The External Effects of Bank Executive Pay: Liquidity Creation and Systemic Risk

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Abstract: We develop a conceptual framework that links executive compensation incentives to the external risks and returns generated by the firm but borne by society. Recent advances in measuring liquidity creation (Berger and Bouwman, 2009) and systemic risk (Acharya, et al. forthcoming) allow us to estimate our framework for U.S. commercial banking companies. We find that CEO pay-performance incentives reduce both positive liquidity creation externalities and negative systemic risk externalities, while pay-risk incentives increase both externalities. Our findings infer a tradeoff for bank regulators: Restrictions on executive pay aimed at reducing systemic risk likely necessitate a reduction in system-wide liquidity creation.

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1. Introduction

In a market economy, a well-functioning banking system is crucial for allocating credit to and providing payment services for businesses and households. In the process of providing these services for their clients, banks also generate positive and negative externalities. Chief among these social spillovers are liquidity creation and systemic risk.

In the wake of the 2007-2008 financial crisis, banking regulations were rewritten world-wide with the goal of reducing systemic risk in the financial system, with little explicit concern for the potential effects of the new regulations on liquidity creation. Most conspicuous among these regulatory changes are the tighter quantitative restrictions imposed on bank balance sheet leverage and liquidity (Bank for International Settlements 2011, 2013, 2014). Less conspicuous but no less important are the qualitative guidelines that seek to reduce financial sector volatility by encouraging longer term, equity-based compensation for bank decision-makers (Squam Lake 2010, Federal Reserve 2010, 2011, 2016). In this study, we estimate the liquidity creation and systemic risk externalities generated by large U.S. commercial banking companies, and examine how the compensation incentives of top bank executives influence the generation of those positive and negative market spillovers.

Banks create liquidity mainly by financing on-balance sheet loan contracts with callable deposit contracts. But the money created by these transactions provides liquidity for economic agents far beyond a bank's immediate loan and deposit counterparties. This propagation of bank-created liquidity throughout the economy is variously described by macroeconomists in terms of the money creation multiplier and the velocity of money. It is through these processes that actions taken by banks in pursuit of private profits create positive social externalities.

Banks' role in liquidity creation makes them financially fragile. In the classical case, depositors withdraw their funds when they learn (or think) that their bank has suffered losses that may lead to its insolvency; this may be followed by (rational or irrational) fear among depositors at other banks that this bank-specific episode reflects a more general problem, causing contagious depositor runs and resulting in an economy-wide reduction in liquidity, credit and economic activity. In its modern analog, non-deposit creditors can cause the collapse of an already weak financial institution by refusing to roll over their short-term credit contracts, contagious fear leads to a collapse of short-term credit markets, and death-by-illiquidity spreads to other financial institutions. This propagation of risk among banks, financial markets and the macro-economy is typically referred to as systemic risk. It is through these processes that credit, liquidity and interest rate risk taken by banks in pursuit of private profits create negative social externalities.

Strides have been made in the quantification of liquidity creation and systemic risk in recent years. Berger and Bouwman (2009) have provided a comprehensive framework for measuring the liquidity created by commercial banking companies. Acharya, et al. (forthcoming), Adrian and Brunnermeier (2016), Brownless and Engle (2015), Huang, Zhou and Zhu (2011) and others have provided analytic frameworks for measuring the empirical links between banking companies and systemic risk. We can combine these two concepts, and then link them to bank executive compensation, by making two fundamental observations. First, banks make their business decisions with the goal of delivering private gains for bank shareholders, but it is these same business decisions that generate liquidity creation and systemic risk externalities. Because private returns and social spillovers are joint products, empirical measurements of liquidity creation and systemic risk are likely to pool internal private phenomena (benefits and costs to bank shareholders) with external public phenomena (positive and negative externalities). Second, bank business decisions are influenced by the private incentives of bank decision-makers. Hence, the details of bank executive compensation are likely to be important determinants of the positive and negative externalities generated by banks.[1]

We derive an estimable relationship between the private wealth incentives embedded in managers' compensation contracts, the business decisions made by these incentivized managers, and the social spillovers resulting from those decisions. Following Guay (1999) and Core and Guay (2002), we use pay-

[1] Both of these fundamental observations hold in the presence of managerial agency costs. First, bank business decisions aimed at enriching managers at the cost of shareholders are primarily transfers of wealth from one private party to another private party, so our private versus public dichotomy is preserved. Second, managerial agency costs are themselves an example of how bank business decisions can be influenced by private incentives, including compensation-based incentives.

performance sensitivity (delta) and pay-risk sensitivity (vega) to measure the compensation incentives faced by bank CEOs. Following Berger and Bouwman (2009), we measure the gross liquidity created by each bank, and then extract from this measure the liquidity creation externality that is orthogonal to banks' private returns. Following Acharya, et al. (forthcoming), we measure the systemic expected shortfall (SES) of each bank, and then extract from this measure the systemic risk externality that is orthogonal to banks' private risk exposures.[2] We estimate the model using annual panel data on large U.S. commercial banking companies from 1994 through 2010. Our framework has a pleasing and important feature for estimation: Because externalities are unintentional byproducts and hence carry no weight in either managers' or shareholders' objective functions, managers' compensation contracts are strictly exogenous regressors.

We find statistically positive relationships between pay-risk incentives and both measures of externalities. CEO vega is associated with economically large increases in external liquidity creation. This result is especially intuitive: Because banks can create liquidity only by taking private risk—i.e., making loans and issuing deposits exposes banks to credit risk and liquidity risk—incentives for the bank to take more private risk (increased vega) will naturally result in more liquidity creation spillovers. In contrast, CEO vega is associated with relatively small increases in external systemic risk. So at the margin, our results suggest that an additional unit of vega-induced private risk-taking increases positive social spillovers relative to negative social spillovers, on average.

We find statistically negative relationships between pay-performance incentives and both measures of externalities. CEO delta is associated with economically meaningful reductions in external liquidity creation. Again, this is an intuitive result: Incentives that align managers with shareholders (increased delta) can concentrate the manager's personal wealth in the firm, increasing her effective risk aversion and causing her to reduce investment in risky liquidity-creating activities. CEO delta is also associated with economically meaningful reductions in external systemic risk; at the margin, a given increase in delta reduces positive and negative social spillovers by similar amounts.

[2] We perform robustness tests using alternative measures of systemic risk: ΔCoVaR (Adrian and Brunnermeier 2016), adjusted-CoVaR (Sedunov 2011), and SRISK (Brownless and Engles 2015).

By decomposing our measures of externalities into their component parts, we are able to uncover some of the business decision channels through which executive compensation incentives drive external systemic risk and liquidity creation. We find a broad set of business decision channels between CEO pay incentives and systemic risk externalities. By construction, the SES measure decomposes naturally into financial leverage (LEV) and industry downside tail risk (marginal expected shortfall, or MES). We find that both LEV and MES are positively related to CEO vega—thus, when faced with increased incentives to take risk, managers respond both by levering up the bank (i.e., financial risk) and by exposing the bank to industry volatility (i.e., business risk). Similarly, when faced with increases in delta-induced incentives toward risk aversion and shareholder alignment, managers respond by reducing both financial leverage and tail risk. We find only a narrow business decision channel between CEO pay incentives and liquidity creation externalities. Liquidity externalities created via off-balance sheet activities—and more specifically, via loan commitments and lines of credit—are positively related to CEO vega and negatively related to CEO delta. We find no strong evidence of any on-balance channels linking CEO pay incentives to external liquidity creation.

While our findings are robust to changes in test specifications and variable definitions, they can be sensitive to both the business cycle and bank characteristics. For example, the externality-inducing incentive effects of CEO vega vanished during the financial crisis years (2008-2010), perhaps mitigated by increased scrutiny of bank executives by regulators and legislators during that episode. Conversely, the positive influence of CEO vega on external systemic risk was substantially stronger at banks with high probabilities of insolvency (as measured by accounting Z-scores); moreover, the negative influence of CEO delta on external liquidity creation vanished at these banks. These two results suggest that bank CEOs respond differently—becoming less risk averse and/or more sensitive to risk-taking incentives—when faced with potential insolvency, and that this shift in CEO incentives results in greater amounts of both systemic risk and liquidity creation externalities.

This paper makes three distinct contributions. First, we introduce a conceptual and methodological framework for estimating the potential influence of executive compensation incentives on the generation of positive and/or negative externalities. Identification in this framework relies on the textbook definition of an externality: Because the costs or benefits of firm-generated externalities redound to society and not the firm, the compensation incentives of firm executives are exogenous to those externalities. Our framework can be applied to any industry that contains large publicly traded firms and for which empirical estimates of firm-level externalities exist. Second, we break distinctly new ground in the empirical literature on managerial pay incentives. Numerous previous studies have demonstrated strong empirical associations between CEO pay incentives and the returns and risks of private shareholders. We provide empirical evidence that CEO pay incentives can influence return and risk outcomes beyond the private boundaries of the firm—in this case, the systemic risk and liquidity creation externalities generated by banking firms. Third, we address an emergent public policy issue. The economically large estimated delta effects lend support to Federal Reserve rules and guidelines that stress long term, equity-based compensation for bank decision-makers. In contrast, the relatively smaller estimated vega effects offer only limited support for proposals to reduce systemic risk by severely limiting stock options-based compensation (e.g., AFL-CIO 2011). And the consistent finding that delta effects and vega effects work in opposite directions reveals an important policy tradeoff, that compensation-based efforts to reduce systemic risk are likely to also result in reduced liquidity creation.

We remain silent on the question of whether changes in executive pay incentives either dampen or amplify agency problems between bank shareholders and bank managers. Even when the interests of bank managers and bank shareholders are perfectly aligned, the high financial leverage at commercial banks creates moral hazard incentives; bank risk-taking based on these incentives can result in social spillovers that justify prudential bank regulation (Bebchuk and Spamann 2009). We construct our externality measures to be statistically orthogonal to private shareholder returns and risk exposures—thus, our focus is on whether changes in executive pay incentives either dampen or amplify agency problems between the banking industry and the rest of society.

The paper proceeds as follows. In Section 2 we review the primary previous studies on measuring systemic risk, measuring liquidity creation, and modeling the relationship between executive compensation incentives and decision-making at banks. In Section 3 we develop our analytic framework. In Section 4 we describe our data sources and the construction of our main variables. In Section 5 we present the baseline results from our empirical model. In Section 6 we perform a limited investigation of the decision channels through which executive pay incentives are transformed into external liquidity creation and systemic risk. In Sections 7, 8 and 9 we explore, respectively, whether and how our results are affected by re-defining systemic risk, by the pressures that banks experienced during the global financial crisis, and by the possibility of strategic risk-taking by banks. In Section 10 we discuss the implications of our results for bank regulatory policy. Section 11 concludes.

2. Relevant literature

The three main concepts in our analysis are executive pay incentives, bank liquidity creation and bank systemic risk. The former concept is a determining factor of a bank's business decisions; the latter two concepts are outcomes of those business decisions. This section reviews the current literature on how these three concepts are most often measured.

2.1. Systemic risk. There is no standard definition of systemic risk. It can be thought of as the contribution of an individual financial institution toward causing a crisis or a collapse in the financial system, or alternatively, as the impact of a financial system crisis or collapse on an individual financial institution. Risk can propagate through the financial system either directly through counterparty or other bank-to-bank business linkages (e.g., defaults on financial contracts, refusals to roll-over financial contracts at their maturities) or indirectly when actions taken by one bank affect prices in financial markets in which all banks are buyers or sellers (e.g., fire sales of assets).

A complete review of the various studies on systemic risk is beyond scope of this paper. See Brunnermeier and Oehmke (2012) for a full survey of this literature. For the purposes of this study, it is enough to compare and contrast two seminal approaches to measuring systemic risk: The systemic expected shortfall (SES) method of Acharya, et al. (forthcoming) and the change in conditional value at risk (ΔCoVaR) method of Adrian and Brunnermeier (2016).

SES is the propensity of a financial institution to be undercapitalized when the whole system is in distress. The authors show that SES can be expressed conceptually as a function of a bank's financial leverage and its marginal expected shortfall (MES), where MES is the bank's expected return losses when overall returns in the financial system are in the extreme lower tail of its return distribution (e.g., below the 5^{th} percentile).[3] The authors observe 102 large U.S. financial firms one year before the global financial crisis, calculate MES and financial leverage for those firms, and use these values and other firm characteristics to predict the actual equity returns to these firms (i.e., the realized SES) during the crisis. The estimated (cross section) regression parameters from the prediction equation provide a ready-made formula for calculating SES for large U.S. financial firms in any of the years in the neighborhood of the crisis.

CoVaR is the value at risk in the financial system that is conditional on the value at risk of an individual bank i. The authors estimate CoVaR^i_q as the fitted value from a quantile regression of financial system's value at risk (VaR) on bank i's VaR, evaluated at quantile q of i's returns. ΔCoVaR^i_q is simply the predicted change in CoVaR^i_q when bank i's returns decline from the median return quantile (i.e., normal returns) to an extreme tail return quantile (i.e., very large losses). As stated by the authors, this measure has only cross-sectional variation; time series variation can be added by pre-conditioning financial system's VaR and bank i's VaR on a set of macroeconomic state variables (e.g., market interest rates, change in market rates, market-average credit risk spreads, equity market volatility). The authors estimate their models using weekly and quarterly data over 1971-2013; they show that ΔCoVaR estimated using pre-crisis data predicts more than one-third of the lost value in the financial system during 2007-2009.

Both SES and ΔCoVaR generate bank-specific measures of systemic risk, so either could be used as a base measure from which to extract what we refer to as the external portion of systemic risk, i.e., the

[3] Some researchers ignore the bank leverage portion of SES and conduct their analyses based exclusively on the MES portion of SES. We use the full SES measure because, as stated in Acharya, et al. (2014), "…combining *MES* and leverage of financial firms helps understanding their systemic risk better since, as predicted by the theory, financial distress costs of leveraged firms can be large in a crisis."

negative externality or spillover cost imposed by banks on society.[4] ΔCoVaR has two desirable characteristics: It measures the contribution of an individual bank to system-wide risk (SES measures the impact of a system-wide event on an individual bank) and it is parameterized using data from multiple business cycles (SES is parameterized using data from a single recession or crisis). Nevertheless, we feel that SES is the more appropriate measure for the purposes of our study. SES contains both cross sectional and time series variation derived directly from bank characteristics. In ΔCoVaR, the time series variation comes exclusively from macroeconomic state variables; only the cross sectional variation in ΔCoVaR is derived from bank-level returns. In our panel estimation models, it is essential for observations to exhibit within-bank time series variation in both executive compensation incentives and systemic risk externalities.[5]

2.2. Liquidity creation. Banks create liquidity through their normal course of doing business, e.g., making and holding illiquid loans, issuing demandable deposit liabilities, or making off-balance sheet credit commitments (Diamond and Dybvig 1983; Holmstrom and Tirole 1998; Kashyap, Rajan, and Stein 2002). A portion of the liquidity created by a financial institution can be viewed as a positive externality to society, because it stimulates future economic activity between parties who are unrelated to that financial institution.

Although liquidity creation has long been a topic of theorists who model banks, empirical measurement of bank liquidity creation has lagged behind. Deep and Schaefer (2004) proposed the LT gap, a simple measure of liquidity transformation equal to (liquid liabilities – liquid assets)/total assets. This method has two limitations when applied to measuring liquidity creation. First, by focusing only on liquid assets and liabilities with maturities less than one year, the LT gap assumes an artificial maturity threshold above or below which the process of liquidity creation acts differently. Second, the LT gap excludes loan

[4] For example, Adrian and Brunnermeier (2009, page 8) write: "…systemic risk relates to spillovers that amplify initial adverse shocks… Many of these spillovers are externalities. That is, when taking on the initial position with low market liquidity funded with short-term liabilities—i.e., with high liquidity mismatch—individual market participants do not internalize the subsequent individually optimal response in times of crises that imposes (pecuniary) externalities on others."
[5] Expressed another way: If the time series variation in our systemic risk measure is driven entirely by macroeconomic state variables, then that variation will be absorbed into the time fixed effects.

commitments and other off-balance sheet activities that play a role in liquidity creation (Holmstrom and Tirole 1998, Kashyap, Rajan, and Stein 2002). In contrast, Berger and Bouwman (2009) categorize bank assets as liquid, semiliquid, or illiquid, based on the ease, cost, and time for banks to dispose of these assets (liquidate them) without loss of value. Similarly, they categorize bank liabilities and equity as liquid, semiliquid, or illiquid, based on the ease, cost, and time for bank creditors and investors to recover their funds from the bank. Off-balance sheet guarantees and derivatives are similarly categorized. The authors assign a simple set of positive and negative weights to each of the account balances, based on whether the category in question creates liquidity (e.g., business loans, transactions deposits) or absorbs liquidity (e.g., liquid securities holdings, equity capital funding). Bank-level liquidity creation is then the weighted sum of all account balances for each bank. Because the Berger and Bouwman (2009) measure is both comprehensive and straightforward to apply, we use it to measure liquidity creation in this study.

