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Bank Rescues and Bailout Expectations: The Erosion of Market Discipline During the Financial Crisis

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Non-Technical Summary

The recent financial crisis triggered a series of unprecedented public interventions in the financial system. These interventions raised fears about a loss of market discipline. If investors perceive a higher likelihood of future support to troubled financial institutions, this may reduce the incentives to monitor and control risk-taking. In turn, this might increase the probability and severity of future crises. These indirect costs of bailouts might even outweigh the positive short-run gains from improved financial stability, making this issue critically important for policymakers. Yet, there remains a lack of consensus regarding theoretically and empirically sound methods to measure market discipline.

Our paper addresses this gap in the literature by proposing a novel approach to measure market discipline. The validity of our approach depends on a minimal set of assumptions. Building on a parsimonious firm value model, we derive theoretically that the relation between the debt-to-equity hedge ratio and individual firm risk depends on the strength of market participants' bailout expectations. It follows that observing changes in the debt-to-equity sensitivity will allow us to infer changes in bailout expectations and hence market discipline. Importantly, the effect of bailout expectations is independent of any particular assumption regarding the modeling of the firm value. Because the aim of our method is to compare pricing relations during crisis times, this robustness of our methodology is particularly beneficial.

We apply our framework to analyze the strength of market discipline during the recent financial crisis. We find that market discipline substantially deteriorated over the course of the financial crisis, starting with the outbreak of the asset backed commercial paper crisis in August 2007. This deterioration continued after the rescue of Bear Stearns and the unprecedented series of support measures enacted after the failure of Lehman Brothers in 2008. The initiation of the Dodd-Frank Act in June 2009 led to a decrease of bailout expectations. Finally, after the signing of the law in July 2010, perceived bailout probabilities further declined, reaching levels not statistically distinguishable from those in the pre-crisis period.

Further, we analyze the heterogeneity of the development of market discipline across different sub-samples of financial firms. We find that the effect of the rescue of Bear Stearns is particularly severe for investment banks as well as for SIBs. In contrast, following the sector-wide support measures enacted after the Lehman failure, nearly all sub-sample differences in perceived bailout probabilities vanish, reflecting the general willingness to support the financial system that characterized that period.

Overall, our results suggest that market participants rationally adjust their bailout expectations in response to government interventions. Given these findings, policymakers need to take into account the potential effects on market discipline when considering future public responses to financial crises.

Bank Rescues and Bailout Expectations: The Erosion of Market Discipline During the Financial Crisis

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Abstract

We design a novel test for changes in market discipline based on the relation between firm-specific risk, credit spreads, and equity returns. We use our method to analyze the evolution of bailout expectations during the recent financial crisis. We find that bailout expectations peaked in reaction to government interventions following the failure of Lehman Brothers, and returned to pre-crisis levels following the initiation of the Dodd-Frank Act. We do not find such changes in market discipline for non-financial firms. Finally, market discipline is weaker for government-sponsored enterprises (GSEs) and systemically important banks (SIBs) than for investment banks.

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1 Introduction

The recent financial crisis triggered a series of unprecedented public interventions in the financial system. These interventions raised fears about a loss of market discipline. If investors perceive a higher likelihood of future support to troubled financial institutions, this may reduce the incentives to monitor and control risk-taking. In turn, this might increase the probability and severity of future crises. These indirect costs of bailouts might even outweigh the positive short-run gains from improved financial stability, making this issue critically important for policymakers. Yet, there remains a lack of consensus regarding theoretically and empirically sound methods to measure market discipline.

Our paper addresses this gap in the literature by proposing a novel approach to measure market discipline. We use this approach to analyze the impact of public intervention during and following the 2007-2008 financial crisis in the United States. The validity of our approach depends on a minimal set of assumptions. Building on a parsimonious firm value model, we derive theoretically that the relation between the debt-to-equity hedge ratio and individual firm risk depends on the strength of market participants' bailout expectations. It follows that observing changes in the debt-to-equity sensitivity will allow us to infer changes in bailout expectations and hence market discipline. Importantly, the effect of bailout expectations is independent of any particular assumption regarding the modeling of the firm value. Because the aim of our method is to compare pricing relations during crisis times, this robustness of our methodology is particularly beneficial.

We focus on several key events relevant to market discipline: the outbreak of the asset backed commercial paper turmoil in August 2007, the rescue of Bear Stearns in March 2008, the failure of Lehman Brothers and subsequent support measures in September 2008, and the signing of the Dodd-Frank act in July 2010. Our results show a considerable decline of market discipline following the outbreak of the asset backed commercial paper crisis. Bailout expectations further increase after the rescue of Bear Stearns and ultimately peak after the Lehman collapse and the unprecedented series of public interventions thereafter. Following the announcement of the Dodd-Frank act in June 2009, estimated bailout probabilities started to decline again, reaching pre-crisis levels after the signing of the law in July 2010. Further, we find evidence for significant cross-sectional differences in estimated bailout probabilities for government-sponsored enterprises (GSEs), systemically important banks (SIBs) and investment banks (IBs). We also use our approach to analyze the development of market discipline for non-financial firms and find no comparable effects. This reassures that we can interpret our results as driven by differences in bailout expectations.

Our paper adds to the empirical literature analyzing market discipline. From a theoretical point of view, market discipline as a regulatory tool has been advocated by, among others, Calomiris and Kahn (1991) and Calomiris (1999). Flannery (2001), Bliss and Flannery (2001) as well as Hellwig (2005) provide a structured overview on the distinction between different notions of market discipline and their implications. As Bliss and Flannery (2001) point out, market discipline consists of two distinct components. First, *monitoring* refers to market prices reflecting the condition of a bank, in particular the probability of default.[1] Second, *influence* describes how this market information translates into incentives for managers to alter risk taking behavior.[2] By analyzing how the riskiness of banks is reflected in its different security prices, our paper relates to the first category in this classification.

In line with much of the empirical literature on measuring market discipline, our framework is conceptually based on a structural firm value approach. Yet, in contrast to earlier work, our approach does not rely on a specific firm value model. Furthermore, it is based on second moments, i.e. we analyze the co-movement of equity and debt returns. We thereby use our theoretical finding that the effective debt-to-equity sensitivity negatively depends on the size of the perceived bailout probability. Hence, we extend the work by Schaefer and Strebulaev (2008) and Campello et al. (2008) on estimating debt-to-equity sensitivities to the specifics of financial firms. Further, our method does not require the non-credit risk related components of bond and CDS spreads to be zero or time invariant. It is thus consistent with the findings by Collin-Dufresne et al. (2001) and Elton et al. (2001) on bond spreads suggesting that a significant part of credit spreads is unexplained by credit risk factors.

[1] Avery et al. (1988) and Gorton and Santomero (1990) are early studies also analyzing the monitoring function of market discipline. They reject the notion that yield spreads reflect individual bank risks, a finding shared by Krishnan et al. (2005). By contrast, Flannery and Sorescu (1996), Hannan and Hanweck (1988), Hancock and Kwast (2001), Jagtiani et al. (2002), Morgan and Stiroh (2001), Sironi (2003), and Gropp et al. (2006) find significant relations between debt spreads and bank risks. Flannery (1998) provides an extensive survey on the early evidence in this literature strand. Analyzing the role of implicit guarantees in the financial crisis, Kelly et al. (2016) show an inconsistency between individual firm and sector-wide option-implied tail risks, indicating a perceived guarantee for the financial sector as a whole. Acharya et al. (2015) analyze the risk-sensitivity of credit spreads of financial institutions. Schweikhard and Tsesmelidakis (2012) compare equity-implied credit spreads to actual credit default swap (CDS) quotes and ascribe the wedge between the two to bailout expectations. In the literature on sovereign risk, Dell'Ariccia et al. (2006) show how changes in bailout expectations affect the pricing of risk.

