CEO Compensation Regulations in the Banking Industry*

Ikuo Takei†[1]

[1] *Asia School of Business*
[1] *Massachusetts Institute of Technology Sloan School of Management*

September 29, 2024

[Click here for most recent version]

Abstract

How do CEO compensation regulations in the banking industry affect systemic risk-taking and financing decisions? Using a novel and comprehensive U.S. bank executive dataset, I find that pre-crisis CEO cash bonus sensitivity and unexercisable stock options contributed to the poor performance and failures during the global financial crisis. In an estimated dynamic financing model of banks, managerial conflicts lead to higher failure rates during crises and excessive lending in the long run. Counterfactual simulations show that capping bonuses above salary and deferring bonuses reduces failure rates by 12 basis points while suppressing lending by 47 basis points.

Keywords: deferred compensation, bank executives, structural estimation
JEL Classification: G21, G32, J33, M12

*I thank Dean Corbae, Oliver Levine, Roberto Robatto, Erwan Quintin, and participants at International Conference Computing in Economics and Finance, North American Summer Meeting of Economic Society, Sydney Banking and Financial Stability Conference, University of Wisconsin-Madison, Waseda University, and Yu-cho Foundation. This paper is a substantial revision of the second chapter of my dissertation, previously circulated under various titles. A preliminary (latest) version of the paper received computational support from the Center for High Throughput Computing (Center for Technology, Strategy & Sustainability at the Asia School of Business). I also gratefully acknowledge the financial support from the Yu-cho Foundation. All errors are my own.

†Contact: ikuo.takei@asb.edu.my and itakei@mit.edu

Strong criticism arises after the Global Financial Crisis (GFC) of 2007-2009, alleging that Chief Executive Officer (CEO) compensation spurs excess risk-taking in the U.S. banking industry.[1] More recently, the bank failures in 2023 highlight an importance of senior management's incentives. Bank for International Settlements (2023) reports the failure of Silicon Valley Bank's managers are focused on short-term profit fueled by remuneration policies over sound risk management. In light of these controversies, U.S. policymakers proposed rules, including the Dodd-Frank Wall Street Reform in July 2010, suggesting to mandate clawbacks of executive compensation, though these provisions have not been fully implemented.[2] After revisions of this proposal, the new compensation regulations are aimed to reduce excessive compensation for preventing material financial loss.[3] Some policymakers endorse compensation regulation more strongly than other types of regulations. While a number of prudential policies have been implemented since the GFC, direct control of CEO incentives by regulating compensation packages has been adopted in countries outside the United States. The European Union (EU) implements bonus regulations in 2014 that limit bankers' cash bonuses to the same amount as their base pay or twice that amount, which remains effective as of 2024. However, limited evidence for the entrenchment perspective creates doubt about the effectiveness of compensation regulations. In fact, the UK introduced a bonus cap in 2014 but abandoned the decade-old restriction in 2024.

The paper examines how proposed compensation regulations influence systemic risk-taking and financing decisions of bank CEOs. To investigate this, I construct a novel, comprehensive dataset on CEO compensation contracts and financial performance in the U.S. banking sector. Unlike the majority of the literature, this paper extends the analysis to Small and Medium-sized Banks (SMBs) are not listed in S&P 1500 but still shares are publicly traded. This choice is motivated by two facts. Firstly, SMBs, unlike big banks, encountered even greater challenges during the financial crisis. One piece of evidence shows that 113 SMBs still owed Troubled Asset Relief Program (TARP) money five years after the financial crisis, while most big banks had repaid TARP funds (Coles et al. (2006)). Secondly, a comprehensive sample including both SMBs and large banks provides valuable insights for scholars and policymakers by illustrating the quantitative impact of executive compensation structures, as the conflicts between bank managers and shareholders are common across banks of all sizes.

To explore the relationship among compensation regulations, bank CEO's incentive, and systemic risk-taking, this paper undertakes two steps in its analysis. The first approach is a reduced-form analysis, while the second approach involves the analysis of a structurally

[1] Detailed discussions on the policy implications and key opinions from policymakers are provided in the Appendix A.1.

[2] The Dodd-Frank Act is a comprehensive package of financial regulations aimed at preventing a recurrence of the financial crisis. Three proposals for incentive-based compensation arrangements were published in 2010, 2016, and 2024. The 2024 proposal, currently under review, reintroduces and seeks feedback on the regulatory text previously proposed in 2016, with certain modifications. This proposal has not yet been finalized or implemented.

[3] The United Kingdom implements the Remuneration Code, which requires executives and other employees to defer a large portion of their bonus compensation. Kleymenova and Tuna (2021) find that this regulation increases systemic risk-taking and leads to higher rates of unforced CEO turnover, illustrating unintended consequences of regulating executive compensation.

estimated dynamic financing model of banks. These two approaches are complementary. The reduced-form analysis provides greater transparency due to its linear specification and closed-form representation but is limited in extending policy implications to counterfactuals and struggles to disentangle endogenous relationships, particularly in how banks take risks and make inter-temporal financing decisions on their own balance sheets. In contrast, the structurally estimated model is less transparent due to the lack of a closed-form solution but allows researchers to test more sophisticated policy counterfactuals, such as comparing deferred compensation, capping cash bonuses, and banning stock options.

Initially, I apply cross-sectional regression models to examine the connection of bank CEO compensation structure and bank performance. Contrary to widespread beliefs among policymakers about managerial entrenchment causing excess risk-taking, empirical research (Bebchuk and Spamann (2009); Fahlenbrach and Stulz (2011); Cheng et al. (2015)) finds no evidence linking poor bank performance during the financial crisis to CEO compensation, aside from shareholdings, based on a sample of financial institutions, including investment banks and brokerages, listed in the S&P 1500. My paper constructs a dataset encompassing roughly 10 times larger sample compared to Fahlenbrach and Stulz (2011) (hereafter, FS (2011)). The comprehensive sample allows me to disentangle banks to other types of financial institutions, controlling heterogeneity stemming from differences in financial industry groups. The main specification is a cross-sectional regression of changes in returns during the crisis on the structure of bank CEO compensation in the pre-crisis period, while controlling for various bank characteristics. I argue that cash bonus sensitivity—a measure of the extent to which cash bonuses are tied to the size of bank performance—and the presence of unexercisable stock options contribute to excessive risk-taking by banks, as reflected in returns and failures during the GFC. Furthermore, I address potential endogeneity bias, considering that compensation structures and bank performance may be jointly determined. This bias, as argued by Cheng et al. (2015), suggests that riskier firms may offer higher total pay as compensation for the extra risk in equity. The robustness of my results remains evident even after altering the regression model and corresponding estimator. With the findings of cash bonuses and stock options cause poor bank performance, restricting cash bonuses and stock options are a natural way to improve stability.

While the reduced-form analysis provides empirical evidence of a relationship between CEO compensation and risk-taking, it cannot assess how alternative compensation regulations might affect bank stability. This gap is addressed by the structural model, which allows me to simulate counterfactual scenarios under various regulatory regimes. For instance, capping cash bonuses might negatively affect lending over the long run, but reduced-form analysis cannot assess counterfactual scenarios beyond the model's framework. The remaining part of the paper examines which proposed compensation regulations could effectively reduce risk-taking to address issues in bank CEO's short-termism. I focus on two key questions. First, how does managerial turnover contribute to short-termism and influence bank managers' decisions on risk-taking and lending? Second, what types of proposed compensation regulations could improve stability and financial intermediation? Specifically, is the cap on cash bonuses relative to salary appropriate, and which is more effective: a bonus cap or deferred bonuses? To address these policy questions, I estimate a dynamic financing model that incorporates risk-taking, volatile insured deposit flows, external equity financing constraints, capital requirements, and managerial compensation structures, including salary, cash bonuses, shareholdings, and stock options. Since salary constitutes the majority of CEO compensation, turnover prompts CEOs to prioritize short-term profits over shareholders' long-term interests.

The dynamic model enables in-depth theoretical testing. I document several banking facts that interact with managerial compensation and bank financial decisions. In the data, I find that salary exhibits decreasing returns to scale with bank size over time. The cross-sectional relationship between salary and non-financial firm size, known as "Roberts's law," is well established. I identify a distinct pattern in the banking industry that is crucial for explaining why bank CEOs tend to be risk-averse, effectively. Unlike in non-financial firms, the data supports the fact that temporary variations in salary changes are explained by bank size. Consequently, risk aversion arises from banks' exposure to volatile insured deposit flows, coupled with the high cost of raising equity and the need to comply with capital regulations. These constraints make deposits and equity imperfect substitutes. Bank CEO builds up equity as a buffer against volatile deposit flows. The model treats volatile insured deposit flows as exogenous and endogenously generates the distribution of bank sizes. The concavity of the salary function is steeper for smaller banks, incentivizing them to build larger equity buffers. As a result, the model produces a simulated pattern in which capital ratios are inversely related to bank size. The precautionary savings mechanism in banking aligns quantitatively with the empirical data.

My model deviates from the standard assumption that managerial incentives are aligned with shareholding, yet the model still fits the data well. After confirming that the model matches the data, I conduct a counterfactual analysis by adjusting compensation contracts and turnover rates to assess their influence on risk-taking and lending. The results show that higher shareholdings (lower CEO turnover) increases (decreases) short-termism, leading to more (less) bank failures during crises and decreased (increased) lending over the long run. The model finds a counter-intuitive result on increasing shareholdings do not necessary contribute on financial soundness. I argue that managerial conflicts are not solely captured by shareholdings in either the model or the reduced-form analysis. Managers, required to hold their equity until the end of their tenure but allowed to sell it immediately upon resignation, tend to exhibit more short-term behavior than shareholders, even when their compensation consists entire of shareholdings.

Afterward, I run several counterfactual policy scenarios, including (i) the Dodd-Frank proposal—a combination of deferred dividends and deferred bonuses, (ii) the EU bonus cap—a combination of the bonus cap and deferred bonuses, (iii) pure debt-based compensation (Bebchuk and Spamann (2009)), and (iv) an option ban, comparing these to the existing compensation plan as a benchmark.[4,5] These compensation regulations could affect financial stability and intermediation both quantitatively and qualitatively. For example, since deferred compensation functions like binary options, deferred bonuses and dividends could,

[4]Other forms of debt-based compensations proposed in the literature include subordinated debt compensation (Tung (2011)) and convertible equity compensation (Gordon (2010)), both of which are common types. However, these forms of compensation are not examined in this paper.

[5]Hayes et al. (2012) find a causal relationship between option-based compensation and risk-taking using the exogenous change of the revised accounting standard as an instrument.

in theory, enhance risk-taking behavior (Edmans and Liu (2011)). The model finds that deferred compensation, bonus caps, contingent debt, and option bans reduce bank failures, though the magnitude of these effects varies across compensation regulations. The effects on loans are mixed, with both positive and negative outcomes.

This study directly informs ongoing debates around bank CEO compensation regulations, such as the proposed Dodd-Frank revisions and the EU bonus cap, offering quantitative insights into their likely effects on systemic risk-taking and financial stability.

Roadmap. The remainder of the paper is organized as follows. Section 1 provides literature overview. Section 2 explains sample construction. In Section 3, I provide reduced-form evidence. Section 4 introduces the estimated model and provides counterfactual experiments. Section 5 concludes.

1 Literature Overview

My paper builds on the literature examining bank risk-taking and CEO compensation, with a focus on salary, cash bonuses, shareholdings, and stock options. The closest related paper in reduced-form analysis is FS (2011). FS (2011) find that banks where CEOs' incentives are better aligned with those of shareholders did not perform better during the crisis. Contrary to the prevailing policy discussions, they find no evidence that a larger fraction of cash bonuses and options led to worse bank performance during the crisis. Moreover, Berger et al. (2016) do not find any evidence of a direct impact from the shareholdings of a bank CEO on bank failure. Some researchers improving the measurement of compensation sensitivities on risk-taking. Bai and Elyasiani (2013); DeYoung et al. (2013); Armstrong et al. (2021) find that greater compensation sensitivity to stock price volatility, known as Vega, increases bank instability. Although cash bonuses are relatively small compared to salary, they still exhibit significant sensitivity to a firm's value. Guay et al. (2019) argues that bonus plans in non-financial firms exhibit greater performance sensitivities than previously estimated. Despite the central role of cash bonuses in the banking sector, there is no evidence supporting the entrenchment perspective thus far. My research contributes by providing empirical evidence in support of the entrenchment perspective.

The scarcity of empirical evidence in the banking literature raises a critical question: why do regulators need to intervene in bank CEOs' compensation structures? Researchers suggest that short-termism is a significant source of corporate governance issues. Kolasinski and Yang (2018) develop a short-termism measure based on equity duration, concluding that short-termism was a root cause of the subprime crisis. Iqbal and Vähämaa (2019) document that managerial risk-taking incentives increase the level of systemic risk during the financial crisis. This paper quantifies the extent of short-termism resulting from CEO turnover.

A series of papers suggests that interventions in bank executive compensation structures can affect financial stability. In contract theory, Edmans and Liu (2011); Bennett et al. (2015) argue that CEO inside debt reduces default risk. However, some research challenges the effectiveness of compensation regulation. Shareholders may offer bonuses to share risks, which can lead to unintended consequences, such as impairing banks' risk-sharing capacity

(Efing et al. (2015)). John et al. (2000); Bolton et al. (2015) argue that Federal Deposit Insurance Corporation (FDIC) insurance premiums or Credit Default Swap (CDS)-based compensation can correct risk-taking incentives. While these arguments are largely qualitative, this paper provides quantitative insights.

This study also contributes to the literature on dynamic models in corporate finance applied to banking. In line with policymakers' discussions on the dynamic trade-offs between short-term profits and long-term stability, my model extends the static trade-offs in Allen and Gale (2000) to a dynamic framework. Additionally, my model builds on Glover and Levine (2017) by adapting their corporate finance model for banking, allowing counterfactual experiments such as banning stock options. There are several important departures from their model. First, I relax the assumption of constant returns-to-scale technology in revenue generation, allowing bank size to be endogenously determined. This adjustment is essential for capturing the trade-offs between risk-taking and lending. Second, I recast the model to be fully dynamic, rather than assuming that the CEO retires annually and a new CEO takes over. This approach aligns with policymakers' discussions on short-termism and allows the model to match empirical data, where the average CEO tenure is approximately 10 years. Nikolov and Whited (2014) develop a dynamic corporate financing model with agency conflicts to explain corporate cash policy in non-financial firms. This paper emphasizes the key distinction between financial and non-financial firms: dynamic corporate financing in banking centers on the uncertainty of insured deposit flows, rather than firm-specific productivity, as in non-financial firms. Bolton et al. (2020) presents a theoretical model where banks imperfectly control volatile insured deposit flows, while Corbae and D'Erasmo (2021) provides a calibrated quantitative model in which banks face idiosyncratic and persistent funding shocks.

Even though my model is adapted to the banking sector, the agent's trade-offs resemble those in the seminal paper by Huggett (1993) on a heterogeneous agent model in discrete time, in which households are risk-averse, financially constrained, and exposed to idiosyncratic and persistent income shocks. In a Huggett model, household risk-aversion incentivizes them to build up net worth as buffers, leading to an endogenous wealth distribution. Similarly, in my model, banks are effectively risk-averse. Risk-aversion arises not from concavity of manager's utility function, but because salary, a largest component in CEO compensation, is concave in relation to bank size. Additionally, external equity financing contributes concavity of manager's pay-offs, with risk-aversion intensifying when financing needs are high.

2 Data

The primary data source for this study is S&P Capital IQ. Since the data is not available in a structured format on Wharton Research Data Services, it was collected manually. For publicly listed bank holding companies and stand-alone commercial banks, balance sheets and income statements are extracted from annual reports (Form 10-K), while CEO compensation data is sourced from proxy statements (SEC Form DEF 14A). Market data, including equity prices for banks listed on major exchanges such as NYSE, NASDAQ, Arca, and Bats, is also sourced from S&P Capital IQ. Additionally, Intercontinental Exchange (ICE) provides S&P Capital IQ with data for stocks traded on markets such as Pink Sheets and the OTC Bulletin Board.[6]

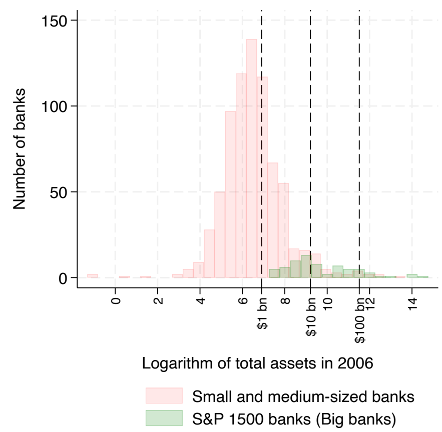
I collect data for all companies classified under Standard Industry Classification (SIC) code 6020 (commercial banks) from S&P Capital IQ. The sample includes community banks, regional banks, banks traded on major U.S. stock exchanges, and those traded in Over-The-Counter (OTC) markets. I narrow down the sample to a specific geographic region within the U.S. and exclude banks that do not report total assets, executive salaries, or market capitalization. The final sample consists of 719 commercial banks at the end of the 2006 fiscal year. While many studies on bank CEO compensation rely on Execucomp, which is limited to banks listed on the S&P 1500, my novel dataset includes an additional 650 commercial banks not listed on the S&P 1500, significantly increasing the sample size. For comparison, FS (2011) utilize a full sample of 95 financial institutions, including both bank holding companies and investment banks (SIC codes between 6000 and 6300) for the fiscal year 2006. Their subsample of 83 banks excludes non-depository institutions. Berger et al. (2016) study a total sample of 341 commercial banks from Q1 2006 to Q3 2010, with a particular focus on hand-collecting data from failed banks. In contrast, my dataset includes nearly twice as many non-failed banks compared to their study. Technical details for constructing variables from S&P Capital IQ are provided in Appendix A.2.

To facilitate comparison with previous studies, I construct a subsample of S&P 1500 banks based on the sample firms listed in the appendix of FS (2011), manually correcting any discrepancies in bank names to ensure an exact match. This process identifies 69 banks, which I refer to as big banks or S&P 1500 banks. The remaining 650 banks are categorized as small and medium-sized banks (SMBs), with their size distribution in 2006 measured by total assets, as shown in Figure 1). The size distribution reveals significant heterogeneity among banks not listed in the S&P 1500. For example, not every "SMBs" are smaller than S&P 1500 banks". In the subsequent sections, I compare the characteristics of SMBs to those of S&P 1500 banks.

[6]The OTC Bulletin Board and Pink Sheets require U.S. banks with non-SEC-registered securities to follow the disclosure guidelines outlined in the OTCQX Rules for U.S. Banks.

Figure 1: Size Distribution of Small and Medium-sized and S&P 1500 Banks.

This figure presents a histogram illustrating the size distribution of small and medium-sized banks (SMB) and S&P 1500 banks (i.e., big banks). The horizontal axis represents the logarithm of total assets measured in 2006. The three horizontal dotted lines indicate thresholds of \$1 billion, \$10 billion, and \$100 billion in total assets. According to the Federal Reserve, banks with total assets below \$10 billion are classified as community banks, those with assets between \$10 billion and \$100 billion as regional banks, and those with assets exceeding \$100 billion as national banks. The \$1 billion threshold identifies banks targeted for regulation under the Dodd-Frank Proposal. Given that the size of banks has grown over time, most banks have surpassed this threshold by 2024. The sample of commercial banks used in this analysis is constructed from S&P Capital IQ, with big banks defined as those listed on the S&P 1500, based on the bank name list provided in the appendix of FS (2011).