2.3. Business mix and executive compensation. A bank's business mix and business policies are determined by its top executives, and the incentives embedded in executive compensation packages are primary factors that help shape these managerial decisions. The relationship between executive compensation, firm business policies, and firm risk has been extensively studied in the corporate finance literature.

In recent years, firms have increasingly included stock grants and stock options grants in executive compensation packages (Murphy 1999, Perry and Zenner 2000). As a result, the personal wealth of CEOs has become more sensitive to the price of firm shares (Hall and Liebman 1998). These wealth effects can be approximated by the measures delta and vega (Guay 1999, Core and Guay 2002). Delta measures the sensitivity of CEO wealth to changes in the firm share price; the delta of a compensation contract will increase with the number of company shares granted to the manager. Vega measures the sensitivity of CEO wealth to change in the volatility of the firm's share price; the vega of a compensation contract will increase with the number of company share call options granted to the manager. Empirical studies tend to find positive (negative) links between high-vega (high-delta) contracts and managerial risk-taking in oil exploration, derivatives usage, financial leverage, R&D investment, strategic diversification and strategic focus (e.g., Smith and Stulz 1985, Cohen, et al. 2000, Knopf, Nam and Thornton 2002, Rajgopal and Shevlin 2002, Coles, Daniel, and Naveen 2006). John and John (1993) propose that managers with high delta may be willing to take more risk if they can shift this risk to debt holders, but empirical studies of this possibility are largely inconclusive.

A small number of studies have investigated executive incentives and risk-taking in the banking industry. Chen, Steiner, and Whyte (2006) find that option-based compensation at U.S. banks during the 1990s was positively associated with market-based risk measures. Cheng, Hong and Scheinkman (2010) find that the residual pay to bank executives (the portion of total compensation not explained by bank size) is also positively related to market-based risk. Minnick, Unal and Yang (2011) find that banking companies run by executives with high pay-performance sensitivity are less likely to make value-reducing acquisitions. DeYoung, Peng and Yan (2013) find that CEO vega increased significantly at large U.S. commercial banks during the 2000s; that CEO vega was positively related to market-based risk measures; and that CEOs that were awarded higher vega contracts subsequently chose riskier business policies. Acharya, Litov and Sepe (2013) find that the sensitivity of aggregate pay to bank non-executives to bank performance prior to the financial crisis was positively associated with poor bank financial performance during the financial crisis.

A handful of studies have examined the causes and consequences of bank-generated externalities, including but not limited to executive compensation. Sedunov (2014), in a study that focuses mainly on the properties of an augmented measure of CoVaR, conducts an ancillary regression test that finds no statistical relationship between systemic risk and executive compensation.[6] Boyd and Heitz (2016) compare the production costs and systemic risk associated with U.S. banking companies that are too-big-to-fail; they conclude that the costs of increased systemic risk exceed the savings from scale economies. Berger, Roman and Sedunov (2016) find that bailouts of U.S. banks via the TARP program tended to reduce systemic risk. Diaz and Huang (2013) study U.S. bank holding companies and find that firms with better corporate governance (as measured by an index of 50 governance-related factors) tend to create greater

[6] Sedunov (2014) presents this result in a footnote and does not subject this finding to any robustness tests.

amounts of liquidity. Fungacova, Turk Ariss and Weill (2013) find that likelihood of failure among Russian banks increases if they create excessive amounts of liquidity. Our methodology provides a potentially unifying framework for considering the findings of these previous studies.

3. Analytic framework

To date, both the theoretical literature (starting with Jensen and Meckling 1976) and the empirical literature on executive compensation have focused on private outcomes: The shareholder's returns and the manager's personal utility. In this study we focus on public outcomes: The positive and negative externalities that spillover beyond the boundaries of the firm. Because externalities are by definition extra-market processes, they are difficult to measure and value. We exploit recent advances in measuring liquidity creation (Berger and Bouwman 2009) and systemic risk (Acharya, et al., forthcoming) as starting points for estimating the values of positive and negative externalities generated by banking companies.

We begin with the standard notion that the firm's managers may act in their own self-interest rather than making decisions that maximize firm value (Berle and Means 1932), and that shareholders attempt to counter these principal-agent problems by designing compensation contracts to incentivize managers to make value-maximizing business decisions. Simplifying to a one-period framework, we can express the results of this corporate governance problem as follows:

$$\pi = \pi(X(delta,\ vega)) \tag{1}$$

$$\sigma^{\pi} = \sigma^{\pi}(X(delta,\ vega)) \tag{2}$$

where *private return* π and *private risk* σ^{π} are shareholder wealth outcomes generated by the business decisions *X* made by bank management, which in turn are influenced by the incentives *delta* and *vega* embedded in her compensation contract. In the Appendix 1, we provide a standard stylized model of how the features of executive compensation contracts (salary, stock grants, and stock options grants) map into managerial compensation incentives (delta, vega) and hence influence managerial risk aversion.

Our interest here lies not in how executive compensation incentives affect the production of shareholder risk and return, but rather in how compensation incentives lead unintentionally to the production of positive and/or negative externalities. To illustrate, assume that a bank issues demand deposits and invests those funds in a small or middle-market business loan. These business decisions are made with a clear objective of generating shareholder returns from the interest margins, fees and operating expenses associated with the loan and deposit contracts.[7] But agents outside of the bank also benefit from this process of financial intermediation. The money that a bank creates by issuing deposits and extending credit will circulate in the economy, where it can be used free-of-charge to facilitate transactions among other agents who are not customers of the bank. These liquidity creation externalities, or ***public returns***, are byproducts of the private profit-seeking actions of bank management.

Bank shareholders derive no more or no less value from this external liquidity creation than does any other member of society; as a result, these liquidity spillovers do not figure into the bank's private shareholder value maximization problem. But some of the liquidity created by the bank is a direct and immediate consequence of its pursuit of private returns—that is, the bank provides liquidity to its borrowers by holding their illiquid financial claims, and the bank provides liquidity to its depositors by issuing them demandable debt contracts. The total amount of liquidity created by the bank is simply the sum of the internalized (private) liquidity creation and the external (public) liquidity creation. Because both parts this sum are derived from the same managerial business decisions, we can express total liquidity creation as:

$$L = L(X(delta, vega)) \tag{3}$$

Berger and Bouwman (2009) provide a tractable method for calculating the total liquidity created by an individual bank during a given span of time. We propose using the following straightforward regression approach to separate total liquidity creation L into its internalized and externalized components:

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[7] These business decisions might also be influenced by their impact on the personal utility of the manager. For now, we simply assume that the manager faces wealth incentives (delta, vega) that successfully align her interests with those of the shareholders.

$$L^M{}_i = a + b \cdot \pi_i + \varepsilon^L{}_i \tag{4}$$

where L^M is any available empirical measurement of total liquidity creation, π is private shareholder returns, ε^L is the ordinary least squares residual term, and i indexes banks. By definition, OLS residuals are orthogonal to the right-hand side regressors. Hence, if L^M is a reasonable measure of total liquidity creation and if private returns π is correctly specified, then the estimated $\hat{\varepsilon}^L$ will be natural measures of external liquidity creation.

With the estimated liquidity creation externalities $\hat{\varepsilon}^L$ in-hand, we can test whether and how these positive spillovers are influenced by the contractual wealth incentives of bank managers, as follows:

$$\hat{\varepsilon}^L{}_{i,t} = \alpha + \gamma \cdot delta_{i,t-1} + \lambda \cdot vega_{i,t-1} + \delta \cdot controls_{i,t} + \mu_{i,t} \tag{5}$$

where time t is measured in years as compensation contracts are typically repriced annually. Identification in this second-step regression should be free of endogeneity concerns: While managerial contracts (and hence *delta* and *vega*) are written with private returns π in mind, the public returns $\hat{\varepsilon}^L$ are consumed outside the firm and shareholders care little about them. Because $\hat{\varepsilon}^L$ is orthogonal to private returns, then *delta* and *vega* should be uncorrelated with the error term $\mu_{i,t}$.

We follow a parallel process to evaluate whether and how managerial wealth incentives influence the bank's generation of negative externalities. Returning to our example, a bank seeking to earn private returns by funding business loans with demand deposits is exposing its shareholders to risk: Making the business loan (as opposed to investing in a Treasury security) exposes shareholders to credit risk, and funding the loan with demand deposits (as opposed to fixed maturity finance) exposes shareholders to both liquidity risk and interest rate risk. But these internal business decisions can also impose risks on agents outside of the bank. Bad outcomes regarding its own credit risk (its loans default), liquidity risk (its depositors run), and interest rate risk (its margins collapse) exposures can result in collateral damage to other financial institutions. Some of this damage to other financial institutions will be direct, e.g., capital losses on equity and debt securities issued by the distressed bank, capital losses on derivatives contracts priced on the underlying value or risk of the distressed bank, or counterparty losses on bilateral financial contracts with the distressed bank. Damage can also occur through indirect channels, e.g., contagion-like losses on investments in or contracts with firms and/or customers who themselves are directly exposed to the distressed bank, or increased financing costs due disruptions in financial markets caused by the distressed bank. These indirect risk outcomes can be considered systemic risk externalities, or *public risks*, as they are byproducts of private business decisions that spillover to parties that are not associated with the initial bilateral risk-taking.

Because the initial bilateral risk-taking was a business decision made by bank management, we can express systemic risk creation as:

$$S = S(X(delta,\ vega)) \tag{6}$$

Although private risk σ^{π} and public risk S are theoretically separable concepts, they are difficult to measure separately. Benoit, et al. (2013) show that SES and other measures of systemic risk can be expressed as transformations of market risk measures (such as beta) and demonstrate that empirical rankings of U.S. banks by systemic risk and market risk are similar. We propose using the following straightforward regression to separate measured systemic risk into its internalized and externalized components:

$$S^{M}{}_{i} = a + b \cdot \sigma^{\pi}{}_{i} + \varepsilon^{S}{}_{i} \tag{7}$$

where S^M is measured systemic risk, σ^{π} is private shareholder risk, ε^S is the ordinary least squares residual term, and i indexes banks. By definition, OLS residuals are orthogonal to the right-hand side regressors. Hence, if S^M is a reasonable measure of systemic risk and if private risk σ^{π} is correctly specified, then the estimated $\hat{\varepsilon}^S$ will capture the systemic risk externality.

With the estimated systemic risk externalities $\hat{\varepsilon}^S$ in-hand, we can test whether and how these negative spillovers are influenced by the contractual wealth incentives of bank managers, as follows:

$$\hat{\varepsilon}^S_{i,t} = \alpha + \gamma \cdot delta_{i,t-1} + \lambda \cdot vega_{i,t-1} + \delta \cdot controls_{i,t} + \nu_{i,t} \tag{8}$$

As in (5), identification in this second-step regression should be free of endogeneity concerns: While managerial contracts (and hence *delta* and *vega*) are written with private risk σ^π in mind, the public risk $\hat{\varepsilon}^S$ is consumed outside the firm and shareholders care little about it. Because $\hat{\varepsilon}^S$ is orthogonal to private risk, then *delta* and *vega* should be uncorrelated with the error term $\nu_{i,t}$.

Identification in the above framework depends squarely on the implementation of equations (4) and (7) that we use to separate measured liquidity creation L^M and measured systemic risk S^M into their orthogonal private (the fitted values $\hat{L}^M$ and $\hat{L}^S$) and public ($\hat{\varepsilon}^L$ and $\hat{\varepsilon}^S$) components. Clearly, equations (4) and (7) are not the true models of liquidity creation and systemic risk generation. For example, equation (4) is misspecified because we omit from π any of the variables in the true model that measure public returns. Given these omitted variables, the coefficients *b* will be biased (i.e., they are not the π coefficients from the true model) and hence the residuals ε^L will also be biased (i.e., they are not the residuals that would obtain from a well-specified model). However, it is not our objective to estimate the true model, and the vector of estimated OLS residuals $\hat{\varepsilon}^L$ has the property that we desire: corr($\hat{\varepsilon}^L$,π)=0. It is crucial, of course, that we fully specify the vector π with multiple measures of private returns; as we purge greater amounts of private return from L^M, the ε^L become purer measures of liquidity creation spillovers.[8] Parallel arguments apply for the efficiency of equation (7).

A notable concern arises if managers make business decisions with the objective of increasing their chances of receiving a government bailout during an economic crisis. A bank might emphasize growth in

[8] Because we are not performing inference in equation (2), we are unconcerned with the statistical significance of the coefficients; multicollinearity is to be expected. Because we are not attempting to estimate the true model, we are unconcerned with goodness-of-fit; low adjusted R-square statistics are to be expected.

order to become 'too-big-to-fail' or coordinate its business policies with other banks to create a 'too-many-to-fail' scenario (Acharya and Yorulmazer 2007). In cases like these, systemic risk becomes an intentional objective of bank managers' business policy choices—and likely also an intentional consideration when bank directors choose *delta* and *vega*—and we can no longer assume that business decisions are being made exogenous of systemic risk. These phenomena are most likely to occur at large banks and/or among banks with highly correlated financial performance; we take these possibilities into account when we specify our baseline models and also in various robustness tests.

4. Data and variables

We estimate our model using an unbalanced panel of 945 firm-year observations of 127 different U.S. commercial banking companies (SIC code 6020) between 1994 and 2010. The data are collected from a number of primary sources. We obtain the information necessary to construct the CEO compensation variables (delta, vega) from the Execucomp database; during our sample period, Execucomp contains information on between 46 and 74 commercial banking companies each year. We obtain bank affiliate-level data on liquidity creation from Christa Bouwman's website and then aggregate these data up to the bank holding company level.[9] From the Center for Research in Securities Prices (CRSP) database we obtain data necessary to construct our measures of systemic risk, systematic risk, and other stock return-related variables. From the Federal Reserve Y-9C financial statement database we obtain the data necessary to construct our measures of accounting-based returns and risks, as well as a number of control variables. We construct an index of annual economic conditions for each banking company based on data from the Federal Reserve Bank of Philadephia's Coincident Index of Economic Conditions and the Federal Deposit Insurance Corporation's Summary of Deposits database. The boundaries of our 1994 to 2010 data set are determined by the Summary of Deposits database (which starts in 1994) and the data on Christa Bouwman's

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[9] See https://sites.google.com/a/tamu.edu/bouwman/data.

website (which ends in 2010). Definitions and summary statistics for all of the variables used in our tests can be found in Tables 1 and 2, respectively.

4.1. Compensation incentives. The two primary test variables in our model are CEO *Delta* and CEO *Vega* (Guay 1999, Core and Guay 2002).[10] *Vega* measures the CEO's pay-risk sensitivity, that is, how the CEO's personal wealth changes (in thousands of 2010 dollars) with an increase in the volatility of her bank's stock returns. We define *Vega* as the partial derivative of the bank's stock option value with respect to a 0.01 change in the bank's stock return volatility, multiplied by the number of options owned by the CEO. We calculate the value of stock options using the Black-Scholes (1973) model modified by Merton (1973) to account for dividends payouts. *Delta* measures the CEO's pay-performance sensitivity, that is, how the CEO's personal wealth changes (in thousands of 2010 dollars) with an increase in her bank's stock price. We define *Delta* as (a) the bank's stock price multiplied by 1%, then multiplied again by the number of shares owned by the CEO, plus (b) the partial derivative of the bank's stock option value with respect to stock price, multiplied by 1% of the current stock price, then multiplied again by the number of stock options owned by the CEO.

