Bank Bailouts, Bail-ins, or No Regulatory Intervention? A Dynamic Model and Empirical Tests of Optimal Regulation *

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Abstract

We develop and test a dynamic model of optimal regulatory design of three regimes to deal with distress of large banking organizations. These are 1) bailout, as under TARP; 2) bail-in, as under Orderly Liquidation Authority; and 3) no regulatory intervention, as under Financial CHOICE Act. We find that no regulatory intervention is suboptimal relative to the other two regimes and that only bail-in provides incentives for banks to rebuild capital preemptively during distress. Empirical tests of changes in capital ratios and speeds of adjustment when shifting from the pre-crisis bailout regime to the post-crisis bail-in regime corroborate model predictions.

JEL Classification Codes: G21, G28

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"I was never able to convince the American people that what we did with TARP was not for the banks. It was for them. It was to save Main Street. It was to save our economy from a catastrophe." **(Henry Paulson, former Secretary of the Treasury, Five Years from the Brink, Bloomberg BusinessWeek, Sep 2013).**

"Eliminating OLA would be a major mistake because these are essential tools for ensuring that financial stress does not escalate into a catastrophic crisis. We saw what happens without OLA. We saw it...it's 2008. We don't want that again." **(Ben Bernanke, former Chairman of the Federal Reserve System 2006-2014, Remarks at the Brookings Institution Falk Auditorium on Is Dodd-Frank's Failure Resolution Regime Failing?, Jun 2017)**

"Every promise of Dodd-Frank has been broken...Fortunately there is a better, smarter way. It's called the Financial Choice Act. It stands for economic growth for all, but bank bailouts for none. We will end bank bailouts once and for all. We will replace bailouts with bankruptcy." **(Jeb Hensarling, Financial Services Committee Chairman, Press Releases, House Approves Financial Choice Act to Boost Economy, End Bank Bailouts and Toughen Penalties for Fraud, Jun 2017).**

1 Introduction

As seen in the financial crisis of 2007-2009, the failure of large, complex financial institutions (e.g., Lehman Brothers) can cause or worsen a financial crisis, threaten the financial system, and cause large real economic losses. To mitigate such problems, regulators design regimes for handling the financial distress and impending potential failure of large banking organizations. In particular, when the capital ratios of such institutions reach critically low levels, regulators decide among regimes of 1) bailouts, government injections of capital; 2) bail-ins, private sector injections of capital; or 3) no regulatory intervention, allowing the institutions to fail.

Coupled with these regimes, regulators employ other prudential regulatory tools as "first lines of defense" to reduce the chances that the institutions become financially distressed and trigger the resolution regimes. Such tools include traditional capital standards that impose capital minimums based on historical patterns, and stress tests that base capital minimums on forward-looking adverse scenarios. These tools often come with restrictions on financial institutions that fail to meet the standards, such as limits on dividends and share buybacks.

These resolution regimes are key topics of debate, as witnessed by the quotes above that defend each of the three regimes. Prior to the financial crisis, most large, complex U.S. bank holding companies (BHCs) likely perceived that they were in a bailout regime, which was actualized by the Troubled Asset Relief Program (TARP) and other bailouts during the crisis. After the crisis, the Dodd-Frank Act of 2010 imposed the Orderly Liquidation Authority (OLA), a type of bail-in in which shareholders of distressed institutions lose their shares and junior debtholders have some or all of their debt claims turned into equity capital. The Financial CHOICE Act – which would replace OLA with a no-regulatory-intervention regime of bankruptcy for large BHCs – is currently under congressional consideration. In February 2018, the U.S. Treasury recommended keeping OLA for the largest institutions, and making bankruptcy easier for others.

Researchers and practitioners recognize structural differences among these regimes. However, there is no consensus on how these regimes should be optimally designed, and how aggressive these regimes should be in taking actions against distressed banks, such as intervening at relatively high or low bank capital ratios. Nor is there an agreement on the relative benefits of each regime. Addressing these questions requires not only static analysis of the *ex post* consequences of the regimes, but also dynamic analysis of how the anticipation of bailout, bail-in, and no regulatory intervention affects the *ex ante* behavior of the financial institutions. These regimes may differ in the incentives they generate for the institutions to manage their own capital to avoid regulatory intervention or default.

We contribute to these debates by dynamically modeling the regimes and empirically testing the model's implications. We explicitly model one single BHC which owns one bank. BHCs choose their initial capital structures – bank capital and senior debt, BHC shareholders' equity, and subordinated debt – in response to the three regulatory regimes, as well as any subsequent recapitalization decisions. In the model, the representative bank's asset value is stochastic and subject to infrequent negative random jumps or sudden falls in capital, such as those due to financial crises. These jumps may result in regulatory interventions or default.

In the bailout regime, regulators inject equity capital and acquire a fair-priced partial stake when the bank's capital falls to some critical distress level. Under bail-in, existing BHC shareholders' equity is wiped out and subordinated debt converts to BHC shares, possibly at a loss. For both of these regimes, regulators optimize for each BHC the trigger points – the capital ratios at which interventions occur. Finally, under no regulatory intervention, the BHC is allowed to fail. To mimic the regulatory environment, we also incorporate stress tests into bail-in and no-regulatory-intervention regimes. If the bank's capital ratio falls below the stress test critical capital ratio (i.e., fails the stress test), the BHC has to suspend dividends and retain earnings to rebuild its capital. In response to the prevailing regime, the BHC maximizes its own private value by endogenously choosing its initial capital structure. It also dynamically adjusts its capital ratio over time, choosing whether and at what capital ratio it raises additional equity to avoid bailout, bail-in, or default.

In designing socially optimal policies, the regulator maximizes a very simple social welfare function that balances the benefits of the efficient provision of financial services by large financial institutions with costs of disruptions to the financial system and the real economy associated with the failure of these institutions. Motivated by this objective, we assume that the regulator maximizes the value of the BHC minus the expected external social costs from its default. In doing so, regulators take into account the self-optimizing responses of the BHC. Each of the three regimes is optimally designed to use the tools at hand (bailout, bail-in, stress test) to incentivize the BHC to make capital structure decisions that enhance financial system stability without significant harming their private values.

The model is calibrated to be roughly consistent with the observed characteristics of large U.S. BHCs prior to and after the financial crisis. We calculate and compare optimally-designed pure-play bailout, bail-in, and no-regulatory-intervention regimes, assuming that the BHC chooses its optimal capital structure strategies to maximize shareholder value for each of the regimes.

We find that the optimally-designed bailout and bail-in regimes attain comparable values of social welfare function and both dominate the no-regulatory-intervention regime, suggesting that more intrusive regulatory policies of bailouts and bail-ins are more effective in reducing chances of bank failures than the stress test alone that is employed in the no-regulatory-intervention regime. However, bailouts produce somewhat lower social welfare values than bail-ins if the costs of using and risking taxpayers' funds and transaction costs of raising and distributing these funds are incorporated in the social welfare function.

Several other factors also favor bail-ins over bailouts. Both the dynamic model and the empirical results suggest that bail-ins provides BHCs better incentives to hold higher capital and to recapitalize during financial distress, resulting in a safer banking industry. We also find that the optimal trigger for the bail-in regime occurs at a higher capital ratio than for the bailout regime, providing strong incentives for the BHCs to choose higher capital ratios and manage their capital more prudently under the bail-in regime.

Our findings demonstrate that the optimal resolution design requires a delicate balance. For example, a bail-in regime should not be too aggressive, i.e., should not intervene at such a high capital ratio as to inefficiently constrain bank's activity. However, it needs to be aggressive enough to provide incentives that promote socially prudent behavior.

Another implication is that a "one size fit all" resolution design is suboptimal. Instead, regulators should implement regulations on a case-by-case basis that reflect each BHC's individual characteristics. For a given regime and set of bank characteristics, there are interior solutions for both the optimal regulatory trigger and the stress test critical capital ratio that maximizes social value. Thus, each regime should allow for regulatory discretion in setting triggers across BHCs, as opposed the same rules uniformly applied to all institutions.

Importantly, several of the outcomes are unique to the dynamic model, and go beyond the limits of static models. For example, the effects of high asset volatility on the optimal bailout trigger are directly opposite to the effects on the optimal bail-in trigger. In our model, the regulator is optimally less aggressive under the bailout regime for banks with more volatile assets, triggering bailouts at lower capital ratios than for those with less volatile assets. In contrast, for bail-ins, the regulator is optimally more aggressive for banks with higher asset volatility. The main reason is that the two regimes structurally differ in the incentives they create for BHCs. Higher volatility increases the debt overhang problem, which can reduce the BHCs' incentive to preemptively raise capital to avoid wiping out shareholders, necessitating more aggressive optimal bail-in for these BHCs. This argument does not apply for bailouts, which provide no incentives for BHCs to rebuild their own capital. Such findings cannot be derived from a static model in which the optimal dynamic adjustments of BHCs' capital structures in response to regulation are not taken into account.

Another model implication is that when the regime shifts from bail-in to no regulatory intervention, the BHCs optimally responds by increasing capital. This implication is again inconsistent with static intuition, under which the threat of being "wiped out" in bail-in resolution implies higher initial capital. In contrast, in the dynamic model, the BHC endogenously pre-commits to rebuild capital in response to negative shocks in the bail-in regime. This pre-commitment leads to lower costs of debt, higher debt capacity, lower initial capital, and larger tax shields. In contrast, the no-regulatory-intervention regime provides no such pre-commitment.

We acknowledge several limitations of our model. First, we deliberately abstract from regulatory ambiguity and assume that all agents know which regime is in place. The purpose is to see which pure-play regime is best in terms of maximizing social value. We recognize that some regulatory ambiguity is unavoidable in practice.

The model may also overstate the net social benefits of the bailouts by assuming that bailouts occur in a timely fashion that avoids direct subsidies or "free money" to failing institutions. When public funds are injected, the regulator takes a fair-market stake in the bank, which leads to dilution of the existing shareholders. In practice, however, bailouts are often executed too late and subsidize bank shareholders at taxpayer expense. In addition, the model may understate the social benefits of the bail-in regime relative to bailouts by focusing only on capital structure decisions. The bail-in regime may have additional benefits in terms of reducing incentives to shift into riskier assets, and lessening unfair competitive advantages of banks that are too big or interconnected to fail. While these other effects are important, they cannot all easily be incorporated into a single comprehensive dynamic model.[6]

Finally, the stress tests in our model are a combination of actual stress tests and capital standards. They combine the restrictions on dividend payments and share buybacks of stress tests and the minimum requirements of capital standards. We do not model the forward-looking adverse scenarios of the real-world stress tests because they are difficult to incorporate in our dynamic model and would detract from our main focus on resolution regimes.

We empirically test a number of model predictions. Specifically, we test how well BHC capital decisions correspond to the predictions about shifting from a bailout to a bail-in regime using the observed shift from the bailout period before the financial crisis to the bail-in period after the financial crisis.

For these tests, we specify 2000:Q3 to 2007:Q2 as the bailout period, when the largest U.S. BHCs likely expected that they would be bailed out in the event of severe financial distress. We use the time after the passage of the Dodd-Frank Act put OLA into effect from 2010:Q3 to 2017:Q2 as the bail-in period. We exclude the tumultuous period of the financial crisis itself in which the bailouts actually occurred from the empirical analysis.

We use quarterly financial data for the top 50 publicly traded U.S. BHCs during the bailout and bail-in periods. We consider the eight large, complex U.S. banking organizations designated as Globally Systemic Important Banks (G-SIBs) as the treatment group most likely to be subject to bailouts and bail-ins, and the remaining 42 BHCs as the control group. As argued in the empirical section below, our empirical approach is based on the assumption that these G-SIBs were more likely to expect bailouts than the other BHCs prior to the financial crisis and more likely than

[6]To illustrate, Veronesi and Zingales (2010) and Glasserman and Wang (2015) find subsidies to TARP bailouts' recipients, and Tsesmelidakis and Merton (2013) find subsidies to financial institutions that are considered "too big to fail" in terms of cheaper funding costs.

the others to expect bail-ins after Dodd Frank. We recognize that this division is imperfect. In robustness tests, we experiment with alternative treatment and control groups, and the results are largely robust.

We test the model predictions that in moving from the bailout period to the bail-in period, the treated G-SIB group raised their capital ratios more and increased their speeds of adjustment toward target capital ratios more than the control group. The data are consistent with both predictions, and line up remarkably well with the quantitative predictions of the model as well. For example, the model base case predicts a 2.7 percentage point increase in the BHC's optimal capital ratio when moving from the bailout to the bail-in regime, while the difference-in-difference empirical results show 1.0 to 2.7 percentage point increases in the G-SIBs capital ratios relative to the control group moving from pre-crisis to post-crisis. Similarly, our empirical results for speed of adjustment toward target capital ratios show that G-SIBs more than doubled their adjustment speeds post-crisis, while the control group BHCs did not significantly change their adjustment speeds, consistent with model predictions that the bail-in regime provides incentives to recapitalize.

The remainder of the paper is organized as follows. Section 2 briefly discusses our contributions to the theoretical and empirical literatures. Section 3 provides information on regulatory environments of the past, present, and potential future to put the paper into context. Section 4 presents the dynamic model of the three regimes, giving a timeline, followed by model implications and empirical predictions. Section 5 offers our empirical analysis, and Section 6 contains conclusions and policy implications. Appendix A presents the analytics of the model solution, and Appendix B gives additional empirical results.

2 Contributions of the Paper

We add to the theoretical and empirical literatures on regulatory resolution regimes. Some theory papers use dynamic continuous-time models to tackle related issues. Hugonnier and Morellec (2017) show that banking organizations facing minimum liquidity and leverage requirements choose more reserves and higher capital, lowering the likelihood of default and reducing losses given default. Sundaresan and Wang (2016) examine optimal leverage choices when facing runs and closure. They find that institutions optimally set the levels of subordinated debt and capital such that the endogenous default boundary coincides with closure boundary. Unlike these papers, we examine the effects of bailout, bail-in, and no-regulatory-intervention regimes, and the transitions between regimes. Another key contribution is that we analyze the optimal terms of the regulatory regimes.

There are also several static models of optimal regulatory interventions. Philippon and Schnabl (2013) solve for the optimal regulatory intervention via equity injection to reduce a debt overhang problem. Farhi and Tirole (2012) also characterize optimal regulation, including minimum liquidity requirements and restrictions on liquid assets. Allen, Carletti, Goldstein, and Leonello (2017) consider an equilibrium model in which bank runs and depositors' decisions are endogenously determined by the amount of government guarantees. In contrast to these static models, our model is dynamic, and allows for BHC's capital structure to be endogenously determined, depending on the "aggressiveness" of the regulatory interventions. Thus, we model the optimal responses of the BHCs to the regulatory regimes, and form the optimal regulatory regimes based on these optimal responses of the BHCs.

Turning to the empirical literature, we contribute to the findings on banking capital structure determinants by analyzing the effects of the different regulatory regimes and prudential regulatory tools. This literature finds that in addition to regulation, BHCs' capital structures are influenced by financial factors (e.g., Berger, DeYoung, Flannery, Lee, and Öztekin, 2008) and governance pressures from other stakeholders (e.g., Flannery and Sorescu, 1996; Morgan and Stiroh, 2001; Martinez Peria and Schmuckler, 2001; Calomiris and Wilson, 2004; Ashcraft, 2008; Flannery and Rangan, 2008; Lepetit, Saghi-Zedek, and Tarazi, 2015).

We also add to the empirical findings on bailouts, most of which focus on the U.S. TARP program. Most of the findings suggest increases in credit supply from the TARP bailouts (e.g., Berrospide and Edge, 2010; Black and Hazelwood, 2013; Li, 2013; Duchin and Sosyura, 2014; Puddu and Walchli, 2015; Bassett and Demiralp, 2016; Chavaz and Rose, 2017; Berger and Roman, 2017; Chu, Zhang, and Zhao, forthcoming). The results also suggest improved real economic outcomes (Berger and Roman, 2017), increases in individual institution risk (e.g., Black and Hazelwood, 2013; Duchin and Sosyura, 2014), but reductions in systemic risk due to the increases in bank capital (Berger, Roman, and Sedunov, 2018).

Finally, we add to the empirical literature on bail-ins, which is mostly focused on Europe, where bail-ins have occurred. This research finds that bail-ins increase market discipline by depositors, bondholders, stockholders, and CDS holders (Schafer, Schnabel, and Weder, 2016; Boccuzzi and De Lisa, 2017; Giuliana, 2017; Bonfim and Santos, 2018; Brown, Evangelou, Stix, 2018; Neuberg, Glasserman, Kay, and Rajan, 2018). Some also find reduced systemic risk and greater taxpayer protection (e.g., Pellerin and Walter, 2012; Conlon and Cotter, 2014; Avgouleas and Goodhart, 2015; Klimek, Poledna, Farmer, and Thurner, 2015). However, others report undesirable consequences including increased stock market volatility (Leone, Porretta, and Riccetti, 2017), problems in handling simultaneous insolvencies of several large banks and international cooperation (e.g., Persaud, 2014; Mitts, 2015; Avgouleas and Goodhart, 2016; Hadjiemmanuil, 2016). Still others find harm for households that own deposits and subordinated debt at bailed-in banks (Pigrum, Reininger and Stern, 2016; Zenios, 2016; Boccuzzi and De Lisa, 2017) bank borrowers and other connected stakeholders (e.g., Beck, Da-Rocha-Lopes, and Silva, 2017).

In contrast to these studies of actual bailouts and bail-ins, our empirical analysis focuses on the effects of *expectations* of bailouts pre-crisis and *expectations* of bail-ins after the Dodd Frank Act imposed OLA on the capital structures of the BHCs most likely to be subject to bailouts and bail-ins. This setup allows us to test the implications of the dynamic theoretical model, which predicts higher bank capital ratios and faster adjustments toward target capital ratios under expectations of bail-in than expectations of bailout. As noted, our empirical results are highly consistent with the predictions of the theoretical model.

3 Background on Regulatory Regimes

To put the paper in context, we provide background information on four time periods in the U.S. with different regulatory regimes – the pre-crisis bailout regime, the crisis period in which the bailouts were realized, the post-crisis bail-in period, and the potential future period in which no regulatory intervention might prevail.

3.1 Pre-Crisis Bailout Regime

Prior to the financial crisis, large U.S. BHCs likely had reasonable expectations that they were too big to fail and were likely to be bailed out, rather than undergo no regulatory intervention. Bail-in was not a possibility under the laws at that time. All U.S. BHCs were subject to the Basel I risk-based capital standards and non-risk-based leverage requirements. They were also subject to the Prompt Corrective Action (PCA) rules of the FDIC Improvement Act of 1991, which specifies mandatory and discretionary actions to be taken by regulators as capital fell below various trigger points. Under least-cost resolution policies, the FDIC is required to resolve critically undercapitalized institutions capital ratios below 2% by means that minimize the present value of net long-term losses to the FDIC.[7]

While the banking system performed relatively well for a long period of time, PCA rules were not strictly followed and no large commercial banking organizations were closed, potentially due to systemic risk considerations (e.g., Dell'Ariccia, Detragiache, and Rajan 2008; Correa, Lee, Sapriza, and Suarez, 2014).

3.2 Financial Crisis Period in which Bailouts Occurred

During the crisis, expectations of bailouts of large BHCs in financial distress were realized. Among the many assistance programs, the U.S. Treasury TARP injected more than $200 billion in preferred equity capital into 709 financial institutions through the Capital Purchase Program (CPP), with most of the funds going to the largest eight BHCs, all of which were required to participate. Each institution received 1% to 3% of its risk-weighted assets or $25 billion, whichever was smaller.[8]

3.3 Post-Crisis Bail-in Regime

After the crisis, the Dodd-Frank Act introduced the Orderly Liquidation Authority (OLA). OLA is triggered for a large BHC when the Treasury Secretary, in consultation with the President, as well as two-thirds of the Federal Reserve and FDIC boards, finds that the BHC is in default or danger of default, and its failure would have serious adverse financial stability consequences. The critical point of distress may be due to a severe capital shortfall, a liquidity problem, or both. When OLA is triggered, the FDIC temporarily takes over the BHC and fires its management, while banks and other holding company subsidiaries continue to operate. There is also a bail-in in which shareholders are wiped out and subordinated debtholders and possibly other uninsured creditors have part of their debt claims turned into equity capital, so that the BHC becomes well capitalized. The BHC is then returned to private hands with new management.[9]

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[7] For more details for the FDIC resolution process see https://www.fdic.gov/bank/analytical/banking/2001sep/ /article1.html and https://www.fdic.gov/bank/historical/managing/history1-02.pdf.

