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

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Abstract

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

JEL Classification Codes: G21, G28

Key Words: Banks, Bailouts, Bail-ins, OLA, Bankruptcy, Regulation, Capital Structure.

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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 recent financial crisis, the failure of just one large, complex financial institution (i.e., Lehman Brothers) can greatly exacerbate a financial crisis and cause very 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 must decide among resolution 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 these standards, such as limits on dividends and share buybacks.

The resolution regimes are key topics of debate, as witnessed by the quotes above that defend each of the three regimes. Prior to the recent 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 2008 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 part of their debt claims turned into equity capital. Finally, the Financial CHOICE Act, which would replace the OLA bail-in with no regulatory intervention is currently under congressional consideration. In February 2018, the U.S. Treasury recommended correcting defects in OLA, rather than eliminating it, but also suggested changes to make it easier for bank failures to be handled in bankruptcy.

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

We contribute to these debates by developing a dynamic model of these regimes and empirical tests of the model's implications. We explicitly model how BHCs adjust their capital structures – bank capital and BHC shareholders' equity and subordinated debt – in response to three regulatory regimes. In the model, the representative BHC's asset value is stochastic and subject to infrequent negative random jumps or sudden falls in capital, such as those due to financial crises, that may result in immediate regulatory resolution or default. We assume that a certain fraction of bank's senior debt is continuously rolled over, creating debt rollover risk. This structure reflects the fact that in practice, bank senior debt combines short- and long-term deposits, overnight federal funds, and repos that are rolled over relatively quickly.

In the bailout regime, regulators inject equity capital and acquire a partial stake when the bank's capital falls to some critical distress level. Under bail-in, existing shareholders' equity of a distressed BHC is wiped out and the subordinated debt converts to BHC shares, possibly at a loss. For both of these regimes, regulators optimize for each BHC the trigger point – the capital ratio at which intervention occurs. Finally, under no regulatory intervention, the BHC is allowed to fail. In response to the prevailing regime, the BHC maximizes its own private value by endogenously choosing its initial capital structure, subject to tax deductibility of debt. It also dynamically adjusts its capital ratio over time, taking into account transactions costs, choosing whether and at what capital ratio it raises additional equity to avoid triggering bailout, bail-in, or default.

In designing socially optimal policies, we assume that regulators maximize the value of the BHC minus the expected default costs imposed on the rest of the financial system. In doing so, regulators take into account the self-optimizing responses of the BHCs. The regimes are optimally designed to incentivize banks to make capital 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. The model findings suggest that optimally-designed bail-ins with triggers tailored to the characteristics of individual BHCs provide the best incentives for BHCs to rebuild capital prior to financial distress. In anticipation of bail-in, a distressed BHC chooses to recapitalize to preempt the risk that its equity stake may be wiped out. In contrast, neither bailout nor the no-intervention regimes produce incentives to rebuild capital during distress. A key implication of the model is that the optimal trigger point for the bail-in regime occurs at a higher capital ratio than the optimal trigger for the bailout regime, a key feature that provides strong incentives for the BHCs to manage their own capital ratios more prudently under the bail-in regime.

Our findings also demonstrate that the optimal resolution design requires a delicate balance. For example, a bail-in coupled with the stress test should not be too aggressive as to constrain bank's activity – although bail-in expectations need to exert enough incentives to promote a socially prudent capital structure behavior.

Another implication of the analysis is that a "one size fit all" resolution approach is suboptimal. Instead, regulators should implement regulations on a case-by-case basis that reflect each BHC's individual characteristics. That is, for a given regime and set of bank characteristics, there is an interior solution for both the optimal regulatory trigger point to exercise bailout or bail-in and the minimum capital requirement that maximizes the value of the banks minus the expected default costs imposed on the rest of the financial system. Thus, the conditions under which bailout or bail-in is triggered should allow for regulator discretion, as opposed to a single set of rules uniformly applied to all institutions.[6]

Importantly, several of the model outcomes regarding optimal bailout and bail-in interventions

[6]This is consistent with the "creative ambiguity" principle of Freixas (1999), developed in the context of liquidity bailouts.

go beyond the limits of static models. For example, the effects of high BHC asset volatility on the optimal bailout trigger are directly opposite to the effects on the optimal bail-in trigger. In our model, the regulator optimally employs less aggressive bailout strategies for BHCs 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 BHCs 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, thereby 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. These findings – which follow quite logically from the dynamic model – cannot be derived from a static model in which the optimal dynamic adjustments of BHCs' capital structures in response to the regulation are not taken into account.

Another implication of the model is that when the regime shifts from bail-in to no regulatory intervention, the BHCs optimally responds by increasing capital rather than reducing it. 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, BHC is endogenously pre-committed to rebuild capital in response to negative shocks. This pre-commitment leads to lower costs of debt, higher debt capacity, lower initial capital, and larger tax shields.

The theoretical model has a number of predictions that we are able to test empirically. These predictions include how BHCs would react to changes in regulatory regimes, such as the observed shift from a bailout regime before the financial crisis to a bail-in regime post-crisis. Thus, we test how well BHC capital decisions correspond to the model's predictions about shifting from a bailout to a bail-in regime.

For these tests, we specify the time span from 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. Of these 50 BHCs, 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.[7] All eight of these BHCs (Bank of America, Bank of New York Mellon, Citigroup, Goldman Sachs, JP Morgan Chase, Morgan Stanley, State Street Bank, Wells Fargo) were bailed out by 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, it is reasonable to assume that before the financial crisis, these institutions believed that that they were too big or too important to fail, and would likely to bailed out in the event of a crisis. It is also reasonable that after OLA was in effect, these institutions believe that they are subject to bail-ins, given their systemic importance and treatment under TARP. Thus, the eight G-SIBs are considered the bailout and bail-in treatment group. The remaining 42 smaller BHCs in the top 50 are less likely to have expected bailouts pre-crisis and bail-ins post crisis, and are considered the control group that is closest in other characteristics to the treatment group. We recognize that this division into treated and control groups is imperfect. In robustness tests, we experiment with alternative treatment groups, and the results are largely robust.