[2] Examples include Keeley (1990), Demirguc-Kunt and Detragiache (2002), Gropp and Vesala (2004), Gropp et al. (2011), Dam and Koetter (2012), and Duchin and Sosyura (2014).

The remainder of the paper is structured as follows. Section 2 derives theoretically how the relation between firm-specific risks, credit spreads, and equity returns depends on bailout expectations. Section 3 describes how this result is used to design an empirical strategy to measure changes in market discipline. Section 4 describes our data set and Section 5 presents and discusses the results of our empirical analysis. Finally, Section 6 concludes.

2 Theory

As we are measuring changes in market discipline over considerable time intervals, it is crucial to impose as few assumptions as possible about structural relations in order to maintain a maximum level of robustness. Hence, we base our analysis only on two general assumptions unlikely to be violated even during periods of severe market turmoil.

First, we rely on the fact that the debt-to-equity sensitivity is fundamentally driven by the unobservable ratio of the first derivatives of debt and equity with respect to the firm value, also known as the (debt-to-equity) hedge ratio. While the true functional form of the hedge ratio is unknown and any approximation highly model-dependent, we show that it unambiguously increases for declining firm values and generally increases in a firm's risk.

Second, we draw upon the fact that public bailouts favor debt over equity such that the *effective* debt-to-equity elasticity in the presence of bailouts will be lower than the *fundamental* elasticity in the absence of bailouts.

2.1 The debt-to-equity elasticity and the hedge ratio

The structural firm value approach pioneered by Merton (1974) serves as the starting point of our analysis. It states that the prices of equity E and debt D can be interpreted as derivatives on the firm value F and thus be evaluated using option pricing theory. Accordingly, changes in the value of equity and debt are both driven by changes in the underlying firm value and therefore structurally linked via the debt-to-equity elasticity (Schaefer and Strebulaev, 2008)

$$\beta_{D,E} = \frac{\partial D}{\partial E}\frac{E}{D} = \frac{D_F}{E_F}\frac{E}{D} = HR \cdot \frac{1}{L}, \tag{1}$$

where $L = \frac{D}{E}$ denotes leverage, the hedge ratio is defined as $HR = \frac{D_F}{E_F}$ and single subscripts denote first derivatives.

Schaefer and Strebulaev (2008) estimate the hedge ratio based on a simple Merton model and show that it predicts co-movements of stock and bond prices for non-financial firms. However, there are two principle drawbacks to applying this approach to financial institutions. First, financial institutions are highly leveraged firms with low implied asset volatilities. A simple Merton model as well as most of its diffusion-only extensions (e. g. Black and Cox, 1976) cannot be reasonably calibrated to capture this.[3] Second, a constant risk for financial firms with illiquid assets is the inability to fund those assets, even when the financial institution itself is still considered solvent (see, for instance, Diamond and Dybvig, 1983). That is, financial institutions are severely prone to default due to liquidity and funding problems, a feature not captured by the theoretical firm value approach.

Instead we base our framework on a more general insight from option pricing theory. We show that the hedge ratio is unambiguously increasing for declining firm values F, i.e.

$$\frac{\partial HR}{\partial F} = \frac{D_{FF}}{E_F^2} < 0 \tag{2}$$

with D_{FF} denoting the second derivative of debt with respect to the underlying firm value and $D_{FF} < 0$ (see Appendix A.1). Similarly, it increases for higher fundamental risks X as long as $D_{FX} = -E_{FX} > 0$, where D_{FX} and E_{FX} are the cross derivatives with respect to the firm value F and fundamental risk measure X (see Appendix A.2).

Intuitively, the hedge ratio is the quotient of the first derivatives of two options on the firm value with the same strike price and depends on the moneyness of the underlying options. When the firm is very healthy, the risk of bankruptcy is very low and changes in the firm value mainly affect the residual claim, i. e. the stock price. The hedge ratio thus becomes very small for low levels of risk. If, however, the firm value is very low and default becomes more likely, small changes in the firm value strongly affect the value of debt as compared to the value of equity, i. e. D_F (E_F) strongly increases (decreases) relative to the low risk case.

[3]In most cases, traditional firm value models imply a flat zero default probability and hence a zero credit spread even for longer time horizons. Obtaining positive model-implied credit spreads requires additional uncertainty about the distance to default, for instance by introducing jumps (Zhou, 2001) or a non-observable default barrier (Finger et al., 2002).

Similarly, for higher fundamental risks X, the probability of bankruptcy increases and it is therefore less likely that the equity option ends up in the money. As a result, $E_{FX} < 0$ will generally be satisfied for any relevant fundamental risk measure X.

2.2 Bailout probabilities and the hedge ratio

The pivotal characteristic of a bailout is the rescue of the bondholders. Hence, in the case of a bailout, the firm's debt becomes essentially default risk-free. However, the effects of public interventions often go beyond securing individual firms' debt repayments and may also feature policies directly affecting the value of equity.[4]

We adjust the structural firm value framework to allow for the possibility of a general public intervention: the market values of the bond and the stock, D^* and E^*, reflect the firm value F as well as the present values of any potential (government sponsored) debt guarantee G or equity support S. Given an exogenous bailout probability PB, the effective hedge ratio HR^* becomes:

$$HR^* = \frac{(1 - PB) \cdot D_F}{E_F + PB \cdot S_F} < HR \tag{3}$$

where the inequality holds if $E_F > -S_F$ (see Appendix A.3).

Economically speaking, $E_F > -S_F$ states that for declining firm values, the fundamental equity value declines more strongly than the present value of the government support rises. It corresponds to the requirement that observable equity prices remain at least marginally sensitive to the firm value. For the case of public capital injections and distressed mergers, the value of S depends on the price at which the new capital is injected or existing capital is sold. While S might actually be positive or negative[5], the size of the dilution effect will generally depend on the firm value at the time of bailout. Additionally, given the inherently

[4]The recent crisis was no exception. It featured injections at distressed levels (e.g. capital injections for large financial institutions under TARP), distressed and forced mergers (Bear Stearns, Wachovia), nationalizations and take-overs by a public national authority (Fannie Mae and Freddie Mac) or official insolvency procedures (Lehman Brothers, Washington Mutual).

[5]For example over the weekend of the Bear Stearns rescue, the 5-year CDS rate on Bear Stearns improved by over 350 bps but the stock price plummeted by 90% as a direct response to the bailout. The Economist (2008) notes that the real value of the bank probably exceeded the acquisition price substantially. This would imply that shareholders did not only not benefit from the bailout but even suffered from it.

asymmetric payout behavior of bailouts, equity holders still hold the full upside potential of the firm ex ante. Hence, it is straightforward to argue that equity values will continue to be sensitive to the firm value, even in the presence of government bailouts.

One special case of Eq. (3) would be if only bondholders are bailed out but stockholders are left with a complete loss of capital. For instance, in the case of equity nationalizations, it holds that $S = 0$ as equity holders do not profit from the debt bailout. To avoid a market-wide collapse of the financial system, it might be necessary to guarantee or actually repay bank debt obligations. Yet, it might be unnecessary to compensate the equity holders, as only the former trigger an actual default event. Because the bailout payment to the debtors only materializes if the firm is already in default and the full firm value is then transferred to the debt holders, the equity holders remain unaffected by the potential bailout, i.e. $E^* = E$ and hence $E^*_F = E_F$. In that case, the effective hedge ratio in Eq. (3) simplifies to the product of the fundamental hedge ratio HR, adjusted for the probability of no government intervention $(1 - PB)$, i.e.

$$HR^* = (1 - PB) \cdot HR \;\; if \; S = 0. \tag{4}$$

Note that Eq. (4) also holds as a linear approximation of Eq. (3) for the general case with equity bailout effects.