[8] Other bailouts during the crisis include expanded access to Federal Reserve liquidity through the discount window and Term Auction Facilities (TAF), Federal Reserve quantitative easing (QE) programs, and additional bank guarantees provided by the Federal Deposit Insurance Corporation (FDIC).

[9] See Pellerin and Walter (2012) for details on OLA.

The crisis also resulted in the U.S. stress tests, the 2009 Supervisory Capital Assessment Program (SCAP), and the current Comprehensive Capital Analysis and Review (CCAR), and Dodd-Frank Act Stress Tests (DFAST). These are essentially forward-looking capital requirements intended to ensure that large banking organizations have sufficient capital to remain viable and continue lending even under future adverse conditions (quantitative assessment), and ensure adequate risk management (qualitative assessment).

During the post-crisis period, Basel III capital standards are phased in between January 2013 and January 2019, which apply to all U.S. BHCs with assets over $500 million. These standards represent an increase in required capital. There are also capital conservation buffers that raise the effective capital ratios higher, as well as add-ons for all 30 G-SIBs, including eight large U.S. BHCs.

3.4 Potential Future No-Regulatory-Intervention Regime

The Financial CHOICE Act, H.R.10 of the 115th Congress, was introduced in the U.S. House of Representatives on April 26, 2017 by Representative Jeb Hensarling, and passed the House on June 8, 2017. It would repeal certain provisions of the Dodd-Frank Act of 2010 and other laws. In particular, the CHOICE Act would repeal OLA and allow the FDIC to liquidate a failing financial institution if the institution's imminent failure threatens financial stability. It would establish Chapter 11 bankruptcy for large, complex financial institutions, and under some circumstances convert them into Chapter 7 liquidation bankruptcy.[10]

4 Model

4.1 Model description and time line

We model a bank's dynamic capital structure under three regulatory regimes – bailout, bail-in, and no regulatory intervention. Bank's asset values are stochastic and described by a jump-lognormal process. Random negative jumps of stochastic size are infrequent, representing severe runs or financial crises. Bank cash flows are proportional to assets. Dividends are calculated as a residual cash flow after interest payments, and interest payments are tax deductible.

[10] For more details on the Financial CHOICE Act, see https://www.congress.gov/bill/115th-congress/house-bill/10.

At time 0, the bank issues senior debt and capital, where the bank capital is owned by its BHC. The bank's capital ratio is the ratio of equity to total assets. The BHC can issue both its own shareholders' equity and subordinated debt to finance the bank's capital, often referred to as double leverage.

The capital structures of a representative bank and its holding company are shown in Figure 1 (the figure is not drawn to scale to ease exposition). The bank's capital structure is shown on the left with the 9% of assets financed by capital and 91% by senior debt, roughly corresponding to ratios observed for typical large banks. The right side shows an amalgam of the capital structure of the bank and the BHC that owns it, in which the BHC's shareholders' equity and subordinated debt are superimposed over the bank's capital. In this case, the 9% bank capital ratio is funded by 7% shareholders' equity and 2% subordinated debt.

Both subordinated and senior debt require continuous coupon payments and have the same maturity, but the subordinated debt is junior and absorbs losses first if the bank defaults or is bailed in. At maturity, par values are paid to claimants if neither restructuring nor default have not occurred in prior periods. Following Leland (1994) and Titman and Tsyplakov (2005), we assume that a certain fraction of bank's senior liabilities is continuously repaid at par and reissued at market price, such that the principal value remains unchanged. This structure reflects the fact that in practice, liabilities of large banks are combinations of short- and long-term deposits, overnight federal funds, term wholesale deposits and repo financing instruments, which are rolled over. The higher the rollover rate, the shorter is the effective maturity of senior liabilities relative to subordinated debt. For simplicity, we assume that the rollover rate is constant.

At time 0, the regulator announces that the regulatory regime is bailout, bail-in, or no regulatory intervention. In regimes with stress tests (bail-in and no regulatory intervention), the regulator also specifies a minimum capital requirement below which the bank cannot pay dividends and must retain earnings to rebuild its capital. We assume no regulatory ambiguity – the regulator pre-commits to the trigger point at which the bailout or bail-in will occur for each individual bank as well as the minimum capital requirement.

In anticipation of expected future regulatory interventions, the BHC chooses the bank's capital ratio, and the size of BHC subordinated debt. We assume that subordinated debt remains a constant percentage of total debt through time. The initial capital of the bank is chosen to maximize the market value of the BHC, i.e., the total market value of the equity, senior liabilities and subordinated debt reaches its maximum. After time 0, the bank can raise equity (of any size) multiple times before maturity to move away from trigger or default boundaries. When the bank raises equity capital, it incurs transaction costs with fixed and variable components. The strategy of raising capital is endogenous and chosen to maximize the existing shareholders' equity.

In the bailout regime, the regulator steps in and injects equity capital when the bank's capital ratio declines to or below the trigger point. Consistent with the TARP program discussed in Section 3, we assume that the regulator injects 2% equity as a fraction of the bank assets, and takes a fair market stake in the bank's equity, diluting the claims of the existing shareholders. The shareholders do not incur any transaction costs for the equity injected by the regulator. Notably, in the case of a very large jump, existing shareholders may be wiped out and the market value of the regulator's equity stake might be less than the amount injected. The regulator can bail out the bank multiple times.

Figure 2A illustrates the sequence of events for the bailout regime (again not drawn to scale). It shows on the left the initial capital structure of the BHC, followed by the middle which shows the capital structure after a negative shock that reduces capital to the trigger. We use a bailout trigger of 2.9% capital ratio here, which turns out to be socially optimal for our base case discussed below. The right part of the figure shows the capital structure after the regulator injects equity of 2%.

In the bail-in regime, the regulator steps in as soon as the bank capital ratio declines to or below the predetermined trigger, and the existing shareholders' equity is wiped out. Subordinated debt converts to bank shares at fixed market value. The face value of subordinated debt determines the market value of equity to be owned by subordinated debt holders (could be potentially below par), where the exact number of new shares is calculated after bail-in intervention.[11] After bail-in, the bank continues to operate until maturity or default. Figure 2B illustrates the sequence of events for the bail-in regime. As above, the left part shows the initial capital structure. As shown in the middle and right part of the figure, in response to the negative shock, the regulator intervenes and wipes out existing equity, as well as converts the subordinated debt to equity. The socially optimal bail-in trigger of 3.6% capital ratio shown in the figure (as derived in the model below) is higher than the socially optimal bailout trigger.

[11] The remaining market value of equity stake (if any) will be owned by the regulator.

For the no-regulatory-intervention regime, bankruptcy occurs without intervention. We assume that the BHC files for bankruptcy, when the shareholder's equity declines to zero. In case of default, the BHC is liquidated, shareholders are wiped out, subordinated debt holders are partially or fully wiped out, and the holders of senior liabilities recover the bank's unlevered assets minus proportional default costs. Figure 2C shows the no-regulatory-intervention regime. Regulators allow the BHC to be liquidated and the senior debtholders recover bank assets minus default costs.

For the bailout and bail-in regimes, if asset values fall instantly below book value of senior debt due to the arrival of a large negative jump, the bank is classified as in technical default. For such cases, we assume that the regulator is not able to intervene, the bank defaults, and the BHC is liquidated. Shareholders and subordinated debt holders are wiped out, and the holders of senior liabilities recover the bank assets minus default costs.

To mimic the regulatory regime observed after the crisis (see Section 3), we assume that in the bail-in and no-regulatory-intervention regimes, the regulator also conducts stress tests. BHCs that fail the tests (i.e., if its capital ratio declines below the critical level) eliminate dividends to retain earnings and build capital. We assume no uncertainty about the capital ratio set by the stress tests. These stress tests mimic a combination of actual stress tests and capital standards to allow us to focus on the resolution regimes.

The model quantifies socially-optimal terms of each regulatory regime, including the combination of the critical trigger capital ratios at which the regulator intervenes as well as the stress test parameters. Consistent with observations from the financial crisis, we assume that bank failures create negative externalities for the financial system through interconnections and contagion that make other banks more vulnerable to losses. The regulator socially optimizes by maximizing the value of the bank minus the expected value of the negative externalities from default. In our base case specification, we assume that the external cost of bank default is moderate – a multiple of one times the expected default costs to the bank stakeholders. This weighting scheme effectively assumes that for every $1 of expected costs of default to bank stakeholders, an additional $1 is imposed on the rest of the financial system and the real economy.We also conduct a sensitivity analysis in which this multiple is relatively small, such as for a failure of a smaller institution (0.5 times expected bank default costs), and relatively large, such as for a Lehman-like failure (10 times expected bank default costs).

4.1.1 Value of bank assets

We assume that the bank's assets follows a log-normal stochastic process with random negative jumps with a stochastic jump size. The arrival of the jump discontinuously reduces the value of the bank's assets.[12] Jumps such as runs or financial crises represent a real-world "frictions" that preclude the possibility of the firm issuing equity fast enough to prevent such events.

We assume that the independent and uniform random variable $Y \in [0,1]$ describes the magnitude of the jump as a percentage of assets. Arrival times are independent and follow a Poisson process (Merton (1990)). Specifically, the probability that a jump arrives during time interval Δt is $\lambda \Delta t$, where λ is a risk-neutral arrival intensity describing the expected number of jumps per year. The expected change in assets due to jumps is $-\lambda k$, where $k = \mathbb{E}^Q(Y)$ and $\mathbb{E}^Q$ is the expectation under risk neutral measure Q. The value of bank's unlevered assets before taxes is therefore:

$$\frac{dV}{V} = (r - \alpha - \lambda k)dt + \sigma dW_V + dq, \tag{1}$$

where r is a short-term risk-free rate assumed to be constant; α is the payout rate; W_V is a Weiner process under the risk-neutral measure; and σ is the instantaneous volatility coefficient; $dq = (Y-1)dN_t$ describes fluctuations in bank assets due to jumps, where N_t is a Poisson process. Given payout rate of α, bank's assets generate continuous after-tax cash flows of αV.

At any time, the BHC can increase bank capital by raising equity of any amount. If the bank issues equity of $\triangle V$, the value of the bank's assets at time $t+1$ is:

$$V_{t+} = V_t + \triangle V. \tag{2}$$

When the bank issues equity, it incurs transaction costs TC, with both a fixed component (proportional to the level of its current assets) and a variable component (proportional to the size of newly raised equity $\triangle V$). Thus, transaction costs $TC = e_1 V_t + e_2 \triangle V$, where e_1 and e_2 are positive constants.

[12] Such jumps allow for the possibility of shocks that cause asset value to fall far enough and fast enough to cause an instant bail-out, bail-in, or default. Andersen and Buffum (2002) also assumes jumps in asset value process.

4.1.2 Senior debt and subordinated debt

At time 0, the BHC chooses the bank's senior debt and the BHC's subordinated debt. They require continuous coupon payments at the rate of f and c and principal payments of F and C at maturity, respectively. By assumption, the subordinated debt is a one-time choice, and the percentage ρ of total debt, i.e., $\rho = \frac{C}{C+F}$ remains unchanged until maturity. The senior debt is continuously retired (repaid at par value F) and reissued at constant rollover rate m. Retired senior debt is reissued at market price D. With higher m, the effective duration of senior debt is shorter than its maturity T. The annual net refunding cost is $m \cdot (F - D)$, where D is the market value of the senior debt. Given a payout rate from bank's assets, α, the bank pays continuous after-tax dividend net of interest payments of $(\alpha V - (1-\tau) \cdot (f+c) - m \cdot (F-D))$, where τ is the corporate tax rate. Interest payments for both senior liabilities and subordinated debt are tax deductible. We assume that bank's dividend is the residual after interest and taxes. We further assume that the bank cannot sell its assets (for example, due to debt covenants) and cannot change its dividend rate.[13]

At time t, the bank capital ratio is measured as the ratio of assets minus senior liabilities as a fraction of assets, i.e.,$\frac{(V_t-F)}{V_t}$. The bank is liquidated any time if $\frac{(V_t-F)}{V_t} < 0$. The book value of shareholders equity is measured as $BE_t = \frac{(V_t-F-C)}{V_t}$. The bank is viewed as in technical default (but not necessarily in liquidation) if the book value of the shareholders' equity falls to or below 0.

4.1.3 Reorganization Regimes of Distressed Banks

Bailout Regime The bailout regime is described by $\theta_{bailout}$, the critical capital ratio that triggers the bailout. If at any time t before maturity the bank's capital ratio falls to or below the trigger, i.e., $\frac{(V_t-F)}{V_t} = \theta_{bailout}$ or $\frac{(V_t-F-C)}{V_t} < 0$, regulators inject equity of 2% of assets, taking a fair market value equity stake in the bank. With jumps in the asset value process, bank assets can fall instantly by a large amount so that its capital ratio can instantly decline below the trigger $\theta_{bailout}$, but above the default boundary, $0 < \frac{(V_t-F)}{V_t} < \theta_{bailout}$. In such cases, the regulator also injects equity. If the size of the realized jump is large enough, bank assets can fall through the regulatory boundary and below the no-regulatory-intervention boundary, $\frac{(V_t-F)}{V_t} < 0$. In this case, we assume that the regulator closes the bank and liquidates its assets. In liquidation, and subordinated debtholders are

[13]These two assumptions are common for dynamic models of firms or Merton-style structual models (e.g., Leland, 1998; Titman and Tsyplakov, 2005).

both wiped out, and senior bank debtholders recover the bank's assets minus proportional default costs or $(1 - DC) \cdot V_t$, where $0 < DC < 1$. In the comparative statics, we vary $\theta_{bailout}$ to find the socially-optimal $\theta^*_{bailout}$.

Bail-in Regime The bail-in regime is characterized by two variables, $\theta_{bail-in}$, the critical bank's capital ratio that triggers bail-in, and $\theta_{ST_{bail-in}}$, the stress test capital critical point, where $\theta_{bail-in}$ $< \theta_{ST_{bail-in}}$. If at time t before maturity, the bank's capital ratio falls to or below the bail-in trigger, i.e., if $\frac{(V_t - F)}{V_t} \leq \theta_{bail-in}$, the regulator executes the bail-in.[14]Bank shareholders are wiped out, and subordinated debt automatically converts to C dollars worth of shares. The bank's total debt size declines from $F + C$ to F, and the bank continues to operate. After bail-in, the bank continues servicing the remaining debt, so after tax dividends are $(1 - \tau) \cdot (\alpha V - f - m \cdot (F - D))$.At maturity, the bank repays the par value of F.

In the event of a large negative jump to bank assets, the capital ratio can instantly decline below a regulatory trigger but above the default boundary, i.e., $\theta_{bail-in} > \frac{(V_t - F)}{V_t} > 0$, and $\frac{(V_t - F - C)}{V_t} > 0$. For such a situation, existing shareholders are wiped out, reallocating the entire residual equity value to subordinated debt holders. These subordinated debtholders will likely take losses because bank's equity value is less than par value C.

If the realized jump is large enough so that it instantly reduces bank ratio below the no-regulatory-intervention boundary, i.e., if $\frac{(V_t - F)}{V_t} < 0$, the regulator liquidates the bank. In this case, and holders of subordinated debt are both wiped out, and senior debtholders recover the bank's assets minus proportional default costs.

In the bail-in regime, the regulator also runs the stress test (ST) with critical capital ratioand, $\theta_{ST_{bail-in}}$. If the bank's capital ratio declines below $\theta_{ST_{bail-in}}$, the bank fails the stress test, and the bank must retail all its residual cash flows to rebuild capital.[15]

Regime with No Regulatory Intervention Under no regulatory intervention, the bank files for bankruptcy and is liquidated if its assets fall such that the book value of the shareholders' equity declines to zero or below, i.e., if $\frac{(V_t - F - C)}{V_t} \leq 0$. Shareholders and subordinated debtholders

[14]We also assume the bail-in is invoked if the book value of the shareholders' equity declines to 0.

[15]As such, the bank has to reduce its asset payout ratio from α to α_{ST} so that it's dividend payout is zero (or non-positive), i.e., $\alpha_{ST} V_t - c - f - m \cdot (F - D_t)) \leqq 0$. Thus, any time t, $\alpha_{ST_{bail-in}} = MIN\{\alpha \ , \ \frac{c + f + m \cdot (F - D_t)}{V_t}\}$, if $\frac{(V_t - F)}{V_t} < \theta_{ST_{bail-in}}$.

are wiped out, and senior debtholders recover the bank's unlevered assets V_t minus proportional default costs. In the no-regulatory-intervention regime, the regulators also conduct the stress test. The bank fails the stress test if its capital ratio declines below the critical ratio, i.e., if $\theta_{ST_{NoIntervention}} < \frac{(V_t - F)}{V_t}$. In such case, the bank will retain all its residual cash flows and rebuild its capital.

4.1.4 Capital Structure Decisions of the BHC

We assume that there is no uncertainty about the regulatory regime. At time 0, the BHC has assets valued at V_0 and cash flows from them at αV_0, and chooses to finance assets with senior liabilities F (with coupon rate f). Thus, the bank's initial capital ratio is $\frac{(V_0 - F)}{V_0}$. The BHC also chooses the size of the subordinated bond C (with coupon c), so that the initial book value of the shareholders equity is $E_0 = V_0 - F - C$, and the leverage of the BHC is $\frac{C}{E_0}$. The market value of the bank's equity $E(V_t, F, C, t)$ is a function of its asset value V_t, the size of senior debt F and subordinated debt C, and time $t \leq T$, as well as the expected regulatory intervention.

At time 0, the BHC chooses the capital structure that maximizes the total market value of the combined debt and equity taking into account that the bank will implement optimal recapitalization strategy in the future: $B = \max_{F,C}[E(V_0, F, C, 0) + F + C]$, where $E(V_0, F + C, 0) > 0$. At any time $t > 0$, the bank's chooses the optimal recapitalization strategy to maximize the market value for the existing shareholders. Details of the optimization are in Appendix A.

4.1.5 Optimal Regulatory Regimes

The regulator sets the trigger ratios of each regime to maximize the time 0 market value of the bank minus expected external costs of bank default imposed on the rest of the financial system and the real economy, taking into account the self-optimizing response of the BHC. We assume that the expected external costs of bank default are proportional to the expected private default costs of the bank, $w \times (Expected\ Default\ Costs)$, where parameter w is a multiplier. The higher is w, the higher are the social costs of bank default relative to private value of the BHC, and the regulator's objective is more focused on reducing such costs. For the base case, we choose $w = 1$, and in a sensitivity analysis, we vary w from 0.5 to 10.

The optimal bailout policy is described by the optimal trigger $\theta^*_{bailout}$. For the bailout regime, the regulator solves the following optimization problem:

$$\theta^*_{bailout} = \underset{\theta_{bailout}}{\arg\max}\{\max_{F,C}[E(V,F,C,0)\ + F + C] - w \times (Expected\ \ Default\ \ Costs)\}, \quad (3)$$

where the value in curly brackets is the social welfare function of the regulator and $\max_{F,C}[E(V,F,C,0) + F + C]$ is the self-optimized value of the BHC for a given bailout trigger $\theta_{bailout}$.

The optimal bail-in is characterized by the pair of optimal trigger and stress test critical capital ratio $\{\theta^*_{bail-in}\ , \theta^*_{ST_{bail-in}}\}$. For the bail-in regime, the regulator optimizes by solving the following:

$$\{\theta^*_{bail-in}\ , \theta^*_{ST_{bail-in}}\} = \underset{\theta_{bail-in},\ \theta_{ST_{bail-in}}}{\arg\max}\ \{\max_{F,C}[E((V,F,C,0)\ +F+C] - w \times (Expected\ \ Default\ \ Costs)\}. \quad (4)$$

Finally, the no-regulatory-intervention regime is characterized by the stress test critical capital ratio only, $\theta_{ST_{NoIntervention}}$. The regulator solves:

$$\theta^*_{ST_{NoIntervention}} = \underset{\theta_{ST_{NoIntervention}}}{\arg\max}\ \{\max_{F,C}[E((V,F,C,0)\ +F+C] - w \times (ExpectedDefaultCosts)\}. \quad (5)$$

4.1.6 Base Case Calibration of Parameter Values

To calibrate the model, we collect quarterly financial data for the 50 largest publicly traded U.S. BHCs between 2000:Q3 and 2017:Q2 and we report summary statistics separately for the bailout period (2000:Q3-2007:Q2), when banks were likely to expect bailouts, and bail-in period (2010:Q3-2017:Q2), when banks were more likely to expect bail-ins. We divide these BHCs into the eight globally systemically important banks (G-SIBs) that are most likely subject to bailout and bail-in interventions and the 42 other large BHCs. Most of our information comes from the Federal Reserve's Y-9C Consolidated Financial Statements.

