank at the time of the decision. Therefore, the bank takes an expectation of the value of continuing based on its type, for example, $\mathbb{E}_{j'|j}(V_C(z, l, b, j, j'))$.

A bank that continues operating must pay back both insured deposits, δ^j, at the exogenous rate $(1 + r_D)$, and their uninsured debt, b. Only then does the bank receive their new deposit base, $\delta^{j'}$. The bank then chooses their new equity value, e', next period's loans, l', and next period's debt, b', at price $q(z, l', b', \delta^{j'})$. The price of debt depends on the bank's leverage, pinned down by their choices of l' and b' and their deposits $\delta^{j'}$, and varies by the bank's current return realization, z. Banks can either pay dividends to their shareholders, $d > 0$, or issue seasoned equity, $d < 0$. Issuing seasoned equity incurs a proportional cost $\lambda^j \in [0, 1]$. To continue, the bank must also pay operating costs, $c_O^j(l')$. This cost consists of both a fixed fee, c_{O1}^j, and two variable costs, c_{O2}^j and c_{O3}^j, such that $c_O^j(l') = c_{O1}^j + c_{O2}^j l' + c_{O3}^j l'^2$. All three cost parameters, c_{O1}, c_{O2}, and c_{O3}, will be positive. Therefore, the costs are increasing and convex in the amount of loans issued and differ by bank type j. These costs can be thought of as including maintenance costs, charter fees, deposit insurance fees, and loan monitoring costs.

The objective of a continuing bank is to maximize its current and future dividend streams, which are represented here by d and the discounted expected continuation value, $\beta \mathbb{E}_{z'|z} V(z', l', b', j')$. These choices are subject to the balance sheet constraint — new assets, l', must be equal to the new value of equity, e', deposits, $\delta^{j'}$, and debt, $q(z, l', b', \delta^{j'})b'$. Equity, e', is equal to the returns from lending, zl, subtracting the repayment of deposits, $(1 + r_D)\delta^j$, and debt, b, the issuance of dividends or costly equity, $(1 - \lambda^j \mathbb{1}_{d<0})d$, and the payment of operating costs, $c_O^j(l')$. The bank is also subject to a capital requirement. The bank's only asset, l', is given a risk-weight of one, so the bank's ratio of equity to loans must be above a threshold of α. The value of the continuing bank is

$$
\begin{gathered}
V_C(z, l, b, j, j') = \max_{d, l', b'} \quad d + \beta \mathbb{E}_{z'|z} V(z', l', b', j') \\
\text{s.t.} \\
l' = e' + \delta^{j'} + q(z, l', b', \delta^{j'})b' \\
e' = zl - (1 + r_D)\delta^j - b - (1 - \lambda^{j'} \mathbb{1}_{d<0})d - c_O^{j'}(l') \\
\frac{e'}{l'} \geq \alpha \\
l' \geq 0, \quad b' \geq 0
\end{gathered} \tag{4}
$$

For the bank with an equity ratio above α_r but below α, the problem of continuing while dividend restricted, $V_{C,R}(z, l, b, j, j')$, is identical to the problem described in Equation 4 except there is an additional requirement that $d \leq 0$. This says that the bank cannot issue dividends in this period, and instead must issue equity in order to raise its capital ratio.

A bank that is bailed out also chooses dividends/equity issuance, new loans, and new debt, but its new equity value is increased by an injection of $\tau(z, l, b, j)$ by the government. Therefore, the problem of a bailed out bank can be written as

$$
\begin{aligned}
V_O(z,l,b,j,j') = \max_{d,l',b'} \quad & d + \beta \mathbb{E}_{z'|z} V(z',l',b',j') \\
& \text{s.t.} \\
l' &= e' + \delta^{j'} + q(z,l',b',\delta^{j'})b' \\
e' &= zl - (1+r_D)\delta^j - b - (1-\lambda^{j'}\mathbb{1}_{d<0})d - c_O^{j'}(l') + \tau(z,l,b,j) \\
\frac{e'}{l'} &\geq \alpha \\
l' &\geq 0, \quad b' \geq 0
\end{aligned} \tag{5}
$$

The value of $\tau(z,l,b,j)$ is the amount of equity needed by the bank to satisfy the beginning of the period capital requirement, α. Therefore, $\tau(z,l,b,j)$ must be

$$
\begin{aligned}
\frac{e+\tau(z,l,b,j)}{zl} &= \alpha \\
\frac{zl - b - (1+r_D)\delta^j + \tau(z,l,b,j)}{zl} &= \alpha \\
zl - b - (1+r_D)\delta^j + \tau(z,l,b,j) &= \alpha zl \\
\tau(z,l,b,j) &= b + (1+r_D)\delta^j - (1-\alpha)zl
\end{aligned} \tag{6}
$$

Each period, new banks can enter by paying an entry cost, c_E. Only after paying this cost do new banks receive their initial type and return realization. Initial return realizations will be distributed according to the distribution $\bar{G}(z)$ and the distribution over the types will be $\Phi(j)$. Φ will be chosen to match the type distribution of new entrants in the data.

A new bank with an initial z and j' will then solve

$$
\begin{aligned}
V_E(z,j') = \max_{d,l',b'} \quad & d + \beta \mathbb{E}_z(V(z',l',b',j')) \\
& \text{s.t.} \\
l' &= e' + \delta^{j'} + q(z,l',b',\delta^{j'})b' \\
e' &= -(1-\lambda^{j'})d - c_O^{j'}(l') \\
\frac{e'}{l'} &\geq \alpha \\
l' &\geq 0, \quad b' \geq 0, \quad d < 0
\end{aligned} \tag{7}
$$

where d is restricted to being less than zero, representing equity issuance. In general equilibrium, the mass of entrants will be pinned down based on demand and supply for bank equity. For now, as I am targeting a stationary distribution under partial equilibrium, the mass of entrants will be set equal to the mass of liquidated banks.

4.1 Timing

The timing for the benchmark model is as follows:

1. Incumbent bank realizes return on lending from last period and therefore, its new equity to assets ratio. Bank is either sent into resolution or decides to continue operating or to enter resolution.

   - **Bank enters resolution:** The bank is either bailed out or liquidated, based on a predetermined probability.
     - **Liquidation:** The bank uses the proceeds from the sale of loans to repay deposits and uses the funds to repay the receivership costs, the insured deposits, and 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. It repays deposits and uninsured debt. The bank realizes its new type and receives the corresponding deposit base. It chooses dividend or equity issuance, next period's debt, and next period's lending.
   - **Bank decides to continue:** The bank repays deposits and uninsured debt. It realizes its new type, receives the corresponding deposit base, and then chooses dividend or equity issuance, next period's debt, and next period's lending.

2. New banks pay the entry cost and receive their initial return realization and type. They will choose to lend, borrow, and issue equity.

3. Households choose how much to consume, debt to lend, and bank stock to purchase.

4.2 Prices

The value of owning bank stock comes from the expected future dividend streams. Because the value of the bank, $V(z, l, b, j)$, is equal to the expected (with respect to the new j') dividend payout and the continuation value representing future dividends, the price of this stock is equal to $V(z, l, b, j) - \mathbb{E}_{j'|j}(d(z, l, b, j, j'))$. The rate of return banks must pay on insured deposits will be exogenous and equal to $(1 + r_D)$.