The distributions of both *Delta* and *Vega* are highly rightward skewed, that is, the dollar incentives given to CEOs *via* stock grants and stock options increase at an increasing rate with banking company size. The magnitude of this skewedness, as well its implications for estimation and inference, is easily apparent by looking at the summary statistics for *Delta* and *Vega* in Table 2. We make three adjustments to cope with this. First, we winsorize *Delta* and *Vega* (as well as all of the variables used in our tests) at the 1st and 99th percentiles of their sample distributions. Second, we apply the natural log transformation to both *Delta* and *Vega* prior to estimation. Third, in order to draw our inferences based on relevant changes in CEO incentives, we interpret the economic magnitudes of the estimated coefficients based on one standard

[10] In alternative tests, we calculated *Delta* and *Vega* based on the aggregate compensation attributes of the top five managers at each banking company (including the CEO) as reported in the Execucomp database. Our baseline results (Tables 3 and 4) are strongly robust to using these alternative measures of executive compensation incentives. The results of these tests are displayed in Appendix 2.

deviation changes in the regression variables *lnDelta* and *lnVega* rather than changes in the underlying levels of *Delta* and *Vega*.

4.2. Liquidity creation. Total liquidity creation (*TLC*) is a constructed based on the so-called 'cat-fat' method outlined in Berger and Bouwman (2009). We provide only a brief overview of this elegant, albeit ad hoc, measurement method here.

Begin by classifying every item that appears on (or off) a bank's balance sheet as either 'illiquid', 'semi-liquid' or 'liquid'. (1) An illiquid item on the asset-side of the balance sheet (e.g., business loans) indicates that the bank has taken an illiquid position in exchange for increasing the liquidity of its customers. A weight of 0.5 is applied to the dollar value of these items. In contrast, a liquid item on the asset-side of the balance sheet (e.g., cash, securities) indicates that the bank has remained liquid rather than extending liquidity, and these items receive a weight of -0.5. (2) On the other side of the balance sheet, a liquid item (e.g., transactions deposits) indicates that the bank has financed its assets while accepting liquidity risk, and a weight of 0.5 is applied to the dollar value of these items. In contrast, an illiquid item (e.g., equity, subordinated debt) indicates that the bank has financed its assets without accepting liquidity risk, and these items receive a weight of -0.5. (3) Some off-balance sheet items (e.g., loan commitments) are considered illiquid and their asset-equivalent values are weighted by 0.5, while some off-balance sheet items (e.g., liquid derivatives contracts) are considered liquid and their asset-equivalent values are weighted by -0.5. (4) All other on- and off-balance sheet are defined as semi-liquid and receive a weight of zero.

TLC is calculated in straightforward fashion as the sum of all these weighted items. While these measures are crude and the approach is somewhat ad hoc, there is a strong underlying economic logic: A bank that issues \$100 of transactions deposits (0.5×\$100) and uses those funds to make \$100 of business loans (0.5×\$100) *creates* \$100 worth of liquidity. In contrast, a bank that issues \$100 of equity securities (-0.5×\$100) and uses those funds to purchase \$100 of U.S. Treasuries (-0.5×\$100) *consumes* \$100 worth of liquidity. Dividing *TLC* by total bank assets yields liquidity creation per dollar of assets (*TLCA*).

A common criticism of the Berger and Bouwman (2009) method is that it does not capture the liquidity created by banks that securitize the loans that they originate, a potentially important shortcoming given the importance of loan securitization in the U.S. financial system. This criticism is misplaced. A bank creates liquidity only when it *holds* an *illiquid* loan. In contrast, when a bank sells a loan in exchange for cash—regardless of whether it is a straight loan sale, or a loan sale into a securitization pool—the selling bank is no longer creating liquidity. Rather, the liquidity is now being created by the financial institution that purchased the loan or loan-backed security, because it traded a liquid asset (cash) in exchange for an illiquid asset. Moreover, a loan that is sellable (e.g., a conforming mortgage) is by definition not an illiquid asset, so originating and/or holding that loan does not by itself create any liquidity; if the loan is funded with newly issued liquid deposits then some liquidity is created *via* this choice of financing, but if the loan is funded with newly issued equity or long-term debt capital then liquidity is actually absorbed.[11]

As calculated, the variable *TLCA* pools the liquidity creation associated with the generation of private shareholder returns with the liquidity creation that spills over to the public. We separate these two components using equation (4), which regresses *TLCA* on a vector of bank private return variables π, such that the residuals ε^{TLCA} capture the liquidity creation externalities. We specify the private returns vector π with six variables known to be key indicators of bank performance: Return on equity (*ROE*), return on assets (*ROA*), the market-to-book ratio (*Market-to-Book*), net interest income scaled by assets (*Interest Margin*), the annual change in market capitalization scaled by assets (*ΔMktCap/Assets*), and the annual share price return predicted from a three-factor market model (*Expected Return*). As shareholders themselves, bank managers share in the private returns related to these six measures of absolute bank performance—but in addition, bank managers receive private returns (via bonus-incentive clauses in their contracts) based on the bank's performance *relative to* its peers. Hence, to more fully capture the private returns generated by the bank, we also include in π the six above performance variables specified in relative terms, for example, as $ROA_{i,t}$ minus *industry average* ROA_t, where we use SIC=6020 to define the industry.

[11] Berger and Bouwman (2009) include in their paper a "securitization-adjusted" version of their liquidity creation measure. As stated by the authors, this adjustment is incomplete because it is based on industry-level securitization data; high quality bank-level securitization data is not collected by U.S. bank regulators and hence is unavailable. Our results are strongly robust when we re-estimate Table 3 using the Berger and Bouwman (2009) securitization-adjusted measure. The results of these alternative tests are displayed in Appendix 2.

4.3. Systemic Risk. Systemic estimated shortfall (*SES*) is our primary measure of systemic risk. Acharya, et al. (forthcoming) define *SES* as the propensity of a bank to be undercapitalized when the banking system as a whole is undercapitalized. Logically, this propensity should increase with a bank's financial leverage (i.e., its proximity to being undercapitalized) and with the bank's expected losses during a financial crisis (i.e., its valuation in the tail of the banking system's loss distribution). Following Acharya, et al., we measure a bank's financial leverage (*LEV*) as the market value of its assets divided by the market value of its equity, and we measure the bank's expected losses during a crisis (*MES*, or marginal expected shortfall) as (the negative of) its average daily stock returns on the 5 percent of the trading days each year during which the banking system suffers its largest valuation losses. Acharya, et al. regress the cumulative percentage stock returns during the financial crisis (July 2007-December 2008) for large U.S. financial institutions—which they refer to as 'realized SES'—on the values of *LEV* and *MES* for these banks during the twelve months leading up to the crisis. We calculate *SES* using the following formula based on their cross sectional regression:

$$SES_{i,crisis} = 0.15*MES_{i,crisis-1} + 0.04*LEV_{i,crisis-1} \quad (9)$$

We use the parameters in (9) to calculate annual fitted value measures of *SES* for every bank-year observation in our data.[12]

As calculated, the variable *SES* pools the risk-taking associated with the generation of private shareholder returns with the risk-taking that spills over to the public. We separate these two components using equation (7), which regresses *SES* on a vector of bank private risk variables σ^{π}, such that the residuals ε^{SES} capture the systemic risk externalities. We specify the private risk vector σ^{π} with six variables known to be key indicators of bank riskiness: The standard deviation of *ROE*, the standard deviation of *ROA*, an

[12] The original estimates can be found in Table 4 and Appendix B of Acharya et al (forthcoming). The authors also include a constant term and dummy variables for non-bank financial institutions. As including these terms are meaningless for our purposes, we drop them from our equation (8).

accounting-based measure of insolvency risk (*Z Score*), systematic risk from a three-factor model (*Beta*), the standard deviation of idiosyncratic return from a three-factor model (*Std(Idio. Return)*), and the standard deviation of equity returns (*Std(Returns)*).[13] We also include each of these six risk variables in relative terms, for example, as $Beta_{i,t}$ – *industry average* $Beta_t$.

5. Baseline results

We estimate the first-stage equations (4) and (7) for our full sample of 945 bank-year observations, using pooled OLS and no right-hand side variables other than those defined above for the vectors π and σ^{π}. Because these first-stage estimations are orthogonalization exercises from which we draw no statistical inference, there is no *a priori* reason for adding structure.[14] We estimate the second-stage equations (5) and (8) using OLS with year and bank-CEO fixed effects. The test variables are the one-year lagged values of *lnDelta* and *lnVega*, and statistical inference is performed using standard errors clustered at the bank-CEO level.[15] The vector of *controls* is parsimonious and includes lagged bank size (*lnAssets*), lagged CEO tenure (*lnCEOtenure*), and the Philadelphia Fed's Coincident Index of State Economic Conditions, weighted by the distribution of bank *i*'s deposits across each State (*Econ Index*).

5.1. Liquidity creation model. Table 3 shows the baseline results for the liquidity creation model. In column 1 we use a naïve single-equation approach in which *TLCA* is not orthogonalized to private returns, and we find no statistical association between bank liquidity creation and either *lnDelta* or *lnVega*. This

[13] We use a three-factor market model to estimate *Beta* and *Std(Idio. Return).* The three factors are daily returns on a CRSP value-weighted market portfolio, daily 3-month T-Bill yields, and daily 2-year to 10-year Treasury spreads.

[14] Including fixed effects terms in the first-stage regressions would absorb the time-invariant and bank-invariant variation in *TLCA* and *SES*, some of which (i.e., the external portions of *TLCA* and *SES*) we wish to capture in the spillovers $\hat{\varepsilon}_{TLCA}$ and $\hat{\varepsilon}_{SES}$. Hence, we exclude fixed effects from the first-stage equations. But even if the true values of the externalities ε_{TLCA} and ε_{SES} were observable (thus making the first-stage equations unnecessary), the true externality measures would still contain unobservable time-invariant and bank-invariant components. So we include fixed effects in the second-stage regression because excluding them would result in biased estimates of our test coefficients on *lnDelta* and *lnVega*.

[15] Using bank-CEO (rather than bank) fixed effects and clustering standard errors at the bank-CEO level (rather than the bank level) recognizes that compensation packages, executive incentives, and executive preferences can change substantially upon the hiring of a new CEO. Our results are strongly robust to using bank fixed effects and/or clustering standard errors at the bank level.

stands in sharp contrast to the results in the remainder of Table 3 for which we use our two-stage methodology.

We estimate the first-stage orthogonalization equation for three different specifications of the private return vector π. In column 2 we include only the absolute versions of the private return variables; in column 4 we add the relative versions of the private return variables; and in column 6 we use the industry averages of the private return variables. These first-stage regressions explain between 11% and 13% of the variation in *TLCA*. These relatively low goodness-of-fit do not concern us—indeed, a very high first-stage R-square might indicate that we were stripping off not only the private returns associated with liquidity production, but also a portion of the external returns that we wish to leave in the regression residuals. Only one of the six private returns variables (*Interest Margin*) exhibits statistical significance, which for two reasons is unsurprising. These six measures of private returns are strongly correlated which each other (see Table 5) and this multicolinearity will naturally exaggerate the coefficient standard errors; this is of no consequence, however, given that statistical inference is not our objective in this first stage. And of the six private return regressors, *Interest Margin* captures most directly the financial flows (interest revenues and interest expenses) thrown off by the two primary components of bank liquidity generation (loans and deposits).

The second-stage test equations are displayed in columns 3, 5 and 7. The coefficient on *lnDelta* is statistically negative in all three cases; based on the estimates in column 3, a one standard deviation increase in *lnDelta* is associated a 0.27 standard deviation decrease in external liquidity creation $\hat{\varepsilon}_{TLCA}$.[16] The coefficient on *lnVega* is statistically positive in all three cases, with a one standard deviation increase in *lnVega* associated with a 0.25 standard deviation increase in $\hat{\varepsilon}_{TLCA}$. The directions of these effects are consistent with the stylized theoretical framework presented in Appendix 1: An increase in vega or decrease in delta increases managers' incentives to take risk; this higher desired level of risk can be accomplished

[16] The calculation is (-0.0296*0.54)/0.060 = -0.2664, where the standard deviations 0.54 and 0.060 are the average de-meaned (within) standard deviations reported in the final column of Table 2. Unless otherwise indicated, all other similar calculations follow the same format.

(e.g., *via* higher credit risk, liquidity risk, and/or interest rate risk) by increasing the bank's liquidity-generating activities; and external liquidity creation increases as a byproduct of this increased private risk-taking.

Why might CEO compensation incentives be unrelated to the bank's total liquidity creation (*TLCA* in column 1) yet be strongly related to the bank's external liquidity creation ($\hat{\varepsilon}_{TLCA}$ in columns 3, 5 and 7)? Assume an increase in CEO vega, which incents the manager to increase the bank's return volatility. This can be accomplished changing the composition of bank liquidity creation, while leaving the total amount of bank liquidity unchanged: Credit risk can be increased by reallocating the existing loan portfolio from high quality borrowers to low quality borrowers; liquidity risk can be increased by reallocating existing business lending from term loans to credit lines; and interest rate risk can be increased by altering the durations of existing loans and deposits. (Assuming a decrease in CEO delta leads to similar risk-increasing incentives.) Moreover, there is no *a priori* theoretical reason why total liquidity creation per dollar of assets should be related to CEO compensation incentives. Large commercial banking companies have numerous ways to generate earnings and risk, and many of these business lines (e.g., securities brokerage, securities trading, investment banking, insurance sales, risk management services, private wealth management) are unrelated to liquidity generation or net liquidity generation.

5.2. Systemic risk model. Table 4 shows the baseline results for the systemic risk model. The test coefficients on *lnDelta* and *lnVega* are statistically significant in both the naïve single-equation model (column 1) and our full two-stage models (columns 3, 5 and 7) and carry similar magnitudes across all of these models. The coefficient on *lnDelta* is statistically negative in all cases; based on the estimates in column 3, a one standard deviation increase in *lnDelta* is associated with a 0.41 standard deviation decrease in $\hat{\varepsilon}_{SES}$. The coefficient on *lnVega* is statistically positive in all cases, with a one standard deviation increase in *lnVega* associated with an economically small 0.05 standard deviation increase in $\hat{\varepsilon}_{SES}$. These results imply that business decisions made by relatively less risk-averse (high-vega or low-delta) managers generate greater amounts of systemic risk externalities.

Why might the results in our full two-stage model be so similar to the results in the naïve one-stage model? We note that measures of bank liquidity creation are not designed to measure external effects; rather, they capture total liquidity creation and our two-stage model (Table 3) is necessary to separate the public and private portions of bank liquidity creation. In contrast, all measures of systemic risk are designed explicitly to measure external effects; hence, our two-stage model (Table 4) has little separation left to do. Nevertheless, the results indicate that some separation is still occurring. Of the six private risk variables, only systematic risk (*Beta*) carries a statistically significant coefficient in the first-stage; this is fitting, as systematic risk is the major driver of (well-diversified) private shareholder risk in finance theory, and it has also been closely linked to systemic risk in empirical research (Benoit, et al. 2014, Guntay and Kupiec 2014). The separation accomplished in the first-stage regressions is reflected in uniformly smaller coefficients on *lnDelta* and *lnVega* in the second-stage regressions (about 35% smaller for *lnDelta* and about 20% smaller for *lnVega*). And the relatively large R-square statistics in the first-stage regressions (ranging from 0.222 to 0.292) indicate that private returns are explaining a substantial portion of the variation in measured systemic risk.

5.3. Examining a key presumption. A crucial presumption in our analysis is that the first-stage regressions substantially strip private returns π and private risk-bearing σ^{π} from the initial measures of liquidity creation *TLCA* and systemic risk *SES*, so that the first-stage residuals $\hat{\varepsilon}^{TLCA}$ and $\hat{\varepsilon}^{SES}$ are good estimates of the true externalities. We cannot formally test the soundness of this presumption because the true externalities cannot be observed; what we can do is test the robustness of our main findings to changes in the first-stage orthogonalizations. We do so by re-estimating the baseline liquidity creation and systemic risk models in sequential fashion, adding private return and private risk variables one-at-a-time to the first-stage regressions.