Table 1 reports several statistical measures that can be used to approximate the volatility of bank's assets.The accounting return on assets over the preceding twelve quarters varies between 0.2% and 1.2%, and is slightly lower for G-SIBs and for the bailout period. Another measure of asset risk is a standard deviation of asset growth, which varies between 4% and 11.8%. Based on these observations, the volatility of bank assets is set at $\sigma = 5$ %.

Senior liabilities include deposits, overnight federal funds, term wholesale deposits and repo financing instruments and other bank debt. In case of insolvency, insured depositors recover 100% of their values. However, other senior debt liabilities will not necessarily recover full value. To estimate the deadweight cost of insolvency, we calculate the ratio of insured deposits to other senior debt. This ratio is around 40% for the entire sample and is lower for G-SIBs at around 16%. Given that between 16% and 40% of senior liabilities (insured deposits) recover 100% value, we assign the proportional default costs for senior bank liabilities at 10%., i.e., $DC = 10\%$. For the base case, both subordinated bond and senior debt mature in six years.

Transaction costs of raising new equity are assumed to be $e_1 = e_2 = 0.025\%$, reflecting both fixed and proportional components. Butler, Grullon and Weston (2005) document investment banking fees for equity issuance around 5%. If we assume equity issuance is 5% of total capitalization and equity capital is 10% of assets, then total fixed transaction costs are $5\% \times 5\% \times 10\% = 0.025\%$ of asset value.

We assume that a negative jump describes a catastrophic type event like a major crisis, characterized by a very low probability but significant losses. Thus, we assume that an annual probability of a negative jump is $\lambda = 3\%$, representing an economic environment in which a major financial crisis happens on average every 33 years. The jump size Y_t is assumed to be uniformly distributed on $[0, 1]$. Thus, conditional on arrival, a jump leads on average to a 50% loss in asset value, or $k = -0.5$. Due to jumps, the risk neutral diffusion drift of the value process is adjusted upward by $-\lambda k = 1.5\%$.

Table 1 also reports three capital ratio variables, corresponding to the three commonly-used measures of regulatory capital: 1) *CAPLEV*, Tier 1 capital divided by total unweighted assets; 2) *CAPTIER1*, Tier 1 capital divided by risk-weighted assets; 3) *CAPTOTAL*, Tier 1 and Tier 2 capital divided by risk-weighted assets.[16]Details of these capital ratios are in Table 1 and are also described later in the empirical analysis. Table 1 also reports market-to-book ratios. In the empirical analysis below, we compare the model generated optimal capital ratios and market-to-book ratio with empirically observed ones.

[16]Risk-weighted assets is a weighted sum of assets and off-balance-sheet activities that measure the perceived credit risk under the Basel I Accord.

The maturity of senior liabilities and subordinated debt is $T = 10$ years. The coupon rates f and c are set so that initial market prices of the senior debt and the subordinated bond approximately equal their par values of F and C, respectively.[17] We calculate credit spreads at origination as the difference between coupon rates and the risk-free rate. We also measure the bank's average cost of debt by calculating its weighted-average spread.

Expected default costs are a function of bank's unlevered assets at time 0, $\frac{(Expected\ \ Default\ Costs)}{V_0}$. We measure the total expected default costs and expected costs of recapitalization both as percentages of unlevered assets at time 0. By analyzing the size of default costs as a function of the bail-in terms, we can gauge the incentive-driven efficiency of trading off tax benefit of debt and expected default costs. We also calculate the expected value of future net equity issuances measured *ex ante* as a fraction of assets at time 0. We also calculate the ratio of the market value of the bank as a percentage of assets, $\frac{E+F+C}{V_0}$, roughly corresponding to the market-to-book ratio.

We assume complete markets for the claims against the bank's assets, so that the equity, senior debt, and subordinated debt can be regarded as tradable financial claims for which the usual pricing conditions hold. The market values are functions of three variables: asset value, V, face value of total debt, $F+C$ (or F if the bail-in intervention has already taken place), and time, $t \leq T$. Equity value has to satisfy a stochastic control problem with fixed and free boundary conditions, where the decision variable is the size of equity issuance. Default is called any time book equity is 0 or negative, i.e., if $V_t - F - C < 0$. These valuation problems are described in detail in Appendix A.

The numerical algorithm used to compute the values of equity and debt is based on the finite-difference method augmented by policy iteration. Specifically, we approximate the solution to the dynamic programming on a discretized grid of the state space $(V, \{F,\ F + C\}, t)$. At each node on the grid, the partial derivatives are computed using Euler's method. The backward induction procedure starts at terminal date T, at which the values for senior debt, the subordinated bond and equity are determined by payoff to holders of subordinated debt, senior debt, and holders of BHC equity. The backward recursion using time steps Δt takes into account the bank's optimal strategy to raise capital.

[17] We use several numerical iterations to approximately find par coupon rates for senior debt and the subordinated debt.

4.2 Model Results

We use numerical solutions of the model to address the question as to how terms of regulatory regimes affect the BHC's initial capitalization decision, the size of the subordinated debt and future recapitalization strategy. We start with an analysis of base-case parameters. For each regime, we vary the critical capital ratios at which the regulator takes actions and find the optimal initial capital structure at which the *ex ante* market value of the BHC is maximized. The socially-optimal regulatory terms are obtained using numerical search by varying parameters of each regulatory regime, taking into account the optimal responses of the BHC.

4.2.1 The Base Case

Results for Bailout Regime Figure 3 show the model-implied BHC's optimal initial capital and subordinated debt ratios as functions of the bailout trigger capital ratio $\theta_{bailout}$ at which the regulator injects 2% equity. As the regulator becomes more aggressive, intervening at higher capital ratios, the BHC chooses higher initial capital and subordinated debt ratio. This is because bailouts are not "free money," the regulator takes a fair market value stake in the bank and does not subsidize. In addition, bailouts dilute the claims of the shareholders, so banks hold more capital to avoid these bailouts. As $\theta_{bailout}$ increases, the expected default costs and BHC value both decline, and expected future equity injections by the regulator increase. The model demonstrates that the relation between the BHC's value minus the cost of the negative externality and regulatory aggressiveness exhibits an inverse U-shape, implying an interior solution for the socially-optimal bailout trigger point. For the base case, the regulator optimally bails out the BHC at $\theta^*_{bailout} =$ 2.9% capital. At the optimal bailout trigger, the BHC's initial capital ratio subordinated debt ratios are 9.6% and 2.7%, respectively.

There are several trade-offs when designing the optimal bailout trigger point. As the graphs show, if the regulator waits longer and bails out the BHC at lower capital than socially-optimal, there are expected external costs due to both higher jump risk and lower initial capital. If the regulator bails out at higher than the socially-optimal trigger, then it overly restricts the bank's initial capital structure choice, leading to lower BHC value. Importantly, in anticipation of bailout, the BHC does not have incentives to raise equity capital on its own when the BHC loses capital. Notably, both the model-generated optimal capital ratio and the leverage of the BHC are within empirically observable values reported in Table 1.

Results for Bail-in The bail-in regime is described by two parameters: the bail-in trigger point $\theta_{bail-in}$, and the minimum capital buffer determined by the stress test, $\theta_{ST_{bail-in}}$. Figure 4 displays initial BHC's capital structure decisions as functions of bail-in triggers, for three different levels of stress test buffers, 2.5%, 3.5%, and 4.5% above the bail-in trigger. As shown, the BHC increases initial capital as the trigger point increases, but the size of the subordinated debt is not monotonic.

The design of the social optimum requires analysis of the interplay of two real options, where the timing of regulatory decision to exercise the bail-in impacts the BHC's initial capital structure and timing of the BHC's decision to raise equity. The model also predicts an interior solution for the combination of the socially optimal bail-in trigger and stress test cushion. The social value exhibits inverse U-shaped relations with both the aggressiveness of the bail-in intervention and the strictness of the stress tests. For the base case, the optimal policy combination is the trigger $\theta^*_{bail-in}$ = 3.6%, and 3.5% for the stress test capital cushion above the trigger, making $\theta^*_{ST_{bail-in}}$ =7.0%.

In designing the optimal bail-in and stress test terms, the regulator faces the following trade-offs. If the regulator bails-in very aggressively at relatively high capital, the BHC has stronger incentives to have higher initial capital and to rebuild capital. Both BHC value and expected external costs decline, and the difference between the two (i.e., the value maximized by the regulator) declines precipitously for bail-in triggers set significantly above the socially optimum. Also, an inefficiently high bail-in trigger does not necessarily result in stronger incentives to rebuild capital compared to the socially optimal trigger. As graphs show, if the bail-in trigger increases from 3.6% (optimal) to 4.5%, the bank's initial optimal capital ratio increases by about 0.5 percentage point, and BHC value declines by 0.25%, while expected default costs decline by only 0.04 percentage point. On the other hand, if the bail-in trigger is set too low, the BHC chooses to operate with lower capital, resulting in higher expected external costs and a socially suboptimal outcome.

Thus, the bail-in trigger should not be set so high as to cause unnecessarily large losses to BHC value. Nor should it be set so low that it diminishes the credible threat of bail-in that can induce incentives to operate at healthy levels of capital and to rebuild capital to preempt bail-in.

Results for No Regulatory Intervention In the no-regulatory-intervention case, the regulator has only one tool, the stress test. Figure 5 illustrates the optimal initial capital structure as a function of the stress test critical capital ratio $\theta_{ST_{NoIntervention}}$, which varies between 7% and 11%. As the critical ratio increases, the BHC chooses slightly more capital and higher subordinated debt. As a result, the expected external costs decline only slightly with an increase in the critical capital ratio. To achieve the social optimum, the regulator sets $\theta^*_{ST_{NoIntervention}} = 8\%$ capital. The size of subordinated is close to zero, reflecting weak incentives to use loss-absorbing debt instruments.

The findings support the idea that in the absence of other regulatory tools, under no regulatory intervention, the stress test critical capital ratio is stricter than in the bail-in regime. Importantly, in the no-regulatory-intervention regime, the BHC has no incentives to raise equity capital during distress because such transaction will benefit debtholders at the expense of shareholders.

4.2.2 Comparison of the Regimes for the Base Case

Table 3 compares the three optimally constructed regimes for the base case. All BHC decisions are optimal responses to the corresponding socially-optimized regimes. As the regulatory environment transitions from bailout to bail-in, and BHC optimally responds by increasing capital from 9.6% to 12.3%, and subordinated debt increase from 2.7% to 3.0%.

The expected equity issuance in bail-in is lower than the equity expected to be injected by the regulator under bailout. Comparing the market value minus expected default costs, this is very similar for the bailout and bail-in regimes, and much lower for the no-regulatory-intervention regime. However, the total deadweight costs that include both expected transaction costs of raising equity capital and expected default costs are lower under bail-in. The no regulatory intervention implies the largest expected default costs, despite the fact that the BHC initially chooses higher capital.

When bail-in is replaced by no regulatory intervention, optimal initial capital increases rather than decreases, which conflicts with static intuition. In static intuition, the threat of being "wiped out" in bail-in resolution would straightforwardly imply higher initial capital to avoid losses. In contrast, in the dynamic model, the bail-in threat pre-commits the BHC to rebuild capital in the future in response to negative shocks. This pre-commitment reduces marginal costs of debt, increasing debt capacity and leading to larger tax shields and lower initial capital.

4.2.3 Comparative Statics for Asset Risk Parameters and other Parameters

We next present comparative statics for parameters that describe the riskiness of bank assets and the probability of negative jumps, and the rollover rate of the BHC's senior debt. Parameter values are varied around the base case reported in Table 2.

Comparative Statics for Bailout We consider cases of volatility of assets of $\sigma = 4\%$ and $\sigma = 6\%$ relative to the base case of $\sigma = 5\%$. As Table 4 Panel 1 illustrates, when BHCs have less volatile assets, the regulator optimally bails out at higher capital ratios relative to those with more volatile assets. A bank with $\sigma = 4\%$ is optimally bailed-out when the capital ratio declines to 4.5%, while for $\sigma = 6\%$, the bailout occurs at 1.3% capital. Despite bailing out riskier banks at later stages of distress, the likelihood of bailout and expected equity injections by the regulator are higher for banks with more volatile assets. In anticipation of bailout, riskier banks optimally select slightly lower initial capital, but significantly smaller subordinated debt.[18]

Intuitively, bailouts can be viewed as exercises of real options. In our setting, the option to wait longer (i.e., bailout at lower capital) has higher value for more volatile assets. The effects of jumps in BHC asset values on regulatory policy is qualitatively different. More frequent jumps introduce greater skewness in the asset return distribution and a "fatter tail" for negative returns. During normal times without jumps, such asset values experience higher expected drift, implying less distress risk relative to assets with less frequent jumps. In contrast, with higher jump probabilities, there is a higher likelihood that the regulator will be unable to bailout such a BHC.

Table 4 Panel A reports results for the model with jump probabilities of $\lambda = 2\%$ and 4% relative to base case of 3%. When λ increases from 2% to 4%, the optimal bailout policy is more aggressive – the trigger point increases from 0.5% to 5.6% capital. Expecting a more aggressive bailout strategy, the BHC with a greater jump risk optimally chooses higher initial capital and the size of the subordinated debt.[19]

We also vary m, the rollover rate of senior debt. Comparative statics presented in Table 4 Panel 1 demonstrate that for higher m, optimal bailout intervention is slightly less aggressive. As to the

[18] A BHC with asset volatility of $\sigma = 4\%$ optimally chooses an initial capital of 9.75% and subordinated debt of 4.1%. In comparison, the bank with asset volatility of $\sigma = 6\%$ initially chooses capital of 8.9% and subordinated debt of 0.9%.

[19] As λ increases from 2% to 4%, the BHC's initial capital increase from 8.9% to 10.7%, and subordinated debt increases from 0.4% to 5.0%.

BHC's optimal response: the BHC holds less capital and subordinated debt. This occurs because the higher rollover rate makes debt less risky, increasing debt capacity.

Comparative Statics for Bail-in Table 4 Panel B shows that when asset volatility is higher, the regulator is optimally more aggressive, invoking bail-in at higher capital ratios and raising the critical capital ratio for the stress test. The reason is that higher volatility increases the debt overhang problem which can reduces the BHCs' incentive to pre-emptively raise capital. In anticipation of this reduced incentive, bail-in policy has to be more aggressive for more volatile banks. Facing a more aggressive bail-in, BHCs with more volatile assets optimally hold significantly higher initial capital and subordinated debt, and pre-commit to raise more future equity.

The effects of jump risk on optimal bail-in design are more complex. With more frequent jumps, the ability of bail-ins to control default risk and preserve value is diminished. Higher jump risk also weakens BHC's incentives to recapitalize because it diminishes the BHC's ability to reduce likelihood of bail-in or default by raising equity and holding a larger capital buffer. Thus, a more aggressive bail-in policy would not significantly strengthen the BHC's incentives to raise equity. In fact, a more aggressive bail-in may be counterproductive as it produces only incremental incentives to rebuild capital, but overly constrains the BHC's capital structure decisions. Thus, socially-optimal bail-in policy is less aggressive for BHCs with more jump risk. The stress test should also be less strict and set the critical capital ratio lower. Quantitatively, as the frequency of asset jump increases from 2% to 4%, the optimal bail-in trigger decreases from 3.9% to 1.6%, and the BHC's optimal initial capital decreases from 14.3% to 10.5%.

Notably, the effects of both high volatility and high jump risk on the optimal bail-in trigger are opposite to those of the optimal bailout trigger. The main reason is that the two regimes structurally differ in the incentives they create for BHCs. Bail-ins incentivize BHCs to recapitalize to mitigate the possibility of shareholders being wiped out, whereas bailouts provide safety cushions for BHC shareholders.

Turning to debt rollover rate, the model predicts that the regulator optimally employs less aggressive bail-in triggers and less stringent stress tests for BHCs with higher rollover rates. In response, these BHCs hold slightly less capital and subordinated debt. As discussed above, a higher rollover rate reduces the cost of debt and the debt overhang problem. The lesser debt overhang problem increases incentives for BHCs to replenish capital during distress.

Comparative Statics for No Regulatory Intervention As Table 4 Panel C shows, under the no-regulatory-intervention regime, the regulator optimally imposes higher stress test critical capital ratios for banks with more volatile assets, which inducing BHCs to hold more capital, but choose very little subordinated debt.

With regard to jump risk, the optimal stress critical capital ratio is lower for greater jump risk, resulting in BHCs holding less capital. Intuitively, during normal times when there are no jumps, bank assets experience higher returns due to higher drift, which reduces default risk.

Finally, under no regulatory intervention, changes in debt rollover rate have minimal impact on the optimal stress test critical capital ratio and BHC optimal capital structure.

Sensitivity Analysis for Expected Social Costs of Bank Default As discussed above, we model the expected external social costs of bank default for the financial system and the real economy as proportional to the expected private costs of default to the bank's stakeholders. That is, we assume that the disruption costs to the rest of society is $w \times (Expected\ \ Default\ \ Costs)$, where expected default costs is the expected private default costs, and w is a multiple that takes on the value 1 in the model base case. The regulator maximizes the private value of the bank minus these expected external costs of default. As w increases, the expected external social costs of default become more important, and the regulator becomes more concerned about reducing the likelihood of bank default.

Table 4 Panel A documents comparative statics in which we vary w and compare the key outcomes of the model. Specifically, for values of w of 0.5, 1, and 10, we tabulate the optimal regulatory triggers and stress test critical capital ratios, the optimal responses of the BHC, and the regulator's social value function for the three regimes. As shown in the panel, as w increases, the social optimum requires that the regulator use progressively more aggressive regulatory policies. Specifically, as w increases from 1 to 10, the optimal bailout trigger increases from 2.9% to 6.5% capital ratio. In response, the BHC increases its capital ratio from 9.6% to 12.7%, as well as holding more subordinated debt. Similarly, for the bail-in, an increase in w leads to more aggressive optimal bail-in trigger and a more stringent stress test. The bail-in optimal trigger increases from 3.6% to 5.5% capital ratio, and the stress test critical ratio increases from 7.1% to 9.6%. The BHC responds to these more aggressive policies with higher capital and larger subordinated debt. In both the bail-out and bail-in regimes, the market value of the bank and the expected default costs decline, and the regulator's social value function declines as well. For the no-regulatory-intervention regime, the increase in w leads to only a slightly more aggressive stress test and negligible change in expected default costs. This suggests that the stress test alone is a relatively weak tool in incentivizing banks to choose more prudent capital structure policies compared to the more intrusive regulatory tools like bailout or bail-in.

Importantly, the relative effectiveness of the regimes is highly robust to changes in the multiplier w. Our findings of rough equivalence between the bailout and bail-in regimes and significantly worse social performance of the no-regulatory-intervention regime hold for all values of w. Not surprisingly, the comparisons also show that the no-regulatory-intervention regime is especially inefficient when the negative externalities of bank default are high.

4.2.4 Effects of Regulatory Regime Changes for BHC's with Different Characteristics

We next explore how BHC risk characteristics affect the change in the optimal capital structure in response to regulatory change. We consider the change from a bailout regime to a bail-in regime, as actually occurred, as well as a regime transition from bail-in to no regulatory intervention as envisioned under the Financial CHOICE Act (see Section 3).

Table 5 Panel A reports the changes in optimal triggers and BHC optimal responses for different asset volatility, jump risk and debt rollover rate. The model predicts that shifting from bailout to bail-in, banks with higher asset volatility optimally increase capital and subordinated debt significantly. In contrast, BHCs with higher jump probability react by decreasing both capital and subordinated debt. Finally, BHCs with higher rollover rate slightly increase both capital and subordinated debt.

Table 5 Panel B shows optimal responses to a transition from the bail-in regime to the no-regulatory-intervention regime. The panel shows for most of the parameters, relatively modest increases in the optimal stress test critical capital ratios and BHC optimal capital ratios.