In reality, households do not directly lend uninsured debt to banks. Instead, they invest in intermediaries, such as mutual funds, who pool the investors' money together to lend to a portfolio of banks. Therefore, in the model, households will invest funds in intermediaries who will lend to the banks. 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 $\Delta(z, l, b, \delta^j)$ as the exit decision for a bank with return z, loans l, debt b, and deposits δ^j. If this bank chooses to exit, $\Delta = 1$, and otherwise, $\Delta = 0$. Then, define the set of return realizations such that a bank would choose to exit as

$$X(l, b, \delta^j) = \{z \in Z : \Delta(z, l, b, \delta^j) = 1\}. \tag{8}$$

Recall that z is independent of δ^j. The profit an intermediary makes on a loan contract to a bank with current return z, new loans l', new debt b', and new deposits $\delta^{j'}$ is then

$$\begin{aligned}\Omega(z,l',b',\delta^{j'}) = \underbrace{-q(z,l',b',\delta^{j'})b'}_{\text{debt lent}} + \frac{1}{1+r_f}[&\underbrace{(1-\sum_{z'\in X(l',b',\delta^{j'})} G(z'|z))b'}_{\text{repayment - no exit}} \\ &+ \underbrace{(1-\rho(j',l'))\sum_{z'\in X(l',b',\delta^{j'})} \min\{b', \max\{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}, 0\}\}G(z'|z)}_{\text{repayment - liquidation}} \\ &+ \underbrace{\rho(j',l')\sum_{z'\in X(l',b',\delta^{j'})} b'G(z'|z)]}_{\text{repayment - bailout}}\end{aligned} \tag{9}$$

Only in liquidation does the intermediary risk partial or zero repayment of the debt claim b'. In equilibrium, intermediaries will make zero profit on each loan contract. The price of a given contract can then be solved as

$$\begin{aligned}q(z,l',b',\delta^{j'}) = \frac{1}{1+r_f}[&(1-(1-\rho(j',l'))\sum_{z'\in X(l',b',\delta^{j'})} G(z'|z)) \\ &+ (1-\rho(j',l'))\sum_{z'\in X(l',b',\delta^{j'})} \min\{1, \max\{\frac{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\}G(z'|z)].\end{aligned} \tag{10}$$

4.3 Too Big To Fail Subsidy

The TBTF subsidy for 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

$$\text{Discount}(z,l',b',\delta^{j'}) = 1 - q(z,l',b',\delta^{j'}). \tag{11}$$

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

$$\begin{aligned}q^{\rho=0}(z,l',b',\delta^{j'}) = \frac{1}{1+r_f}[&(1-\sum_{z'\in X^{\rho=0}(l',b',\delta^{j'})} G(z'|z)) \\ &+ \sum_{z'\in X^{\rho=0}(l',b',\delta^{j'})} \min\{1, \max\{\frac{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\}G(z'|z)].\end{aligned} \tag{12}$$

The TBTF subsidy can be thought of as the decrease in the discount due to the possibility of bailout, or

$$
\begin{aligned}
\text{TBTF subsidy}(z, l', b', \delta^{j'}) &= \text{Discount}^{\rho=0}(z, l', b', \delta^{j'}) - \text{Discount}(z, l', b', \delta^{j'}) \\
&= -q^{\rho=0}(z, l', b', \delta^{j'}) + q(z, l', b', \delta^{j'}) \\
&= \frac{1}{1+r_f}[\sum_{z' \in X^{\rho=0}(l', b', \delta^{j'})} G(z'|z) \\
&- \sum_{z' \in X^{\rho=0}(l', b', \delta^{j'})} \min\{1, \max\{\frac{c_F^{j'} z' l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\} G(z'|z) \\
&- (1 - \rho(j', l')) \sum_{z' \in X(l', b', \delta^{j'})} G(z'|z) \\
&+ (1 - \rho(j', l')) \sum_{z' \in X(l', b', \delta^{j'})} \min\{1, \max\{\frac{c_F^{j'} z' l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\} G(z'|z)].
\end{aligned}
\tag{13}
$$

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

$$
\begin{aligned}
&= \frac{\rho(j', l')}{1+r_f}[\sum_{z' \in X(l', b', \delta^{j'})} G(z'|z) \\
&- \sum_{z' \in X(l', b', \delta^{j'})} \min\{1, \max\{\frac{c_F^{j'} z' l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\} G(z'|z)].
\end{aligned}
\tag{14}
$$

The final term of Equation 14, the repayment value under liquidation, cannot be greater than the first term in the brackets. Therefore, the TBTF subsidy is always greater than or equal to 0 as long as the set of exits is 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.

4.4 Equilibrium

Denote the decision rules of a bank continuing in the industry with loan return z, prior loans l, debt b, of current type j, and new type j' as $h_C^l(z, l, b, j, j')$ for the new lending decision and $h_C^b(z, l, b, j, j')$ for the new debt decision. Similarly, the decision rules for a bailed-out bank are $h_O^l(z, l, b, j, j')$ and $h_O^b(z, l, b, j, j')$. Let Z, L, B, and J be the sets of loan returns, loans, debt, and bank types, respectively and $\bar{Z} \subset Z, \bar{L} \subset L$, $\bar{B} \subset B$, and $\bar{J} \subset J$. The mass of incumbent banks with return z, loans l, debt b, and of type j is $\Gamma(z, l, b, j)$.

Define M as the mass of entrants, which is assumed to be equal to the mass of liquidated banks in that period. Therefore, M is equal to

$$M = \sum_{Z} \int_{L,B} \sum_{J} (1 - \rho(j,l))\Delta(z,l,b,\delta^j)\Gamma(z,dl,db,j). \tag{15}$$

The decision rules of the entrants are $h^l_E(z,j')$ and $h^b_E(z,j')$. The law of motion for the cross-sectional distribution of banks is then given by

$$\begin{aligned}\Gamma'(\bar{Z},\bar{L},\bar{B},\bar{J}) = &\sum_{\bar{Z}} \int_{\bar{L},\bar{B}} \{\sum_{\bar{J}} \sum_{Z} \int_{L,B} \sum_{J} [(1-\Delta(z,l,b,\delta^j))\mathbb{1}_{l'=h^l_C(z,l,b,j,j'),b'=h^b_C(z,l,b,j,j')} \\ &+ \rho(j,l)\Delta(z,l,b,\delta^j)\mathbb{1}_{l'=h^l_O(z,l,b,j,j'),b'=h^b_O(z,l,b,j,j')}]\Gamma(z,dl,db,j)F(j'|j)\}dl'db'G(z'|z) \\ &+ M \sum_{\bar{Z}} \int_{\bar{L},\bar{B}} \sum_{\bar{J}} \mathbb{1}_{l'=h^l_E(z,j'),b'=h^b_E(z,j')}\Gamma(z,dl,db,j')\Phi(j')\bar{G}(z)\end{aligned} \tag{16}$$

A stationary equilibrium is a list $\{V^*, q^*, \Delta^*, \Gamma^*, \Omega^*, M^*\}$ such that:

1. Given q, the value function V^* is consistent with the firm's optimization problem in Equation 1.

2. The set Δ^* 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 $q^*(z,l',b',\delta^{j'})$, $\Omega^*(z,l',b',\delta^{j'}) = 0$.

4. Γ^* and M^* are stationary measures consistent with bank decision rules and the law of motion for stochastic variables.