3 Reduced-form Analysis

In Section 3.1, I analyze how bank performance evolved before and after the GFC, focusing on four risk-taking measures: Return on Assets (ROA), Return on Equity (ROE), buy-and-hold returns, and bankruptcy as the main dependent variables. I then present the summary statistics of banks' financials and CEO compensation in Section 3.2. Finally, Section 3.3 summarizes the regression results.

3.1 Timeline of Returns and Failure in the GFC

I report the evolution of ROA as a proxy for bank performance before and after the GFC in Figure 2. The left-hand side panel represents the sample of SMBs, while the right-hand side panel represents the sample of S&P 1500 banks. ROA decreases during the GFC, starting in the 3rd quarter of 2007, reaching a low point at the end of 2008, and then gradually recovering in both the SMB and S&P 1500 bank samples. There is considerable heterogeneity in ROA, with this heterogeneity increasing during the GFC, particularly at the lower tail of banks. ROE and buy-and-hold returns exhibit similar patterns.

Figure 2: Evolution of the Rate of Returns from 2005Q4 to 2011Q4.

The figure shows the cross-sectional and time series of Return on Assets (ROA). ROA is defined as net income divided by total assets. The solid line represents the median ROA, and the shaded area covers the range from the 25th to the 75th percentile for each period. The sample consists of commercial banks over 24 quarters, from the fourth quarter of 2005 to the fourth quarter of 2011. The full sample is divided into two groups: SMBs on the left and S&P 1500 banks on the right. The S&P 1500 group includes shares traded on the NYSE, NYSE Arca, NYSE MKT, NASDAQ Global Select Market, NASDAQ Select Market, and NASDAQ Capital Market.

A direct measure of bank failure is the number of bankruptcy filings. Between July 2007 and December 2010, a total of 30 banks filed for bankruptcy in my sample (Table 1). Of these, 26 are SMBs. Therefore, the majority of bankruptcies during the crisis are associated with SMBs. Figure 3 illustrates the evolution of the numbers of bankruptcies in my final sample from 2000 to 2019. The years 2009 and 2010 mark the first and second peaks of bankruptcy during the GFC. There is a lag between the onset of bankruptcy and its impact on accounting returns, as the bankruptcy process takes time to unfold. I classify all the banks that filed for bankruptcy between July 2007 to December 2010 as bankruptcies in the cross-sectional regression analysis in Section. In 2009 and 2010, more than half of bankruptcies eventually resulted in Chapter 7 liquidation.

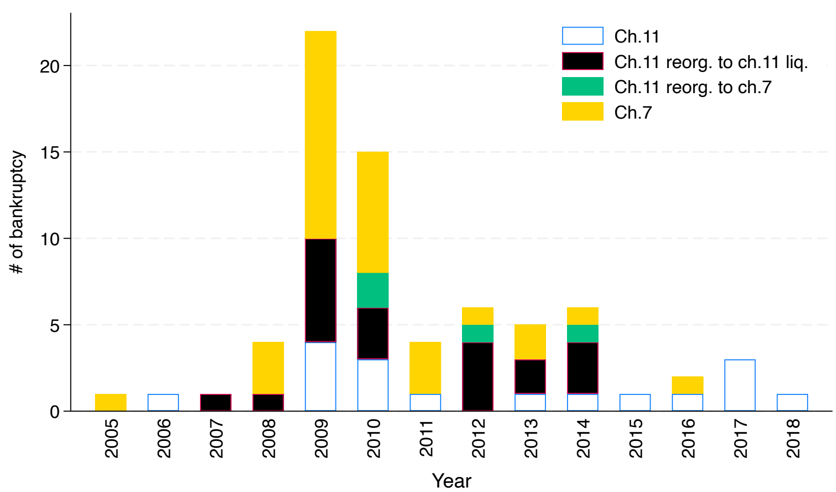
Table 1: Summary Statistics of Bank Failure from July 2007 to December 2010.

The table presents summary statistics on bankruptcy from July 2007 to December 2010. "Banks filed bankruptcy" refers to the sum of banks that filed for Chapter 11, transitioned from Chapter 11 to Chapter 7, or filed directly for Chapter 7.

	Small and medium-sized banks		S&P1500 banks	
	# of events	Frequency	# of events	Frequency
Banks filed bankruptcy	26	0.040	4	0.058

Figure 3: Number of Bankruptcy Filings Before and After the Financial Crisis.

The figure shows the evolution of the number of bankrupt financial firms from 2000 to 2019. No bankruptcies were reported between 2000 and 2004, or in 2019. The numbers represent the total banks that filed for Chapter 11 or Chapter 7 bankruptcy during this period, based on the voluntary petition filing date. The sample includes both S&P 1500 banks and small and medium-sized banks (SMBs).



3.2 Summary Statistics of Bank Financials and CEO Compensation

Tables 2 through 3 present key summary statistics of banks' financial statements and CEO compensation for the fiscal year 2006—before the GFC. Moreover, Table 2 calculates cumulative returns over periods during the crisis, spanning from July 1, 2006, to December 31, 2008. These periods exclude the time in 2009 when shareholder uncertainty about potential bank nationalizations is rising. The average size of SMBs (S&P 1500 banks) is \$2.3 billion (\$37.6 billion). The average ROA of SMBs is 0.86% in 2006, declining to 0.31% during the crisis period. The buy-and-hold returns are a performance measure that calculates the income and capital gains a stock investor earns over a given period. The buy-and-hold returns of SMBs during the crisis average -42%. I find no statistically significant difference in return measures during the crisis between SMBs and S&P 1500 banks. Table 3 reports bank CEO compensation structure, including cash dependency, ownership, and options.

Three parameters that characterize the compensation structure—cash bonus sensitivity (θ_B), shareholdings (θ_S), and options (θ_O)—are used in both the reduced-form analysis and the dynamic model. There are two key findings regarding cash bonuses. First, the bonus-to-revenue ratio—the elasticity of annual incentives based on performance—is 0.17% on average for SMBs with a standard deviation of 0.29%. The compensation structure in the SMB sample exhibits notable heterogeneity, with the standard deviation of the bonus-to-revenue ratio ("Percentage ownership from shares") being 4 (5) times larger than that in the FS (2011) sample of S&P 1500 banks. Unlike bank profits, revenue is a good measure of earnings because it is non-negative, making the elasticity of annual incentives non-negative.[7] Cash bonus sensitivity includes both CEOs who receive and do not receive cash bonuses. In 2006, 52% of SMB CEOs receive non-zero cash bonuses. The ratio of cash compensation to total compensation averages 85% in the SMB sample, significantly higher than the 57% for S&P 1500 banks. On average, cash bonuses account for around 10% of cash compensation in both SMBs and S&P 1500 banks. Therefore, salary constitutes the majority of cash compensation for CEOs.

The average percentage ownership of shares (θ_S) is 2.6% in the SMB sample, which is larger compared to the S&P 1500 banks, where the average is 0.7% (Table 3). Although the ownership percentage is smaller in S&P 1500 banks, their sizes of asset and equity are more than 10 times larger than those of SMBs (Table 2). This difference explains why the value of CEO shareholdings is significantly higher in S&P 1500 banks than in SMBs.

The average unexercisable option-to-total share ratio (θ_O) is 0.2% in both the SMB and S&P 1500 bank samples, which is lower than the average exercisable options-to-total shares ratio. This discrepancy arises because unexercisable options are recently issued, while exercisable options were issued in the past. In the next section, I investigate the conditional relationship between risk-taking outcomes and pre-crisis compensation structures.

[7] Banks use various performance measures in their annual incentive plans. The 1996–1997 Annual Incentive Plan Design Survey by Towers Perrin reveals that 19 out of 21 U.S. finance and insurance corporations use earnings metrics such as net income, pre-tax net income, and returns on assets, equity, and capital.

Table 2: Cross-sectional Data Summary Statistics of Banks Financial Statements for Fiscal Year of 2006 and Periods of Crisis.

This table presents summary statistics of bank financials in period of 2006 and returns of crisis. Absolute values are reported in million of dollars, while ratios are expressed as percentages. Buy-and-hold returns are calculated as the total returns of banks, including dividends and capital gains, from July 1, 2007, to December 31, 2008, divided by the share price on July 1, 2007. The "Difference" column in the table reports the results of a t-test comparing each statistic between SMBs and S&P 1500 banks. Asterisks (*, **, and ***) denote p-values from t-tests of statistical significance at the 0.1, 0.05, and 0.01 levels, respectively (two-sided).

	Small and medium-sized banks				S&P1500 banks				Difference
	Number	Mean	Median	Std.Dev.	Number	Mean	Median	Std.Dev.	Mean
Period of 2006									
Total assets (million dollars)	650	2333.48	648.59	10428.12	69	37602.72	10571.82	48773.90	-35269.24***
Total liabilities	650	2070.65	588.34	9029.48	69	32936.84	9804.32	41854.68	-30866.19***
Market capitalization	650	483.63	104.03	2369.02	69	7493.40	2055.08	9836.25	-7009.77***
ROA (%)	650	0.86	0.90	0.57	69	1.28	1.26	0.41	-0.42***
ROE (%)	650	9.43	9.95	5.67	69	13.27	12.92	4.74	-3.84***
Cash/total assets (%)	650	5.08	3.75	4.35	69	3.91	3.23	2.60	1.18**
Book-to-market ratio	650	0.61	0.60	0.19	69	0.52	0.50	0.16	0.09***
Tier 1 capital ratio (%)	650	12.87	11.88	4.93	69	10.14	9.80	2.69	2.73***
Periods of Crisis									
ROA (%)	624	0.31	0.66	1.51	69	0.50	0.86	1.55	-0.19
ROE (%)	621	3.69	7.38	15.49	67	4.97	7.57	15.31	-1.28
Buy-and-hold returns (%)	600	-41.89	-44.35	32.78	62	-42.04	-44.36	31.70	0.15

Table 3: Cross-sectional Data Summary Statistics of Bank CEO Compensation for Fiscal Year 2006 of Small and Medium-sized Banks and Banks Listed on S&P1500.

The table presents summary statistics of bank CEO compensation. Absolute values are reported in thousands of dollars, while ratios are expressed as percentages. Compensation is categorized into annual compensation, equity portfolio value, and equity portfolio incentives. "Cash compensation" refers to the sum of salary, cash bonuses, and other forms of cash payments. Percentage ownership from shares is calculated as the ratio of the number of shares held by bank CEOs to the total number of shares issued by the banks. The difference in means between SMBs and S&P 1500 banks is shown in the rightmost column, with p-values from t-tests indicated by asterisks. $*$, $**$, and $***$ denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively (two-sided).

	Small and medium-sized banks				S&P1500 banks				Difference
	Number	Mean	Median	Std.Dev.	Number	Mean	Median	Std.Dev.	Mean
Compensation Structure and Cash Dependency									
Total compensation (thousand dollars)	650	788.91	422.92	1952.20	69	5293.92	2602.20	6491.80	-4505.01***
Cash compensation	650	523.28	348.00	739.83	69	2145.34	1495.68	1985.08	-1622.05***
Salary and others	650	448.20	307.46	601.97	69	1754.18	1187.70	1545.94	-1305.97***
Salary	650	287.51	240.00	153.95	69	716.80	737.50	235.85	-429.28***
Bonus	650	61.88	3.85	161.75	69	182.81	0.00	369.96	-120.93**
All other compensation	650	52.49	27.68	94.50	69	190.25	119.49	196.59	-137.75***
Salary and others/assets (%)	650	0.06	0.05	0.05	69	0.01	0.01	0.01	0.05***
Salary/assets (%)	650	0.05	0.04	0.04	69	0.01	0.01	0.01	0.04***
Bonus/revenue (%, θ_B)	647	0.17	0.01	0.29	69	0.03	0.00	0.08	0.14***
Bonus is paid (%)	650	51.85	100.00	50.00	69	28.99	0.00	45.70	22.86***
Bonus/salary ratio above 100%	650	0.04	0.00	0.19	69	0.12	0.00	0.32	-0.08
Cash compensation/compensation (%)	647	84.55	90.41	17.37	69	57.04	50.64	21.49	27.50***
Bonus/cash compensation (%)	647	9.90	1.74	14.00	69	10.96	0.00	19.40	-1.07
Ownership									
Percentage ownership from shares (%, θ_S)	527	2.58	0.85	5.38	60	0.66	0.28	1.15	1.92***
Value shares	650	229.75	0.00	1199.94	69	3892.37	1142.82	5231.55	-3662.62***
Annual stock grant	650	78.07	0.00	536.14	69	1098.67	306.23	1852.84	-1020.60***
Options									
Unexercisable options/shares (%, θ_O)	650	0.22	0.00	0.45	69	0.21	0.12	0.38	0.01
Exercisable options/shares (%)	650	0.89	0.43	1.25	69	0.67	0.41	0.86	0.22
Annual option grant	650	69.52	0.00	344.48	69	966.20	389.91	1321.52	-896.68***
Value unvested stock	650	129.59	0.00	723.64	69	2127.73	451.61	3488.27	-1998.15***

3.3 Empirical Results

3.3.1 Cross-sectional Regressions

In this section, I argue that pre-crisis bonus-to-revenue ratio and unexercisable option-to-total share ratio explain the bank performance and failure in the crisis. The cross-sectional regression model is specified as follows:

$$\begin{aligned}
\text{Risk-taking}_{i,\text{crisis}} &= \beta_0 + \beta_1 \left(\text{Bonus/revenue}_{i,\text{pre-crisis}} + \beta_6/\beta_1 \mathbb{1}_{\text{Bonus}_{i,\text{pre-crisis}}>0}\right) \\
&+ \beta_2 \text{Ownership from shares}_{i,\text{pre-crisis}} \\
&+ \beta_3 \text{Unexercisable options/total shares}_{i,\text{pre-crisis}} \\
&+ \beta_4 \text{Salary and others/total assets}_{i,\text{pre-crisis}} \\
&+ \beta_5 \text{Exercisable options/total shares}_{i,\text{pre-crisis}} \\
&+ \text{Controls}_{i,\text{pre-crisis}} + \varepsilon_i \qquad (1)
\end{aligned}$$

In Equation (1), the subscript i of each variable serves as an index for banks and their matched bank CEOs in 2006. The matched CEOs might be differ from the pre-crisis to the post-crisis period due to some CEOs resigning from their positions. $\text{Risk-taking}_{i,\text{crisis}}$ is represented by *ex-post* realized and expected bank-level gains/losses measured during the crisis, while the right-hand side variables represent *ex-ante* measures of the bank CEO's risk-taking incentives observed prior to the crisis. I run regressions for three bank performance indices: ROA, ROE, and buy-and-hold returns. All returns in the cross-sectional regressions are computed as the returns of banks from July 1, 2006, to December 31, 2008. The coefficients β_j where $j \in \{1, 2, 3, 4, 5\}$ indicate the sensitivity of each compensation component to risk-taking, β_0 is the constant term, and ε_i represents the error term. I choose compensation ratios instead of the levels of compensation to address issues related to scaling. Since cash bonuses are rewarded based on the bank's performance, the bonus-to-revenue ratio θ_B is interpreted as the size of cash bonus sensitivity, similar to the bonus beta calculated by Guay et al. (2019). The number of stocks and options are divided by the total number of shares. Salary and others are scaled by total assets. In addition to the linear specification of compensation ratios, β_6 is a coefficient of the bonus payment indicator $\mathbb{1}_{\text{Bonus}_{i,\text{pre-crisis}}>0}$, which equals one if $\text{Bonus}_{i,\text{pre-crisis}}$ is strictly positive and zero otherwise. The coefficient β_6 captures the potential for cash bonuses to incentivize both positive and negative risk-taking. A positive sign of β_6 indicates an increase in bank performance during the crisis, conditional on banks where cash bonuses are paid.If $\beta_1 < 0$ and $\beta_6 > 0$, the bonus-to-revenue ratio θ_B has an inflection point at $-\beta_6/\beta_1 (> 0)$. Banks with a bonus-to-revenue ratio above this inflection point ($\theta_B > -\beta_6/\beta_1$) exhibit negative performance during the Global Financial Crisis (GFC), which can be interpreted as bad risk-taking. Conversely, banks below the inflection point ($\theta_B < -\beta_6/\beta_1$) perform better. The estimates of $\beta_1 < 0$ and $\beta_6 > 0$ are consistent with the idea that capping cash bonuses reduces incentives for bad risk-taking. I begin by presenting results on accounting returns—return on assets (ROA) and return on equity (ROE)—followed by market returns, and finally, bank failures.

ROA and ROE. Table 4 presents the Ordinary Least Squares (OLS) estimates where accounting returns are the dependent variable. Excessive risk-taking is associated with a larger decline in ROA and ROE during the crisis. I test whether poor performance is predicted by CEO incentives, as measured by compensation. The first five specifications in Panel A of Table 4 use five key compensation ratios as independent variables: cash bonus sensitivity, shareholdings, unexercisable options, salary, and exercisable options, respectively. Cash bonus sensitivity and unexercisable options remain statistically significant and robust across specifications. In the benchmark specification (6) of Panel A, a one standard deviation increase in the bonus-to-revenue (unexercisable option-to-total share) ratio of 0.29% (0.45%) results in a -0.32% (-0.26%) reduction in ROA, calculated as $-1.11 \times 0.29\%$ ($-0.58 \times 0.45\%$). Appendix Table A1 confirms the robustness of these results when changing the risk-taking measure from ROA to ROE, with no change in the quantitative impact. Estimated coefficients satisfy $\beta_1 < 0$ and $\beta_6 > 0$. The inflection point for the bonus-to-revenue ratio is 0.39% (calculated as $-\beta_6/\beta_1$), while the mean bonus-to-revenue ratio is 0.17%. This suggests that a bonus cap is more effective than banning cash bonuses in reducing excessive risk-taking, as it sets an upper limit on bonus payments, encouraging banks with high cash bonus sensitivity to pay cash bonuses to their CEOs. Column (7) in Panel A includes regressors to explore the heterogeneity of coefficients of interest by size categories: SMBs and S&P 1500 banks. I find that cash bonus sensitivity and options have even more negative coefficients for S&P banks compared to SMBs, as the interaction terms are negative and statistically significant at the 5% level.

Market Returns. Consistent with the empirical findings on ROA and ROE, buy-and-hold returns further declined for banks with higher incentives to take risks. Columns (1) through (5) in Panel B of Table 4 regress buy-and-hold returns on each of the five compensation variables. Similar to the results for ROA and ROE, cash bonus sensitivity and unexercisable options remain the most robust. To account for lagged return dependency and control for bank characteristics, the OLS estimates of my primary model, presented in Equation (1), are reported in column (6) of Panel B in Table 4. Buy-and-hold returns represent the market returns on shareholdings. Coefficients on bonus-to-revenue ratio, unexercisable options, exercisable options, and bonus indicator are statistically significant. 0.29% increase in bonus-to-revenue ratio, equivalent to one standard deviation, leads to a $-11.3\%(= -39 \times 0.29\%)$ drop in buy-and-hold returns. One standard deviation increase in unexercisable option-to-total share 0.46% decreases $-5.0\%(= -11 \times 0.45\%)$. Since the mean drop of buy-and-hold returns in the crisis is -42%, cash bonus sensitivity and unexercisable options have economic significance as well. Similar to ROA and ROE specifications, estimated coefficients satisfy $\beta_1 < 0$ and $\beta_6 > 0$. The inflection point is 0.38% (calculated as $-\beta_6/\beta_1$), which is close to the estimate for ROA.