Taken together, this implies that for higher bailout probabilities the effective hedge ratio increasingly diverges from its fundamental value and converges to zero if bailouts are assumed to be certain. In addition, Appendix A.6 discusses why a similar result can be expected for the debt-to-equity sensitivity.

3 Empirical strategy

In the following, we describe how the theoretical insights derived in Section 2 can be used to build an empirical framework for measuring changes in market discipline.

3.1 How to measure market discipline

For the empirical implementation of our market discipline measure, we assume a linear relation between the hedge ratio and firm i's leverage and other risk measures X_i,[6] i. e.

$$HR_{i,t} = \gamma_0 + \gamma_L L_{i,t} + \sum_{j=1}^{k} \gamma_j X_{i,t}^j. \tag{5}$$

To measure variation in bailout expectations across time or across firms, we describe a firm's bailout probability as a function of its firm type and time:

$$(1 - PB_{i,t}) = (1 - \sum_j PB_j D_{i,j}) \cdot (1 - \sum_T PB_T D_{t,T}). \tag{6}$$

Here, $D_{i,j}$ takes the value of one if firm i is of type j and zero otherwise. $D_{t,T}$ takes the value of one if time t belongs to period T. Accordingly, PB_j represents the respective difference of the estimated bailout probability of firms of type j as compared to all other firms. PB_T represents the respective difference of the estimated bailout probability in period T as compared to the period before the financial crisis.

Combining Eq. (1), (4), (5), and (6) and using the negative relation between debt returns and CDS spread changes yields our main estimation equation:

$$\begin{aligned}\Delta CDS_{i,t} = \quad & c + (1 - \sum_j PB_j D_{i,j}) \cdot (1 - \sum_T PB_T D_{t,T}) \cdot (\beta_0 + \beta_L L_{i,t} + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E \\ & ... + \beta_Z \cdot Z_{i,t} + \epsilon_{i,t} \end{aligned} \tag{7}$$

where $\Delta CDS_{i,t}$ is the change in the CDS spread of firm i, $r_{i,t}^E$ its corresponding equity return, and $Z_{i,t}$ is a vector of possible control variables.

The specification of Eq. (7) takes into account that the leverage term enters the debt-to-equity sensitivity twice and with opposing expected marginal effects. In Eq. (1), it enters

[6]For a further discussion of the restrictiveness of this assumption, see Appendix B.

indirectly through its impact on the hedge ratio and directly via its inverse. By modeling the influence of leverage in a linear form, we take the most parsimonious approach. This also follows Campello et al. (2008), who estimate the debt-to-equity sensitivity as a function of leverage, stock volatility, and interest rates. Based on the derivations in Section 2.1 and Appendix B and in line with the results by Campello et al. (2008), we expect negatively signed coefficients for all β_j as well as β_L.

Due to the addition of the bailout interaction terms, Eq. (7) becomes inherently nonlinear and we estimate the model using nonlinear least squares. As a robustness analysis, we employ an alternative two-stage estimation procedure based on ordinary least squares (OLS). In the first stage, the fundamental CDS-to-equity semi-elasticity is estimated for the control period and in the second stage the evolution of bailout probabilities $PB_{i,t}$ is again estimated through a series of time period dummies (see Section 5.3.2).

Finally, it is important to acknowledge that the impact of government interventions goes beyond direct debt guarantees or equity value transfers. On the one hand, bailouts and other government actions during the financial crisis had a stabilizing effect on the market as a whole. They improved the asset values of the financial sector's balance sheets and lowered the underlying assets' price volatility. On the other hand, equity holders should benefit from improved refinancing conditions due to increased bailout expectations, lowering their cost of capital. This in turn allows them to take on more leverage upfront. For instance, this could be done by taking on more debt explicitly. Alternatively, leverage can be increased by paying out higher dividends to equity holders or paying higher salaries to corporate insiders, implicitly reducing the firm's assets relative to a given level of debt. Yet, the important point to note is that our empirical framework was derived for any level of firm risk. It remains valid as long as we properly condition the hedge ratio on the relevant risk measures such as leverage and volatility.

3.2 Measuring firm specific risks

We now discuss how we measure firm-specific risks in the financial sector.

3.2.1 Asset value risks

Classical firm value models emphasize the importance of leverage and asset volatility as the main determinants of credit risk. Gorton and Santomero (1990) use the framework proposed by Black and Cox (1976) to test whether implied asset volatilities of junior bank debt are related to other credit risk proxies. However, they find no significant relation. By contrast, Flannery and Sorescu (1996) and Balasubramnian and Cyree (2011) find that junior bank debt yield spreads are sensitive to variables such as leverage and stock volatility. Campello et al. (2008) estimate the impact of leverage and stock volatility on the debt-to-equity sensitivity. In our setup, we prefer forward-looking option-implied at-the-money (ATM) call option volatilities to historical volatilities as the former should contain more information about associated future risks. Regarding a leverage proxy, we include the quasi market leverage defined by the ratio of book debt to the market value equity.

3.2.2 Option-implied skewness

Recent contributions to the empirical asset pricing literature show that option surfaces contain information about the implied distribution of future stock returns. Various measures of idiosyncratic implied skewness have been successfully used in order to establish the link between skewness and stock returns, see for instance Yan (2011) or Rehman and Vilkov (2012), using the model-free implied skewness measure from Bakshi et al. (2003) or Xing et al. (2010). We follow Xing et al. (2010) and calculate our measure of skewness as the difference between the equity option implied volatilities of an out-of-the-money (OTM) put and an at-the-money (ATM) call with a remaining maturity of one year and stock deltas of 0.2 and 0.5 respectively:

$$Skewness_{i,t} = vol_{i,t}^{OTM\ Put} - vol_{i,t}^{ATM\ Call} \tag{8}$$

Similarly to Collin-Dufresne et al. (2001), we interpret a higher implied skewness as an indicator for higher implied default risk.

3.2.3 Funding risk

As financial institutions are refinancing a large fraction of their liabilities by rolling over short-term debt, they are subject to potential liquidity and funding shortages. In order to capture this source of risk, we compute the yield spread between financial commercial paper (FCP) and non-financial commercial paper (NFCP) with a remaining time to maturity of one month. As this FCP spread is based on a broad range of commercial paper, it should largely mirror the relative ease and difficulty of financial institutions of acquiring short-term funding. Nevertheless, not all financial institutions rely on short-term funding to the same extent. Accordingly, funding risk should differ among individual firms. In order to account for this heterogeneity, we interact the FCP spread with the firm-specific ratio of short-term debt (STD) to total liabilities (TL), i. e.

$$Fundingrisk_{i,t} = (FCP_t - NFCP_t) * \frac{STD_{i,t}}{TL_{i,t}}. \tag{9}$$

Short-term debt is thereby defined as current debt maturing within one year. It does not include deposits, as the yield spreads mainly apply to wholesale funding.

3.3. Controlling for determinants of CDS spreads outside the firm value model

The empirical literature on the determinants of credit spreads has identified a series of factors potentially affecting CDS changes that remain outside our current framework. To rule out that these factors systematically vary with those explicitly included in our model, we also add a list of control variables to our analysis.

3.3.1 Aggregate risk factors

We include a broad set of aggregate risk factors which have been shown to determine credit risk spreads, for instance by Collin-Dufresne et al. (2001), Elton et al. (2001), and Schaefer and Strebulaev (2008). This set of risk factors includes the 10-year treasury rate, the slope of the treasury rate (calculated by the difference between the 10-year and 2-year treasury rate), the VIX index, and Moody's corporate BBB-spread.