4.3 Model Results for Alternative Social Welfare Functions

As discussed above, in our main results, we choose a very simple social welfare function in order to avoid imposing relatively arbitrary assumptions. Specifically, the regulator maximizes the market value of the bank less the expected disruption costs to the rest of society caused by bank default. These expected disruption costs are assumed to be equal to the expected private costs of default to the bank's stakeholders. In effect, we assume that the disruption costs amount to the costs of another bank defaulting. Thus, for the main model, we assume that the expected disruption costs to the rest of society is $w\times$(*Expected Default Costs*), where *Expected Default Costs* is expected private default costs, and w is a weight (multiplier) that takes on the value 1.

In this section, we consider three sets of alternative social welfare functions, each of which applies various weights to different potential costs to society. We first vary w, so that external disruption costs of default is a different multiple of expected private costs of default. Second, in the main model, we assume that there are no additional social costs to employing and risking taxpayer public funds for private sector bailouts. Here, we alternatively assume here that there is a social cost of using public funds that is a proportion w_2 of the amount of the government's equity injection. Including such costs is consistent with the disapproval in much of the society stemming from significant risk imposed on taxpayers from being forced to pay for the TARP bailouts. Finally, in the main model, we assume there are no administrative or financial transaction costs of collecting and distributing the bailout funds. Here, we include such public transactions costs and assume that they equal a proportion w_3 of the private sector transaction costs of raising the same amount of equity, TC.

Importantly, in all of these cases, we derive outcomes based on the assumption that the regulator re-optimizes based on the alternative social welfare function and the BHCs react with choices that optimize for their shareholders.

4.3.1 Varying the Expected External Disruption Costs of Bank Default

As indicated, we resolve- the model allowing the expected external disruption costs of default to be different multiples of the expected private costs of default to the bank's stakeholders. We now assume that expected costs to the rest of society is $w\times$(*Expected Default Costs*), where w takes on the values 0.5, 1.0, and 10.0. The middle value of 1.0 is the value in the main model shown earlier, and is repeated here for ease of comparison. A multiplier of 10.0 does not seem unreasonable for a large bank, given the trillions of dollars of GDP lost and financial wealth wiped out during the financial crisis in part as a result of the Lehman Brothers bankruptcy. As w increases, the expected external disruption costs of default become more important, and the regulator becomes more concerned about reducing the likelihood of bank default.

Table 6 Panel A documents the results, holding all of the other model parameters at their base case settings. For the different values of w, we tabulate the optimal regulatory triggers and stress test critical capital ratios, the optimal responses of the BHC, and the values of the alternative social welfare function. As shown in the panel, as w increases, the social optimum requires that the regulator use progressively more aggressive regulatory policies. Specifically, as w increases from 0.5 to 10, the optimal bailout trigger increases from 0.5% to 6.5% capital ratio. In response, the BHC increases its capital ratio from 7.3% to 12.7%, as well as holding more subordinated debt. Similarly, for the bail-in, an increase in w leads to more aggressive optimal bail-in trigger and a more stringent stress test. The bail-in trigger increases from 2.0% to 5.5% capital ratio, and the stress test critical ratio increases from 5.5% to 9.6%. The BHC responds to these more aggressive policies with higher capital and more subordinated debt. In both the bailout and bail-in regimes, the market value of the bank and the expected default costs decline, and the regulator's social value function declines as well. For the no-regulatory-intervention regime, the increase in w leads to only a slightly more aggressive stress test and negligible changes in BHC behavior. This suggests that the stress test alone is a relatively weak tool in changing bank behavior compared to the more intrusive regulatory tools like bailout or bail-in.

Importantly, the relative effectiveness of the regimes in terms of the social welfare function is highly robust to changes in the weight w. Our findings of comparable values of the social welfare function for the optimal bailout and bail-in regimes and their dominance over the no-regulatory-intervention regime remains robust for the different values of expected external disruption costs of default. Not surprisingly, the no-regulatory-intervention regime is especially socially inefficient when the negative externalities of bank default are high.

4.3.2 Introducing Additional Costs of Employing and Risking Taxpayer Funds into the Bailout Regime

We next include in the social welfare function additional costs of using and risking public taxpayer funds to bail out the private-sector BHCs. We now assume additional social costs of $w_2 = 0.0$, 0.25, and 0.5 times the amount of funds taken from taxpayers to bail out the BHCs in the bailout regime. The value 0.0 corresponds to our main model assumption of no additional costs associated with using and risking public funds.

Table 6 Panel B shows the findings for this alternative social welfare function that now takes into account additional costs of using taxpayer funds. Not surprisingly, the regulator becomes less aggressive in bailing out the BHC by significantly lowering the bailout trigger, reducing expected public equity injections. The BHC responds by holding less initial capital and less subordinated debt. As w_2 increases from 0.o to 0.5, the bailout optimal trigger declines from a 2.9% to a 0.5% capital ratio. In response to this less aggressive bailout, the BHC reduces its capital ratio from 9.6% to 7.33%. Importantly, inclusion of the cost of using taxpayer funds decreases value of the social welfare function for the optimal bailout regime significantly, reducing it below the value for the bail-in regime for $w_2 = 0.5$. Note that there is no effect on the bail-in and no-intervention regimes that have no use of public funds.

4.3.3 Introducing Expected Transaction Costs of Injecting Bailout Funds into Social Welfare Function

It seems reasonable that the government's costs of administering programs like TARP and the financial costs of raising funds from public taxpayers to transfer to private sector BHCs may be substantial and comparable to private sector transaction costs. We next solve the dynamic model assuming that the government bears transaction costs equal to $w_3 = 0.0$, 0.5, and 1.0 times private sector transaction costs of raising the same amount of funds TC, where the value 0.0 corresponds to our main model assumption of no public transactions costs. As w_3 increases, the regulator takes into account more of these additional expected transaction costs in the event of bailouts. Again, this does not affect the bail-in and no-intervention regimes that have no use of public funds.

Table 6 Panel C tabulates the findings, holding all of the other model parameters at their base case values. As w_3 increases, the regulator employs a less aggressive bailout trigger. Specifically, as w_3 increases from 0.0 to 1.0, the optimal bailout trigger declines from 2.9% to 0.9% capital ratio. In response, the initial bank's optimal capital ratio declines from 9.6% to 7.8%. Subordinated debt declines as well. Another key takeaway from Panel C is that by taking into account the expected transaction cost of bailouts, the bailout regime becomes less socially efficient. Similar to the case of including cost of using and risking taxpayer funds in Panel B, Panel C shows that the value of the social welfare function for the optimal bailout regime falls below the value for the bail-in regime for $w_3 = 1.0$. Again, there is no effect on the bail-in and no-intervention regimes that have no use of public funds, and the transactions costs of private equity issuance are already included in the main model. Finally, we note that our findings that taking into account the risk and transactions costs from using public funds in bailouts significantly reduce the value of the alternative social welfare functions would be even greater if they were included together

5 Empirical Tests

The theoretical model has a number of empirical predictions that we test for consistency with the data. We focus on the responses to the shift from expectations of bailouts pre-crisis to bail-ins after the crisis of BHCs that are most likely to be subject to bailouts and bail-ins.

Other model predictions – such as the optimal timing and the design of the bail-in interventions and the potential future shift to a no-regulatory-intervention regime – are not testable with available data. Bail-ins have yet to be triggered and the no regulatory intervention regime has not been put into place.

5.1 Data Sources and Sample

We use quarterly financial data for the largest 50 top-tier publicly traded U.S. BHCs from 2000:Q3 to 2007:Q2 as the bailout period, and from 2010:Q3 to 2017:Q2 as the bail-in period.[20] Of these 50, we consider the eight very large, complex U.S. banking organizations that are designated as Global Systemically Important BHCs (G-SIBs) as the treatment group, those most likely to be subject to bailouts and bail-ins.[21] The remaining 42 large BHCs are considered the control group, but are closest in other characteristics to the treatment group. All eight of the G-SIBs (Bank of America, Bank of New York Mellon, Citigroup, Goldman Sachs, JP Morgan Chase, Morgan Stanley, State Street Bank, Wells Fargo) were bailed out in the TARP program during the financial crisis, and seven of them were in the initial group of nine involuntary participants in TARP in October 2008. Thus, our empirical design is based on the assumption that before the financial crisis, these institutions believed that that they were too big or too important to fail and would more likely be bailed out in the event of a crisis than the remaining 42 institutions. It is also reasonable to assume that after OLA was in effect, these institutions expected that they were more likely to be subject to bail-ins, given their systemic importance and treatment under TARP.

Other evidence supports choosing the eight G-SIBs as the bailout and bail-in treatment group.

[20] We focus on top-tier BHCs that are not owned by other BHCs. Lower-tier companies are included as part of the larger entities.

[21] There are currently 30 G-SIBs around the world designated by the Financial Stability Board (FSB), in consultation with Basel Committee on Banking Supervision (BCBS) and national authorities.

The major rating agencies traditionally rate large BHCs with and without consideration of external government support in addition to the institutions' intrinsic strength, with the difference referred to as "uplift." Since the passage of Dodd Frank, this "uplift" has largely disappeared for the eight G-SIBs, with Moody's and Fitch specifically citing OLA as a basis for doing so (Moody's Investor Services, 2013, 2015; Standard & Poor's Rating Services, 2015; Fitch Ratings, 2014).[22] We recognize that this division into treatment and control groups is imperfect. Some BHCs below the cutoff likely expected bailouts pre-crisis and may fear bail-ins post-crisis.

Fortunately, in robustness tests in Appendix B, we find that our results are generally consistent to using alternative definitions for treated and control groups. We specifically define treated alternatively as dummies for the BHCs subject to the original Supervisory Capital assessment stress test program (SCAP) and the subsequent stress tests programs, the Comprehensive Capital Analysis and Review (CCAR) and Dodd-Frank Act stress testing (DFAST) programs (about 18 institutions), and for the SIFIs, BHCs with over $50 billion in assets (about 30 institutions). We also limited the control group to only the non-GSIB SIFIs.[23]

Table 1 Panel A provides definitions of our variables. We collect data from the Y-9C Consolidated Financial Statements for BHCs, market equity from the Compustat database, and M&A data from the Federal Reserve Bank of Chicago website for the pre-crisis (2000:Q3-2007:Q2) and post-crisis (2010:Q3-2017:Q2) periods. The resulting dataset is an unbalanced panel containing 2,800 BHC-quarter observations for 56 quarters. We exclude financial crisis observations to avoid contamination of the results from this period. The financial crisis was a period of extreme volatility, and the bailouts during the crisis were much more extensive than was likely expected, covering both large and small banks.

5.2 Capital Measures and Other Variables

The most important capital structure indicator in the model is the bank's capital ratio. We employ three capital ratios. *CAPLEV* is our baseline specification, Tier 1 capital divided by total unweighted assets. *CAPTIER1* is Tier 1 capital divided by risk-weighted assets. *CAPTOTAL* is Tier 1 plus Tier 2 capital divided by risk-weighted assets. All three measures are used in bank

[22] Consistent with reduced government support, the competitive advantages of the largest BHCs in terms of lower funding costs have also declined or reversed (Government Accountability Office, 2014).

[23] About 11.9% of our observations are G-SIBs, 26.1% are SCAPs, and 37.0% are SIFIs.

regulation. We also construct measures of "do-nothing capital" for each of the three regulatory capital ratios: *DNK_LEV*, *DNK_TIER1*, and *DNK_TOTAL*, equal to capital plus net income minus lagged dividends divided by the appropriate denominators. These correspond to what the capital ratio would be if the BHC "did nothing": kept dividend payments constant and let the remaining cash flow accrue to capital (Berger, DeYoung, Flannery, Lee, and Oztekin, 2008).

We include several other BHC characteristics as controls, following the bank capital structure literature: profitability (*ROA*), the ratio of net earnings over total assets; asset volatility (*STDROA*), the standard deviation of accounting return on assets over the preceding twelve quarters; charter value proxied by the market-to-book ratio (*MKTBOOK*); number of acquisitions in the following year (*NMERGER*); size (*LNASSETS*), the natural log of total assets; retail deposits (*RETAILDEPOSITS*), the ratio of retail deposits to total assets; business loans (*BUSINESSLOAN*), the ratio of total business loans to total loans; liquidity (*LIQUIDITY*), the ratio of liquid assets to total assets; off-balance-sheet activities (*OBS10*), a dummy for BHCs that hold derivatives with notional amounts that exceed ten times the value of assets; jump risk (*CDLOANS*), the ratio of construction and land development loans to total loans; and rollover risk (*ROLLOVER*), the ratio of debt and liabilities maturing in one year or less to total BHC debt and liabilities.

The reasons behind including these controls are straightforward. More profitable and higher market-to-book BHCs may choose higher capital ratios to protect their franchise value. Riskier BHCs are expected to have higher capital ratios for protection. BHCs with higher external growth strategies may require extra capital for unpredictable acquisition opportunities. Larger BHCs generally hold relatively less capital due to greater diversification, scale economies in risk management, greater ability to raise equity on short notice, and/or a "too-big-to-fail" expectation for the largest institutions. A greater retail deposit base can reduce pressure from counterparties to hold capital. However, BHCs with more counterparty risk concerns such as loan or off-balance-sheet customers may choose higher capital ratios to assure these counterparties.

5.3 Summary Statistics

Table 1 Panels B and C show summary statistics for the bailout and the bail-in periods, respectively. Statistics are shown for All Top 50 BHCs, as well as the treatment and control groups, G-SIBs and nonG-SIBs, respectively.

We focus on the change in the capital behavior of the BHCs from the bailout period to the bail-in period. The theoretical model predicts that changing from a bailout to a bail-in regime would result in higher capital ratios. Table 1 shows that these G-SIBs increased their capital ratios from the bailout to the bail-in period in ranges of 1.6% to 4.9%, similar to the model prediction range of 2.9% to 3.6%. Additional statistics for the full sample are in Appendix B Table B.1.

5.4 Regression Results

We next use regression analyses to test the model predictions for capital.

5.4.1 Difference-in-Difference Analysis

Empirical Framework We use difference-in-difference (DID) models to test model predictions that treated BHCs would increase capital ratios relative to changes in the same ratios by the control group when moving from the bailout to the bail-in period. The DID regression has the following form for BHC b at time t:

$$Y_{\text{b,t}} = \begin{array}{c} \beta_1 BAIL-IN\ PERIOD_{\text{t}} \times TREATED_{\text{b}} \\ +\beta_2 X_{\text{b,t-1}} + \beta_3 TIME_{\text{t}} + \beta_4 BHC_{\text{b}} + \varepsilon_{\text{b,t}} \end{array} \tag{6}$$

$Y_{b,t}$ is a capital ratio chosen by the BHC, either *CAPLEV, CAPTIER1*, or *CAPTOTAL*. *TREATED*$_b$ is a dummy for G-SIBs. *BAIL-IN PERIOD*$_t$ is a dummy for the bail-in period 2010:Q3-2017:Q2 after the Dodd Frank Act Title II OLA came into effect. *TREATED*$_b$ and *BAIL-IN PERIOD*$_t$ terms do not appear by themselves because they would be perfectly collinear with the fixed effects discussed below. *BAIL-IN PERIOD*$_t \times$ *TREATED*$_b$ is the DID term and captures the effect of the treatment (i.e., threat of bail-in). Positive coefficients on the DID terms would indicate that the regulatory regime change induced BHCs to hold higher capital ratios. We also include BHC control variables, $X_{b,t-1}$, time fixed effects $TIME_t$, and BHC fixed effects BHC_b. $\varepsilon_{b,t}$ represents an error term.

Main Regression Results Table 7 shows our main results. In columns 1-3, we find that conditional on a very strong set of controls, the G-SIBs increased all their capital ratios statistically and economically significantly more than the control group when moving from the bailout period to the bail-in period, consistent with model predictions. The estimated coefficients on the DID terms in the capital equations suggest the regime change resulted in increases of 1.0 to 2.7 percentage points. These are large increases relative to the typical capital ratios of large BHCs. These findings qualitatively and quantitatively match the 2.7 percentage points predicted by the model in Table 3. For robustness, we repeat our tests using SCAPs and SIFIs for the treatment groups in Appendix B. In additional untabulated results, we exclude Goldman Sachs and Morgan Stanley, which became BHCs during the financial crisis, to alleviate concerns that results may be driven by them. We also rerun tests using a more stringent sample which includes only BHCs with total assets above $50 billion, esentially comparing capital decisions for G-SIBs with other non-GSIB SIFIs. We find similar results across all these checks. Our results suggest that some combination of the implementation of the bail-in regime, application of the stress tests, and other policies were successful in inducing banks to hold significantly more capital.

Subsample Tests Table 8 shows the DID model by subsamples of high and low volatility risk (Panel A), jump risk (Panel B), and rollover risk (Panel C) to test additional model predictions. In all cases, the splits use the medians of the risks as the cutoff points. For asset volatility risk, we use as proxy *STDEVROA*, the standard deviation of *ROA* over the previous 12 quarters. For jump risk, we use *CDLOANS*, construction and land development loans divided by total loans.[24] For rollover risk, we use *ROLLOVER*, the proportion of total debt and liabilities maturing in one year or less.

In two of the three cases, the results support the model predictions. Specifically, in Panel A, G-SIBs with higher asset volatility risk have higher capital ratios in the bail-in period, as predicted by the model. The estimated coefficients on the DID terms for low versus high asset volatility BHCs suggest the regime change resulted in capital increases in the range of 0.1 to 1.5 percentage points more for the high asset volatility G-SIBs, while the model in Table 6 suggests changes in the range of -1.5 to 3.0 percentage points. In Panel B, G-SIBs with lower jump risk also have higher capital ratios in the bail-in period. The estimated coefficients on the DID terms for low versus high jump risk BHCs suggest the regime change resulted in capital increases ranging from 0.6 to 2.3 percentage points more for the low jump risk G-SIBs, while the model predicts a range of -4.0 to 3.4 percentage points. Thus, both the asset volatility and jump risk results support the model's

[24] These loans are found elsewhere to be strong predictors of bank failure (e.g., Cole and White, 2012).

predictions.

An exception where the empirical results and model predictions diverge is rollover risk. G-SIBs with lower rollover risk are associated with higher capital ratios in the bail-in period, differing from the model prediction that G-SIBs with higher rollover risk increase capital more.

5.4.2 Partial Adjustment Analysis

Empirical Framework The dynamic model predicts that bail-ins provide incentives for BHCs to rebuild capital prior to financial distress, whereas bailouts do not. We cannot precisely test this model implication empirically because in reality, recapitalizations occur in both the bailout and bail-in periods and are influenced by many other regulatory and non-regulatory changes. Instead, to empirically operationalize this model prediction, we test whether banks recapitalize faster to their targets in bail-in period than in the bail-out period using a partial adjustment model.

We apply a partial speed of adjustment empirical model as in Berger, DeYoung, Flannery, Lee, and Oztekin (2008) totest whether the treated BHCs increased their speed of adjustment relative to the control group moving from the bailout to the bail-in period. We model the target capital ratio $k^*_{i,t}$ as a function of the firm's characteristics:

$$k^*_{it} = \frac{K^*{}_{it}}{A_{it}} = \gamma X_{\,i,t\text{-}1} \tag{7}$$

$K^*{}_{it}$ is the target (desired) book value of capital; $\mathrm{A}_{i,\,t}$ is the book value of assets; γ is a vector of coefficients, and $X_{i,t-1}$ is a set of BHC characteristics that determine target capital. BHCs do not always remain at their target capital ratios because of adjustment costs.

Because adjusting capital is costly, we use a partial adjustment framework. We start with "do-nothing capital" or DNK, what the capital ratio would be if the bank was passive and "did nothing," kept dividend payments constant at last year's rate and let remaining earnings accrue to capital. BHCs close a constant proportion λ of the gap between its target capital ratio $k_{*i,\,t}$ and DNK in each period:

$$k_{i,t} - DNK_{\,i,t} = \lambda(k^*_{i,t} - DNK_{\,i,t}) + \zeta_{\,it}, \tag{8}$$

$DNK_{i,t}$ is the "do-nothing capital ratio" $= (K_{i,t-1} + NI_{i,t} - DIV_{i,t-1})/A_{i,t}$, and it is BHC i 's *pro forma* capital ratio at time t if it maintains the prior year's dividend payments and maintains outstanding a constant number of shares; $NI_{i,t}$ is the net income of the i^{th} BHC in the current period; $DIV_{i,t-1}$ is the dollar dividend payments by the i^{th} BHC in period *t-1*; λ is a scalar adjustment speed at which the BHC actively moves away from $DNK_{i,t}$ and toward $k^*_{i,t}$. In the analysis, we also allow λ to differ for treated and non-treated BHCs, and allow the effects of the control variables to differ as well. ζ_{it} is a random error.