Table 6 displays the results of this exercise for the liquidity creation model. We add the right-hand side private risk variables in descending order of their correlations with *TLCA*. This exercise has substantially diminishing effects on first-stage goodness of fit: The first <u>two</u> private return variables (*Market-to-Book* and *Interest Margin*) explain 9.2% of the variation in the dependent variable, while the additional four private return variables (*ROA*, Δ*MktCap/Assets*, *ROE* and *Expected Returns*) explain only an additional 2.1%. (And note that in Table 3, the additional six industry private return variables explain only an additional 2.4% of the variation in the dependent variable.) This exercise also has non-diminishing effects on the economic and statistical magnitudes of the coefficients on *lnDelta* and *lnVega*.

Table 7 displays the results of this exercise for the systemic risk model. We add the right-hand side private risk variables in descending order of their correlations with *SES*. Again, we find diminishing effects on first-stage goodness of fit: The first two private risk variables (*Std(ROE)* and *Std(ROA)*) explain 15% of the variation in the dependent variable, while the additional four private risk variables (*Std(Idio. Return)*, *Std(Return)*, *Beta* and *Z score*) explain only an additional 7.2%. (And note that in Table 4, the additional six industry private risk variables explain only an additional 7.1% of the variation in the dependent variable.) The magnitudes and statistical significance of the *lnDelta* and *lnVega* are strongly robust throughout this exercise.

To be sure, the results presented in Tables 6 and 7 fall short of formal proof that our first-stage regressions are fully isolating external liquidity creation and external systemic risk. But these results, together with those already presented in Tables 3 and 4, indicate that (a) the estimated coefficients on *lnDelta* and *lnVega* are statistically and economically robust to increasingly thorough first-stage specifications and (b) further additions to the first-stage specifications are likely to provide only minimal additional explanatory power.

6. Business decisions

We now turn briefly to the channels through which executive wealth incentives result in positive and negative externalities. As modeled above, liquidity externalities are the byproducts of the business decisions X made by incentivized managers in pursuit of private shareholder returns. We can show these channels more formally. Substituting equations (1) and (3) into equation (4) and solving for the liquidity externality yields:

$$\varepsilon^L = L(X(delta,vega)) - b\cdot\pi(X(delta,vega)) - a \tag{10}$$

where we have suppressed the subscripts *i*. Taking the derivative with respect to executive compensation incentives, applying the chain rule, and rearranging once again yields:

$$\frac{\partial \varepsilon^L}{\partial(delta,vega)} = \left[\frac{\partial L}{\partial X} - b\cdot\frac{\partial \pi}{\partial X}\right]\left[\frac{\partial X}{\partial(delta,vega)}(delta, vega)\right] \tag{11}$$

The first bracket is the change in external liquidity creation ε^L for a marginal change in business decisions *X* (i.e., the difference between the total liquidity $\partial L/\partial X$ created and the intended liquidity $b\cdot\partial\pi/\partial X$ created by a change in business decisions) while the second bracket is the elasticity of business decisions *X* with respect to executive wealth incentives *delta* and *vega*. Finally, assume there are $K = (1,k)$ categories of business decisions *X*. To the extent that (a) executive wealth incentives have separable effects on each category of business decisions and (b) each category of business decisions has a separable effect on external liquidity creation, we can disaggregate (11) into *K* separate business decision-specific effects:

$$\frac{\partial \varepsilon_k^L}{\partial(delta,vega)} = \left[\frac{\partial L}{\partial X_k} - b\cdot\frac{\partial \pi}{\partial X_k}\right]\left[\frac{\partial X_k}{\partial(delta,vega)}(delta, vega)\right] \tag{12}$$

Proceeding in parallel fashion yields a similar expression for external systemic risk:

$$\frac{\partial \varepsilon_k^S}{\partial(delta,vega)} = \left[\frac{\partial S}{\partial X_k} - b\cdot\frac{\partial \pi}{\partial X_k}\right]\left[\frac{\partial X_k}{\partial(delta,vega)}(delta, vega)\right] \tag{13}$$

By construction, both *LTCA* and *SES* are separable across broad categories of business decisions, which allows us to estimate the *K* separate elements of (12) and (13). Following Berger and Bouwman (2009), we disaggregate *LTCA* into three broad areas of business activity: On-balance sheet activities, off-balance derivatives exposures, and off-balance sheet credit commitments. As shown in equation (9), *SES* is easily disaggregated into two broad areas of risk exposure: *MES* captures the bank's sensitivity to market shocks and thus can be loosely associated with banks' investment decisions while *LEV* measures the bank's financial leverage and thus can be associated with banks' financing decisions.[17]

We apply our two-stage methodology to each of the disaggregated components of *LTCA* and *SES*. As shown in Table 8, the channel between CEO wealth incentives and external liquidity creation runs chiefly through off-balance sheet credit commitments—that is, through the pre-approved but still unused portions of revolving business credit facilities, consumer credit cards, and home equity lines of credit. These contracts give customers the option of initiating loans sometime in the future; the bank collects origination and facility fees immediately, but does not have to provide costly funding for these loans until the customers initiate them. So credit commitments expose banks to greater credit risk as well as greater liquidity risk, while at the same time increasing the current period earnings. Hence, both high-vega and low-delta CEOs have clear incentives to engage in off-balance sheet credit lines, as verified by the results in column 8. The non-significant coefficients on *lnDelta* and *lnVega* in column 2 can be interpreted as follows: While on-balance sheet activities provide channels for incentivized CEO decision-making to influence liquidity creation associated with private returns, on-balance sheet activities do not (on average) serve as channels through which CEO wealth incentives result in liquidity spillovers.

As shown in Table 9, both financial leverage *LEV* and sensitivity to negative industry shocks *MES* serve as channels through which CEO wealth incentives influence systemic risk externalities. If a CEO responds to high-vega (or low-delta) risk-taking incentives by increasing her bank's financial leverage, her bank also generates as a byproduct more systemic risk. If the CEO responds to these same risk-taking incentives by making business decisions that increase her bank's exposure to negative industry shocks, her bank also creates as a byproduct more external liquidity.

[17] As specified in equation (9), we disaggregate SES_t into its lagged components MES_{t-1} and LEV_{t-1}.

7. Alternative measures of systemic risk

Because systemic risk cannot be directly observed or directly measured, numerous competing models for estimating the systemic risk of banks have materialized over the past decade. All of these models suffer from one or more shortcomings. As described above, SES is measured relative to a benchmark systemic event; as a result, estimates of SES necessarily become less accurate for years long before or long after the year in which the benchmark event occurred. Our annual 1994-2010 SES estimates are based on the benchmark financial crisis event in 2008, so our estimates of SES in the 1990s may be especially susceptible to measurement error. In Table 10 (first two columns) we re-estimate our baseline systemic risk model from Table 4 for the shorter 2000-2010 sample period. The coefficients on *lnDelta* and *lnVega* are now 13% and 15% larger, respectively, in absolute magnitude relative to our baseline model.

The SRISK method of measuring systemic risk (Brownlees and Engle 2015) provides a second way to avoid this potential measurement error problem. Like SES, SRISK measures a bank's expected capital shortfall conditional on a systemic event and contains both cross-sectional and time-series variation, but SRISK does not rely on an actual benchmark systemic event. We estimate *SRISK* each year for each bank and normalize these estimates by bank assets.[18] The coefficients on *lnDelta* and *lnVega* are robust to using *SRISK* in place of *SES* (see Table 10, columns 3 and 4): A one standard deviation increase in *lnDelta* (*lnVega)* is associated with a 0.37 standard deviation decrease (a 0.04 standard deviation increase) in external systemic risk.

As discussed above, ΔCoVaR estimations of systemic risk (Adrian and Brunnermeier 2016) exhibits no bank-specific time series variation, and hence are incompatible with our panel data modeling approach. Nevertheless, we re-estimate our systemic risk model for two different ΔCoVaR approaches. First, we use Adrian and Brunnermeier's (2016) original ΔCoVaR approach—we refer to this as *classic-ΔCoVaR*—which generates a single estimate of systemic beta for each bank, with time series variation

[18] Like Brownlees and Engles (2015), we estimate monthly measures of SRISK for each bank, but then we calculate the annual measure that we need as the average of the monthly estimates. For purposes of tractability, we assume that equity returns of the bank and the market follow a bivariate normal distribution.

coming only from the macroeconomic state variables. Second, we use Sedunov's (2014) *adapted-ΔCoVaR* approach, which injects bank-specific time series variation into systemic beta by executing the estimations on five-year rolling windows of data.[19] Not surprisingly, the *classic-ΔCoVaR* approach results in statistically non-significant coefficients on both *lnDelta* and *lnVega*, but we do find a modicum of robustness using the *adapted-ΔCoVaR* approach (see Table 10, columns 7 and 8). The *lnDelta* coefficient is statistically zero, but the *lnVega* coefficient is statistically positive albeit relatively small: A one standard deviation increase in *lnVega* is associated with a 0.02 standard deviation increase in *adapted-ΔCoVaR*.

8. Financial crisis

It is natural to wonder whether and to what degree our results are driven by disruptions related to the financial crisis. To investigate, we interact a financial crisis dummy (*Crisis*=1 in 2008, 2009 and 2010) with *lnDelta* and *lnVega* in the second-stage liquidity creation and systemic risk regressions. The results are displayed in Table 11 (columns 1 and 2).

The derivative $\partial\varepsilon_{TLCA}/\partial Crisis$ = 0.211 in column 1 indicates that external liquidity creation increased by 1.16 standard deviations at the average bank in our data during the financial crisis.[20] This is consistent with two stylized facts of the crisis years that are consistent with liquidity creation: Investors fled short-term credit markets for the relative safety of bank deposits, while firms and households turned to banks for precautionary sources of credit and liquidity (Kashyap, Rajan and Stein 2002, Gatev and Strahan 2006, Pennacchi 2006, Acharya and Mora 2015). In contrast, the derivative $\partial\varepsilon_{SES}/\partial Crisis$ = 0.00539 in column 2 is statistically zero. Remembering that SES is an *ex ante* measure of systemic risk, this indicates that the potential for systemic risk outcomes neither increased nor decreased during the crisis years.

The impact of CEO delta on the liquidity and systemic risk externalities is unchanged during the crisis years—the derivatives $\partial\varepsilon_{TLCA}/\partial lnDelta(Crisis=1)$ and $\partial\varepsilon_{SES}/\partial lnDelta(Crisis=1)$ are statistically

[19] For both approaches, we use weekly bank asset returns, weekly asset returns on the banking sector, and macroeconomic state variables to estimate *ΔCoVaR*.
[20] The calculation is 0.211/0.182 = 1.159.

negative and are insignificantly different from their non-crisis year values—but the positive effect of CEO vega on the externalities vanishes during the crisis years, as indicated by the statistically zero derivatives $\partial\varepsilon_{TLCA}/\partial$*lnVega(Crisis=1)* and $\partial\varepsilon_{SES}/\partial$ln*Vega(Crisis=1)*. This is consistent with a shift in bank manager objectives during the financial crisis—perhaps under pressure by bank regulators—away from risk-taking and toward rebuilding their balance sheets.

Although we characterize external liquidity creation as a positive externality, there may be times when banks individually or collectively produce 'too much' liquidity. Excess extensions of credit can result in asset bubbles—which are prone to rapid collapse, with attendant macroeconomic distress—and during these episodes a marginal increase in liquidity could constitute a negative externality. We explore this notion by determining which years during our 1994-2010 sample period might be associated with excess liquidity creation, applying a standard Hodrick-Prescott filter on an annual 1970-2012 data time series for aggregate U.S. commercial bank lending-to-GDP. Figure 1 summarizes the analysis, which identifies 2004 and 2007 as the two largest positive outliers during our sample period. We define a dummy variable *Credit Bubble* equal to one for these years, and interact it with *lnDelta* and *lnVega* in the second-stage liquidity creation regression. The results are displayed in Table 11 (column 3).

The derivative $\partial\varepsilon_{TLCA}/\partial$*Credit Bubble* = 0.232 indicates that the liquidity creation externality did indeed increase during these bubble years. But the influence of CEO delta and on external liquidity creation is unchanged during the crisis years, as indicated by the derivatives $\partial\varepsilon_{TLCA}/\partial$*lnDelta(Credit Bubble=1)* and $\partial\varepsilon_{TLCA}/\partial$*lnDelta(Credit Bubble=1)* which are both insignificantly different from their non-credit bubble year values. Hence, to the extent that our credit bubble variable is capturing the worst of the excess credit build-up prior to the financial crisis, we find no evidence that CEO wealth incentives were a driving force for those excesses.

9. Strategic risk-taking behavior

The manner in which bank managers respond to wealth incentives may vary with the strategic circumstances facing their banks. Managers at too-big-to-fail banks may respond more aggressively to risk-taking incentives, given the special regulatory protections they are likely to receive should they become insolvent. We might expect similar risk-taking behaviors by managers at banks with returns that closely track those of other large banks, given the broad-based regulatory protections that are likely during 'too-many-to-fail' scenarios. And managers of banks with high probabilities of insolvency may also exhibit greater sensitivity to risk-taking incentives, given that the potential for upside gains outweigh the limited downside losses in this state of nature. To test these notions, we define three dummy variables—*TBTF* equals one for banks with assets greater than \$100 billion, *Herding* equals one if the correlation of bank daily returns and industry daily returns exceeds the 90^{th} percentile of the sample distribution, and *Insolvency* equals one if the bank Z-score is below the 10^{th} percentile of the sample distribution—and we interact those variables with *lnDelta* and *lnVega* in the second-stage liquidity creation and systemic risk regressions. The results are displayed in Table 12.

On average, the size-adjusted externalities generated by too-big-to-fail banks, herding banks, and close-to-insolvency banks are no different than those generated by the other banks in the data (see the six statistically non-significant derivatives $\partial\varepsilon_{TLCA}/\partial\theta$ and $\partial\varepsilon_{SES}/\partial\theta$). However, we find three instances in which CEO wealth incentives are tilted toward greater external risk generation among these banks. In our baseline models, we find robust evidence that systemic risk externalities increase with CEO vega; the results in Table 12 indicate that these CEO vega effects are stronger by an order of magnitude at both herding banks and at close-to-insolvency banks (see the statistically positive coefficients on *lnVega*θ* and the derivatives $\partial\varepsilon_{SES}/\partial \ln Vega(\theta=1)$ in columns 4 and 6). Our baseline models also show robust evidence that liquidity creation externalities decrease with CEO delta; the results in Table 12 indicate that these CEO delta effects disappear at close-to-insolvency banks (see the statistically positive coefficient on *lnDelta*θ* and the statistically zero derivative $\partial\varepsilon_{TLCA}/\partial lnDelta(\theta=1)$ in column 5).[21]

[21] For completeness, we note a number of other instances in which our robust baseline results become statistically non-significant in Table 12 when evaluated at θ=1: $\partial\varepsilon_{TLCA}/\partial lnDelta$ in column 1; $\partial\varepsilon_{TLCA}/\partial lnVega$ in columns 1 and 3; and $\partial\varepsilon_{SES}/\partial lnVega$ in column 2. However, none of these results are accompanied by statistically significant coefficients on the associated interaction terms *lnDelta*θ* or *lnVega*θ*.

10. Policy implications

For our results to have meaningful implications for regulatory policy, we must demonstrate that the estimated coefficients in our models translate into macro-economically meaningful changes in market externalities. Table 13 shows some back-of-the-envelope calculations that gross-up our baseline bank-level liquidity externality results to the banking system level. Table 14 shows a parallel set of calculations for systemic risk externalities.

