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CEO OPTION COMPENSATION, RISK-TAKING INCENTIVES, AND SYSTEMIC RISK IN THE BANKING INDUSTRY

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CEO Option Compensation, Risk-Taking Incentives, and Systemic Risk in the Banking Industry*

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Abstract

This study predicts and finds that chief executive officer (CEO) risk-taking incentives induced by stock option compensation increase a bank's contribution to systemic distress risk and systemic crash risk. We also predict and find that this CEO incentive–systemic risk relation operates through three channels: (i) a bank's engagement in non-interest income-generating activities, (ii) investments in innovative financial products such as collateralized debt obligations and credit default swaps, and (iii) maturity mismatch associated with on short-term debt financing. Finally, the CEO incentive–systemic risk relation is moderated by information transparency, bank size, market liquidity, and financial crisis. We also discuss relevant policy implications.

Keywords: Executive Compensation, CEO Risk-Taking Incentives, Systemic Risk, Banking

JEL Classifications: G01, G21, G32

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1. Introduction

This paper examines the relation between chief executive officer (CEO) risk-taking incentives induced by stock option compensation and a bank's contribution to systemic risk. Systemic risk has long been a major concern of banking regulators, since the banking industry is vulnerable to shocks and is exposed to high systemic risk (Diamond and Dybvig, 1983; Shleifer and Vishny, 2010) and systemic risk is the precursor of economic-wide downturns and crises (Acharya et al., 2012a; Allen et al., 2012b). The financial crisis of 2008–2009 further underlines the significance of systemic risk in the banking sector. In response to the crisis, the U.S. Congress enacted the Dodd–Frank Wall Street Reform and Consumer Protection Act (Dodd–Frank Act) in 2010. The act provides a framework to identify, measure, and regulate systemic risk. It also provides a legal basis for establishing the Financial Stability Oversight Council to oversee and maintain the stability of the financial system. Moreover, recognizing that the (then) current executive compensation practices encourage excessive risk taking and possibly caused the financial crisis of 2008–2009, the Dodd–Frank Act mandates the adoption of "say on pay" votes for all public firms to facilitate shareholders' monitoring of executive compensation practices. In a similar vein, the U.S. Treasury Department also imposed restrictions on executive incentive compensation in firms receiving funds from the Troubled Asset Relief Program (TARP), established in 2008.

A bank's risk-taking behavior, such as its engagement in non-interest income-generating activities or credit derivative businesses, engenders negative externalities from the bank to the banking sector, thereby increasing systemic risk (Brunnermeier et al., 2011; Eagle et al., 2012; Rodríguez-Moreno et al., 2012). However, little is known about whether and how executive incentive compensation affects a bank's contribution to systemic risk and the financial crisis. Since the passage of the Frank–Dodd Act, the issue has received much attention from banking regulators, the popular press, and academic researchers, with mixed arguments advanced with respect to the impact of CEO risk-taking incentives on systemic risk.

On one hand, incentive compensation for bank CEOs, such as stock option compensation, has been blamed as a major cause that induces CEOs to take high-risk projects, thereby "building up" systemic risk and contributing to the financial crisis (Binder, 2009; OECD, 2009; Financial Crisis Inquiry Commission, 2011).[1] Similarly, Bebchuk et al. (2010) and Dallas (2011) claim that stock compensation provides bank executives with incentives to seek short-term results and excessive risk

[1] For instance, in his testimony on the U.S. Treasury budget on June 9, 2009, U.S. Treasury Secretary Timothy Geithner argued that "what happened to compensation and the incentives in creative risk-taking did contribute in some institutions to the vulnerability … in this financial crisis." Alan Blinder, the former vice-chairman of the Board of Governors of the Federal Reserve System, declares that poor incentives "built into the compensation plans of many financial firms" and "incentives that encourage excessive risk-taking" are one of the most fundamental causes of the credit crisis (Binder, 2009). The OECD (2009) maintains that the remuneration system has contributed to the financial crisis via encouraging excessive short-term thinking and blindness to risk. The final report of the Financial Crisis Inquiry Commission (2011) accuses that too often the compensation systems "encouraged the big bet—where the payoff on the upside could be huge and the downside limited."

taking. On the other hand, Murphy (2012) argues that bank executive compensation should not be blamed as a major cause of the financial crisis of 2008–2009 because its structure involves relatively low salaries, low bonus thresholds, large unvested or unexercisable stock options, and high penalties for failure. This argument suggests that the structure of bank executive compensation can effectively control banks' risk-taking incentives and constrain their contribution to the financial crisis.

Stock option compensation is an important type of bank executive incentive compensation. Our analysis focuses on the risk-taking incentives it induces, because it is designed to provide such incentives. Prior research provides little evidence of its relation with systemic risk but provides mixed evidence regarding its effect on bank-level performance and risk, in normal times and during the financial crisis of 2008–2009. For example, Fahlenbrach and Stulz (2011) report no relation between CEO option compensation and bank performance during the financial crisis of 2008–2009.[2] Chesney et al. (2012) also show that stock option incentives cannot explain the asset risk taking of U.S. financial institutions prior to the crisis. In contrast, other studies reveal that the convex payoff structure of option compensation generates risk-taking incentives, induces excessive risk-taking behavior, and increases bank risk in general and default risk in particular (Mehran and Rosenberg, 2009; Balachandran et al., 2010; Bolton et al., 2010; Inderst and Pfeil, 2011). In addition, Thanassoulis (2012) and Acharya et al. (2012b) suggest analytically that when banks compete for executive talents and CEOs are highly mobile across banks, CEO compensation arrangements, including option compensation, induce incentives for short-termism and excessive risk taking and increase default risk. Even if option-based risk-taking incentives increase bank risks, bank-specific risk cannot cause a sector-wide financial crisis unless it is highly contagious and can spill over to other banks. Risk contagion, rather than bank-specific risk, is at the heart of systemic risk (De Bandt and Hartmann, 2000). Therefore, whether CEO risk-taking incentives induced by stock option compensation exacerbate risk contagion and systemic risk is still an empirical question. The primary objective of this study is to provide large-sample, systematic evidence in this unexplored issue.

Prior studies suggest several potential channels through which option-induced CEO risk-taking incentives affect a bank's contribution to systemic risk. Specifically, option-based compensation creates incentives for CEOs to undertake risky business activities or operations, such as non-interest income-generating activities, and/or to rely heavily on risky short-term debt financing (Mehran and Rosenberg, 2009; DeYoung et al., 2010; Vallascas and Hagendorff, 2011). Banks' use of recently developed financial derivatives—such as credit default swaps (CDSs) and asset securitization, in particular, and collateralized debt obligations (CDOs)—and reliance on short-term debt to finance new real estate–related financial instruments are especially blamed as the main causes for the financial crisis of 2008–2009 (Brunnermeier, 2009; Diamond and Rajan, 2009). In this study, we further

[2] However, this evidence cannot refute the charges against equity compensation, because accounting and market performance deteriorate and diminish the power of any performance-based incentive plans during a financial crisis. When option values drop to almost zero and stock prices slump sharply during a financial crisis, neither can motivate risk-averse mangers to work harder or take more risk to maximize their own wealth or that of their shareholders.

investigate whether these business operations or practices serve as channels through which stock option compensation for bank CEOs influences a bank's contribution to systemic risk.

We propose that bank executives' risk-taking incentives induced by CEO stock option compensation increase a bank's contribution to systemic risk and that the relation operates through three channels: non-interest income-generating activities, maturity mismatch, and innovative financial products. In particular, stock option compensation induces CEOs to conduct relatively high-risk businesses or operations such as undertaking non-interest income-generating activities, maintaining a high level of maturity mismatch by cutting down cash holdings and increasing short-term debt financing (Chava and Purnanandam, 2010; Suntheim, 2011), and engaging in innovative financial products (CDSs and asset securitization, particularly with CDOs). Such behavior, in turn, not only increases bank-level distress and crash risk (e.g., Campbell et al., 2008; Balachandran et al., 2010; Benmelech et al., 2010) but also exacerbates risk spillover and contagion via increasing fundamental uncertainties facing banks (Allen and Gale, 1998, 2004; Caballero and Krishnamurthy, 2008). More significantly, the convex payoff structure of stock option compensation induces bank herding in conducting these short-termist risky activities to inflate stock price and the value of stock option compensation at the possible expense of the banks' long-term performance (Acharya and Yorulmazer, 2005). Herding in non-interest income-generating activities further increases asset commonality and interconnectedness that enhance risk contagion and engender excessive systemic risk (Allen et al., 2012; Billio et al., 2012). Bank herding in maintaining high maturity mismatch aggravates risk contagion and systemic risk through interbank lending markets, since these rely largely on short-term interbank financing to provide liquidity during periods of financial distress (Diamond and Rajan, 2005; Iyer and Peydró, 2011). Herding in asset securitization and/or CDS businesses forms natural risk contagion channels by constructing an interconnected contractual network among banks, increasing joint default risk and counterparty risk (Hansel and Krahnen, 2007; Krahnen and Wilde, 2007; Biais et al., 2010; Liu, 2010).

To examine the aforementioned research questions, we construct a large sample of publicly traded bank holding companies (BHCs) and commercial banks in the U.S. from 1992 to 2009. We obtain two measures for a bank's contribution to systemic risk using the percentile regression method, extending the work of Adrian and Brunnermeier (2011): (i) a bank's contribution to systemic distress risk, that is, the marginal increase in the banking sector's distress risk, given that a bank is in distress, and (ii) a bank's contribution to systemic crash risk, that is, the marginal increase in the banking sector's crash risk, given that a bank's stock price crashes. Following Core and Guay (1999), we use the sensitivity of CEO option compensation to stock return volatility, that is, *Vega*, to proxy for CEO risk-taking incentives induced by CEO option compensation.[3]

[3] Also following Core and Guay (1999), we use the sensitivity of new CEO option grants and of previously granted options to stock return volatility to gauge the CEO risk-taking incentives they respectively induce.

Briefly, our main results reveal the following. First, option-induced CEO risk-taking incentives are positively associated with a bank's contribution to systemic distress risk and systemic crash risk. Second, banks with higher CEO risk-taking incentives possess a larger portion of non-interest income, a larger magnitude of maturity mismatch, and a higher level of CDSs and asset securitization such as CDOs, all of which are positively associated with a bank's contribution to systemic distress risk and systemic crash risk. The findings support our prediction that option-induced CEO risk-taking incentives increase a bank's contribution to systemic (distress and crash) risk through three channels, that is, non-interest income-generating activities, maturity mismatch, and innovative financial products.

An interesting, but yet unexplored, question is whether different components of stock option compensation induce different risk-taking incentives and contribute differently to systemic risk. The freedom to cash out equity contributes substantially to CEO excessive short-term risk taking, but restrictive stock options help to mitigate excessive risk taking and encourage long-term value creation (Romano and Bhagat, 2009; Bebchuk and Spamann, 2010). Therefore, we predict that the effect of risk-taking incentives on enhancing risk contagion is stronger (weaker) when the incentives are induced by previous (new) option grants. Our findings are consistent with this prediction. Specifically, CEO risk-taking incentives induced by previously granted options (new option grants) are positively (weakly) associated with a bank's contribution to systemic distress risk and systemic crash risk.

We further conjecture that bank characteristics such as information transparency and bank size and other conditioning variables, including bank-specific market liquidity and financial crises, affect the positive relation between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk. Further analysis reveals that information transparency and bank size attenuate the positive relation, whereas the financial crisis and the lack of market and bank-specific liquidities accentuate this relation. Moreover, we also find that the financial crisis magnifies the relation through exacerbating risk contagion and spillover, but not through increasing bank-specific risk. Further, we demonstrate that our main results are robust to the potential endogeneity of option-induced CEO risk-taking incentives, to alternative measures for option-induced CEO risk-taking incentives, and to alternative systemic risk measures.

Our study contributes to the literature on bank CEO compensation, bank risk, and financial crisis and has immediate policy implications. First, this study extends the literature on CEO equity compensation and systemic risk by presenting original evidence supporting a positive relation between option-induced CEO risk-taking incentives and a bank's contribution to systemic (distress and crash) risk. We further demonstrate that the relation operates through three channels: (i) a bank's engagement in non-interest income-generating activities, (ii) its use of innovative financial products, and (iii) maturity mismatch. The evidence suggests that inappropriate CEO option compensation design could be one cause for the recent financial crisis by encouraging CEO herding in conducting risky business activities, which increases risk contagion and contributes to systemic risk.

In addition, evidence that the risk-taking incentives induced by previous (new) option grants increase (do not increase) the contribution to systemic risk helps us identify the source for the relation between CEO risk-taking incentives and systemic risk. The results also support the argument that freedom to cash out equity (restricted stock options) contributes to (mitigates) excessive risk taking (Romano and Bhagat, 2009; Bebchuk and Spamann, 2010). They also endorse Dittmann and Maug's (2007) thesis that optimal compensation schemes should involve minimum stock option holdings. Evidence regarding the moderating effect of a financial crisis also provides additional insights into the relation between stock option compensation and systemic risk by showing that the effect of risk-taking incentives on systemic risk in crisis times is mainly through increased risk contagion. Evidence regarding the moderating effect of transparency, bank size, and market illiquidity also sheds light on the relation between option compensation and systemic risk.

Second, this study contributes to the strand of research on executive compensation, bank risk, and bank performance by providing the initial evidence that advances our understanding about the differential effects of option-induced CEO risk-taking incentives in non-crisis and crisis periods. In particular, we show that in crisis times CEO risk-taking incentives exacerbate bank-specific risks and do not enhance bank performance. The evidence is consistent with Fahlenbrach and Stulz's (2011) finding of an insignificant relation between CEO equity portfolios and bank performance during the financial crisis and extends it to the settings of bank risk and systemic risk.

Finally, evidence in this study sheds new light on the regulatory controversy over the role of stock option compensation in the financial crisis and carries direct policy implications. Our findings endorse policy makers' criticism that executive pay arrangements have produced excessive risk-taking incentives and contributed to the recent financial crisis (OECD, 2009; Bebchuk and Spamann, 2010; Financial Crisis Inquiry Commission, 2011). The result that CEO risk-taking incentives induced by previous (new) option grants increase (do not increase) a bank's contribution to systemic risk provides an important policy implication for executive compensation reform: It could be a wise risk management strategy for banking and financial market regulators to constrain the exercise of (previously granted) CEO stock options and impose strict restrictions on new option grants.

The remainder of this paper is organized as follows. Section 2 develops our hypotheses. Section 3 describes the data, measurements, and models. Section 4 conducts the empirical analysis, while Section 5 presents further analysis and robustness checks. The final section concludes the paper.

2. Hypothesis Development

The convexity of the payoff structure inherent in stock option compensation provides CEOs with an incentive to undertake risky businesses and activities. Specifically, CEOs gain when stock prices exceed the exercise price of stock options but do not lose when they fall below the exercise price and the value of option compensation increases monotonically with stock return volatilities (Knopf et al., 2002). This situation generates risk-taking incentives that motivate CEOs to conduct risky operations, for example, taking on non-interest income-generating activities, engaging in innovative financial products such as asset securitization (particularly CDOs) and CDSs, and keeping high levels of short-term debt and maturity mismatch. These operations are inherently risky, increase return volatility, and exacerbate bank-specific distress risk and stock price crash risk, which can eventually trigger a sector-wide or economy-wide financial crisis when bank risk is contagious. Moreover, option-induced risk-taking incentives encourage CEOs to herd in their risk taking, since such herding further inflates option value but the convex payoff structure of option compensation imposes no costs for the associated increase in joint failure or joint crash risk (Acharya and Yorulmazer, 2005; Kirkpatrick, 2009). Herding in risk taking engenders risk contagion and spillover in the banking sector by increasing commonality in risky assets or debts among banks, thereby exacerbating common risk exposure and a bank's contribution to systemic risk. Risk-taking incentives induced from previously granted (and thus less restrictive to exercise) options could exhibit a stronger positive relation with contribution to systemic risk than newly granted (and thus more restrictive to exercise) options (Romano and Bhagat, 2009; Bebchuk and Spamann, 2010). In the following, we further elaborate this CEO incentive–systemic risk relation and develop testable hypotheses.