3.3.2 Market liquidity

We address market liquidity concerns in three ways. First, we include the change in the difference between the ten year swap rate and the ten year treasury rate, *Swap Spread*, as an aggregate liquidity proxy. Second, we employ the level and change of the stock specific Amihud (2002) ratio, *Amihud*, as a proxy for stock liquidity. Third, in a robustness check, we add the level and change of the absolute difference between Markit and Datastream

CDS price quotes, *CDS Price Heterogeneity*, as a proxy for firm specific CDS liquidity. The intuition is that a stronger disagreement among the two data sources about the actual price of the same CDS indicates a larger intransparency of the market resulting from a greater degree of illiquidity.

4 Data

Our data set combines information from several different sources covering the period from January 1, 2004 to September 30, 2014. We include the whole Markit universe of US financial institutions. Non-financial firms are selected based on the CDX NA IG and CDX NA HY constituents list for series 11. We drop firms with static CDS prices over large parts of the overall sample. Accompanying daily equity prices are obtained from CRSP, equity option quotes from Optionmetrics, interest rate data from the Federal Reserve Bank, and quarterly balance sheet information from Compustat. For the variable *CDS Price Heterogeneity* we additionally match CDS quotes from Datastream.

We ignore daily observations where market information on either the change in the CDS level or the equity return for a given institution is not available. Some of the CDS time series are not updated on a daily basis, suggesting illiquidity and a lack of trading activity. We thus omit observations where the CDS level changes by more than 100 basis points in absolute value or not at all between two trading days. Further, we delete all observations where credit spreads exceed 2,000 basis points (bps) as liquidity in CDS markets for highly distressed firms is likely very low. In addition, we ignore all observations for Countrywide Financial, Bear Stearns, Merrill Lynch, Lehman Brothers, Wachovia, Washington Mutual, and CIT Group after their announced takeovers or bankruptcies in 2008.

We aggregate this daily information to weekly frequencies. If more than one daily observation is missing within a particular week, we drop the corresponding weekly observation. Finally, we winsorize all included variables at the 1% level. Table 1 provides descriptive statistics for the final sample of 45 US financial institutions as well as for the 164 included non-financial firms.[7]

[7] A list of included financial firms can be found in Table 2, for non-financial firms see the Online Appendix.

5 Results

We now present the results of our analysis. We begin by testing the analytically derived link between firm risks and the hedge ratio. We then analyze the heterogeneity of bailout probabilities across firms as well as across time. Finally, we test the robustness of our main findings to a host of potential alternative specifications.

5.1 The risk sensitivity of the hedge ratio

Before analyzing the evolution of market discipline, we first validate our approach by testing the presumed link between firm risks and the hedge ratio. We do so by estimating Eq. (7) over the whole sample using OLS and firm fixed effects, omitting the dummy variables for the moment.

Panel A of Table 3 shows the respective regression results for the financial sample. As we use standardized risk measures, the coefficient of r^E can be interpreted as the average relation between changes in CDS spreads and stock returns. On average, a ten percentage point decline of the stock price is associated with a rise of the CDS spread by 9-11 basis points. This compares well with the empirical results of approximately ten basis points for the A-rating category by Collin-Dufresne et al. (2001).

Furthermore, the coefficients of the interaction terms between the equity return and the risk proxys, $r^E \cdot X$, correspond to the β_j and β_L in Eq. (7). As expected, all interaction terms (Leverage, Volatility, Skewness, Fundingrisk) are negative. The reported p-values in the row "Risk-sensitive hedge ratio" refer to an F-test of the joint null hypothesis of all risk coefficients being zero. While not all risk coefficients are individually significant, the F-test always rejects the null-hypothesis that the credit-spread-to-equity semi-elasticity does *not* depend on individual firm risk.

For the purpose of this paper we are primarily interested in using our framework to analyze the development of market discipline for financial firms. However, the derived framework should also extend to non-financial firms. Hence, as an additional test of the validity of our approach, we run the same regressions also for the sample of non-financial firms. The only difference is that for non-financial firms we exclude Fundingrisk as an individual risk measure.[8] Panel B of Table 3 reports the respective results. Again, we see that the coefficients of

[8]Recall that the inclusion of Fundingrisk was particularly motivated by the specificity of the business

all individual risk measures are negative and even individually significant in all specifications.

5.2 Measuring differences in market discipline

We now analyze the variation in the risk adjusted credit spread sensitivity. As outlined in Section 3, we interpret such variation as reflecting differences in perceived bailout probabilities. The PB-coefficients in Table 4 and thereafter can be interpreted as the differences in bailout expectations relative to other firm types or the pre-crisis period respectively.

5.2.1 Differences in market discipline across the financial sector

A natural starting point for the measurement of market discipline is the analysis of cross-sectional differences in bailout expectations. If our methodology correctly identifies differences in perceived bailout probabilities, we should observe systematic differences among sub-samples of financial institutions. We distinguish among three different classes of financial firms.

First, we make use of the three government-sponsored enterprises in our sample, namely Fannie Mae, Freddie Mac, and Sallie Mae. As these firms are backed by the government, we would expect particularly high estimated bailout probabilities. Second, we analyze systemically important banks. Almost by definition, failures of such institutions represent a bigger threat to the stability of the economy than the collapse of other banks. As a result, one should expect that estimated bailout probabilities are larger for SIBs. Finally, we look at investment banks. Historically, in the spirit of the Glass-Steagall Act, investment banks were regarded as having a smaller impact on the real economy as compared to deposit banks. Accordingly, bailout probabilities should be smaller for them, as the costs of their failure were expected to be smaller in real economic terms.

The corresponding results can be found in Part A of Table 4. The very high estimate of PB_{GSE} implies that market participants perceive actual default risk of these institutions to be almost negligible. For investment banks, PB_{IB} indicates perceived bailout probabilities to be substantially lower than for other financial institutions, which is in line with the historical interpretation. For systemically important banks, PB_{SIB} shows a positive and statistically significant effect.

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model of financial institutions, see Section 3.2.

In addition, Part B of Table 4 reports the estimated coefficients of the fundamental credit spread-to-equity semi-elasticity. The coefficients of the risk measures β_L and β_j are in line with the OLS results from Section 5.1. As this finding holds true for all specifications in Tables 4-8, in the following we focus the discussion on the estimated bailout probabilities in Part A of the respective tables.

5.2.2 The development of market discipline during the crisis

We now proceed to analyze the development of market discipline as a response to major events during the crisis. The respective results can be found in Part A of Table 5. The p-values in the four rows of Part C refer to F-tests of the null hypothesis of the bailout probabilities in the two respective periods being equal.

The asset backed commercial paper crisis. The first event we consider is the outbreak of the asset backed commercial paper (ABCP) crisis in August 2007 and subsequent support activities like the introduction of the Term Auction Facility (TAF) by the Federal Reserve. The outbreak of the ABCP crisis is generally interpreted as marking the starting point of the financial crisis.

In the end of July and the beginning of August 2007, hedge funds by Bear Stearns as well as BNP Paribas investing into subprime mortgages went bankrupt or halted withdrawals. This raised further suspicions among market participants regarding the quality of collateral typically pledged for asset backed commercial paper. In turn, ABCP spreads soared and problems about the roll-over of short-term debt appeared (Kacperczyk and Schnabl, 2010). To counteract arising liquidity problems, the Fed provided massive liquidity injections into the market, lowered the discount rate, and increased the maturity of discount-window loans to 30 days. In December, the introduction of the Term Auction Facility served as the next step in a series of liquidity supporting activities as a reaction to the ABCP market turmoil (Cecchetti, 2009).

These activities by the Federal Reserve represent substantial support to the financial system. Although the actions taken can primarily be interpreted as liquidity support and not yet an explicit bailout, they clearly indicate the commitment of the authorities to support the financial system in times of crisis. Accordingly, the perceived bailout probability of market participants should increase during this period.