4.5 Computational Algorithm

The computational algorithm I will use to estimate the benchmark model is:

0) Make an initial guess of the price schedule $q^0(z,l,b,\delta^j)$ and set ϵ_p and ϵ_g to be very small and positive.

1) Solve the bank problem to obtain exit, loan, debt, and dividend/equity decision rules as well as value functions.

2) Check the zero profit condition. For every z, l, b, and δ^j, if $|\Omega(z,l,b,\delta^j)| > \epsilon_p$, update the price and repeat from step 1. The new price will be set to

$$q^1(z,l',b',\delta^{j'}) = \frac{1}{1+r_f}(1-(1-\rho(j',l')) \sum_{z' \in X^0(l',b',\delta^{j'})} G(z'|z)$$
$$+ (1-\rho(j',l')) \sum_{z' \in X^0(l',b',\delta^{j'})} \frac{\min\{1, \max\{\frac{c_F^{j'} z'l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\}}{b'} G(z'|z))$$

If $|\Omega(z,l,b,\delta^j)| < \epsilon_p$, continue to step 3.

3) Solve the entrant problem to obtain loan, debt, and equity decision rules.

4) Make an initial guess of the stationary distribution of banks Γ_0.

5) Using Γ_0, calculate the mass M of banks who are liquidated. This is equal to the mass of entrants.

6) Solve for Γ^1 using Equation 16. If $||\Gamma^1 - \Gamma^0|| > \epsilon_g$, replace $\Gamma^0 = \Gamma^1$ and repeat from Step 5. Continue until $||\Gamma^1 - \Gamma^0|| < \epsilon_g$.

4.6 Data & Estimation

All parameters in the model will be informed from data. The main data for this project will be Bankscope data for the time period 1990-2006. This dataset consists of bank-level financial data for banks in various countries, including the EU. I will consolidate all variables to the parent level, as is consistent in the literature (see Acharya et. al. (2021)). Other data will include data on government interventions for EU banks. I will use the database created in Acharya et. al. (2021), which is hand-collected data from the State Aid Register of the European Commission. This data includes the bank, country, type of intervention, date of intervention, and amount of funds used in the intervention.

Parameters $c^j_{O1}, c^j_{O2}, c^j_{O3}, \lambda^j, c^j_R$, and c^j_F will be estimated using Simulated Method of Moments by matching moments from the banking and government intervention datasets described previously to moments from the model. Table 1 displays the parameters and moments. There is not a one-to-one correspondence between each parameter and moment and the set is overidentified — there are more moments than parameters. For now, I use the value of the parameters given in Table 2.

Using data from interest earned on deposits and deposit levels for the banks, I will set r_D, the return on insured deposits, to the median interest rate on deposits during the time period of 1990-2006. Additionally, the risk-free rate for intermediaries, r_f, will be set equal to this amount so that the price of uninsured debt is always greater than or equal to the price of insured deposits. Because the households who own the banks can save money risk-free through deposits, the bank's discount factor, β, will equal $\frac{1}{1+r_D} = \frac{1}{1+r_f}$. The relevant Basel Accords for my time period, Basel I and II, required that banks in member countries had ratios of tier 1 capital to assets of at least 4%. Therefore, I will set the capital requirement in the model, α, to be 4%. The percentage that will send a bank to resolution, α_r, will be set to 2%.

For my current results, I focus solely on one type of bank, or $J = 1$. I consider these banks to be big banks, as the implicit bailout and explicit bail-in policies are for bigger banks. As I have not completed the estimation of the model yet, the results in the following section will be from using the reasonably chosen parameters shown in Table 2.

The loan returns can take on three values, $\{z_H, z_M, z_L\}$ equal to 1.08, 1.05 and 0.9, respectively. The third state, z_L, is to represent a "crisis state" in which the bank obtains an extremely low return (or can be thought of as high fraction of loan defaults). The loan returns will follow a Markov process, where z_H and z_M are fairly persistent, but z_L is more of a temporary shock. The process can be found in Table 3.

The difficult parameter to set is ρ. As the bailout policy was an implicit belief held by banks and their creditors, there is no clear policy choice of ρ. However, the literature on estimation of the TBTF subsidy suggests that it existed for only the biggest of big banks. Therefore, I set ρ to be an increasing function of loans, the banks' only asset. For now, I choose $\rho = .85$ for $l \geq \bar{l}$ and $\rho = 0$ for $l < \bar{l}$ where $\bar{l} = 100$ billion €.

5 Results

5.1 Benchmark Model

Table 5 summarizes key moments from the benchmark model (first column), under the parameters in Table 2. The liquidation rate in the model is only 0.65%. The percentage of banks who enter resolution, however, is 3.27%, meaning that 2.62% of banks in the equilibrium are bailed out each period.

In the model, only the banks with the lowest return, z_L, enter resolution. Further, these banks all violate the 2% capital requirement and are required to enter resolution, rather than choose to do so at the beginning of the period. There are two types of banks that enter resolution in equilibrium: very small banks and very large and levered banks. The small banks are liquidated at a rate of 0.19% and have no uninsured debt to repay. The larger banks, however, have a median uninsured debt to loans ratio of 79.15%. When these banks are liquidated, the creditors are never fully repaid, but receive a median repayment of 92.22% of their claim. Consequently, shareholders always receive zero in the event of liquidation. In a bailout, however, the value of a bailed out bank to the shareholders ranges from 2.9-6.6 billion €. Bailed out banks significantly reduced their loans and debt following the bailout. The smaller of bailed out banks issue dividends in the period as they choose to become banks that will exit if the z_L return is drawn again. Other bailed out banks issue more equity, so that there is a zero percent chance they will exit next period and they can grow again instead.

The steady state distribution of banks across loans and uninsured debt can be found in Figure 2. The only banks with low uninsured debt to loans ratios are those that are below the TBTF threshold at 100 billion €. All banks that are above this threshold and are hence eligible for the bailout have substantially high ratios. Note that there are no banks with loans just under the 100 billion €. Due to the possibility of bailout, any bank slightly under the threshold would prefer to be over the threshold.

Table 6 presents the distribution of banks across the three loan return states. This distribution is not equal to the ergodic distribution as suggested by the Markov process for z, seen in Table 4. The steady state distribution has slightly greater weight in the z_H state than the ergodic distribution and slightly less in the z_M or z_L states. This is due to banks exiting when they are in the z_L state, decreasing this mass. Additionally, 90% of z_L banks receive the z_M return in the next period. Due to the exit of these z_L banks, fewer banks are moving to the z_M state than is suggested by the ergodic distribution.

Figure 1 plots the stationary distribution of debt to loans ratios. The distribution is clustered around 80%, with only a small percentage of banks holding zero or close to zero uninsured debt. These banks are small banks, below the TBTF threshold. No bank above the threshold holds a small or zero percentage of uninsured debt.

While the loans in the model are short-term, they end up being very persistent. The median change in loans from one period to the next is zero and the average change is -0.1%. Banks with z_H weakly increase their loans. Banks with z_M increase their loans if they are under the TBTF threshold of 100 billion €. All of these banks increase their loans by enough to be over the TBTF threshold next period. These banks have a 5% chance of receiving the z_L return next period. If they do, they may want to exit, so they guarantee that their chance of bailout is greater than zero. For the z_M banks already above the TBTF threshold, these banks weakly decrease their loans, but still choose loan values above the TBTF threshold. All banks with the z_L return weakly decrease their loans. These banks earn very low returns on their current loans, making it difficult to afford large loan issuances this period. Even further, they have a 10% chance of drawing the z_L return again, higher than for the other two states. Therefore, debt prices are higher for these banks than banks with higher returns, making it difficult to fund lending through debt issuance. Instead, these banks lend little amounts and hope for the z_M return next period in order to grow again.