2.1 Option-Induced CEO Risk-Taking Incentives, Risky Business Policies, and a Bank's Contribution to Systemic Risk

The convex payoff structure of stock option compensation provides CEOs with an incentive to implement risky business policies (Guay, 1999; Rajgopal and Shivaram, 2002; Coles et al., 2006) and thus increases bank-specific distress risk and crash risk. This structure also encourages CEOs to herd in risk-taking activities, which in turn amplifies the spillover and contagion of these bank-specific risks to other banks in the banking sector and contributes to sector-wide systemic risk. In particular, stock option compensation incentivizes CEOs to engage in high-risk investments such as non-interest income-generating activities, private *mortgage-backed security (MBS)* investments, risky bank acquisitions, or innovative financial products, which eventually increase a bank's fundamental risk (Chen et al., 2006; Mehran and Rosenberg, 2009; DeYoung et al., 2010; Manso, 2011; Cheng et al., 2012).[4] By motivating CEOs to cut down cash holdings and increasing short-term debt financing (Chava and Purnanandam, 2010), option-induced risk-taking incentives also contribute to high maturity mismatch and bank-specific liquidity risk and thus raise bank distress risk (Campbell et al., 2008). As a result, option-induced CEO risk-taking incentives further increase bank distress risk and stock price crash risk (Balachandran et al., 2010; Benmelech et al., 2010). Balachandran et al. (2010)

[4] Using alternative market-based risk measures, Chen et al. (2006) report that CEO stock option holdings increase risk taking. Mehran and Rosenberg (2009) show that stronger CEO risk-taking incentives lead to riskier investments and higher equity return volatilities. DeYoung et al. (2010) extend the literature to the setting of non-interest income-generating activities and private mortgage-backed security investments. Cheng et al. (2012) show that stock option compensation is correlated with price-based risk measures, including market beta, return volatility, the sensitivity of stock prices to the ABX subprime index, and tail cumulative return performance, even after controlling for insider stock ownership.

demonstrate that stock option compensation increases the default risk in financial firms. Benmelech et al. (2010) analytically show that risk-taking incentives compel CEOs to implement suboptimal investment policies while concealing bad news about future growth, which in turn leads to severe overvaluation and subsequent stock price crashes. Bank-specific distress risk and crash risk are the sources of systemic risk and financial crisis: When these bank-specific risks spill over to other banks and are amplified in the process, they spark a financial crisis. Anecdotal evidence in the recent financial crisis also demonstrates this point.[5]

Bank-specific risk cannot affect systemic risk and ignite financial crisis if it does not spill over or is not contagious; therefore, spillover and contagion of bank-specific distress risk and crash risk are crucial to systemic risk (Brunnermeier and Oehmke, 2012). Option-induced CEO risk-taking incentives aggravate risk contagion and systemic risk by directly increasing bank fundamental uncertainties via implementing risky business policies. Prior research on systemic risk suggests that bank fundamental uncertainties facilitate risk contagion and spillover in the financial system. Specifically, Allen and Gale (1998, 2004) and Gertler et al. (2011) show analytically that bank uncertainty regarding the return of long-term investments induces bank runs. Caballero and Krishnamurthy (2008) demonstrate that uncertainties about bank asset payoffs and business environments lead to severe flight to quality and systemic risk. Consistent with these theoretical predictions, Adrian and Brunnermeier (2011) and Hovakimian et al. (2012) show that banks with higher uncertainties contribute more to systemic risk.

More significantly, option-induced CEO risk-taking incentives further augment the spillover and contagion of bank-specific distress and crash risks by inducing herding among banks in risky business operations and thus enhancing bank assets or liability commonality and interconnectedness that increase common risk exposures. Acharya and Yorulmazer (2005) show analytically that the convex payoff of limited liability induces bank owners to collectively maximize their option value by holding correlated portfolios, since they are not concerned about the associated increase in joint failure risk, given the convex payoff structure of limited liability. The analysis implies that the similar convex payoff structure inherent in CEO stock option compensation also induces bank herding in excessive risk taking. In particular, as other banks perform risky activities with high short-term profits, it is optimal for CEOs with option compensation, especially exercisable option compensation, to herd in these risky but presently highly profitable activities to increase their option compensation value. This is because even though such herding can hurt long-term bank performance, the convex payoff structure of option compensation imposes no costs on the possibility of joint failure associated therewith.[6] In a related vein, Kirkpatrick (2009) criticizes that executive incentive systems such as stock option compensation maturing in the short run encourage a bank's short-term risk-taking and

[5] For example, the 2008–2009 financial crisis stems from the collapses or forced mergers/bailouts of Bear Stearns, AIG, Fannie Mae, Freddie Mac, Lehman Brothers, IndyMac Bank, Merrill Lynch, Wachovia, Washington Mutual, and many others.

[6] This line of reasoning is similar in spirit to Scharfstein and Stein's (1990) thesis that managers inefficiently mimic investments by other managers due to their consideration of rational reputation.

herding behavior and, in turn, influence financial institutions' sensitivity to shocks and lead to unsustainable balance sheet positions.

Herding in risky non-interest income-generating investments increases business similarity, asset commonality, and contractual interconnectedness among banks, thus enhancing information contagion among correlated banks. This is because bank stakeholders rely on information from other correlated banks to guide their business, given the high information asymmetry in the banking industry (Chen, 1999; Allen et al., 2012a; Billio et al., 2012). Allen et al. (2012a) argue and provide evidence that herding in risky investment portfolios and relying on short-term borrowings interact with each other and thus increase systemic risk. From a different perspective, Mondschean and Pecchenino (1995) and Pecchenino (1998) analytically show that bank herding behaviors induce and magnify cyclical fluctuations, implying that bank herding in risk taking could exacerbate risk contagion and contribute to systemic risk.

Similarly, herding in taking high liquidity risk and maintaining high maturity mismatch directly increase banks' common risk exposure through relying heavily on interbank lending and a common liquidity pool for liquidity provision, thus enhancing risk contagion and amplification. The interbank lending market serves as an interconnected network that facilitates the spread of liquidity risk and failure among banks connected along the debt contractual chains. Iyer and Peydró (2011) find that the interbank debt linkage propagates failure shock. Further, in market downturns, the fear of risk contagion in interbank markets causes lending banks to reduce or withdraw liquidity provision in a panic, which dries up market liquidity, forces borrowing banks to fire-sale illiquid assets (Bleakley and Cowan, 2010), and stimulates depositors and other stakeholders to withdraw their transactions (Gorton, 2009a, 2009b; Iyer and Peydró, 2011). In addition, following the failure of participating banks, the common liquidity pool will shrink and aggravate the liquidity shortage, leading to a sector-wide meltdown, even without depositor panic (Diamond and Rajan, 2005). **Rodrib and Velasco (1999) and** Adrian and Brunnermeier (2011**) report empirical evidence that** maturity mismatch contributes to systemic risk.

Option-induced CEO risk-taking incentives, in particular, motivate herding in investments in financial innovative products, for example, asset securitization (particularly CDOs) and CDSs, because such risky activities yield high short-term benefits. By nature, certain innovative financial products such as CDOs and CDSs enhance debt or loan interconnectedness among banks for both on- and off-balance sheet debt obligations, forming natural channels that precipitate sector-wide risk contagion and systemic risk (Adrian and Shin, 2008; Billio et al., 2012). Beck et al. (2011) also show that these financial innovations increased systemic distress risk during the recent financial crisis. Herding in asset securitization increases correlated default via enhancing cross-bank loan or debt interconnectedness (Hansel and Krahnen, 2007; Krahnen and Wilde, 2007). For example, the "originate to distribute" business model of CDOs and collateralized loan obligations (CLOs) contribute to the transfer of default risk among banks and leads to an increase in the joint default risk in the banking sector (Nijskens and Wagner, 2011). The model also increases common credit risk exposure among banks and interconnectedness in the debt contractual network by inducing securitization-active banks to lend more, by packaging and distributing low-quality loans to others, and by distributing the senior tranches of CDOs or CLOs to institutional investors who may not otherwise invest in high-risk instruments (Shivdasani and Wang, 2011). This herding also increases the likelihood of neglected risks embedded in CDOs or CLOs finally being realized and investors flying to the safety of traditional securities in panics, bringing about market crashes without high leverage (Gennaioli et al., 2012).

Option-induced CEO risk-taking incentives motivate herding in CDSs when banks with risky investments (e.g., subprime mortgages or CDOs) use CDSs to reduce regulatory capital requirements and transfer credit risk or to speculate on the default risk of securitized loans and structured-finance securities.[7] This behavior further exacerbates risk contagion and contributes to systemic risk. Specifically, CDSs increase the counterparty risks of both protection sellers and buyers by (i) reducing protection buyers' incentives to screen the lending ex ante and monitor it ex post (Arping, 2004; Morrison, 2005; Stulz, 2010) and (ii) undermining protection sellers' incentives to manage their own balance sheet risk due to their asymmetric cost–benefit tradeoff of risk control when the protection buyer is insolvent (Biais et al., 2010). In addition, CDSs reinforce the risk contagion effects of asset securitization, especially CDOs, by encouraging CDS buyers to originate and distribute more risky loans (Morrison, 2005). In addition, CDSs enhance the interconnectedness between financial institutions by facilitating the sharing of default risk among contractual parties (Allen and Carletti, 2006; Liu, 2010) and by augmenting risk contagion among otherwise independent entities (Biais et al., 2010). This interconnectedness and "risk circularity" nature of CDSs facilitate tying counterparties together through chains of over-the-counter derivatives contracts, which in turn aggravates the risk contagion and joint default risk of banks during economic distress (European Central Bank, 2009). In sum, CEO risk-taking incentives spur herding in innovative financial products such as CDOs and CDSs. As such, banks' engagement in innovative or derivative financial products forms a natural channel that exacerbates risk contagion and contributes to systemic (default and crash) risk.

Collectively, an important testable implication from the above analyses is that option-induced CEO risk-taking incentives motivate banks to engage in non-traditional risky businesses, including non-interest income-generating activities and innovative financial products, and to maintain high maturity mismatch. This in turn increases a bank's contribution to systemic risk by exacerbating the spillover and contagion of bank-specific risk to other banks (as well as the overall economy) and by amplifying

[7] Banks use limited CDSs for both hedging and speculation (Crotty, 2009; Minton, et al., 2009). According to Minton et al. (2009), only 23 large banks out of 395 banks in the sample used CDSs to hedge an average of only 2% of their loans during 1999–2005. Most of their derivatives positions were held for trading rather than for hedging purposes. A 2007 report by Fitch Ratings summarizes that "58% of banks that buy and sell credit derivatives acknowledged that 'trading' or gambling is their 'dominant' motivation for operating in this market, whereas less than 30% said that 'hedging/credit risk management' was their primary motive" (Crotty, 2009).

bank-specific distress risk and crash risk in the process. To provide large-sample, systematic evidence on the issue, we test the following hypotheses in alternative form.

H1: *CEO risk-taking incentives induced by stock option compensation increase a bank's contribution to systemic risk.*

The above analyses also imply that CEO risk-taking incentives increase a bank's contribution to systemic risk through three channels: (i) banks' engagement in non-interest income-generating activities, (ii) maturity mismatch due to excessive reliance on short-term debt financing, and (iii) banks' use of innovative financial products such as asset securitization (particularly CDOs) and CDSs. To provide empirical evidence regarding these unexplored issues, we propose and test the following three channel hypotheses in alternative form.

H2a: *CEO risk-taking incentives induced by stock option compensation increase a bank's contribution to systemic risk through the non-interest income channel.*

H2b: *CEO risk-taking incentives induced by stock option compensation increase a bank's contribution to systemic risk through the maturity mismatch channel.*

H2c: *CEO risk-taking incentives induced by stock option compensation increase a bank's contribution to systemic risk through asset securitization (particularly CDOs) and CDS channels.*

2.2 Conjectures about the Decomposition of Option-Based CEO Risk-Taking Incentives and a Bank's Contribution to Systemic Risk

The two components of CEO stock option compensation, that is, (i) new option grants and (ii) previously granted exercisable and unexercisable options, can induce different CEO risk-taking incentives. Many new option grants are restrictive and do not allow managers to sell for a specified period after vesting, usually five to 10 years, whereas previously granted stock options allow more freedom to cash in on them. Bebchuk and Spamann (2010) argue that managerial equity compensation, including stock options, motivates managers to engage in short-termist risk, taking it so as to inflate current stock and/or option prices at the expense of long-term firm value, and that the freedom to cash out equity substantially distorts risk-taking incentives. Romano and Bhagat (2009) observe that restricted stock options help to mitigate excessive risk taking that increases systemic risk and instead focus on creating and sustaining long-term firm value. Both studies suggest that CEO stock option grants should be restricted for at least two to four years after CEO resignations or dismissals. We expect excessive risk-taking incentives generated from CEO new option grants to not be as strong as those from previously granted options and hence the hypothesized positive relation between CEO risk-taking incentives induced from previously granted options (new option grants) and the contribution to systemic risk is stronger (weaker). Given the lack of empirical evidence, we also aim to provide large-sample systematic evidence on this unexplored question.

3. Research Design

3.1 Data Description

Our initial sample includes all publicly traded BHCs and commercial banks in the U.S., namely, banks with two-digit Standard Industrial Classification (SIC) codes 60 and 61 and with SIC code 6712, respectively, from 1992 to 2009.[8] We delete banks with SIC code 6163 (loan brokers) from the sample because they are pure brokerage or investment banks. We also delete non-banking firms within SIC code 6199. We extract financial statement data from Compustat, the Report of Condition and Income (Call Report), or the FR Y-9C report filed by a commercial bank or BHC with the U.S. Federal Reserve. We obtain CEO compensation data from ExecuComp and stock price and return data from the Center for Research in Security Prices (CRSP). To be included in the final sample, all the data required to compute systemic risk and stock option compensation variables should be available from the sources identified previously. We mainly use the linkage database available at the website of the Federal Reserve Board of New York to merge FR Y-9C report and Call Report data with Compustat, CRSP, and ExecuComp data for BHCs. We also manually identify and merge the Call Report data and other relevant data for commercial banks. We winsorize all variables at 1% and 99% of their empirical distributions to control for the effect of extreme outliers. Our final sample contains an unbalanced panel of 2,223 bank–quarters for 119 unique banks for the period 1992–2009.

3.2 Measures for a Bank's Contribution to Systemic Risk

Recent literature on systemic risk presents many systemic risk measures but reaches no consensus regarding which one is the best. Bisias et al. (2012) provide a thorough review of these measures. Among others, the aggregate systemic risk measure developed by Allen et al. (2012b), denoted *CATFIN*, uses the principal components of the 1% value at risk (*VaR*) and the expected shortfall for a cross section of financial firms to predict economic downturns one year ahead. The network-based systemic risk measures proposed by Billio et al. (2012) capture the interconnectedness of monthly stock returns among financial institutions based on principal component analysis and Granger causality tests. Unfortunately, these measures are not bank specific and are inapplicable to our study. In contrast, Acharya et al. (2010) adopt the marginal expected shortfall measure, *MES*, which captures expected bank loss when the overall market declines substantially. Similarly, Acharya et al. (2012a) develop an *SRISK* measure that gauges a bank's expected capital undercapitalization in a

[8] In particular, the final sample includes banks with SIC code 6020, 6021,6022, 6025, 6029, 6030, 6035, 6036, 6060, 6090, 6141, 6153, 6162, and 6712. Banks with SIC code 6020 are state commercial banks, banks with SIC code 6022 are savings institutions, and banks with SIC code 6035 are federally chartered.

financial crisis. Both measures are bank specific but focus on a bank's risk exposure rather than its negative externality to a systemic crisis.[9] Adrian and Brunnermeier (2011) propose the *CoVaR*-based systemic risk measure as the *VaR* of asset returns in the financial sector conditional on the *VaR* of a bank's asset return.[10] It is a bank-specific measure and explicitly accounts for the contribution and externality of a bank's distress to overall distress in the financial sector. Further, this measure considers information asymmetry and captures the effects of CEO risk-taking incentives on systemic risk and is thus better fitted for our research setting.

Extending Adrian and Brunnermeier (2011), this study develops two sets of *CoVaR*-based measures for a bank's contribution to systemic risk: (i) a bank's contribution to systemic distress risk, *ΔCoVaR5_at* and *ΔCoVaR_at*, based on the 5% and 1% *CoVaR* of asset returns, respectively, and (ii) a bank's contribution to systemic crash risk, *ΔCoVaR5_stk* and *ΔCoVaR_stk*, based on 5% and 1% *CoVaR* of stock returns, respectively. The term *ΔCoVaR5_at* (*ΔCoVaR_at*) refers to negative one (-1) times the marginal difference between the 5% (1%) *CoVaR* of quarterly market-based asset returns in the financial system when a bank's quarterly market-based asset return is at its 5% (1%) *VaR*, and when it functions in its median state. This measure is the systemic risk measure used by Adrian and Brunnermeier (2011) and Brunnermeier et al. (2011). Similarly, *ΔCoVaR5_stk* (*ΔCoVaR_stk*) refers to negative one (-1) times the marginal difference between the 5% (1%) *CoVaR* of quarterly stock return in the financial system when a bank's quarterly stock return is at its 5% (1%) *VaR* and when it functions in its median state. The first set of measures focuses on the negative externality of a bank's asset distress to other banks in the financial sector, while the second emphasizes a bank's contribution to stock price crash risk in the financial sector. Their estimation procedures are explained below, while more details are provided in Appendix B.

First, we measure $\Delta CoVaR5\_at_w^i$ as the marginal difference between the 5% *VaR* of weekly market-based asset return in the financial system when bank *i*'s weekly market-based asset return is at its 5% *VaR* ($CoVaR\_at^{system|i,5\%}$), and the same 5% *VaR* when bank *i*'s weekly market-based asset return functions in its median state ($CoVaR\_at^{system|i,median}$):

$$\Delta CoVaR5\_at_w^i = CoVaR\_at^{system|i,5\%} - CoVaR\_at^{system|i,\ median} \quad (1)$$

Next, we gauge a bank's contribution to systemic distress risk in a fiscal quarter $\Delta CoVaR5\_at_{it}$ by taking the quarterly cumulative $\Delta CoVaR5\_at_w^i$ across all weeks within the quarter and multiplying it by negative one (-1), with a higher value of $\Delta CoVaR5\_at_{it}$ indicating a higher contribution of bank *i* to systemic distress risk in quarter *t*. We define *ΔCoVaR_at* following the same procedure but use 1%

[9] Huang et al. (2009) and Giglio (2010) develop CDS-based measures that gauge systemic distress risk from CDS prices that content information about joint default risk of the bond issuer and the protection seller. These measures, however, are only applicable to large banks with CDS transactions.