The coefficient PB_{ABCP} in Part A of Table 5 reflects the change of bailout expectations after August 2007 as compared to before the crisis. Indeed, we see that the perceived bailout probability increased substantially by approximately 30 percentage points relative to the pre-crisis period. This increase in bailout expectations is also statistically significant. An even finer split of this period indicates that the increase in bailout probabilities is more likely to be associated with the introduction of the TAF rather than the outbreak of the ABCP crisis.[9]

The rescue of Bear Stearns. The next event of interest is the bailout of Bear Stearns in March 2008. In response to the de-facto bankruptcy of Bear Stearns, the Federal Reserve supported J.P. Morgan in acquiring the failing investment bank by guaranteeing $30 billion worth of creditors' claim. Of course, banks had already been supported by the government on previous occasions, giving rise to the general notion of "too-big-to-fail". Nevertheless, the event contains substantial informational value as it was the first time an investment bank was explicitly supported by the government. We would therefore expect that after the rescue of Bear Stearns market discipline declined further.

Focusing on the coefficient PB_{BSC} in Part A of Table 5, we see that after the rescue of Bear Stearns perceived bailout probabilities rise even further to 60 percentage points relative to the pre-crisis period. As indicated by the low p-value in Part C of Table 5, the further manifestation of bailout expectations after Bear Stearns is also significant when compared to the outbreak of the ABCP crisis.

The failure of Lehman Brothers. Arguably the pivotal event of the financial crisis was the failure of Lehman Brothers in September 2008. However, for the purpose of our analysis, the failure of Lehman Brothers actually marks the starting point of a period of successive government actions in the fall of 2008. Most notably, the post-Lehman period includes the bailout of AIG and the introduction of TARP as well as other worldwide financial sector rescue packages. The short time span between these events renders it impossible to distinguish their individual effect on market discipline. Thus, we proceed by testing their joint effect.

Given this multiplicity of events, there are two alternative hypotheses: on the one hand, one might expect that the failure of Lehman Brothers led to a re-establishment of market

[9] Results not shown but available upon request.

discipline. Contrary to the case of Bear Stearns, Lehman Brothers was not supported. Accordingly, these two events could have opposing effects on future bailout expectations and market discipline. Thus, a decline of perceived bailout probabilities in reaction to the non-rescue of Lehman Brothers seems a natural hypothesis.

On the other hand, the failure of Lehman Brothers was not an isolated incident but rather preceded interventions like the bailout of AIG and the introduction of TARP. These interventions contradict the view that government support for financial institutions had become less likely. In addition, the magnitude of the financial turmoil following the Lehman Brothers bankruptcy might have convinced market participants that policy makers would not allow comparable events to take place again. This might have increased the perceived likelihood of future support measures even further. Overall, this could have induced a further decline in market discipline, overshadowing the potential signal sent by the non-intervention in the Lehman filing.

Our empirical results are strongly in line with a further decline in market discipline after the Lehman default. The estimated coefficient PB_{LEH} suggests an 80 percentage point increase in bailout expectations relative to the pre-crisis period. A formal test on the equivalence of PB_{BSC} and PB_{LEH} is strongly rejected, representing a firm belief of market participants that future bailouts would be even more likely than after the rescue of Bear Stearns.

The Dodd-Frank Act. The failure of Lehman Brothers intensified discussions about necessary changes in the regulation of financial institutions. On June 17, 2009 President Barack Obama presented a blue print for the legal response to the financial crisis in the form of the Dodd-Frank Act. The proposal included measures targeting the too-big-to-fail problem, as well as the resolution of financial institutions in case of failure. Accordingly, if successfully and credibly implemented, this proposal should have led to a decrease of future bailout expectations.

However, it took over a year until the reform was ultimately signed in July 2010. This period included several substantial adjustments of the initial proposal and a general uncertainty about the content, timing, and actual implementation of the reform (Schäfer et al., 2016). Therefore, we allow perceived bailout probabilities to differ during the announcement and negotiation period between June 2009 and July 2010 ($DF-A$) and following the final confirmation and signing of the reform after July 2010 ($DF-S$).

PB_{DF-A} and PB_{DF-S} in Part A of Table 5 state the corresponding perceived bailout probabilities according to our estimation. The value of PB_{DF-A} confirms that bailout probabilities were indeed perceived to be substantially lower after the initiation of the reform as compared to the aftermath of the Lehman failure. As the p-value in the row $PB_{LEH} = PB_{DF-A}$ indicates, this drop by almost 30 percentage points is also statistically significant. Yet, the economically and statistically significant value of PB_{DF-A} indicates that market discipline was still below pre-crisis levels during the drafting process of the Dodd-Frank Act. Only when the law was actually signed did bailout expectations return to pre-crisis levels. With PB_{DF-S} being insignificant, we conclude that the Dodd-Frank Act was successful in establishing a credible framework for resolving even systemically important institutions and restoring market discipline.

Overall, the results corroborate the conjecture that market discipline decreased significantly over the course of the financial crisis. Bailout expectations started to rise after the outbreak of the ABCP crisis and increased even further after the rescue of Bear Stearns and the far-reaching government interventions following the Lehman failure. Only after the implementation of the Dodd-Frank Act did market discipline revert to pre-crisis levels.

5.2.3 The heterogeneity of the development of market discipline

Market discipline for non-financial firms. Given that the vast majority of government interventions concerned financial institutions, market discipline should be less affected among non-financial firms. If the sensitivity of the hedge ratio to firm-specific risk weakens to the same extent for non-financial firms as it does for financial institutions, it might be that our market discipline measure picks up changes in pricing structures not necessarily related to changes in bailout expectations. The analysis of the non-financial sector can therefore be interpreted in the spirit of a placebo treatment.

We re-run our analysis based on a sample of non-financial firms. Table 6 reports the respective estimation results, revealing no similar pattern to that observed for the financial sector. Only in the period after the Lehman failure do we observe a limited rise in bailout probabilities, potentially reflecting some spillover effects from the financial sector rescue packages. We conclude that there are no comparable effects for non-financial firms to those reported for financial institutions. The distinctive pattern in the risk adjusted CDS sensitivity appears to be specific to financial institutions and hence we can exclude broader changes in the general financial markets as a potential confound.

Investment banks vs. other financial institutions. Specification (2) of Table 7 reports even more disaggregated results for the comparison of investment banks and non-investment banks. We focus on the periods after the Bear Stearns and Lehman Brothers events, respectively. As the rescue of Bear Stearns concerned one of the major investment banks, the informational content regarding future bailouts should be stronger for similar institutions. In line with this argument, the increase of bailout expectations is larger for investment banks as can be seen by the comparison of PB_{ABCP} and PB_{BSC}. While the already elevated bailout probability for non-investment banks takes only a moderate further increase, the respective increase for investment banks amounts to more than 30 percentage points. Hence, even though the difference in bailout expectations between these two types of financial institutions narrowed, at that time market participants still perceived a higher bailout probability for non-investment banks.

This differential assessment disappears in the period following the failure of Lehman Brothers. After September 2008, the situation in financial markets escalated and turned into a full-scale financial crisis. In turn, interventions after Lehman Brothers were supportive for the entire financial system. In fact, both sub-samples display a further increase in bailout probabilities. The levels are now almost indistinguishable from each other. The Dodd-Frank Act prolongs this parallel development. In the period after the presentation of the initial reform proposal, bailout probabilities decrease for both investment banks as well as non-investment banks. Finally, after the actual signing of the law, bailout probabilities are statistically indistinguishable from pre-crisis levels once again for both sub-samples.