Of the banks not being liquidated, 54.14% of banks issue seasoned equity rather than issuing dividends. Figure 3 plot the dividend versus equity issuance of banks, broken down by z. Red represents dividend issuance while blue represents seasoned equity issuance. For banks above the TBTF threshold and with the z_H or z_M returns, the biggest banks issue dividends. As these banks are already large, they issue dividends and stay around the same size. However, for the smaller of the big banks, these banks issue equity in order to grow to be the largest of the big banks and issue positive dividends in the future. A similar pattern holds true for banks below the TBTF threshold. For banks with z_L and above the threshold, however, the opposite is true. Those banks that are smaller issue dividends and shrink substantially. The banks that are bigger though, actually issue equity in order to remain relatively larger, so if they draw the z_M return next period, they can then issue dividends.

To calculate the TBTF subsidy on debt prices, I first solve for the equilibrium in which $\rho = 0$ for all l. In this equilibrium, there are more z, l, b combinations at which banks enter resolution when $l <= 100B$, but fewer combinations at which banks enter resolution if they are above the TBTF threshold. Given that shareholders earn zero in liquidation, resolution is less attractive to big banks when the probability of bailout is zero. As the exit decisions of banks differ between the two equilibrium, the TBTF subsidy must be calculated using Equation 13. Using the distribution from the benchmark model, I find that the median TBTF subsidy of all banks over the TBTF threshold is 151 basis points. While this estimate overestimates the TBTF subsidy for European banks found in Carbo-Valverde et. al. (2013), the model is not yet estimated to the data.

5.2 Counterfactual

I will now adapt the model to replace the bailout policy with a modified version of the bail-in tool in BRRD. While there have been instances of bail-ins in the EU following the GFC, these bail-ins occured before the final revisions to BRRD in 2019. Therefore, banks and their creditors may not have been fully expecting a bail-in before those resolution events. Additionally, the bail-in tool is not the only change to banking policy that occurred via either BRRD or other regulations in the EU following the GFC. In order to properly calibrate the model to a true bail-in regime, I would also need to include all of these other 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 have differed if the bail-in policy was in place from 1990-2006 instead of the implicit bailout policy.

In this counterfactual model, if a bank chooses to exit, it is bailed in with a probability of $\mu(j, l)$ and liquidated with a probability of $1 - \mu(j, l)$. The value of a bailed-in bank to the shareholders is $V_I(z, l, b, j)$, which is defined below in Equation 18. The bank problem is now

$$V(z, l, b, j) = \max\{W(z, l, b, j), \mu(j, l)V_I(z, l, b, j) + (1 - \mu(j, l))V_L(z, l, b, j)\}, \tag{17}$$

where $W(z, l, b, j)$ and $V_L(z, l, b, j)$ are the same as under the benchmark model (Equations 3 and 2).

Bail-in allows the bank to continue to operate by forgiving the old debt, but imposes the losses of the bank onto the shareholders and creditors. In practice, shareholders will lose some amount of their claims, perhaps all, while creditors will have some converted to equity and the rest remaining as debt. The amount of debt converted to equity will depend on the capital requirement. For now, I will assume all uninsured debt is converted into equity in the new bank. Current shareholders will only receive shares in the new bailed-in bank if the value of the shares are greater than the creditors' initial claims. Otherwise, the current shareholders will lose their shares and the value of the bank to them will be zero. The bail-in decision must be made before the realization of the new bank type, j'. Therefore, the value of the bailed-in bank to the *original* shareholders is

$$V_I(z,l,b,j) = \max\{0, \mathop{\mathbb{E}}_{j'|j}(V_C^I(z,l,j,j')) - b\}). \tag{18}$$

$V_C^I(z,l,j,j')$ is equivalent to $V_C(z,l,0,j,j')$ in Equation 4 aside from two exceptions:

1. The bailed-in bank must pay an extra cost c_B^j to reflect the cost of the bail-in process.
2. The bailed-in bank cannot issue dividends in the period of the bail-in.

The assumption of the additional resolution cost c_B^j is made for two reasons. First, the cost could reflect opportunity costs. While the bank is being resolved, it may not be able to generate loans or acquire funding at the same capacity as in normal times. Therefore, we can expect some decline in the bank's profitability. Second, BRRD has focused on putting more onus on the banks for their own complexity and failure than on the entities resolving them. For example, BRRD includes a mandata for banks to submit regular recovery plans, outlining their plans to reduce risk and increase capital and liquidity in the case of distress. This demonstrates that these costs are expected to be born by the bank itself and not the governments. The second assumption, that dividends cannot be paid during the period of bail-in, is taken straight from the BRRD and means that $V_C^I(z,l,j,j')$ will more closely resemble $V_{C,R}(z,l,0,j,j')$. Therefore, the problem of a bailed-in bank can be written as

$$\begin{gathered} V_C^I(z,l,j,j') = max_{d,l',b'} \quad d + \beta \mathbb{E}_{z'|z} V(z',l',b',j') \\ \text{s.t.} \\ l' = e' + \delta^{j'} + q_C(z,l',b',\delta^{j'})b' \\ e' = zl - (1+r_D)\delta^j - (1-\lambda^j)d - c_O^j(l') - c_B^j \\ \frac{e}{l'} \geq \alpha \\ l' \geq 0, \quad b' \geq 0, \quad d \leq 0. \end{gathered} \tag{19}$$

The payout to the creditors is then $\min\{b, \mathbb{E}_{j'|j}(V_C^I(z,l,j,j'))\}$.

To price the uninsured debt in the counterfactual model, define $\Delta_C(z,l,b,\delta^j)$ as the exit decision for a bank with return z, loans l, debt b, and deposits δ^j. The set of return realizations such that a bank would choose to exit is

$$X_C(l,b,\delta^j) = \{z \in Z : \Delta_C(z,l,b,\delta^j) = 1\}. \tag{20}$$

The profit an intermediary makes on a loan contract to a bank with current return z, new loans l', new debt b', and new deposits $\delta^{j'}$ is then

$$
\begin{aligned}
\Omega_C(z,l',b',\delta^{j'}) = \underbrace{-q_C(z,l',b',\delta^{j'})b'}_{\text{debt lent}} + \frac{1}{1+r_f}[&\underbrace{(1-\sum_{z'\in X_C(l',b',\delta^{j'})} G(z'|z))b'}_{\text{repayment - no exit}} \\
&+ \underbrace{(1-\mu(j',l'))\sum_{z'\in X_C(l',b',\delta^{j'})} \min\{b', \max\{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}, 0\}\}G(z'|z)}_{\text{repayment - liquidation}} \\
&+ \underbrace{\mu(j',l')\sum_{z'\in X_C(l',b',\delta^{j'})} \min\{b', \mathop{\mathbb{E}}_{j''|j'}(V_C^I(z',l',j',j''))\}G(z'|z)]}_{\text{repayment - bail-in}}
\end{aligned}
\tag{21}
$$