Moving left-to-right across the first row of Table 13, we begin by multiplying a one standard deviation shock to *lnDelta* (0.54) by the estimated coefficient on *lnDelta* from Table 3, column 3 (-0.0296). This results in an annual reduction in external liquidity creation of $0.0160 per dollar of assets for the average bank in our data. Multiplying this by the average annual aggregate assets at the banks in our data (about $4.24 trillion) results in an annual aggregate reduction in external liquidity creation of $67.9 billion. Dividing this by the average annual aggregate liquidity created by the banks in our data (about $2.27 trillion) yields an economically meaningful 2.99% reduction in system-wide liquidity creation. By comparison, a standard deviation increase in *lnVega* results in a 2.75% *increase* in system-wide external liquidity creation.

The results for external systemic risk in Table 14 are more disparate. A standard deviation across-the-board increase in *lnDelta* results in an estimated 6.80% reduction in external systemic risk, while the same size increase in *lnVega* results in just a small 0.76% increase in external systemic risk. Thus, if our policy objective is to reduce systemic risk externalities, and if our policy instrument is bank executive compensation, then encouraging banks to award stock grants to their CEOs (increasing delta) would be a much more effective than discouraging banks from awarding stock option grants to their CEOs (decreasing vega). Such a strategy would be consistent with the spirit of Federal Reserve guidelines (2011) that stress greater reliance on long-term equity-based compensation.

But such a strategy will cause two ancillary effects, both of which reduce the beneficial effects of external liquidity creation. Assume that regulation calls for banks to increase *lnDelta* by one standard deviation via increased stock grants, which according to our calculations will successfully drive down systemic risk by 6.80%. First, as shown in Table 13, this increase in CEO delta also reduces system-wide liquidity creation by 2.99%. Second, if banks are required to increase one form of CEO compensation (stock grants), then they will want to offset the pay increase with some other form of pay decrease. If this offset is accomplished with a reduction in cash salary, then the reduction in liquidity creation would likely be limited to 2.99%. But if this offset is accomplished with a reduction in stock option compensation, then there will be a further reduction in liquidity creation—perhaps a 2.75% reduction, assuming the offset required a one standard deviation reduction in *lnVega*. Thus, in this crude example, the overall cost of reducing system-wide systemic risk by 6.80% might be as much as a 5.74% reduction in system-wide liquidity creation.

Moreover, our data suggest that this policy tradeoff became stronger during the financial crisis. The OLS regressions shown in Table 15 indicate a relatively robust positive relationship between ε_{TLCA} and ε_{SES}. Over the full sample period, an additional unit of external systemic risk is associated with an additional 0.5534 units of external liquidity creation on average. The data suggest a regime shift somewhere around 2006-2007. The regression intercept increases from -0.0446 to +0.0556, equivalent to a 0.55 standard deviation increase in ε_{TLCA} during the crisis years, consistent with our earlier findings. The regression slope increases from 0.5919 to 0.6512, indicating a 10% higher opportunity cost (i.e., reduced liquidity creation) associated with reduced systemic risk.

11. Conclusions

The global financial crisis has given economic policymakers pause to rethink bank regulation. Regulators have traditionally focused on constraining the scope of banks' decision-making, placing restrictions on permissible banking activities and the manner in which banks can finance those activities. In the wake of the crisis, regulators have adopted an additional, more primary, and potentially more powerful focus: Altering the personal wealth incentives of banks' key decision-makers by constraining the content of their compensation contracts.

A small body of research examines the links between bank executive compensation and bank financial performance (e.g., Chen, Steiner, and Whyte 2006; Cheng, Hong and Scheinkman 2010; Minnick, Unal and Yang 2011; DeYoung, Peng and Yan 2013). But there is little evidence regarding the influence of compensation incentives on the positive and negative externalities that spillover naturally from the business decisions made by these executives. In this paper, we examine the historical empirical relationships between bank executive pay incentives and bank systemic risk generation, which we characterize and measure as a negative social externality or spillover cost. In parallel fashion, we study the historical relationships between banker pay and bank liquidity creation, which we characterize and measure as a positive social externality or spillover benefit.

We find statistically strong and economically meaningful relationships between social spillovers and executive compensation incentives at large U.S. banking companies between 1994 and 2010. Increases in CEO pay-for-performance incentives (i.e., CEO delta) are associated with non-trivial reductions in both external liquidity creation and external systemic risk. Increases in CEO pay-for-risk incentives (i.e., CEO vega) are associated with statistically significant though somewhat smaller increases both externalities. These results suggest a vexing regulatory policy tradeoff: Regulatory rules designed to dampen the risk-taking incentives of bank executives—which logically should reduce both internal bank risk and banks' contributions to systemic risk—may result in reduced system-wide liquidity creation.

We generate our findings within a conceptual framework that connects banker pay incentives—through their business policy decisions—to the risk and return spillovers generated by the bank but borne by society. From this conceptual framework, we derive an estimable relationship between executive pay incentives and the social externalities. Because externalities are by definition unintentional byproducts, and hence carry no weight in managers' or shareholders' objective functions, our framework has a pleasing and important feature for empirical identification: Executive compensation incentives are strictly exogenous regressors. Recent conceptual advances in bank performance metrics provide us with quantitative starting points for measuring bank-generated externalities. We measure external liquidity creation (a positive externality) by isolating the portion of the Berger and Bouwman (2009) liquidity creation measure that is orthogonal to bank shareholder private returns. We measure external systemic risk (a negative externality) by isolating the portion of the Acharya, et al. (forthcoming) systemic expected shortfall measure that is orthogonal to bank shareholder private risk.

Our framework is general and could theoretically be applied to firms in any industry. We apply our framework to large U.S. commercial banking companies in this study, in hopes of informing bank regulators' efforts to reduce banking system risk by shaping the characteristics of bank executive compensation. Some of these efforts have been more reactive than well-reasoned, and are unlikely to have significant or long-lasting impacts—for example, the tight restrictions on executive compensation at banks that accepted Troubled Asset Relief Program (TARP) capital infusions under The Emergency Economic Stabilization Act (2008), and the adoption of non-binding shareholder 'Say-on-Pay' rules by the U.S. Securities and Exchange Commission (2011) in accordance with the Dodd-Frank Wall Street Reform and Consumer Protection Act (2010). More thoughtfully considered efforts—such as the bank executive pay guidelines jointly issued by U.S. bank regulatory agencies (Federal Reserve 2011), which encourage long-term, equity-based compensation for bank executives—are more likely to be informed by research such as ours. Nevertheless, it is not clear whether these guidelines will alter executive compensation incentives (i.e., delta and vega) by enough to drive the potentially large changes in systemic risk and liquidity creation indicated by our results. Moreover, in a post-crisis regulatory environment in which bank executives enjoy less scope for risk-taking—e.g., tighter restrictions on financial leverage, balance sheet liquidity, and permissible banking activities—the links between executive pay incentives and social externalities may be weaker than during our largely pre-crisis sample period.

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Appendix 1: A stylized example of incentivized manager decision making

This stylized example follows closely from previous work by Ross (2004) and Lewellen (2006). Assume that the manager's utility is a function of her terminal wealth W. Let $U(W)$ be strictly increasing and strictly concave (that is, $U'(W) > 0$ and $U''(W) < 0$) and at least twice continuously differentiable in wealth. The manager's terminal wealth is the payoff of a compensation scheme:

$$W = f(P) = C + \alpha * n * P + \lambda * \max(P - K, 0) \quad (1)$$

where C is salary, n is the number of shares outstanding, α is the proportion of those shares owned by the manager, λ is the number of call options, P is the share price and K is the call option strike price. For simplicity, we assume that both α and λ are positive and we allow P to be stochastic with expected value eP and variation σ_P.[22]

The parameters of the compensation scheme are chosen exogenously by the board of directors. As written, $f(P)$ is increasing and differentiable at all values of P except for at the strike price K; the resulting kink in $f(P)$ generates convexity in the neighborhood of P=K and this convexity increases with the number of options λ.[23] For simplicity, we can express these characteristics of managerial compensation as $f'(P) > 0$ and $f''(P) > 0$.

It is commonplace in the empirical literature to express these compensation incentives in terms of the manager's delta and the manager's vega. Delta is the change in the manager's terminal wealth from a unit increase in bank value, or $\partial W/\partial P = f'(X)$, and is often referred to as pay-price sensitivity. It is easy to see from (1) that delta increases with the amount of stock grants $\alpha * n$ and stock options λ awarded the

[22] It is easy to justify the assumption that $\alpha > 0$, because financial regulators require inside board members (e.g., top executive managers) to hold at least a small number of qualifying shares in the firm. If we allowed $\lambda = 0$, then manager compensation would be strictly linear in firm value.

[23] If we allowed the stock options to have time value, then $f(P)$ would become continuous and strictly convex in P.

manager, that is, $\partial W/\partial P = f'(P) = \alpha * n + \max(\lambda,0)$. Thus, the manager's absolute risk-aversion with respect to bank share price

$$A_P = -(\partial^2 U/\partial P^2) / (\partial U/\partial P) = A_W * f'(P) - f''(P)/f'(P) \quad (2)$$

is increasing in delta. (Note that $A_W = -(\partial^2 U/\partial W^2)/(\partial U/\partial W) > 0$.) Higher manager delta is associated with less bank risk-taking.[24]

Vega is the change in the manager's terminal wealth from a unit increase in share price volatility, or $\partial W/\partial \sigma_P$, and is often referred to as pay-risk sensitivity. Careful consideration of equation (1) indicates that vega is influenced by the design of the compensation contract. Because the compensation contract is convex in P, an increase in share price volatility σ_P heightens the chance that stock options will be in the money ($P > K$), which increases expected W. That is, vega is positive. Vega becomes more positive with the convexity of terminal wealth $f''(P)$, i.e., on the number of stock options λ in the compensation contract. Finally, given that absolute risk-aversion (2) decreases with $f''(P)$, higher vega is associated with more bank risk-taking.

[24] This stylized example ignores the theoretical possibility that increased delta can cause managerial risk-shifting (John and John 1993). On-the-one-hand, commercial banks are highly levered so there may be strong incentives for shifting risk from shareholders to bondholders (or to taxpayers, at a bank that is too big to fail). On-the-other-hand, empirical studies of the risk effects of executive compensation at commercial banks tend to find a negative association between CEO delta and bank risk (e.g., Fahlenbrach and Stulz 2011, DeYoung, Peng and Yan 2013). Prior studies of non-financial firms also document that CEO delta is negatively associated with leverage and firms' hedging activities (e.g., Knopf, Nam and Thornton 2002, Coles, Daniel, and Naveen 2006). This suggests that the risk aversion-enhancing effect of stock grants dominates any incentives to increase risk and shift it to creditors.

Appendix 2, Table A2.1: Table 3 recalculated for Top-Five executives

Estimating the impact of executive compensation incentives (*lnDelta* and *lnVega*) on external liquidity creation (ε_{TLCA}). All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Column 1 shows results from a naïve single equation model, while columns 2 through 7 show the results from the two-stage model described in equations (4) and (5). Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for all variable definitions.

	Naïve Model	Two-stage Model		Two-stage Model		Two-stage Model	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Dependent variable:	*TLCA*	*TLCA*	ε^{TLCA}	*TLCA*	ε^{TLCA}	*TLCA*	ε^{TLCA}
lnDelta	0.00983		-0.0266**		-0.0446***		-0.0387***
	(0.00973)		(0.0124)		(0.0133)		(0.0128)
lnVega	0.00251		0.00854***		0.00999***		0.00973***
	(0.00202)		(0.00231)		(0.00248)		(0.00245)
lnAssets	-0.0204		0.00709		0.0231		0.0223
	(0.0216)		(0.0248)		(0.0275)		(0.0275)
lnCEOtenure	-0.0295*		-0.0234		-0.0198		-0.0218
	(0.0156)		(0.0170)		(0.0177)		(0.0172)
Econ Index	0.000902		0.000391		-0.00114		-0.000653
	(0.00140)		(0.00179)		(0.00206)		(0.00197)
Constant	0.377	-0.592	-0.0495	-0.105	0.0490	-0.297	-0.0341
	(0.271)	(0.809)	(0.286)	(0.535)	(0.321)	(0.748)	(0.315)
Private return variables							
Market-to-Book		0.725		0.193		0.879	
		(0.781)		(0.423)		(1.038)	
Interest Margin		7.007***		9.890		7.163**	
		(2.568)		(13.59)		(3.219)	
ROA		12.53		7.045		12.50	
		(9.245)		(4.781)		(10.47)	
ΔMktCap/Assets		1.270		1.262		1.411	
		(1.158)		(1.327)		(1.226)	
ROE		-0.929		-0.916		-0.807	
		(0.633)		(0.674)		(0.658)	
Expected Return		-0.201		-0.214		-0.201	
		(0.174)		(0.212)		(0.203)	
Industry return variables							
Industry Market-to-Book				0.745		-0.451	
				(1.360)		(0.977)	
Industry Interest Margin				-2.753		0.780	
				(15.42)		(15.15)	
Industry ROA				5.659		-3.978	
				(6.663)		(6.123)	
Industry ΔMktCap/Assets				0.178		-0.331	
				(0.348)		(0.366)	
Industry ROE				0.133		-0.0563	
				(0.0968)		(0.0805)	
Industry Expected Return				0.00316		0.000263	
				(0.00672)		(0.00588)	
Industry returns specified as:				$Bank_{i,t}$ – Industry $mean_t$		Industry $mean_t$	
Year and Firm-CEO fixed effects	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2		0.113		0.128		0.119	
Within R^2	0.206		0.367		0.365		0.317

Appendix 2, Table A2.2: Table 4 recalculated for Top-Five executives

Estimating the impact of executive compensation incentives (*lnDelta* and *lnVega*) on external systemic risk (ε_{SES}). All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Column 1 shows results from a naïve single equation model, while columns 2 through 7 show the results from the two-stage model described in equations (7) and (8). Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for all variable definitions.

	Naïve Model	Two-stage Model		Two-stage Model		Two-stage Model	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Dependent variable:	*SES*	*SES*	$\hat{\varepsilon}^{SES}$	*SES*	$\hat{\varepsilon}^{SES}$	*SES*	$\hat{\varepsilon}^{SES}$
lnDelta	-0.0303***		-0.0212***		-0.0210***		-0.0211***
	(0.00429)		(0.00331)		(0.00339)		(0.00325)
lnVega	0.000593***		0.000492***		0.000535***		0.000516***
	(0.000181)		(0.000141)		(0.000142)		(0.000150)
lnAssets	0.0256***		0.0176***		0.0161***		0.0163***
	(0.00479)		(0.00504)		(0.00529)		(0.00548)
lnCEOtenure	0.00642		0.00729*		0.00789*		0.00747*
	(0.00453)		(0.00423)		(0.00424)		(0.00446)
Econ Index	-0.00176***		-0.00101**		-0.000876*		-0.000942**
	(0.000471)		(0.000462)		(0.000470)		(0.000453)
Constant	0.197***	0.0568***	0.0552	0.114***	0.0449	0.116***	0.0493
	(0.0582)	(0.0138)	(0.0607)	(0.0231)	(0.0626)	(0.0194)	(0.0622)
Private risk variables							
Std(ROE)		0.298		0.358		0.388	
		(0.230)		(0.238)		(0.237)	
Std(ROA)		-2.181		6.670**		-4.383	
		(2.683)		(3.051)		(2.750)	
Std(Idio. Return)		0.639		2.411		-1.002	
		(0.936)		(2.350)		(1.403)	
Std(Return)		0.116		-3.134		2.563**	
		(0.684)		(2.045)		(1.240)	
Beta		0.0249***		-0.0375***		0.0220***	
		(0.00565)		(0.0131)		(0.00599)	
Z Score		-0.000323		-0.000957		-0.000210	
		(0.000459)		(0.000604)		(0.000449)	
Industry risk variables							
Industry Std(ROE)				-0.00739		0.0256	
				(0.0302)		(0.0249)	
Industry Std(ROA)				-11.00***		11.40***	
				(1.885)		(1.820)	
Industry Std(Idio. Return)				-3.931		3.249	
				(2.945)		(3.332)	
Industry Std(Return)				5.817**		-5.568*	
				(2.661)		(3.130)	
Industry Beta				0.0613***		-0.0623***	
				(0.0168)		(0.0138)	
Industry Z Score				0.000725**		-0.000723***	
				(0.000305)		(0.000250)	
Industry risk specified as:				$Bank_{i,t}$ – Industry $mean_t$		Industry $mean_t$	
Year and Firm-CEO fixed effects	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2		0.222		0.291		0.292	
Within R^2	0.505		0.359		0.227		0.230

Appendix 2, Table A2.3

Table 3 recalculated using Berger and Bouwman adjustment for securitization

Estimating the impact of executive compensation incentives (*lnDelta* and *lnVega*) on external liquidity creation (ε_{TLCA}) that is adjusted for securitization (Berger and Bouwman 2009, Section 6.2). All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Column 1 shows results from a naïve single equation model, while columns 2 through 7 show the results from the two-stage model described in equations (4) and (5). Standard errors appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for all variable definitions.