SIBs vs. non-SIBs. Specification (1) of Table 7 reports comparable disaggregated results for the comparison of SIBs and non-SIBs. Remarkably, bailout expectations for SIBs did not react at all following the outbreak of the crisis in August 2007. Only for the sub-sample of non-SIBs do we see a moderate increase in bailout probabilities. However, the change in bailout expectations after the rescue of Bear Stearns is substantially larger for SIBs than for non-SIBs. In fact, estimated bailout probabilities of SIBs then even slightly exceeded those of non-SIBs. In the following, when support policies essentially targeted the financial system as a whole, bailout probabilities rose to similar levels for all types of financial institutions. In line with the findings from the sub-sample analysis of investment banks, the development during the Dodd-Frank period is basically parallel, with perceived bailout probabilities being marginally higher for SIBs than for non-SIBs after the signing of the bill, albeit not statistically significantly different.

One interpretation of the patterns for investment banks and SIBs is that market participants became aware of systemic importance as a determinant of bailout probabilities only during the crisis, in particular through the support for Bear Stearns. Probably the main motivation to rescue Bear Stearns was that in case of its failure, financial stability might be severely harmed, thereby revealing the systemic importance of the bank. The fact that a SIB was rescued despite being an investment bank was likely interpreted as indicating the general concern of policy makers regarding systemic risk. Accordingly, perceived bailout probabilities for investment banks and SIBs substantially increased.

5.3 Robustness

We now discuss a series of variations to our empirical setup and show that our results are robust.

5.3.1 Effects of time-varying asset volatility

As discussed in Sections 2 and 3, our empirical strategy relies on a general version of a Merton-type firm value model without reference to a specific model class. Yet, given the possibility that asset volatilities are time-varying or stochastic, Appendix C discusses how this might affect our estimation approach, especially during crisis times. We show that our approach remains valid if we appropriately control for changes in asset volatilities. As a consequence, we add the change in implied equity volatilities interacted with period dummies to our baseline regression Eq. (7).

Table 8 reports the respective results. In line with our predictions from Appendix C, we find that the relation between CDS changes and time-varying volatility is indeed not constant during our period of interest. However, the previously identified pattern in the development of perceived bailout probabilities is not affected by this variation but remains qualitatively and quantitatively the same. Therefore, we conclude that the observed evolution of estimated bailout probabilities is not simply reflecting systematic variations of time-varying volatilities.

5.3.2 Linear estimation based on two-stage OLS procedure

As discussed, our results from Section 5.2 are estimated using nonlinear least squares. Alternatively, we employ a two-stage procedure based on OLS: In the first stage, we estimate the structural parameters of the credit spread-to-equity semi-elasticity in the control period. In the second stage, we use these estimates to predict the corresponding values for the whole sample. To see how the credit spread-to-equity sensitivity varies along different time periods, we interact the predicted value with time dummies defined according to the respective periods of interest. This allows us to back out estimated values for PB in different time periods without relying on a nonlinear estimation technique. Table 9 reports that the respective results are similar to those based on the nonlinear least squares estimation.

5.3.3 Further liquidity analysis

Furthermore, we run two additional robustness checks with respect to the potential role of market liquidity: First, we add the level and change of *CDS Price Heterogeneity* as a proxy for firm specific CDS liquidity. Second, we re-run our analysis using CDS price information from Datastream instead of Markit. Yet, our results are robust to these variations.[10]

6 Conclusion

In this paper, we develop a new approach for measuring changes in market discipline. We build on the findings of Schaefer and Strebulaev (2008) and Campello et al. (2008) and exploit the theoretical link between the hedge ratio and firm-specific risks. Our approach has two main advantages. First, our methodology is robust to any specific assumption about the underlying firm value model. Second, it does not implicitly assume that any credit risk unrelated component of CDS spreads is time invariant.

We apply our framework to analyze the strength of market discipline during the recent financial crisis. We find that market discipline substantially deteriorated over the course of the financial crisis, starting with the outbreak of the asset backed commercial paper crisis in August 2007. This deterioration continued after the rescue of Bear Stearns and

[10] Respective estimation results can be found in the Online Appendix.

the unprecedented series of support measures enacted after the failure of Lehman Brothers in 2008. The initiation of the Dodd-Frank Act in June 2009 led to a decrease of bailout expectations. Finally, after the signing of the law in July 2010, perceived bailout probabilities further declined, reaching levels not statistically distinguishable from those in the pre-crisis period.

Further, we analyze the heterogeneity of the development of market discipline across different sub-samples of financial firms. We find that the effect of the rescue of Bear Stearns is particularly severe for investment banks as well as for SIBs. In contrast, following the sector-wide support measures enacted after the Lehman failure, nearly all sub-sample differences in perceived bailout probabilities vanish, reflecting the general willingness to support the financial system that characterized that period.

Overall, our results suggest that market participants rationally adjust their bailout expectations in response to government interventions. Given these findings, policymakers need to take into account the potential effects on market discipline when considering future public responses to financial crises.

Appendix

A Formal derivations

A.1 Derivative of the fundamental hedge ratio with respect to the firm value

$$\frac{\partial HR}{\partial F} = \frac{D_{FF} \cdot E_F - D_F \cdot E_{FF}}{E_F^2} = \frac{D_{FF} \cdot (1 - D_F) + D_F \cdot D_{FF}}{E_F^2} = \frac{D_{FF}}{E_F^2} < 0 \qquad (10)$$

as $E_F = 1 - D_F$ and $D_{FF} = -E_{FF} < 0$.

A.2 Derivative of the fundamental hedge ratio with respect to the fundamental risk X

$$\frac{\partial HR}{\partial X} = \frac{D_{FX} \cdot E_F - D_F \cdot E_{FX}}{E_F^2} = \frac{D_{FX} \cdot (1 - D_F) + D_F \cdot D_{FX}}{E_F^2} = \frac{D_{FX}}{E_F^2} > 0 \qquad (11)$$

for $D_{FX} = -E_{FX} > 0$.

A.3 The relation between the fundamental and the effective hedge ratio

With a most general bailout scheme, the market values of the bond D^* and the stock E^* reflect the firm value F as well as the present values of any potential (government sponsored) debt guarantee G or equity support S. We assume that in case of a bailout the combined value of the risky debt and the debt guarantee is equal to the value of a comparable credit risk-free government bond B. Furthermore, any government actions are assumed to take place with an exogenous probability PB.

$$E^* = E + PB \cdot S \qquad (12)$$

$$D^* = D + PB \cdot G \qquad (13)$$

$$= (1 - PB) \cdot D + PB \cdot B \qquad (14)$$

The partial derivatives with respect to the firm value are given by

$$E_F^* = E_F + PB \cdot S_F,\ D_F^* = (1 - PB) \cdot D_F \tag{15}$$

as $B_F = 0$. Accordingly, for $0 \leq PB < 1$ the effective hedge ratio becomes

$$HR^* = \frac{(1 - PB) \cdot D_F}{E_F + PB \cdot S_F} \tag{16}$$

$$= \frac{D_F}{\frac{E_F}{1-PB} + \frac{PB}{1-PB} \cdot S_F} < \frac{D_F}{E_F} = HR, \tag{17}$$

with the inequality holding for

$$\frac{E_F}{1 - PB} + \frac{PB}{1 - PB} \cdot S_F > E_F \tag{18}$$

$$E_F + PB \cdot S_F > E_F - PB \cdot E_F \tag{19}$$

$$E_F + S_F > 0. \tag{20}$$

A.4 Derivative of the effective hedge ratio with respect to the firm value

For $0 \leq PB < 1$,

$$\frac{\partial HR^*}{\partial F} = \frac{(1 - PB) \cdot D_{FF} \cdot (E_F + PB \cdot S_F) - (1 - PB) \cdot D_F \cdot (E_{FF} + PB \cdot S_{FF})}{(E_F + PB \cdot S_F)^2} \tag{21}$$

$$= -(1 - PB) \cdot \frac{E_{FF} \cdot (E_F + PB \cdot S_F) + (1 - E_F) \cdot (E_{FF} + PB \cdot S_{FF})}{(E_F + PB \cdot S_F)^2} \tag{22}$$

Hence, for Eq. (22) to be negative it is sufficient that $E_F^* = E_F + PB \cdot S_F > 0$ and $E_{FF}^* = E_{FF} + PB \cdot S_{FF} > 0$, i.e. the bailout scheme must not destroy the call-option like incentive structure for equity holders. In particular, equity holders must suffer from lower firm values ($E_F^* > 0$) and they increasingly do so as firm values decline ($E_{FF}^* > 0$).