I conclude that a comprehensive sample confirms the relationship between risk-taking and managerial incentives from compensation. Column (7) in Panel B of Table 4 examines coefficient heterogeneity. In contrast to ROA, the impacts on buy-and-hold returns show no statistically significant differences in point estimates across size categories: SMBs and S&P 1500 banks. Additionally, I compare my results to a selection of specification similar to FS (2011), using the bonus-to-salary ratio as an alternative measure of short-term cash compensation relevance (see Appendix A.3.2). The results remain robust across different measures of bonus incentive size. The strong relationship between returns and compensation is evident in the scatter plots in Appendix A1. Two figures show negative relationships between buy-and-hold returns during the crisis and compensation metrics (bonus-to-revenue ratio and unexercisable options-to-total share ratio) from the pre-crisis period of 2006.

Table 4: Explaining Return on Asset during and Buy-And-Hold Returns during the Financial Crisis.

Tables present results from cross-sectional regressions of ROA in Panel A and buy-and-hold returns in Panel B for bank holding companies and stand-alone banks. ROA is calculated as the ratio of net income from July 2007 to August 2008 divided by total assets at the end of June 2007. "Ownership from shares" refers to the shareholdings of a bank CEO divided by the total number of shares issued. "Salary and others/total assets" is defined as the annual salary plus other cash compensation, excluding cash bonuses, for the fiscal year 2006, divided by total assets at the end of the fiscal year 2006. The "bonus-to-revenue ratio" is calculated as the annual bonus for the fiscal year 2006 divided by the annual revenue for that year. "Exercisable options" and "Unexercisable options" represent the ratios of the number of options to the total number of shares of common stock outstanding. $\mathbb{1}_{\text{Bonus}>0}$ ($\mathbb{1}_{\text{FS}}$) is an indicator function that takes the value of 1 if bank i's bonus payment is strictly positive (or if bank i is in the S&P 1500 group, as in the corresponding sample in FS (2011)). "Lagged returns" refers to the stock returns in 2006. Control variables for bank characteristics include the price-to-book ratio, the logarithm of market capitalization, and the Tier 1 capital ratio at the end of the fiscal year 2006. Columns (1) to (4) use a sample of SMBs, while column (5) includes a sample of both SMBs and large banks. Standard errors are reported in parentheses. Statistical significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Panel A: Return on Asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bonus/revenue (%, θ_B)	-0.559*					-1.112***	-1.125***
	(-1.82)					(-2.86)	(-2.93)
Ownership from shares (θ_S)		-0.00123				-0.00111	-0.000569
		(-0.10)				(-0.08)	(-0.04)
Unexercisable options (θ_O)			-0.491***			-0.583***	-0.582***
			(-3.16)			(-3.15)	(-3.12)
Salary and others/total assets (%)				-4.339**		-1.496	-1.621
				(-2.29)		(-0.58)	(-0.64)
Exercisable options					-0.0338	-0.00119	-0.000810
					(-0.91)	(-0.02)	(-0.02)
$\mathbb{1}_{\text{Bonus}>0}$						0.00432***	0.00428***
						(2.69)	(2.78)
Bonus/revenue (%, θ_B) $\times \mathbb{1}_{\text{FS}}$							-4.237**
							(-2.35)
Ownership from shares (θ_S) $\times \mathbb{1}_{\text{FS}}$							0.0191
							(0.24)
Unexercisable options (θ_O) $\times \mathbb{1}_{\text{FS}}$							-1.153**
							(-2.46)
$\mathbb{1}_{\text{FS}}$							0.00914**
							(2.00)
SMB Sample Only	Yes	Yes	Yes	Yes	Yes	Yes	No
Lagged Returns	No	No	No	No	No	Yes	Yes
Control of Bank Characteristics	No	No	No	No	No	Yes	Yes
Adjusted R-squared	0.010	-0.002	0.021	0.016	-0.001	0.101	0.117
Total Obs.	622	517	624	624	624	506	566

Table 4: Explaining Return on Asset during and Buy-And-Hold Returns during the Financial Crisis (Continued).

Panel B: Buy-And-Hold Returns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bonus/revenue (%, θ_B)	-24.64***					-38.62***	-38.56***
	(-7.12)					(-5.64)	(-5.70)
Ownership from shares (θ_S)		-0.00292				0.117	0.164
		(-0.01)				(0.36)	(0.51)
Unexercisable options (θ_O)			-12.86***			-11.32***	-11.34***
			(-5.78)			(-4.21)	(-4.17)
Salary and others/total assets (%)				-89.97***		32.73	17.06
				(-3.47)		(0.67)	(0.34)
Exercisable options					-5.268***	-3.526***	-3.454***
					(-5.10)	(-2.88)	(-2.76)
$\mathbb{1}_{\text{Bonus}>0}$						0.147***	0.142***
						(3.91)	(3.91)
Bonus/revenue (%, θ_B) $\times \mathbb{1}_{\text{FS}}$							-82.81
							(-1.40)
Ownership from shares (θ_S) $\times \mathbb{1}_{\text{FS}}$							-2.442
							(-0.86)
Unexercisable options (θ_O) $\times \mathbb{1}_{\text{FS}}$							-5.622
							(-0.83)
$\mathbb{1}_{\text{FS}}$							-0.312***
							(-3.02)
SMB Sample Only	Yes	Yes	Yes	Yes	Yes	Yes	No
Lagged Returns	No	No	No	No	No	Yes	Yes
Control of Bank Characteristics	No	No	No	No	No	Yes	Yes
Adjusted R-squared	0.048	-0.002	0.031	0.017	0.040	0.153	0.150
Total Obs.	597	486	600	600	600	476	530

Bank Failures. The preceding sections focus on the intensive margin of ex-post performance measures, such as ROA, ROE, and market returns, all of which are conditional on surviving banks. However, these measures may not be suitable for banks severely and negatively affected by the GFC, particularly those forced to exit the sector due to excessive risk-taking. As an alternative approach, I examine the extensive margin of ex-post performance by estimating logit models for bankruptcy filings at bank holding companies and stand-alone commercial banks. I do not use bank failure as defined by the FDIC—when a bank cannot meet its financial obligations. However, bank failures and bankruptcies are not independent. In fact, bankruptcy in bank holding companies may precede individual bank-level failure. As shown in regression Table 5, both the bonus-to-revenue ratio, shareholdings, and the unexercisable option-to-total share ratio are statistically significant, with positive coefficients, indicating that higher cash bonus sensitivity, shareholdings, and options increase bankruptcy rates during the crisis.

Table 5: Explaining Bank Failure during the Financial Crisis.

The table reports the regression coefficients from running logit regressions of the number of bankruptcies from July 2007 to December 2010. Control variables for bank characteristics include the price-to-book ratio, the logarithm of market capitalization, and the Tier 1 capital ratio at the end of the fiscal year 2006.

	(1)	(2)	(3)	(4)
Bonus/revenue (%, θ_B)	111.3**			203.9***
	(2.35)			(3.06)
Ownership from shares (θ_S)		4.741**		5.879**
		(2.00)		(2.12)
Unexercisable options (θ_O)			80.61***	96.07***
			(3.18)	(2.88)
Salary and others/total assets (%)				9.334
				(0.02)
Exercisable options				6.739
				(0.46)
Control of Bank Characteristics	No	No	No	Yes
Log-Likelihood	-122.281	-113.947	-120.786	-99.231
Total Obs.	716	587	719	576

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.3.2 Modified Control Function Regressions

The previous section assumes the endogeneity problem to be of secondary importance. In this section, I relax that assumption. The endogeneity problem arises when risk-taking and compensation are jointly determined by the bank manager. For example, reverse causality may occur if high levels of risk-taking are rewarded with greater performance sensitivity through cash bonuses. In this case, the error terms ε_i in Equation (1) and cash bonus sensitivity are correlated, violating the OLS assumption and potentially leading to biased estimates. This section employs modified control function regressions to address endogeneity, leveraging heteroskedasticity for identification. The main finding from these regressions is that cash bonuses and unexercisable options causally contribute to increased risk-taking during the contraction period of the GFC, ultimately resulting in a significant decrease in returns and lending activities.

I use two independent sets of system equations: one for cash bonuses and one for options. Below, I explain the system of equations for cash bonuses using the modified control function regression as follows:

$$\text{Bonus/Revenue}_{i,t} = \alpha_{0,i} + \lambda_1 \text{Bonus/Revenue}_{i,t-1} + \alpha' X_{i,t-1} + \xi_{i,t} \tag{2}$$

$$\triangle\text{ROA}_{i,t} = \beta_0 + \beta_1 \text{Bonus/Revenue}_{i,t-1} + \Gamma' X_{i,t-1-s} + \text{year}_t + \eta_{i,t}. \tag{3}$$

Equation (2) captures the determination of the bonus-to-revenue ratio based on one-period lagged bonus-to-revenue ratio and bank characteristics: (i) price-to-book ratio, (ii) the logarithm of market capitalization, and (iii) Tier 1 capital ratio, with $X_{i,t}$ representing a 3-by-1 vector of bank characteristics. The dynamic specification of cash bonus sensitivity reflects the persistence of cash bonus sensitivity observed in the data. Subsequently, the dynamic model in Section 4 specifies cash bonus sensitivity as an AR(1) process, similar to the specification in Equation (3). The subscripts i and t of each variables denote the bank and matched CEO index and time, respectively. Equation (3) models ex-post realized losses as a function of the bonus-to-revenue ratio. α' and Γ' are 1-by-3 transposed vectors of coefficients, with a prime to indicate the transpose of a vector. $\triangle\text{ROA}_{i,t}$ is the first-order difference of ROA. year_t represents year fixed effects to control common factors affecting all banks. $\alpha_{0.i}$ is individual-level fixed effect and β_0 is a constant term. $\xi_{i,t}$ and $\eta_{i,t}$ are error terms.

The parameter of interest is β_1, which measures the magnitude of how much the change in returns is caused by the compensation structure. Endogeneity arises when $\text{Bonus/Revenue}_{i,t-1}$ and $\eta_{i,t}$ are correlated. To address potential endogeneity, a linear projection of the error term $\eta_{i,t}$ is taken, defined as: $\eta_{i,t} = \rho \left(\frac{\sigma_{\eta,m}}{\sigma_{\xi,m}}\right) \xi_{i,t-1} + \omega_{i,t}$ where ρ is the correlation between the error terms $\xi_{i,t}$ and $\eta_{i,t}$. Here, error terms $\sigma_{\xi,m}$ and $\sigma_{\eta,m}$ represent the standard deviation of shocks $\xi_{i,t-1}$ and $\eta_{i,t}$ in "market" $m \in \{1, \dots, M\}$ where M denotes the total number of "markets". "Market" m refers to a segmentation based on heteroskedasticity in the US banking sector. Each bank matched with CEO labeled as i is grouped into a specific market m, which represents a combination of the year and one of the four geographic regions aligned with the Office of the Comptroller of the Currency (OCC) supervision structure. This identification strategy follows Armstrong et al. (2021), the geographic and time variations of error term heteroskedasticity are employed. A potential concern with the model in Equations (2-3) is that β_1 on cash bonus sensitivity is the only coefficient that allows for a causal interpretation. However, to simplify the problem, I consider no more than two endogenous variables at a time.

Substitute the expression for $\eta_{i,t}$ into Equation (3), I get

$$\triangle \text{ROA}_{i,t} = \beta_0 + \beta_1 \text{Bonus/Revenue}_{i,t-1} + \Gamma' X_{i,t-1} + \text{year}_t + \rho \left(\frac{\sigma_{\eta,m}}{\sigma_{\xi,m}} \right) \xi_{i,t-1} + \omega_{i,t}. \quad (4)$$

Crucially, $\text{Bonus/Revenue}_{i,t-1}$ and $\omega_{i,t}$ are constructed to be uncorrelated. I employ an iterative approach to estimate β_1, the coefficient of interest. In the first stage, I use the Arellano-Bond dynamic panel estimator for Equation (3) to estimate the error terms $\xi_{i,t}$. In the second stage, estimating β_1 involves calculating the ratio of standard deviations $\frac{\sigma_{\eta,m}}{\sigma_{\xi,m}}$ for all four regions of OCC supervision and time, then estimating β_1 given the ratio of standard deviations fixed. The process continues by updating $\sigma_{\eta,m}$ based on the estimated parameter β_1 at the first stage, and iterating this process until error terms $\xi_{i,t-1}$ in Equation (2) converges.

Table 6 summarizes the statistics of dependent and independent variables. The data is available at annual frequency from 2000 to 2019. All variables are winsorized at 1% and 99% to mitigate the effect of outliers.

Table 6: Panel Data Summary Statistics of Risk-taking Measures, Compensation, and Bank Characteristics.

The sample period spans from 2000 to 2019, with contraction periods identified in the years 2001, 2008, and 2009. The sample encompasses both big and small and medium-sized banks. All nominal values reported are in real terms of 2006. Unexercisable options represent the ratio of the number of unexercisable options to total shares, expressed as a percentage.

	Full sample				Contraction periods			
	Number	Mean	Median	Std. Dev.	Number	Mean	Median	Std. Dev.
Risk-taking measures								
ΔROA (%)	8,579	-0.034	0.003	0.826	1,565	-0.480	-0.187	1.148
Total loan growth (%)	8,664	7.172	5.076	14.041	1,564	4.412	2.547	13.878
Commercial loan growth (%)	8,618	6.158	5.233	23.775	1,551	1.958	1.613	26.725
Consumer loan growth (%)	8,505	1.443	-1.243	28.997	1,534	1.423	-2.289	32.802
Commercial mortgage growth (%)	8,060	9.593	6.791	20.117	1,420	10.153	7.549	22.520
Residential mortgage growth (%)	7,550	4.892	2.479	23.379	1,296	2.989	0.562	26.921
Deposit growth (%)	9,194	7.393	4.637	13.397	1,582	7.974	5.728	13.777
Annual compensation								
Bonus/revenue (%)	9,309	0.149	0.001	0.265	1,605	0.116	0.000	0.245
Unexercisable options (%)	9,268	0.213	0.000	0.515	1,600	0.265	0.016	0.577
Bank characteristics								
Book to market ratio	9,310	1.032	0.773	0.925	1,605	1.522	1.071	1.279
ln(market capitalization)	9,310	0.543	0.248	1.856	1,605	-0.055	-0.412	1.822
Tier 1 capital ratio (%)	9,310	12.457	12.060	4.061	1,605	11.799	11.560	4.056

Table 7 presents the regression coefficients along with their 10% and 90% confidence intervals, derived using the control function methods. I estimate bootstrapped standard errors using 1,000 resamples to address concerns that certain influential observations—data points with a disproportionate impact on parameter estimates—could distort the accuracy of standard errors. The baseline return measure is ROA, with the right-hand-side variables including one-period lagged compensation ratios and the control function $\Gamma' X_{i,t-1} + \rho \left(\frac{\sigma_\eta}{\sigma_\xi}\right) \xi_{i,t-1}$. Panel A of the table displays the estimates of ROA on the bonus-to-revenue ratio. The main specification in Panel A is shown in column (2), which highlights a significant negative interaction between the bonus-to-revenue ratio and the contraction period indicators for 2001, 2008, and 2009, encompassing both the Dot-Com bubble burst and the GFC. A one standard deviation increase in the bonus-to-revenue ratio results in a $-0.14\%(= -0.52 \times 0.27\%)$ decrease in ROA during contraction periods—a substantial effect considering the average (one standard deviation) ROA change of -0.48% (1.15%) during these periods, as shown in Table 6. The estimated negative coefficient for this interaction term is statistically significant at the 10% level. To examine the effect of endogeneity, I run an alternative regression without the endogeneity correction reported in column (3) by dropping the linear projected error terms $\xi_{i,t-1}$ in Equation (4). The estimated parameters for cash bonus sensitivity remain quantitatively unchanged, suggesting that the endogeneity of the compensation structure in cash bonuses is of lesser concern.

Incentives for non-CEO bank executives may influence decision-making in the boardroom. The results remain robust even when the right-hand-side variables in Equations (2-3) are adjusted from CEO compensation to the average compensation of the top five executives, including non-CEO executives, as shown in specification (4) of Table 7. This robustness check addresses another concern that the CEO has limited control over the bank's decision-making, and the heterogeneity of compensation between CEOs and non-CEOs is substantial. The results are robust under the change in alternative measurement of executive compensation structure.

Panel B in Table 7 examines the causal effect of unexercised options on risk-taking. The point estimate of the cross-term of cash bonus sensitivity and the contraction period indicators is negative and statistically significant at the level of 10%.

Table 7: The Sensitivity of Return on Asset on Bonus during the Contraction Periods.

The dependent variable is ΔROA. The sample period is from 2000 to 2019. I present 10% and 90% confidence intervals in parentheses below the coefficient estimates. I estimate bootstrapped standard errors using 1,000 resamples to address concerns that certain influential observations. The sample includes both large firms and SMBs. Columns (1-2) and (4) include endogeneity correction. For the right-hand side variables, the average bonus-to-revenue ratios of the top 5 highest-paid executives are used.

Panel A: Cash Bonus Sensitivity

	Top executive			Top 5 executives
	(1)	(2)	(3)	(4)
Bonus/revenue$_{i,t-1}$	-0.105	-0.0617	-0.0445	-0.0973
	[-0.214,0.005]	[-0.168,0.045]	[-0.126,0.037]	[-0.309,0.114]
Bonus/revenue$_{i,t-1}$ $\times$ $\mathbb{1}_{[t=01,08,09]}$		-0.516	-0.510	-0.721
		[-0.864,-0.167]	[-0.858,-0.161]	[-1.313,-0.128]
ρ	-0.00776	0.00989		-0.00209
	[-0.064,0.049]	[-0.047,0.066]		[-0.060,0.055]
Endogeneity Correction	Yes	Yes	No	Yes
R-squared	0.124	0.126	0.127	0.125
Total Obs.	7,859	7,859	7,860	7,859

Panel B: Unexercisable Options

	Top executive			Top 5 executives
	(1)	(2)	(3)	(4)
Unexer. options$_{i,t-1}$	0.0234	0.0447	0.0364	0.0240
	[-0.037,0.084]	[-0.015,0.104]	[-0.027,0.100]	[-0.017,0.065]
Unexer. options$_{i,t-1}$ $\times$ $\mathbb{1}_{[t=01,08,09]}$		-0.207	-0.216	-0.0615
		[-0.414,0.000]	[-0.407,-0.026]	[-0.198,0.075]
ρ	-0.0219	-0.00890		-0.0736
	[-0.069,0.026]	[-0.056,0.038]		[-0.145,-0.002]
Endogeneity Correction	Yes	Yes	No	Yes
R-squared	0.124	0.126	0.126	0.129
Total Obs.	7,831	7,831	7,836	7,831

What are the effects of bank CEOs' short-termism on lending and deposit-taking activities during the crisis? Does compensation increase or decrease loans and deposits in the long term? Table 8 applies control function methods to analyze balance sheet growth relative to compensation during contraction periods. The specifications are similar to those in Equation (3), with loan, mortgage, deposit growths serving as the left-hand-side variables. The analysis uncovers two key findings. Firstly, higher bonus-to-revenue ratios lead banks to increase lending in the long term. Secondly, elevated cash bonuses result in a more pronounced contraction in total loans, commercial loans, commercial mortgages, and deposits during the crisis periods of 2001, 2008, and 2009. Models (1-2), (4), and (6) estimate negative coefficients for the interaction term between cash bonus sensitivity and the crisis period indicator, indicating that these negative coefficients contribute to a larger decline in commercial lending and deposit-taking activities during crises. Additionally, the positive coefficients in the first row of Table 8 imply that cash bonuses have a positive effect on loan growth in the long term. Therefore, capping cash bonuses might present trade-offs: while lowering cash bonus sensitivity reduces the adverse impact on loans during crises, it may also diminish CEOs' incentives to increase lending.