	Naïve Model	Two-stage Model		Two-stage Model		Two-stage Model	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Dependent variable:	*TLCA*	*TLCA*	ε^{TLCA}	*TLCA*	ε^{TLCA}	*TLCA*	ε^{TLCA}
lnDelta	0.000654		-0.0305***		-0.0493***		-0.0436***
	(0.00855)		(0.0101)		(0.0127)		(0.0117)
lnVega	0.00171		0.00710***		0.00903***		0.00846***
	(0.00167)		(0.00199)		(0.00216)		(0.00212)
lnAssets	-0.00846		0.0149		0.0253		0.0251
	(0.0215)		(0.0245)		(0.0268)		(0.0268)
lnCEOtenure	-0.0260*		-0.0180		-0.0105		-0.0138
	(0.0152)		(0.0157)		(0.0170)		(0.0164)
Econ Index	0.000807		0.000165		-0.00104		-0.000595
	(0.00134)		(0.00170)		(0.00197)		(0.00187)
Constant	0.393	-0.537	-0.0760	-0.303	-0.00796	-0.468	-0.0866
	(0.260)	(0.839)	(0.268)	(0.518)	(0.298)	(0.749)	(0.292)
Private return variables							
Market-to-Book		0.666		0.125		0.868	
		(0.809)		(0.417)		(1.073)	
Interest Margin		8.092***		18.78		7.519**	
		(2.621)		(13.82)		(3.352)	
ROA		12.31		6.080		13.26	
		(9.625)		(5.025)		(10.86)	
ΔMktCap/Assets		1.454		1.592		1.510	
		(1.196)		(1.362)		(1.265)	
ROE		-0.829		-0.960		-0.807	
		(0.657)		(0.694)		(0.680)	
Expected Return		-0.202		-0.232		-0.220	
		(0.180)		(0.217)		(0.210)	
Industry return variables							
Industry Market-to-Book				0.805		-0.531	
				(1.400)		(1.012)	
Industry Interest Margin				-11.32		9.214	
				(15.72)		(15.63)	
Industry ROA				7.410		-5.555	
				(6.802)		(6.279)	
Industry ΔMktCap/Assets				-0.0550		-0.0568	
				(0.353)		(0.376)	
Industry ROE				0.174*		-0.103	
				(0.0964)		(0.0813)	
Industry Expected Return				0.00401		-0.000948	
				(0.00646)		(0.00587)	
Industry returns specified as:				$Bank_{i,t}$ – Industry $mean_t$		Industry $mean_t$	
Year and Firm-CEO fixed effects	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2		0.123		0.137		0.128	
Within R^2	0.125		0.358		0.382		0.340

Table 1 – Variable Definitions

All variables are observed annually at the firm level between 1994 and 2010.

Assets	Total banking company assets.
Beta	Systematic risk. Coefficient on the market return variable in a three-factor market model estimated annually using daily data. The three factors are CRSP value-weighted stock market return, the 2-to-10 year Treasury yield spread, and the 6-month T-Bill rate.
CEO Tenure	Number of years the current CEO has held this job.
Adapted-ΔCoVaR	The change in the value at risk of the financial system conditional on an individual bank being under extreme events to its median state per the Sedunov's (2014) ΔCoVaR approach. See Sedunov (2014) for details.
$\varepsilon_{Adapted\text{-}\Delta CoVaR}$	External *Adapted-ΔCoVaR*. The value of the residual term from an ordinary least squares regression of *Adapted-ΔCoVaR* on *Std(ROE)*, *Std(ROA)*, *Std(Idio. Return)*, *Std(Return)*, *Beta*, *and Z Score*.
Classic-ΔCoVaR	The change in the value at risk of the financial system conditional on an individual bank being under extreme events to its median state per the Adrian and Brunnermeier's (2016) ΔCoVaR approach. See Adrian and Brunnermeier (2016) for details.
$\varepsilon_{Classic\text{-}\Delta CoVaR}$	External *Classic-ΔCoVaR*. The value of the residual term from an ordinary least squares regression of *Classic-ΔCoVaR* on *Std(ROE)*, *Std(ROA)*, *Std(Idio. Return)*, *Std(Return)*, *Beta*, *and Z Score*.
Crisis	Dummy equal to one for 2008-2010.
Delta	Following Core and Guay (2002), the change in the dollar value of the CEO's wealth for a 1% change in the bank's stock price.
Delta (Top 5)	The change in the dollar value of the top five bank executives' combined wealth for a 1% change in the bank's stock price.
Economic Index	The average value of the Philadelphia Fed's Coincident Index of State Economic Conditions facing the bank, weighted by the share of the bank's deposits across the states in which it operates.
Expected Return	The one-year predicted value from a three-factor market model estimated annually using daily data. The three factors are CRSP value-weighted stock market return, the 2-to-10 year Treasury yield spread, and the 6-month T-Bill rate.
Interest Margin	(Interest Revenue – Interest Expense) / Total Assets
LEV	Following Acharya, et al. (2010, Appendix B), the financial leverage component of *SES*.
Market-to-Book	Market value of total assets divided by book value of total assets.
MES	Following Acharya, et al. (2010, Appendix B), the marginal expected shortfall component of *SES*.
ΔMktCap/Assets	Change in market capitalization divided by total assets.

ROA	Net income divided by total assets.
ROE	Net income divided by equity capital.
SES	Following Acharya, et al. (2010, Appendix B), the systemic expected shortfall.
ε_{SES}	External systemic risk. The value of the residual term from an ordinary least squares regression of *SES* on *Std(ROE)*, *Std(ROA)*, *Std(Idio. Return)*, *Std(Return)*, *Beta*, *and Z Score*.
SRISK	The expected capital shortfall for an individual bank conditional on a systemic event. See Brownlees and Engle (2015) for details.
ε_{SRISK}	External *SRISK*. The value of the residual term from an ordinary least squares regression of *SRISK* on *Std(ROE)*, *Std(ROA)*, *Std(Idio. Return)*, *Std(Return)*, *Beta*, *and Z Score*.
Std(Idio. Return)	Standard deviation of idiosyncratic returns, the residual values predicted from a three-factor market model estimated annually using daily data. The three factors are CRSP value-weighted stock market return, the 2-to-10 year Treasury yield spread, and the 6-month T-Bill rate.
Std(Return)	Standard deviation of daily stock returns over one year.
Std(ROA)	Standard deviation of ROA over 5 years.
Std(ROE)	Standard deviation of ROE over 5 years.
TLCA	Following Berger and Bouwman (2009), the liquidity creation per dollar of assets generated by the bank's on- and off-balance sheet activities.
ε_{TLCA}	External liquidity creation. The value of the residual term from an ordinary least squares regression of *TLCA* on *Market-to-Book*, *Interest Margin*, *ROA*, *ΔMktCap/Assets*, *ROE*, and *Expected Return*.
Vega	Following Core and Guay (2002), the change in the dollar value of the CEO's wealth for a 0.01 change in stock volatility from a Merton option pricing model.
Vega (Top 5)	The change in the dollar value of the top five executives' combined wealth for a 0.01 change in stock volatility from a Merton option pricing model.
Z Score	Distance to default: (ROA + (Equity Capital/Total Assets)) / Standard Deviation of ROA, where Standard Deviation of ROA is measured over 5 years.

Table 2 – Summary Statistics

945 bank-year observations on 1994-2010. Variables winsorized at 1st and 99th percentiles. Dollar variables are in 2010 U.S. dollars.

	Mean	Std. Dev.	25%	50%	75%	**Selected variables** Cross sectional means of firm-CEO specific standard deviations
Systemic risk						
SES	0.095	0.048	0.065	0.082	0.106	0.020
ε_{SES}	0.000	0.040	-0.025	-0.007	0.014	0.019
MES	0.0274	0.0240	0.0124	0.0198	0.0322	0.0144
ε_{MES}	0.0001	0.0128	-0.0083	0.0003	0.0074	0.0103
LEV	2.2617	1.1821	1.5398	1.9855	2.5529	0.4809
ε_{LEV}	-0.0047	0.9876	-0.6100	-0.1870	0.3486	0.4659
SRISK	-0.133	0.070	-0.170	-0.124	-0.086	0.034
ε_{SRISK}	0.000	0.060	-0.031	0.010	0.041	0.030
Classic-ΔCoVaR	0.067	0.029	0.043	0.062	0.081	0.022
$\varepsilon_{Classic\text{-}\Delta CoVaR}$	0.000	0.017	-0.011	-0.001	0.010	0.011
Adapted-ΔCoVaR	0.057	0.028	0.036	0.047	0.080	0.019
$\varepsilon_{Adapted\text{-}\Delta CoVaR}$	0.000	0.019	-0.013	-0.002	0.013	0.014
Liquidity creation						
TLC ($1,000,000s)	38,707	95,834	2,783	6,487	23,601	
TLCA	0.423	0.174	0.331	0.423	0.514	0.048
ε_{TLCA}	-0.017	0.182	-0.139	-0.017	0.089	0.060
TLCA On-balance Sheet	0.2576	0.1343	0.1983	0.2672	0.3376	0.0342
$\varepsilon_{TLCA\ On\text{-}balance\ Sheet}$	0.0001	0.1070	-0.0672	-0.0040	0.0766	0.0423
TLCA Off-balance Sheet	0.1634	0.1193	0.0905	0.1309	0.1976	0.0214
$\varepsilon_{TLCA\ Off\text{-}balance\ Sheet}$	-0.0183	0.1463	-0.1050	-0.0319	0.0518	0.0586
TLCA Derivatives	-0.0004	0.0014	-0.0004	0.0000	0.0000	0.0006
$\varepsilon_{TLCA\ Derivatives}$	0.0000	0.0014	0.0000	0.0004	0.0005	0.0006
TLCA Credit Commitments	0.1638	0.1198	0.0904	0.1311	0.1976	0.0214
$\varepsilon_{TLCA\ Credit\ Commitments}$	-0.0183	0.1466	-0.1059	-0.0321	0.0522	0.0586
Compensation incentives						
Delta ($) (CEO)	525,482	752,954	73,025	223,278	652,675	
lnDelta (CEO)	12.27	1.46	11.20	12.32	13.39	0.54
Delta ($) (Top 5)	1,031,534	1,385,763	174,741	489,768	1,262,262	
*lnDelta (*Top 5*)*	13.05	1.33	12.07	13.10	14.05	0.53
Vega ($) (CEO)	95,058	185,232	2,394	25,312	90,136	
lnVega (CEO)	8.58	4.29	7.78	10.14	11.41	2.04
Vega ($) (Top 5)	212,943	413,808	9,987	58,044	200,585	
*lnVega (*Top 5*)*	9.80	3.77	9.21	10.97	12.21	1.69
Second-stage controls						
Assets ($1,000,000s)	71,849	188,233	6,823	14,439	51,261	
lnAssets	9.89	1.44	8.83	9.58	10.84	
Bottom Z-score	0.10	0.30	0	0	0	

CEO tenure	7.46	5.70	3	6	11
lnCEOtenure	1.70	0.82	1.10	1.79	2.40
Crisis	0.21	0.41	0	0	0
Economic Index	135.69	16.62	124.58	137.61	145.12
TBTF	0.15	0.36	0	0	0
Top CORR	0.10	0.30	0	0	0
First-stage return controls					
Market-to-Book	1.10	0.08	1.04	1.08	1.13
Interest Margin (%)	3.33	0.81	2.93	3.42	3.85
ROA (%)	1.07	0.70	0.93	1.16	1.39
ΔMktCap/Assets (%)	1.73	5.51	-1.35	1.56	4.61
ROE (%)	11.33	11.98	9.34	13.69	16.50
Expected Return (%)	16.02	33.90	-4.88	12.96	36.56
Relative Market-to-Book	0.0416	0.0718	-0.0043	0.0275	0.0697
Relative Interest Margin	-0.0025	0.0078	-0.0057	-0.0018	0.0024
Relative ROA	0.0026	0.0075	-0.0002	0.0024	0.0057
Relative ΔMktCap/Assets	0.0058	0.0464	-0.0191	0.0018	0.0271
Relative ROE	0.0149	0.1240	-0.0058	0.0302	0.0633
Relative Expected Return	-0.4083	1.1724	-0.3163	-0.1296	0.0377
Industry Market-to-Book	1.0536	0.0371	1.0282	1.0522	1.0827
Industry Interest Margin	0.0357	0.0032	0.0333	0.0358	0.0378
Industry ROA	0.0071	0.0061	0.0080	0.0100	0.0106
Industry ΔMktCap/Assets	0.0116	0.0289	-0.0115	0.0166	0.0271
Industry ROE	0.0974	0.0573	0.0874	0.1166	0.1211
Industry Expected Return	0.5681	1.1281	0.1398	0.2974	0.4943
First-stage risk controls					
Std(ROE) (%)	4.29	5.87	1.56	2.54	4.54
Std(ROA) (%)	0.35	0.47	0.12	0.20	0.35
Std(Idio. Return) (%)	1.85	1.17	1.14	1.47	2.15
Std(Return) (%)	2.31	1.47	1.38	1.81	2.65
Beta	1.06	0.47	0.75	1.01	1.34
Z Score	26.02	8.27	22.02	26.00	29.92
Relative Std(ROE)	-0.0353	0.0850	-0.0379	-0.0130	0.0013
Relative Std(ROA)	-0.0003	0.0041	-0.0017	-0.0008	0.0003
Relative Std(Idio. Return)	-0.0074	0.0081	-0.0116	-0.0076	-0.0040
Relative Std(Return)	-0.0048	0.0089	-0.0095	-0.0053	-0.0015
Relative Beta	0.5253	0.3594	0.2827	0.4859	0.7430
Relative Z Score	-4.3771	9.8696	-9.0350	-4.6309	0.5779
Industry Std(ROE)	0.0781	0.0835	0.0272	0.0302	0.0912
Industry Std(ROA)	0.0038	0.0025	0.0022	0.0024	0.0042
Industry Std(Idio. Return)	0.0260	0.0103	0.0193	0.0239	0.0290
Industry Std(Return)	0.0280	0.0120	0.0215	0.0248	0.0296
Industry Beta	0.5340	0.2267	0.3426	0.4464	0.7396
Industry Z Score	30.3938	5.7981	27.3828	30.2391	32.3201

Table 3 – Baseline *TLCA* results

Estimating the impact of executive compensation incentives (*lnDelta* and *lnVega*) on external liquidity creation (ε_{TLCA}). All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Column 1 shows results from a naïve single equation model, while columns 2 through 7 show the results from the two-stage model described in equations (4) and (5). Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for all variable definitions.