For the special case of bailouts only affecting bondholders, i.e. $S = 0$, Eq. (22) becomes

$$\frac{\partial HR^*}{\partial F} = \frac{(1 - PB) \cdot D_{FF} \cdot E_F - (1 - PB) \cdot D_F \cdot E_{FF}}{E_F^2} \tag{23}$$

$$= -(1 - PB) \cdot \frac{E_{FF} \cdot E_F + D_F \cdot E_{FF}}{E_F^2} < 0 \tag{24}$$

as all variables are strictly positive.

A.5 Derivative of the effective hedge ratio with respect to the bailout probability

Taking the first derivative of the effective hedge ratio with respect to the bailout probability shows that the decline in the hedge ratio is monotone in the bailout probability, i.e.

$$\frac{\partial HR^*}{\partial PB} = \frac{-D_F(E_F + PB \cdot S_F) - (1 - PB)D_F \cdot S_F}{(E_F + PB \cdot S_F)^2} \tag{25}$$

$$= -\frac{D_F \cdot (E_F + S_F)}{(E_F + PB \cdot S_F)^2} < 0, \tag{26}$$

if $E_F + S_F > 0$.

Finally, the effective hedge ratio will be zero if, in case of a failure, market participants know with certainty that the respective financial institution will be bailed out.

$$HR^* = 0 \;\; if \; S_F \neq E_F \, and \, PB = 1. \tag{27}$$

A.6 Derivative of the effective debt-to-equity sensitivity with respect to the bailout probability

Appendix A.5 derived that the effective hedge ratio is monotonously declining in the bailout probability PB. In the following, we show that under very general bailout conditions also the debt-to-equity sensitivity is declining in PB, i.e $\frac{\partial \beta^*_{D,E}}{\partial PB} < 0$:

$$\frac{\partial \beta^*_{D,E}}{\partial PB} = \frac{\partial HR^*}{\partial PB} \cdot \frac{1}{L^*} + HR^* \cdot \frac{\partial \frac{1}{L^*}}{\partial PB} \tag{28}$$

As HR^* and L^* are strictly positive and $\frac{\partial HR^*}{\partial PB} < 0$ (see Appendix A.5), a sufficient condition for $\frac{\partial \beta^*_{D,E}}{\partial PB} < 0$ is that $\frac{\partial \frac{1}{L^*}}{\partial PB} < 0$:

$$\frac{\partial \frac{1}{L^*}}{\partial PB} = -\frac{1}{(L^*)^2} \cdot \frac{(G \cdot E^* - D^* \cdot S)}{(E^*)^2} \tag{29}$$

$$= -\frac{1}{(L^*)^2} \cdot \frac{(G \cdot E - D \cdot S)}{(E^*)^2} \tag{30}$$

In turn, this implies that Eq. (30) is negative if

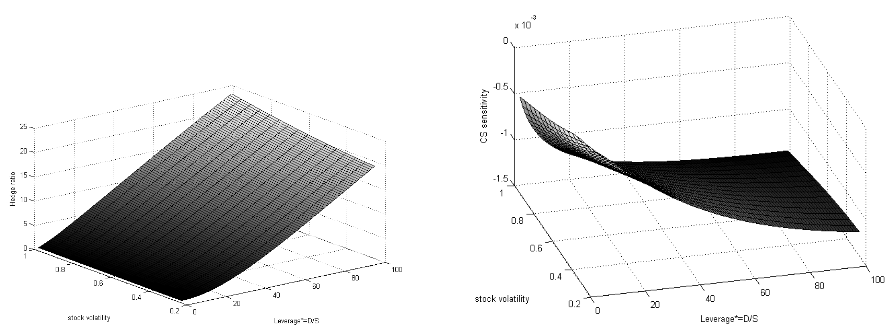
$$\frac{S}{E} < \frac{G}{D}. \tag{31}$$

We conclude that the debt-to-equity sensitivity is declining in the bailout probability PB if the relative equity support value is smaller than the relative debt guarantee value. For instance, Veronesi and Zingales (2010) estimate that the preferred equity infusions in nine of the largest US commercial banks on October 13, 2008 increased the debt values for those banks by +\$119bn while the abnormal variation in the market values of common and preferred equity was -\$2.8bn and +\$6.7bn, respectively. Given that the asymmetric treatment of debt and equity holders is an inherent feature of public bailouts, we expect Eq. (31) to hold in general.

B Discussion of the linearity assumption of the hedge ratio

Assuming a linear functional form for the hedge ratio is restrictive. However, while the linearity assumption may initially look overly simplistic, it is actually the more conservative approach when measuring the impact of bailouts on market discipline. If anything, option pricing theory would predict a concave relation between the hedge ratio and individual risk measures such as leverage and volatility. Additionally, the effect is limited if standard firm value models also imply a near linear relation. In order to visualize the effect for two main risk proxies, volatility and leverage, we use a market-standard model from Finger et al. (2002) in order to derive theoretical debt-to-equity sensitivities and hedge ratios for a set of realistic market parameters as experienced during the crisis. Figure B.1 depicts the hedge ratio and the credit spread-to-equity semi-elasticity for various values of the stock volatility and leverage. The figure inputs are based on the balance sheet data for J.P. Morgan Chase and calibrated to match the CDS level for June 2007, right before the onset of the financial crisis.[11] As can be seen in both plots, even though the functional forms are concave, the credit spread semi-elasticity and the hedge ratio are almost linear in the stock volatility and approximately linear in the stock volatility. Thus, the cost of the linearity assumption seems small relative to the possible gains of including non-traditional risk proxies. Those risk proxies enable us to include factors which are beyond the scope of traditional firm value models such as funding and liquidity measures or option-implied information about future return distributions.

Figure B.1 Illustration of theoretical hedge ratios and credit spread-to-equity semi-elasticities.
Above are the theoretical hedge ratios and credit spread-to-equity semi-elasticities as functions of stock volatility and market leverage, derived from Finger et al. (2002). The model is calibrated using data for J.P. Morgan Chase in June 2007 with a mean recovery rate of $\overline{L} = 0.08$.



[11]In order to ease comparability, we assume the same exogenous parameters as Schweikhard and Tsesmelidakis (2012). Our CDS level calibration for June 2007 yields a mean recovery rate of $\overline{L} = 0.08$ which is comparable in size with the estimated pre-crisis level of 0.03 estimated by Schweikhard and Tsesmelidakis (2012).

C The impact of bailouts on hedge ratios under stochastic asset volatility

As discussed in Section 2, our empirical strategy relies on a general version of a Merton-type firm value model without reference to a specific model class. Yet, given the possibility that asset volatilities are time-varying or stochastic, one potential concern is how this might affect our approach, especially during crisis times. In the following we show that our approach is still feasible in the presence of stochastic firm value and asset price volatility. However, in that case one needs to disentangle the debt-to-equity sensitivity which can be attributed to firm value changes F, and the possible co-movement between debt and equity prices, which stems from shocks to the underlying asset price volatility V.