The data on the G-SIBs during the bailout and bail-in periods correspond quite well with the optimal capital ratios of the calibrated theoretical model. The observed changes in the G-SIB capital ratios are also consistent with model predictions. The base case of the model predicts a 2.7 percentage point increase in the optimal capital ratio when moving from a bailout regime to a bail-in regime, while the G-SIB data for three different frequently-used capital ratios increased between 1.5 and 3.5 percentage points from the bailout period to the bail-in period. Similarly, our difference-in-difference (DID) econometric models – which control for other factors affecting capital ratios – find statistically and economically significant increases in capital ratios of G-SIBs between 1.0 and 2.7 percentage points more than the other 42 BHCs, again affirming the predicted effects of the regime shift predicted by the model. Additionally, the model predicts how the optimal responses of bank capital ratios of treated BHCs differ with asset volatility risks, jump risks, and debt rollover risks. To test these predictions, we conduct subsample analyses using the DID framework, and find that the econometric results are general consistent with the model's predictions.

As discussed above, the dynamic model also predicts that bail-ins provide incentives for treated BHCs to rebuild capital prior to financial distress, whereas bailouts do not. This implies that

[7] 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.

BHCs are likely to adjust to their target capital ratios faster during the bail-in period than the bailout period. We test this empirically using a partial adjustment methodology. We find that G-SIBs adjust their capital ratios significantly more quickly than other large BHCs during the bail-in period, again corroborating model predictions.

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

2 Contributions of the Paper

We add to the theoretical and empirical literatures on regulatory resolution regimes, as well as to research on the prudential tools of capital requirements and stress tests. Two other 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.

Similar to our paper, 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. However, unlike these static models, we consider the dynamics of capital structure as a BHC responds to anticipated regulatory actions.

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 findings on the U.S. stress tests (Supervisory Capital Assessment Program (SCAP), Comprehensive Capital Analysis and Review (CCAR), and Dodd-Frank Act Stress Tests (DFAST)). Some researchers develop models for stress testing using publicly available data to forecast BHC vulnerability and complement supervisory stress tests (e.g., Guerrieri and Welch, 2012; Acharya, Engle, and Pierret, 2014; Covas, Lump, and Zakrajsek, 2014; Kapinos and Mitnik, 2016). Goldstein and Leitner (2017) develop an optimal stress test disclosure policy for the regulator during normal and bad times. The empirical literature finds that the stress tests helped stabilize the financial system (e.g., Hirtle, Schuermann, and Stiroh, 2009), reduced lending (e.g., Calem, Correa, and Lee, 2017; Acharya, Berger, and Roman, forthcoming), and reduced risk taking (Acharya, Berger, and Roman, forthcoming).

Finally, we add to the empirical findings on bailouts. A number of studies estimate the effects of the TARP bailouts on lending (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), competitive distortions (Berger and Roman, 2015; Koetter and Noth, 2015), risk (e.g., Black and Hazelwood, 2013; Duchin and Sosyura, 2014, 2017), real economic outcomes (Berger and Roman, 2017), and systemic risk (Berger, Roman, and Sedunov, 2017).[8]

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.

[8] There are findings for other bailouts in the literature, such as the extraordinary Federal Reserve liquidity provided through the discount window and Term Auction Facility (TAF) during the crisis (e.g., Berger, Black, Bowman, and Dlugosz, 2017).

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.[9]

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 injected more than $200 billion in preferred equity capital into 709 financial institutions through the Capital Purchase Program (CPP), the main component of TARP program, 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.[10]

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

[9] 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.

[10] 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).

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 bank 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.[11]

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 allows 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.[12]

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

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

4 Model

4.1 Model description and the 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 capture infrequent but severe runs or financial crises. Bank's cash flows are proportional to assets. Dividends are calculated as a residual cash flow after interest payments, and interest payments are tax deductible.

At time 0, the bank issues senior debt. The bank's capital is owned by its BHC. The bank's capital ratio is the difference between asset value and senior debt as a percentage of total assets. The BHC can issue subordinated debt to finance part of the bank's capital, often referred to as double leverage.

Both subordinated and senior debt require continuous coupon payments and both 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 maturity. 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. As part of the stress test, 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 the total debt through time. The initial capital of the bank is chosen to maximize the market value of the bank, 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 as soon as the bank's capital ratio declines to a preannounced trigger point or if the bank is in technical default, i.e., if the book value of the shareholder's equity declines to zero. 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.

In the bail-in regime, the regulator steps in as soon as the bank capital ratio declines to or below the predetermined trigger, or if the book value of the shareholder's equity declines to zero, 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.[13] After bail-in, the bank continues to operate until maturity or default.

For the no-regulatory-intervention regime, bankruptcy occurs without intervention. We assume that the bank files for bankruptcy if the bank is in technical default, i.e., when the shareholder's equity declines to or below 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.

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 bank holding company will be liquidated. Shareholders and subordinated debt holders are wiped out,

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

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 eliminate dividends to retain earnings and build capital. We assume that no uncertainty about the minimum capital ratio set by the stress tests.

The model quantifies socially-optimal terms of each regulatory regime, which include 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. We assume that the regulator chooses a socially-optimal strategy so that the expected initial market value of the BHC net of expected default costs is maximized at time 0. We assume the regulator puts equal weights on social losses from expected default costs and the private value of the BHC. This weighting scheme effectively treats \$1 of expected default costs the same as \$1 of private value. We recognize that this is only one of many possible weighting schemes for the regulator's maximization strategy, and the model can be solved for alternative weights. For example, if the regulator is only concerned with expected default costs, the optimal regulation is to set the intervention trigger at very high levels of capital.

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 can discontinuously reduce the value of the bank's assets.[14] Such jumps represent a real-world "friction" in the sense that they 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

[14] 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, the bail-in intervention or even default. Pennacchi (2010) and Andersen and Buffum (2002) also assume jumps in asset value process.

under the risk neutral measure Q. The value of bank's unlevered assets before taxes is therefore described by:

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

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

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

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

4.1.2 Senior debt and subordinated debt

At time 0, the BHC chooses the bank's senior debt as well as the BHC's subordinated debt. Senior debt and subordinated debt require continuous coupon payments at the rate of f and c and principal payments of F and C at maturity, respectively. By assumption, the size of the subordinated debt is a one time choice of the bank, 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. The retired senior debt is reissued at market price D. With higher m, the effective duration of senior debt is shorter than its stated 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 payments 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.[15]

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 zero $\frac{(V_t-F-C)}{V_t} < 0$.