The dependent variable in (5) is the BHC's actively managed capital ratio change, undertaken through a combination of equity issues/repurchases, changes in dividend payments, or adjustments to assets.[25] We substitute (4) into (5) and get the following estimable regression model:

$$k_{i,t} - DNK_{i,t} = X(\lambda\gamma_{i,t\text{-}1} - DNK_{i,t}) + \delta_{i,t}, \tag{9}$$

According to the model, each firm has its own capital target and its own starting place (DNK), and all BHCs adjust at the rate λ. We estimate empirically a standard partial adjustment model for capital structure as in equation (6) using the Blundell-Bond (1998) GMM method, providing an estimate of the speed of adjustment λ and a set of estimated β_s. We run several tests. We estimate λ for all BHCs, separate λ_s for G-SIBs and nonG-SIBs, and also λ_s for G-SIBs above and below the target.

Empirical Results Table 9 Panel A shows the main results for equation (6) using $CAPLEV$,our baseline capital ratio. Columns (1)-(3) and (4)-(6) report results for the bailout period and the bail-in period, respectively. Adjustment speeds represented by the λ coefficients (shaded) are for all BHCs in (1) and (4), for G-SIB and nonG-SIBs in (2) and (5), and for G-SIBs and nonG-SIBs above and below the target capital ratio in (3) and (6).

Columns (1) and (4) suggest that for all BHCs together, the speed of adjustment in the bail-in period is slightly slower than in the bailout period. However, when splitting by G-SIBs and nonG-SIBs in columns (2) and (5), G-SIBs capital adjustment speed more than doubled during the bail-in period while the nonG-SIBs speed decreased slightly, corroborating the model's predictions.

[25] λ ranges from 0 to 1. Low estimated values for λ will indicate that BHCs are passive managers of their capital ratios, doing little to actively manage their capital ratios away from the "do-nothing" capital ratio $DNK_{i,t}$ and toward the desired capital ratio $k^*_{i,t}$. In contrast, a high estimated λ will indicate that BHCs actively manage their capital ratios away from $DNK_{i,t}$ and toward the target capital.

In addition, the t-tests for the difference in coefficients at the bottom of Panel A confirm that there are statistically significant differences in terms of adjustment speed between the G-SIB and nonG-SIB groups in both periods. Importantly, there is a faster speed for G-SIBs in the bail-in period relative to the bailout period. Finally, columns (3) and (6) suggest that there is little difference between the speeds of adjustment for the G-SIBs above and below the target. Thus, the post-crisis bail-in, stress tests, and other policies appear to be successful in inducing the GSIBs to adjust their capital faster. In additional untabulated results, we rerun the analysis excluding Goldman Sachs and Morgan Stanley and using a more stringent sample which includes only BHCs with total assets above $50 billion, comparing G-SIBs with other non-GSIB SIFIs only, and our results are similar. Table 9 Panels B and C repeat our main adjustment speed analysis by using *CAPTIER1* and *CAPTOTAL*. Using these alternative capital ratios, we continue to find similar patterns, suggesting that G-SIBs increased their capital speeds of adjustment in the bail-in period, consistent with the model predictions. However, these results are slightly weaker, likely beacuse *CAPTIER1* and *CAPTOTAL* include risk-weighted assets in their denominator, which may reflect portfolio changes rather than pure capital changes.

6 Conclusions and Policy Implications

After the recent financial crisis, the 2010 Dodd-Frank Act introduced the Orderly Liquidation Authority (OLA), under which regulators of large U.S. bank holding companies (BHCs) essentially shifted from a bailout regime to a bail-in regime. The Financial CHOICE Act currently under congressional consideration would move these institutions to a no-regulatory-intervention regime in which they would default without regulatory involvement. The optimal designs of these regimes, their relative performance in terms of meeting social objectives, and their implications for the behavior of large financial institutions are not well understood and are studied here.

Our dynamic model quantifies the socially optimal design of the three regimes for handling potential failure of large BHCs. Regulators are assumed to maximize a social welfare function that takes into account both the private value to bank stakeholders and the expected disruption costs to the rest of society of bank default for the financial system and the real economy. Each BHC self-optimizes its response to the regime in place, and the regulator socially optimizes, taking the BHC's response into account. We solve the model for the different regimes numerically using values that are calibrated to data for large U.S. BHCs. The regulator chooses the socially optimal capital ratio at which to intervene in both the bailout and bail-in regimes, and also selects optimally-determined stress test critical capital ratios at which to restrict BHC capital payouts in both the bail-in and no-regulatory-intervention regimes.

For these tests, we specify 2000:Q3 to 2007:Q2 as the bailout period, when the largest U.S. BHCs likely expected that they would be bailed out in the event of severe financial distress. We use the time after the passage of the Dodd-Frank Act put OLA into effect from 2010:Q3 to 2017:Q2 as the bail-in period. We exclude the tumultuous period of the financial crisis itself in which the bailouts actually occurred from the empirical analysis.

We also test a number of the model's predictions using data on the top 50 U.S. BHCs for the period 2000:Q3 to 2007:Q2, when bailouts of very large distressed BHCs were likely expected, and the period with OLA in effect from 2010:Q3 to 2017:Q2, when bail-ins may be expected for the very large BHCs in distress. We specify the eight large U.S. BHCs designated as Global Systemically Important Banks (G-SIBs) as the treatment group most likely to be subject to bailouts pre-crisis and bail-ins post-crisis. The other 42 large BHCs are in the control group that are less likely to be affected. We find changes in the BHC capital structures that are consistent with model predictions. Specifically, shifting from the bailout period pre-crisis to the bail-in period post-crisis results in both higher capital ratios and faster capital ratio speeds of adjustment for G-SIBs relative to the control group. Our findings are robust to the use of alternative treatment and control groups.

Our findings have a number of implications. The results of the dynamic model clearly indicate that optimally-designed bailouts and bail-ins dominate the no-regulatory-intervention regime. The latter regime employs only a stress test that restricts capital payouts, which is less effective in reducing the likelihood of bank default than the more intrusive regulatory tools like bailouts and bail-ins.

The results also suggest a rough equivalence in terms of maximizing the social welfare function for optimally-designed bailouts and bail-ins. These findings are robust to a sensitivity analysis in which we vary the expected external disruption costs of bank default between relatively low and high levels. Notably, the no-regulatory-intervention regime performs even more poorly when the expected external social costs of bank default are assumed to be high.

However, optimal bailouts produce lower values for the social welfare function when the bailout costs of employing and risking taxpayers' funds and transaction costs of collecting and distributing these funds are included in this function. Other factors also likely tip the scales toward bail-ins being more beneficial than bailouts. First, the dynamic model shows and the empirical results confirm that a bail-in regime provides BHCs incentives to hold higher capital and to recapitalize during financial distress to preempt having their equity shares wiped out, resulting in a safer banking industry.

Second, the optimal bailouts in the dynamic model involve no subsidies or "free money" for BHCs, as regulators act in a timely fashion and dilute the claims of shareholders. In reality, regulators likely step in later than is optimal and provide government subsidies to BHCs in bailouts. This wastes taxpayer funds and gives unfair competitive advantages to bailed-out BHCs that are often considered too big or interconnected to fail. In contrast, bail-ins do not involve public funds, and hence do not provide such subsidies.

Third, to keep the model manageable, we focus on the bank's capital decisions only. In reality, bail-ins also likely result in more prudential portfolio choices because of reduced incentives to shift into riskier assets as well as higher and more responsive capital ratios.Thus, the benefits of bail-ins in protecting the stability of the banking system are likely greater than the model predictions.

Fourth, our empirical results also support the notion that bail-ins, stress tests, and other post-crisis regulatory policies were generally successful in inducing better capital structure behavior for the very largest BHCs in the bail-in period.

In terms of policy implications, our findings also suggest that "one size fits all" regulatory policies are clearly dominated by approaches that are tailored to individual financial institutions. Banks with different asset volatility, jump risk (exposure to financial crises), and social costs of their defaults should face very different resolution triggers and stress test critical capital ratios.

Finally, we suggest some directions for future research that may further inform policy for dealing with the financial distress of large financial institutions that pose systemic risks. As acknowledged above, our focus on benefits and costs of the pure-play regulatory regimes requires us to abstract from regulatory ambiguity. Future research that focuses directly on the roles of this ambiguity may prove fruitful in enlightening policy on controlling systemic risk and other concerns. In addition, we recommend future research on other important implications of the three regimes, such as off-setting moral hazard risk shifting and reducing competitive advantages bestowed by extra safety net protections of some large financial institutions. It is unlikely that all of these subjects can be tackled in a single effort, but we argue that future research on these individual issues may add significant value in improving policy.

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Figure 1: Capital Structure of a Bank and its Bank Holding Company (BHC)

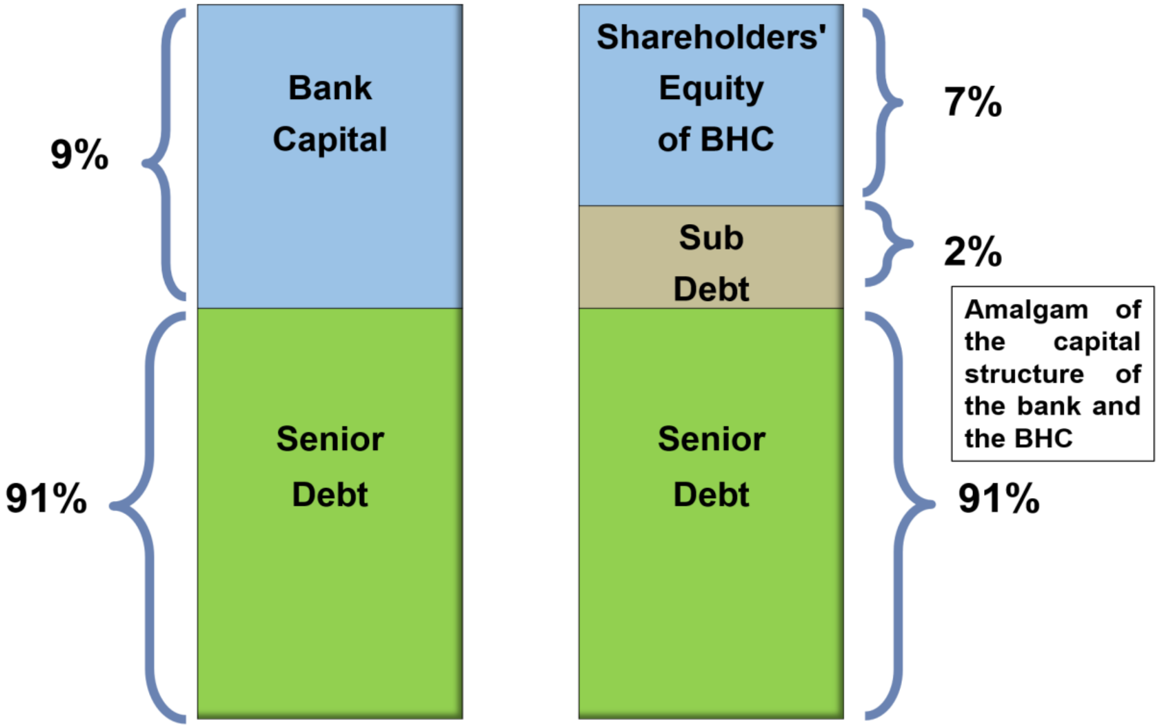
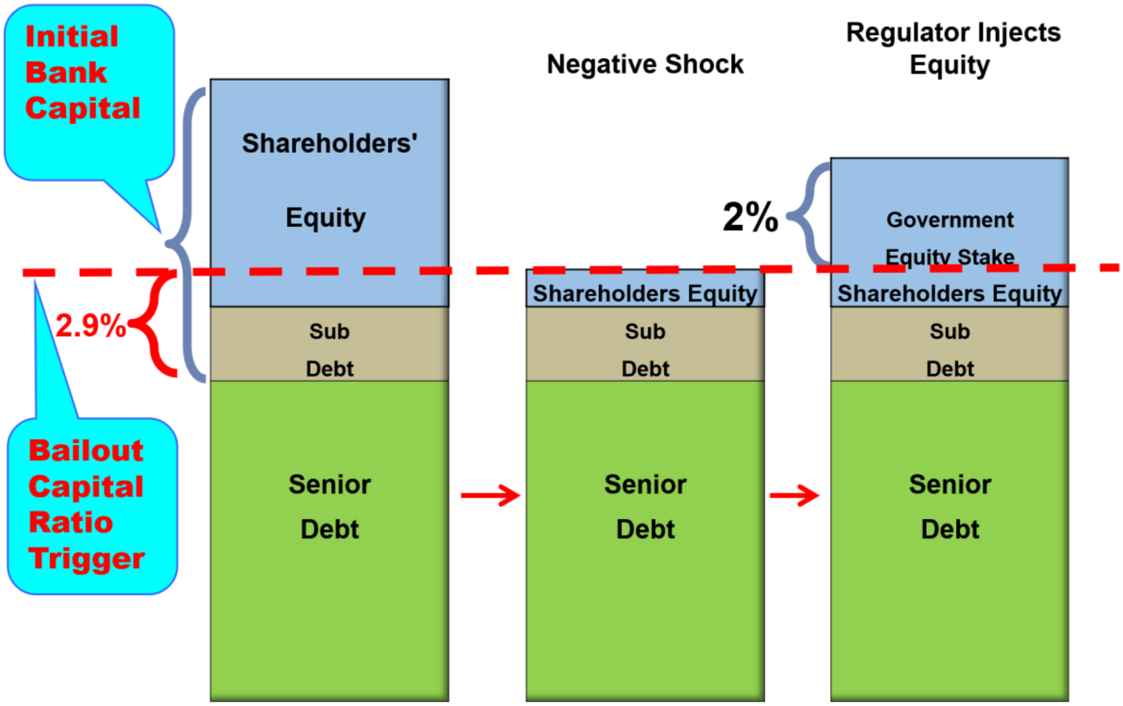
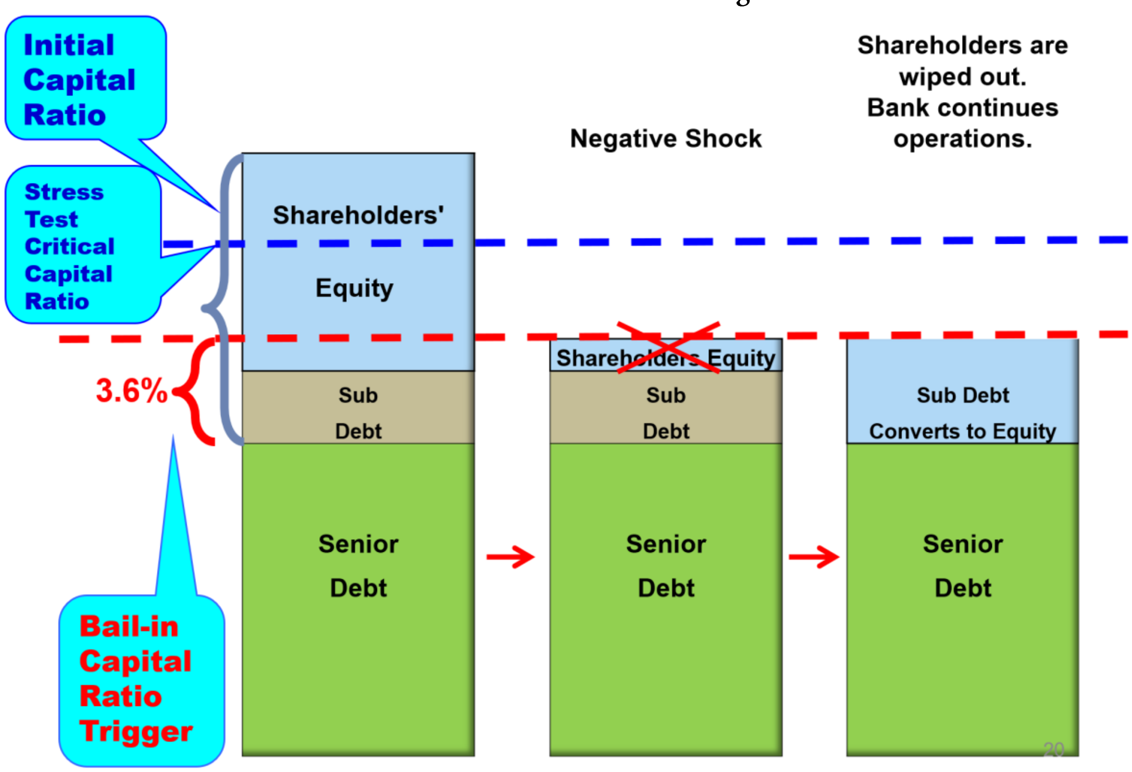


Figure 2: Illustrations of the Three Regimes

2A: Bailout Regime



2B: Illustration of the Bail-in Regime



2C: Illustration of the No Regulatory Intervention Regime

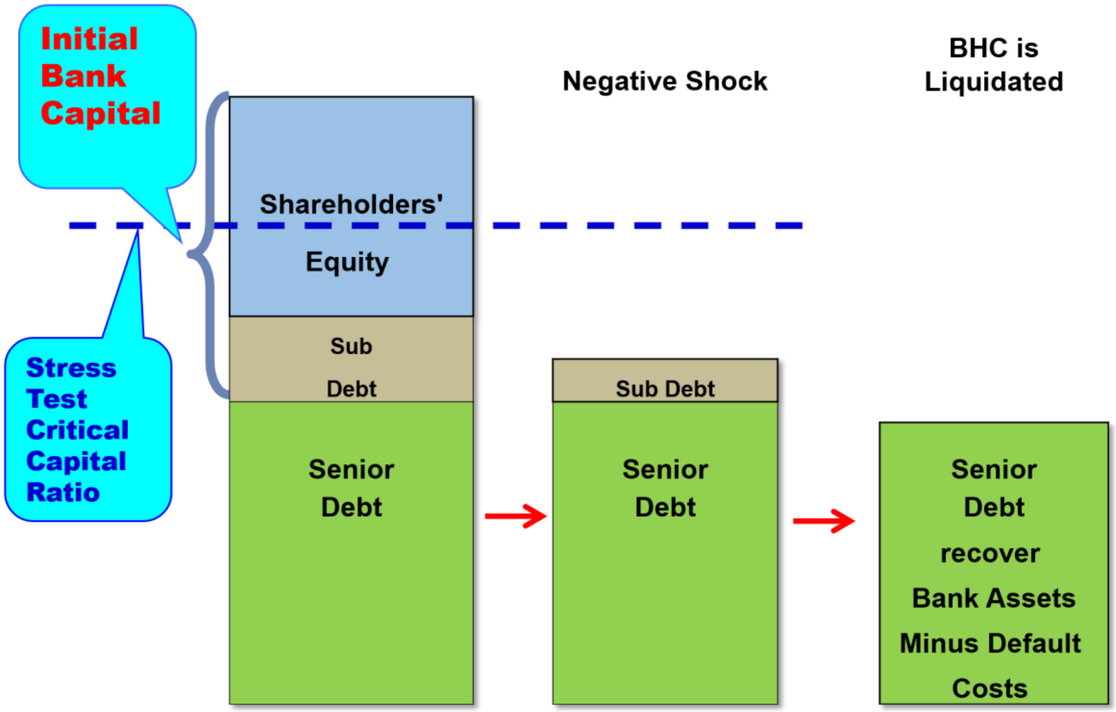


Figure 3: Bailout Regime

This figure illustrates the bailout regime by graphing six different key model ratios as functions of the bailout trigger point $\theta_{bailout}$, which is chosen by the regulator to maximize the social welfare function. Going from left to right and then down, the six figures show the effects of the regulatory ratios on the bank's optimal capital ratio, the BHC's optimal subordinated debt to asset ratio, the BHC's market value to asset ratio, the bank's expected external costs of default relative to assets, the regulator's social value function relative to assets (market value minus expected external costs divided by assets), and the expected equity injection by the regulator relative to assets. For each figure, the horizontal axis shows $\theta_{bailout}$ as a continuous variable, and the curve maps out the corresponding key ratio.