[10] The term *CoVaR* denotes the comovement of *VaR*. Appendix B provides details about the definition of *CoVaR* and calculation method.

rather than 5% *VaR* of market-based asset return. Similarly, *ΔCoVaR5_stk* and *ΔCoVaR_stk* are measured following the same procedures for *ΔCoVaR5_at* and *ΔCoVaR_at,* respectively, except that asset return is replaced with stock return. Following Boyson et al. (2010) and Adrian and Brunnermeier (2011), we use quantile regression analyses to estimate these systemic risk measures.[11]

Alternatively, we use *MES*, *SRISK,* and *%SRISK* as systemic risk measures in robustness checks, considering that many banks simultaneously endure significant loss due to common risk exposure, especially in a crisis period. The term *MES* is the marginal expected shortfall of a stock given that the market return is below its fifth percentile. The term *SRISK* refers to the expected capital shortfall that a bank needs to cover if there is another financial crisis (the broad index falling by 40% over the next six months is viewed as a crisis) and *%SRISK* is the contribution of a financial institution's *SRISK* to the aggregate *SRISK* in the financial sector. Billio et al. (2012) document that institutions that experienced the largest decline in stock prices during the 2008–2009 crisis were the ones that greatly impacted other institutions and not the ones affected by other institutions. Therefore, these measures also partially capture a bank's contribution to systemic risk.

3.3 Measures for CEO Risk-Taking Incentives Induced from Stock Option Compensation and Other Compensation Variables

Our independent variable of interest is CEO risk-taking incentives induced by stock option compensation. It is well established that the convexity of option compensation incentivizes CEOs to undertake risky business because it allows CEOs to share the gains, but not the losses, with shareholders.[12] We measure option-induced CEO risk-taking incentives, using the sensitivity of stock option compensation to stock return volatility, namely, *Vega*. Specifically, *Vega* is gauged as the natural logarithm of the dollar change in the value of CEO stock option holdings resulting from a 1% increase in a bank's stock volatility (Core and Guay, 1999; Chava and Purnanandam, 2010; Kim et al., 2011).[13] We further decompose *Vega* into two components: (i) CEO risk-taking incentives induced from new option grants, *Vega_awards*, and (ii) CEO risk-taking incentives induced from previously granted stock options, *Vega_old*. The variables *Vega_awards* and *Vega_old* are specified as the natural logarithm of the dollar change resulting from a 1% increase in a bank's stock return volatility in the value of a CEO's new option grants and previously granted options, respectively.

[11] The quantile regression estimates the conditional probability that a variable falls below a given threshold (quantile) when another one is also below the same quantile. It is a simple and efficient method to gauge risk contagion or systemic risk, since it requires no distributional assumptions. The quantile regression can be estimated for a large range of possible quantiles and allows for heteroskedasticity (Boyson et al., 2010). Boyson et al. (2010) use it to measure risk contagion in hedging funds, while Adrian and Brunnermeier (2011) employ it to gauge contribution to systemic distress risk.

[12] For more details, see Jensen and Meckling (1976), Guay (1999), and Core and Guay (1999).

[13] The purpose of using the natural logarithm transformation for the *Vega* measure is to normalize its left-skewed distribution such that OLS regression can be applied appropriately.

We also use an abnormal level of *Vega,* one beyond the desired level, denoted *ABVega*, as an alternative measure for CEO risk-taking incentives induced from stock option compensation. Following Core and Guay (1999) and Kim et al. (2011), we specify *ABVega* as the residual from a pooled ordinary least squares (OLS) regression of *Vega* on the market value of equity, idiosyncratic risk, the market-to-book ratio, CEO tenure, free cash flow, and year and quarter dummies.

We use CEO risk-averse incentives induced from equity compensation and CEO incentives induced from cash bonus as control variables because both are correlated with option-induced CEO risk-taking incentives and affect systemic risk.[14] Following Core and Guay (1999), Chava and Purnanandam (2010), and Kim et al. (2011), we gauge CEO risk-averse incentives using the natural logarithm of the dollar change in the value of CEO option and stock holdings resulting from a 1% increase in a bank's stock price, that is, the sensitivity of CEO stock option and equity shareholdings to stock price, denoted *Delta.* Following convention, we measure incentives from the cash bonus, denoted *Bonus*, using the ratio of an executive's cash bonus to total salary.

3.4 Baseline Model and its Estimation

We examine the association between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk using the following lagged regression model:

$$\Delta CoVaR_{it} = \varphi_0 + \varphi_1 VEGA_{it-1} + \varphi_2 COMP_{it-1} + Controls + \varepsilon_{it} \quad (2)$$

where $\Delta CoVaR$ refers to measures for a bank's contribution to systemic distress risk, that is, *ΔCoVaR5_at* or *ΔCoVaR_at*, or a bank's contribution to systemic crash risk, that is, *ΔCoVaR5_stk* or *ΔCoVaR_stk*. The variable of interest, *VEGA*, refers to our metrics for CEO risk-taking incentives induced from stock option compensation, that is, *Vega* or *ABVega*. The variable *COMP* refers to our measures of other CEO compensation variables, such as risk-averse incentives, *Delta*, and cash bonus, *Bonus*. Hypothesis H1 translates to $\varphi_1 > 0$. We estimate Eq. (2) using OLS regression,

14 Prior studies suggest that *Delta* impacts CEO risk taking but the direction is uncertain. Specifically, Chava and Purnanandam (2010) and Brockman et al. (2011) document that CEO risk-averse incentives reduce leverage and short-term debt, respectively, which has implications for decreasing systemic risk, consistent with the argument of Knopf et al. (2002). However, Kim et al. (2011) report that the higher *Delta* of top managers is positively related to firms' future stock price crash risk. The direction of the relation between the cash bonus ratio *Bonus* and contribution to systemic risk is similarly undecided. The benchmark model of Prendergast (1999) predicts a negative relation between cash bonus incentives and risk taking and inferably systemic risk and Balachandran et al. (2010) provide consistent evidence that *Bonus* reduces financial firms' default risk, whereas the multi-task agency model of Holmstrom and Milgrom (1991) suggests that external market variations drive both systemic risk and variable compensation and thus lead to a positive relation between them. Consistent with Holmstrom and Milgrom's (1991) prediction, Balboa et al. (2012) report that non-interest income is positively associated with cash bonus and other compensation variables. Moreover, policy makers and the media criticize that cash bonuses encourage executives to focus on short-term performance at the expense of long-term performance (Bebchuk and Spamann, 2010). Finally, Core and Guay (1998, 1999) report that equity risk-averse incentives and cash bonus are correlated with equity risk-taking incentives, respectively, suggesting that it is necessary to control both when investigating the relation between option-based CEO risk-taking incentives and a bank's contribution to systemic risk.

controlling for year and quarter fixed effects. The significance of all the independent variables is tested, using robust standard errors corrected for bank-level clustering and heteroskedasticity.[15]

3.5 Channel Variables and Channel Tests

We further examine whether option-induced CEO risk-taking incentives influence a bank's contribution to systemic risk through three channels: (i) a non-interest income channel, *N2I*, proxied by the ratio of non-interest income to interest income; (ii) maturity mismatch, *Mismatch*, measured by the ratio of the difference between short-term debt and cash holdings relative to total assets; and (iii) innovative financial instruments, *Securitize*, *CDO*, and *CDS,* where *Securitize* is measured by the natural logarithm of one plus the dollar amount of asset securitization volume in a fiscal quarter, *CDO* refers to the natural logarithm of one plus the dollar amount of CDOs in a fiscal quarter, and *CDS* is proxied by the natural logarithm of one plus the dollar amount of trading CDSs in a fiscal quarter.[16]

We then consider a system of OLS regressions consisting of Eqs. (3) and (4), as shown below, to examine the mediating effect of each channel variable, following Baron and Kenney (1986), Hammersley (2006), and Lang et al. (2012). The purpose of our mediation analysis is to examine whether one variable (i.e., non-interest income, maturity mismatch, or financial innovative products) is an important channel through which another variable (i.e., option-induced CEO risk-taking incentives, captured by *VEGA*) influences our dependent variable (i.e., a bank's contribution to systemic risk). Specifically, we first regress the mediating channel *Channel* on CEO risk-taking incentives *VEGA*, other CEO compensation variables *COMP*, and other controls:

$$Channel_{it} = \beta_0 + \beta_1 VEGA_{it-1} + \beta_2 COMP_{it-1} + Controls1_{it-1} + \upsilon_{it} \quad (3)$$

where *VEGA, COMP* and *Controls1* are measured in lagged form. We then regress our measure of a bank's contribution to systemic risk on the channel variable *Channel,* CEO risk-taking incentives *VEGA*, other CEO compensation variables *COMP*, and other controls:

$$\Delta CoVaR_{it} = \gamma_0 + \gamma_1 Channel_{it-1} + \gamma_2 VEGA_{it-1} + \gamma_3 COMP_{it-1} + Controls2_{it} + \varepsilon_{it} \quad (4)$$

where *Channel, VEGA,* and *COMP* are measured in lagged form, with *Channel* referring to non-interest income *N2I*, maturity mismatch *Mismatch*, or financial innovations *Securitize*, *CDO*, or *CDS*.

[15] When Δ*CoVaR5_at* or Δ*CoVaR_at* is used as a dependent variable, *Controls* include the market-to-book ratio *Mb*, the leverage ratio *Leverage*, equity return volatility *Sigma*, total asset *Size* and its square *Size_sqr*, return on assets *ROA*, the loan-to-asset ratio *Loan*, and year and quarter indicators, following Adrian and Brunnermeier (2011) and Brunnermeier et al. (2011). The variables *Mb*, *Leverage*, *Sigma*, and *Size* are expected to be positively associated with Δ*CoVaR5_at* and Δ*CoVaR_at*, while *Size_sqr* and *Loan* are expected to be negatively associated with them. When Δ*CoVaR5_stk* or Δ*CoVaR_stk* acts as a dependent variable, we add into *Controls* additional stock market variables, such as momentum, *Mom,* and the relative kurtosis of stock returns to the market, *Cokurt*.

[16] Since the distributions of *Securitize*, *CDO*, and *CDS* are skewed, we use the natural logarithm of one plus their raw value to normalize their distributions.

The variable *Controls1* in Eq. (3) differ from *Controls2* in Eq. (4), depending on the specific channel tested,[17] and *Controls2* in Eq. (4) is the same as *Controls* in Eq. (2). Hypotheses H2a to H2c predict that $\beta_1 > 0$ and $\gamma_1 > 0$, which suggests that option-induced CEO risk-taking incentives increase a bank's contribution to systemic risk via a mediating channel.

4. Empirical Results

4.1 Descriptive Statistics

Table 1 presents summary statistics for the variables used in our empirical tests. The mean (median) values of a bank's contribution to systemic distress risk, *ΔCoVaR5_at* and *ΔCoVaR_at*, are 22.296 (19.155) and 27.074 (21.651), respectively, comparable to the corresponding figures reported by Adrian and Brunnermeier (2011) and Brunnermeier et al. (2011).[18] The mean (median) values of a bank's contribution to systemic crash risk, *ΔCoVaR5_stk* and *ΔCoVaR_stk*, are 26.530 (22.678) and 39.931 (34.037), respectively. The mean (median) of other systemic risk measures *MES* and *%SRISK* are 2.857 (1.928) and 0.025 (0.001), respectively. The mean (median) of *SRISK* (in billions of dollars) is -3.015 (-2.997), suggesting that the average bank has $3.015 billion excess prudential capital and need not raise capital in a future crisis and thus has low systemic risk. The mean (median) of *Vega(raw)*, *Vega_old(raw),* and *Vega_awards(raw)*, all denominated in hundreds of thousands of dollars, are 0.995 (0.061), 0.754 (0.059), and 0.212 (0.001), comparable to the figures reported by Chava and Purnanandam (2010) and Guay (1999).

Panel A of Table 2 reports the Pearson correlation coefficients (ρ) for the main testing variables, while Panel B presents the same correlations for our measures of a bank's contribution to systemic distress and crash risks (*ΔCoVaR5_at*, *ΔCoVaR_at*, *ΔCoVaR5_stk*, *ΔCoVaR_stk*, *MES*, *SRISK*, and *%SRISK*) and bank-specific risks (*Sigma*, *Beta*, *VaR_at*, *VaR_stk*, and *Z_Score*). In Panel A, the two measures of a bank's contribution to systemic distress risk, *ΔCoVaR5_at* and *ΔCoVaR_at*, are positively correlated with each other, with ρ = 0.796, which is highly significant at less than the 1% level. The

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17 When maturity mismatch *Mismatch* is used as a dependent variable, *Controls1* includes total asset *Size* and its square *Size_sqr,* return on assets *ROA*, the tier-one capital ratio *CAPR*, the loan-to-asset ratio *Loan*, the net interest margin *Nim*, the bond market liquidity spread *Repo*, and change in the three-month T-bill rate *3M*. When *N2I* or financial innovations are used as dependent variables, *Controls1* includes the market-to-book ratio *Mb*, financial leverage *Leverage*, the ratio of loan loss allowance to total assets *LLA,* total asset *Size* and its square *Size_sqr,* return on assets *ROA*, the tier-one capital ratio *CAPR*, the loan-to-assets ratio *Loan*, and the net interest margin *Nim*.

18 The figures appear higher in magnitude than the corresponding ones reported by Brunnermeier et al. (2011) and Adrian and Brunnermeier (2011), which are around 1.00 to 1.20. This seeming inconsistency is mainly caused by the fact that both studies report the weekly percentage *ΔCoVaR*, while we report the quarterly *ΔCoVaR,* which is approximately equal to the average weekly *ΔCoVaR* in a quarter times thirteen. Therefore, our mean *ΔCoVaR* should be about thirteen times their measure. The inconsistency is also due to the different financial institutions and periods covered in calculating *ΔCoVaR_at*: We use only the BHCs and commercial banks and do not include the 1989 crisis, while Adrian and Brunnermeier (2011) additionally cover investment banks and real estate companies and their sample period additionally covers from 1986 to 1991. In addition, we use only those BHCs and commercial banks with available CEO option compensation data, while Brunnermeier et al. (2011) include all commercial banks and BHCs with available *ΔCoVaR_at* data.

two measures of a bank's contribution to systemic crash risk, *ΔCoVaR5_stk* and *ΔCoVaR_stk,* are also significantly positively correlated with each other, with ρ = 0.898. The two sets of metrics for contribution to systemic distress and crash risks—that is, *ΔCoVaR5_at* and *ΔCoVaR5_stk,* as well as *ΔCoVaR_at* and *ΔCoVaR_stk*—are also significantly positively correlated with each other, with ρ = 0.714 and ρ = 0.486, respectively. These high correlations validate their construct validity and convergent validity.

Note also that the option-induced CEO risk-taking incentives, *Vega*, are significantly positively associated with the following mediating channel variables, through which they affect contribution to systemic risk: non-interest income *N2I*; financial innovations *Securitize*, *CDO*, and *CDS*; and maturity mismatch *Mismatch*. These channel variables are significantly positively associated with the four measures of a bank's contribution to systemic risk. Though only suggestive of the underlying relation, the correlation statistics provide initial evidence in support of H1 and H2a to H2c, that CEO risk-taking incentives tend to increase a bank's contribution to systemic (distress and crash) risk, which operates through the three proposed mediating channels.

As shown in Panel B, all four measures of a bank's contribution to systemic risk are also significantly positively correlated with alternative systemic risk measures within the framework of marginal expected capital shortfalls, that is, *MES*, *SRISK*, and *%SRISK*. These alternative systemic risk measures are also significantly positively associated with each other. The evidence further demonstrates the construct validity and convergent validity for our measures of contribution to systemic risk. Moreover, these systemic risk measures are all positively associated with bank-specific risk measures—return volatility *Sigma*, stock market systematic risk *Beta*, 1% *VaR* for asset return *VaR_at*, 1% *VaR* for stock return *VaR_stk*—except that they are negatively correlated with the Altman (1968) *Z-Score*, a higher value of which indicates lower default risk and greater bank stability. Most correlation coefficients presented in Panel B of Table 2 are highly significant, suggesting that bank-level distress risk and crash risk increase a bank's contribution to systemic risk.

4.2 Results of Main Regressions

4.2.1 The Impact of Option-Induced CEO Risk-Taking Incentives on Systemic Distress Risk

Hypothesis H1 predicts a positive association between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk. To test H1, we estimate our main regression in Eq. (2) and report the results in Table 3. Note in Table 3 that models 1 to 4 use a bank's contribution to systemic distress risk, that is, *ΔCoVaR5_at* and *ΔCoVaR_at*, as the dependent variable, while models 5 to 8 use a bank's contribution to systemic crash risk, that is, *ΔCoVaR5_stk* and *ΔCoVaR_stk*, as the dependent variable. As shown in models 1 and 3 of Table 3, option-induced CEO risk-taking incentives, captured by *Vega*, are positively associated with measures of a bank's contribution to systemic distress risk, *ΔCoVaR5_at* and *ΔCoVaR_at*, at the 1% level, with coefficients (*t*-values) of 1.162 (3.14) and 1.911 (3.56), respectively. These observed associations are economically significant as well: A one standard deviation increase in *Vega* leads to an increase in *ΔCoVaR5_at* of 2.324 in model 1, which corresponds to 10.42% of the mean of *ΔCoVaR5_at*. Similarly, it increases *ΔCoVaR_at* by 3.822 in model 3, which is equivalent to 14.13% of the mean of *ΔCoVaR_at*.

As models 2 and 4 of Table 3 show, when *Delta* and *Bonus* are included as additional controls, we find that the coefficients of *Vega* remain positive and highly significant, confirming that the higher the option-induced CEO risk-taking incentive, the higher a bank's contribution to systemic distress risk. We find, however, that the coefficients for CEO risk-averse incentives derived from option compensation (captured by *Delta*) and those derived from cash bonuses (captured by *Bonus*) are insignificant, which is in line with the mixed evidence and controversy about their effects on CEO incentives (e.g., Holmstrom and Milgrom, 1991; Prendergast, 1999). The results reported in models 1 to 4, taken together, are consistent with H1, suggesting that the higher the sensitivity of option compensation to stock return volatility (captured by *Vega*), the higher a bank's contribution to systemic distress risk (captured by *ΔCoVaR5_at* or *ΔCoVaR_at*).