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

$$
\begin{aligned}
q_C(z,l',b',\delta^{j'}) = \frac{1}{1+r_f}[&(1-\sum_{z'\in X_C(l',b',\delta^{j'})} G(z'|z)) \\
&+ (1-\mu(j',l'))\sum_{z'\in X_C(l',b',\delta^{j'})} \min\{1, \max\{\frac{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\}G(z'|z) \\
&+ \mu(j',l')\sum_{z'\in X_C(l',b',\delta^{j'})} \min\{1, \frac{\mathbb{E}_{j''|j'}(V_C^I(z',l',j',j''))}{b'}\}G(z'|z)].
\end{aligned}
\tag{22}
$$

A TBTF subsidy is not as clear here. Varying μ 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 between ρ and μ and in exit 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.

$$
\begin{aligned}
\text{TBTF subsidy}_C(z,l',b',\delta^{j'}) = \frac{1}{1+r_f}[&-\sum_{z'\in X_C^{\mu=0}(l',b',\delta^{j'})} \min\{1, \max\{\frac{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\}G(z'|z) \\
&+ (1-\mu(j',l'))\sum_{z'\in X_C(l',b',\delta^{j'})} \min\{1, \max\{\frac{c_F^{j'}z'l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\}G(z'|z) \\
&+ \mu(j',l')\sum_{z'\in X_C(l',b',\delta^{j'})} \min\{1, \frac{\mathbb{E}_{j''|j'}(V_C^I(z',l',\delta^{j'},\delta^{j''}))}{b'}\}G(z'|z)].
\end{aligned}
\tag{23}
$$

Once again, if we suppose that in equilibrium, banks make the same exit decisions when $\mu = 0 \ \forall \ j, l$ and $\mu > 0$ for at least one j, l combination, or that $X_C = X_C^{\mu=0}$, then the subsidy is

$$
\begin{aligned}
&= \frac{\mu(j', l')}{1 + r_f} [\sum_{z' \in X_C(l', b', \delta^{j'})} \min\{1, \frac{\mathbb{E}_{j''|j'}(V_C^I(z', l', \delta^{j'}, \delta^{j''}))}{b'}\} G(z'|z) \\
&- \sum_{z' \in X_C(l', b', \delta^{j'})} \min\{1, \max\{\frac{c_F^{j'} z' l' - c_R^{j'} - \delta^{j'}}{b'}, 0\}\} G(z'|z)].
\end{aligned} \tag{24}
$$

The counterfactual equivalents to Equations 15 and 16, or the mass and law of motion equations, respectively, are then

$$
M_C = \sum_Z \int_{L,B} \sum_J (1 - \mu(j, l)) \Delta_C(z, l, b, \delta^j) \Gamma_C(z, dl, db, j) \tag{25}
$$

and

$$
\begin{aligned}
\Gamma'_C(\bar{Z}, \bar{L}, \bar{B}, \bar{J}) = \sum_{\bar{Z}} \int_{\bar{L}, \bar{B}} \{ \sum_{\bar{J}} \sum_Z \int_{L,B} \sum_J [(1 - \Delta_C(z, l, b, \delta^j)) \mathbb{1}_{l'=h_C^l(z,l,b,j,j'), b'=h_C^b(z,l,b,j,j')} \\
+ \mu(j, l) \Delta_C(z, l, b, \delta^j) \mathbb{1}_{l'=h_I^l(z,l,b,j,j'), b'=h_I^b(z,l,b,j,j')}] \Gamma_C(z, dl, db, j) F(j'|j) \} dl' db' G(z'|z) \\
+ M_C \sum_{\bar{Z}} \int_{\bar{L}, \bar{B}} \sum_{\bar{J}} \mathbb{1}_{l'=h_E^l(z,j'), b'=h_E^b(z,j')} \Gamma_C(z, dl, db, j') \bar{\Phi}(j') \bar{G}(z)
\end{aligned} \tag{26}
$$

where $h_I^l(z, l, b, j, j')$ and $h_I^b(z, l, b, j, j')$ are the loan and debt decision rules, respectively, for bailed-in banks.

To solve for the counterfactual model, values for the bail-in cost and the probabilities of bail-in must be chosen. The following results are for the parameterization $\mu = \rho$, for all values of j, l, and $c_B^j = 1$. In the future, I will test different values for c_B^j and μ and study how the solution changes. I expect that the number of bail-ins will decrease in the value of c_B^j and increase in the value of μ. The total number of bank exits is less clear. The decreasing of the TBTF subsidy through either a decrease in μ or an increase in c_B^j could make the banking industry less profitable and therefore increase number of liquidations. This could also lead to fewer entrants.

Table 5 compares distributional moments between the benchmark and counterfactual models. While the liquidation rate has not changed substantially, the rate of big bank resolution via either bailout or bail-in is reduced significantly. In the benchmark model, 2.62% of banks were bailed out in the steady state equilibrium while only 0.02% are bailed in under the counterfactual. The reason for this stark difference is the payout to shareholders and creditors under bailout versus bail-in. In the bailout, creditors were guaranteed 100% of their claim, which led to cheaper prices on uninsured debt for banks. Under bail-in, though, in equilibrium, the value of the new shares that the creditors receive in place of their debt claim range from 91-94% of their original claim. Because the creditors now take a haircut, they price the debt at higher prices, reducing the ability of banks to borrow so much debt. This can be seen in Figures 4 and 5 which plot the distribution of banks across loans and uninsured debt and the histogram of uninsured debt to loans ratios, respectively. Both figures show that the uninsured debt holdings under the counterfactual are much less than under the benchmark model. The median uninsured debt to loans ratio of continuing banks is 51.06% compared to 82.15% under the benchmark.

Additionally, because the creditors are not fully repaid in bail-in, the original shareholders lose their entire claims. This is starkly different from the bailouts where in equilibrium, the value of the bailed out bank to the shareholders ranges from 2.89 to 6.89 billion €(the average value of a bank is 20.38 billion €). Therefore, not only is it more expensive to borrow so much debt, but the shareholders have much more to lose if the bank is bailed in than if it were bailed out. Another way to see that the value of the bail-in for the shareholders is reduced is that there is no longer a stark cutoff in the distribution at the TBTF threshold. In Figure 4, there is positive mass of banks surrounding the 100 billion €cutoff. As the shareholders receive zero from both liquidation and bail-in, they no longer have an incentive to stay above the TBTF threshold.

The steady state distribution across the loan returns z can be found in Table 7. This distribution is closer to the ergodic distribution given by the Markov process for z as described in Table 4, but this means that there are more banks with the z_M and z_L returns in equilibrium. While this implies lending is less productive in equilibrium, the median dividend to loans ratio of continuing banks is now 0.10%, compared to -0.10% under the benchmark.

The higher dividend payments could suggest that the industry is more profitable with the introduction of bail-ins, most likely due to the lower exit rate. However, the concern of regulators is not about the profits of bank shareholders, but the amount of vital banking activity being provided. They are more concerned with if this increase in profitability means more lending by the banks. I calculate the change in total lending between the benchmark and counterfactual models to see if the new regulation decreases lending by the banks in the stationary distribution. I find that total lending under the counterfactual is 4.22% less than under the benchmark model. This decrease is from the shift in the distribution of loans. Banks do not grow as large under the counterfactual as they do under the benchmark, most likely do to the removal of the moral hazard brought on by the bailouts.