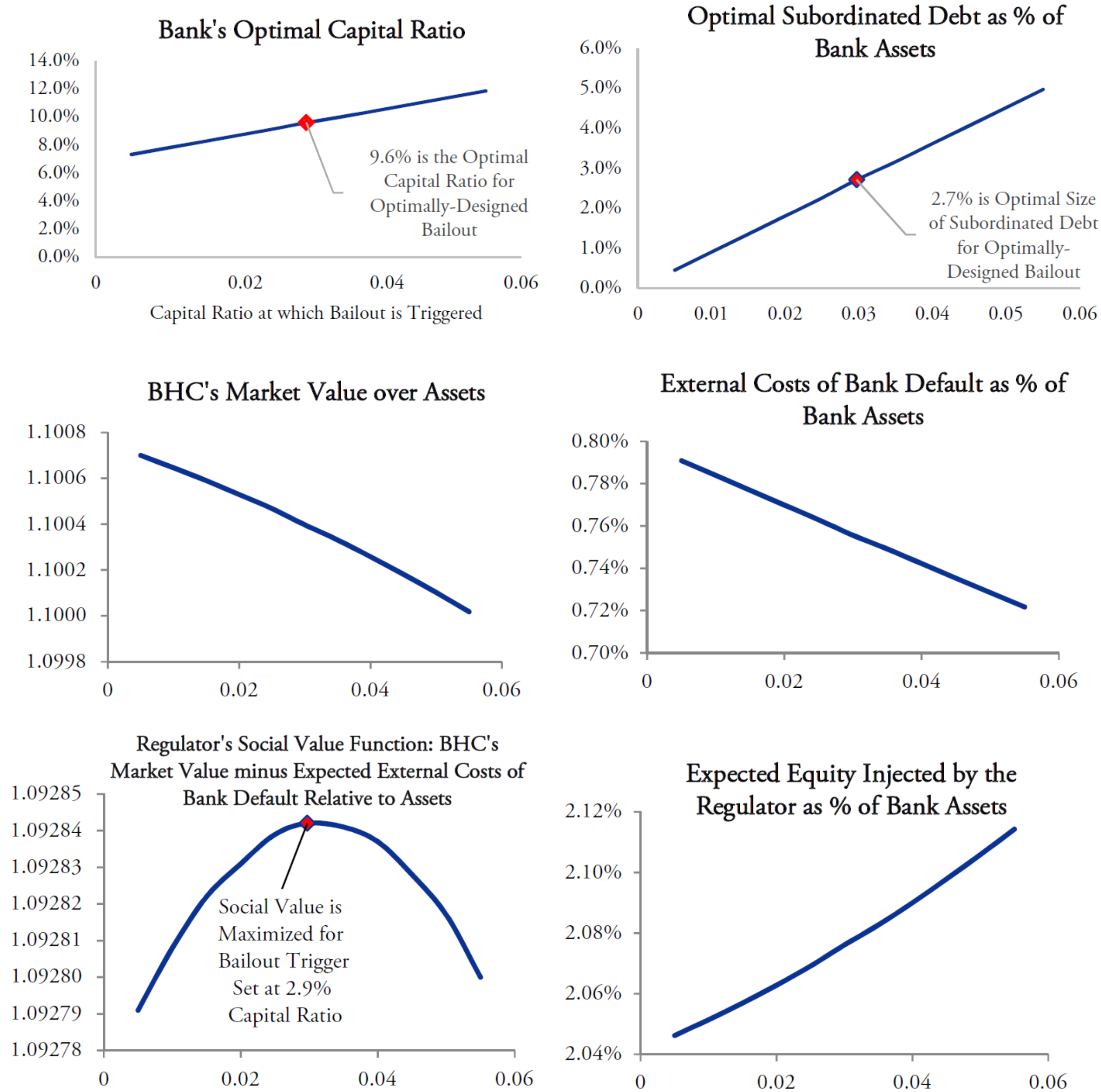


Figure 4: Bail-in Regime

This figure illustrates the bail-in regime by graphing six different key model ratios as functions of the bail-in trigger point $\theta_{bail-in}$ and the stress test critical capital ratio $\theta_{ST_{bail-in}}$, both of which are chosen by the regulator to maximize the social welfare function. Going from left to right and then down, the six figures show the effects of the regulatory ratios on the bank's optimal capital ratio, the BHC's optimal subordinated debt to asset ratio, the BHC's market value to asset ratio, the bank's expected external costs of default relative to assets, the regulator's social value function relative to assets (market value minus expected external costs divided by assets), and the expected equity issuance by the BHC relative to assets. For each figure, the horizontal axis shows $\theta_{bail-in}$ as a continuous variable, and the three curves map out the corresponding key ratio for three different stress test critical capital ratios $\theta_{ST_{bail-in}}$. These represent "cushions" of 2.5%, 3.5%, and 4.5% over $\theta_{bail-in}$.

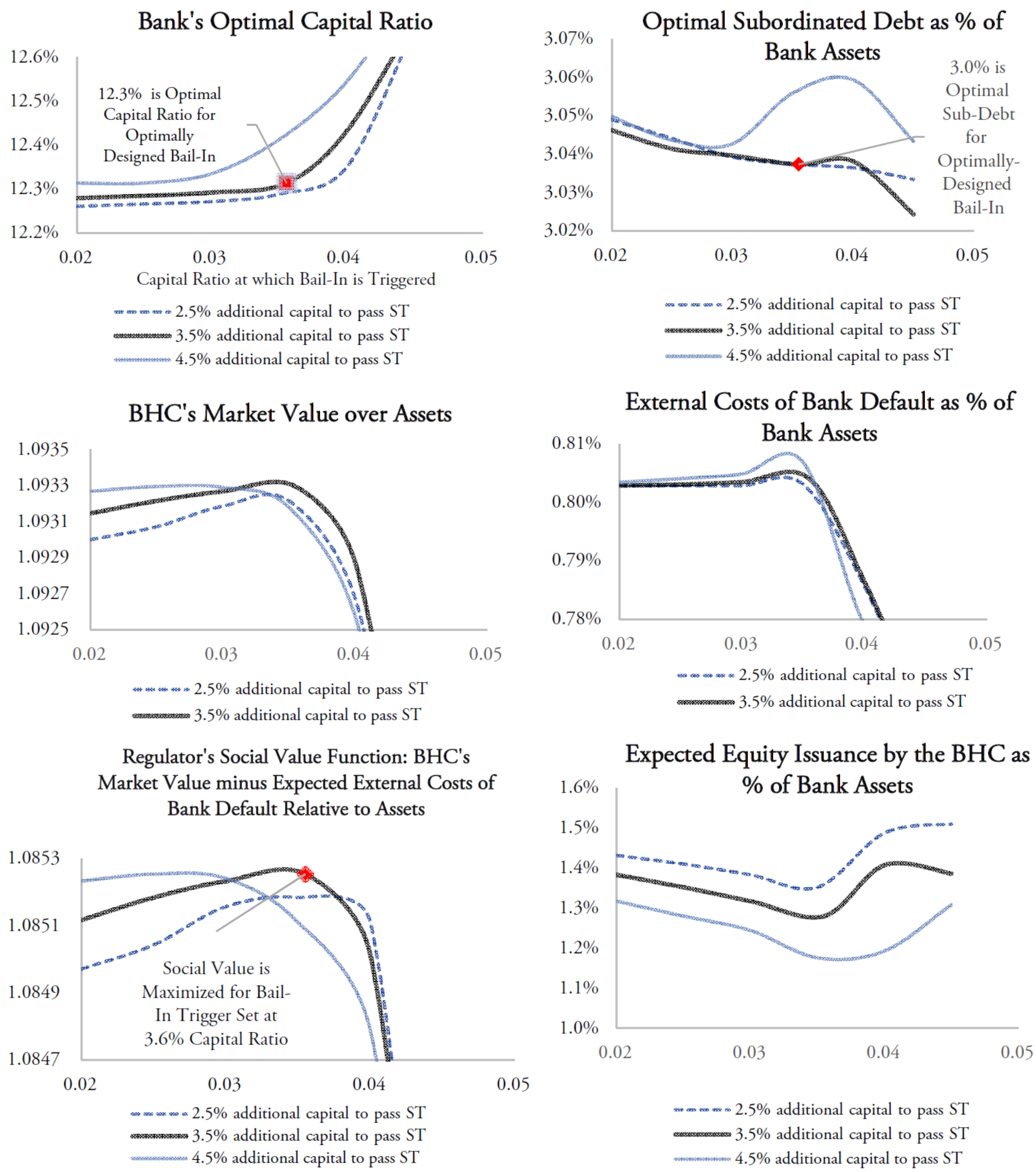


Figure 5: No-Regulatory-Intervention Regime

This figure illustrates the no-regulatory-intervention regime by graphing six different key model ratios as functions of the stress test critical capital ratio $\theta_{ST_{NoIntervention}}$, which is chosen by the regulator to maximize the social welfare function. Going from left to right and then down, the six figures show the effects of the stress test critical capital ratio on the bank's optimal capital ratio, the BHC's optimal subordinated debt to asset ratio, the BHC's market value to asset ratio, the bank's expected external costs of default relative to assets, the regulator's social value function relative to assets (market value minus expected external costs divided by assets), and the expected equity issuance by the BHC relative to assets (which is always 0). For each figure, the horizontal axis shows $\theta_{ST_{NoIntervention}}$ as a continuous variable, and the three curve maps out the corresponding key ratio.

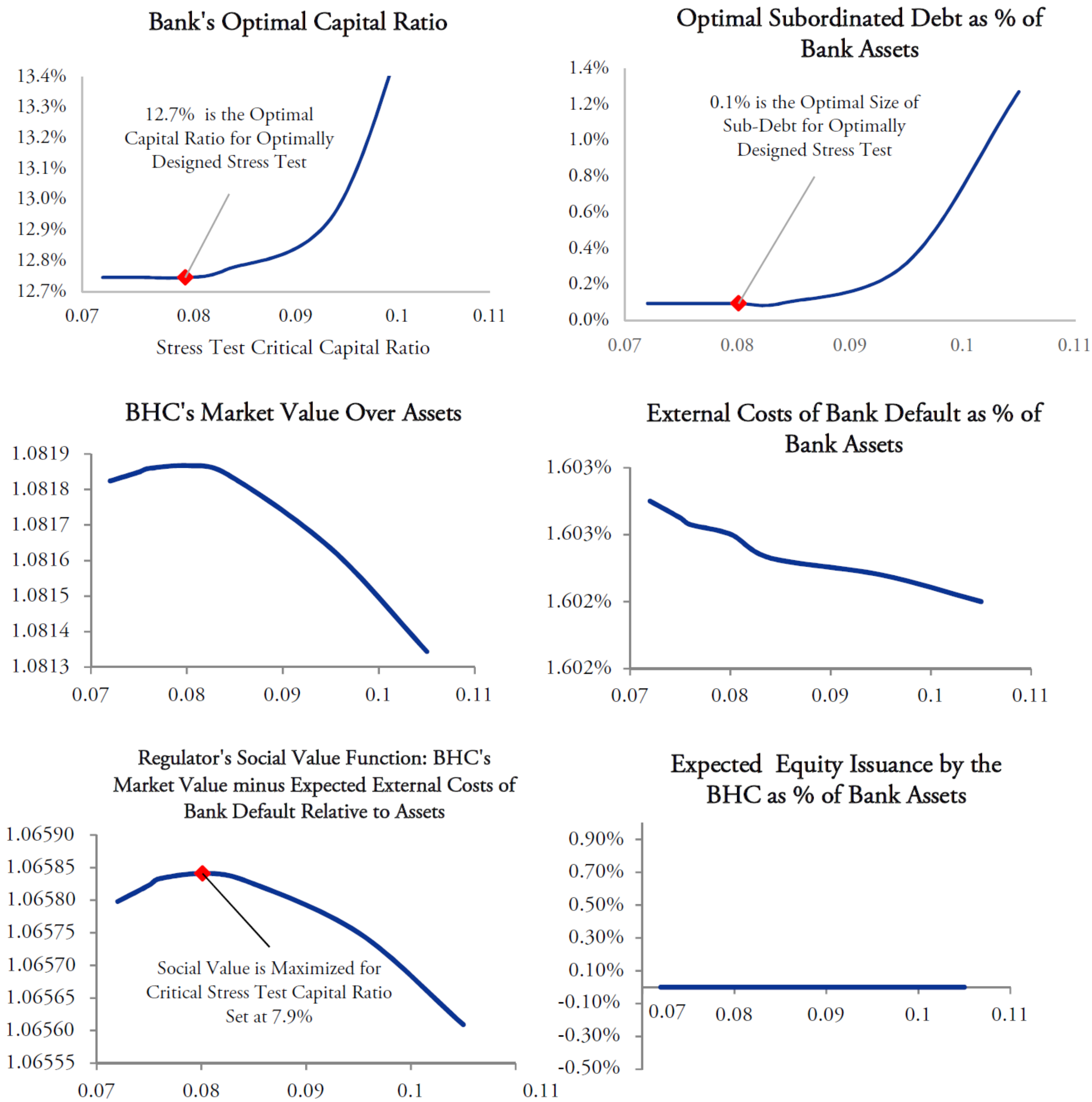


Table 1: Summary Statistics for the Top 50 Largest Publicly Traded U.S. Bank Holding Companies (BHCs) and Globally Systemically Important Institutions (G-SIBs)

This table reports definitions and summary statistics of quarterly financial data for the top 50 largest publicly traded U.S. bank holding companies (BHCs) between 2000:Q3 and 2017:Q2 (excluding the financial crisis period 2007:Q3-2010:Q2). It contains means, medians, standard deviations and number of observations on all the variables used for the calibration of the model and the empirical tests. Panel A provides variable definitions. Panel B shows summary statistics for the bailout period (2000: Q3-2007: Q2). Panel C shows summary statistics for the bail-in period (2010: Q3-2017: Q2).

Panel A: Variable Definitions

Variable	Definition
Capital Structure Variables	
CAPLEV	Ratio of Tier 1 capital to total (unweighted) assets.
CAPTIER1	Ratio of Tier 1 capital to risk-weighted assets.
CAPTOTAL	Ratio of (Tier 1 plus Tier 2) capital to risk-weighted assets.
DNK_CAPLEV	Do-nothing Leverage ratio.
DNK_CAPTIER1	Do-nothing Tier1 capital ratio.
DNK_CAPTOTAL	Do-nothing Total capital ratio.
Treatment Variables	
G-SIB	Dummy equal to 1 if the entity is a globally systemically important institution G-SIB from U.S. as designated by the Financial Stability Board (FSB), in consultation with Basel Committee on Banking Supervision (BCBS) and national authorities, and 0 otherwise. Comprises 8 U.S. G-SIBs.
SCAP	Dummy equal to 1 if the entity is a BHC with over $100 billion total assets that participated in the original Supervisory Capital assessment stress test program (SCAP) and the subsequent stress tests programs, the Comprehensive Capital Analysis and Review (CCAR)and Dodd-Frank Act stress testing (DFAST) programs, and 0 otherwise. Comprises 18 SCAP institutions.
SIFI	Dummy equal to 1 if the entity is a systemically important financial institution (SIFI) with over $50 billion in total assets, and 0 otherwise.
BAIL-IN PERIOD	Dummy equal to 1 if the period is after the Dodd Frank Act Title II ("orderly liquidation authority" (OLA)) was signed (2010:Q3-2017:Q2), and 0 for the bailout period (2000:Q3-2007:Q2).
Control Variables	
ROA	Return on assets defined as net current operating earnings/total assets.
STDEVROA	Standard deviation of (net current operating earnings/total assets) over the past 12 quarters.
MKTBOOK	Market to book ratio.
NMERGER	Number of acquisitions in the following year.
LNASSETS	Natural log of total assets.
ASSETGROWTH	The growth rate of total assets.
RETAILDEPOSITS	Ratio of retail deposits to total assets.
BUSINESSLOAN	Ratio of total business loans to total loans.
LIQUIDITY	Ratio of liquid assets to total assets.
OBS10	Dummy equal to 1 if (total gross notional amount of all derivative contracts)/(total assets) > 10.
CDLOANS	Ratio of construction and land development loans to total loans.
ROLLOVER	Ratio of debt and liabilities maturing in one year or less to total BHC debt and liabilities.

Panel B: Bailout Period (2000:Q3-2007:Q2)

	Top 50 BHCs (N=1,400)		GSIBs (N=140)		NON-GSIBs (N=1,260)	
Variable	mean	sd	Mean	sd	mean	sd
Capital Structure Variables						
CAPLEV	0.075	0.019	0.058	0.006	0.077	0.019
CAPTIER1	0.101	0.027	0.094	0.022	0.102	0.028
CAPTOTAL	0.129	0.023	0.125	0.016	0.129	0.024
DNK_CAPLEV	0.075	0.019	0.058	0.007	0.077	0.019
DNK_CAPTIER1	0.101	0.028	0.094	0.024	0.102	0.028
DNK_CAPTOTAL	0.128	0.024	0.124	0.018	0.129	0.024
Treatment Variables						
G-SIB	0.100	0.300	1.000	0.000	0.000	0.000
SCAP	0.231	0.421	1.000	0.000	0.145	0.352
SIFI	0.331	0.471	1.000	0.000	0.256	0.437
Control Variables						
ROA	0.014	0.008	0.012	0.005	0.014	0.008
STDEVROA	0.004	0.006	0.003	0.002	0.004	0.006
MKTBOOK	1.118	0.096	1.104	0.057	1.120	0.099
NMERGER	0.096	0.369	0.143	0.595	0.091	0.334
LNASSETS	17.679	1.249	20.031	1.006	17.417	0.969
ASSETGROWTH	0.028	0.084	0.035	0.079	0.028	0.085
RETAILDEPOSITS	0.512	0.221	0.283	0.220	0.538	0.206
BUSINESSLOAN	0.424	0.207	0.239	0.116	0.445	0.204
LIQUIDITY	0.049	0.054	0.084	0.097	0.045	0.046
OBS10	0.055	0.228	0.500	0.502	0.006	0.074
CDLOANS	0.073	0.077	0.016	0.017	0.080	0.078
ROLLOVER	0.366	0.278	0.577	0.167	0.342	0.278

Panel C: Bail-in Period (2010:Q3-2017:Q2)

	Top 50 BHCs (N=1,400)		GSIBs (N=192)		NON-GSIBs (N=1,208)	
Variable	mean	sd	Mean	sd	mean	sd
Capital Structure Variables						
CAPLEV	0.095	0.043	0.074	0.014	0.099	0.045
CAPTIER1	0.135	0.052	0.143	0.022	0.134	0.055
CAPTOTAL	0.156	0.051	0.169	0.021	0.153	0.054
DNK_CAPLEV	0.096	0.044	0.075	0.014	0.099	0.046
DNK_CAPTIER1	0.136	0.053	0.144	0.023	0.134	0.057
DNK_CAPTOTAL	0.156	0.053	0.170	0.022	0.154	0.056
Treatment Variables						
G-SIB	0.137	0.344	1.000	0.000	0.000	0.000
SCAP	0.292	0.455	1.000	0.000	0.180	0.384
SIFI	0.409	0.492	1.000	0.000	0.315	0.465
Control Variables						
ROA	0.011	0.016	0.008	0.004	0.011	0.017
STDEVROA	0.007	0.011	0.005	0.006	0.008	0.012
MKTBOOK	1.037	0.138	0.997	0.029	1.044	0.147
NMERGER	0.048	0.248	0.089	0.419	0.041	0.207
LNASSETS	18.025	1.423	20.692	0.837	17.601	0.961
ASSETGROWTH	0.021	0.110	0.009	0.041	0.023	0.118
RETAILDEPOSITS	0.660	0.236	0.316	0.198	0.714	0.192
BUSINESSLOAN	0.434	0.197	0.205	0.094	0.471	0.184
LIQUIDITY	0.069	0.070	0.139	0.098	0.058	0.057
OBS10	0.086	0.280	0.625	0.485	0.000	0.000
CDLOANS	0.037	0.034	0.010	0.010	0.041	0.034
ROLLOVER	0.314	0.293	0.399	0.227	0.300	0.300

Table 2: Base Case Parameter Values

This table shows the base case parameter values for the theoretical model.