4.1.3 Reorganization Regimes of Distressed Banks

Bailout Regime The bailout regime is described by variable $\theta_{bailout}$, 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 3% of assets, taking a fair market value equity stake in the bank. With jumps in the asset value process, the 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 will also inject 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 both wiped out, and senior bank debtholders recover the bank's assets V_t minus proportional default costs $(1 - DC) \cdot V_t$, where DC is a positive constant, $0 < DC < 1$. 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 minimum regulatory capital requirement, 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.[16] The bank shareholders are wiped out, and subordinated debt automatically converts to C dollars worth of shares. The

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

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

bank's total debt size declines from $F + C$ to F, and the bank continues to operate. In the post-bail-in periods, 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 they will own bank's equity, which 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) and imposes minimum regulatory capital requirement, $\theta_{ST_{bail-in}}$. If the bank's capital ratio declines below the minimum capital ratio, i.e., if $\frac{(V_t - F)}{V_t} < \theta_{ST_{bail-in}}$, the bank fails the stress test, and the bank will have to retains all its residual cash flows to rebuild capital.[17]

Regime with No Regulatory Intervention Under no regulatory intervention, we assume that there is no intervention from the regulator. The bank files for bankruptcy and is liquidated if its assets fall to the level V_t such that the book value of the shareholders' equity declines to zero or below, i.e., if $\frac{(V_t - F - C)}{V_t} \leqq 0$. Shareholders and subordinated debtholders 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 same stress test as in the bail-in regime. The bank fails the stress test if its capital ratio declines below the critical ratio, i.e., if $\theta_{ST_{NoIntervention}} <$ In such case, the bank will retain all its residual cash flows and rebuild its capital. Thus, the no-regulatory-intervention regime is characterized by one regulatory variable, $\theta_{ST_{NoIntervention}}$.

[17] 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, $\alpha_{ST_{bail-in}} = MIN\{\alpha \quad , \frac{c + f + m \cdot (F - D_t)}{V_t}\}$, if $\frac{(V_t - F)}{V_t} < \theta_{ST_{bail-in}}$.

4.1.4 Capital Structure Decisions of the Bank

We assume that there is no uncertainty about the regulatory regime. At time 0, the BHC with unlevered assets valued at V_0 and cash flows from assets at αV_0 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 function of 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. Details of the optimization problem are in Appendix A.

4.1.5 Optimal Regulatory Intervention

As noted, the regulator sets the parameters of each regime such that time 0 market value of the bank minus expected default costs is maximized, taking into account the optimal initial response and subsequent recapitalization strategy at the bank. Optimal bailout policy is described by one parameter $\theta^*_{bailout}$; optimal bail-in is characterized by the pair $\{ \theta^*_{bail-in} , \theta^*_{ST_{bail-in}} \}$; and optimal regime for the ordinary default is described by $\theta^*_{ST_{NoIntervention}}$. For example, for the bail-in regime, the regulator solves the following optimization problem: $\{ \theta^*_{bail-in}, \theta^*_{ST_{bail-in}} \} = \underset{\theta_{bail-in}, \theta_{ST_{bail-in}}}{\arg\max} \{\max_{F,C}[E((V_0, F, C, 0) \ + F + C] - DefaultCosts\}$.

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. We divide these 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. Because of extreme volatility in the banking sector during the crisis, we exclude the period of crisis (from 2007:Q3 to 2010: Q2) and 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.

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 unsubordinated debt liabilities. 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 the economic environment in which a 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) Tier 1 leverage ratio, which is Tier 1 capital divided by total unweighted assets; 2) *CAPTIER1* (Tier 1 risk-based capital ratio), which is Tier 1 capital divided by risk-weighted assets; 3) *CAPTOTAL* (Total capital risk-based capital ratio), which is Tier 1 and Tier 2 capital divided by risk-weighted assets[18]. Depending on the measure, capital ratios are varied between 5.8% and 16.9% and overall are slightly lower for the G-SIBs in the bailout period. However, all capital ratio measures increased in the bail-in period. Finally, Table 1 reports market-to-book ratios that are varied between .99 to 1.12. We will compare the model generated optimal capital ratios and market-to-book ratio with empirically observed ones.

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.[19] 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-averagespread.

We calculate expected default costs as 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 percentage 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/insolvency is called any time book equity is 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

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

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

the dynamic programming on a discretized grid of the state space $(V, \{F \quad , \quad F + C\}, t)$. At each node on the grid, the partial derivatives are computed according to Euler's method. The backward induction procedure starts at the terminal date T , at which the values for senior debt, the subordinated bond and equity are determined by payoff to subordinated holders, holders of the senior debt, and holders of bank equity. The backward recursion using time steps Δt takes into account the bank's optimal strategy to raise capital.

4.2 Model Results

We use numerical solutions of the model to address the main question as to how terms of regulatory regimes affect the bank's initial capitalization decision, the the size of the subordinated debt and future recapitalization strategy. We start with an analysis of base-case parameters. For each of the three regulatory regimes, we vary the critical capital ratios at which the regulator intervenes 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 response of the BHC.

4.2.1 The Base Case

Results for Bailout Regime Figure 1 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 responds by choosing higher initial capital and subordinated debt ratio. 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 default costs 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 should optimally bailout 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, it exposes the BHC to disproportionately higher expected default costs due to both higher jump risk and lower initial capital. If the regulator bails out at higher than 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 2 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 always 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, then BHC has stronger incentives to have higher initial capital and to rebuild capital. Both BHC value and expected default 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 3.55% (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 default 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 the likelihood of bail-in.