Table 8: The Sensitivity of Balance Sheet Growths on Bonus-to-revenue During the Contraction Periods.

Dependent variables are balance sheet growths. Sample period is from 2000 to 2019. I present 10% and 90% confidence intervals in parentheses below the coefficient estimates. I estimate bootstrapped standard errors using 1,000 resamples to address concerns that certain influential observations. The sample is for both large and SMBs.

	(1) Total Loan Growth	(2) Commercial Loan Growth	(3) Consumer Loan Growth	(4) Commercial Mortgage Growth	(5) Residential Mortgage Growth	(6) Deposit Growth
Bonus/revenue$_{i,t-1}$	11.06	8.340	8.753	7.654	13.63	11.14
	[8.796,13.314]	[4.261,12.418]	[3.501,14.006]	[4.027,11.282]	[8.910,18.346]	[9.089,13.197]
Bonus/revenue$_{i,t-1} \times \mathbb{1}_{[t=01,08,09]}$	-9.803	-7.871	-4.410	-13.32	-2.776	-6.625
	[-13.253,-6.352]	[-14.471,-1.271]	[-16.785,7.965]	[-19.259,-7.375]	[-12.913,7.361]	[-10.370,-2.880]
ρ	-0.0325	-0.0158	-0.0276	0.0202	-0.0545	-0.0620
	[-0.079,0.014]	[-0.064,0.033]	[-0.077,0.022]	[-0.026,0.066]	[-0.111,0.002]	[-0.108,-0.016]
R-squared	0.182	0.071	0.032	0.075	0.039	0.092
Total Obs.	7,757	7,723	7,613	7,269	6,870	7,829

4 Dynamic Model

The reduced-form analysis in Section 3 establishes a link between risk-taking and bank CEOs' incentives. To provide economic intuitions for these findings, this section presents a structural estimation of a dynamic model using the Simulated Method of Moments (SMM) estimator. Then, I conduct counterfactual experiments on compensation regulations to assess the impact of bank CEOs' incentives on risk-taking and lending.

As of 2024, the United States has no bank CEO compensation regulations. Proposed regulations aim to address issues created by CEOs' short-termism. I model short-termism by incorporating CEO turnover, which causes CEOs to focus more on short-term gains rather than long-term stability. The model reflects the fact that bank CEOs derive utility not only from shareholding but also from salary, cash bonuses, and options. I show that salary exhibits decreasing returns to scale relative to bank size. The model's bank size distribution is endogenous, and salary effectively introduces risk aversion, while bank CEOs face uncertainty in insured deposit inflows and outflows. The key economic channel in the model is precautionary savings. The dynamic model utilizes a novel database of bank CEO compensation for structural estimation, as I explain in Section 4.2.

4.1 Technology, Preference, Population, and Equilibrium

The model casts in discrete time with an infinite horizon ($t = 1, 2, \ldots$). The model frequency is annual, corresponding to the real-data frequency. To ease notation, the variable x represents the current period t and x' represents the next period $t+1$.

There are two agents in the economy: the bank manager and a representative household. The bank manager (also referred to as the CEO) controls the bank's decision-making. The representative household constitutes the majority of the shareholders and delegates decision-making to the bank manager. The assumption of an atomistic bank manager simplifies the problem by treating share prices as given and approximating that equity payouts are unaffected by the CEO's compensation. In the model, shares granted to the CEO, including those from executed stock options, are immediately repurchased by the bank to keep the total number of shares constant over time. The bank manager's utility is risk-neutral. Both the bank manager and the representative household discount their utility by the same rate, β.

The model focuses on inter-temporal trade-offs of "systemic" (or "correlated") risk-taking. Nature picks the economy-wide state $c \in \{0, 1\}$ from either a normal state ($c = 0$) or a systemic banking crisis state ($c = 1$) featuring widespread bank failures. The occurrence and resolution of systemic banking crises are treated as transitory events to avoid introducing additional state variables into the model.

Bank Manager. Banks have access to a loan production technology. Table 9 provides a summary of the economy-wide states and loan production technology. I first explain the risk-taking technology in the normal state ($c = 0$). The loan production technology provides a simplified depiction of the key trade-offs between the short-term benefits on loan returns and the long-term costs associated with bank failure. Extending the static environment in Allen and Gale (2000), the probability of success in loan production in the normal state ($c = 0$) is modeled as $p(S) = 1 - \eta_0 S^{\eta_1}$, where $S(p) \in \left[0, (1/\eta_0)^{1/\eta_1}\right]$ represents the level of risk-taking. I will later define the probability of success in loan production during a banking crisis sate ($c = 1$).

Loan revenue given by ASl^{α_l}, where A is a scaling factor of loan returns, l represents the outstanding of loans, $\alpha_l \in (0, 1)$ denotes the returns to scale (Table 9). Loan production incurs variable costs of loans, δ_l. I set a scaling factor of loan returns $A = 1/(\bar{p}\beta) - 1$. The parameter $\eta_0 \in [0, 1]$ governs another scaling factor of returns on risk-taking, and $\eta_1 \in [0, \infty)$ is the elasticity of returns on risk-taking. I parameterize $\eta_0 = 1 - \bar{p}$ with the long-run average rate of success of $\bar{p}$. These parameterizations lead to $p(S = 1) = \bar{p}$, indicating that a risk-taking level of one ($S = 1$) matches the average success rate. To see the dependency of risk-taking S on the success probability in normal state p, I can express risk-taking as $S(p) = \{(1 - p)/(1 - \bar{p})\}^{1/\eta_1}$, which satisfies the following relationships: $S' < 0$, indicating that returns decrease with a higher success rate, and $S'' \leq 0$, reflecting decreasing marginal returns on loan returns, for all $p \in [0, 1]$. Decreasing marginal returns ensure an interior solution for optimally choosing the level of risk-taking. When a bank fails, its share price drops to zero in the model, causing shareholders to incur real costs from the failure.

The model captures systemic risk-taking by setting the probability of success lower during banking crisis periods ($c = 1$) than during non-crisis periods ($c = 0$). Define $\Lambda(p(S))$ is a weighted average of the probability of success: $\Lambda(p(S)) = \Pi p + (1 - \Pi)\{1 - \lambda_p(1 - p)\}$. The parameters of Π and $1 - \Pi$ are the probabilities of normal and banking crisis states, respectively. In a crisis state, failure rate $1 - p$ increases by a fixed proportion λ_p (Table 9). Therefore, $\lambda_p(1 - p)$ gives the failure rate in banking crisis states. The model introduces two states, $c \in \{0, 1\}$, to replicate the clustering of bankruptcies during periods of systemic banking crises (Appendix A.5). The clustering of bankruptcies is a result of concentration in loan portfolio. Friend et al. (2013) find that SMBs with high exposure to commercial real estate loans experienced high failure rates following the crisis. These banks had been increasing their commercial real estate loans for several decades during non-crisis periods, until the financial crisis (DiSalvo et al. (2016)). Therefore, risk-taking S can also be interpreted as the loan portfolio weights on specific sectors, such as commercial real estate.

Table 9: States of Non-Crisis and Systemic Banking Crises and Loan Production Technology

State	Prob.	Loan Revenue	Failure Rate
Non-crisis ($c = 0$)	Π	ASl^{α_l}	$1 - p(S)$
Banking Crisis ($c = 1$)	$1 - \Pi$		$\lambda_p(1 - p(S))$

In the model, bank CEO turnover is the primary source of short-termism. Turnover can be either exogenous or endogenous. Turnover is not uncommon; the average CEO tenure is around 10 years (Appendix A.4). Exogenous CEO resignations are modeled with a common probability α_v in each period. Bank failure also results in CEO turnover; however, the rate of CEO turnover due to bank failure is an order of magnitude smaller than turnover for other reasons. Once CEOs leave their position, they no longer receive salaries or cash bonuses and proceed to sell shares and exercise options. Bank managers hold stocks and wait to exercise options until the end of their contract or upon termination. In practice, banks require CEOs and other executive officers to maintain a minimum level of stock ownership to align incentives, typically set as a fixed multiple of their salary. Endogenous turnover occurs when banks fail. When an old CEO resigns, a new CEO takes over with the same compensation structure and financials. If a bank fails, a new CEO assumes control as if the bank had survived the period in which it failed. This treatment simplifies the aggregation calculation.

The risk-neutral bank manager lives through infinite periods and decides on (i) risk-taking S (or equivalently, success probability p) and (ii) next period equity e' given the state vector z and current period equity e. The state vector $z \equiv (\theta_B, \ln \delta_d)$ has elements of cash bonus sensitivity θ_B and the logarithm of deposit capacity $\ln \delta_d$. In practice, bonus plans typically rely on accounting performance measures such as earnings per share, operating income, or sales in non-financial firms (Edmans et al. (2017)). Additionally, cash bonus sensitivity is determined by the compensation committee, and the bank CEO has limited control over setting the compensation structure in the short run. In the model, banks set cash bonuses as performance-based pay, linked to revenue as a measure. Cash bonus sensitivity (θ_B) varies across banks and persistent within-banks. The estimated AR(1) parameter of cash bonus sensitivity is 0.7 reported in Panel A of Appendix Table A5. The second element of the state vector z is the logarithm of deposit capacity $\ln \delta_d$. Each bank has its own upper bound on the amount of deposits it can undertake, and these capacities vary over time. To incorporate the persistence observed in the data, I model cash bonus sensitivity θ_B and the logarithm of deposit capacity $\ln \delta_d$ using a one-period lagged Vector Auto Regression (VAR) process (details are in Appendix A.7). Given the small size of the correlation between cash bonus sensitivity and the logarithm of deposits, correlation between these shocks is set to zero in the VAR model.

Banks finance their loans l through deposits d and equity e, with deposits being a relatively inexpensive source of funding compared to equity. Deposit rates are denoted as r_d, which is equal to $\beta_d r_f$, where β_d is the deposit rate pass-through, and $r_f = \beta^{-1} - 1$ is the risk-free rate. Since the majority of retail deposits are insured by the FDIC, cross-sectional difference in individual banks' default risks are not priced into deposit rates r_d. Matching the deposit spread $r_f - r_d$ is particularly important since Egan et al. (2022) estimates that deposit productivity accounts for two-thirds of the median bank's value. The bank does not have access to external equity financing due to information frictions between the managers and shareholders. The equity financing constraint reflects the reality that seasoned equity offerings (SEOs) are rare and typically small in scale (Wang et al. (2022)).

In the model, compensation pay is endogenous, while the compensation contract is exogenous. Compensation pay refers to the monetary amount received by CEOs, whereas the compensation contract defines the structure of this payment, including elements such as pay-for-performance sensitivity and the number of option contracts. Since both bank performance and share price are endogenously determined, compensation pay is also endogenously determined. The bank CEO receives four different types of compensation: salary, cash bonuses, shareholdings, and stock options. I model salary as $\theta_F l^{\alpha_F}$ where θ_F and α_F are fixed parameters across banks and time, capturing scaling factors. Since bank size l is endogenous, salary pay is also endogenous. Shareholdings θ_S and stock option ratios θ_O are also fixed across banks and time. Unlike in contract theory, I do not treat the compensation contract as endogenous, as the paper's focus is to provide quantitative insights into how bank CEOs respond to changes under the suboptimal compensation contracts observed in real data.

Optimization Problem. The bank manager maximizes their lifetime utility $w(z,e)$ given the equilibrium share price $v(z,e)$:

$$\begin{aligned} w(z,e) &= \max_{\Phi=(S,e')} \theta_F l^{\alpha_F} \\ &+ \max\{\theta_B, 0\} \max\{ASl^{\alpha_l} - r_d d, 0\} \\ &+ \theta_S D(e,S,e') \\ &+ (1-\alpha_w)\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[w(z',e')\right] \\ &+ \alpha_w \beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[\theta_S v(z',e') + \theta_O \max\{v(z',e') - \text{ATM}, 0\}\right], \end{aligned} \tag{5}$$

subject to constraints:

$$l = d + e \tag{6}$$

$$D(e,S,e') = (1-\tau_{\text{eff}})\left[(1-\tau_{\text{c}})\{ASl^{\alpha_l} - r_d d - \delta_l l\} + \tau_{\text{c}}\delta_l l - (e'-e)\right], \tag{7}$$

$$D \geq 0, \quad \text{(External equity issuance constraint)} \tag{8}$$

$$\text{ATM} = v(z,e|\Phi) - D, \quad \text{(At the money)} \tag{9}$$

$$d = \min\left\{\delta_d, \bar{d}\right\}, \quad \text{(Deposit capacity)}$$

$$\frac{e}{\bar{d}+e} = \bar{\chi} \quad \text{(Capital requirement).} \tag{10}$$

Eq. (5) provides the manager's per-period utility, continuation values, and terminal values. Φ is a set of policy functions with respect to control variables: risk-taking S and next period equity e'. The first term on the right hand-side of Eq. (5) represents the fixed salary. In the second term is the bonus, a revenue-based payment calculated as cash bonus sensitivity θ_B multiplied by revenue $ASl^{\alpha_l} - r_d d$. The model allows cash bonus sensitivity θ_B to take negative values, but the realized bonus payment must remain positive; otherwise, it will be zero (e.g., $\max\{\theta_B, 0\}$). In the third term, the bank manager receives a fraction θ_S of the dividends D. The fourth term represents the continuation value if the bank succeeds in loan production with probability $\Lambda(p(S))$ and avoids forced turnover with probability $1-\alpha_w$. The fifth term represents the terminal payoffs from shareholdings and stock options for a resigned CEO. In practice, the strike price is set at-the-money, following the modeling assumption in Glover and Levine (2017). The stock option is not dividend-protected; therefore, the strike price (ATM) is the ex-dividend price.

Eqs. (6-10) show the key constraints that managers face. Eq. 6 represents the balance sheet constraint. The before-tax equity payout $\tilde{D}$ is equal to profit minus the change in internal equity, $e' - e$. The before-tax profit is equal to loan revenue minus the costs of deposits, $r_d d$, and loan depreciation, $\delta_l l$. τ_c denotes the corporate tax rate, and depreciation on loans is tax-deductible. D denotes the equity payout (Eq. (6)). τ_{eff} is labeled as the effective dividend costs, which includes regulatory compliance costs, signaling costs, and other costs associated with dividends that are not captured by the model. The after-tax equity payout, D, is constrained to be positive, and the bank manager cannot not issue external equity to meet financing needs (Eq. (8)). The fourth term defines the ex-dividend price of the stock (Eq. (9)), which is the cum-dividend price v minus the equity payout D. ATM denotes the strike price of the stock option compensation.

Deposit capacity δ_d captures bank's exposure to the quantity risks of in- and out-flowing deposits. The majority of deposits are demand deposits, which depositors can withdraw at any time. Eq. (10) imposes a capital requirement on banks, which contributes to the manager's risk aversion. Banks can accept deposits up to their deposit capacity unless the deposit size exceeds the capital requirement given the size of equity. $\bar{d}$ represents the maximum amount of deposits under the capital requirement ratio $\bar{\chi}$.

Equilibrium. To close the model, I define the equilibrium. The stationary competitive industrial equilibrium is a collection of (i) managers maximizes their utility as in Equation (5) given the equilibrium share price v, (ii) given manager's policy functions $\Phi = (S(z,e), e'(z,e))$, the representative household optimizes her portfolio. The representative household has no direct power to prevent the bank manager from deviating from the shareholders' interests, except through the market for shareholding. The Appendix A.8.1 shows the household's optimization problem. With market clearing condition of fixed supply of total share, share price v follows

$$v(z,e|\Phi) \quad = \quad D(e,S,e') + \Lambda(p(S))\beta\mathbb{E}_{z'|z}\left[v(z',e'|\Phi)\right]. \tag{11}$$

Formal derivation of this Euler equation (11) is in Appendix A.8.1. In Equation (11), the representative household prices shares as the sum of expected discounted cash flows. Since there are no fixed operational costs and external equity issuance is prohibited, leading to positive equity payout $D \geq 0$, the bank's value $v(z,e|\Phi) \geq 0$ is positive in all states. Positive equity payouts allow me to abstract from endogenous exit and ensure that shareholders are protected by limited liability.

I solve Eqs. (5-11) numerically by discretizing the value function into a finite number of grid points. The numerical algorithm follows the procedure documented in Appendix A.8.3.

4.2 Structural Estimation and Identification

Calibrated parameters are reported in Panel A and B, estimated parameters are summarized in Panel C, and validation of deposit capacity is reported in Panel D, all of those in Table 10.

Benchmark Parameters. Discount factor β of 0.96 targets annual real interest rates of $r_f = 4\%$. The bank executive turnover rate α_v is set as 10% in the model, closely aligning with 9% annual turnover rate observed in data from 2000 to 2018. The turnover rate in the data is presented in Appendix A.4. I use cross-country and US data to set parameters on systemic banking crises (Appendix A.5). The probability of a banking crisis $1 - \Pi$ is 5.5%, based on cross-country evidence from periods between 1800 and 2016 in the Global Crises Data. The number of failure in banking crisis increases by $\lambda_p \sim 11$ according to US historical events, using data compiled by the FDIC. The deposit rate pass-through is set to 0.3, a close estimate based on Drechsler et al. (2017). Assuming real interest rates are equal to the Federal Funds Rate, the deposit rate is $r_d = 1.2\% (= 0.3 \times 4\%)$ in the long-run. The persistence of deposit capacity κ_{δ_d} is estimated from a dynamic panel regression using the Arellano-Bond estimator. Unobserved deposit capacity δ_d is well-approximated with observed realized deposits d. Later, I validate this approximation holds true in the model by checking $\delta_d \simeq d$. Normalization of real values in the model is achieved by setting the average deposit capacity $\bar{\delta}_d$ to 1. The capital requirement ratio $\bar{\chi}$ is set to 6% in the model, which is the midpoint of the minimum capital ratios of Tier 1 to Risk-Weighted Assets (RWA) of 4% and 8% of total capital to RWA in Basel I and II since 1988. In Basel III, the Tier 1 capital ratio was raised to 6% by 2015. The decreasing returns to scale parameter α_l is estimated outside the model using panel regression of revenue on total assets in the data. The estimate gives a 1% increase in total assets increases revenue by 0.89%. Corporate tax rate τ_c is set to 35%.