With respect to the results for the control variables in models 1 to 4, the following is noteworthy. First, as shown in models 1 and 2, bank size, *Size,* is positively associated with a bank's contribution to systemic distress risk. This finding is consistent with the notion that, relative to small banks, large banks tend to contribute more to systemic distress risk in the banking industry ("too-big-to-fail" effects). Second, the significantly negative coefficient of *Size-sqr* is consistent with the finding of Brunnermeier et al. (2011), that the effect of bank size on contribution to systemic distress risk is non-linear with an inverted U-shape, though most observations (97.20% of the sample) fit a positive linear relation. Finally, return volatility *Sigma* is significantly positively related to a bank's contribution to systemic distress risk, consistent with the findings of prior research, that bank uncertainty increases the contribution to systemic risk (Caballero and Krishnamurthy, 2008; Adrian and Brunnermeier, 2011).

4.2.2 The Impact of Option-Induced CEO Risk-Taking Incentives on Systemic Crash Risk

While models 1 to 4 of Table 3 focus on the impact of *Vega* on systemic distress risk, models 5 to 8 focus on *Vega'*s effect on systemic crash risk, captured by *ΔCoVaR5_stk* and *ΔCoVaR_stk*. Similar to the results of models 1 to 4, the coefficient of *Vega* is positive and highly significant at less than the 1% level in models 5 and 6, and, though insignificant in model 7, becomes positively significant in model 8 at the 10% level. In short, our results show that option-induced CEO risk-taking incentives have significantly positive impacts on a bank's contribution to systemic crash risk in three out of four models. We interpret this finding as evidence supporting H1. We find that the significantly positive coefficients of *Vega* are economically significant as well: For example, in model 5, a one standard deviation increase in *Vega* (2.000) leads to an increase in *ΔCoVaR5_stk* of 1.782, or 6.72%. In short, the results presented in models 5 to 8, taken together, suggest that the higher the option-induced CEO risk-taking incentives (*Vega*), the larger the bank's contribution to systemic crash risk.

With respect to the results for control variables in models 5 to 8, the following is apparent. First, the coefficients of *Bonus* are significantly negative in models 6 and 8. This finding is in line with the result of Balachandran et al. (2010) that CEO incentives induced from cash bonuses decrease the default risk of financial firms. Second, similar to the case in models 2 and 4, the coefficients of *Delta* are insignificant in models 6 and 8, suggesting that CEO *risk-averse* incentives, captured by *Delta*, have no significant effect on a bank's contribution to systemic crash risk. Finally, the results for the other controls are generally consistent with those reported by Adrian and Brunnermeier (2011) and Brunnermeier et al. (2011). Specifically, bank size *Size*, return volatility *Sigma*, and daily return kurtosis *Cokurt* are positively associated with a bank's contribution to systemic crash risk, while momentum *Mom* is inversely associated with it. The coefficients of the market-to-book ratio *Mb* and profitability *ROA* are positive when significant.

4.3 Channel Analyses: Do Non-Interest Income, Maturity Mismatch, and Financial Innovations Matter?

Our analyses thus far show that option-induced CEO risk-taking incentives are an important factor that exacerbates systemic distress risk and systemic crash risk in the banking industry. We now examine potential channels through which CEO risk-taking incentives increase a bank's contribution to systemic risk, as predicted in H2a to H2c. Tables 4 and 5 report the estimated results for OLS regressions in Eqs. (3) and (4). We first regress each of our channel variables on *Vega* and other variables, as specified in Eq. (3), and then regress systemic distress risk *(ΔCoVaR5_at*) or systemic crash risk (*ΔCoVaR5_stk*) on each of our channel variables, *Vega,* and other variables, as specified in Eq. (4). Table 4 reports the regression results for testing whether non-interest income *N2I* and maturity mismatch *Mismatch* act as the channel variable. Table 5 presents the estimation results of regressions using one of three financial innovations, that is, *Securitize, CDO,* or *CDS*, as the channel variable.

4.3.1 Do Non-Interest Income-Generating Activities Serve as a Mediating Channel?

Models 1 to 3 of Table 4 report the estimated results for non-interest income *N2I*. In model 1, where non-interest income *N2I* is regressed on option-induced CEO risk-taking incentives *Vega*, we find that *N2I* is significantly positively associated with *Vega*, significant at the 1% level. The finding is in line with evidence reported in related studies (Mehran and Rosenberg, 2007; Balachandran et al., 2010; DeYoung et al., 2010) and suggests that stock option compensation incentivizes bank CEOs to engage in non-interest income-generating activities that are generally riskier than the traditional interest income-generating business. In models 2 and 3, a bank's contributions to systemic distress risk and crash risk, captured by *ΔCoVaR5_at* and *ΔCoVaR5_stk*, respectively, are regressed on non-interest income *N2I* and CEO risk-taking incentives *Vega.* We find that the coefficients of *N2I* are positive and significant at the 5% and 10% levels, respectively. The finding suggests that as banks engage more actively in non-interest income-generating activities, their contributions to systemic distress risk and systemic crash risk tend to increase. This result is in line with the implications from previous related research (Chen et al., 2006; Mehran and Rosenberg, 2007; Brunnermeier et al., 2011). As shown in both models 2 and 3, *Vega* per se remains significantly positive, even after *N2I* is accounted for, suggesting that *N2I* is not the only mediating channel that affects the relation between CEO risk-taking incentives and systemic risk. In short, the results in models 1 to 3 of Table 4 are consistent with the view that non-interest income-generating activities serve as a channel through which CEO risk-taking incentives influence a bank's contribution to systemic distress and crash risks, which strongly supports H2a.

To further investigate potential sources for the mediating effect of non-interest income on the relation between CEO risk-taking incentives and systemic risk, we further decompose non-interest income *N2I* into three components: (i) trading income *T2I*, (ii) investment banking and venture capital income *V2I*, and (iii) other income *O2I*.[19] Untabulated results show that option-induced CEO risk-taking incentives, that is, *Vega*, lead to an increase in *T2I*, *V2I,* and *O2I* when using each of these three components as the dependent variable. Except for *T2I,* which has an insignificant coefficient, the variables *V2I*, *O2I,* and *Vega,* are significantly positively associated with systemic distress risk (*ΔCoVaR5_at*) and systemic crash risk (*ΔCoVaR5_stk*). These results demonstrate that option-induced CEO risk-taking incentives cause systemic risk to increase mainly via the part of non-interest income associated with investment banking and venture capital but not with trading income.

4.3.2 Does Maturity Mismatch Serve as a Mediating Channel?

Similar in format to models 1 to 3, models 4 to 6 of Table 4 present the OLS regression results for testing H2b, that maturity mismatch serves as a mediating channel through which option-induced CEO risk-taking incentives (captured by *Vega*) exacerbate both systemic distress risk and systemic crash risk. As shown in model 4, where *Vega* is regressed on *Mismatch*, the coefficient of *Vega* is positive and significant at the 5% level. The finding suggests that option-induced CEO risk-taking incentives encourage bank CEOs to maintain higher maturity mismatch (heavier use of short-term debt) and is in line with evidence reported in prior studies (Knopf et al., 2002; Chava and Purnanandam, 2010). As shown in models 5 and 6, the results of OLS regressions of systemic

[19] The definitions of each component of non-interest income *T2I*, *V2I,* and *O2I* are as follows: *T2I* proxies for trading income—which includes trading revenue, net securitization income, and the gain (loss) of loan sales and real estate sales—and is measured as the ratio of trading income to interest income; *V2I* proxies for investment banking and venture capital income—which includes investment banking and advisory fees, brokerage commissions, and venture capital revenue—and is measured as the ratio of investment banking and venture capital income to interest income; and *O2I* proxies for other income and is measured as the ratio of other income to interest income. Other income includes fiduciary income, deposit service charges, net servicing fees, service charges for safe deposit boxes and sales of money orders, rental income, credit card fees, gains on non-hedging derivatives, and so forth.

distress risk (*ΔCoVaR5_at*) and systemic crash risk (*ΔCoVaR5_stk*), respectively, on *Mismatch* and *Vega* show that the coefficient of *Mismatch* is significantly positive at the 1% level in model 5, but insignificantly positive in model 6. This finding is consistent with H2b, suggesting that the higher the maturity mismatch, the higher the bank's contribution to systemic risk. This result is in line with Diamond and Rajan's (2009) argument that an important cause for the recent financial crisis is that banks largely finance new real-estate-related financial instruments with short-term debt, which increases banks' contribution to systemic risk. Our result also corroborates the finding of Bleakley and Cowan (2010) that firms with short-term debts pay higher financing costs and tend to liquidate assets at fire sale prices during periods of capital outflows. In short, the evidence presented in models 4 to 6 of Table 4, taken together, indicates that maturity mismatch serves as a mediating channel through which option-induced CEO risk-taking incentives exacerbate a bank's contribution to systemic distress and crash risks, as hypothesized in H2b.

4.3.3 Does the Use of Innovative Financial Products Serve as a Mediating Channel?

Hypothesis H2c is concerned with whether and how a bank's involvement in innovative financial products serves as a mediating channel through which option-induced CEO risk-taking incentives exacerbate systemic distress risk and systematic crash risk. Table 5 reports the OLS regression results for testing H2c. Models 1 to 3 of Table 5 present the OLS regressions results for the asset securitization channel *Securitize*. Similarly, models 4 to 6 report those for the CDO channel *CDO*, while models 7 to 9 present those for the CDS channel *CDS*.

The estimation results in models 1, 4, and 7 show that the CEO risk-taking incentives captured by *Vega* are significantly positively associated with *Securitize*, *CDO*, and *CDS*, respectively. The OLS results in models 2 and 3 indicate that asset securitizations are significantly positively associated with systemic distress risk (*ΔCoVaR5_at*) and systemic crash risk (*ΔCoVaR5_stk*), respectively. This evidence, together with the result in model 1, suggests that asset securitizations act as a mediating channel through which option-induced CEO risk-taking incentives impact a bank's contribution to systemic distress risk and systemic crash risk. Similarly, the OLS results in models 5 and 6 and in models 8 and 9 indicate that a bank's use of CDOs and CDSs, respectively, significantly increases its contribution to systemic distress risk (*ΔCoVaR5_at* in models 5 and 8) and systemic crash risk (*ΔCoVaR5_stk* in models 6 and 9). These findings also suggest that CDOs and CDSs serve as mediating channels through which CEO risk-taking incentives exacerbate a bank's contribution to systemic (distress and crash) risk.

The above findings corroborate the criticism that the extensive usage of innovative financial products such as CDOs and CDSs contributed to the recent financial crisis through sharing default risk (Liu, 2010) or increasing counterparty risk and joint default risk (Hansel and Krahnen, 2007; Krahnen and Wilde, 2007; Biais et al., 2010). The results in Table 5 also strongly corroborate H2c, that option-induced CEO risk-taking incentives increase a bank's contribution to systemic risk through the channel of innovative financial products, such as asset securitization (particularly CDOs) and CDSs. Moreover, the results in models 2 and 3, 5 and 6, and 8 and 9 also clearly show that the coefficients of *Vega* remain significantly positive, even after the impact of each channel variable is accounted for, suggesting that these channels are not the only ones that mediate the relation between option-induced CEO risk-taking incentives and systemic (distress and crash) risk. Collectively, our results suggest that CEO stock option compensation coupled with a bank's usage of risky financial innovation products amplifies risk contagion, which could eventually trigger an economy-wide financial crisis.

4.4 Decomposition of CEO Risk-Taking Incentives

Previous research argues that CEOs' unrestricted options to cash out equity contribute to excessive short-termism (Bebchuk and Spamann, 2010), whereas restricted stock options help to mitigate excessive risk taking (Romano and Bhagat, 2009). We now test whether the impact of option-induced CEO risk-taking incentives differ systematically, depending on whether options in the compensation contracts are newly awarded or were previously granted. For this purpose, we decompose option-induced CEO risk-taking incentives *Vega* into those induced from new option grants, *Vega_awards,* and those induced from previous option grants, *Vega_old*, and then estimate our main regression in Eq. (2) after replacing *Vega* with *Vega_awards* and *Vega_old*.

Table 6 presents the results of OLS regressions. Across models 1, 3, 5, and 7, we find that CEO risk-taking incentives induced from the sum of previous exercisable and unexercisable option grants, *Vega_old*, is significantly positively associated with a bank's contributions to systemic distress risk (*ΔCoVaR5_at* and *ΔCoVaR_at*) and systemic crash risk (*ΔCoVaR5_stk* and *ΔCoVaR_stk*).[20] In contrast, models 2, 4, 6, and 8 show that CEO risk-taking incentives induced from new option grants, *Vega_awards*, is generally insignificantly associated with systemic risk measures, except for model 4, where its coefficient is weakly significant (t = 1.82). The above results suggest that the impacts of CEO risk-taking incentives on exacerbating systemic risk are mainly driven by previous option grants. Newly awarded options, in fact, do not significantly impact the risk contagion effects of CEO risk-taking incentives because they are more restrictive by nature, which is consistent with our predictions. Overall, the results in Table 6 provide the useful policy implication that the use of stock option compensation should be constrained if the policy objective is to control systemic (distress and crash) risk in the economy in general and the banking sector in particular.

[20] Since *Vega_awards* and *Vega_old* are highly correlated, with a Pearson correlation of 0.640, we regress systemic risk measures on *Vega_awards* or *Vega_old* separately rather than on both simultaneously to avoid multicollinearity. In addition, we decompose previous option grants *Vega_old* into exercisable and unexercisable option grants and find that both are still positively associated with a bank's contribution to systemic distress risk and systemic crash risk.

5. Further Analyses and Robustness Checks

5.1 Moderating Effects of Bank Size and Information Transparency

Some bank characteristics, such as bank size and information transparency, affect the relation between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk. Bank businesses are complex by nature and are subject to relatively high information opaqueness and asymmetries between insiders and outside stakeholders (Morgan, 2002). This information problem about complex business operations and high agency costs (e.g., relatively high cost of monitoring banks by outside stakeholders) tends to precipitate the contagion of bank distress risk and crash risk among banks or their transmission to other banks in the banking sector (Jacklin and Bhattacharya, 1988; Caballero and Simsek, 2009). Hence we expect the positive relation between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk to be more pronounced when banks are faced with lower information transparency.

How does bank size, which can be a proxy for information transparency, or the inverse of information opaqueness, moderate the positive relation between the two? On the one hand, analysts, institutional investors, the media, and other monitoring parties prefer to follow or monitor larger banks and thus contribute to their more timely and comprehensive information discovery process (Cheng et al., 2011). This finding suggests that larger banks have lower information opaqueness and stronger external monitoring and thus mitigates the effects of option-induced CEO risk-taking incentives on exacerbating a bank's contribution to systemic risk. On the other hand, larger banks also engender so-called too-big-to-fail effects.[21] Implicit government bailout creates moral hazard problems and increases bank risk, especially maturity mismatch, which in turn exacerbates a bank's contribution to systemic risk (Duchin and Sosyura, 2011; Dam and Koetter, 2012; Farhi and Tirole, 2012). Meanwhile, bank creditors have few incentives to monitor excessive CEO risk taking (John et al., 2000, 2010). As a result, the too-big-to-fail effect is likely to enhance the risk contagion effects of option-induced CEO risk taking. The net effect of bank size is thus unclear and should depend on which effect, the information effect or the too-big-to-fail effect, is dominant.

We measure information opaqueness, or the lack of information transparency, by analyst forecast dispersion *Disp* and bid–ask spread *Hlspread*.[22] Table 7 reports the OLS regression results on the moderating effects of bank size and information opaqueness. As shown in models 1 and 4, the interaction term, *Vega*Size*, is significantly negatively associated with *ΔCoVaR5_at* and

[21] Considering the vulnerability of the banking industry to contagious bank runs and the importance of the banking sector to the whole economy (Levine, 1997, 2004), governments provide an implicit too-big-to-fail regulatory guarantee to make banks more credible to depositors in the case of a financial crisis (O'Hara and Shaw, 1990).

[22] See Appendix A for the exact definitions of *Disp* and *Hlspread*.

ΔCoVaR5_stk. This means that the impact of option-induced CEO risk-taking incentives on increasing a bank's contribution to systemic risk is less prominent for larger banks than for smaller banks.

Models 2 and 3 show that the coefficients of *Vega*Disp* and *Vega*Hlspead* are both insignificant. However, models 5 and 6 show that the coefficients of *Vega*Disp* and *Vega*Hlspread* are positively and highly significant at less than the 1% level. This finding suggests that in an environment of higher information uncertainty, the impact of CEO risk-taking incentives on a bank's contribution to systemic risk is more pronounced. Stated another way, the improved transparency mitigates the risk contagion effects of CEO risk-taking incentives. Consistent with our expectations and the notion that information opaqueness increases systemic risk (Jones et al., 2012), we find that the two information uncertainty measures per se, *Disp* and *Hlspread*, are significantly positively associated with a bank's contribution to systemic crash risk, as shown in models 5 and 6, respectively.

5.2 Moderating Effects of Market Illiquidity and Financial Crisis

In this section, we further examine whether market illiquidity and financial crisis moderate the relation between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk. We expect that market illiquidity strengthens the positive relation between option-induced CEO risk-taking incentives and a bank's contribution to systemic risk. When the capital market is more illiquid, asset sales have greater impacts on short-run price (Amihud, 2002). Adrian and Shin (2010) and Longstaff (2010) show that during the financial crisis of 2008–2009, market illiquidity operated as a risk contagion channel, especially for subprime asset-backed CDOs. The evidence suggests that market illiquidity accentuates the effects of CEO risk-taking incentives on exacerbating risk contagion.