Results for No Regulatory Intervention In the no-regulatory-intervention case, the regulator has only one tool, the stress test. Figure 3 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 default 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, implying 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, the BHC optimally responds by increasing capital from 9.6% to 12.3%. In addition, the size of the subordinated debt increase slightly 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. The expected default costs are little bit lower in the bailout 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, including asset volatility and the probability of negative jumps, as well as 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. The BHC with $\sigma = 4\%$ is optimally bailed-out when the capital ratio declines to 4.5% or below. In comparison, 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 actually higher for BHCs with more volatile assets. In anticipation of bailout, riskier banks optimally select slightly lower initial capital, but significantly smaller subordinated debt.[20]

Intuitively, the bailout decision can be viewed as an exercise of a real option. 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 compared to assets with less frequent jumps. On the other hand, with higher jump probabilities, there is a higher likelihood the arrival of a large negative jump that can instantly reduce BHC's assets below senior liabilities and below the default boundary. As such, there is a higher likelihood that the regulator will be unable to bailout such a BHC.

Table 4 Panel 1 reports the 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

[20] 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%.

bailout strategy, the BHC with a greater jump risk optimally chooses higher initial capital and the size of the subordinated debt.[21]

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 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 2 shows that when dealing with banks with higher asset volatility, 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, the 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 the optimal bail-in design are more complex. When BHC assets are subject to more frequent jumps, the ability of bail-ins to control default risk and preserve value is diminished. A higher jump risk also weakens BHC's incentives to recapitalize because higher jump risk 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 counter-productive as it produces only incremental incentives to rebuild capital, but overly constrains the BHC's capital structure decisions, leading to larger tax shield losses. 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 strikingly opposite to those of the optimal bailout trigger. The main reason is that the two

[21] 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%.

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 test for BHCs with higher rollover rate, and 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 noted, the only mechanism available to the regulator under no regulatory intervention is the stress test. As Table 4 Panel 3 shows, the regulator optimally imposes a higher stress test capital ratio for BHCs with more volatile assets, which induces these BHCs to hold more capital, but to choose very little subordinated debt.

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

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

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 1 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 2 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.

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. Notably, many of the 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 no regulatory intervention has not yet been implemented.

5.1 Data Sources and Sample

We use quarterly financial data for the largest 50 top-tier publicly traded U.S. BHCs between 2000:Q3 and 2017:Q2.[22] Of these 50 BHCs, we consider the eight very large, complex U.S. banking organizations that are designated as Globally Systemic Important BHCs (G-SIBs) as the treatment group, those most likely to be subject to bailouts and bail-ins. The remaining 42 large BHCs are considered the control group, but are closest in other characteristics to the treatment group. 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 cutoffs.

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 for our analyses to avoid contamination of the results from this period. The financial crisis was a period

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

of extreme volatility, and the bailouts during the crisis were much more extensive than was likely expected, covering both small and large banks.

5.2 Capital Measures and Other Variables

We construct three capital ratio variables as our main dependent variables. *CAPLEV* is our baseline specification, calculated as 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. 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 a G-SIB dummy for the BHCs in our treatment group. In alternative tests in Appendix B, we also consider dummies for the original 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).[23]

We also 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.

[23] About 11.9% of our observations are G-SIBs, 26.1% are SCAPs, and 37% are SIFIs.

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

As briefly introduced in Section 4.1.6, 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, G-SIBs, and nonG-SIBs.

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%, within 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 in response to moving from the bailout to the bail-in regime. The DID regression has the following form for BHC b at time t:

$$Y_{\mathrm{b,t}} = \begin{array}{c} \beta_1 BAIL-IN\ PERIOD_{\mathrm{t}} \times TREATED_{\mathrm{b}} \\ +\beta_2 X_{\mathrm{b,t\text{-}1}} + \beta_3 TIME_{\mathrm{t}} + \beta_4 BHC_{\mathrm{b}} + \varepsilon_{\mathrm{b,t}} \end{array} \tag{3}$$

$Y_{b,t}$ is a capital ratio chosen by the BHC, either *CAPLEV, CAPTIER1*, or *CAPTOTAL*. $TREATED_b$is a dummy which takes a value of 1 for G-SIBs. $BAIL\text{-}IN\ PERIOD_t$ is a dummy equal to one for the bail-in period 2010:Q3-2017:Q2 after the Dodd Frank Act Title II OLA came into effect. $TREATED_b$ and $BAIL\text{-}IN\ PERIOD_t$ terms do not appear by themselves because they would be perfectly collinear with the fixed effects discussed below. $BAIL\text{-}IN\ PERIOD_t \times TREATED_b$ 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. 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 Our main results are shown in Table 6. 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 regime to the bail-in regime, 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, and find similar results. Our results suggest that some combination of the implementation of the bail-in regime and the application of the stress tests are successful in inducing banks to hold significantly more capital.

Subsample Tests Table 7 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 as proxy *CDLOANS*, the construction and land development loans divided by total loans. These loans are found elsewhere to be strong predictors of bank failure (e.g., Cole and White, 2012). For rollover risk, we use *ROLLOVER*, total debt and liabilities maturing in one year or less divided by total debt and liabilities.

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 regime, 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 5 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 in the range of 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 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 As discussed above, the dynamic model predicts that bail-ins provide incentives for BHCs to rebuild capital prior to financial distress, whereas bailouts do not. This implies that BHCs are likely to adjust to their target capital ratio faster during the bail-in period than the bailout period. To test this, we apply a partial speed of adjustment empirical model as in Berger, DeYoung, Flannery, Lee, and Oztekin (2008) to estimate BHCs' capital structure decision in reaction to the regulatory change from the bailout regime prior to the crisis to the bail-in regime after the crisis. We model the target capital ratio $k*_{i,t}$ as a function of the firm's characteristics:

$$k^*_{\text{i,t}} = \frac{K^*_{\text{it}}}{A_{\text{it}}} = \gamma X_{\text{i,t-1}} \tag{4}$$

K^*_{it} is the target (desired) book value of capital; $\text{A}_{i,t}$ 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. In our adjustment model, BHCs close a constant proportion of the gap between its current capital ratio and its target capital ratio $k*_{it}$ each period.

$$k_{\text{i,t}} - DNK_{\text{i,t}} = \lambda(k^{*}{}_{\text{i,t}} - DNK_{\text{i,t}}) + \zeta_{\text{it}}, \tag{5}$$

$DNK_{i,t}$ is the "do-nothing capital ratio" $= (K_{i,t-1}+NI_{i,t}-DIV_{i,t-1})/A_{it}$, 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 $k*_{it}$. 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. We specify the partial-adjustment process in terms of $(k_{i,t}-DNK_{i,t})$ to separate a BHC's capital ratio into an active component and a passive component.[24] We substitute (4) into (5) and get the following estimable regression model:

$$k_{\text{i,t}} - DNK_{\text{i,t}} = X(\lambda\gamma_{\text{i,t-1}} - DNK_{\text{i,t}}) + \delta_{\text{i,t}}, \tag{6}$$

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 βs.