The change in repayment to creditors is also reflected in the TBTF subsidy. The median subsidy on debt prices under the counterfactual is 0 basis points, much smaller than the 151 basis point subsidy in the benchmark. However, this is more due to the fact that there is a larger proportion of big banks who have no probability of exiting next period under the counterfactual than under the benchmark. When a bank has no probability of entering resolution next period, the price of its debt is set at $\frac{1}{1+r_F}$, and therefore, there is no TBTF discount as this bank is already safe. Therefore, I look at the maximum TBTF subsidy under each equilibrium. Under the benchmark, this is 339 basis points, and is reduced to

227 basis points under the counterfactual, due to the reduced value to shareholders under the bail-in than the bailout. almost half of the median subsidy of 19 basis points under the benchmark.

6 Conclusion and Next Steps

In this paper, I develop a model of the EU banking industry to evaluate the effects of resolution policies on industry dynamics. Heterogeneous banks fund risky lending via a mix of equity, insured deposits, and uninsured debt in order to maximize current and future dividends to shareholders. Banks are subject to capital requirements, and when they fall below this requirement, are sent into resolution. In the benchmark model, big banks have a probability of being bailed out instead of the standard liquidation. The bailout is an equity injection that guarantees the repayment to current creditors. Therefore, in equilibrium, creditors price their debt to big banks lower than would be suggested due to their risk. This TBTF subsidy on the debt is heavily documented in the literature. I then adapt the model to replace this probability of bailout for big banks with one of a simplified version of the bail-in tool included in the BRRD. 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 99% 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 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 debt to loans ratio under the counterfactual than benchmark to avoid needing to exit and having no funds to pay out to shareholders. The "too big to fail" subsidy is reduced under the counterfactual to reflect decreased payouts to creditors under bail-in.

In my model, the bail-in policy decreases the leverage of banks and leads to less liquidation of banks as well as a substantially lower failure rate of big banks. The TBTF subsidy on the debt of the big banks is reduced. These findings suggest that the bail-in policy achieves its goal of promoting market discipline and enhancing financial stability.

The next step for this paper will be to estimate the model to the pre-Global Financial Crisis period using Simulated Method of Moments. I will also study the sensitivity of the bail-in results to the bail-in probability parameter, μ, the TBTF threshold, $\bar{l}$, and the fixed cost of bail-in, c_B. Additionally, I would like to build in more features of the bail-in tool. For example, I am currently converting all uninsured debt into equity in the bail-in. In the future, I will convert uninsured debt until a capital requirement is met and then the rest of the debt will remain as debt claims. An additional feature is that the EU has created a Resolution Fund to assist in the resolution of big banks, which is funded ex-ante by imposing a cost onto large banks in the industry. Then, if the bail-in tool is used on a bank and a minimum of 8% of total liabilities have already been imposed as losses on the shareholders and creditors, the fund could provide a loan to the bailed in bank. However, my model suggests that bail-in is very rare. Therefore, imposing a ex-ante cost on the banks for such a rare event may be an unnecessary burden. It may be optimal to fund the Resolution Fund ex-post, as is written in the US's Orderly Liquidation Authority policy. By writing this Resolution Fund into my model, I can evaluate situations such as these.

One final aspect to banking I would like to incorporate into my model is to allow the banks to invest in safe securities instead of only loans. Extensive literature states that the TBTF subsidy on debt allowed banks to do more risky lending than they would if the debt were more expensive. Adding safe securities as another asset to the model would allow me to study the mix of safe securities and risky loans banks make under each resolution policy.

Finally, I plan to perform additional counterfactual experiments. First, I will study the effect of size-dependent capital requirements in both the benchmark and counterfactual environment. Size-dependend capital requirements, which were included in many post-crisis reforms, may reduce the need for special resolution policies for big banks in the first place if they assist big banks in being more prepared to absorb losses in the first place. Additionally, I would study a new form of resolution that is a mix of bailout and bail-in. This policy was suggested in the US during the GFC, but was passed over in favor of bailouts. In this policy, shareholders of the failing big bank would automatically lose their claims, as is expected to happen in a bail-in. However, the bank would be recapitalized via equity injections as in the bailouts rather than converting the debt claims as in bail-ins. This will preserve the value of creditors, but not shareholders. Therefore, we would still expect to find a TBTF subsidy on the debt of big banks. However, because the shareholders will automatically lose everything in the event of failure, they may still take the necessary precautions to prevent themselves from failing. Evaluating this counterfactual will assist in decomposing two channels of the resolution policies, guarantees to creditors and guarantees to shareholders, to determine which plays a greater role in bank decisions.

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Table 1: Parameters and Moments

Parameters	Moments
c^j_{O1}	Exit Rate of Each Type
c^j_{O2}	Median Change in Assets for Continuing Incumbents of Each Type
c^j_{O3}	Median Debt/Assets for Continuing Incumbents of Each Type
c^j_R	Median Debt/Assets for Liquidated Banks of Each Type
λ^j	Median Equity Issuance/Assets for Continuing Incumbents of Each Type
c^j_F	Standard Deviation of Debt/Assets for Continuing Incumbents of Each Type
	Median Percentage of Assets Received as Bailout Funds

Table 2: Current Parameter Values

c_{O1}	2.0
c_{O2}	0.011
c_{O3}	0.0001
c_R	1.0
λ	0.0625
c_F	0.72
r_D	0.0176
β	0.9827
r_F	0.0176
α	0.04
α_r	0.02
δ	18B

Table 3: Markov Process for Loan Returns

	z_H	z_M	z_L
z_H	.75	.24	.01
z_M	.2	.75	.05
z_L	0	.9	.1

Table 4: Ergodic Distribution Across Z

	z_H	z_M	z_L
Mass	0.4291	0.5364	0.0346

Table 5: Benchmark and Counterfactual Model Moments

	Benchmark	Counterfactual
Liquidation Rate	0.65%	0.44%
Bailout/Bail-in Rate	2.62%	0.02%
Median Loans	129.55 B	101.14 B
Median Uninsured Debt to Loans Ratio of Continuing Banks	82.15%	51.06%
Median Change in Loans of Continuing Banks	-0.33%	0.00%
Median Dividend to Loans Ratio of Continuing Banks	-0.10%	0.10%
Median Uninsured Debt to Loans Ratio of Bailout/Bail-in Banks	79.15%	83.27%
Median Change in Loans of Bailout/Bail-in Banks	-82.81%	-12.91%
Median Dividend to Loans Ratio of Bailout/Bail-in Banks	-0.52%	-0.93%