In contrast, the moderating effect of a financial crisis is more subtle. Financial crisis reduces the wealth of risk-averse CEOs (Fahlenbrach and Stulz, 2011) and thus weakens their option-induced risk-taking incentives (Carpenter, 2000; Ross, 2004). A crisis also renders most stock options out of the money and directly reduces their incentive power. A counterargument maintains that crisis can still breed excessive CEO risk taking because option devaluation during a crisis reduces possible CEO losses from bets and thus induces CEOs to conduct highly risky investments to obtain more private gains. Further, increased market illiquidity in crisis times also magnifies the risk contagion effects of option-induced CEO risk-taking incentives.

We measure market illiquidity by the bond market illiquidity, *Repo,* and the stock market illiquidity, *Mktilliq*, and use an indicator variable, *Crisis,* to proxy for the financial crisis of 2008–2009. Table 8 reports the OLS regression results. The interaction terms *Vega*Crisis*, *Vega*Repo*, and *Vega*Mktilliq* are added one by one, along with *Crisis*, *Repo*, and *Mktilliq*, respectively. The coefficients of *Vega*Repo* and *Vega*Mktilliq* are insignificant in models 2 and 3. We find, however, that the same coefficients are both significant and positive in models 5 and 6, suggesting that in an environment of higher market illiquidity, the positive impact of option-induced CEO risk-taking incentives (captured by

Vega) on a bank's contribution to systemic crash risk (captured by ∆*CoVaR5_stk*) becomes more pronounced. In addition, we note that each of the market illiquidity measures per se, *Repo* and *Mktilliq*, has a positive impact on a bank's contribution to systemic crash risk. We interpret the above results in such a way that market illiquidity magnifies the positive relation between *Vega* and ∆*CoVaR5_stk* through accelerated risk contagion (Amihud, 2002; Adrian and Shin, 2010; Longstaff, 2010).

Although we have no directional prediction about the impacts of financial crisis, models 1 and 4 of Table 8 indicate that the coefficient of *Vega*Crisis* is positively significant, suggesting that the positive relation between CEO risk-taking incentives and a bank's contribution to systemic (distress and crash) risk was strengthened further during the financial crisis of 2008–2009. The results may have two causes: (i) risk contagion among banks with high CEO risk-taking incentives became stronger during the financial crisis, ceteris paribus and (ii) during the financial crisis, additional CEO risk-taking incentives induced by option devaluation dominated the reduced risk-taking incentives caused by diminished CEO wealth. These two factors contribute to a net increase in the impact of CEO risk-taking incentives on systemic risk contribution. Our analyses below provide additional insights into which cause is more important.

5.3 Reconciling Our Results with the Findings of Fahlenbrach and Stulz (2011)

Fahlenbrach and Stulz (2011) find that CEO risk-taking incentives before the financial crisis were not associated with bank performance during the financial crisis. In contrast, we find that option-induced CEO risk-taking incentives lead to an increase in a bank's contribution to systemic risk. Does our finding contradict that of Fahlenbrach and Stulz (2011)? Note that our study focuses on the effect of CEO risk-taking incentives on sector-wide systemic risk, whereas Fahlenbrach and Stulz (2011) examine their association with bank-level performance in crisis times, which does not necessarily spill over to the banking sector. To reconcile our study with that of Fahlenbrach and Stulz (2011), we examine the associations of lagged CEO risk-taking incentives, *Vega*, with future four-quarter-ahead bank performance, *ROA*, and bank-level crash risk, *VaR_stk*, in the crisis period, the non-crisis period, and the whole sample period. Table 9 reports the regression results.

In models 1 to 4 of Table 9, we regress bank performance, *ROA*, on option-induced CEO risk-taking incentives, *Vega*, with the results for the whole sample reported in models 1 and 2, those for the crisis period in model 3, and those for the non-crisis period in model 4. The CEO risk-taking incentives *Vega* are positively associated with *ROA* and the association is significant at the 10% level in models 1 and 4, though it is insignificant in the crisis period (model 3). This finding suggests that CEO risk-taking incentives increase bank performance in non-crisis times (model 4) but not in crisis times (model 3). The coefficient of the interaction term, *Vega*Crisis*, is positive but insignificant in model 2, reconfirming the result using the subsample in the crisis period (model 3). The above evidence is consistent with the results of Fahlenbrach and Stulz (2011) but, unlike these authors, we interpret that option-induced CEO risk-taking incentives lose their incentive effect on bank performance during the crisis period, in which option holdings are generally out of the money, and CEO risk aversion increases with the shrinkage of CEO wealth.

Models 5 to 8 in Table 9 report the regression results of the bank-specific crash risk measure, *VaR_stk*, on CEO risk-taking incentives (*Vega*) for the whole sample in models 5 and 6, for the crisis period in model 7, and for the non-crisis period in model 8. As shown in models 5 to 8, the coefficient of *Vega* is significantly positive across all models, suggesting that CEO risk-taking incentives increase bank-level crash risk in both the non-crisis and crisis periods. However, the coefficient of *Vega*Crisis* is insignificant (model 6), implying that crisis does not aggravate the relation between CEO risk-taking incentives and bank-level crash risk. The above results, combined with the results in models 1 and 4 in Table 8, suggest that during financial crisis, the magnified relation between CEO risk-taking incentives and systemic risk contribution is mainly driven by increased sector-wide risk contagion rather than increased bank-specific risk.

In short, when bank-specific performance, *ROA*, and bank-specific crash risk, *VaR_stk*, are regressed against lagged CEO risk-taking incentives, we obtain results qualitatively identical to those reported by Fahlenbrach and Stulz (2011). The results in Table 9, along with those in Table 8, also indicate that option-induced CEO risk-taking incentives increase a bank's contribution to sector-wide systemic risk and bank-specific risks and the financial crisis of 2008–2009 intensified the effect of CEO risk-taking incentives on a bank's contribution to systemic risk mainly through magnifying risk contagion.

5.4 Endogeneity of Option-Induced CEO Risk-Taking Incentives

The use of lagged CEO *Vega* and *Delta* in Eqs. (2) and (3), respectively, helps us alleviate, but does not purge, potential endogeneity with respect to option-induced CEO risk-taking incentives that arises from the joint determination of CEO risk-taking incentives and systemic risk or a channel variable. We employ a two-stage least squares (2SLS) instrumental variable (IV) regression method to address this endogeneity issue. Specifically, we use CEO tenure, free cash flow, and firm age as IVs for option-induced CEO risk-taking incentives, *Vega,* and option-induced risk-averse incentives, *Delta*, since they impact CEO option compensation and do not directly affect systemic risk or channel variables (Core and Guay, 1999; Coles et al., 2006). The regression results are reported in Table 10.

As shown in models 1 and 2 of Table 10, we find that the CEO risk-taking incentives *Vega* predicted by these IVs continue to have a positive and significant impact on a bank's contribution to systemic distress risk and systemic crash risk. Models 3 to 7 confirm that *Vega* is still significantly and positively associated with non-interest income (*N2I*), maturity mismatch (*Mismatch*), and innovative financial products (*Secure*, *CDO*, and *CDS*), respectively, consistent with previously reported results. We conduct *F*-tests of the excluded exogenous variables in the first-stage IV regression that reject the null hypothesis that the IVs do not explain differences in *Vega* and *Delta* at the 1% level in all model specifications. We also conduct Sargan (1958) and Basmann (1960) tests of over-identifying restrictions (OIR) for the IVs. We find that the OIR tests do not reject the null hypotheses that these IVs are uncorrelated with the residuals and thus confirm their validity. In short, the results reported in Table 10 suggest that our main results are unlikely to be driven by potential endogeneity in the relation between option-induced CEO risk-taking incentives or channel variables and a bank's contribution to systemic (distress and crash) risk.

5.5 Alternative Measures for Option-Induced CEO Risk-Taking Incentives

We alternatively measure CEO risk-taking incentives using excessive option-induced incentives, beyond a desired level, denoted *ABVega*, following Core and Guay (1999) and Kim et al. (2011). Specifically, we measure *ABVega* using the residual estimated from an OLS regression of *Vega* on the market value of equity, idiosyncratic risk, the market-to-book ratio of the bank, CEO tenure, free cash flow, and year and quarter dummies. Using *ABVega* instead of *Vega*, we re-examine the baseline model in Eq. (2) and report the estimated results in Table 11. As shown in models 1 and 2, *ABVega* continues to be significantly positively associated with contribution to systemic distress risk and systemic crash risk, reconfirming our previous results.

5.6 Alternative Measures for a Bank's Contribution to Systemic Risk

To check whether our results are robust to the use of alternative measures for a bank's contribution to systemic risk, we consider *MES* in Acharya et al. (2010), as well as *SRISK* and *%SRISK* in Acharya et al. (2012a) as alternative measures of a bank's contribution to systemic risk. Although these alternative measures focus on a bank's exposures to the financial crisis rather than the bank's negative externalities to the financial sector, they can also gauge contributions to systemic risk when many banks endure substantial losses simultaneously.

Using these measures, we run the baseline regression in Eq. (2) to re-examine the relation between CEO risk-taking incentives and a bank's contribution to systemic distress and crash risks. As shown in models 3 to 5 of Table 11, the coefficients of *Vega* are positive and highly significant across all three models with *MES*, *SRISK,* and *%SRISK*, respectively, as the dependent variable. In short, our earlier results remain qualitatively unchanged and are robust to the use of *MES*, *SRISK,* and *%SRISK* as alternative measures of systemic risk.

6. Conclusion

This study examines the relation between CEO risk-taking incentives induced by stock option compensation and a bank's contribution to systemic risk for a sample of U.S. BHCs and commercial banks for the period 1992–2009. We find that option-induced CEO risk-taking incentives are positively associated with a bank's contribution to systemic distress risk and systemic crash risk, consistent with the argument that CEOs' risk-taking incentives motivate them to engage in and herd in risky business activities, which increases distress and crash risks in individual banks and amplifies risk spillover and contagion to other banks. We also find that non-interest income-generating activities, maturity mismatch, and innovative financial products, including asset securitizations (particularly CDOs) and CDSs, act as mediating channels for the positive relation between CEO risk-taking incentives and a bank's contribution to systemic risk. Moreover, we find that CEO risk-taking incentives induced from previous (new) option grants are positively (weakly) associated with a bank's contribution to systemic risk, in line with the notion that the freedom (restriction) of cashing out on stock options encourages (confines) excessive CEO risk taking that increases systemic risk. Further analysis reveals that information opaqueness, market illiquidity, and financial crisis amplify this positive relation, whereas bank size mitigates it. The results are robust to potential endogeneity, alternative measures of option-induced CEO risk-taking incentives, and alternative systemic risk measures.

This study contributes to the literature on executive compensation and financial crisis by documenting original and strong evidence on the impact of CEO risk-taking incentives induced by stock option compensation on a bank's contribution to sector-wide systemic risk. The evidence also extends previous studies connecting managerial incentives to bank-specific performance and risk and sheds additional light on the role of CEO option-based compensation schemes in systemic risk contagion and financial crisis. Evidence reported in this study has immediate policy implications for compensation reform in the post-crisis era and recommends the usage of more restrictive stock option compensation plans for CEOs.

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Table 1. Descriptive Statistics

This table reports summary statistics for the variables in this study. The variables *Delta (raw), Vega (raw), Vega_awards (raw),* and *Vega_old (raw)* are the original values of *Delta, Vega, Vega_awards,* and *Vega_old,* respectively, denominated in hundreds of thousands of dollars. The variables *Size* and *Sizemv (raw)* are denominated in billions of dollars. The detailed definitions for all the variables are provided in Appendices A and B.

Variable Name	Mean	Median	STD	Q1	Q3
ΔCoVaR5_at (%)	22.296	19.155	16.096	11.671	28.594
ΔCoVaR_at (%)	27.074	21.651	23.473	11.783	35.548
ΔCoVaR5_stk (%)	26.530	22.678	15.374	16.994	31.698
ΔCoVaR_stk (%)	39.931	34.037	24.091	24.428	48.799
MES (%)	2.857	1.928	2.640	1.271	3.158
SRISK	-3.015	-2.997	8.978	-9.338	-0.191
%SRISK	0.025	0.001	0.104	0.000	0.007
Vega (raw)	0.995	0.061	11.309	0.020	0.281
Vega_awards (raw)	0.212	0.001	7.577	0.000	0.004
Vega_old (raw)	0.754	0.059	6.367	0.019	0.264
ABVega	0.000	0.089	1.569	-0.877	0.905
Delta (raw)	434.824	96.865	1952.569	31.525	267.134
Bonus (%)	34.513	37.626	27.807	0.000	54.811
N2I (%)	41.872	30.374	44.072	19.084	46.691
Mismatch (%)	7.438	4.916	7.741	3.083	8.559
Securitize	3.470	0.000	6.452	0.000	0.000
CDO	0.120	0.000	1.264	0.000	0.000
CDS	0.709	0.000	3.306	0.000	0.000
VaR_at	11.605	9.154	7.871	6.609	13.428
VaR_stk	0.126	0.101	0.078	0.076	0.150
Sigma (%)	36.483	26.695	28.571	20.152	40.250
Cokurt	3.499	2.709	3.461	2.039	3.746
CAPR (%)	9.162	9.535	4.014	7.960	11.360
ROA (%)	0.279	0.313	0.281	0.228	0.386
LLA (%)	0.996	0.927	0.554	0.724	1.180
Leverage	0.099	0.080	0.086	0.034	0.143
Mb	2.113	1.972	1.044	1.444	2.638
Size	0.750	0.118	2.289	0.056	0.488
Size_sqr	5.800	0.014	36.580	0.003	0.238
Repo	0.332	0.279	0.323	0.075	0.529
3M	0.005	0.000	0.101	-0.019	0.055
Mom	0.043	0.048	0.223	-0.067	0.161
Sizemv (raw)	1.07	0.20	2.72	0.09	077
Nim	3.698	3.860	1.256	3.220	4.450
Disp	0.034	0.013	0.062	0.010	0.029
Hlspread (%)	0.783	0.597	0.587	0.414	0.892
Mktilliq	-0.238	-0.162	0.194	-0.349	-0.092

Table 2. Correlation Matrix for the Main Testing Variables and Bank Risk Measures

Panel A reports the Pearson correlations for the main testing variables in this study and Panel B reports them for various bank risk measures. The superscript * indicates that a Pearson correlation is statistically significant at the 1% confidence level. Detailed definitions are provided in Appendices A and B.

Panel A. Correlation Matrix for the Main Testing Variables

	ΔCoVaR5_ at	*ΔCoVaR_at*	*ΔCoVaR5_stk*	*ΔCoVaR_stk*	*Vega*	*Vega_old*	*Vega_awards*	*N2I*	*Mismatch*	*Securitize*	*CDO*	*CDS*
ΔCoVaR5_at	1											
ΔCoVaR_at	0.796*	1										
ΔCoVaR5_stk	0.714*	0.498*	1									
ΔCoVaR_stk	0.658*	0.486*	0.898*	1								
Vega	0.114*	0.097*	0.150*	0.112*	1							
Vega_old	0.103*	0.087*	0.129*	0.087*	0.892*	1						
Vega_awards	-0.026	-0.014	-0.028	-0.026	0.803*	0.640*	1					
N2I	0.189*	0.205*	0.109*	0.117*	0.334*	0.272*	0.110*	1				
Mismatch	0.196*	0.319*	0.089*	0.109*	0.193*	0.118*	0.025	0.459*	1			
Securitize	0.143*	0.055*	0.157*	0.129*	0.399*	0.353*	0.075*	0.364*	0.072*	1		
CDO	0.088*	0.016	0.226*	0.224*	0.052*	0.019	-0.004	0.002	0.046	0.166*	1	
CDS	0.053*	0.008	0.191*	0.206*	0.065*	0.033	-0.007	0.009	0.098*	0.217*	0.776*	1

Panel B. Correlation Matrix for the Bank Risk Measures

	ΔCoVaR5_at	*ΔCoVaR_at*	*ΔCoVaR5_stk*	*ΔCoVaR_stk*	*MES*	*SRISK*	*%SRISK*	*Sigma*	*Beta*	*VaR_at*	*VaR_stk*	*Z-Score*
ΔCoVaR5_at	1											
ΔCoVaR_at	0.796*	1										
ΔCoVaR5_stk	0.714*	0.498*	1									
ΔCoVaR_stk	0.658*	0.486*	0.898*	1								
MES	0.532*	0.418*	0.604*	0.563*	1							
SRISK	0.123*	0.073*	0.239*	0.247*	0.341*	1						
%SRISK	0.260*	0.196*	0.319*	0.281*	0.466*	0.280*	1					
Sigma	0.503*	0.386*	0.661*	0.613*	0.273*	0.423*	0.751*	1				
Beta	0.250*	0.195*	0.252*	0.238*	0.255*	0.342*	0.654*	0.406*	1			
VaR_at	0.368*	0.298*	0.321*	0.323*	0.320*	0.471*	0.806*	0.662*	0.531*	1		
VaR_stk	0.402*	0.339*	0.413*	0.409*	0.317*	0.470*	0.774*	0.611*	0.542*	0.977*	1	
Z-Score	-0.025	-0.016	-0.078*	-0.074*	-0.250*	-0.567*	-0.310*	-0.308*	-0.182*	-0.274*	-0.301*	1

Table 3. Relations between Option-Induced CEO Risk-Taking Incentives and a Bank's Contribution to Systemic Distress Risk and Systemic Crash Risk