Parameter	Value
The volatility of bank assets	σ = 5%
Asset cash flow yield	α = 5%
The risk-free rate	r = 5%
The proportional default costs	DC = 20%
Maturity of subordinated debt and senior debt	10 years
Tax rate	35%
Rollover rate of senior debt	m=20%
Transaction costs of raising equity	e1 = e2 = 0.025%
The jump size	k = - 0.5, i.e., the jump size is uniformly distributed between 1 and 0, implying an average loss of 50% .
The annual probability of jump	λ = 3% per year

Table 3: Optimal Regulatory Policy

This table shows the optimal regulatory policy for the three regulatory regimes and the bank's optimal response and other ratios for the base case parameter values.

Regulatory Regime	Optimal Regulatory Capital Ratio Trigger	Optimal Stress Test Critical Capital Ratio	Optimal BHC Initial Capital Ratio	Optimal BHC Initial Subordinated Debt Ratio	BHC Market Value to Assets	Expected Default Costs to Assets	Expected Transaction Costs to Assets	Expected Default Cost plus Transaction Costs to Assets	Expected Equity Injection by the Regulator	Expected Equity Issuance Rate by the BHC	Bank Value Minus w × Expected Default Costs To Assets
Bailout	2.9%	-	9.6%	2.7%	1.100	0.8%	0.9%	1.6%	2.1%	0.0%	1.0928
Bail-in	3.6%	7.1%	12.3%	3.0%	1.093	0.8%	0.4%	1.2%	0.0%	1.3%	1.0853
No Regulatory Intervention	-	8.0%	12.7%	0.1%	1.082	1.6%	0.0%	1.6%	0.0%	0.0%	1.0658

Table 4: Comparative Statics of Optimal Regime Terms and Regulator Responses

This table shows comparative statics for optimal bailout terms (Panel A), optimal bail-in terms (Panel B) and optimal terms of no regulatory intervention (Panel C) as well as the optimal bank's response for parameters for each of the regime around base case parameter values. Panel 4 documents comparative statics in which we vary parameter w, the external costs of bank default weight, using values of w of 0.5, 1, and 10, and report the optimal regulatory triggers, stress test critical capital ratios, and the optimal response of the BHC for all three regimes.

	Optimal Regulatory Capital Ratio Trigger	Optimal Stress Test Critical Capital Ratio	Optimal BHC Initial Capital Ratio	Optimal BHC Initial Subordinated Debt Ratio	Expected Default Costs to Assets	Expected Equity Injection by The Regulator	Expected Equity Issuance Rate by the BHC
Panel A:	**Bailout Regime**						
Volatility of Assets							
4%	4.5%	-	9.8%	4.1%	0.78%	1.32%	0.00%
5%	3.0%	-	9.6%	2.7%	0.76%	2.08%	0.00%
6%	1.1%	-	9.0%	0.9%	0.73%	2.90%	0.00%
Jump Probability							
2%	0.5%	-	8.9%	0.4%	0.55%	2.24%	0.00%
3%	3.0%	-	9.6%	2.7%	0.76%	2.08%	0.00%
4%	5.6%	-	10.7%	5.0%	0.92%	1.94%	0.00%
Debt Rollover Rate							
0.10	5.5%	-	12.2%	4.9%	0.71%	1.96%	0.00%
0.20	3.0%	-	9.6%	2.7%	0.76%	2.08%	0.00%
0.30	1.5%	-	8.2%	1.4%	0.78%	2.06%	0.00%
Panel B:	**Bail-in Regime**						
Volatility of Assets							
4%	3.0%	6.0%	10.2%	2.6%	0.82%	0.00%	0.73%
5%	3.6%	7.1%	12.3%	3.0%	0.80%	0.00%	1.28%
6%	4.1%	8.0%	14.3%	3.5%	0.80%	0.00%	1.87%
Jump Probability							
2%	3.9%	7.5%	14.3%	3.5%	0.66%	0.00%	1.38%
3%	3.6%	7.1%	12.3%	3.0%	0.80%	0.00%	1.28%
4%	1.6%	6.1%	10.5%	2.8%	0.97%	0.00%	1.25%
Debt Rollover Rate							
0.10	4.5%	8.0%	13.4%	4.1%	0.76%	0.00%	1.26%
0.20	3.6%	7.1%	12.3%	3.0%	0.80%	0.00%	1.28%
0.30	3.1%	7.6%	11.7%	2.8%	0.82%	0.00%	1.33%
Panel C:	**No Regulatory Intervention Regime**						
Volatility of Assets							
4%	-	6.6%	10.9%	0.1%	1.34%	0.00%	0.00%
5%	-	7.9%	12.7%	0.1%	1.60%	0.00%	0.00%
6%	-	8.2%	14.5%	0.1%	1.81%	0.00%	0.00%
Jump Probability							
2%	-	8.2%	14.2%	0.1%	1.56%	0.00%	0.00%
3%	-	7.9%	12.7%	0.1%	1.60%	0.00%	0.00%
4%	-	7.4%	11.7%	0.1%	1.62%	0.00%	0.00%
Debt Rollover Rate							
0.10	-	8.2%	12.3%	0.2%	1.53%	0.00%	0.00%
0.20	-	7.9%	12.7%	0.1%	1.60%	0.00%	0.00%
0.30	-	5.8%	13.1%	0.1%	1.53%	0.00%	0.00%

Table 5: Comparative Statics for the Change in Optimal Capital Structure

This table shows comparative Statics for the change in optimal capital structure and ratios bank changes as the regulation transitions 1) from bailout to bail-in (OLA) (in Panel A), and from bail-in to Table also reports the changes in optimally designed regulatory triggers and minimum capital requirement no intervention regime (Panel B). Table also reports the changes in optimally designed regulatory triggers and minimum capital requirement for the stress test.

	Optimal Regulatory Capital Ratio Trigger	Optimal Stress Test Critical Capital Ratio	Optimal BHC Initial Capital Ratio	Optimal BHC Initial Subordinated Debt Ratio	Expected Default Costs to Assets	Expected Equity Issuance
Panel A:	**Transition from Bailout to Bail-in**					
Volatility of Assets						
4%	-1.5%	-	0.5%	-1.6%	0.0%	-0.6%
5%	0.6%	-	2.7%	0.3%	0.0%	-0.8%
6%	3.0%	-	5.3%	2.6%	0.1%	-1.0%
Jump Probability						
2%	3.4%	-	5.4%	3.1%	0.1%	-0.9%
3%	0.6%	-	2.7%	0.3%	0.0%	-0.8%
4%	-4.0%	-	-0.2%	-2.2%	0.0%	-0.7%
Debt Rollover Rate						
0.10	-1.0%	-	1.1%	-0.9%	0.0%	-0.7%
0.20	0.6%	-	2.7%	0.3%	0.0%	-0.8%
0.30	1.6%	-	3.4%	1.4%	0.0%	-0.7%
Panel B:	**Transition from Bail-in to No-Regulatory-Intervention Regime**					
Volatility of Assets						
4%	-	0.6%	0.7%	-2.5%	0.52%	-0.73%
5%	-	0.9%	0.4%	-2.9%	0.80%	-1.28%
6%	-	0.2%	0.2%	-3.4%	1.00%	-1.87%
Jump Probability						
2%	-	0.7%	-0.1%	-3.4%	0.90%	-1.38%
3%	-	0.9%	0.4%	-2.9%	0.80%	-1.28%
4%	-	1.4%	1.1%	-2.7%	0.65%	-1.25%
Debt Rollover Rate						
0.10	-	0.2%	-1.1%	-3.9%	0.77%	-1.26%
0.20	-	0.9%	0.4%	-2.9%	0.80%	-1.28%
0.30	-	-1.8%	1.4%	-2.7%	0.71%	-1.33%

Table 6: Alternative Social Welfare Functions

This table shows the results of the regulator re-optimizing using three different sets of alternative social welfare functions, each of which applies various weights to different potential costs to society. In Panel A, we allow the expected external disruption costs of default to be different multiples of the expected private costs of default by subtracting w times the expected private costs from the alternative social welfare function for values of w of 0.5, 1, and 10. In Panel B, we take into account that employing and risking taxpayer public funds for private sector bailouts may reduce social welfare by subtracting w_2 times the expected bailout injection amount using values of 0, 0.25, and 0.50. In Panel C, we adjust the social welfare function by subtracting off administrative and financial transaction costs of collecting and distributing the bailout funds of w_3 = 0, 0.5, and 1.0 times the private sector transaction costs of raising the same amount of equity. In all cases, the reported outcomes are based on the assumption that the regulator re-optimizes based on the alternative social welfare function and the BHCs react with choices that optimize for their shareholders.

Panel A: Vary the External Costs of Bank Default

Regime	External Costs of Default Weight (w)	Optimal Regulatory Capital Ratio Trigger	Optimal Stress Test Critical Capital Ratio	Optimal BHC Initial Capital Ratio	Optimal BHC Initial Subordinated Debt Ratio	BHC Market Value over Assets	Expected Default Costs to Assets	Expected Equity Injection by the Regulator	Expected Equity Issuance Rate by the BHC	Bank Value Minus w × Expected Default Costs to Assets
Bailout Regime										
	0.5	0.5%	-	7.3%	0.5%	1.1007	0.79%	2.05%	0.0%	1.097
	1.0	2.9%	-	9.6%	2.7%	1.1004	0.76%	2.08%	0.0%	1.093
	10.0	6.5%	-	12.7%	5.4%	1.0993	0.71%	2.14%	0.0%	1.029
Bail-in Regime										
	0.5	2.0%	5.5%	10.6%	1.7%	1.0937	0.87%	0.0%	1.39%	1.089
	1.0	3.6%	7.1%	12.3%	3.0%	1.0933	0.80%	0.0%	1.28%	1.085
	10.0	5.5%	9.6%	14.2%	4.9%	1.0927	0.74%	0.0%	1.24%	1.019
No Regulatory Intervention Regime										
	0.5	-	7.6%	12.6%	0.7%	1.0820	1.61%	0.0%	0.0%	1.074
	1.0	-	7.9%	12.7%	0.7%	1.0819	1.60%	0.0%	0.0%	1.066
	10.0	-	8.4%	12.8%	0.8%	1.0818	1.60%	0.0%	0.0%	0.922

Panel B: Vary the Penalty on Regulatory Equity Injection

Penalty (w_2) on Regulatory Equity Injection in the Social Welfare Function	Optimal Regulatory Capital Ratio Trigger	Optimal BHC Capital Ratio	Optimal BHC Initial Subordinated Debt Ratio	BHC Market Value over Assets	Expected Default Costs to Assets	Bank Value minus Expected Default Costs to Assets	Expected Equity Injection by the Regulator	Expected Transaction Costs to Assets	Bank Value Minus Default Costs minus w_2*(Expected Equity Injections)
0 (base case)	2.9%	9.6%	2.7%	1.1004	0.756%	1.092841	2.0757%	0.858%	1.0928
0.25	1.6%	8.2%	1.4%	1.1006	0.777%	1.092822	2.0569%	0.848%	1.0877
0.5	0.5%	7.3%	0.5%	1.1007	0.791%	1.092791	2.0462%	0.846%	1.0826

Panel C: Vary the Penalty on Transaction Costs

Penalty (w_3) on Transaction Costs in the Social Welfare Function	Optimal Regulatory Capital Ratio Trigger	Optimal BHC Capital Ratio	Optimal BHC Initial Subordinated Debt Ratio	BHC Market Value over Assets	Expected Default Costs to Assets	Bank Value minus Expected Default Costs to Assets	Expected Equity Injection by the Regulator	Expected Transaction Costs to Assets	Bank Value Minus Default Costs minus w_3*(Transaction Costs)
0 (base case)	2.9%	9.6%	2.7%	1.1004	0.756%	1.092841	2.08%	0.858%	1.0928
0.5	1.7%	8.4%	1.4%	1.1006	0.775%	1.092828	2.06%	0.850%	1.0886
1	0.9%	7.8%	0.7%	1.1007	0.784%	1.092808	2.05%	0.848%	1.0844

Table 7: Effect of Regime Change on BHC Capital – Difference-in Difference (DID) Analysis (Main Results)

This table reports the difference-in-difference regression estimates for analyzing the effect of the regulatory regime change from bailout to bail-in on BHCs' capital decisions. We report estimation results for G-SIB and non-G-SIB BHCs. The dependent variable is one of the BHC capital ratios *CAPLEV* (Tier 1 leverage ratio), *CAPTIER1* (Tier 1 risk-based capital ratio) or *CAPTOTAL* (the total risked-based capital ratio). *G-SIB* is a dummy equal to 1 if the entity is a G-SIB and 0 otherwise. *BAIL-IN PERIOD* is a dummy equal to 1 for the bail-in period (2010: Q3-2017: Q2), and 0 for the bailout period (2000:Q3-2007:Q2). We include a set of characteristics that affect BHC capital decisions (*ROA, STDEVROA, MKTBOOK, NMERGER, LNASSETS, RETAILDEPOSITS, BUSINESSLOAN, LIQUIDITY, OBS10, CDLOANS, ROLLOVER*) and all regressions include BHC and time fixed effects. All variables are defined in Table 1. *, **, and *** denote significance at 10%, 5%, and 1% level.

	Difference-in-Difference (DID) Analysis		
	(1)	(2)	(3)
VARIABLES	CAPLEV	CAPTIER1	CAPTOTAL
G-SIB × BAIL-IN PERIOD	0.010***	0.023***	0.027***
	(6.793)	(11.375)	(13.090)
ROA	0.052**	0.087**	0.093**
	(2.070)	(2.472)	(2.569)
STDEVROA	0.176***	0.351***	0.420***
	(6.081)	(8.754)	(10.178)
MKTBOOK	0.025***	0.029***	0.003
	(6.210)	(5.019)	(0.437)
NMERGER	-0.001	0.000	-0.000
	(-1.358)	(0.120)	(-0.494)
LNASSETS	-0.010***	-0.012***	-0.013***
	(-9.447)	(-8.474)	(-9.094)
RETAILDEPOSITS	-0.007***	-0.006*	-0.007*
	(-2.636)	(-1.646)	(-1.725)
BUSINESSLOAN	0.016***	-0.028***	-0.015***
	(4.067)	(-5.077)	(-2.589)
LIQUIDITY	0.041***	0.069***	0.044***
	(5.371)	(6.495)	(4.011)
OBS10	-0.000	0.002	0.006
	(-0.042)	(0.588)	(1.591)
CDLOANS	-0.031***	0.011	0.033***
	(-3.700)	(0.928)	(2.789)
ROLLOVER	0.001	-0.000	-0.001
	(0.909)	(-0.127)	(-0.664)
Time FE	YES	YES	YES
BHC FE	YES	YES	YES
No. Observations	2,796	2,796	2,796
R-squared	0.928	0.917	0.899

Table 8: Effect of Regime Change on BHC Capital – Difference-in Difference (DID) Analysis (Subsample Tests)

This table reports the regression estimates for analyzing the effects of the regulatory regime change from bailout to bail-in on capital adjustment speed using a difference-in-difference approach and several subsample analyses. The dependent variable is one of the capital measures *CAPLEV, CAPTIER1,* or *CAPTOTAL*. Panel A reports results using splits by BHC asset volatility risk (*STDEVROA*) using median as a cutoff. *STDEVROA* is the standard deviation of ROA over the previous 12 quarters. Panel B reports results using splits by BHC jump risk (*CDLOANS*) using median as a cutoff. *CDLOANS* is construction and development loans over total loans. Panel C reports results using splits by BHC rollover risk (*ROLLOVER*) using median as a cutoff. *ROLLOVER* is the ratio of debt and liabilities maturing in one year or less to BHC total debt and liabilities. *G-SIB* is a dummy equal to 1 if the entity is a G-SIB and 0 otherwise. *BAIL-IN PERIOD* is a dummy equal to 1 for the bail-in period (2010: Q3-2017: Q2), and 0 for the bailout period (2000:Q3-2007:Q2). We include a set of characteristics that affect BHC capital decisions (*ROA, STDEVROA, MKTBOOK, NMERGER, LNASSETS, RETAILDEPOSITS, BUSINESSLOAN, LIQUIDITY, OBS10, CDLOANS, ROLLOVER*) and all regressions include BHC and time fixed effects. All variables are defined in Table 1. *, **, and *** denote significance at 10%, 5%, and 1% level.

Panel A: Asset Volatility Risk

	Low Asset Vol	**High Asset Vol**	**Low Asset Vol**	**High Asset Vol**	**Low Asset Vol**	**High Asset Vol**
Proxy	***STDEVROA***		***STDEVROA***		***STDEVROA***	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPLEV	CAPLEV	CAPTIER1	CAPTIER1	CAPTOTAL	CAPTOTAL
G-SIB × BAIL-IN PERIOD	0.009***	0.010***	0.013***	0.028***	0.019***	0.029***
	(4.648)	(4.749)	(4.742)	(9.646)	(6.887)	(9.473)
Other Bank Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
No. Observations	1,394	1,393	1,394	1,393	1,394	1,393
R-squared	0.815	0.961	0.840	0.949	0.755	0.935

Panel B: Jump Risk

	Low Jump Risk	**High Jump Risk**	**Low Jump Risk**	**High Jump Risk**	**Low Jump Risk**	**High Jump Risk**
Proxy	***CDLOANS***		***CDLOANS***		***CDLOANS***	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPLEV	CAPLEV	CAPTIER1	CAPTIER1	CAPTOTAL	CAPTOTAL
G-SIB × BAIL-IN PERIOD	0.012***	0.005	0.025***	0.002	0.029***	0.007
	(6.629)	(0.914)	(9.631)	(0.269)	(10.521)	(0.824)
Other Bank Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
No. Observations	1,396	1,391	1,396	1,391	1,396	1,391
R-squared	0.957	0.764	0.943	0.839	0.931	0.732

Panel C: Rollover Risk

	Low Rollover Risk	**High Rollover Risk**	**Low Rollover Risk**	**High Rollover Risk**	**Low Rollover Risk**	**High Rollover Risk**
Proxy	***ROLLOVER***		***ROLLOVER***		***ROLLOVER***	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPLEV	CAPLEV	CAPTIER1	CAPTIER1	CAPTOTAL	CAPTOTAL
G-SIB × BAIL-IN PERIOD	0.014***	0.005***	0.025***	0.018***	0.030***	0.022***
	(3.289)	(3.394)	(4.012)	(8.400)	(4.811)	(9.963)
Other Bank Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
No. Observations	1,393	1,390	1,393	1,390	1,393	1,390
R-squared	0.961	0.884	0.948	0.880	0.941	0.825

Table 9: Effect of Regime Change on BHC Capital – Partial Adjustment Analysis

This table reports the regression estimates for analyzing the effects of the regulatory regime change from bailout to bail-in on capital adjustment speed using equation (6) and system GMM. Panel A reports the main capital adjustment speed regression estimates using CAPLEV, our baseline capital ratio and differences in regression coefficients. Panel B reports the main capital adjustment speed regression estimates using CAPTIER, and Panel C reports results using CAPTOTAL respectively. CAPLEV is the Tier 1 leverage ratio, CAPTIER1 is Tier 1 risk-based capital ratio, and CAPTOTAL is the total risked-based capital ratio. *G-SIB* is a dummy equal to 1 if the entity is a G-SIB and 0 otherwise. *BAIL-IN PERIOD* is a dummy equal to 1 for the bail-in period (2010: Q3-2017: Q2), and 0 for the bailout period (2000:Q3-2007:Q2). We include a set of characteristics that affect BHC capital decisions (*ROA, STDEVROA, MKTBOOK, NMERGER, LNASSETS, RETAILDEPOSITS, BUSINESSLOAN, LIQUIDITY, OBS10, CDLOANS, ROLLOVER*) and interactions between G-SIB and the BHC characteristics. All variables are defined in Table 1. *, **, and *** denote significance at 10%, 5%, and 1% level.