Table 6: Benchmark Distribution Across Z

	z_H	z_M	z_L
Mass	0.4363	0.5299	0.0338

Table 7: Counterfactual Distribution Across Z

	z_H	z_M	z_L
Mass	0.4321	0.5336	0.0343

Figure 1: Benchmark Model Distribution of Debt to Loans Ratio

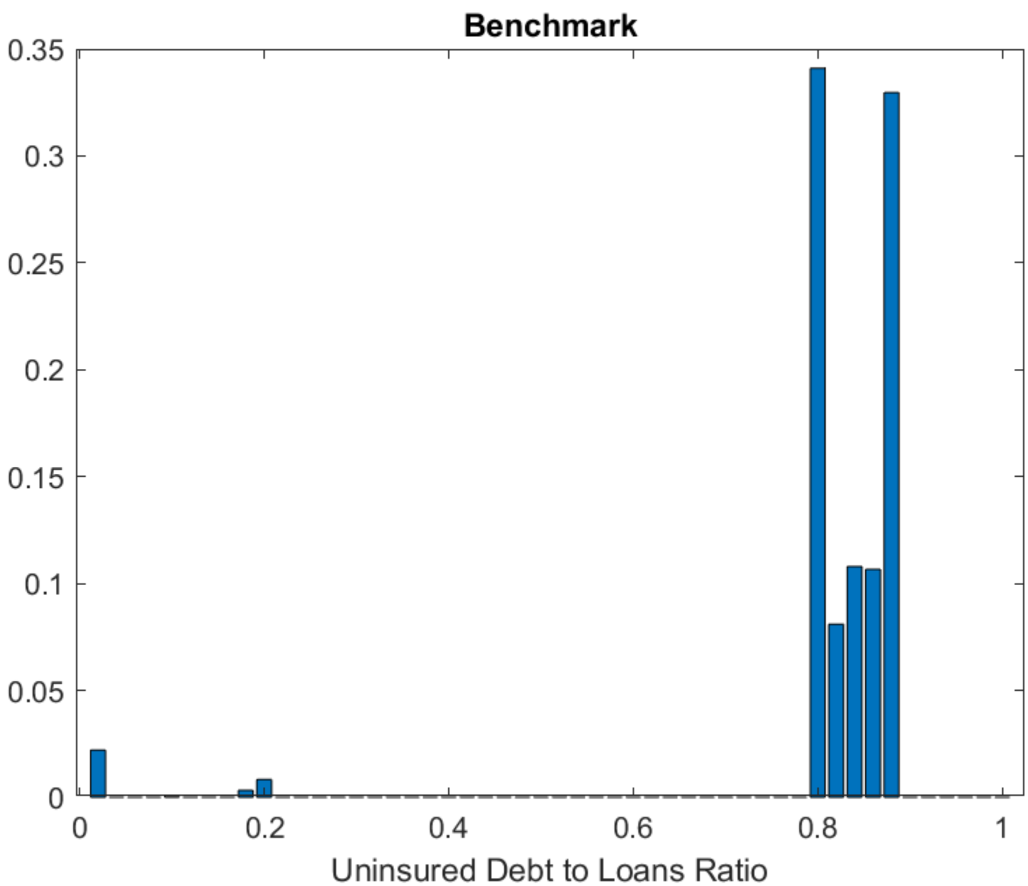

Figure 2: Benchmark Model Distribution Across Loans and Uninsured Debt

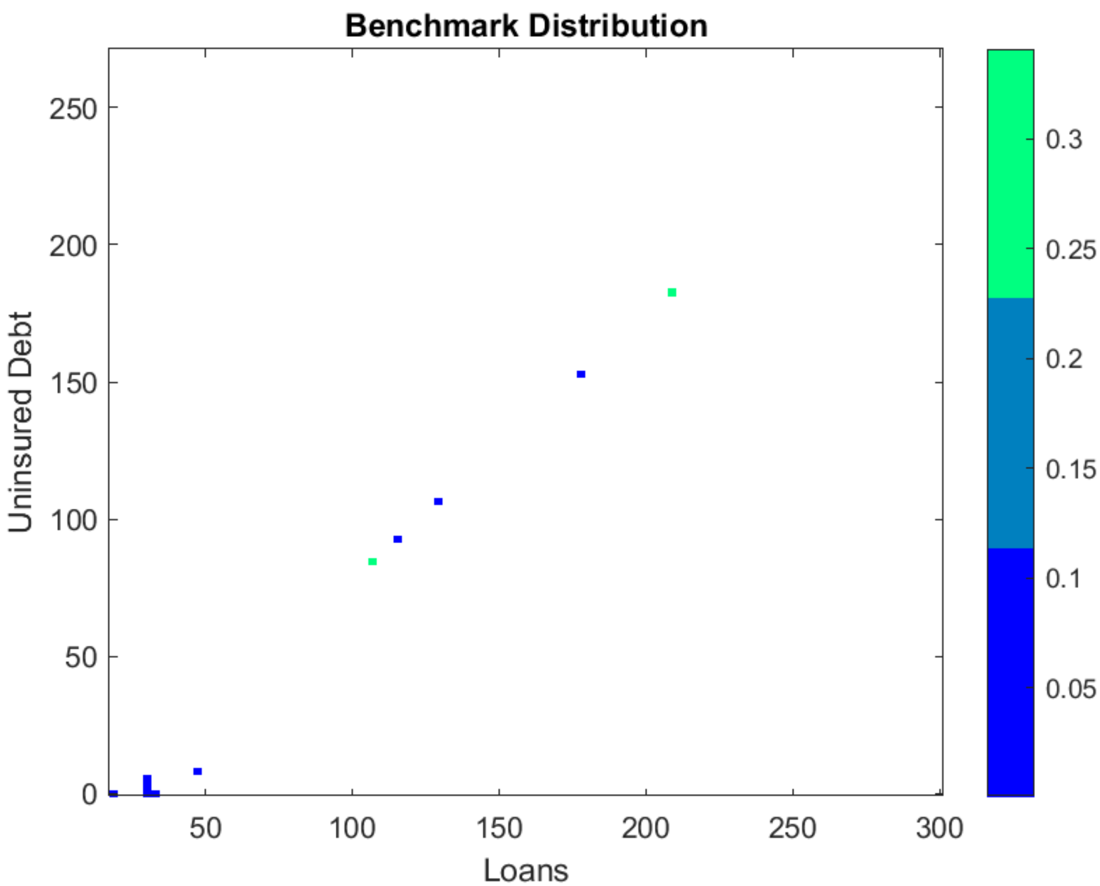