	Naïve Model	Two-stage Model		Two-stage Model		Two-stage Model	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Dependent variable:	*TLCA*	*TLCA*	$\hat{\varepsilon}^{TLCA}$	*TLCA*	$\hat{\varepsilon}^{TLCA}$	*TLCA*	$\hat{\varepsilon}^{TLCA}$
lnDelta	0.00237		-0.0296***		-0.0470***		-0.0409***
	(0.00931)		(0.0106)		(0.0126)		(0.0116)
lnVega	0.00169		0.00722***		0.00896***		0.00844***
	(0.00180)		(0.00201)		(0.00220)		(0.00218)
lnAssets	-0.0170		0.00540		0.0191		0.0191
	(0.0219)		(0.0242)		(0.0269)		(0.0270)
lnCEOtenure	-0.0294*		-0.0196		-0.0133		-0.0163
	(0.0156)		(0.0165)		(0.0171)		(0.0167)
Econ Index	0.000866		0.000571		-0.000834		-0.000394
	(0.00142)		(0.00174)		(0.00198)		(0.00190)
Constant	0.387	-0.592	-0.0617	-0.105	0.0274	-0.297	-0.0539
	(0.272)	(0.809)	(0.279)	(0.535)	(0.309)	(0.748)	(0.306)
Private return variables							
Market-to-Book		0.725		0.193		0.879	
		(0.781)		(0.423)		(1.038)	
Interest Margin		7.007***		9.890		7.163**	
		(2.568)		(13.59)		(3.219)	
ROA		12.53		7.045		12.50	
		(9.245)		(4.781)		(10.47)	
ΔMktCap/Assets		1.270		1.262		1.411	
		(1.158)		(1.327)		(1.226)	
ROE		-0.929		-0.916		-0.807	
		(0.633)		(0.674)		(0.658)	
Expected Return		-0.201		-0.214		-0.201	
		(0.174)		(0.212)		(0.203)	
Industry return variables							
Industry Market-to-Book				0.745		-0.451	
				(1.360)		(0.977)	
Industry Interest Margin				-2.753		0.780	
				(15.42)		(15.15)	
Industry ROA				5.659		-3.978	
				(6.663)		(6.123)	
Industry ΔMktCap/Assets				0.178		-0.331	
				(0.348)		(0.366)	
Industry ROE				0.133		-0.0563	
				(0.0968)		(0.0805)	
Industry Expected Return				0.00316		0.000263	
				(0.00672)		(0.00588)	
Industry returns specified as:				$Bank_{i,t}$ – Industry $mean_t$		Industry $mean_t$	
Year and Firm-CEO fixed effects	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2		0.113		0.128		0.119	
Within R^2	0.201		0.366		0.367		0.317

Table 4 – Baseline SES results

Estimating the impact of executive compensation incentives (*lnDelta* and *lnVega*) on external systemic risk (ε_{SES}). All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Column 1 shows results from a naïve single equation model, while columns 2 through 7 show the results from the two-stage model described in equations (7) and (8). Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for all variable definitions.

	Naïve Model	Two-stage Model		Two-stage Model		Two-stage Model	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Dependent variable:	*SES*	*SES*	$\hat{\varepsilon}^{SES}$	*SES*	$\hat{\varepsilon}^{SES}$	*SES*	$\hat{\varepsilon}^{SES}$
lnDelta	-0.0218***		-0.0143***		-0.0136***		-0.0136***
	(0.00491)		(0.00372)		(0.00378)		(0.00367)
lnVega	0.000521***		0.000423***		0.000461***		0.000426***
	(0.000150)		(0.000116)		(0.000121)		(0.000123)
lnAssets	0.0194***		0.0130**		0.0113**		0.0114**
	(0.00498)		(0.00517)		(0.00550)		(0.00565)
lnCEOtenure	0.00842*		0.00831*		0.00871*		0.00825*
	(0.00508)		(0.00459)		(0.00465)		(0.00488)
Econ Index	-0.00157***		-0.000880*		-0.000748		-0.000814*
	(0.000478)		(0.000470)		(0.000476)		(0.000461)
Constant	0.171***	0.0568***	0.0370	0.114***	0.0271	0.116***	0.0313
	(0.0627)	(0.0138)	(0.0656)	(0.0231)	(0.0676)	(0.0194)	(0.0674)
Private risk variables							
Std(ROE)		0.298		0.358		0.388	
		(0.230)		(0.238)		(0.237)	
Std(ROA)		-2.181		6.670**		-4.383	
		(2.683)		(3.051)		(2.750)	
Std(Idio. Return)		0.639		2.411		-1.002	
		(0.936)		(2.350)		(1.403)	
Std(Return)		0.116		-3.134		2.563**	
		(0.684)		(2.045)		(1.240)	
Beta		0.0249***		-0.0375***		0.0220***	
		(0.00565)		(0.0131)		(0.00599)	
Z Score		-0.000323		-0.000957		-0.000210	
		(0.000459)		(0.000604)		(0.000449)	
Industry risk variables							
Industry Std(ROE)				-0.00739		0.0256	
				(0.0302)		(0.0249)	
Industry Std(ROA)				-11.00***		11.40***	
				(1.885)		(1.820)	
Industry Std(Idio. Return)				-3.931		3.249	
				(2.945)		(3.332)	
Industry Std(Return)				5.817**		-5.568*	
				(2.661)		(3.130)	
Industry Beta				0.0613***		-0.0623***	
				(0.0168)		(0.0138)	
Industry Z Score				0.000725**		-0.000723***	
				(0.000305)		(0.000250)	
Industry risk specified as:				$Bank_{i,t}$ – Industry $mean_t$		Industry $mean_t$	
Year and Firm-CEO fixed effects	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2		0.222		0.291		0.292	
Within R^2	0.460		0.317		0.170		0.173

Table 5
Pearson correlations of first-stage regressors
Bolded coefficients are significant at the 5% level.

Panel A: TLCA model								
	with TLCA		1	2	3	4	5	6
Market-to-Book	**0.243**	*Market-to-Book*	**1.000**					
Interest Margin	**0.213**	*Interest Margin*	**0.115**	**1.000**				
ROA	**0.148**	*ROA*	**0.559**	**0.228**	**1.000**			
ΔMktCap/Assets	**0.144**	*ΔMktCap/Assets*	**0.506**	**0.069**	**0.247**	**1.000**		
ROE	**0.079**	*ROE*	**0.497**	**0.129**	**0.939**	**0.231**	**1.000**	
Expected Return	0.054	*Expected Return*	**0.384**	**0.082**	**0.285**	**0.834**	**0.282**	**1.000**

Panel B: SES model								
	with SES		1	2	3	4	5	6
Std(ROE)	**0.389**	*Std(ROE)*	**1.000**					
Std(ROA)	**0.379**	*Std(ROA)*	**0.952**	**1.000**				
Std(Idio. Return)	**0.363**	*Std(Idio. Return)*	**0.581**	**0.610**	**1.000**			
Std(Return)	**0.361**	*Std(Return)*	**0.529**	**0.573**	**0.972**	**1.000**		
Beta	**0.355**	*Beta*	**0.364**	**0.411**	**0.324**	**0.387**	**1.000**	
Z Score	**-0.234**	*Z Score*	**-0.600**	**-0.595**	**-0.292**	**-0.239**	**-0.143**	**1.000**

Table 6
Impact of private return variables on first-stage regressions and second-stage results

Robustness tests of the *TLCA* model. Column (6) repeats the results from Table 4, column 4. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

Panel A: First-stage orthogonalization
Right-hand side regressors are added in decreasing order of their correlations ρ with TLCA.

	[1]	[2]	[3]	[4]	[5]	[6]
Dependent:	*TLCA*	*TLCA*	*TLCA*	*TLCA*	*TLCA*	*TLCA*
Market-to-Book	0.988	0.900	0.962	0.908	0.832	0.725
(ρ = 0.243)	(0.959)	(0.961)	(0.996)	(0.935)	(0.877)	(0.781)
Interest Margin		8.040***	8.240***	8.219***	6.893**	7.007***
(ρ = 0.213)		(2.732)	(2.695)	(2.687)	(2.665)	(2.568)
ROA			-1.104	-1.048	12.16	12.53
(ρ = 0.148)			(1.243)	(1.238)	(9.272)	(9.245)
ΔMktCap/Assets				0.155	0.201	1.270
(ρ = 0.144)				(0.254)	(0.277)	(1.158)
ROE					-0.987	-0.929
(ρ = 0.079)					(0.704)	(0.633)
Expected Return						-0.201
(ρ = 0.054)						(0.174)
Constant	-0.639	-0.810	-0.874	-0.818	-0.708	-0.592
	(1.028)	(1.021)	(1.056)	(0.991)	(0.913)	(0.809)
Fixed effects	No	No	No	No	No	No
Adjusted R^2	0.058	0.092	0.091	0.091	0.103	0.113

Panel B: Second-stage test regression (partial results)

	[1]	[2]	[3]	[4]	[5]	[6]
Dependent:	ε_{TLCA}	ε_{TLCA}	ε_{TLCA}	ε_{TLCA}	ε_{TLCA}	ε_{TLCA}
lnDelta	-0.0139	-0.0153	-0.0190*	-0.0232**	-0.0283***	-0.0296***
	(0.00988)	(0.00978)	(0.00971)	(0.00984)	(0.0105)	(0.0106)
lnVega	0.00471***	0.00536***	0.00549***	0.00599***	0.00707***	0.00722***
	(0.00177)	(0.00196)	(0.00196)	(0.00198)	(0.00202)	(0.00201)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm-CEO fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Compensation	CEO	CEO	CEO	CEO	CEO	CEO

Table 7
Impact of private risk variables on first-stage regressions and second-stage results

Robustness tests of the *SES* model. Column (6) repeats the results from Table 5, column 4. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

Panel A: First-stage orthogonalization. Right-hand side regressors are added in decreasing order of their correlations ρ with SES.						
	[1]	[2]	[3]	[4]	[5]	[6]
Dependent:	*SES*	*SES*	*SES*	*SES*	*SES*	*SES*
Std(ROE)	0.321***	0.250	0.251	0.302	0.310	0.298
(ρ = 0.389)	(0.0613)	(0.247)	(0.226)	(0.241)	(0.237)	(0.230)
Std(ROA)		0.942	-0.408	-0.895	-1.942	-2.181
(ρ = 0.379)		(2.775)	(2.403)	(2.551)	(2.575)	(2.683)
Std(Idio. Return)			0.872***	-0.588	0.704	0.639
(ρ = 0.363)			(0.228)	(1.001)	(0.929)	(0.936)
Std(Return)				1.174	0.0438	0.116
(ρ = 0.361)				(0.739)	(0.680)	(0.684)
Beta					0.0245***	0.0249***
(ρ = 0.355)					(0.00537)	(0.00565)
Z score						-0.000323
(ρ = -0.234)						(0.000459)
Constant	0.0808***	0.0806***	0.0690***	0.0685***	0.0479***	0.0568***
	(0.00331)	(0.00326)	(0.00463)	(0.00451)	(0.00606)	(0.0138)
Fixed effects	No	No	No	No	No	No
Adjusted R^2	0.151	0.150	0.177	0.183	0.221	0.222
Panel B: Second-stage test regression (partial results)						
	[1]	[2]	[3]	[4]	[5]	[6]
Dependent:	ε_{SES}	ε_{SES}	ε_{SES}	ε_{SES}	ε_{SES}	ε_{SES}
lnDelta	-0.0155***	-0.0155***	-0.0147***	-0.0154***	-0.0142***	-0.0143***
	(0.00383)	(0.00381)	(0.00364)	(0.00380)	(0.00362)	(0.00372)
lnVega	0.000424***	0.000432***	0.000436***	0.000444***	0.000392***	0.000423***
	(0.000122)	(0.000121)	(0.000122)	(0.000123)	(0.000116)	(0.000116)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm-CEO fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Compensation	CEO	CEO	CEO	CEO	CEO	CEO

Table 8 – Components of liquidity creation

Estimating the impact of executive compensation incentives (*lnDelta* and *lnVega*) on components of external liquidity creation (ε_{TLCA}). *On-balance sheet* measures liquidity created via balance sheet assets and liabilities. *Off-balance sheet* equals total liquidity creation minus *on-balance sheet*. *Derivatives* measures the portion of *off-balance sheet* generated by derivatives positions. *Credit Commitments* measures the portion of *off-balances sheet* generated by credit commitments. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	On-balance Sheet		*Off-balance Sheet*		*Derivatives*		*Credit Commitments*	
	TLCA	ε_{TLCA}	*TLCA*	ε_{TLCA}	*TLCA*	ε_{TLCA}	*TLCA*	ε_{TLCA}
lnDelta		0.00610		-0.0391***		4.09e-05		-0.0391***
		(0.00717)		(0.00907)		(7.16e-05)		(0.00906)
lnVega		0.00108		0.00667***		-2.31e-05		0.00669***
		(0.00137)		(0.00151)		(1.69e-05)		(0.00151)
lnAssets		-0.0591***		0.0643***		0.000253		0.0641***
		(0.0164)		(0.0190)		(0.000220)		(0.0190)
lnCEOtenure		-0.0324***		0.0168		-0.000365**		0.0173
		(0.0122)		(0.0121)		(0.000177)		(0.0121)
Econ Index		0.00139		-0.000485		-1.40e-05		-0.000470
		(0.000902)		(0.00124)		(1.54e-05)		(0.00124)
Constant	0.276***	0.266	-0.788	-0.353*	-0.00261	-6.42e-05	-0.785	-0.353*
	(0.00670)	(0.195)	(0.847)	(0.183)	(0.00194)	(0.00252)	(0.847)	(0.184)
Private returns variables								
Market-to-Book	-0.214**		0.939		0.00166		0.937	
	(0.0959)		(0.812)		(0.00156)		(0.813)	
Interest Margin	9.638***		-2.631		0.0130		-2.644	
	(1.678)		(1.599)		(0.0186)		(1.609)	
ROA	0.361		12.17		-0.0135		12.18	
	(1.878)		(9.400)		(0.0218)		(9.405)	
ΔMktCap/Assets	0.114		1.156		0.000799		1.155	
	(0.165)		(1.190)		(0.00205)		(1.190)	
ROE	-0.223*		-0.706		0.000608		-0.707	
	(0.135)		(0.643)		(0.00139)		(0.643)	
Expected Return	-0.0336		-0.167		-0.000144		-0.167	
	(0.0229)		(0.179)		(0.000222)		(0.179)	
Year and Firm-CEO fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.353		0.111		0.004		0.110	
Within R^2		0.307		0.472		0.134		0.472

Table 9 – Components of systemic risk

Estimating the impact of executive compensation incentives (*Delta* and *Vega*) on the components of external systemic risk (ε_{SES}). Marginal expected shortfall (*MES*) is the (negative of) bank i's average daily stock returns on the 12 worst trading days of each year for the broad stock market index. Financial leverage (*LEV*) is the market value of bank i's assets divided by the market value of its equity. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

	MES		*LEV*	
	[1]	[2]	[3]	[4]
Dependent variable:	*MES*	ε_{MES}	*LEV*	ε_{LEV}
lnDelta		-0.00116**		-0.358***
		(0.000573)		(0.0949)
lnVega		0.000105**		0.0102***
		(4.64e-05)		(0.00291)
lnAssets		0.00186*		0.316**
		(0.00112)		(0.129)
lnCEOtenure		0.00109		0.204*
		(0.00102)		(0.115)
Econ Index		0.000123*		-0.0222*
		(7.22e-05)		(0.0117)
Constant	-0.0143***		1.460***	
	(0.00271)		(0.342)	
Private risk variables				
Std(ROE)	-0.107***		8.063	
	(0.0281)		(5.775)	
Std(ROA)	2.360***		-65.70	
	(0.365)		(67.33)	
Std(Idio. Return)	-1.695***		23.43	
	(0.215)		(23.43)	
Std(Return)	1.816***		-4.537	
	(0.162)		(17.14)	
Beta	0.0242***		0.535***	
	(0.00169)		(0.141)	
Z Score	7.78e-05		-0.00824	
	(8.31e-05)		(0.0114)	
Year and Firm-CEO fixed effects	No	Yes	No	Yes
Adjusted R^2	0.694		0.190	
Within R^2		0.771		0.298

Table 10 – Alternative measures of systemic risk

Estimating the impact of executive compensation incentives (*Delta* and *Vega*) on external systemic risk creation. Columns 1-2: *SES* for 613 bank-year observations on the shorter 2000-2010 sample window. Columns 3-4: *SRISK* adapted from Brownless and Engle (2015). Columns 5-6: *ΔCoVaR* estimated as in Adrian and Brunnermeier (2016). Columns 7-8: *ΔCoVaR* estimated using five-year rolling windows as in Sedunov (2014). The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