This table presents the OLS estimation results of regressing a bank's contribution to the systemic distress risk measure *ΔCoVaR5_at* or *ΔCoVaR_at* and a bank's contribution to the systemic crash risk measure *ΔCoVaR5_stk* or *ΔCoVaR_stk* against the lagged measure for CEO risk-taking incentives induced from the stock option compensation *Vega*, other CEO incentive measures *Delta* and *Bonus*, and other control variables. Models 1 and 2 use *ΔCoVaR5_at* as a dependent variable, models 3 and 4 use *ΔCoVaR_at* as a dependent variable, models 5 and 6 use *ΔCoVaR5_stk* as a dependent variable, and models 7 and 8 use *ΔCoVaR_stk* as a dependent variable. The *t*-statistics are adjusted for bank-level clusters, model details are provided in Eq. (2) in the text, and variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	*ΔCoVaR5_at*		*ΔCoVaR_at*		*ΔCoVaR5_stk*		*ΔCoVaR_stk*	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$Vega_{i,t-1}$	1.162***	0.995**	1.911***	1.718***	0.891***	1.044***	0.480	0.869*
	(3.14)	(2.55)	(3.56)	(2.74)	(3.57)	(3.57)	(1.08)	(1.79)
$Delta_{i,t-1}$		0.144		0.176		-0.094		-0.034
		(0.39)		(0.32)		(-0.37)		(-0.09)
$Bonus_{i,t-1}$		-0.010		0.009		-0.067***		-0.138***
		(-0.34)		(0.17)		(-3.26)		(-3.03)
$Leverage_{i,t-1}$	2.751	2.913	8.208	8.800	12.672*	12.902*	18.370	22.980
	(0.25)	(0.25)	(0.51)	(0.55)	(1.84)	(1.72)	(1.24)	(1.62)
$Size_{i,t-1}$	2.137*	2.239*	-1.030	-1.084	4.047***	4.792***	6.929***	8.343***
	(1.66)	(1.72)	(-0.73)	(-0.72)	(4.10)	(4.60)	(5.34)	(6.47)
$Size\_sqr_{i,t-1}$	-0.164**	-0.168**	-0.035	-0.031	-0.206***	-0.247***	-0.303***	-0.383***
	(-2.08)	(-2.11)	(-0.40)	(-0.34)	(-2.80)	(-3.27)	(-3.23)	(-4.13)
$ROA_{i,t-1}$	1.239	1.102	-4.453	-4.760	5.267**	5.683**	5.360	6.949*
	(0.53)	(0.47)	(-1.27)	(-1.31)	(2.18)	(2.29)	(1.45)	(1.92)
$Mb_{i,t-1}$	1.279	1.425	2.616*	2.655*	0.497	0.866	2.123*	3.043**
	(1.37)	(1.50)	(1.71)	(1.71)	(0.68)	(1.08)	(1.90)	(2.49)
$Loan_{i,t-1}$	-4.227	-4.068	-32.141*	-31.922				
	(-0.61)	(-0.57)	(-1.67)	(-1.65)				
$Sigma_{i,t-1}$	0.351***	0.342***	0.371***	0.368***	0.249***	0.250***	0.373***	0.394***
	(8.44)	(8.72)	(6.35)	(6.47)	(5.92)	(5.72)	(5.30)	(5.52)
$Mom_{i,t-1}$					-6.886***	-6.778***	-6.989**	-6.253**
					(-4.21)	(-4.24)	(-2.45)	(-2.15)
$Cokurt_{i,t-1}$					0.503***	0.527***	0.551*	0.602**
					(2.79)	(3.00)	(1.90)	(2.13)
Intercept	15.438***	14.643***	37.371***	35.594***	7.156**	9.277***	5.845	8.989*
	(3.11)	(2.73)	(3.18)	(2.84)	(2.19)	(2.94)	(1.20)	(1.82)
Year and Quarter Dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bank-Specific Cluster	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	2,034	2,019	2,034	2,019	2,223	2,191	2,223	2,191
R-Squared	0.439	0.432	0.342	0.338	0.643	0.644	0.566	0.579

Table 4. Mediating Effects of Non-Interest Income and Mismatch on Relations between Option-Induced CEO Risk-Taking Incentives and a Bank's Contribution to Systemic Distress and Crash Risks

This table presents the OLS estimation results of testing whether non-interest income *N2I* and maturity mismatch *Mismatch* act as mediating channels for relations between the option-induced CEO risk-taking incentives *Vega* and a bank's contribution to systemic distress risk and crash risk *ΔCoVaR5_at* and *ΔCoVaR5_stk*, respectively. Models 1 to 3 present the results for the OLS regressions that regress *N2I* on lagged *Vega* and other controls in model 1 and that regress *ΔCoVaR5_at* and *ΔCoVaR5_stk* on lagged *N2I*, lagged *Vega,* and other controls in models 2 and 3, respectively. Models 4 to 6 present the OLS regression results that regress *Mismatch* on lagged *Vega* and other controls in model 4 and that regress *ΔCoVaR5_at* and *ΔCoVaR5_stk* on lagged *Mismatch*, lagged *Vega,* and other controls in models 5 and 6, respectively. The *t*-statistics are adjusted for bank-level clusters, model details are provided in Eqs. (3) and (4) in the text, and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	Non-interest income			Mismatch		
	N2I	***ΔCoVaR5_at***	***ΔCoVaR5_stk***	**Mismatch**	***ΔCoVaR5_at***	***ΔCoVaR5_stk***
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
$Vega_{i,t-1}$	3.421***	0.790**	0.944***	0.337**	0.814**	1.020***
	(2.71)	(2.07)	(3.09)	(2.02)	(2.14)	(3.46)
$N2I_{i,t-1}$		0.053**	0.020*			
		(2.11)	(1.69)			
$Mismatch_{i,t-1}$					0.468***	0.071
					(4.20)	(0.78)
$Delta_{i,t-1}$	1.026	0.099	-0.047	0.106	0.104	-0.100
	(1.44)	(0.27)	(-0.17)	(0.66)	(0.28)	(-0.39)
$Bonus_{i,t-1}$	0.158	-0.021	-0.062***	0.050***	-0.031	-0.069***
	(1.38)	(-0.73)	(-3.24)	(2.84)	(-1.07)	(-3.39)
$Leverage_{i,t-1}$	66.324	-1.347	15.554*		4.735	13.839*
	(1.10)	(-0.12)	(1.87)		(0.42)	(1.88)
$Size_{i,t-1}$	-0.185	2.215*	4.598***	-0.541	2.328*	4.703***
	(-0.04)	(1.73)	(4.53)	(-0.98)	(1.88)	(4.44)
$Size\_sqr_{i,t-1}$	-0.190	-0.157**	-0.237***	0.021	-0.167**	-0.243***
	(-0.86)	(-2.04)	(-3.24)	(0.83)	(-2.21)	(-3.19)
$ROA_{i,t-1}$	42.187*	-0.341	3.775	-1.488	2.180	5.812**
	(1.81)	(-0.13)	(1.40)	(-1.14)	(1.00)	(2.39)
$Mb_{i,t-1}$	8.467***	1.007	0.767		1.214	0.771
	(2.64)	(1.02)	(0.89)		(1.42)	(0.99)
$Loan_{t-1}$	-129.266**	3.004		-31.199***	11.453*	
	(-2.44)	(0.42)		(-3.57)	(1.80)	
$Sigma_{i,t-1}$		0.328***	0.296***		0.327***	0.247***
		(8.28)	(8.54)		(8.51)	(5.58)
$CAPR_{i,t-1}$	-0.256			0.035		
	(-0.33)			(0.26)		
$Nim_{i,t-1}$	-4.902**			-0.662		
	(-2.19)			(-1.16)		
$LLA_{i,t-1}$	4.628					
	(1.07)					
$Mom_{i,t-1}$			-6.356***			-6.884***
			(-3.58)			(-4.28)
$Cokurt_{i,t-1}$			0.394***			0.514***
			(2.79)			(2.88)
$3M_{i,t-1}$				-1.998***		
				(-3.67)		
$Repo_{i,t-1}$				1.570		
				(0.03)		
Intercept	80.973**	9.947*	9.419***	28.215***	1.161	9.037***
	(2.43)	(1.79)	(2.95)	(4.87)	(0.19)	(2.85)
Year and Quarter Dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bank-Specific Cluster	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	1,954	2,019	2,007	2,014	2,019	2,191
R-Squared	0.398	0.447	0.660	0.439	0.465	0.645

Table 5. Mediating Effects of Innovative Financial Products on Relations between Option-Induced CEO Risk-Taking Incentives and a Bank's Contribution to Systemic Distress and Crash Risks

This table presents the OLS estimation results of examining whether innovative financial products such as asset securitization *Securitize,* CDOs *CDO*, and CDSs *CDS* act as channels for relations between option-induced CEO risk-taking incentives *Vega* and a bank's contribution to systemic distress risk and crash risk measures *ΔCoVaR5_at* and *ΔCoVaR5_stk*. Models 1 to 3 present the results for the OLS regressions that regress *Securitize* on lagged *Vega* and other controls in model 1 and that regress *ΔCoVaR5_at* and *ΔCoVaR5_stk* on lagged *Securitize*, lagged *Vega,* and other controls in models 2 and 3, respectively. Models 4 to 6 present the results for the OLS regressions that regress *CDO* on lagged *Vega* and other controls in model 4 and that regress *ΔCoVaR5_at* and *ΔCoVaR5_stk* on lagged *CDO*, lagged *Vega,* and other controls in models 5 and 6, respectively. Models 7 to 9 present the results for the regressions that regress *CDS* on lagged *Vega* and other controls in model 7 and that regress *ΔCoVaR5_at* and *ΔCoVaR5_stk* on lagged *CDS*, lagged *Vega,* and other controls in models 8 and 9, respectively. The *t*-statistics are adjusted for bank-level clusters, model details are provided in Eqs. (3) and (4) in the text, and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variables	*Securitize*	*Securitize ΔCoVaR5 _at*	*ΔCoVaR5 _stk*	*CDO*	*CDO ΔCoVaR5 _at*	*ΔCoVaR5 _stk*	*CDS*	*CDS ΔCoVaR5 _at*	*ΔCoVaR5_stk*
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
$Vega_{i,t-1}$	0.499***	0.780**	0.925***	0.076***	0.876**	0.848***	0.199***	0.842**	0.800***
	(2.832)	(2.05)	(3.10)	(2.68)	(2.29)	(2.96)	(3.13)	(2.23)	(2.85)
$Securitize_{i,t-1}$		0.417***	0.193*						
		(3.06)	(1.90)						
$CDO_{i,t-1}$					1.653**	2.459***			
					(2.24)	(6.71)			
$CDS_{i,t-1}$								0.829**	1.234***
								(2.38)	(6.54)
$Delta_{i,t-1}$	0.155	0.089	-0.054	-0.011	0.142	-0.032	-0.006	0.144	-0.031
	(1.41)	(0.26)	(-0.21)	(-1.16)	(0.39)	(-0.12)	(-0.25)	(0.39)	(-0.12)
$Bonus_{i,t-1}$	0.021*	-0.018	-0.061***	-0.005*	-0.005	-0.049**	-0.012**	0.007	-0.032*
	(1.65)	(-0.63)	(-3.13)	(-1.91)	(-0.16)	(-2.53)	(-2.22)	(0.21)	(-1.70)
$Leverage_{i,t-1}$	10.222**	-1.922	14.033	1.485**	1.692	14.538*	2.659*	1.609	14.741*
	(2.14)	(-0.17)	(1.65)	(2.35)	(0.16)	(1.85)	(1.84)	(0.15)	(1.97)
$Size_{i,t-1}$	1.719***	1.502	4.357***	-0.296	2.869**	5.622***	0.101	2.188**	4.587***
	(2.76)	(1.23)	(4.59)	(-1.49)	(2.23)	(7.01)	(0.24)	(2.07)	(6.68)
$Size\_sqr_{i,t-1}$	-0.059	-0.142**	-0.233***	0.044***	-0.248***	-0.364***	0.038	-0.197***	-0.288***
	(-1.48)	(-2.04)	(-3.41)	(2.63)	(-2.74)	(-6.85)	(1.29)	(-2.92)	(-5.87)
$ROA_{i,t-1}$	1.689	0.444	3.271	0.102	0.430	2.530	0.190	0.304	2.342
	(1.47)	(0.18)	(1.36)	(0.83)	(0.19)	(1.13)	(0.45)	(0.12)	(1.04)
$Mb_{i,t-1}$	-1.025***	1.849**	1.250	-0.038	1.547*	1.215	-0.047	1.446	1.046
	(-3.79)	(2.07)	(1.39)	(-0.77)	(1.67)	(1.42)	(-0.39)	(1.58)	(1.26)
$Loan_{t-1}$	0.551	-4.154		-0.497	-3.937		-1.304	-3.418	
	(0.18)	(-0.62)		(-1.36)	(-0.56)		(-1.36)	(-0.52)	
$Sigma_{i,t-1}$		0.341***	0.301***		0.325***	0.275***		0.318***	0.266***
		(8.62)	(8.95)		(8.41)	(8.89)		(8.30)	(8.57)
$CAPR_{i,t-1}$	-0.009			0.001			0.005		
	(-0.11)			(0.05)			(0.23)		
$Nim_{i,t-1}$	-0.102			0.081			0.055		
	(-0.40)			(1.51)			(0.49)		
$LLA_{i,t-1}$	-0.280			0.165*			0.110		
	(-0.46)			(1.78)			(0.60)		
$Mom_{i,t-1}$			-6.842***			-6.630***			-6.707***
			(-3.99)			(-3.88)			(-4.06)
$Cokurt_{i,t-1}$			0.415***			0.430***			0.409***
			(2.95)			(2.96)			(2.86)
Intercept	1.147	14.261***	8.950***	0.630**	14.063***	8.074***	1.836**	13.920***	8.803***
	(0.43)	(2.785)	(2.84)	(2.05)	(2.71)	(2.67)	(2.12)	(2.74)	(2.85)
Quarter Dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bank - Specific Clusters	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	2,013	2,019	2,011	2,013	2,019	2,011	2,013	2,019	2,011
R-Squared	0.531	0.447	0.665	0.398	0.442	0.682	0.398	0.445	0.687

Table 6. Relations between the Components of Option-Induced CEO Risk-Taking Incentives and a Bank's Contribution to Systemic Distress and Crash Risks

This table presents the OLS estimation results of regressing a bank's contribution to systemic distress risk *ΔCoVaR5_at* or *ΔCoVaR_at* and to systemic crash risk *ΔCoVaR5_stk* or *ΔCoVaR_stk*, respectively, on the lagged components of CEO risk-taking incentives derived from previous option grants *Vega_old,* new option grants *Vega_awards*, and other control variables. Models 1 to 8 use *ΔCoVaR5_at*, *ΔCoVaR_at*, *ΔCoVaR5_stk,* and *ΔCoVaR_stk* as dependent variables, respectively. The *t*-statistics are adjusted for bank-level clusters, model details are provided in Eq. (2) in the text, and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	*ΔCoVaR5_at* Model 1	*ΔCoVaR5_at* Model 2	*ΔCoVaR_at* Model 3	*ΔCoVaR_at* Model 4	*ΔCoVaR5_stk* Model 5	*ΔCoVaR5_stk* Model 6	*ΔCoVaR_stk* Model 7	*ΔCoVaR_stk* Model 8
Vega_old$_{i,t-1}$	1.432***		2.256***		1.389***		1.463**	
	(2.99)		(2.77)		(3.52)		(2.19)	
Vega_awards$_{i,t-1}$		0.474		1.144*		0.371		-0.010
		(1.25)		(1.82)		(1.24)		(-0.02)
Delta$_{i,t-1}$	0.385	0.567	0.093	0.315	-0.006	0.180	-0.114	0.145
	(0.88)	(1.25)	(0.13)	(0.43)	(-0.02)	(0.51)	(-0.23)	(0.30)
Bonus$_{i,t-1}$	-0.001	0.011	0.078	0.090	-0.068**	-0.056**	-0.137***	-0.119**
	(-0.04)	(0.29)	(1.31)	(1.50)	(-2.62)	(-2.11)	(-2.72)	(-2.31)
Leverage$_{i,t-1}$	6.352	7.375	7.384	8.336	13.075	14.080	18.013	19.513
	(0.49)	(0.57)	(0.38)	(0.43)	(1.51)	(1.61)	(1.25)	(1.34)
Size$_{i,t-1}$	1.642	2.091	-2.671*	-2.119	4.313***	4.839***	7.733***	8.464***
	(1.19)	(1.46)	(-1.70)	(-1.32)	(4.01)	(4.11)	(4.99)	(4.97)
Size_sqr$_{i,t-1}$	-0.130	-0.153*	0.065	0.038	-0.211***	-0.238***	-0.335***	-0.372***
	(-1.60)	(-1.78)	(0.69)	(0.38)	(-2.88)	(-2.95)	(-3.07)	(-3.16)
ROA$_{i,t-1}$	-0.276	0.332	-4.714	-3.749	3.401	3.917	4.052	4.577
	(-0.10)	(0.11)	(-1.12)	(-0.85)	(1.42)	(1.56)	(1.15)	(1.27)
Mb$_{i,t-1}$	1.074	1.221	1.050	1.230	0.701	0.868	3.052**	3.309**
	(0.96)	(1.08)	(0.60)	(0.69)	(0.75)	(0.92)	(2.09)	(2.26)
Loan$_{t-1}$	0.261	0.256	-23.058	-22.946				
	(0.04)	(0.03)	(-1.63)	(-1.54)				
Sigma$_{i,t-1}$	0.332***	0.335***	0.351***	0.357***	0.279***	0.281***	0.432***	0.432***
	(7.24)	(7.07)	(5.97)	(5.93)	(8.16)	(7.93)	(7.04)	(6.97)
Mom$_{i,t-1}$					-8.271***	-8.080***	-7.475**	-7.601**
					(-4.06)	(-3.94)	(-2.06)	(-2.20)
Cokurt$_{i,t-1}$					0.368***	0.399***	0.402*	0.450*
					(2.71)	(2.67)	(1.82)	(1.90)
Intercept	13.633**	10.476	33.968***	32.268***	13.109***	8.752**	14.595**	6.397
	(2.15)	(1.50)	(3.00)	(2.79)	(3.62)	(2.01)	(2.59)	(0.88)
Year and Quarter Dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bank -specific Cluster	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	1,422	1,422	1,422	1,422	1,530	1,530	1,530	1,530
R-Squared	0.448	0.436	0.339	0.326	0.661	0.651	0.603	0.598