Empirical Results Table 8 Panel A shows the main results for equation (6) using *CAPLEV*. 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

[24]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 $DNK_{\text{i,t}}$ 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 $DNK_{\text{i,t}}$ and toward the target capital.

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 adjust their capital ratios much faster during the bail-in period, corroborating the model's predictions. In addition, the t-tests for the difference in coefficients in Panel D 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 policies of bail-in and stress tests appear to be successful in inducing the GSIBs to adjust their capital faster.Table 8 Panels B and C repeat our main adjustment speed analysis by using *CAPTIER1* and *CAPTOTAL*. Using these alternative measures of capital, we continue to find that G-SIBs have significantly faster capital speeds of adjustment in the bail-in period, consistent with the model predictions. However, for these additional tests, the t-tests for the difference in coefficients in Panel D do not show any statistical significance in these adjustment speeds. The reason may be that *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, large U.S. bank holding companies (BHCs) moved from a bailout regime to a bail-in regime under the Orderly Liquidation Authority (OLA) of the 2010 Dodd Frank Act. The Financial CHOICE Act under congressional consideration would shift these institutions to a no-regulatory-intervention regime in which they would be allowed to fail. The implications of these regime changes are not well understood and are studied here.

We present a dynamic model to quantify the socially optimal design of the three regimes for handling potential failure of large U.S. BHCs. Each BHC optimizes its response to the regime in place to maximize its private value, and the regulators respond optimally with actions that also take into account the expected costs imposed on the rest of the financial system in case of default. We also test a number of the model's predictions using data on the U.S. BHCs prior to and after the financial crisis. We find that the changes in the BHC capital structures are consistent with the model's predictions. Specifically, shifting from the bailout regime to the bail-in regime results in both higher capital ratios and faster capital speeds of adjustment for the largest BHCs.

Importantly, the model has a number of rather clear policy implications. "One size fits all" policies are clearly dominated by approaches that are tailored to individual financial institutions. In addition, an optimally-designed bail-in regime provides incentives for BHCs to rebuild capital preemptively during financial distress that are lacking in the bailout and no-intervention regimes. Both the theory and the empirical results support the notion that post-crisis regulatory policies are generally successful in inducing better BHC capital structure behavior.

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Figure 1: Bailout Regime

This figure shows bailout regime graphs which look at the model-implied bank's optimal initial capital ratio and the optimal size of the subordinated debt (i.e., the capital structure at which the market value of bank's senior debt, subordinated debt, and equity is maximized at time 0) as a function of critical capital ratio at which the regulator bails out the bank by injecting 3% equity. We assume that the bank fully anticipates regulatory bailout. The graphs also depict the regulator's expected future equity injections measured ex-ante as % of the bank's unlevered assets at time 0. Expected default costs are calculated as % of the bank's unlevered assets at time 0. In the base case, the regulators trigger the bailout when the bank's capital ratio declines to a predetermined ratio which is varied. The optimal regulatory policy is characterized by the crucial capital ratio that triggers the bailout, at which the market value of bank minus default costs is maximized (i.e., social welfare is maximized). The squared dots on the graph depicts banks response to the optimal regulatory policy. The remaining parameter values are as in the base case reported in Table 2.