	SES (2000-2010)		*SRISK*		*Classic-ΔCoVaR*		*Adapted-ΔCoVaR*	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	SES	ε_{SES}	*SRISK*	ε_{SRISK}	$\Delta CoVaR$	$\varepsilon_{\Delta CoVaR}$	$\Delta CoVaR$	$\varepsilon_{\Delta CoVaR}$
lnDelta		-0.0162***		-0.0205***		0.000253		0.00191
		(0.00515)		(0.00644)		(0.00119)		(0.00147)
lnVega		0.000487***		0.000635***		8.43e-05		0.000128*
		(0.000121)		(0.000149)		(0.000220)		(6.95e-05)
lnAssets		0.0146**		0.0129		-0.00291		-0.000292
		(0.00672)		(0.00826)		(0.00208)		(0.00470)
lnCEOtenure		0.0113*		0.0134*		0.000610		0.00217
		(0.00648)		(0.00733)		(0.00167)		(0.00281)
Econ Index		-0.000567		-0.000732		0.000267*		0.000475
		(0.000594)		(0.000636)		(0.000153)		(0.000327)
Constant	0.0415***	0.0108	-0.256***	0.0728	0.0373***	-0.00552	0.0155***	
	(0.0101)	(0.111)	(0.0211)	(0.119)	(0.00408)	(0.0245)	(0.00466)	
Std(ROE)	0.476**		0.107		0.0576*		0.0244	
	(0.191)		(0.185)		(0.0327)		(0.0377)	
Std(ROA)	-3.083		5.284**		-2.248***		-0.0562	
	(2.231)		(2.636)		(0.496)		(0.519)	
Std(Idio. Return)	-0.0477		0.492		-1.896***		-2.140***	
	(1.095)		(1.123)		(0.384)		(0.410)	
Std(Return)	0.741		-0.244		3.267***		2.714***	
	(0.832)		(0.823)		(0.297)		(0.321)	
Beta	0.0212***		0.0266***		-0.00441**		0.00853***	
	(0.00625)		(0.00811)		(0.00209)		(0.00201)	
Z Score	3.58e-05		0.00263***		-4.68e-05		0.000211	-0.0500
	(0.000347)		(0.000687)		(0.000124)		(0.000153)	(0.0681)
Observations	613	613	945	945	871	871	677	677
Year and Firm-CEO fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.355		0.215		0.633		0.522	
Within R^2		0.273		0.324		0.418		0.342

Table 11 – Financial crisis effects

Estimating the impact of executive compensation incentives (*Delta* and *Vega*) on external liquidity creation per bank asset dollar (ε_{TLCA}) and on external systemic risk creation (ε_{SES}). Results shown for second-stage externality equations; first-stage orthogonalization equations are estimated but not shown. In columns 1 and 2, θ = *Crisis* is a dummy variable equal to one during years 2008-2010. In column 3, θ = *Credit Bubble* is a dummy variable equal to 1 in the years 2004 and 2007, during which aggregate increases in U.S. commercial bank lending far exceeded expected lending, as indicated by a standard Hodrick-Prescott filter. All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

	θ = *Crisis*	θ = *Crisis*	θ = *Credit Bubble*
	[1]	[2]	[3]
Dependent:	ε_{TLCA}	ε_{SES}	ε_{TLCA}
θ	0.205**	0.0217	0.213**
	(0.0917)	(0.0291)	(0.0917)
lnDelta	-0.0298***	-0.0136***	-0.0300***
	(0.0110)	(0.00388)	(0.0109)
lnDelta * θ	0.00140	0.000490	0.00305
	(0.0103)	(0.00348)	(0.00692)
lnVega	0.00727***	0.000421***	0.00715***
	(0.00207)	(0.000112)	(0.00204)
lnVega * θ	-0.000875	-0.00237	0.000713
	(0.00428)	(0.00185)	(0.00338)
lnAssets	0.00554	0.0125**	0.00533
	(0.0244)	(0.00523)	(0.0243)
lnCEOtenure	-0.0194	0.00800*	-0.0200
	(0.0160)	(0.00481)	(0.0167)
Econ Index	0.000545	-0.000890*	0.000563
	(0.00174)	(0.000477)	(0.00174)
Constant	-0.0592	0.0399	-0.0583
	(0.279)	(0.0660)	(0.278)
$\partial\varepsilon_{TLCA}/\partial lnDelta$ (θ=1)	-0.0284**		-0.0270**
$\partial\varepsilon_{TLCA}/\partial lnVega$ (θ=1)	0.00640		0.00786**
$\partial\varepsilon_{TLCA}/\partial\theta$	0.211**		0.232**
$\partial\varepsilon_{SES}/\partial lnDelta$ (θ=1)		-0.0131***	
$\partial\varepsilon_{SES}/\partial lnVega$ (θ=1)		-0.00195	
$\partial\varepsilon_{SES}/\partial\theta$		0.0204	
Year and Firm-CEO fixed effects	Yes	Yes	Yes
Within R^2	0.366	0.320	0.367

Table 12 – Strategic risk-taking effects

Estimating the impact of executive compensation incentives (*Delta* and *Vega*) on external liquidity creation per bank asset dollar (ε_{TLCA}) and on external systemic risk creation (ε_{SES}). Results shown for second-stage externality equations; first-stage orthogonalization equations are estimated but not shown. In columns 1 and 2, θ = *TBTF* is a dummy variable equal to one if bank assets are greater than \$100 billion. In columns 3 and 4, θ = *Herding* is a dummy variable equal to one if the correlation of the bank's daily returns with the industry daily returns is greater than 0.8165, which is the 90th percentile of the sample distribution. In columns 5 and 6, θ = *Insolvency* is a dummy variable equal to one if the bank's Z-score is less than 17.44, which is the 10th percentile of the sample distribution. All estimations use ordinary least squares and 945 bank-year observations on 1994-2010. The variables *lnDelta*, *lnVega*, *lnAssets* and *lnCEOtenure* are lagged one year. Standard errors are clustered at the bank-CEO level and appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

	θ = *TBTF*		θ = *Herding*		θ = *Insolvency*	
	[1]	[2]	[3]	[4]	[5]	[6]
Dependent:	ε_{TLCA}	ε_{SES}	ε_{TLCA}	ε_{SES}	ε_{TLCA}	ε_{SES}
θ	0.0373	0.0915*	0.0468	-0.0105	-0.125***	0.0253
	(0.147)	(0.0547)	(0.0511)	(0.0188)	(0.0476)	(0.0296)
lnDelta	-0.0268***	-0.0134***	-0.0292***	-0.0147***	-0.0338***	-0.0128***
	(0.00969)	(0.00367)	(0.0107)	(0.00382)	(0.0110)	(0.00363)
lnDelta * θ	0.00551	-0.0138	-0.00425	0.000712	0.0234**	-0.00404
	(0.0262)	(0.00840)	(0.00931)	(0.00328)	(0.00957)	(0.00527)
lnVega	0.00560***	0.000415***	0.00716***	0.000447***	0.00721***	0.000322**
	(0.00176)	(0.000116)	(0.00201)	(0.000118)	(0.00219)	(0.000127)
lnVega * θ	0.00462	0.000792	-0.00370	0.00306*	0.000344	0.00288*
	(0.00795)	(0.00126)	(0.00463)	(0.00173)	(0.00321)	(0.00147)
lnAssets	-0.00524	0.0132**	0.00425	0.0138***	0.00865	0.0111**
	(0.0236)	(0.00534)	(0.0243)	(0.00521)	(0.0241)	(0.00497)
lnCEOtenure	-0.0171	0.00789*	-0.0213	0.00885*	-0.0184	0.00683
	(0.0169)	(0.00445)	(0.0168)	(0.00467)	(0.0162)	(0.00455)
Econ Index	0.000930	-0.000883*	0.000604	-0.000866*	0.000651	-0.000884*
	(0.00159)	(0.000475)	(0.00175)	(0.000460)	(0.00170)	(0.000461)
Constant	-0.0198	0.0299	-0.0570	0.0303	-0.0817	0.0492
	(0.297)	(0.0663)	(0.280)	(0.0649)	(0.272)	(0.0642)
$\partial\varepsilon_{TLCA}/\partial lnDelta$ (θ=1)	-0.0213		-0.0335**		-0.0104	
$\partial\varepsilon_{TLCA}/\partial lnVega$ (θ=1)	0.0102		0.00346		0.00756**	
$\partial\varepsilon_{TLCA}/\partial\theta$	0.0889		0.0149		-0.000639	
$\partial\varepsilon_{SES}/\partial lnDelta$ (θ=1)		-0.0272***		-0.0140***		-0.0168***
$\partial\varepsilon_{SES}/\partial lnVega$ (θ=1)		0.00121		0.00351**		0.00321**
$\partial\varepsilon_{SES}/\partial\theta$		0.00539		0.00248		0.00747
Year and Firm-CEO fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Within R^2	0.389	0.327	0.368	0.322	0.375	0.337

Table 13 – Effects of CEO incentives on aggregate liquidity creation externality

Estimating the impact of changes in executive compensation incentives on total external liquidity creation (*LC*) in the economy. Estimates based on regression parameters in Table 3, column 3. *lnDelta* and *lnVega* are demeaned by subtracting the average value within a firm-CEO pair, and the distributional statistics for the demeaned variables are based on the cross-sectional averages of the distributional statistics for each firm-CEO pair. All dollar amounts are in millions.

$$\%\Delta\ in\ aggregate\ external\ LC\ from\ Delta = \frac{\hat{\beta}_{lnDelta} * \Delta_{lnDelta} * \$\ assets\ in\ system}{\$\ of\ annual\ LC\ in\ system}$$

$$\%\Delta\ in\ aggregate\ external\ LC\ from\ Vega = \frac{\hat{\beta}_{lnVega} * \Delta_{lnVega} * \$\ assets\ in\ system}{\$\ of\ annual\ LC\ in\ system}$$

[1]	[2]	[3]	[4] = [2]*[3]	[5]	[6] = [4]*[5]	[7]	[8] = [6]÷[7]
Change in executive compensation incentives	**Δ*lnDelta* or Δ*lnVega***	$\hat{\beta}_{lnDelta}$ **or** $\hat{\beta}_{lnVega}$	**Δ external TLC per $ assets at average bank**	**$ of assets in system**	**Δ external $ of TLC in system**	**$ of annual TLC in system**	**%Δ in aggregate external TLC**
Increase *lnDelta* by one standard deviation	0.54	-0.0296	-0.0160	4,241,593	-67,865	2,270,182	-2.99%
Increase *lnVega* by one standard deviation	2.04	0.00722	0.0147	4,241,593	62,351	2,270,182	2.75%

Table 14 – Effects of CEO incentives on aggregate systemic risk externality

Estimating the impact of changes in executive compensation incentives on total external systemic risk (*SR*) in the economy. Estimates based on regression parameters in Table 4, column 3. *lnDelta* and *lnVega* are demeaned by subtracting the average value within a firm-CEO pair, and the distributional statistics for the demeaned variables are based on the cross-sectional averages of the distributional statistics for each firm-CEO pair. All dollar amounts are in millions.

$$\%\Delta\ in\ aggregate\ external\ SR\ from\ Delta = \frac{\hat{\beta}_{lnDelta} * \Delta_{lnDelta} * \$\ equity\ in\ system}{\$\ of\ annual\ SES\ in\ system}$$

$$\%\Delta\ in\ aggregate\ external\ SR\ from\ Vega = \frac{\hat{\beta}_{lnVega} * \Delta_{lnVega} * \$\ equity\ in\ system}{\$\ of\ annual\ SES\ in\ system}$$

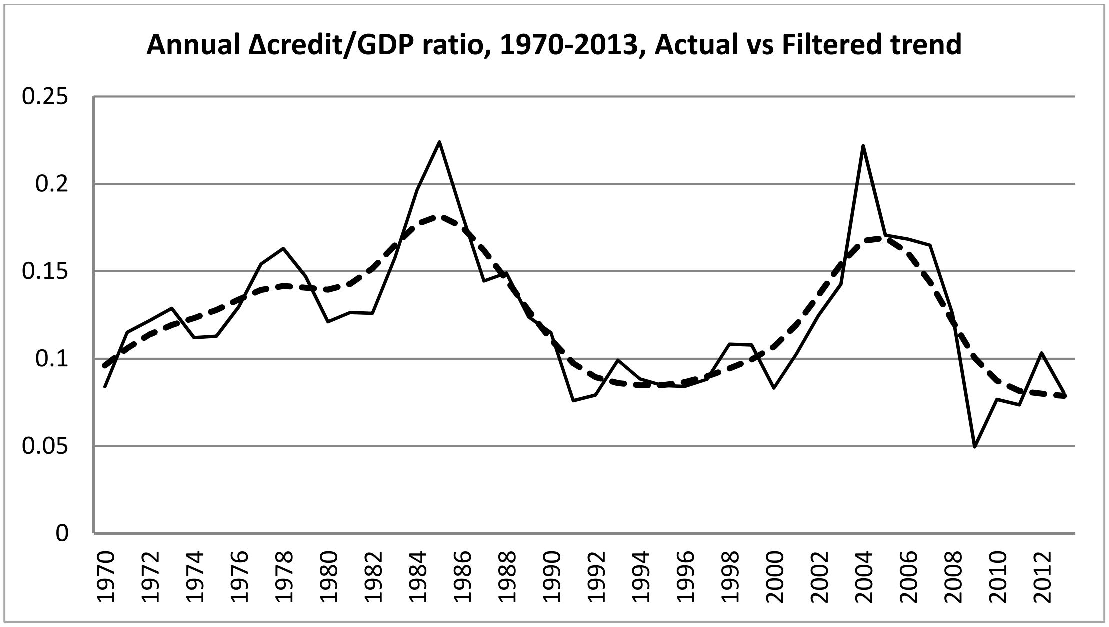
[1]	[2]	[3]	[4] = [2]*[3]	[5]	[6] = [4]*[5]	[7]	[8] = [6]÷[7]
Change in executive compensation incentives	**Δ*lnDelta* or Δ*lnVega***	$\hat{\beta}_{lnDelta}$ **or** $\hat{\beta}_{lnVega}$	**Δ external SR per $ equity at average bank**	**$ of equity in system**	**Δ external $ of SR in system**	**$ of annual SES in system**	**%Δ in aggregate external SR**
Increase *lnDelta* by one standard deviation	0.54	-0.0143	-0.00772	610,539	-4,713	69,324	-6.80%
Increase *lnVega* by one standard deviation	2.04	0.000423	0.000863	610,539	527	69,324	0.76%

Table 15 – Relationship between positive and negative externalities

Estimating the relation between external liquidity creation per bank asset dollar (ε_{TLCA}) and external systemic risk creation (ε_{SES}). All estimations use pooled ordinary least squares. Standard errors appear in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels. See Table 1 for full set of variable definitions.

$\varepsilon_{TLCA} = \alpha + \beta \cdot \varepsilon_{SES} + \varepsilon$	α	β	Obs	R^2
Full sample				
1994-2010	-0.0173***	0.5534***	945	0.0146
	(0.0059)	(0.1480)		
Pre- and post-crisis subsamples				
1994-2006	-0.0446***	0.5919***	687	0.0144
	(0.0069)	(0.1861)		
2007-2010	0.0556***	0.6512***	258	0.0339
	(0.0102)	(0.2463)		
Annual subsamples				
1994	-0.0133	0.4850	64	0.0204
1995	-0.0400	0.3453	57	0.0096
1996	-0.0605***	0.4344	64	0.0099
1997	-0.0876***	-0.3893	47	0.0062
1998	-0.1222***	0.0169	48	0.0000
1999	-0.0502*	0.2999	52	0.0019
2000	-0.0693**	1.9895**	51	0.0646
2001	-0.0709**	3.1806***	48	0.1833
2002	-0.0293	0.7092	49	0.0174
2003	-0.0170	0.5170	51	0.0141
2004	-0.0430*	0.9275	54	0.0208
2005	-0.0010	0.9786	56	0.0297
2006	0.0345	0.6736	46	0.0292
2007	0.0749***	1.6097**	58	0.0769
2008	0.0503**	0.6706	74	0.0263
2009	0.0423*	0.9465**	66	0.0821
2010	0.0732***	-0.0031	60	0.0000

Figure 1



Annual Δcredit/GDP ratio, 1970-2013, Actual vs Filtered trend
0.25
0.2
0.15
0.1
0.05
0
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012