Panel A: CAPLEV

	BAILOUT PERIOD (2000:Q3-2007:Q2)			BAIL-IN PERIOD (2010:Q3-2017:Q2)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPLEV	CAPLEV	CAPLEV	CAPLEV	CAPLEV	CAPLEV
λ	0.886***			0.808***		
	(14.141)			(23.520)		
$\lambda_1 \times$ *G-SIB*		0.388***			0.926***	
		(2.882)			(29.754)	
$\lambda_2 \times$ *nonG-SIB*		0.904***			0.811***	
		(14.598)			(23.987)	
$\lambda_{11} \times$ *G-SIB_above*			0.460***			0.928***
			(2.723)			(33.928)
$\lambda_{12} \times$ *G-SIB_below*			0.431**			0.916***
			(2.318)			(26.118)
$\lambda_{21} \times$ *nonG-SIB_above*			0.931***			0.835***
			(16.746)			(28.013)
$\lambda_{22} \times$ *nonG-SIB_below*			0.927***			0.831***
			(17.045)			(23.695)
Other BHC Controls	YES	YES	YES	YES	YES	YES
G-SIB × Other BHC Controls	YES	YES	YES	YES	YES	YES
No. Observations	1,400	1,400	1,400	1,400	1,400	1,400

Differences in Regression Coefficients

	Group	BAILOUT	BAIL-IN	BAILIN-BAILOUT
Coefficient	*G-SIB*	0.388***	0.926***	0.538***
t-statistic		(2.882)	(29.754)	(3.884)
Coefficient	*nonG-SIB*	0.904***	0.811***	-0.093
t-statistic		(14.598)	(23.987)	(-1.315)
Coefficient	*G-SIB - nonG-SIB*	-0.516***	0.115**	0.631***
t-statistic		(12.160)	(6.290)	(4.071)

Panel B: CAPTIER1

	BAILOUT PERIOD (2000:Q3-2007:Q2)			BAIL-IN PERIOD (2010:Q3-2017:Q2)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPTIER1	CAPTIER1	CAPTIER1	CAPTIER1	CAPTIER1	CAPTIER1
λ	0.844***			0.797***		
	(16.146)			(17.183)		
$\lambda_1 \times$ *G-SIB*		0.563***			0.843***	
		(2.996)			(16.965)	
$\lambda_2 \times$ *nonG-SIB*		0.843***			0.789***	
		(16.689)			(16.331)	
$\lambda_{11} \times$ *G-SIB_above*			0.503***			0.920***
			(3.558)			(24.153)
$\lambda_{12} \times$ *G-SIB_below*			0.468***			0.934***
			(3.222)			(21.233)
$\lambda_{21} \times$ *nonG-SIB_above*			0.886***			0.798***
			(26.840)			(16.860)
$\lambda_{22} \times$ *nonG-SIB_below*			0.878***			0.791***
			(24.774)			(14.671)
Other BHC Controls	YES	YES	YES	YES	YES	YES
G-SIB × Other BHC Controls	YES	YES	YES	YES	YES	YES
No. Observations	1,400	1,400	1,400	1,400	1,400	1,400

Panel C: CAPTOTAL

	BAILOUT PERIOD (2000:Q3-2007:Q2)			BAIL-IN PERIOD (2010:Q3-2017:Q2)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPTOTAL	CAPTOTAL	CAPTOTAL	CAPTOTAL	CAPTOTAL	CAPTOTAL
λ	0.695***			0.770***		
	(9.417)			(17.329)		
$\lambda_1 \times$ *G-SIB*		0.451**			0.801***	
		(2.386)			(19.936)	
$\lambda_2 \times$ *nonG-SIB*		0.707***			0.774***	
		(9.057)			(16.309)	
$\lambda_{11} \times$ *G-SIB_above*			0.353**			0.887***
			(2.296)			(43.015)
$\lambda_{12} \times$ *G-SIB_below*			0.311**			0.894***
			(1.974)			(40.967)
$\lambda_{21} \times$ *nonG-SIB_above*			0.743***			0.750***
			(10.829)			(11.642)
$\lambda_{22} \times$ *nonG-SIB_below*			0.728***			0.727***
			(9.838)			(8.988)
Other BHC Controls	YES	YES	YES	YES	YES	YES
G-SIB × Other BHC Controls	YES	YES	YES	YES	YES	YES
No. Observations	1,400	1,400	1,400	1,400	1,400	1,400

A Appendix: Analytics of the model

In the following subsections we present the valuation approach of the bank's equity, senior liabilities, and subordinated debt for the regime of bail-in. A valuation for bail-out and the ordinary bankruptcy is similar, expect that some boundary conditions are different.

A.1 Valuation of the bank's equity for the case with bail-in

In this section, we present valuation of the bank's equity for the case before bail-in $E(V, F+C, t)$, and after the bail-in intervention $E(V, F, t)$. The value of equity is a function of its asset value V; debt principal of senior and subordinated debt $F+C$, if no bail-in intervention took place in prior periods, and time t ($\leq T$).

First, we describe the valuation of equity for the case in which the bail-in intervention has already taken place in prior periods. For this case, subordinated debt is converted to equity, and the bank continues paying interest of its senior debt f and has to pay off its par value F at maturity. At maturity date T, the value of the bank's equity is

$$E(V, F, T) = \max(0, \ \ V - F). \tag{1}$$

Any time prior to maturity, using standard arbitrage arguments, the value of the equity $E(V, F, t)$ is given by the solution to the following partial integro-differential equation (PIDE):

$$\begin{gathered} \tfrac{\sigma^2 V^2}{2}\tfrac{\partial^2 E}{\partial V^2} + (r - \alpha - \lambda \cdot k)\tfrac{\partial E}{\partial V} + \tfrac{\partial E}{\partial t} + \alpha V - (1-\tau)\cdot f \\ -m\cdot(F-D) - rE - \lambda \cdot \mathbb{E}_t^Q\{E(Y\cdot V, F, t) - E(V, F, t)\} = 0, \\ \text{for any } V > F, \end{gathered} \tag{2}$$

where $\mathbb{E}^Q$ is the expectation operator under the risk neutral measure Q. In this equation, αV is the after-tax cash flow generated by the bank's assets and $\alpha V - (1-\tau)\cdot f - m\cdot(F-D)$ is the dividend payout to the shareholders; and the last term represents the expected change in equity value due to jumps.

If the bank's capital ratio declines below the minimum capital ratio specified by the stress test, i.e., if $\frac{(V_t - F)}{V_t} < \theta_{ST_bail-in}$,then the bank will have to retain all its residual cash flows. As such, the bank has to reduce its asset payout ratio from α to α_{ST} so that it's dividend payout is zero (or non-positive), i.e., $\alpha_{ST}V_t - (1-\tau)f - m\cdot(F-D_t)) \leqq 0$. Thus, any time t, $\alpha_{ST_bail-in} = MIN\{\alpha, \ \frac{(1-\tau)f + m\cdot(F-D_t)}{V_t}\}$, if $\frac{(V_t - F)}{V_t} < \theta_{ST_bail-in}$, and parameter α is replaced by $\alpha_{ST_bail-in}$ in the above equation.

Note that after the subordinated debt converts, the bank will not elect to raise equity capital because such transaction would dilute the shareholders' value and will benefit holders of the senior debt at the shareholders' expense.

Now, consider the valuation of the bank's equity for the case if the bail-in has not been invoked in the prior periods. At maturity $t = T$:

$$\begin{cases} E(V, F + C, T) = V - C - F, \text{ if } \frac{V-F}{V} > \theta_{bail-in}, \text{ and } \frac{V-F-C}{V} > 0, \text{ no bail-in intervention,} \\ E(V, F + C, T) = 0, \text{ if } \frac{V-F}{V} < \theta_{bail-in}, \text{ or } \frac{V-F-C}{V} < 0, \text{ and } V \geq F. \end{cases}$$

Prior to maturity, $t < T$, the bank can choose to raise equity. The choice of equity issuance maximizes the market value of the bank's exisitng equity. The solution involves determining free boundary conditions that divide the state space $(V, \{F + C\}, t)$ into four regions that characterize the bank's choices: the *no equity issuance* region, the *equity issuance* region, the bail-in intervention region, and the *default* region.[1]

In the *no equity issuance* region, it is not optimal for the bank to issue new equity capital. In this region, the equity value $E(V, F + C, t)$ equals the instantaneous cash flow net of coupon payment plus the expected value of the equity at time $t + \Delta t$ calculated under the risk neutral measure Q:

$$\begin{aligned} E(V, F + C, t) = {} & [\alpha V - (1 - \tau) \cdot (f + c) - m \cdot (F - D)]dt \\ & + e^{-rdt}\mathbb{E}^Q\{E(V_{t+dt}, F + C, t + dt)\}, \quad t + dt \leq T. \end{aligned} \tag{3}$$

In this region, the equityholders will not choose to issue equity and the following inequalities must hold for any ΔV:

$$\begin{cases} [\alpha V_t - (1 - \tau) \cdot (f + c) - m \cdot (F - D)]dt + e^{-rdt}\mathbb{E}^Q(E(V_{t+dt} + \triangle V, F + C, t + dt)) - \triangle V - TC < \\ \alpha V_t - (1 - \tau) \cdot (f + c) - m \cdot (F - D)]dt + e^{-rdt}\mathbb{E}^Q(E(V_{t+dt}, F + C, t + dt)), \\ \text{for any } \triangle V > 0, \end{cases} \tag{4}$$

i.e., equity issuance is not profitable, where TC are transaction costs of raising equity, $TC = e_1 \cdot V_t + e_2 \cdot \triangle V$. The value of the equity $E(V_t, F + C, t)$ in the *no equity issuance* region is given by the solution to the following PIDE:

[1] For brevity, we omit the discussion of the technical detail of boundary and "high contact" conditions that applied to the value function E. For details see Oksendal and Sulem (2007).

$$\begin{cases} \frac{\sigma^2 V^2}{2}\frac{\partial^2 E}{\partial V^2} + (r-\alpha-\lambda\cdot k)\frac{\partial E}{\partial V} + \frac{\partial E}{\partial t} + \alpha V - (1-\tau)\cdot(f+c) \\ -m\cdot(F-D) - rE - \lambda\cdot \mathbb{E}_t^Q\{E(Y\cdot V, F+C, t) - E(V, F+C, t)\} = 0, \\ \text{for any } \frac{V-F}{V} > \theta_{bail-in}, \text{ and } \frac{V-F-C}{V} > 0. \end{cases} \tag{5}$$

The bank will raise new capital if the net benefit of raising capital exceeds the transaction costs TC. This condition characterizes a region where equityholders raise equity and increase the size of the bank capital. In the equity issuance region, the value of the bank's equity $E(V, F+C, t)$, $t < T$, can be determined by maximizing the expected value of equity, over all sizes of the new equity issuance $\triangle V$:

$$E(V, F+C, t) = [\alpha V - (1-\tau)\cdot(f+c) - m\cdot(F-D)]dt +$$
$$e^{-rdt}\mathbb{E}^Q(\max_{\triangle V > 0}[E(V_{t+dt} + \triangle V, F+C, t+dt) - \triangle V - TC]), \text{ for } t < T. \tag{6}$$

In the *bail-in* region, the banks capital ratio is below the trigger $\theta_{bail-in}$, and the following condition is held $0 < \frac{V-F}{V} \leq \theta_{bail-in}$, or if $0 < \frac{V-F-C}{V} \leq 0$. In this region, the subordinanted debt converts to equity at the dollar amount of shares C, and the equity value for the existing stockholders is wiped out:

$$E(V, F+C, t) = 0\ . \tag{7}$$

In the *bail-in* region, the holders of subordinanted debt take over the bank.[2] As we pointed out earlier, a large negative jump can instantly reduce the value of bank's assets to some level V' well below the face value of the total debt so that $V' - F - C < 0$, but above the default level $V' > F$. In this region, the value of the holders of subordinanted debt will be $E(V', F, t)$. In the default region, the equity value $E = 0$.

A.2 Valuation of the senior debt

To calculate the value of the senior debt, we need to consider the shareholders' optimal strategy to raise capital. At maturity date T, the value of the bank's debt is

$$\begin{cases} D(V,T) = F, \text{ if } V \geq F, \text{ otherwise}, \\ D(V,F,t) = (1-DC)\cdot V, \text{ if } V < F. \end{cases} \tag{8}$$

[2] We assume that the remaining fraction of equity value $E(V, F, t) - C$ belongs to the regulator of the bank.

where DC represents proportional default costs ($0 \leq DC \leq 1$). Any time prior to maturity $t < T$, the value of debt satisfies:

$$\begin{cases} \frac{\sigma^2 V^2}{2}\frac{\partial^2 D}{\partial V^2} + (r - \alpha - \lambda \cdot k)\frac{\partial D}{\partial V} + \frac{\partial D}{\partial t} + f + m \cdot (F - D) - rD - \\ \lambda \cdot \mathbb{E}_t^Q\{D(Y \cdot V, F + C, t) - D(V, F + C, t)\} = 0, \\ \text{if } E(V, F + C, t) \geq 0, \;\; \text{no prior bail-in intervention} \\ \frac{\sigma^2 V^2}{2}\frac{\partial^2 D}{\partial V^2} + (r - \alpha - \lambda \cdot k)\frac{\partial D}{\partial V} + \frac{\partial D}{\partial t} + f + m \cdot (F - D) - rD - \\ \lambda \cdot \mathbb{E}_t^Q\{D(Y \cdot V, F, t) - D(V, F, t)\} = 0, \text{ if the bail-in has taken place in prior periods.} \end{cases} \tag{9}$$

In the bail-in region, the value of the senior debt is

$$D(V, F + C, t) = D(V, F, t), \; if \quad 0 \leq \frac{V - F}{V} \leq \theta, \text{ or } \frac{V - F - C}{V} \leq 0 \text{ and } 0 \leq \frac{V - F}{V}. \tag{10}$$

In the region where the bank issues equity and increases its capital by $\triangle V$, the value of senior debt satisfies:

$$D(V, F + C, t_+) = D(V + \triangle V, F + C, t). \tag{11}$$

In the default region, the assets are transferred to the holders of the senior debt:

$$D(V, F, t) = (1 - DC) \cdot V. \tag{12}$$

A.3 Valuation of the subordinated debt

Holders of subordinanted debt have lower priority at default, and for most parameter will recover zero value. To calculate the value of subordinanted debt, we need to consider the bank's strategy to raise capital as well the possibility of bank being bailed-in. At the maturity date T, if the bail-in has not taken place in prior periods, the value of the subordinated debt, $Z(V, F + C, T)$ is

$$\begin{cases} Z(V, F + C, T) = C, \;\; \frac{V-F}{V} \geq \theta_{bail-in}, \text{ and } 0 < \frac{V-F-C}{V}, \\ Z(V, F + C, T) = \min\{(V - F), \;\; C\}, \text{ if } 0 < \frac{V-F}{V} < \theta \text{ , or } 0 < \frac{V-F-C}{V} < 0 \text{ and } \frac{V-F}{V} \geq \theta_{bail-in}, \\ Z(V, F + C, T) = 0, \text{ otherwise.} \end{cases} \tag{13}$$

Any time prior to maturity $t < T$, the value of subordinated debt satisfies:

$$\begin{gathered} \frac{\sigma^2 V^2}{2}\frac{\partial^2 Z}{\partial V^2} + (r - \alpha - \lambda \cdot k)\frac{\partial Z}{\partial V} + \frac{\partial Z}{\partial t} + c - rZ - \lambda \cdot \mathbb{E}_t^Q\{Z(Y_t \cdot V, F + C, t) - Z(V, F + C, t)\} = 0, \\ \text{if } \frac{V-F}{V} \geq \theta_{bail-in}, \text{ and } 0 < \frac{V-F-C}{V}. \end{gathered} \tag{14}$$

At the bail-in intervention boundary, the value of the subordinated debt is

$$Z(V, F + C, t) = \min\{E(V, F, t), C\}, \tag{15}$$

and the bank remains operational and is taken over by the holders of the subordinated debt.

In the region where the bank issues equity and increases its capital by $\triangle V$ at t, the value of subordinated debt satisfies:

$$Z(V, F + C, t_+) = Z(V + \triangle V, F + C, t). \tag{16}$$

In the default region:

$$Z(V, F + C, t_+) = 0. \tag{17}$$

B Appendix: Additional Tests for "Bank Bailouts, Bail-ins, or No Regulatory Intervention? A Dynamic Model and Empirical Tests of Optimal Regulation"

Table B.1: Additional Summary Statistics for the Bailout and Bail-in Periods Together – Top 50 BHCs and G-SIBs

This table reports summary statistics of the variables for our analysis. It contains means, medians, standard deviations and number of observations on the regression variables used to examine the effect of the regulatory regime change from bailout to bail-in on BHCs' capital decisions. This table contains summary statistics for the full sample (2000:Q3-2017:Q2, excluding the crisis period (2007:Q3-2010:Q2)) for all BHCs, G-SIBs, and non-G-SIBs.

	All BHCs (N=2,800)		GSIBs (N=332)		NON-GSIBs (N=2,468)	
VARIABLES	mean	sd	Mean	sd	mean	sd
Capital Structure Variables						
CAPLEV	0.085	0.035	0.067	0.014	0.087	0.036
CAPTIER1	0.118	0.045	0.122	0.033	0.117	0.046
CAPTOTAL	0.142	0.042	0.150	0.029	0.141	0.043
DNK_CAPLEV	0.085	0.035	0.068	0.014	0.088	0.037
DNK_CAPTIER1	0.118	0.046	0.123	0.034	0.118	0.047
DNK_CAPTOTAL	0.142	0.043	0.151	0.031	0.141	0.045
Treatment Variables						
G-SIB	0.119	0.323	1.000	0.000	0.000	0.000
SCAP	0.261	0.439	1.000	0.000	0.162	0.369
SIFI	0.370	0.483	1.000	0.000	0.285	0.452
BAIL-IN PERIOD	0.500	0.500	0.578	0.495	0.489	0.500
Control Variables						
ROA	0.012	0.013	0.010	0.005	0.012	0.014
STDEVROA	0.006	0.009	0.005	0.005	0.006	0.010
MKTBOOK	1.078	0.125	1.042	0.068	1.083	0.131
NMERGER	0.072	0.315	0.111	0.500	0.067	0.280
LNASSETS	17.852	1.350	20.413	0.967	17.507	0.969
ASSETGROWTH	0.025	0.098	0.020	0.061	0.025	0.102
RETAILDEPOSITS	0.586	0.240	0.302	0.208	0.624	0.218
BUSINESSLOAN	0.429	0.202	0.219	0.105	0.458	0.195
LIQUIDITY	0.059	0.063	0.116	0.101	0.051	0.052
OBS10	0.070	0.256	0.572	0.495	0.003	0.053
CDLOANS	0.055	0.062	0.012	0.014	0.061	0.064
ROLLOVER	0.340	0.286	0.474	0.222	0.322	0.289

Table B.2: Effect of Regime Change on BHC Capital – Additional Results for SCAP and SIFI BHCs

This table reports the difference-in-difference regression estimates for analyzing the effect of the regulatory regime change from bailout to bail-in on BHCs' capital decisions using SCAP and SIFIs BHC groups. The dependent variable is one of the BHC capital ratios *CAPLEV* (Tier 1 leverage ratio), *CAPTIER1* (Tier 1 risk-based capital ratio) or *CAPTOTAL* (the total risked-based capital ratio). *SCAP* is a dummy equal to 1 if the entity is a SCAP and 0 otherwise. *SIFI* is a dummy equal to 1 if the entity is a SIFI and 0 otherwise. *BAIL-IN PERIOD* is a dummy equal to 1 for the bail-in period (2010: Q3-2017: Q2), and 0 for the bailout period (2000:Q3-2007:Q2). We include a set of characteristics that affect BHC capital decisions (*ROA, STDEVROA, MKTBOOK, NMERGER, LNASSETS, RETAILDEPOSITS, BUSINESSLOAN, LIQUIDITY, OBS10, CDLOANS, ROLLOVER*) and all regressions include BHC and time fixed effects. All variables are defined in Table 1. *, **, and *** denote significance at 10%, 5%, and 1% level.

	Difference-in-Difference (DID) Analysis					
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CAPLEV	CAPTIER1	CAPTOTAL	CAPLEV	CAPTIER1	CAPTOTAL
SCAP × BAIL-IN PERIOD	0.008***	0.011***	0.012***			
	(7.567)	(7.671)	(7.624)			
SIFI × BAIL-IN PERIOD				0.012***	0.015***	0.011***
				(11.503)	(10.143)	(7.624)
All Other BHC Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
BHC FE	YES	YES	YES	YES	YES	YES
No. Observations	2,796	2,796	2,796	2,796	2,796	2,796
R-squared	0.928	0.915	0.895	0.930	0.916	0.895