Table 7. Moderating Effects of Bank Size and Information Transparency on Relations between Option-Induced CEO Risk-Taking Incentives and Contribution to Systemic Distress and Crash Risks

This table presents the OLS estimation results of regressing a bank's contribution to systemic distress risk *ΔCoVaR5_at* and to systemic crash risk *ΔCoVaR5_stk* against lagged CEO risk-taking incentives *Vega,* interactions of *Vega* with bank size *Size* and bank information opaqueness measures *Disp* and *Hlspread*, and other control variables. Models 1 to 3 regress *ΔCoVaR5_at* on lagged CEO risk-taking incentives *Vega*; its interactions with *Size*, *Disp*, and *Hlspread*; and other control variables, respectively. Models 4 to 6 regress *ΔCoVaR5_stk* on lagged *Vega*; interactions of *Vega* with *Size* and *Disp*, *Hlspread;* and other control variables, respectively. The *t*-statistics are adjusted for bank-level clusters, and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	Dependent Variable: *ΔCoVaR5_at* Model 1	Model 2	Model 3	Dependent Variable: *ΔCoVaR5_stk* Model 4	Model 5	Model 6
$Vega_{i,t-1}*Size_{i,t-1}$	-0.350***			-0.447***		
	(-2.79)			(-3.659)		
$Vega_{i,t-1}*Disp_{i,t-1}$		-4.572			24.810**	
		(-0.419)			(2.059)	
$Vega_{i,t-1}*Hlspread_{i,t-1}$			0.444			1.782***
			(0.729)			(3.889)
$Disp_{i,t-1}$		12.572			78.758***	
		(0.40)			(2.66)	
$Hlspread_{i,t-1}$			-3.814			7.393**
			(-1.19)			(2.60)
$Vega_{i,t-1}$	1.129***	1.113**	0.603	1.207***	0.564	-0.238
	(2.78)	(2.51)	(1.221)	(3.931)	(1.55)	(-0.74)
$Delta_{i,t-1}$	0.127	0.168	0.057	-0.111	-0.089	-0.009
	(0.35)	(0.46)	(0.16)	(-0.44)	(-0.33)	(-0.03)
$Bonus_{i,t-1}$	-0.014	0.012	-0.006	-0.071***	-0.063***	-0.041**
	(-0.47)	(0.39)	(-0.22)	(-3.40)	(-2.94)	(-2.11)
$Leverage_{i,t-1}$	2.056	4.666	1.655	12.534*	16.332**	15.903**
	(0.18)	(0.33)	(0.15)	(1.67)	(2.13)	(2.33)
$Size_{i,t-1}$	2.471*	0.107	2.282*	5.060***	4.890***	4.599***
	(1.83)	(0.21)	(1.81)	(4.57)	(4.70)	(4.90)
$Size\_sqr_{i,t-1}$	-0.196**		-0.174**	-0.281***	-0.250***	-0.245***
	(-2.29)		(-2.26)	(-3.47)	(-3.79)	(-3.65)
$ROA_{i,t-1}$	0.936	0.884	0.579	5.425**	4.696**	2.768
	(0.40)	(0.39)	(0.26)	(2.243)	(1.99)	(1.28)
$Mb_{i,t-1}$	1.543	1.539	1.535	0.966	1.393	0.777
	(1.63)	(1.55)	(1.62)	(1.212)	(1.64)	(0.90)
$Sigma_{i,t-1}$	0.336***	0.356***	0.427***	0.245***	0.267***	0.272***
	(8.74)	(9.24)	(9.96)	(5.73)	(7.26)	(7.31)
$Loan_{t-1}$	-3.806	-3.552	-3.444			
	(-0.55)	(-0.43)	(-0.50)			
$Mom_{i,t-1}$				-6.210***	-7.671***	-6.452***
				(-3.88)	(-4.378)	(-4.028)
$Cokurt_{i,t-1}$				0.489***	0.592***	0.390***
				(2.88)	(2.688)	(2.718)
Intercept	14.741***	8.545	13.995***	10.093***	3.385	5.875*
	(2.82)	(1.31)	(2.74)	(3.27)	(0.79)	(1.80)
Quarter Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Bank-Specific Cluster	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,034	1,762	2,020	2,191	1,891	2,054
R-Squared	0.445	0.447	0.452	0.653	0.665	0.675

Table 8. Moderating Effects of Financial Crisis and Market Illiquidity on Relations between Option-Induced CEO Risk-Taking Incentives and Contribution to Systemic Distress and Crash Risks

This table presents the OLS estimation results of regressing a bank's contribution to systemic distress risk *ΔCoVaR5_at* or systemic crash risk *ΔCoVaR5_stk* on lagged CEO risk-taking incentives *Vega,* the interactions of *Vega* with financial crisis *Crisis* and bond and stock market illiquidity measures *Repo* and *Mktilliq,* and other control variables. Models 1 to 3 regress *ΔCoVaR5_at* on lagged *Vega*; the interactions of *Vega* with *Crisis*, *Repo*, and *Mktilliq*; and other control variables, respectively. Models 4 to 6 regress *ΔCoVaR5_stk* on lagged *Vega*; the interactions of *Vega* with *Crisis*, *Repo*, and *Mktilliq*; and other control variables, respectively. The *t*-statistics are adjusted for bank-level clusters and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	Dependent Variable: *ΔCoVaR5_at* Model 1	Model 2	Model 3	Dependent Variable: *ΔCoVaR5_stk* Model 4	Model 5	Model 6
$Vega_{i,t-1}$*Crisis	2.199*			4.544***		
	(1.81)			(5.16)		
$Vega_{i,t-1}$*$Repo_{i,t-1}$		62.215			167.976***	
		(1.02)			(3.54)	
$Vega_{i,t-1}$*$Mktilliq_{i,t-1}$			0.975			2.245**
			(0.582)			(2.26)
Crisis	10.809*			24.322***		
	(1.67)			(4.99)		
$Repo_{i,t-1}$(*1000)		1.308***			0.712***	
		(5.14)			(3.89)	
$Mktilliq_{i,t-1}$			-0.469			10.381***
			(-0.11)			(3.72)
$Vega_{i,t-1}$	0.816**	0.722*	1.244**	0.572**	0.254	1.511***
	(2.19)	(1.93)	(2.301)	(2.16)	(0.92)	(3.94)
$Delta_{i,t-1}$	0.125	0.131	0.134	-0.042	0.001	-0.028
	(0.34)	(0.36)	(0.36)	(-0.16)	(0.00)	(-0.10)
$Bonus_{i,t-1}$	0.000	-0.007	-0.008	-0.034*	-0.048**	-0.052***
	(0.01)	(-0.21)	(-0.28)	(-1.78)	(-2.52)	(-2.63)
$Leverage_{i,t-1}$	2.778	3.486	2.619	15.897**	15.566**	16.819**
	(0.24)	(0.30)	(0.23)	(2.38)	(2.28)	(2.45)
$Size_{i,t-1}$	2.221*	2.180*	2.214*	4.526***	4.590***	4.556***
	(1.87)	(1.69)	(1.71)	(5.82)	(4.67)	(4.66)
$Size\_sqr_{i,t-1}$	-0.174**	-0.164**	-0.167**	-0.249***	-0.239***	-0.238***
	(-2.39)	(-2.08)	(-2.12)	(-4.47)	(-3.41)	(-3.35)
$ROA_{i,t-1}$	0.781	0.387	0.996	2.785	3.130	2.852
	(0.36)	(0.18)	(0.43)	(1.30)	(1.33)	(1.24)
$Mb_{i,t-1}$	1.455	1.279	1.435	0.936	0.838	1.086
	(1.53)	(1.35)	(1.48)	(1.16)	(0.99)	(1.28)
$Sigma_{i,t-1}$	0.337***	0.268***	0.342***	0.287***	0.289***	0.292***
	(8.82)	(6.13)	(8.62)	(9.62)	(8.26)	(8.95)
$Loan_{i,t-1}$	-3.994	-4.805	-4.176			
	(-0.58)	(-0.67)	(-0.59)			
$Mom_{i,t-1}$				-6.725***	-6.403***	-6.861***
				(-4.26)	(-3.93)	(-4.14)
$Cokurt_{i,t-1}$				0.382***	0.329**	0.438***
				(2.69)	(2.44)	(2.92)
Intercept	13.714***	17.600***	12.534**	8.582***	9.393***	12.831***
	(2.64)	(3.30)	(2.36)	(2.88)	(2.85)	(4.67)
Year and Quarter Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Bank-Specific Cluster	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,005	2,005	2,005	2,054	2,054	2,054
R-Squared	0.438	0.460	0.433	0.684	0.670	0.665

Table 9. Reconciling Our Results with Those of Fahlenbrach and Stulz (2011): Relations between Option-Induced CEO Risk-Taking Incentives and Bank-Specific Performance and Risk Measures

This table presents the OLS estimation results for regressing the bank performance variable *ROA* and bank-specific crash risk measure *VaR_stk* on lagged CEO risk-taking incentives *Vega*, the interaction of *Vega* with financial crisis *Crisis*, and other control variables in models 1 to 4 and models 5 to 8, respectively. Models 1 and 5 report the OLS regression results for the whole sample period without considering the effects of financial crisis and models 2 and 6 incorporate the effect of financial crisis by adding *Crisis* and the interaction *Vega*Crisis* as further controls. Models 3 and 7 report the OLS regression results for the subsample of the financial crisis period and models 4 and 8 report the OLS regression results for the subsample of the non-crisis period. The *t*-statistics are adjusted for bank-level clusters and detailed variable definitions are provided in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent	Dependent Variable: *ROA*				Dependent Variables: *VaR_stk*			
Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$Vega_{i,t-1}$*Crisis*		0.019				0.009		
		(0.96)				(1.54)		
$Vega_{i,t-1}$	0.007*	0.005	0.024	0.005*	0.003**	0.002*	0.013*	0.002*
	(1.83)	(1.52)	(1.17)	(1.71)	(2.50)	(1.82)	(1.95)	(1.91)
Crisis		-0.185**				0.106***		
		(-2.03)				(3.57)		
$Delta_{i,t-1}$	0.003	0.003	0.022	0.002	-0.001	-0.001	-0.004	-0.000
	(0.94)	(0.96)	(1.33)	(0.87)	(-0.88)	(-0.90)	(-0.89)	(-0.50)
$Bonus_{i,t-1}$	-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000
	(-0.08)	(0.27)	(0.16)	(-0.11)	(-0.08)	(0.36)	(-0.62)	(0.29)
$Leverage_{i,t-1}$					0.032	0.032	0.021	0.003
					(0.95)	(0.86)	(0.19)	(0.11)
$Sizemv_{i,t-1}$	0.004	0.002	-0.011	0.003	0.001	0.000	0.004	-0.000
	(0.63)	(0.282)	(-0.481)	(0.599)	(0.34)	(0.04)	(0.45)	(-0.23)
$ROA_{i,t-1}$	0.313***	0.313***	0.201***	0.440***	-0.021*	-0.022*	-0.018	-0.013
	(4.72)	(4.829)	(3.126)	(4.460)	(-1.96)	(-1.93)	(-1.46)	(-1.21)
$Mb_{i,t-1}$	0.069***	0.069***	0.224***	0.042***	0.000	0.000	-0.023*	0.001
	(7.11)	(7.085)	(6.928)	(5.145)	(0.13)	(0.10)	(-1.73)	(0.21)
$Sigma_{i,t-1}$					0.001***	0.001***	0.001**	0.002***
					(9.76)	(8.86)	(2.54)	(10.90)
$Mom_{i,t-1}$					-0.020*	-0.019*	-0.083**	0.013
					(-1.74)	(-1.73)	(-2.51)	(1.42)
$Cokurt_{i,t-1}$					-0.002***	-0.002***	-0.007	-0.000**
					(-3.66)	(-3.59)	(-1.22)	(-2.02)
$CAPR_{i,t-1}$	-0.000	-0.000	0.019	-0.002	0.000	0.000	0.005	-0.000
	(-0.06)	(-0.10)	(1.25)	(-0.893)	(0.74)	(0.67)	(1.37)	(-0.01)
Intercept	0.141**	0.143**	-0.441	0.152***	0.105***	0.106***	0.247***	0.047***
	(2.60)	(2.61)	(-1.32)	(2.94)	(4.58)	(4.67)	(2.74)	(3.09)
Year and Quarter Dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bank-Specific Cluster	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	1,491	1,491	250	1,241	1,481	1,481	250	1,231
R-Squared	0.490	0.492	0.365	0.424	0.720	0.724	0.446	0.380

Table 10. Robustness Check for the Endogeneity of CEO Risk-Taking Incentives: Relations between Option-Based CEO Risk-Taking Incentives and Channel Variables and a Bank's Contribution to Systemic Risk

This table presents the 2SLS IV estimation results of examining the relation of CEO risk-taking incentives with a bank's contribution to systemic risk and the mediating effects of channel variables. We use CEO tenure, free cash flow, and firm age as IVs for CEO risk-taking incentives *Vega* and CEO risk-averse incentives *Delta* in all models. The dependent variables in Models 1 and 2 are the systemic distress risk measure *ΔCoVaR5_at* and the systemic crash risk measure *ΔCoVaR5_stk,* respectively, while those in Models 3 to 7 are non-interest income *N2I*, maturity mismatch *Mismatch*, securitization *Secure*, CDOs *CDO*, and CDSs *CDS*, respectively. The 5% critical value for the OIR-test (one degree of freedom) is 3.84. The *t*-statistics are adjusted for robust standard errors, model details are provided in Eqs. (2) and (3) in the text, and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	*ΔCoVaR5_at* Model 1	*ΔCoVaR5_stk* Model 2	*N2I* Model 3	*Mismatch* Model 4	*Secure* Model 5	*CDO* Model 6	*CDS* Model 7
$Vega_{i,t-1}$	11.875***	13.771***	80.107***	7.473***	7.983***	1.162***	2.930***
	(3.25)	(4.06)	(3.48)	(3.78)	(3.43)	(2.87)	(3.40)
$Delta_{i,t-1}$	-0.303	-2.622*	-29.029***	-2.817***	-2.332**	-0.367**	-0.876**
	(-0.17)	(-1.69)	(-2.95)	(-3.27)	(-2.26)	(-2.09)	(-2.40)
$Bonus_{i,t-1}$	-0.173***	-0.233***	-0.629*	-0.053*	-0.063**	-0.017***	-0.045***
	(-3.36)	(-4.79)	(-1.92)	(-1.72)	(-2.04)	(-2.93)	(-3.68)
$Leverage_{i,t-1}$	-34.111***	-0.603	-30.665		-3.178	-0.316	-2.128
	(-4.18)	(-0.08)	(-0.59)		(-0.63)	(-0.41)	(-1.15)
$Size_{i,t-1}$	-4.909***	-2.783	-34.830***	-3.348***	-1.421	-0.807***	-1.016**
	(-2.69)	(-1.52)	(-3.18)	(-3.44)	(-1.32)	(-4.40)	(-2.46)
$Size\_sqr_{i,t-1}$	0.209*	0.182*	1.876***	0.181***	0.119*	0.080***	0.109***
	(1.89)	(1.72)	(2.78)	(3.19)	(1.93)	(7.82)	(4.69)
$ROA_{i,t-1}$	-3.955	0.678	8.519	-3.385**	-0.066	-0.131	-0.443
	(-1.40)	(0.31)	(0.38)	(-2.08)	(-0.05)	(-0.59)	(-0.69)
$Mb_{i,t-1}$	-0.078	-1.247	1.369		-1.995***	-0.162*	-0.377*
	(-0.09)	(-1.48)	(0.24)		(-3.80)	(-1.74)	(-1.83)
$Loan_{i,t-1}$	-5.749		-119.393***	-34.097***	6.824**	0.341	0.647
	(-1.53)		(-3.48)	(-10.77)	(2.05)	(0.68)	(0.53)
$CAPR_{i,t-1}$			1.156	0.175	0.162	0.012	0.056
			(0.96)	(1.27)	(1.36)	(0.65)	(1.24)
$Nim_{i,t-1}$			-1.312	-0.495	0.079	0.060	0.025
			(-0.36)	(-1.32)	(0.24)	(1.19)	(0.20)
$LLA_{i,t-1}$			-14.188		-2.509**	-0.209	-0.849*
			(-1.12)		(-2.05)	(-1.11)	(-1.83)
$3M_{i,t-1}$				-2.043			
				(-0.60)			
$Repo_{i,t-1}$				-43.211			
				(-0.21)			
$Sigma_{i,t-1}$	0.350***	0.320***					
	(8.30)	(9.64)					
$Mom_{i,t-1}$		-2.856					
		(-0.77)					
$Cokurt_{i,t-1}$		-0.240					
		(-1.15)					
Intercept	73.009***	85.043***	557.549***	71.464***	44.503***	6.955***	17.972***
	(3.23)	(4.06)	(3.78)	(6.08)	(3.09)	(2.79)	(3.34)
Year and Quarter Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,701	1,819	1,645	1,701	1,700	1,700	1,700
OIR test chi squared	0.583	2.811	0.912	2.647	0.003	1.442	1.053

Table 11. Robustness Check for Alternative CEO Risk-Taking Incentive Measure and Alternative Systemic Risk Measures: Relations between Option-Induced CEO Risk-Taking Incentives and a Bank's Contribution to Systemic Risk