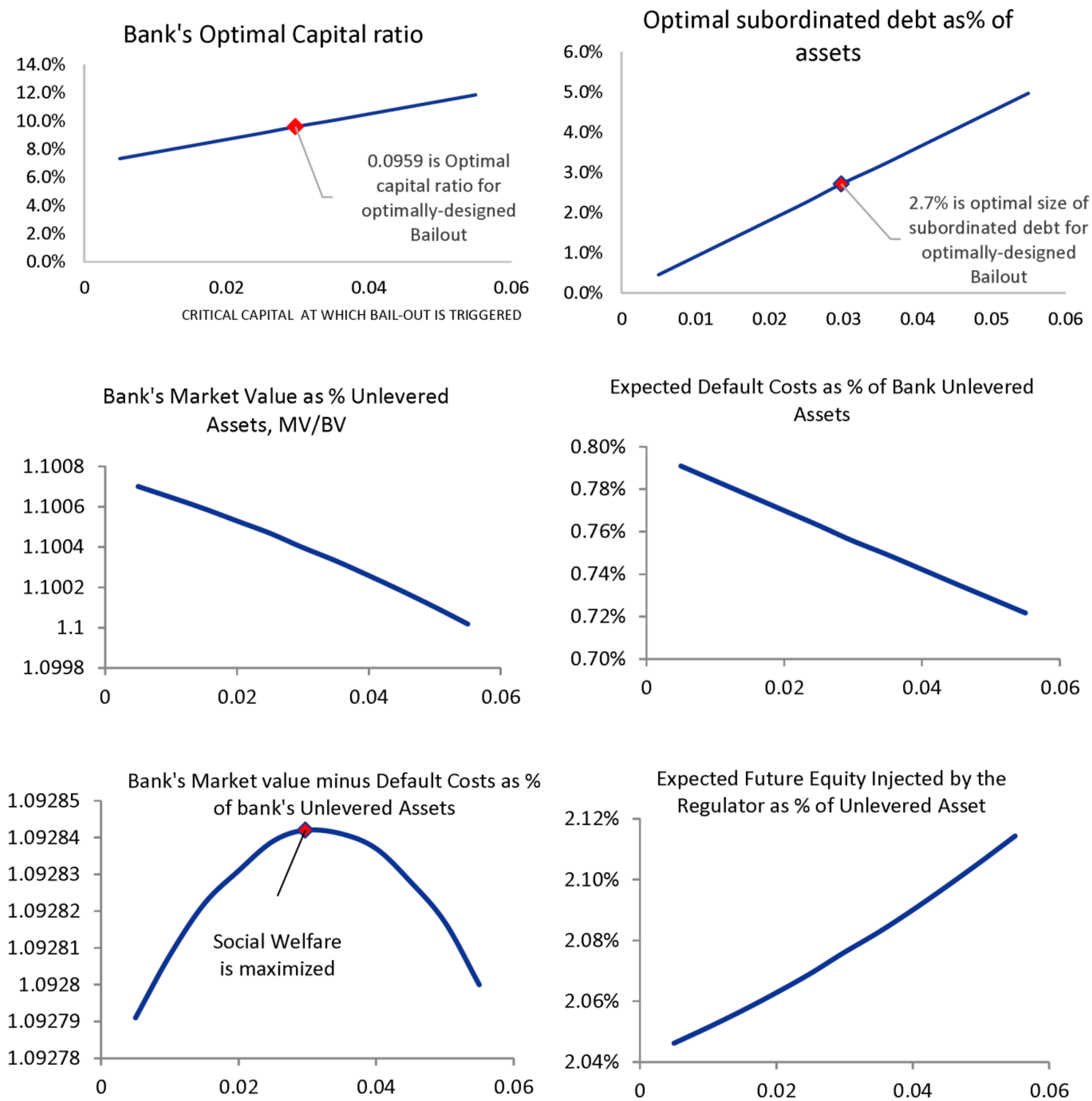

Figure 2: Bail-in Regime

This figure shows bail-in regime graphs which look at the model-implied bank's optimal initial capital ratio and the size of the subordinated debt (i.e., the capital structure at which the total market value of bank's senior debt, subordinated debt, and equity is maximized at time 0) as a function of critical capital ratio at which (or below which) the regulator invokes bail-in, At bail-in the regulator wipes out existing equity and converts bank's subordinated debt into equity. The graphs are presented for three different Stress Test (ST) policies. The ST is characterized by the additional capital "cushion" requirement above the critical capital ratio (at which the bail-in is invoked). If the bank's capital ratio is declines below the ST "cushion", the bank has to retain its dividends to rebuild capital. The graphs are depicted for three ST "cushion" requirements of 2.5%, 3.5% and 4.5% capital. The graph also depicts the bank's expected future equity issuance measured ex-ante as % of the bank's unlevered assets at time 0. Expected default costs are calculated as % of the bank's unlevered assets at time 0. The optimal regulatory policy is characterized by two variables: 1) the optimal crucial capital ratio that triggers the bail-in and the optimal size of the capital "cushion" of the ST. For the optimal bail-in, the market value of bank minus default costs is maximized (i.e., social welfare is maximized). The squared dots on the graph depicts banks response to the optimal regulatory policy. The remaining parameter values are as in the base case reported in Table 2.