Panel B in Table 10 explains parameters regarding with compensation structure selected outside the model. The elasticity of salary is estimated from dynamic panel regression using the Arellano-Bond estimator. Salary and bank size exhibits a strong log-linear correlation. A fixed-effect model estimated elasticity of salary is 0.3 which predicts 1% increase in bank size increases salary by 0.3% (Appendix A.6). In non-financial firm, cross-sectional difference in salary is explained by firm size but has weaker power to explain temporal changes within firm, which is often referred as "Roberts's law". I find a log-linear relationship holds not only cross-sectional but also temporal variations in data of bank size and CEO's salary. Temporal relationship is essential for modeling dynamic financing problems of the bank. In turn, on average, the number of CEO's shareholding (unexercisable stock option) to total shares is $\theta_S \sim 2\%$ ($\theta_O \sim 0.3\%$) in the data. The estimated persistency of cash bonus sensitivity θ_B is 0.7 from dynamic panel regression (Appendix A.6). At last, cash bonus sensitivity $\bar{\theta}_B$ is set to zero in the model.

Panel C in Table 10 reports the SMM estimated parameters inside model. Computational details are provided in Appendix A.8.3. To identify six parameters—θ_F, η_1, σ_{θ_B}, σ_{δ_d}, δ_l, and τ_{eff}—I use six moments. Six moments are the average bonus-to-salary ratio; failure rate; variance of bonus-to-revenue ratio; variance of deposit growth; the average leverage; the average market-to-book ratio. A couple of parameters are interpretable. The estimated variable costs of loans δ_l are consistent with an estimate of mean franchise costs of 2% for the banking business in DeMarzo et al. (2024). The effective dividend costs τ_{eff} are 68% in the model. Excluding expenses incurred by banks beyond corporate taxes and loan depreciation, the model produces a price-to-book ratio unusually higher than that observed in the data.

Identification. Figure 4 examines the sensitivity of moments to changes in model parameters. Each row represents a parameter, and each column represents a moment. Steep and monotonic relationships between the six parameters and six moments provide strong identification (Figure 4). The invertibility of the moment matrix ensures that each parameter contributes distinct information, further supporting identification, as evident from the standard errors of the estimated parameters (shown in parentheses in Panel C of Table 10). The invertibility is explained as follows. Horizontally, three moments—the variance of the bonus-to-salary ratio, the variance of deposit growth, and the price-to-book ratio—correspond to three parameters: σ_B, σ_{δ_d}, and τ_{eff}, respectively, with each parameter being the large and sole factor in the model that explains its corresponding moment in the data through a one-to-one relationship. The identification of the remaining three parameters, θ_F, η_1, and δ_l is explained sequentially. Since σ_B is matched to the variance in deposit growth, the bonus-to-salary ratio informs the size of θ_F. In turn, τ_{eff} is already determined by the price-to-book ratio but also influences leverage. The two cost parameters, δ_l and τ_{eff}, are identified separately, due to the different timing of cost realization. Floating loan costs δ_l are incurred before the bank distributes cash flows, affecting both the market and book value of equity, resulting in a neutral response on the price-to-book ratio. Conversely, the effective dividend costs τ_{eff} are paid after the distribution of cash flows as retained earnings. Higher effective dividend costs reduce τ_{eff} dividends while keeping the book value of equity the same, leading to a negative relationship between effective dividend costs and the price-to-book ratio. Returning to the discussion on identification of remaining parameters, floating loan costs δ_l are adjusted to ensure that the size of simulated leverage remains consistent with real data. Lastly, the elasticity of risky investment η_1 is identified by the failure rate. Changes in the elasticity of risky investment η_1 affects only the failure rate, while keeping other moments unchanged.

Panel D in Table 10 checks that the fraction of deposits is equal to capacity (i.e., the fraction of banks facing $d = \delta_d$) is 99%, and only 1% of banks have a binding capital ratio constraint. The average deposits in the simulated (real) data is 1.047 (14.020 in log-million-dollars and 1227.4 in billion-dollars).[8] Given that deposits are nearly equal to deposit capacity, one unit in the model corresponds to 1227.4 billion dollars in 2006, adjusted by inflation.

[8]The average deposits may exceed 1, while the mean of the logarithm of deposit capacity, $\ln(\delta_d)$, is zero. Since deposit capacity δ_d follows a log-normal distribution, the mean of δ_d is given by $\exp\left((1-\kappa_{\delta_d})\ln\bar{\delta}_d + \frac{1}{2}\sigma^2_{\delta_d}/(1-\kappa_{\delta_d})^2\right)$. Given that $\bar{\delta}_d = 1$ and estimated variance $\sigma^2_{\delta_d} > 0$, the mean of δ_d is strictly greater than 1.

Table 10: Calibrated and Estimated Model Parameters, Model Simulated Data Moments, and Real Data Moments.

Those tables report calibrated and estimated model parameters, with standard errors, and comparison between model simulated- and real-data. In Panel C, the standard errors of the estimated parameters are reported in parentheses. The p-value is reported inside the brackets.

	Value	Description	Source
Panel A: Technology and Financial Frictions Selected Outside Model			
β	0.9600	Manager's and Shareholder's Discount Factor	Standard Parameter
α_w	0.1000	Exogenous Turnover Rate	9% Per Annum
Π	0.9448	One minus Probability of Banking Crisis	Long-Run Cross-Country Average
λ_p	10.9835	Crisis Failure Rate/Non-crisis Failure Rate	Ratios of US Historical Average
$\bar{p}$	0.9985	Normalization of Returns on Loan Production	Long-Run Success Rate
β_d	0.3000	Deposit Rate Pass-through	DSS (2017)
κ_{δ_d}	0.9069	Persistency of Deposit Capacity	Panel Regression
$\bar{\delta}_d$	1.0000	Average of Deposit Capacity	Normalization
$\bar{\chi}$	0.0600	Capital Requirement Ratio	Regulation
α_l	0.8575	Decreasing Returns to Scale	Panel Regression
τ_c	0.3500	Corporate Tax Rate	Standard Parameter
Panel B: Compensation Structure and Dynamics Selected Outside Model			
α_F	0.3453	Elasticity of Salary	Panel Regression
θ_S	0.0218	Manager's Total Stock Holding to Total Shares	S&P Capital IQ
θ_O	0.0032	Manager's Unexercised Stock Option to Shares	S&P Capital IQ
κ_{θ_B}	0.6934	Persistency of Bonus Sensitivity	Panel Regression
$\bar{\theta}_B$	0.0000	Long-Run Bonus Sensitivity	Frequency of Bonus Payment

Panel C: Estimated Parameters

	Description	Estimate
θ_F	Scaling Factor of Salary	0.00032 (0.00005)
η_1	Elasticity of Risky Investment	14.6010 (1.5501)
σ_{θ_B}	Volatility of Bonus Sensitivity	0.0032 (0.0009)
σ_{δ_d}	Volatility of Deposit Capacity	0.1264 (0.0071)
δ_l	Variable Costs of Loans	0.0144 (0.0010)
τ_{eff}	Effective Dividend Costs	0.6882 (0.0229)

Panel D: Model Simulated Deposit Capacity δ_d and Deposit d

Description	Model
Fraction of Deposits is Equal to the Capacity	0.989
Average Deposits	1.047

Figure 4: Comparative Statics of Moments For A Change in Model Parameters.

The number of simulated sample is $S = 50$. The time period is $T = 1000$ with the burn-in period of $T = 40$. The solid lines represent the relationship between the model parameters and simulated moments, while the vertical dotted lines correspond to the estimated parameters. The vertical axis lists the targeted moments, which include the Bonus-to-Salary Ratio, Failure rate, variance of Bonus to Revenue, variance of Deposit Growth, Leverage, and P/B ratio. The P/B ratio is the ratio of market capitalization to the book value of equity. The horizontal axis lists the estimated parameters being analyzed, which are denoted as θ_F, η_1, σ_{θ_B}, σ_{δ_d}, δ_l, and τ_{eff}. Each cell in the grid represents the relationship between a specific targeted moment and an estimated parameter. I vary the estimated parameters from -5% to +5%.

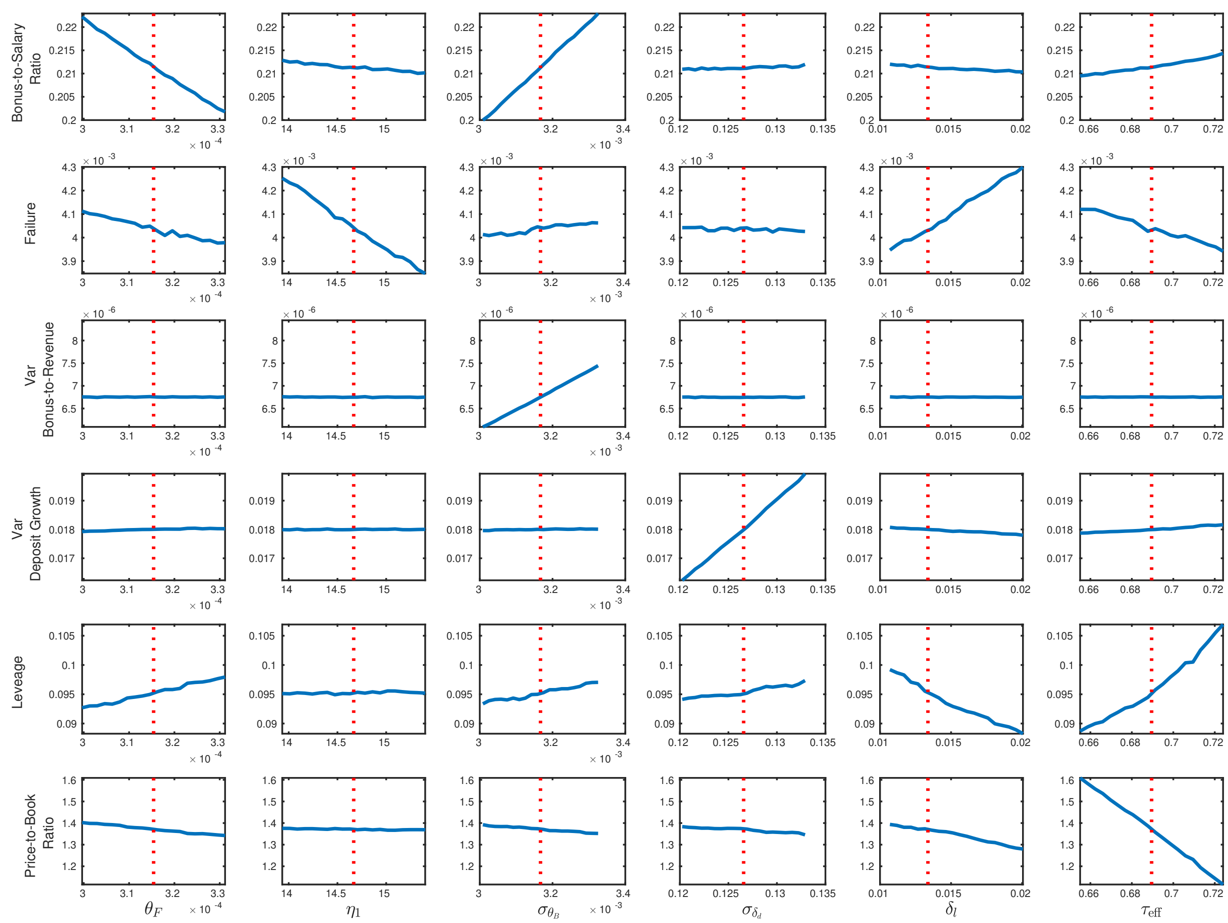


Table 11: Targeted Moments in Model Estimation.

This table reports the simulated versus the real-data moments, along with t-statistics for the pairwise differences. The real-data sample includes bank financials and compensation from 2000 to 2019.

Description	Model	Data	t-test of difference
Average of Bonus-to-Salary Ratio	0.212	0.211	-0.002
Failure Rate (bps)	41	40	-0.001
Variance of Bonus-to-Revenue Ratio $\times 1,000$	0.007	0.007	-0.000
Variance of Deposit Growth	0.018	0.018	-0.000
Average of Leverage	0.096	0.097	0.018
Average of P/B Ratio	1.367	1.378	0.016

Model Fit. Table 12 evaluates the model performance by comparing simulated moments with the real-data. The logarithms of loans and deposits are highly persistent in both the model generated- and the real-data. The standard deviation of loan growth is approximately 12% in the model and 16% in the data. Due to the high volatility of the exogenous deposit capacity growth rate, loan growth also becomes highly volatile. The model understates the volatility of equity growth observed in the data, with a volatility of 16% compared to 24% in the data. The capital requirement in the model is 6%, and the model-generated standard deviation of capital ratio is 3.4%, compared to 2.8% in the data. The motives for saving in equity arise from two channels. The first channel is the precautionary motive, driven by capital constraints, the costly nature of external equity financing, and decreasing returns to scale in salary. For instance, if a bank experiences a positive deposit capacity shock and its capital requirement is binding due to insufficient internal equity, it may miss profitable lending opportunities because external equity issuance is prohibited. Additionally, holding more equity reduces salary variability due to decreasing returns to scale. Therefore, banks are inclined to hold extra equity in advance as a capital buffer to mitigate the adverse impact on the manager's value. The second channel is the presence of effective dividend costs. The marginal benefit of saving in equity becomes higher compared to paying dividends when effective dividend costs are greater. The distributional characteristics of the compensation structure, reported in Panel B, are consistent between the simulated and real data. Half the number of the banks paid cash bonuses to their CEOs, and the model also replicates the pattern where only 3% and 5% of banks paid cash bonuses greater than the CEO's salary in the simulated and real data, respectively. Histogram of bonus-to-salary ratio is reported in Figure 5.

The manager's optimal policies are illustrated in Figure 6. Cash bonus sensitivity θ_B increases the size of equity both in the current-period equity e and in the next-period equity e' (Panel (a)), while decreasing the probability of success in normal periods p (Panel (b)). Cash bonuses encourage managers to expand the bank's size rather than distribute dividends to shareholders. In turn, the economic intuition of the probability of success, discussed in Appendix Section A.8.2, is as follows: since cash bonuses are short-term payments, higher cash bonus sensitivity lowers the marginal return on survival. This relative decline in marginal benefits incentivizes increased risk-taking, as bankers aim to maximize bonuses, which consequently reduces the likelihood of successful loan production. The simplified model in Appendix Section A.8.2, solving an analytically tractable model of bank manager's decision-making, abstracts from the decreasing returns-to-scale in salary and revenues relative to total assets, making the model scale-invariant in terms of total assets. This simplification raises important policy concerns: while capping bonuses can reduce risk-taking, it may also negatively impact lending. In the next section 4.3, I quantify the impact of a bonus cap and compare it with other types of compensation regulations proposed by policymakers.

Table 12: Validation of Model Predictions Against Data of Bank Financials and Compensation.

The table compares moments from the model with real data that are not used in the estimation. All variables are expressed in real terms, with the sample period spanning from 2000 to 2019. The autocorrelation of logarithms and cross-correlation of loans and deposits are calculated using demeaned logarithms at the bank level to account for unobserved heterogeneity in the data. Leverage is defined as the equity-to-loan ratio. In the data, equity payouts in the model are matched with cash dividends. The 'Fraction of Banks Paying CEO Bonuses' is calculated as the ratio of banks paying non-zero bonuses to the total number of banks in each period. In the model, the "Fraction of Banks Paying CEO Bonuses Equal to or Greater than Salary" is defined as the ratio of banks where bonuses $\max\{\theta_B, 0\} \max\{ASl^{\alpha_l} - r_d d, 0\}$ are equal to or greater than the salary $\theta_F l^{\alpha_F}$.

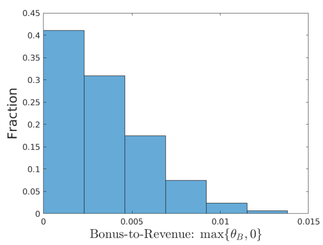
Moments	Model	Data
Panel A: Balance Sheets and Profits and Losses		
Auto Corr. of ln Loans	0.9110	0.9376
Auto Corr. of ln Deposits	0.9069	0.9375
Std. Dev. of Loan Growth	0.1226	0.1619
Corr(ln Loans, ln Deposits)	0.9929	0.9827
Std. Dev. of Equity Growth	0.1579	0.2377
Std. Dev. of Leverage	0.0346	0.0276
Mean of Equity Payout per Equity	0.0053	0.0028
Std. Dev. of Equity Payout per Equity	0.0062	0.0024
Panel B: Compensation		
Fraction of Banks Paying CEO Bonuses	0.5000	0.5082
Fraction of Banks Paying CEO Bonuses Equal to or Greater than Salary	0.0349	0.0461

Figure 5: Model Validation of Cash Bonus Sensitivity and Bonus-to-Salary Ratio.

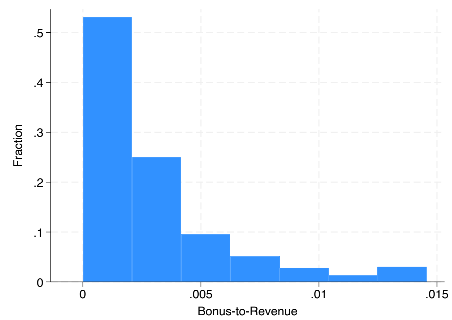
These histograms compare cash bonus sensitivity and the bonus-to-salary ratios in the model and real-world data. In the model, (observed cash bonus sensitivity) the bonus-to-salary ratio is calculated as $\max\{\theta_B, 0\}$ $(\max\{\theta_B, 0\} \max\{ASl^{\alpha_l} - r_d d, 0\} / (\theta_F l^{\alpha_F}))$. In both the model and data, I drop cash bonus sensitivity is equal or less than zero. The simulated data is pooled, with the number of simulated samples set at $S = 50$, and the time period at $T = 1000$, including a burn-in period of $T = 40$. The histogram of the real-world data is based on pooled data from 2000 to 2019.

Cash Bonus Sensitivity

(a) Model

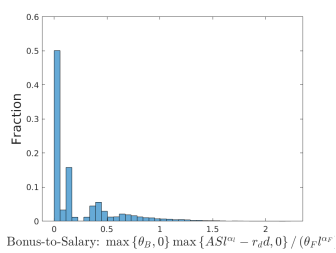


(b) Data



Bonus-to-Salary

(c) Model



(d) Data

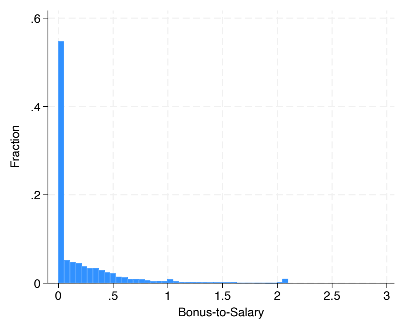
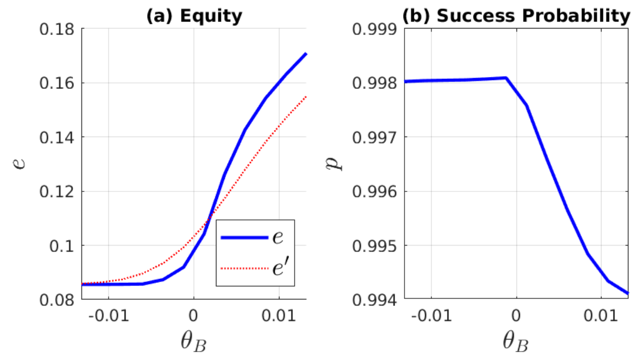


Figure 6: Optimal Equity and Risk-Taking.

These figures plot optimal current-period equity e (dotted line) and next-period equity e' (solid line) on the left-hand side as functions of cash bonus sensitivity θ_B. On the right-hand side , the probability of success in normal periods p is plotted as a function of cash bonus sensitivity θ_B. The plotted policy functions represent averages over the ergodic distribution of the model, conditioned upon cash bonus sensitivity θ_B.