Figure 3: Benchmark Model Dividend versus Equity Issuance Decision

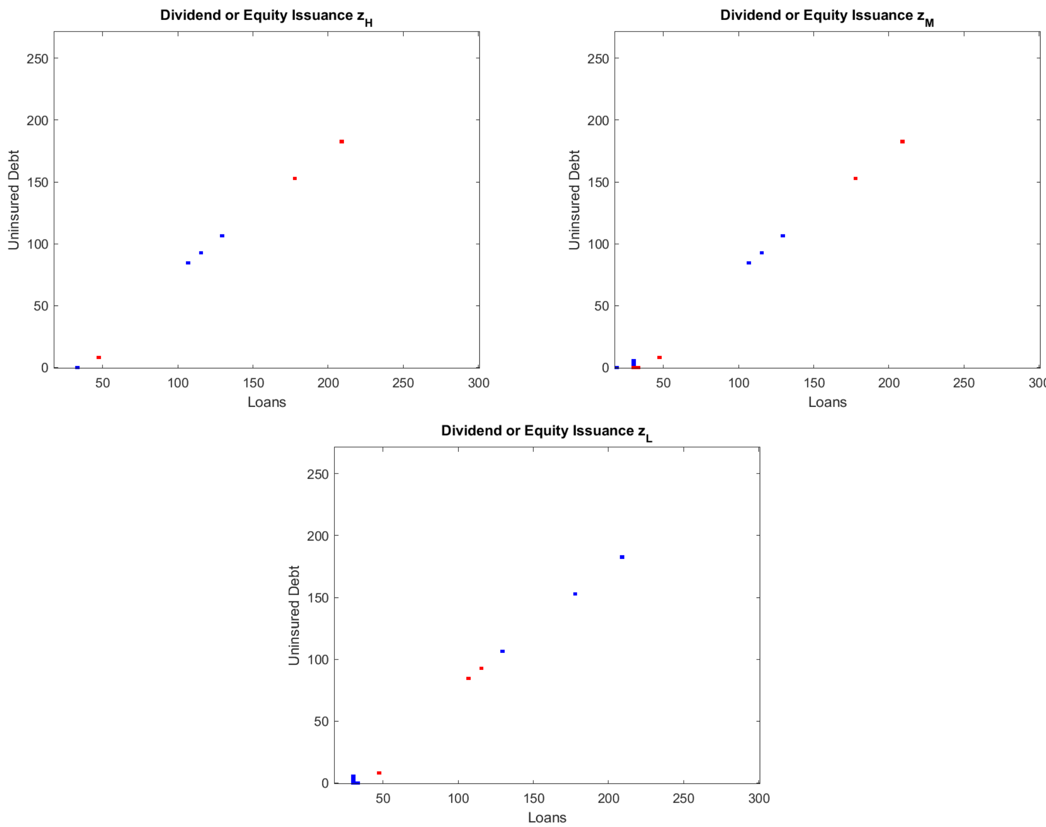

Figure 4: Counterfactual Model Distribution Across Loans and Uninsured Debt

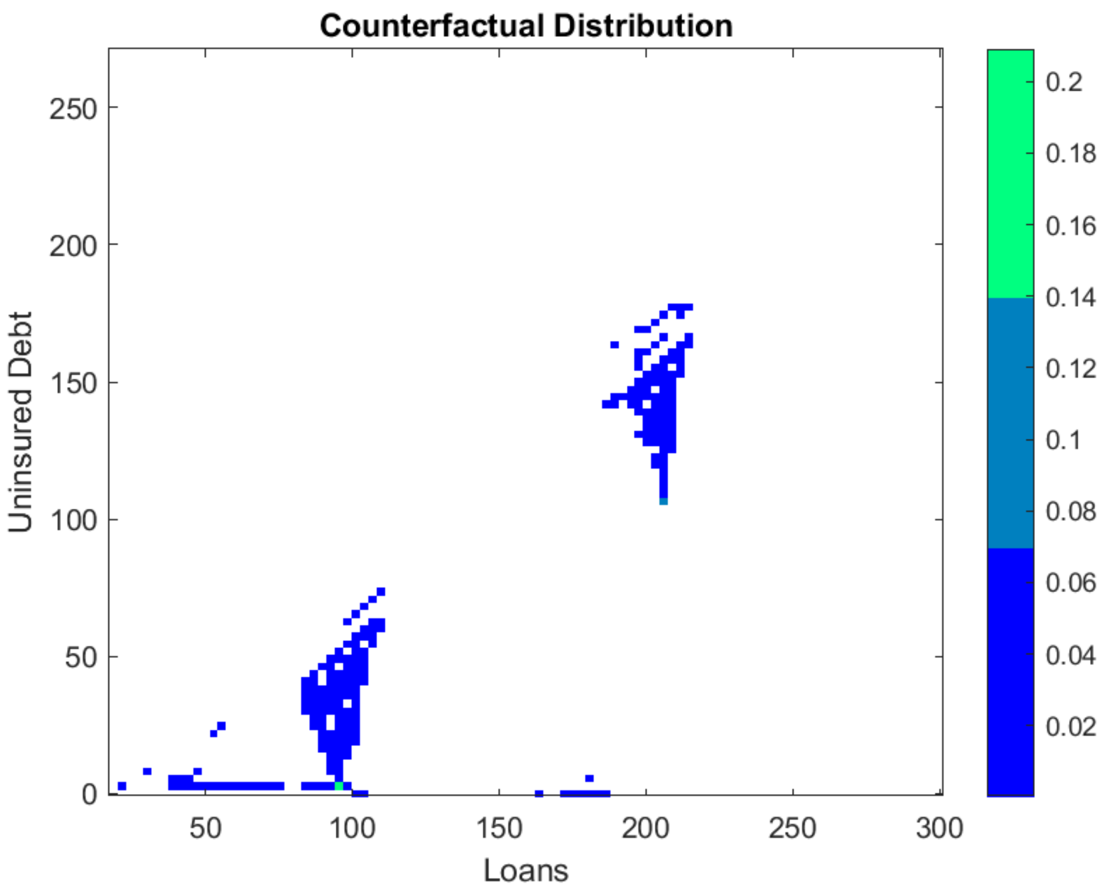

Figure 5: Counterfactual Model Distribution of Debt to Loans Ratio

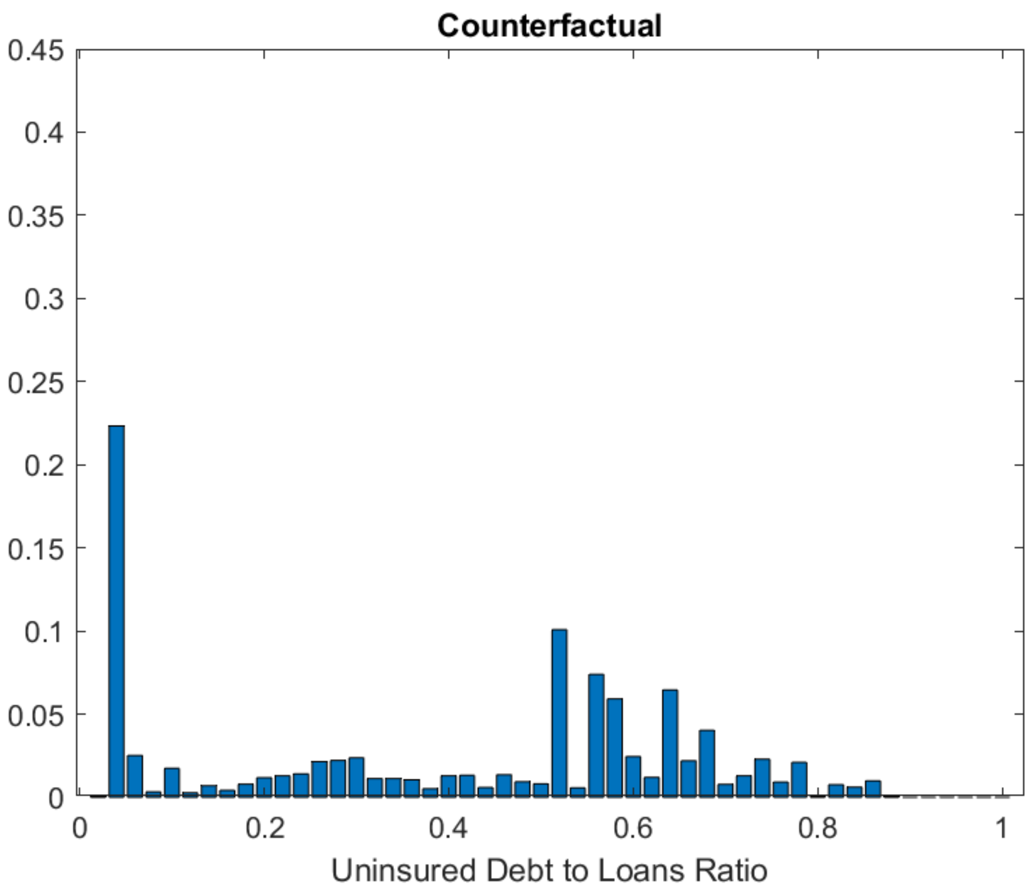

Figure 6: Counterfactual Model Dividend versus Equity Issuance Decision