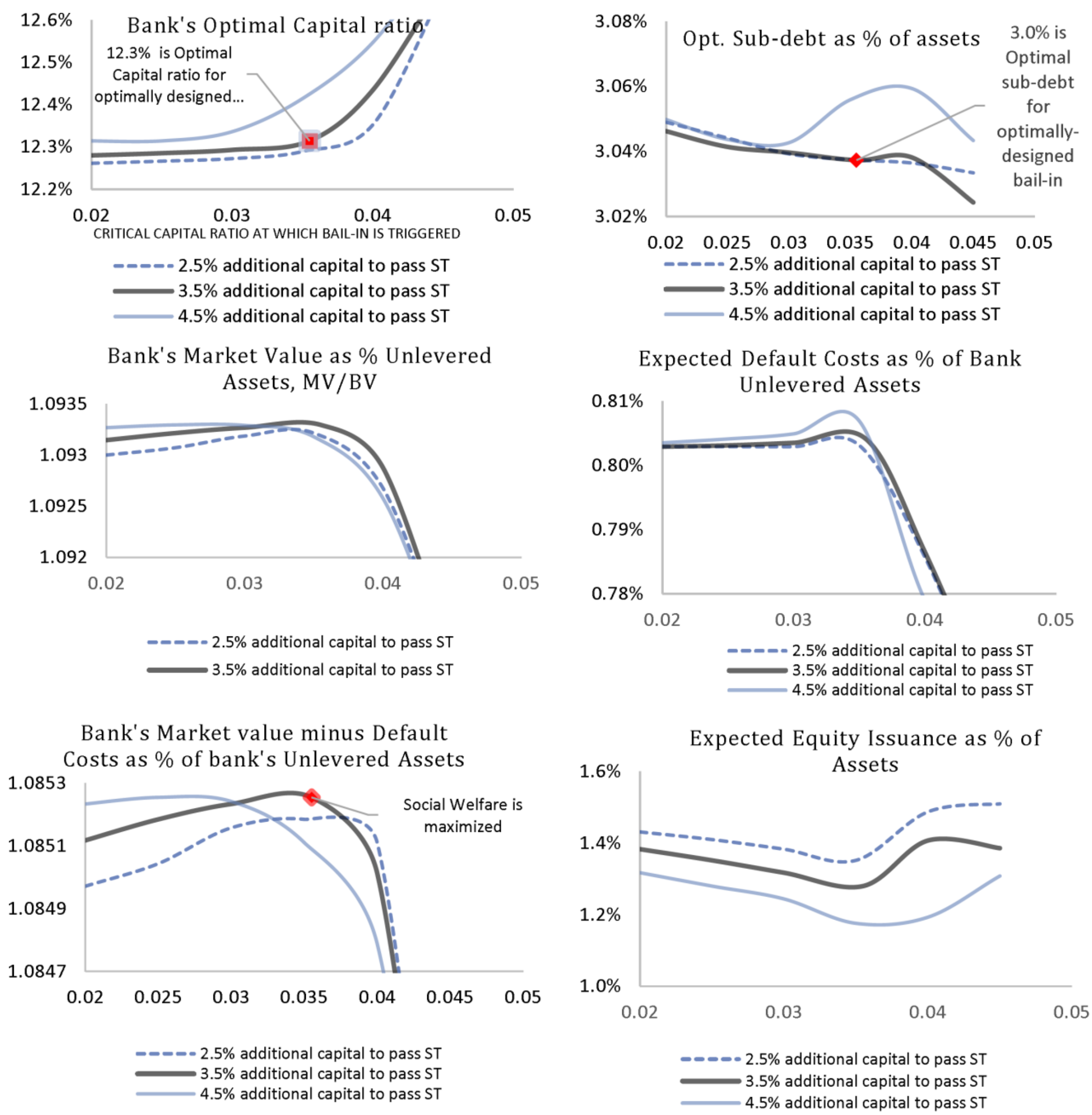

Figure 3: No-Regulatory-Intervention Regime

This figure shows the no-regulatory-intervention regime graphs which look at the model-implied bank's optimal initial capital ratio and the optimal size of subordinated debt (i.e., the capital structure at which the market value of bank's senior debt, CoCo, and equity is maximized at time 0) as a function of critical capital ratio at which (or below which) the bank fails the regulatory Stress Test. Below this capital ratio, the bank has to retain dividends to rebuild capital. In the no-regulatory-intervention test, three is no other intervention, and the bank defaults as soon as the equity holder's equity declines to zero. Expected default costs are calculated as % of the bank's unlevered assets at time 0. The optimal regulatory policy is characterized by the crucial capital ratio for the ST, at which the market value of the bank minus default costs is maximized (i.e., social welfare is maximized). The squared dots on the graph depicts the banks optimal response to the optimal ST policy. The remaining parameter values are as in the base case reported in Table 2.

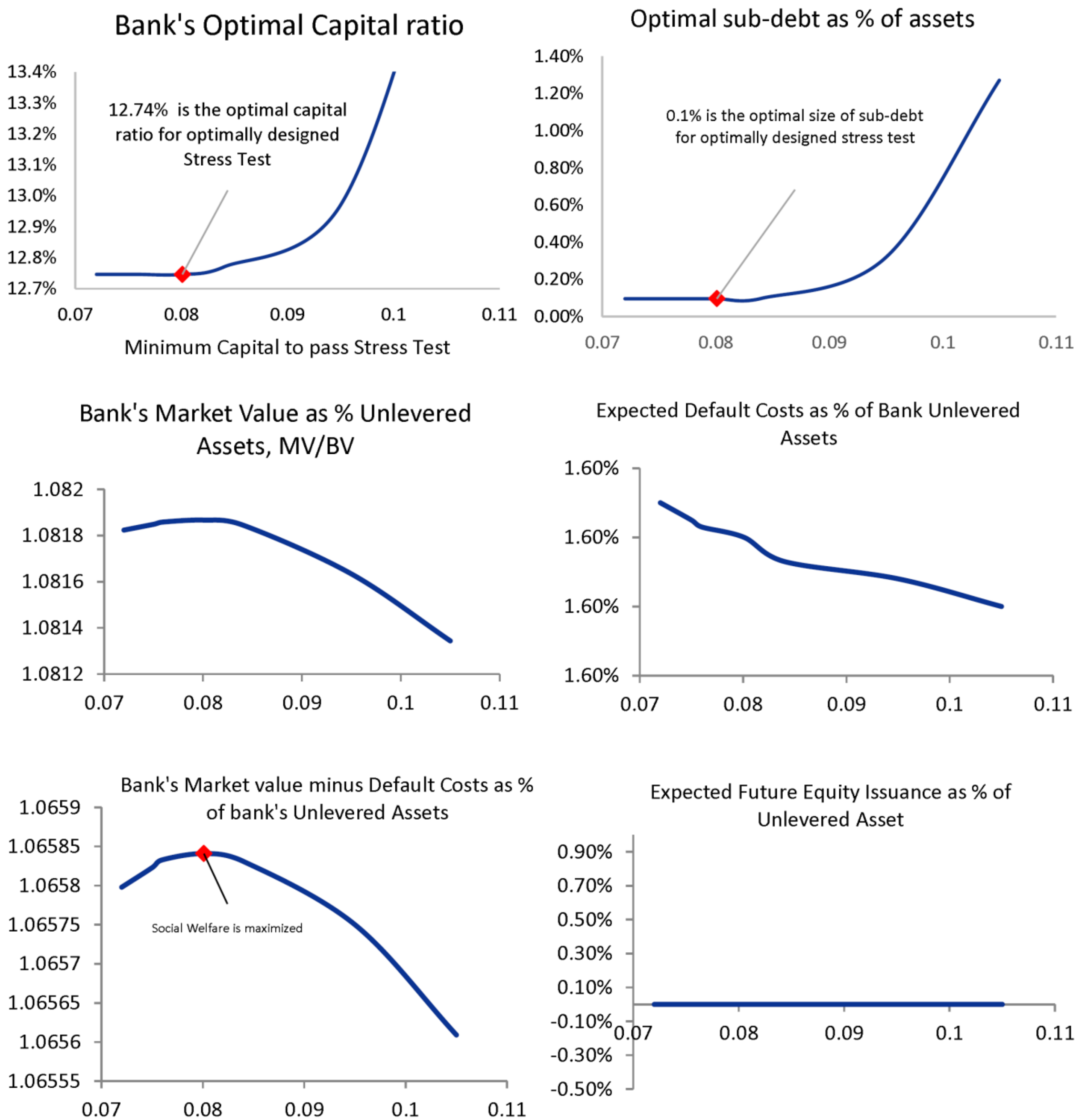

Table 1: Summary Statistics for the Top 50 Largest Publicly Traded U.S. Bank Holding Companies (BHCs) and Globally Systemically Important Institutions (G-SIBs)

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. ** represents the expected value of equity injection by the regulator.