4.3 Results

4.3.1 Specifications of Counterfactual Experiments

In this section, I analyze the effects of policy counterfactuals, focusing on two sets of simulations. The first set aims to understand the impact of short-termism on failure rates and loans. I set the turnover rates α_v, from 10% in the benchmark scenario to 5% in the counterfactual. Additionally, I explore the effects of increasing managers' shareholdings, a commonly discussed remedy among policymakers to address agency conflicts. The second set of counterfactual simulations compares proposals for regulating compensation schemes. The main counterfactual policy scenarios include (i) the Dodd-Frank proposal, (ii) the EU bonus cap, (iii) contingent debt, and (iv) an option ban.[9]

In the following section, I outline the manager's problem in each counterfactual scenario. The shareholder's problem remains unchanged, and compensation contracts are suboptimal in both the benchmark and counterfactual scenarios.

Dodd-Frank Proposal. The Dodd-Frank proposal combines deferred bonuses and deferred dividends. The manager's problem under Dodd-Frank proposal:

[9] In the model, the clawback policy functions similarly to deferred compensation. As a result, I use the terms "deferred compensation" and "clawback policy" interchangeably. Several key assumptions are made. First, the model assumes a deferral period of one year. Second, the timing of clawback payments is set one period ahead, with the manager assumed to save cash at a net return rate of r_f. Cash from deferred bonuses and dividends grows at a rate of $1+r_f$ after one period and is discounted by β, leading to no change in present value terms. Thus, the net contribution of the risk-free return and the discount factor is zero. Therefore, the model's prediction serves as a lower bound on the impact of regulatory changes in real-world proposals, which typically span 3-7 years (Appendix A.8.5). To model multi-period deferrals, the deferred compensation or clawback provisions are introduced as a new state variable, which complicates solving the model.

$$
\begin{aligned}
w(z,e) &= \max_{\Phi=(S,e')} \theta_F l^{\alpha_F} \\
&+ \{(1-\tau)+\tau\Lambda(p(S))\} \max\{\theta_B, 0\} \max\{ASl^{\alpha_l} - r_d d, 0\} \\
&+ \{(1-\tau)+\tau\Lambda(p(S))\} \theta_S D(e,S,e') \\
&+ (1-\alpha_w)\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[w(z',e')\right] \\
&+ \alpha_w\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[\theta_S v(z',e') + \theta_O \max\{v(z',e') - \text{ATM}, 0\}\right]. \qquad (12)
\end{aligned}
$$

This reform introduces deferred bonuses and deferred dividends. Deferred bonuses (dividends) repay a fraction of an expected failure rate $1-\Lambda(p(S))$ of the bonuses (dividends) to shareholders in the 2nd (3rd) term of Equation (12). τ represents the weight of deferred compensation for bonuses and dividends. I set $\tau = 50\%$. Compared to the benchmark model in Equation (5), the bank CEO faces reduced incentives to pursue riskier strategies aimed at maximizing short-term returns through bonuses and dividends. Depending on the model parameters, the bank manager may adjust loan issuance either upwards or downwards.

EU Bonus Cap. The EU bonus cap combines a bonus cap and deferred bonuses. After the implementation of EU bonus cap-like compensation regulation in the US banking industry, the manager's problem becomes:

$$
\begin{aligned}
w(z,e) &= \max_{\Phi=(S,e')} \theta_F l^{\alpha_F} \\
&+ \left[\{(1-\tau)+\tau\Lambda(p(S))\} \min\left\{\max\{\theta_B, 0\}\left(ASl^{\alpha_l} - r_d d\right), \underbrace{\theta_F l^{\alpha_F}}_{\text{bonus cap}}\right\}\right] \\
&+ \theta_S D(e,S,e') \\
&+ (1-\alpha_w)\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[w(z',e')\right] \\
&+ \alpha_w\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[\theta_S v(z',e') + \theta_O \max\{v(z',e') - \text{ATM}, 0\}\right]. \qquad (13)
\end{aligned}
$$

Here, $\theta_F l^{\alpha_F}$ represents the fixed salary, which is set as the bonus cap in the 2nd term of Equation (13). Although the term "EU Bonus Cap" suggests only capping bonuses, the implemented regulation combines the bonus cap with deferred bonuses. Under the EU bonus cap, bonuses cannot exceed the fixed salary. Additionally, the EU introduces a parameter τ that governs the proportion of bonuses that are deferred. I impose a deferred bonus weight τ of 50%, which is in the middle of the 40-60% range that the EU and UK use to restrict the fraction of variable pay that must be deferred.

Contingent Debt. As far as the author knows, there is no specific guidance in the proposals on the proportion of salary that should be converted into a debt contract. It is more likely to be accepted by bankers if total compensation remains unchanged across many states of the world. Following this approach, contingent debt-based compensation sets a fraction τ of the salary to be converted into a debt contract, which becomes contingent on the bank's failure. The total cost of CEO compensation remains unchanged from the benchmark in a state of success. Similar to deferred dividends, a fraction τ of the salary must be repaid to shareholders to cover losses in the event of a bank failure. The manager's problem is defined as:

$$
\begin{aligned}
w(z,e) &= \max_{\Phi=(S,e')} (1-\tau)\theta_F l^{\alpha_F} + \tau\Lambda(p(S))\theta_F l^{\alpha_F} \\
&+ \max\{\theta_B, 0\} \max\{ASl^{\alpha_l} - r_d d, 0\} \\
&+ \theta_S D(e,S,e') \\
&+ (1-\alpha_w)\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[w(z',e')\right] \\
&+ \alpha_w\beta\Lambda(p(S))\mathbb{E}_{z'|z}\left[\theta_S v(z',e') + \theta_O \max\{v(z',e') - \text{ATM}, 0\}\right].
\end{aligned}
$$

4.3.2 Results on Counterfactual Experiments

Table 13 presents the results from the benchmark (Panel A) and counterfactual experiments (Panels B and C), based on the model specifications described in Section 4.3.1, reporting their effects on failure rates during crises and long-run loan outcomes. In all simulation, The simulated sample consists of $S = 50$, with $T = 1000$ time periods, a burn-in period of $T = 40$, and $N = 500$ hypothetical banks.[10] The longer time horizon compared to simulations in estimation allows me to ensure finite sample performance and accurately compute the average failure rate during a crisis.

In Panel B, I examine the effects of incentive misalignment between the manager and shareholders, stemming from compensation structure and turnover. I run a counterfactual model (b) without agency conflicts, setting the turnover rate to zero and increasing shareholdings by 3 standard deviations from the benchmark model. The counterfactual simulation shows a reduction in failure rates by 19 basis points and a 3.0% decrease in loans. Therefore, the estimated dynamic model suggests that incentive misalignment leads to excess risk-taking and over-investment in loans.

Next, I decompose the factors contributing to incentive misalignment, focusing on turnover and compensation structure separately. First, I quantify the impact of short-termism due to managerial turnover (model (c)). Reducing the turnover rate α_v from 10% in the benchmark to 5% in the counterfactual increases loans by 1.4%, while the failure rate during a crisis decreases from 291 basis points to 231 basis points. Second, I challenge the common view that higher equity holdings lead to better outcomes in model (d). In contrast, my model shows that in a counterfactual scenario where equity holdings are one standard deviation higher, loan sizes decrease, and the failure rate rises from 291 basis points to 364 basis points. This exercise helps explain the reduced-form findings in Section 3.3 and FS (2011), which suggest that greater managerial shareholdings are associated with higher failure rates and poorer performance during crises. Although this result may seem counterintuitive—since larger shareholdings are expected to align managers' interests with shareholders and reduce

[10]Michaelides and Ng (2000) suggests that $S = 10$ provides a reasonable size for finite sample performance. However, I adopt a more conservative sample size. A longer sample is necessary to calculate failure rates during crises, as both bank failure and banking crises occur infrequently in both the model and real-world data.

excessive risk-taking—I argue that managerial conflicts are not solely captured by shareholdings (θ_S) in either the model or the reduced-form analysis. Managers, required to hold their equity until the end of their tenure but allowed to sell it immediately upon resignation, tend to exhibit more short-term behavior than shareholders, even when their compensation consists entirely of shareholdings. Thus, larger shareholdings do not necessarily mitigate short-termism, as their impact depends on the relative influence of short-termism driven by both compensation structure and managerial turnover.

In Panel C, I conduct seven counterfactual policy experiments (models (e-k)) as shown in Table 13. These policies reflect common proposals discussed by scholars and policymakers. Two of the most favorable policies are the EU bonus cap and the 100% bonus cap. The EU bonus cap (100% bonus cap) reduces loans by 47 basis points (43 basis points) in the long run, while lowering the failure rate during crises by 12 basis points (15 basis points). Models (g)-(i) explore individual scenarios where only deferred dividends, only deferred bonuses, and only a 100% bonus cap are introduced, respectively. Deferred dividends reduce the failure rate by 7 basis points while increasing loans by 6 basis points. Contingent debt and banning stock options have limited effects on failure rates, reducing them by only 2-4 basis points.

Table 13: Counterfactual Simulations of Counterfactual Compensation Regulations.

Tables in Panels A, B, and C calculate the failure rates during crises and the long-run behavior of loans. The simulated sample consists of $S = 50$, with $T = 1000$ time periods, a burn-in period of $T = 40$, and $N = 500$ hypothetical banks. Failure rates represent the average across banks, using failure probability as each bank's optimal risk-taking choice. Loans are calculated as the aggregate sum of individual banks' loans, with the total measure of all banks normalized to 1. In Panel B, the second row reduces turnover rates from 10% (the benchmark) to 5% (the counterfactual), corresponding to an increase in the shareholding ratio by $+1$ standard deviation observed in real data. The third row conducts an experiment raising shareholdings from 212 bps as the benchmark to 689 bps as the counterfactual. Panel C reports on CEO compensation policy proposals in the United States. The "Bonus Cap 100%" model limits bonuses to 100% of salary. The Dodd-Frank proposal model implements both deferred bonuses and dividends. The EU Bonus Cap model introduces a 100% bonus cap, with those bonuses deferred. The Contingent Debt model swaps 25% of salary for deferred debt compensation. An option ban sets unexercised options to zero (i.e., $\theta_O = 0$). The last row runs an experiment lowering shareholdings θ_S from 212 bps (the benchmark) to 202 bps as the counterfactual.

Policy	Failure in Crisis (bps)	Change (bps)	Loans	Change (%)	Deferred Dividends	Bonus Cap	Deferred Bonuses
Panel A: US Banking Sector							
(a) Benchmark	291	n.a.	1.153	n.a.			
Panel B: Agency Conflict							
(b) No Agency Conflict (Zero Turnover and Shareholdings $+3\sigma$)	271	-19	1.119	-2.95			
(c) Low Turnover (10% $\rightarrow$ 5%)	231	-60	1.169	1.35			
(d) High Shareholdings (Shareholdings $+1\sigma$)	340	49	1.124	-2.51			
Panel C: Compensation Regulations							
(e) Dodd-Frank Proposal	284	-7	1.154	0.02	✓	✓	
(f) EU Bonus Cap	278	-12	1.148	-0.47		✓	✓
(g) Deferred Dividends	283	-7	1.154	0.06	✓		
(h) Deferred Bonuses	285	-6	1.153	-0.03		✓	
(i) Bonus Cap 100%	276	-15	1.148	-0.43			✓
(j) Contingent Debt	289	-2	1.154	0.04			
(k) Banned Option	287	-4	1.152	-0.09			

5 Conclusion

This paper makes a twofold contribution to the literature. First, it provides new evidence linking bank performance to shortcomings in CEO compensation structures. I construct a novel dataset covering both large banks and small- to medium-sized banks (SMBs). The reduced-form analysis reveals an economically significant positive relationship between systemic risk-taking and compensation, specifically cash bonuses and unexercisable stock options. These regression results remain robust across various bank performance measures, including buy-and-hold returns, ROA, ROE, and bank failure. Endogeneity concerns are addressed using the control function method, which allows me to establish a causal relationship between CEO compensation structures—particularly cash bonus sensitivity and unexercisable stock options—and risk-taking. The results remain consistent across different specifications and estimation methods.

Second, I develop a quantitative banking model with dynamic financing choices to assess the effects of shareholdings, bonuses, and stock options on systemic risk-taking. The model incorporates decreasing returns to scale in salary, idiosyncratic and persistent deposit inflows and outflows, external equity financing costs, and capital requirements. I estimate the model using U.S. data and demonstrate its consistency with the empirical findings from the reduced-form analysis. Additionally, I conduct a comparison of proposed but unimplemented U.S. regulations discussed by policymakers. In a counterfactual analysis, I find that the EU bonus cap is among the most favorable compensation regulations when compared to a model without managerial conflicts between the CEO and shareholders. The EU bonus cap effectively reduces failure rates during crises while preventing over-investment in loans.

Future research could explore how other banking regulations and frictions interact with CEO compensation incentives. Extending dynamic banking models to include detailed compensation structures, such as fixed salaries and bonuses, in a general equilibrium framework would help derive welfare implications for CEO compensation regulations and other micro- and macro-prudential measures.

References

Allen, F. and D. Gale (2000). *Comparing financial systems*. MIT press.

Armstrong, C., A. Nicoletti, and F. S. Zhou (2021). Executive stock options and systemic risk. *Journal of Financial Economics*.

Bai, G. and E. Elyasiani (2013). Bank stability and managerial compensation. *Journal of Banking and Finance 37*(3), 799–813.

Bank for International Settlements (2023). Report on the 2023 banking turmoil.

Bebchuk, L. A. and H. Spamann (2009). Regulating bankers' pay. *Georgetown Law Journal 98*, 247.

Bennett, R. L., L. Güntay, and H. Unal (2015). Inside debt, bank default risk, and performance during the crisis. *Journal of Financial Intermediation 24*(4), 487–513.

Berger, A. N., B. Imbierowicz, and C. Rauch (2016). The roles of corporate governance in bank failures during the recent financial crisis. *Journal of Money, Credit and Banking 48*(4), 729–770.

Bolton, P., Y. Li, N. Wang, and J. Yang (2020). Dynamic banking and the value of deposits. Technical report, National Bureau of Economic Research.

Bolton, P., H. Mehran, and J. Shapiro (2015). Executive compensation and risk taking. *Review of Finance 19*(6), 2139–2181.

Cheng, I.-H., H. Hong, and J. A. Scheinkman (2015). Yesterday's heroes: compensation and risk at financial firms. *The Journal of Finance 70*(2), 839–879.

Coles, J. L., N. D. Daniel, and L. Naveen (2006). Managerial incentives and risk-taking. *Journal of Financial Economics 79*(2), 431–468.

Corbae, D. and P. D'Erasmo (2021). Capital buffers in a quantitative model of banking industry dynamics. *Econometrica 89*(6), 2975–3023.

DeMarzo, P., A. Krishnamurthy, and S. Nagel (2024). Interest rate risk in banking.

DeYoung, R., E. Y. Peng, and M. Yan (2013). Executive compensation and business policy choices at us commercial banks. *Journal of Financial and Quantitative Analysis 48*(1), 165–196.

DiSalvo, J., R. Johnston, et al. (2016). Banking trends: The growing role of cre lending. *Economic Insights 1*(3), 15–21.

Drechsler, I., A. Savov, and P. Schnabl (2017). The deposits channel of monetary policy. *The Quarterly Journal of Economics 132*(4), 1819–1876.

Dudley, W. (2014). Enhancing financial stability by improving culture in the financial services industry. Technical report, Federal Reserve Bank of New York.

Edmans, A., X. Gabaix, and D. Jenter (2017). Executive compensation: A survey of theory and evidence. *The handbook of the economics of corporate governance 1*, 383–539.

Edmans, A. and Q. Liu (2011). Inside debt. *Review of finance 15*(1), 75–102.

Efing, M., H. Hau, P. Kampkötter, and J. Steinbrecher (2015). Incentive pay and bank risk-taking: Evidence from austrian, german, and swiss banks. *Journal of International Economics 96*, S123–S140.

Egan, M., S. Lewellen, and A. Sunderam (2022). The cross-section of bank value. *The Review of Financial Studies 35*(5), 2101–2143.

Erickson, T. and T. M. Whited (2000). Measurement error and the relationship between investment and q. *Journal of political economy 108*(5), 1027–1057.

Fahlenbrach, R. and R. M. Stulz (2011). Bank ceo incentives and the credit crisis. *Journal of Financial Economics 99*(1), 11–26.

Financial Stability Forum (2009). Fsf principles for sound compensation practices. *Basel*, 1–16.

Friend, K., H. Glenos, and J. B. Nichols (2013). An analysis of the impact of the commercial real estate concentration guidance. *Federal Reserve Board and Office of the Comptroller of the Currency*.

Gabaix, X. and A. Landier (2008). Why has ceo pay increased so much? *The quarterly journal of economics 123*(1), 49–100.

Glover, B. and O. Levine (2017). Idiosyncratic risk and the manager. *Journal of Financial Economics 126*(2), 320–341.

Gordon, J. N. (2010). Executive compensation and corporate governance in financial firms: The case for convertible equity-based pay.

Guay, W. R., J. D. Kepler, and D. Tsui (2019). The role of executive cash bonuses in providing individual and team incentives. *Journal of Financial Economics 133*(2), 441–471.

Hayes, R. M., M. Lemmon, and M. Qiu (2012). Stock options and managerial incentives for risk taking: Evidence from fas 123r. *Journal of Financial Economics 105*(1), 174–190.

Huggett, M. (1993). The risk-free rate in heterogeneous-agent incomplete-insurance economies. *Journal of economic Dynamics and Control 17*(5-6), 953–969.

Iqbal, J. and S. Vähämaa (2019). Managerial risk-taking incentives and the systemic risk of financial institutions. *Review of Quantitative Finance and Accounting 53*(4), 1229–1258.

John, K., A. Saunders, and L. W. Senbet (2000). A theory of bank regulation and management compensation. *The Review of Financial Studies 13*(1), 95–125.

Kleymenova, A. and I. Tuna (2021). Regulation of compensation and systemic risk: Evidence from the uk. *Journal of Accounting Research 59*(3), 1123–1175.

Kolasinski, A. C. and N. Yang (2018). Managerial myopia and the mortgage meltdown. *Journal of financial economics 128*(3), 466–485.

Michaelides, A. and S. Ng (2000). Estimating the rational expectations model of speculative storage: A monte carlo comparison of three simulation estimators. *Journal of econometrics 96*(2), 231–266.

Nikolov, B. and T. M. Whited (2014). Agency conflicts and cash: Estimates from a dynamic model. *The Journal of Finance 69*(5), 1883–1921.

Tung, F. (2011). Pay for banker performance: structuring executive compensation for risk regulation. *Northwestern University Law Review 105*, 1205.

Wang, Y., T. M. Whited, Y. Wu, and K. Xiao (2022). Bank market power and monetary policy transmission: Evidence from a structural estimation. *The Journal of Finance 77*(4), 2093–2141.

A Internet Appendix

A.1 Policy Debates on Bank CEO Compensation Post-GFC

The Financial Stability Forum (2009) report notes that *"High short-term profits led to generous bonus payments to employees without adequate regard to the longer-term risks they imposed on their firms,"* raising concerns in short-termism in banking sector.