This table presents the OLS estimation results of examining the relation between CEO risk-taking incentives and a bank's contribution to systemic risk, using the alternative CEO risk-taking incentive measure *ABVega* and alternative systemic risk measures *MES*, *SRISK,* and *%SRISK*. Models 1 and 2 regress the systemic distress risk measure *ΔCoVaR5_at* and the systemic crash risk measure *ΔCoVaR5_stk* on the lagged abnormal level of CEO risk-taking incentives measure *ABVega* and other control variables, respectively. Models 3 to 5 regress alternative systemic risk measures *MES*, *SRISK,* and *%SRISK,* respectively, on lagged *Vega* and other controls. The *t*-statistics are adjusted for firm-level clusters, model details are provided in Eq. (2) in the text, and detailed variable definitions are available in Appendices A and B. The superscripts ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Independent Variable	*ΔCoVaR5_at* Model 1	*ΔCoVaR5_stk* Model 2	*MES* Model 3	*SRISK* Model 4	*%SRISK* Model 5
$Vega_{i,t-1}$			0.044***	0.246*	0.012***
			(2.70)	(1.80)	(2.67)
$ABVega_{i,t-1}$	0.768*	1.091***			
	(1.84)	(3.24)			
$Delta_{i,t-1}$	0.480	0.141	-0.001	-0.132**	-0.000
	(1.12)	(0.44)	(-0.05)	(-2.22)	(-0.02)
$Bonus_{i,t-1}$	-0.004	-0.069***	-0.001	-0.014	-0.000
	(-0.110)	(-3.058)	(-0.53)	(-0.91)	(-0.30)
$Leverage_{i,t-1}$	-6.783	19.216**	-0.707*	-2.227	0.176**
	(-0.52)	(2.33)	(-1.72)	(-0.86)	(2.08)
$Size_{i,t-1}$	2.484*	5.127***	0.135**	-5.114***	0.039***
	(1.75)	(5.02)	(2.36)	(-4.90)	(5.06)
$Size\_sqr_{i,t-1}$	-0.167**	-0.230***	-0.006	0.530***	-0.002***
	(-2.06)	(-3.48)	(-1.34)	(9.96)	(-4.20)
$ROA_{i,t-1}$	0.681	3.336	0.399*	-0.668	-0.028
	(0.26)	(1.31)	(1.97)	(-0.63)	(-1.62)
$Mb_{i,t-1}$	2.293**	1.742	0.029	-0.719***	-0.036**
	(2.02)	(1.57)	(0.84)	(-4.03)	(-2.38)
$Sigma_{i,t-1}$	0.343***	0.295***	0.060***	0.072***	0.001***
	(8.34)	(8.56)	(18.92)	(2.95)	(5.2)
$Loan_{i,t-1}$	-7.079				
	(-1.145)				
$Mom_{i,t-1}$		-7.763***	-0.412**	-0.779	-0.090***
		(-4.05)	(-2.14)	(-0.67)	(-3.14)
$Cokurt_{i,t-1}$		0.387**	0.058***	0.002	-0.001
		(2.40)	(3.35)	(1.80)	(-0.69)
Intercept	11.476**	5.071	-1.273***	3.2354***	1.037***
	(2.24)	(1.60)	(-4.29)	(3.26)	(31.59)
Year and Quarter Dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Firm-Specific Clusters	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	1,701	1,819	2,191	1,833	603
R-Squared	0.463	0.685	0.868	0.677	0.398

Appendix A. Variable Definitions

A Bank's Contribution to Systemic Risk Measures

$\Delta CoVaR5\_at_{it}$: proxy for bank *i*'s contribution to systemic distress risk in quarter *t* calculated based on 5% *VaR* of the market-based return of total assets. It is measured as negative one times the marginal difference in the quarterly 5% *CoVaR* of the financial system when a bank's quarterly market-based asset return is at its 5% *VaR* and when it is in its median state in quarter *t*. A higher value indicates a bank's higher contribution to systemic distress risk. Appendix B describes the calculation details.

$\Delta CoVaR\_at_{it}$: proxy for bank *i*'s contribution to systemic distress risk in quarter *t*. It is calculated in terms of the 1% *VaR* of the market-based return of total assets.

$\Delta CoVaR5\_stk_{it}$: proxy for bank *i*'s contribution to systemic crash risk in quarter *t.* It is calculated based on 5% *VaR* of stock return and value-weighted market return. It is measured as negative one times the marginal difference in 5% *CoVaR* of the financial system when a bank's quarterly stock return is at its 5% *VaR* and when it is in its median state in quarter *t*. A higher value indicates a bank's higher contribution to systemic crash risk. Appendix B provides the estimation details.

$\Delta CoVaR\_stk_{it}$: proxy for bank *i*'s contribution to systemic crash risk in quarter *t*. It is an alternative to $\Delta CoVaR5\_stk$ and is calculated in terms of 1% *VaR* of the stock return and value-weighted market return.

MES_{it}: proxy for a bank's marginal expected shortfall, given severe market decline. It is calculated as negative one times the average daily stock return of bank *i* over those worst days when the daily market return is below its 5 percentile in a one-year window, following Acharya et al. (2010). A higher value indicates higher bank systemic risk.

$SRISK_{it}$: expected capital shortfall (in billions of dollars) that a bank needs to cover if there is a financial crisis, following Acharya et al. (2012a). A higher value indicates higher bank systemic risk.

$\%SRISK_{it}$: contribution of bank *i*'s *SRISK* to the aggregate *SRISK* in the financial sector, calculated following Acharya et al. (2012a). It is equal to zero if a bank's *SRISK* is negative and equal to the ratio of *SRISK* over aggregate *SRISK* in the banking sector if *SRISK* is positive.

Bank-Level Risk Measures

VaR_at_{it}: negative one times the 1% percentile of the distribution of weekly market-based return of total assets over the previous one hundred weeks. It is calculated for bank *i* at the end of fiscal quarter *t*. A higher value indicates higher bank distress risk.

VaR_stk$_{it}$: negative one times the 1% percentile of the distribution of weekly stock return over the previous one hundred weeks for bank *i.* It is calculated at the end of fiscal quarter *t*. A higher value indicates higher bank crash risk. The weekly stock return is calculated as the natural logarithm of one plus the residual from the regression model

$$RET_{it} = \beta_{0i} + \beta_{1i}RET_{mt-2} + \beta_{2i}RET_{mt-1} + \beta_{3i}RET_{mt} + \beta_{4i}RET_{mt+1} + \beta_{5i}RET_{mt+2} + \varepsilon_{it}$$

Beta$_{it}$: sensitivity of the stock return of bank *i* at the end of quarter *t* to the CRSP value-weighted market return calculated over a twelve-month rolling window.

Sigma$_{it}$: standard deviation of the daily stock return (in percentage) for bank *i* at the end of quarter *t*.

Z_Score$_{it}$: Altman (1968) *Z*-score that proxies for bankruptcy risk for bank *i* at the end of quarter *t.* It is calculated as 3.3**ROA* + 1.2*(net working capital/total assets) + 1.0*(sales/total assets) + 0.6*(market equity/book debt) + 1.4*(accumulated retained earnings/total assets). A higher value indicates lower bankruptcy risk.

Compensation Variables

Vega$_{it}$: natural logarithm of the dollar change in value of a CEO's option holdings in bank *i* resulting from a 1% increase in stock volatility at the end of fiscal quarter *t*.

Vega_old$_{it}$: natural logarithm of the dollar change in the value of a CEO's exercisable and unexercisable option holdings previously granted in bank *i* resulting from a 1% increase in stock volatility at the end of fiscal quarter *t*.

Vega_awards$_{it}$: natural logarithm of the dollar change in the value of a CEO's newly granted option holdings in bank *i* resulting from a 1% increase in stock volatility at the end of fiscal quarter *t*.

ABVega$_{it}$: proxy for abnormal CEO risk-taking incentives induced from option compensation. It is estimated as the residual from an OLS regression of *Vega*$_{it}$ on the market value of equity, idiosyncratic risk, the market-to-book ratio, CEO tenure, free cash flow, and year and quarter dummies, following Core and Guay (1999) and Kim et al. (2011).

Delta$_{it}$: natural logarithm of the dollar change in the value of a CEO's option and stock holdings in bank *i* resulting from a 1% increase in stock price at the end of fiscal quarter *t*.

Bonus$_{it}$: ratio of a CEO's cash bonus to total salary for bank *i* at the fiscal quarter-end *t*.

Channel Variables

$N2I_{it}$: proxy for non-interest income. It is calculated as the ratio of non-interest income to interest income for bank *i* at the end of fiscal quarter *t*.

$Securitize_{it}$: proxy for asset securitization. It is measured as the natural logarithm of one plus the dollar amount of total securitization of bank *i* at the fiscal quarter-end *t*.

CDO_{it}: proxy for CDOs. It is measured as the natural logarithm of one plus the dollar amount of total CDOs for bank *i* at the fiscal quarter-end *t*.

CDS_{it}: proxy for CDSs. It is measured as the natural logarithm of one plus the dollar amount of total CDSs for bank *i* at the fiscal quarter-end *t*.

$Mismatch_{it}$: proxy for short-term liquidity risk. It is measured as the ratio of short-term debt minus cash holdings to total assets for bank *i* at the end of fiscal quarter *t*.

Moderating Variables

$Disp_{it}$: proxy for uncertainty in the information environment. It is calculated as the mean standard deviation of analyst forecasts for bank *i* in quarter *t* - 1.

$Hlspread_{it}$: proxy for uncertainty in the information environment. It is calculated as the average of the daily high and low spreads for bank *i* in quarter *t,* following Corwin and Schultz (2011).

$Repo_t$: proxy for bond market illiquidity at the quarter-end *t.* It is measured as the difference between the three-month general collateral repo rate and the three-month T-bill rate, calculated at quarter-end *t*.

$Mktilliq_{it}$: proxy for stock market illiquidity for bank *i* at the quarter-end *t*. It is measured as -1 times the monthly raw market-wide liquidity adjusted for tick size changes, estimated following Boyson et al. (2010), where monthly raw market-wide liquidity is calculated as the value-weighted monthly average of the daily ratios of absolute return to dollar volume for NYSE-listed common stocks, after dropping the top and bottom 1% observations each month.

Crisis: dummy for the 2008–2009 financial crisis period. It is equal to one for the period July 2007 to March 2009 and zero otherwise.

Control Variables

$Leverage_{it}$: ratio of long-term debt to total assets for bank *i* at the end of quarter *t*.

$Loan_{it}$: ratio of total loans to total assets for bank *i* at the end of quarter *t*.

$Size_{it}$: total assets (in billions of dollars) of bank *i* at the end of quarter *t*.

$Size\_sqr_{it}$: squared value of total assets (in billions of dollars) for bank *i* at the end of quarter *t*.

ROA_{it}: ratio of income before extraordinary items to total assets for bank *i* at the end of quarter *t*.

Mb_{it}: market-to-book ratio for bank *i* at the end of quarter *t*.

$CAPR_{it}$: tier-one capital ratio for bank *i* at the end of quarter *t*.

LLA_{it}: ratio of loan loss allowance to total assets for bank *i* at the end of quarter *t*.

Nim_{it}: proxy for net interest margin. It is calculated as the ratio of net interest revenue to interest-bearing assets for bank *i* at the end of quarter *t*.

Mom_{it}: buy-and-hold stock returns for bank *i* over the previous eleven-month period ending one month prior to quarter *t*.

$Cokurt_{it}$: kurtosis of daily returns relative to that of the market of bank *i* over the twelve-month period ending at quarter-end *t*.

$Sizemv_{it}$: natural logarithm of market capitalization (in billions of dollars) for bank *i* at the end of fiscal quarter *t*.

$3M_t$: change in the three-month T-bill rate at quarter-end *t*.

Appendix B. Computation of a Bank's Contribution to Systemic Distress Risk and Systemic Crash Risk

Following Adrian and Brunnermeier (2011), we estimate two measures for a bank's contribution to systemic distress risk, $\Delta CoVaR5\_at_{it}$ and $\Delta CoVaR\_at_{it}$, using a quantile regression method. We first run the following 5% quantile regressions for the weekly returns of market-based total assets for bank *i* and for the whole financial system, respectively:

$$R^i_t = \alpha^i + \beta^i Z_{t-1} + \varepsilon^i \quad \text{(b1)}$$

$$R^{system}_t = \alpha^{system|i} + \beta^{system|i} Z_{t-1} + \beta^{system|i} R^i_{t-1} + \varepsilon^{system|i} \quad \text{(b2)}$$

where R^i_t is the weekly return of the market value of total assets of bank *i* at time *t,* expressed as $R^i_t = [AT^i_t*(MV^i_t/BV^i_t)]/[AT^i_{t-1}*(MV^i_{t-1}/BV^i_{t-1})]-1$, in which AT^i_t is the book value of total assets and MV^i_t and BV^i_t are the market and book values of bank *i*'s equity at time *t,* respectively. The term R^{system}_t is the value-weighted average of the weekly return of the market-valued total assets of all banks in the financial system at time *t*, using the market-valued assets $AT^i_t*(MV^i_t/BV^i_t)$ as weight:

$$R^{system}_t = \sum_{i=1}^{N} \frac{AT^i_t * (MV^i_t/BV^i_t) * R^i_t}{\sum_j^N AT^j_t * (MV^j_t/BV^j_t)} \quad \text{(b3)}$$

The term Z_{t-1} is the vector of macroeconomic and financial factors measured in the previous period, including stock market return, equity volatility, liquidity risk, interest rate risk, term structure, default risk, and real estate returns. We use the weekly value-weighted equity returns (excluding *American depositary receipts*) with all distributions to proxy for the market return. Volatility is the standard deviation of the natural logarithm of stock returns three months prior to time *t*. Short-term liquidity risk is the difference between the three-month LIBOR rate and the three-month T-bill rate. Interest rate risk is the change in the three-month T-bill rate. We use the change in the slope of the yield curve—the yield spread between the ten-year T-bond rate and the three-month T-bill rate—to proxy for the term structure. Default risk is the change in the credit spread between ten-year BAA corporate bonds and the ten-year T-bonds. Real estate returns are calculated based on the Federal Housing Finance Agency (FHFA) house price index.

We input the estimated bank-specific coefficients from models (b1) and (b2) into models (b4) and (b5), respectively, and calculate bank *i*'s 5% *VaR* as the predicted value from model (b4) and estimate systemic distress risk conditional on bank *i* in distress, $CoVaR^{system|i}$, as the predicted asset return of the banking system in model (b5), which uses $VaR^{i,5\%}_t$ estimated from model (b4) and the lagged value of the state variables as inputs:

$$VaR^{i,5\%}_t = \hat{R}^{i,5\%}_t = \alpha^i + \beta^i Z_{t-1} \quad \text{(b4)}$$

$$CoVaR^{system|i,5\%} = \hat{R}^{system}_t = \alpha^{system|i,5\%} + \beta^{system|i,5\%} Z_{t-1} + \beta^{system|i,5\%} VaR^{i,5\%}_t \quad \text{(b5)}$$

Next, we run 50% quantile (median) regressions using models (b6) and (b7) below, respectively, to obtain their bank-specific coefficient estimates:

$$R^i_t = \alpha^{i,median} + \beta^{i,median} Z_{t-1} + \varepsilon^{i,median} \quad \text{(b6)}$$

$$R^{system}_t = \alpha^{system|i,median} + \beta^{system|\,i,median} Z_{t-1} + \beta^{system|i,median} R^i_{t-1} \quad \text{(b7)}$$

We use the bank-specific coefficients estimated from models (b6) and (b7) to calculate the median asset return for bank *i*, $R^{i,median}_t$, and the systemic risk conditional on bank *i* functioning in its median state, $CoVaR^{system|median}$:

$$R^{i,median}_t = \alpha^{i,median} + \beta^{i,median} Z_{t-1} \quad \text{(b8)}$$

$$CoVaR^{system|median} = \hat{R}^{system}_t$$

$$= \alpha^{system|i,median} + \beta^{system|i,median} Z_{t-1} + \beta^{system|i,median} R^{i,median}_{t-1} \quad \text{(b9)}$$

Bank *i*'s contribution to systemic distress risk at a weekly frequency is estimated as the marginal difference between 5% *CoVaR* of the weekly market-based asset return in the financial system when bank *i*'s weekly market-based asset return is at its 5% *VaR* and when it is in its median state:

$$\Delta CoVaR5\_at_w^i = CoVaR^{system|\,i,5\%} - CoVaR^{system|\,i,median} \quad \text{(b10)}$$

We then calculate our measure for bank *i*'s contribution to systemic distress risk $\Delta CoVaR5\_at_{it}$ as negative one times the accumulation of the weekly $\Delta CoVaR5\_at_w^i$ over a quarter. We calculate another measure for bank *i*'s contribution to systemic distress risk in terms of 1% *VaR* of the market-based asset return, $\Delta CoVaR\_at_{it}$, following the same procedures as shown above, except that we estimate the 1% and 50% quantile regressions rather than the 5% and 50% quantile regressions.

Likewise, we calculate measures for bank *i*'s contribution to systemic crash risk, $\Delta CoVaR5\_stk_{it}$ and $\Delta CoVaR\_stk_{it}$, by replacing $R^{i,5\%}_t$ and $R^{i,median}_t$ in all models above into weekly stock returns and weekly median stock returns, respectively, and substituting R^{system} with equal-weighted market-level stock returns. The detailed procedures for calculating $\Delta CoVaR5\_stk_{it}$ and $\Delta CoVaR\_stk_{it}$ parallel those for estimating $\Delta CoVaR5\_at_{it}$ and $\Delta CoVaR\_at_{it}$, respectively.