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	BHC value minus expected default costs to assets	Expected transaction costs to assets	Expected default cost plus transaction costs to assets	Expected equity issuance to just before transaction costs
Bailout	2.9%	-	9.6%	2.7%	1.100	0.8%	1.0928	0.9%	1.6%	2.1%**
Bail-in	3.6%	7.1%	12.3%	3.0%	1.093	0.8%	1.0853	0.4%	1.2%	1.3%
No Regulatory Intervention	-	8.0%	12.7%	0.1%	1.082	1.6%	1.0658	0.0%	1.6%	0.0%

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

This table shows comparative statics for optimal bailout terms (Panel 1), optimal bail-in terms (Panel 2) and optimal terms of no regulatory intervention (Panel 3) as well as the optimal bank's response for parameters for each of the regime around base case parameter values.

	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 to just before transaction costs
Panel 1:	**Bailout Regime**					
Vol of Assets						
4%	4.5%	-	9.8%	4.1%	0.78%	1.32%
5%	3.0%	-	9.6%	2.7%	0.76%	2.08%
6%	1.1%	-	9.0%	0.9%	0.73%	2.90%
Jump Probability						
2%	0.5%	-	8.9%	0.4%	0.55%	2.24%
3%	3.0%	-	9.6%	2.7%	0.76%	2.08%
4%	5.6%	-	10.7%	5.0%	0.92%	1.94%
Debt Rollover Rate						
0.10	5.5%	-	12.2%	4.9%	0.71%	1.96%
0.20	3.0%	-	9.6%	2.7%	0.76%	2.08%
0.30	1.5%	-	8.2%	1.4%	0.78%	2.06%
Panel 2:	**Bail-in Regime**					
Vol of Assets						
4%	3.0%	6.0%	10.2%	2.6%	0.82%	0.73%
5%	3.6%	7.1%	12.3%	3.0%	0.80%	1.28%
6%	4.1%	8.0%	14.3%	3.5%	0.80%	1.87%
Jump Probability						
2%	3.9%	7.5%	14.3%	3.5%	0.66%	1.38%
3%	3.6%	7.1%	12.3%	3.0%	0.80%	1.28%
4%	1.6%	6.1%	10.5%	2.8%	0.97%	1.25%
Debt Rollover Rate						
0.10	4.5%	8.0%	13.4%	4.1%	0.76%	1.26%
0.20	3.6%	7.1%	12.3%	3.0%	0.80%	1.28%
0.30	3.1%	7.6%	11.7%	2.8%	0.82%	1.33%
Panel 3:	**No Regulatory Intervention Regime**					
Vol of Assets						
4%	-	6.6%	10.9%	0.1%	1.34%	0.00%
5%	-	7.9%	12.7%	0.1%	1.60%	0.00%
6%	-	8.2%	14.5%	0.1%	1.81%	0.00%
Jump Probability						
2%	-	8.2%	14.2%	0.1%	1.56%	0.00%
3%	-	7.9%	12.7%	0.1%	1.60%	0.00%
4%	-	7.4%	11.7%	0.1%	1.62%	0.00%
Debt Rollover Rate						
0.10	-	8.2%	12.3%	0.2%	1.53%	0.00%
0.20	-	7.9%	12.7%	0.1%	1.60%	0.00%
0.30	-	5.8%	13.1%	0.1%	1.53%	0.00%

Table 5: Comparative Statics for the change in optimal capital structure

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 1), and from bail-in to Table also reports the changes in optimally designed regulatory triggers and minimum capital requirement no intervention regime (Panel 2). 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 to just before transaction costs
Panel 1:	**Transition from bailout to bail-in**					
Vol 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 2:	**Transition from bail-in to no-regulatory-intervention regime**					
Vol 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: 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 7: 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 8: 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, Panel B reports the main capital adjustment speed regression estimates using CAPTIER, and Panel C reports results using CAPTOTAL respectively. Panel C reports differences in regression coefficients. 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)		
λ_1 × *G-SIB*		0.388***			0.926***	
		(2.882)			(29.754)	
λ_2 × *nonG-SIB*		0.904***			0.811***	
		(14.598)			(23.987)	
λ_{11} × *G-SIB_above*			0.460***			0.928***
			(2.723)			(33.928)
λ_{12} × *G-SIB_below*			0.431**			0.916***
			(2.318)			(26.118)
λ_{21} × *nonG-SIB_above*			0.931***			0.835***
			(16.746)			(28.013)
λ_{22} × *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

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)		
λ_1 × *G-SIB*		0.563***			0.843***	
		(2.996)			(16.965)	
λ_2 × *nonG-SIB*		0.843***			0.789***	
		(16.689)			(16.331)	
λ_{11} × *G-SIB_above*			0.503***			0.920***
			(3.558)			(24.153)
λ_{12} × *G-SIB_below*			0.468***			0.934***
			(3.222)			(21.233)
λ_{21} × *nonG-SIB_above*			0.886***			0.798***
			(26.840)			(16.860)
λ_{22} × *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

Panel D: Differences in Regression Coefficients

Differences in Regression Coefficients

D1. CAPLEV

	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)

D2. CAPTIER1

	Group	BAILOUT	BAIL-IN	BAILIN-BAILOUT
Coefficient	*G-SIB*	0.563***	0.843***	0.280
t-statistic		(2.996)	(16.965)	(1.439)
Coefficient	*nonG-SIB*	0.843***	0.789***	-0.054
t-statistic		(16.689)	(16.331)	(-0.771)
Coefficient	*G-SIB - nonG-SIB*	-0.280	0.054	0.334
t-statistic		(-1.440)	(0.780)	(1.615)

D1. CAPTOTAL

	Group	BAILOUT	BAIL-IN	BAILIN-BAILOUT
Coefficient	*G-SIB*	0.451**	0.801***	0.350
t-statistic		(2.386)	(19.936)	(1.812)
Coefficient	*nonG-SIB*	0.707***	0.774***	0.067
t-statistic		(9.057)	(16.309)	(0.736)
Coefficient	*G-SIB - nonG-SIB*	0.256	0.028	-0.228
t-statistic		(-1.250)	(0.440)	(-1.065)

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:

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

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).

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

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 $\triangle V$:

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

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:

$$E(V, F+C, t) = 0\ . \quad (7)$$

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

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

[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)	
Variable	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