William Dudley, President and CEO of the Federal Reserve Bank of New York, emphasized the importance of focusing on the incentives facing banks and their employees, stating that *"an effective regulatory regime and comprehensive supervision are not sufficient"* (U.S. Chamber of Commerce, Washington DC, March 26, 2018). Dudley suggests that bank CEO compensation *"needs to be a shift in the mix of deferred compensation away from equity and towards debt"* to improve financial stability and rebuild public trust (Dudley (2014)). Similarly, Timothy Geithner, United States Secretary of the Treasury, highlighted the role of compensation structures in the financial crisis, noting in his testimony to Congress on June 6, 2009, that *"although many things caused this crisis, what happened to compensation and the incentives in creative risk-taking did contribute in some institutions to the vulnerability that we saw in this financial crisis."*

A few anecdotes like the AIG bonus payments controversy support the views of incentive misalignment to the failure of financial institutions. The American International Group (AIG) is scheduled to pay $450 million in bonuses to employees after receiving a $170 billion bailout from the U.S. government.

A.2 Compensation Variables from S&P Capital IQ

I identify the bank CEO by choosing the executive officer with the highest salary at the end of the fiscal year of 2006. Unfortunately, S&P Capital IQ does not provide the complete history of the job title. The only information available in the current and former job titles for each executive officer is reported in DEF 14A. I presume that the highest salary officer is the bank CEO. Although this individual may hold a title such as president or chairman instead of CEO, any of these roles should represent the bank's top management, responsible for making major corporate decisions.

One of the key variable "Percentage ownership from shares" is not available from the Excel Plug-in in S&P Capital IQ. I combine hand-collecting and web scraping techniques to build the database. First, I manually download "Insider Holdings" html formatted file from S&P Capital IQ for every bank CEO on the name list. Second, I use a script language Python with Beautiful Soup to extract "Percentage ownership from shares" from the row "% Of CSO" in a HTML formatted file.

The list of names of a failed bank is found in FDIC:

1. I match the institutional name on the list of FDIC to the identifier of S&P Capital IQ CIQ code using the Excel Plug-in function CIQRANGE function with Capital IQ Metric "IQ_COMPANY_ID_QUICK_MATCH".

2. I manually hand-correct when the matching fails using additional information about the location provided by both FDIC and S&P Capital IQ.

3. I use Capital IQ Metric "IQ_IMM_PARENT_CIQID" to find the parent bank. I also check there are no grandparent banks exist in my sample using Capital IQ Metric "IQ_ULT_PARENT_CIQID" to find the ultimate parent bank.

4. I use both child and parent bank name to construct an identifier of banks are taken over by FDIC.

The market capitalization is calculated from the product of outstanding shares and the stock price of the bank. Outstanding shares are as of the end of the fiscal year of 2006. Since the initial filing date of the balance sheet period end is not available in S&P Capital IQ, I use the end of the fiscal year of 2006 stock price to compute the market capitalization.

A.3 Robustness of Cross-sectional Analysis

A.3.1 Alternative Measure for Accounting Returns: Return on Equity

Table A1: Return on Equity during the Financial Crisis and Bonus, Ownership, and Options of 2006 for SMB.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bonus/revenue (%, θ_B)	-5.451*					-12.09***	-11.96***
	(-1.94)					(-2.83)	(-2.83)
Ownership from shares (θ_S)		-0.0611				-0.0757	-0.0660
		(-0.43)				(-0.49)	(-0.42)
Unexercisable options (θ_O)			-4.498***			-5.184***	-5.181**
			(-2.82)			(-2.59)	(-2.55)
Salary and others/total assets (%)				-26.80**		-5.971	-7.383
				(-2.17)		(-0.27)	(-0.34)
Exercisable options					-0.337	-0.0609	-0.0548
					(-0.84)	(-0.11)	(-0.10)
$\mathbb{1}_{\text{Bonus}>0}$						0.0410**	0.0387**
						(2.38)	(2.33)
Bonus/revenue (%, θ_B) $\times \mathbb{1}_{\text{FS}}$							-35.64*
							(-1.72)
Ownership from shares (θ_S) $\times \mathbb{1}_{\text{FS}}$							0.0848
							(0.11)
Unexercisable options (θ_O) $\times \mathbb{1}_{\text{FS}}$							-9.705**
							(-2.36)
$\mathbb{1}_{\text{FS}}$							0.0553
							(1.15)
SMB Sample Only	Yes	Yes	Yes	Yes	Yes	Yes	No
Lagged Returns	No	No	No	No	No	Yes	Yes
Control of Bank Characteristics	No	No	No	No	No	Yes	Yes
Adjusted R-squared	0.009	-0.001	0.016	0.005	-0.001	0.088	0.099
Total Obs.	619	513	621	621	621	502	560

A.3.2 Replication Exercise of Fahlenbrach and Stulz (2011) for Commercial Banks

One issue in comparing the results from my paper to FS (2011) is that my regression model specification and sample are different from FS (2011). To conduct a fair comparison, I closely replicate the FS (2011) regression model specification and sample using a different dataset. The results are reported in Table A2. The key differences in specification between approaches the approaches in this paper (Table 4) and FS (2011) are (i) I exclude salary from the numerator of the bonus variable and (ii) I use revenue as the denominator of the bonus variable.

The specification (1) in Table A2 gives a close replication of the specification (9) in Table 4 of FS (2011).[11] I find consistent results that cash bonus-to-salary ratio is statistically insignificant in both approaches. Moreover, the book to market ratio has a negative sign and statistically significant coefficient in both specifications. In turn, I change the big bank sample to SMB sample in the specification (3). I find a statistically significant negative coefficient to cash bonus/salary, which corresponds to findings in Section 3.3. Bonuses contribute on risk-taking and the main result is not driven by the denominator of bonus relevance, cash bonus/salary measure used in Table A2. My result holds for a similar setting to the previous literature and SMB sample brings new insights into the study.

[11] Due to data limitations, I do not include the explanatory variable "Equity risk (%)"—defined as the percentage change in the equity portfolio value for a 1% increase in stock volatility—in the regression. This variable was not statistically significant in FS (2011). Additionally, while FS (2011) use delta-weighted options for the sum of exercisable and unexercisable stock options, I calculate "Ownership (%)" as the sum of shareholdings, exercisable, and unexercisable stock options, divided by the total number of shares outstanding.

Table A2: Comparison Between Full Sample and Big Bank Sample Using Fahlenbrach and Stulz (2011) Specification.

The left-hand-side table presents regressions of buy-and-hold returns on compensation and control variables for two distinct samples. Data from Capital IQ is used in the left-hand-side table, while the right-hand-side table relies on Execucomp. Columns (1) and (2) of the left-hand-side table represent Small and Medium-sized Businesses (SMBs) and S&P 1500 firms, respectively. The right-hand-side table replicates the regression from Table 4 in FS (2011) on page 19. The sample size for big banks in column (2) of the left-hand-side table is smaller than that of the S&P 1500 sample in the right-hand-side table, as I exclude brokerage firms to control for industry differences within financial institutions, following FS (2011).
Independent variables: "Cash bonus/salary" is defined as the total of cash compensation, including salary, bonuses, and other forms of cash compensation. "ln(Ownership)" is calculated as the natural logarithm of the sum of shareholdings, exercisable options, and unexercisable options, divided by total shares outstanding. In the right-hand-side table, "Equity risk" is defined as the percentage change in the CEO's equity portfolio value for a 1% change in stock volatility, based on all option series held by the CEO which my specifications omit due to data availability.

Standard errors are reported in parentheses. p-values from t-tests indicated by asterisks. $*$, $**$, and $***$ denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively

Panel A: Sample from Capital IQ

	(1) SMBs	(2) S&P 1500
Cash bonus/salary	-0.102**	0.0263
	(0.0427)	(0.0334)
ln(Ownership)	-0.0371***	-0.0600
	(0.0107)	(0.0486)
Stock return	-0.0220	-0.494
	(0.0984)	(0.391)
Book-to-market ratio	-0.0836	-1.109***
	(0.0946)	(0.266)
ln(market capitalization)	0.0708***	-0.0984***
	(0.0166)	(0.0346)
Tier 1 capital ratio (%)	0.00714*	0.00972
	(0.00377)	(0.00938)
Adjusted R-squared	0.099	0.237
Total Obs.	478	54

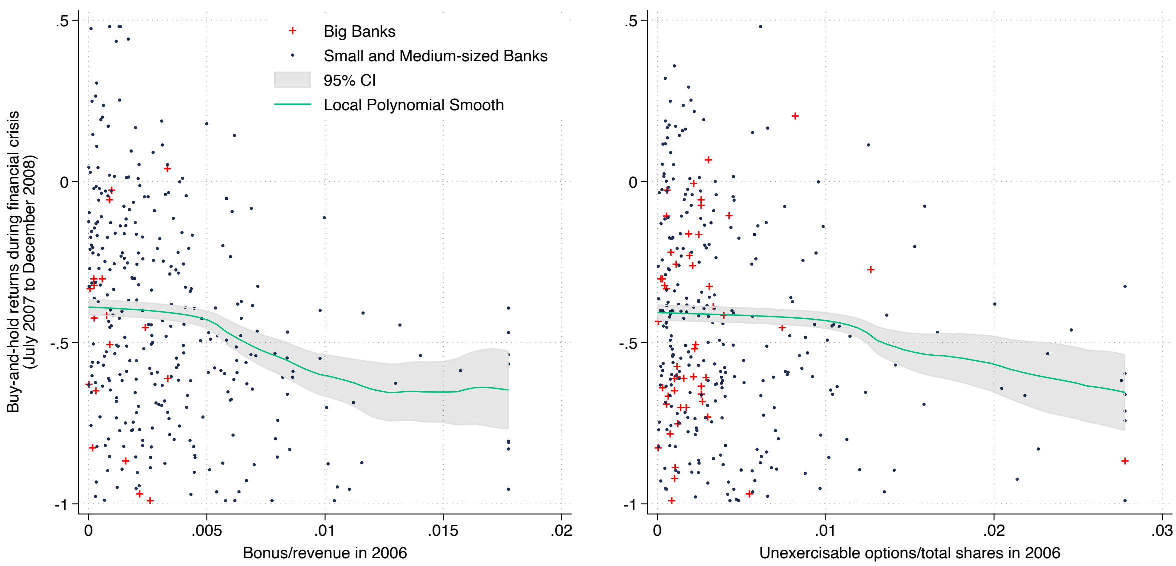
Panel B: Sample from ExecuComp

	FS (2011)
Cash bonus/salary	0.015
	(0.025)
ln(Ownership)	-0.049
	(0.032)
Stock return	-0.310
	(0.304)
Book-to-market ratio	-0.577***
	(0.240)
ln(Market capitalization)	-0.035
	(0.036)
Tier 1 capital ratio (%)	0.039**
	(0.018)
Adjusted R-squared	0.230
Total Obs.	77

A.3.3 A Direct Comparison of Bonus Structures and Stock Options

Figure A1: Buy-and-hold Returns and Bank CEO Compensation.

The figures depict scatter plots illustrating buy-and-hold returns during the financial crisis, categorized by bonus-to-revenue and unexercisable options-to-total shares in 2008. The financial crisis is defined as spanning from July 2007 to December 2008. Variables are winsorized at the 1% and 99% levels. The plus and solid circle-shaped markers represent big banks and SMBs, respectively. The solid line represents the local polynomial smoothing using the Epanechnikov kernel function. The grey area indicates the 95% confidence intervals.

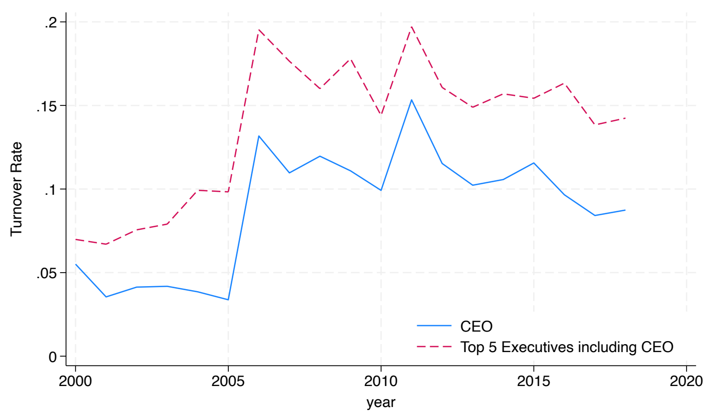


A.4 Turnover Rate

This subsection describes the Bank CEO turnover rate in a sample from Capital IQ. The turnover rate is calculated as the ratio of the number of CEOs who resigned from their positions to the total number of CEOs. CEO resignation is not directly observed in the data, so I use the highest salary among bank executives as a proxy for identifying the CEO. If a person's salary becomes zero or their salary ranking falls below the top two, I assume that the person has resigned from the CEO position. Additionally, I compute the average turnover rate of the top five executives. The average turnover rate of CEOs from 2000 to 2018 is 0.088. This rate increases to 0.110 in the post-2006 sample.

Figure A2: Turnover Rates of Executives of CEOs and Non-CEOs.

The turnover rate is the ratio of the number of CEOs who resigned from their positions to the total number of CEOs. CEO resignation is not directly observed in the data. Instead, I use the highest salary among bank executives as a proxy for identifying the CEO. When a person's salary becomes zero or their salary ranking drops below the top two, I assume that the person has resigned from the CEO position. Turnover rates for the top five executives (the dotted line) are measured differently. If an executive's salary becomes zero or is not available in a given year, I record that the executive left their position in the previous year. This measure includes executives who leave the bank, as well as those whose salaries fall outside the top five earners. For non-top five earners, compensation, including salary, is not required to be disclosed. The sample of turnover rates ends in 2018, as the last year of the original sample does not provide sufficient information to determine whether executives left their positions.



A.5 Banking Crises and Failure Rates

The primary data sources are (i) Global Crises Data by Country collected by Reinhart, Rogoff, Trebesch, and Reinhart and (ii) Failed Bank List compiled by FDIC. Global Crises Data covers more than 70 countries from 1800 to 2016. In the US, the recent banking crisis is from 2007 to 2010. First, I use Global Crises Data to calculate the frequency of banking crises across countries. The probability of banking crises is 5.5% using a full-sample. With excluding a sample post-GFC, the probability of banking crisis is 4.9%, slightly lower than the full sample.

Table A3: Banking Crises of 70 Countries from 1800 to 2016.

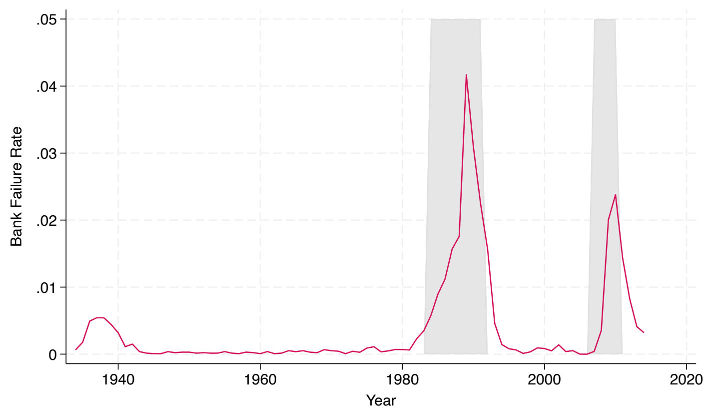
The statistics reported in the table is calculated from Global Crises Data by Country collected by Reinhart, Rogoff, Trebesch, and Reinhart.

	Periods of Banking Crisis/Total Periods
Pre GFC	0.206
Post GFC	0.0494
Full Sample	0.0552

Next, I measure bank failures in periods of banking crises and normal periods in the U.S., respectively. Data source of bank failure and the number of banks is FDIC. The definition of bank failure is the closing of a bank by a federal or state banking regulatory agency. The bank is forced to be closed when it is unable to meet its obligations to depositors and others. The bank failure rate in crisis (normal) periods is 168bps (15bps).

Figure A3: Bank Failure Rates in the U.S.

The shaded areas represent banking crises defined in Global Crises Data by Country collected by Reinhart, Rogoff, Trebesch, and Reinhart. The red solid line is the number of bank failure rate compiled by FDIC. The sample period is from 1934 to 2014.



A.6 Revenue and Salary Sensitivities

This section estimates the size dependencies of revenue and salary. I first check raw data of revenue and salary comparing to bank size measured by total assets. Appendix Figure A4 plots the logarithm of revenue and bank CEO's salary comparing to total assets. Revenue and salary are highly correlated with total assets.

I estimate model parameters of α_l and α_F from fixed-effect panel model. Estimation results are reported in Appendix Table A4. The first (second) regression shows regression coefficients of the logarithm of revenue (salary) on logarithm of total assets. The estimated coefficient of logarithm The slope of logarithm of salary is around 0.3. This slope coefficient implies 1% of increase in total assets predicts 0.3% increase in salary. The bank-level fixed-effects panel model explains 77% of the variation in the data, indicating a strong positive relationship between CEO salary and bank size. I check the robustness of the results by incorporating year fixed-effects to control for bank-specific time trends. The estimated coefficients remain consistent with the baseline results.

Appendix Table A4 proves temporal "Roberts's law" in banking holds for cash salary for banks. Gabaix and Landier (2008) document cross-sectional "Roberts's law"— CEO compensation is proportional to (own firm size)$^\kappa$—for executive compensation for non-financial firms. They find κ is around 0.3. However, temporal prediction does not supported in non-financial firms. Some large banks are subject to a cap of $1 million on executive compensation. The right-hand side of Appendix Figure A4 shows mild bunching around the $1 million threshold. A tax deduction for compensation above $1 million was introduced in 1994 under Section 162(m) of the U.S. Tax Code and remained in effect until its repeal in 2017. As a result, CEOs had an incentive to keep their salaries below the threshold in order to benefit from the tax deduction.

Figure A4: Bank Size Dependency of Revenue and Salary Sensitivities.

Revenue, salary, and total assets are deflated using the Consumer Price Index (CPI). The sample period is from 2000 to 2019. The dotted lines represent fitted lines, while the solid line on the right-hand side of the figure indicates the log-level equivalent of $1 million in 2006 US dollars.

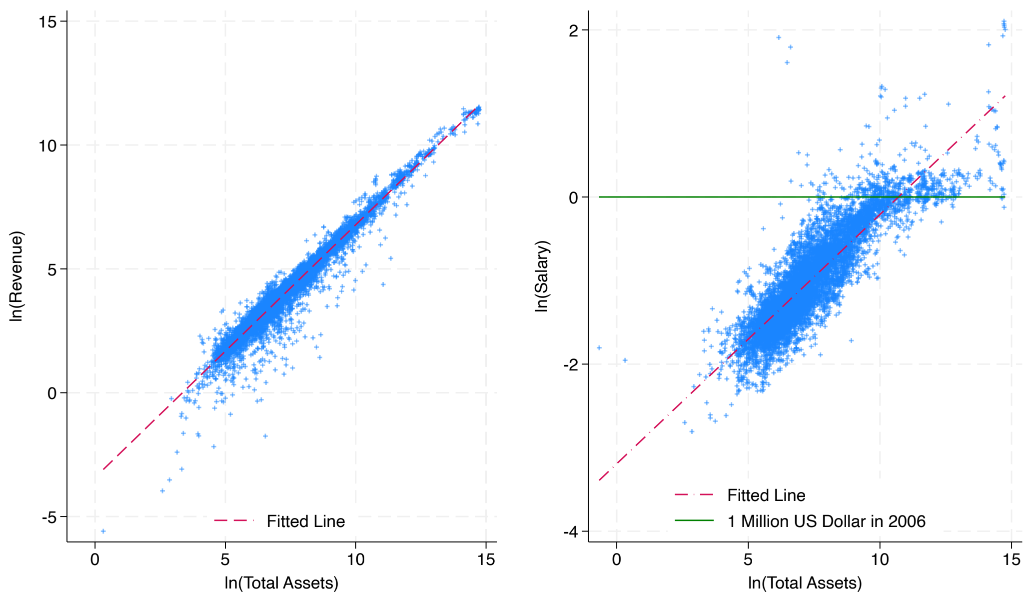


Table A4: Fixed-effect Panel Regression Models of Revenue and Salary.

All model includes bank-level fixed-effects. Models in 2nd and 4th columns add year fixed-effects. Revenue, salary, and total assets are deflated using the CPI. Revenue, salary, and total assets are winsorized at the 1% and 99% levels. The sample period is from 2000 to 2019.

	ln(Revenue)	ln(Revenue)	ln(Salary)	ln(Salary)
ln(Total Assets)	0.858***	0.899***	0.345***	0.286***
	(111.45)	(94.07)	(83.45)	(50.30)
Year Fixed-Effects	No	Yes	No	Yes
Number of Obs.	9205	9205	9310	9310
R-squared	0.955	0.962	0.785	0.788

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

A.7 State Space Discretization of Cash Bonus Sensitivity and Deposit Capacity Process

This section estimates persistently parameters of cash bonus sensitivity and deposits. First, I write down VAR(1) process of cash bonus sensitivity and deposit capacity. Parameters of stochastic process in the model are estimated from inside and outside the model. Second, I discretize continuous-state Markov chains using the Tauchen method.

The stochastic process of exogenous state $z = (\theta_B, \ln \delta_d)'$ is

$$z_{i,t} = \begin{pmatrix} (1-\kappa_{\theta_B})\bar{\theta}_B \\ (1-\kappa_{\delta_d})\ln \bar{\delta}_d \end{pmatrix} + \begin{pmatrix} \kappa_{\theta_B} & 0 \\ 0 & \kappa_{\delta_d} \end{pmatrix} z_{i,t-1} + \varepsilon_{i,t+1},$$

where $\varepsilon_{i,t+1}$ is a vector of idiosyncratic shocks of bank i at time period $t+1$ with variance-covariance matrix of

$$\Sigma = \begin{pmatrix} \sigma^2_{\theta_B} & 0 \\ 0 & \sigma^2_{\delta_d} \end{pmatrix}.$$

$\sigma^2_{\theta_B}$ and $\sigma^2_{\delta_d}$ are volatility parameters are estimated in Section 4.2. To reduce the number of parameters, I impose that the diagonal components of the lagged parameters $z_{i,t-1}$ are zero and that there is no correlation in idiosyncratic shocks $\varepsilon_{i,t+1}$. The standard deviation of the cash bonus sensitivity (deposit capacity) is $\sigma_{\theta_B}/\sqrt{1-\kappa_{\theta_B}}$ ($\sigma_{\delta_d}/\sqrt{1-\kappa_{\delta_d}}$). The long-run state is $\bar{z} = (\bar{\theta}_B, \ln \bar{\delta}_d)'$. Since cash bonus sensitivity and deposit capacity are not observable in real data. In fact, cash bonus sensitivity is only observed when it takes a positive value. However, the model allows cash bonus sensitivity to take both positive and negative values. When cash bonus sensitivity is negative, bank CEOs receive no bonus payments regardless of revenue size. This cut-off corresponds to a situation where the bank, as modeled, faces negative cash bonus sensitivity, which may often be related to an anti-bonus culture. To estimate the persistence parameter of cash bonus sensitivity, I exclude observations where the bonus-to-revenue ratio is zero from the sample. Second, I assume that the observed deposit is proportional to the unobserved deposit capacity. I estimate persistency parameters κ_{θ_B} and κ_{δ_d} outside the dynamic financing model. I run a dynamic panel regression with fixed effects using the Arellano-Bond estimator. The Arellano-Bond estimator addresses potential bias arising from the lagged dependent variable for short-T panel data, which fixed effects introduce correlation between lagged variables and error terms. Estimates are reported in Appendix Table A5.

The persistency parameter of deposits is around 0.85-0.86 for the sample period post-Riegle-Neal Act of 1994. In column (i), the estimator is Arellano-Bond based on a difference-Generalized Method of Moments (GMM) estimation. In column (ii), the estimator is a simple ordinary least squares with fixed effects. Both estimators give similar coefficient estimates. The endogenous bias in a dynamic panel model with fixed effects becomes smaller when the sample of time periods is extended. When I start the sample in 1976, approximately doubling the sample periods from regressions in Panel A, I find the persistency parameter drops to 0.83. This decline in persistency is caused by including samples pre-Riegle-Neal Act of 1994, when the banking system was more dispersed and competitive. So, I conclude that a sample of post-Riegle-Neal Act of 1994 is closer to deposits in- and out-flows observed in recent periods. Since the choice of sample banks and periods does not significantly alter the estimate of κ_{δ_d}, I select the specification in Panel A, column (ii) as my baseline case for exogenous deposit capacity process. Finally, I discretize the cash bonus sensitivity and deposit capacity processes separately.

Table A5: Dynamic Panel Model of Cash Bonus Sensitivity and Deposits.

In Tables of Panels A and B, the Arellano-Bond estimator and the linear least squares estimator with fixed effects are used. For the Arellano-Bond estimator, the instruments are the second-order or higher lagged variables of the logarithm of deposits, and I run a difference-GMM estimation. All variables are winsorized at the 1% and 99% levels and deflated using the consumer price index. Panel A reports dynamic panel model regressions of cash bonus sensitivity and the logarithm of deposits. The data source is S&P Capital IQ. The sample period starts in 2000 and ends in 2019. The dependent variables are cash bonus sensitivity and the logarithm of deposits. The regression of cash bonus sensitivity in the first column of Panel A excludes samples where cash bonus sensitivity is equal to zero. The coefficients are obtained using the Arellano-Bond estimator. The first column includes only samples with positive values of bonus-to-revenue in periods t and $t-1$. In Panel B, the data source is the Call Reports. The dependent variable is the logarithm of deposits. The sample for Columns (1) and (2) starts from the Riegle-Neal Act of 1994 and ends in 2020. The full sample starts in 1976 and ends in 2020, making it longer than the sample in Panel A. Columns (1) and (3) use the Arellano-Bond estimator, while Column (2) uses a linear least squares estimator with fixed effects.

Panel A: S&P Capital IQ Data Contains Publicly Listed Banks from 2000 to 2019

	Bonus-to-Revenue	ln(Deposit)
Lagged Bonus-to-Revenue	0.693***	
	(6.57)	
Lagged ln(Deposit)		0.907***
		(82.56)
N	3497	8536

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Panel B: Call Reports Contain Both Public and Private Banks from 1976 to 2020

	(1) Post Riegle-Neal	(2) Post Riegle-Neal	(3) Full Sample
Lagged ln(Deposit)	0.861***	0.854***	0.827***
	(168.64)	(289.36)	(182.26)
N	194560	194560	426132
Arellano-Bond	Yes	No	Yes
OLS with Fixed-Effects	No	Yes	No

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01

A.8 Model Details

A.8.1 Representative Household Problem

The representative household owns banks which maximizes

$$\max_{\{C_t, x_{i,t}\}_{t=0}^{\infty}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u(C_t) \right],$$

subject to

$$C_t + \sum_i (v_{i,t} - D_{i,t}) x_{i,t+1} + \sum_i d_{i,t+1} = \sum_i \Lambda(p_{i,t}) v_{i,t} x_{i,t} + \sum_i q_t^{-1} d_{i,t},$$

where $u(\cdot)$ is utility function, C_t is consumption, x_t is the size of shareholding, β is discount factor, v_t is cum-dividend share price, d_t is dividends, $\Lambda(p_t)$ is survival rate, q_t is an exogenous price of deposits which is $q_t = (1+r_{d,t})^{-1}$. The equilibrium is the household maximizes utility by choosing the sequence of consumption and shareholdings. Deposit in- and out-flows are exogenous. The market clearing condition of shareholding is $x_t = 1$. The exogenous supply of deposit is $d_t = \bar{d}_t$. The first-order condition (FOC) with respect to consumption c_t:

$$u'(C_t) = \beta \mathbb{E}_t \left[u'(C_{t+1}) q_t^{-1} \right].$$

The FOC with respect to shareholding x_t:

$$(v_{i,t} - D_{i,t}) u'(C_t) = \Lambda(p_{i,t}) \beta \mathbb{E}_t \left[u'(C_{t+1}) v_{i,t+1} \right].$$

The price of shareholding is

$$v_{i,t} = D_t + \Lambda(p_{i,t}) \mathbb{E}_t \left[\frac{\beta u'(C_{t+1})}{u'(C_t)} v_{i,t+1} \right].$$

It follows that the discounted value of equity payouts equals the share price traded in the market. In the absence of aggregate uncertainty, steady-state consumption C in the partial equilibrium models is given by: $C = D - \sum_i (1 - \Lambda(p_i)) v_i + r_d d$ where $q^{-1} - 1 = r_d$. Since aggregate consumption remains constant over time, the stochastic discount factor becomes the discount factor β.

A.8.2 Analytically Tractable Model of Bank Manager's Decision Making

I simplify the benchmark model to derive key insights. The bank manager's value function is as follows:

$$w = \max_S \underbrace{\theta_F l^{\alpha_F}}_{\text{Salary}} + \underbrace{\theta_B AS l^{\alpha_l}}_{\text{Bonus}} + \underbrace{\theta_S (AS l^{\alpha_l} - r_d d)}_{\text{Dividend}} + (1 - \alpha_w) \beta p(S) w.$$

In this setting, the bank manager receives a salary, bonuses, and dividends in each period. This model is an abstraction of full-fledged model in Section without features such as volatile deposit flows, external equity financing constraints, capital requirements, and decreasing returns to scale. For analytical tractability, I set $\eta_1 = 2$ which results in a quadratic function for the probability of loan production success: $p(S) = 1 - \eta_0 S^2$. Loan demand is exogenous and fixed at one (i.e., $l = 1$), and the capital constraint is binding, such that $d = (1 - \bar{\chi})l$. To maintain model simplicity, I assume that the outgoing CEO disposes of shareholdings without selling them in the market, implying the CEO earns zero income and capital gains upon turnover, with a probability of α_w. Solving the bank manager's optimization problem, the Euler equation is:

$$0 = \underbrace{(\theta_B + \theta_S)A}_{\text{MB of risk-taking}} - \underbrace{2(1 - \alpha_w)\beta\eta_o S w}_{\text{MC of risk-taking}}. \tag{14}$$

The optimality condition is met when the marginal benefit (MB) of risk-taking, driven by bonuses and dividends, equals the marginal cost (MC) of risk-taking, reflected in the continuation value. The optimal level of risk-taking is:

$$S = \frac{\theta_B A}{2(1 - \alpha_w)\beta\eta_0 w}$$

By substituting the policy function back into the recursive problem, the manager's value function can be expressed in closed form as:

$$w = \frac{\theta_F - r_d(1 - \bar{\chi}) + \sqrt{\{\theta_F - r_d(1 - \bar{\chi})\}^2 + \frac{1-(1-\alpha_v)\beta}{(1-\alpha_v)\beta} \frac{(\theta_B+\theta_S)^2 A^2}{\eta_0}}}{2\{1 - (1 - \alpha_w)\beta\}}.$$

The manager's value increases with salary (θ_F), cash bonus sensitivity (θ_B), and shareholdings (θ_S). According to Equation 14, the manager balances the marginal benefits and costs of risk-taking. Bonuses and shareholdings directly raise the marginal benefits of risk-taking, while they also have a positive relationship with the continuation value, indirectly raising the marginal costs of risk-taking. The relative magnitude of the marginal short-term benefits and long-term costs arising from agency frictions depends on the specific parameters of the model.

The success probability of loan production is:

$$\begin{aligned} p(S) &= 1 - \eta_0 S^2 \\ &= 1 - \underbrace{\eta_0 \left\{ \frac{\frac{1-(1-\alpha_v)\beta}{(1-\alpha_v)\beta} \frac{(\theta_B+\theta_S)A}{\eta_0}}{\theta_F - r_d(1 - \bar{\chi}) + \sqrt{\{\theta_F - r_d(1 - \bar{\chi})\}^2 + \frac{1-(1-\alpha_v)\beta}{(1-\alpha_v)\beta} \frac{(\theta_B+\theta_S)^2 A^2}{\eta_0}}} \right\}^2}_{\text{Failure Rate}}. \end{aligned} \tag{15}$$

The failure rate decreases as the fixed salary (θ_F). Analytically, cash bonus sensitivity (θ_B) and shareholdings (θ_S) can influence failure rates both positively and negatively.

A.8.3 Computational Algorithm

Algorithm to solve fixed point problem: start from guessing stock value v,

1. Given stock value v, and solve manager's problem. Update manager's policy functions Φ.

2. Update stock value v by solving shareholder's problem. Go back to step 1 until it converges.

I use a couple of tips to increase the speed of computation. I rewrite the control variable S of the optimization problem in Equation (5) to success rate p. Redefining the control variable reduces the number of grid points needed for the simulation while maintaining the precision of the value function iteration. I set the number of grid points for success rate p to 50. I discretize the state space of equity e into 40 piecewise log-linear grid points. The minimum of e on the grid is derived from the minimum value of deposit capacity in the model. Let's say the minimum value of deposit capacity is s $\delta_d^{\min}$; the minimum value of equity is $e^{\min} = \{\bar{\chi}/(1-\bar{\chi})\}\,\delta_d^{\min}$. Without precautionary savings, $e^{\min}$ is the smallest size of equity that banks could hold without facing capital constraints. The upper bound of equity depends on model parameters. I choose $e^{\max} = 0.40$ as most banks choose equity below this upper bound.

To accelerate the speed of value function iteration, the McQueen-Porteus error bounds have an advantage over the standard approach. I estimate the model using a personal desktop with a General-Purpose Graphics Processing Unit (GPGPU) of Nvidia RTX 3090. The value function iteration is written in C/C++ code with OpenACC, a simple API to implement multi-thread GPGPU computing.

A.8.4 Simulated Method of Moments Estimator

The Simulated Method of Moments estimator of $\hat{\Theta}$ is obtained by minimizing the cost function:

$$\hat{\Theta} \;=\; \arg\min_{\Theta} g_N(x,\Theta)'\hat{W}_N g_N(x,\Theta).$$

Θ represents a vector of model parameters. The cost function represents the distance, a measure of the discrepancy between the observed and simulated data. This discrepancy, $g_N(x,\Theta)$, is defined as:

$$g_N(x,\Theta) \equiv (NT)^{-1}\sum_{n=1}^{N}\sum_{t=1}^{T}\left[h(x_{n,t}) - S^{-1}\sum_{s=1}^{S}h(y_{n,t,s}(\Theta))\right].$$

where x is a vector of real-data and $y_{n,t,s}$ is a simulated-data depends on model parameters Θ. Here, the moment from real-data $x_{n,t}$ is:

$$(NT)^{-1}\sum_{n=1}^{N}\sum_{t=1}^{T}h(x_{n,t}).$$

And the moment from simulate-data $y_{n,t,s}$ is:

$$(NTS)^{-1}\sum_{n=1}^{N}\sum_{t=1}^{T}\sum_{s=1}^{S}h(y_{is}(\Theta)).$$

where N, T, and S represents the number of cross-sectional units, time periods, and simulations. The weight matrix $\hat{W}_N$ is a positive definite matrix that coverages in probability to a deterministic definite matrix W. The inverse of the weight matrix $\hat{W}_N$ is estimated as the sample variance-covariance matrix of the real-data moments. The calculation follows the influence-function approach proposed by Erickson and Whited (2000). The asymptotic distribution of SMM estimator is $\sqrt{NT}(\hat{\Theta}-\Theta)\xrightarrow{d}\mathcal{N}(0,\text{avar}(\hat{\Theta}))$ where the asymptotic variance is: $\text{avar}(\hat{\Theta})=\left(1+\frac{1}{S}\right)(J'WJ)^{-1}$. Here, $J\equiv\frac{\partial g_N}{\partial\Theta}$ is the Jacobian matrix of $g_N(\Theta)$. The Richardson extrapolation is a numerical method used to approximate the first-order derivative, which has lower numerical errors compared to Newton's method.

A.8.5 Policy Designs of Compensation Regulations

In September 2009, the Financial Stability Board published the Principles for Sound Compensation Practices. After EU Capital Requirement Directive (CRD) III is published in July 2010, Germany and UK have issued Institutsvergütungsverordnung and the Remuneration Code, respectively. EU CRID IV becomes binding as of January 2014.

Dodd-Frank Proposal. In 2024, six federal regulators—Federal Reserve Board (FRB), Federal Deposit Insurance Corporation (FDIC), Office of the Comptroller of the Currency (OCC), Securities and Exchange Commission (SEC), National Credit Union Administration (NCUA), and Federal Housing Finance Agency (FHFA)—jointly proposed regulations for incentive-based compensation in response to the financial crisis. Covered institutions are financial firms with total assets of $1 billion or more. The proposal defines three categories of covered institutions: Level 1, Level 2, and Level 3. Level 1 and Level 2 institutions have average total consolidated assets greater than or equal to $50 billion and must comply with specific requirements regarding the structure of their incentive compensation for senior executive officers (various top corporate leaders, including the president, the chief executive officer, and the chief operating officer) and significant risk-takers (top-paid non-senior employees).

The regulators require financial firms to defer payment of at least half of executive bonuses for four years (compared to three years on average in the industry). This proposal is a revision to the rule published in 2011. Moreover, the proposal mandates a minimum period of seven years to "clawback" bonuses if it turns out that an executive's actions hurt the financial institution or if a firm has to restate financial results. This rule is intended to implement Section 956 of the Dodd-Frank Act. However, since 2020, this proposal has been in progress because the regulators have failed to agree upon CEO pay restrictions. The regulators are the Department of the Treasury, Federal Reserve System, Federal Deposit Insurance Corporation, Federal Housing Finance Agency, National Credit Union Administration, and Securities and Exchange Commission.

EU Bonus Cap. This cap applies to all banks in the EU since April 2013. The regulation targets senior managers and internal supervisors. Under this regulation, bonuses are restricted to 100% of fixed compensation (i.e., salary). However, with explicitly approval from shareholders, the ratio can be raised to 200% of the fixed compensation. The EU bonus cap applies to all banks operating within the EU, regardless of their size. The EU bonus cap requires that a significant portion of bonuses must be deferred. Typically, at least 40% to 60% of the bonus is deferred, with the exact percentage varying based on the size of the bonus and the position of the employee within the bank. The deferral period usually spans three to five years. During this time, the deferred bonus can be subject to performance adjustments based on the ongoing results of the bank. The deferred bonus helps ensure that bonuses are only fully paid out if the bank continues to perform well over the longer term.

Debt-based Compensation. Dudley (2014) warns the existing risk-taking culture has needed to be improved by designing and implementing deferred compensation away from equity and towards debt. This debt-based compensation disconnects the link from high-powered pay incentives to short-term profits. Senior compensation is important to correct this problem since the "tone at the top" is critical to improving institution's risk-taking culture.