To do so, consider again the general framework of a Merton-type firm value model, this time, however, taking into account stochastic asset volatility:

$$\frac{dD}{D} = \mu_D \cdot dt + \begin{bmatrix} \frac{D_F}{D} & \frac{D_V}{D} \end{bmatrix} \begin{bmatrix} dF \\ dV \end{bmatrix} \tag{32}$$

$$\begin{bmatrix} \frac{dE}{E} \\ dV \end{bmatrix} = \begin{bmatrix} \mu_E \\ 0 \end{bmatrix} \cdot dt + \begin{bmatrix} \frac{E_F}{E} & \frac{E_V}{E} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} dF \\ dV \end{bmatrix} \tag{33}$$

Combining Eq. (32) and (33) yields

$$\begin{aligned} \frac{dD}{D} &= \ldots \cdot dt + \begin{bmatrix} \frac{D_F}{D} & \frac{D_V}{D} \end{bmatrix} \begin{bmatrix} \frac{E_F}{E} & \frac{E_V}{E} \\ 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \frac{dE}{E} \\ dV \end{bmatrix} && (34) \\ &= \ldots \cdot dt + \frac{D_F}{D}\frac{E}{E_F} \cdot \frac{dE}{E} + (\frac{D_V}{D} - \frac{D_F}{D}\frac{E_V}{E_F}) \cdot dV && (35) \\ &= \ldots \cdot dt + \frac{D_F}{E_F}\frac{1}{L} \cdot \frac{dE}{E} + (\frac{D_V}{D} - \frac{D_F}{D}\frac{E_V}{E_F}) \cdot dV. && (36) \end{aligned}$$

Taking into account the exogenous bailout probability PB for bondholders only yields the familiar structural relation between debt and equity returns, augmented only by a stochastic volatility term

$$\frac{dD}{D} = ... \cdot dt + (1-PB) \cdot \frac{D_F}{E_F}\frac{1}{L^*} \cdot \frac{dE}{E} + (1-PB) \cdot (\frac{D_V}{D^*} - \frac{D_F}{D^*}\frac{E_V}{E_F}) \cdot dV. \qquad (37)$$

This implies that once we account for the stochastic volatility effect, our empirical strategy remains valid because the equity return coefficient continues to be proportionally related to the hedge ratio, the inverse of market leverage, and the non-bailout probability $(1-PB)$. In particular, under the general assumption that $D_{FX} > 0$, the hedge ratio is still an increasing function of the firm risk measure X. As a result, we can conclude that even in the presence of stochastic firm value volatility we can test for changes in bailout expectations by testing for structural changes in the hedge ratio.

Yet, the same is not true for changes in the debt-to-volatility semi-elasticity. Eq. (37) shows that even though the volatility sensitivity should decline with increasing bailout probabilities, it remains unclear how the total debt-to-volatility elasticity behaves over time. While general option pricing theory predicts that the direct effect of increasing firm volatility on debt is negative, i.e. $\frac{D_V}{D^*} < 0$, it remains ambiguous how the term $(\frac{D_V}{D^*} - \frac{D_F}{D^*}\frac{E_V}{E_F})$ changes for varying risk levels. This is because the term also takes into account the cross volatility effect on equity. Hence, in the presence of time-varying volatility, changes in bailout expectations can be identified by structural changes in the hedge ratio, but not necessarily by changes in the debt-to-volatility semi-elasticity.

Tables

Table 1: **Summary statistics - financial and non-financial firms.** This table reports summary statistics for the final weekly data sample covering the period January 01, 2004 to September 30, 2014. For the sample of financial firms, it includes all US financial institutions for which CDS price information are available from Markit. For the sample of non-financial firms, it includes all firms from the CDX NA IG and CDX NA HY series 11 constituents list. Further selection criteria are: Possibility to match data from Markit, CRSP, Optionmetrics and Compustat; CDS level below 2,000bps; non-zero, but less than 100bps CDS spread change in absolute value. The daily data is aggregated to weekly frequencies if no more than one daily observation is missing within a particular week. The CDS level and change is denoted in bps. Volatility and Skewness are equity option-implied values denoted in percent. Leverage is defined as the book value of debt to the market value of equity. Asset size is the book value of total assets in billions USD. Fundingrisk is the spread between one-month financial and non-financial commercial paper multiplied by the ratio of short-term debt to total liabilities.

Panel A: Summary statistics for financial firms

Variable	N	Mean	Std. Dev.	Min	Max
CDS level	16,497	131.0	199.6	4.7	1,991.0
CDS change	16,497	0.3	17.5	-75.3	83.2
Stock return	16,497	0.1%	5.0%	-17.1%	19.3%
Asset size	16,497	443.0	563.0	7.40	2,477.0
Leverage	16,497	9.87	10.14	0.12	70.99
Fundingrisk	16,497	0.01	0.02	-0.01	0.12
Volatility	16,497	0.32	0.16	0.15	1.00
Skewness	16,497	0.07	0.04	0.01	0.25
Swap spread	16,497	0.32	0.23	-0.03	0.74
Slope	16,497	1.45	0.95	-0.14	2.83
10 year treasury rate	16,497	3.52	1.03	1.61	5.14
Amihud ratio	16,497	0.16	0.34	0.01	2.31
BBB spread	16,497	1.09	0.48	0.57	3.22
VIX index	16,497	19.17	8.72	10.55	59.90

Panel B: Summary statistics for non-financial firms

Variable	N	Mean	Std. Dev.	Min	Max
CDS level	57,358	234.4	274.0	11.6	1,454.2
CDS change	57,358	0.2	23.0	-87.6	97.5
Stock return	57,358	0.2%	5.0%	-15.4%	16.30%
Asset size	57,358	26.4	39.0	1.9	265.7
Leverage	57,358	1.85	2.37	0.21	16.69
Volatility	57,358	0.35	0.15	0.14	0.93
Skewness	57,358	0.06	0.04	-0.01	0.21
Swap spread	57,358	0.31	0.23	-0.04	0.74
Slope	57,358	1.49	0.95	-0.13	2.83
10 year treasury rate	57,358	3.50	1.01	1.61	5.14
Amihud ratio	57,358	0.55	1.29	0.01	10.41
BBB spread	57,358	1.11	0.51	0.57	3.22
VIX index	57,358	19.63	9.18	10.48	61.15

Table 2: **List of included financial institutions.** This table reports the list of all US financial institutions included in the final sample as well their firm type or systemic importance (SIB) classification. Besides the five major investment banks Bear Stearns, Goldman Sachs, Lehman Brothers, Merrill Lynch, and Morgan Stanley, in addition we classify Countrywide Financial, Bank of America, Citigroup, JP Morgan and Wachovia as investment banks based on their significant shares of trading assets, repo exposures and investment banking income (Source: own calculations based on the Fed's Bank Regulatory Database for Bank Holding Companies). SIB includes all financial institutions classified as a G-SIB by the Financial Stability Board (FSB) as well all other financial institutions subject to the Federal Reserve's annual Comprehensive Capital Analysis and Review (CCAR).

Firm	Firm type	SIB
AMERICAN INTERNATIONAL GROUP	NON-IB	NO
ALLSTATE CORP	NON-IB	NO
AON CORP	NON-IB	NO
AMERICAN EXPRESS CORP	NON-IB	YES
BANK OF AMERICA CORP	IB	YES
BB&T CORP	NON-IB	YES
FRANKLIN RESOURCES INC	NON-IB	NO
BANK OF NY MELLON CORP	NON-IB	YES
BEAR STEARNS COMPANIES INC	IB	NO
CITIGROUP INC	IB	YES
COUNTRYWIDE FINANCIAL INC	IB	NO
CIT GROUP INC	NON-IB	NO
COMERICA BANK	NON-IB	YES
CNA FINANCIAL CORP	NON-IB	NO
CAPITAL ONE FINANCIAL CORP	NON-IB	YES
E TRADE FINANCIAL CORP	NON-IB	NO
FAENNIE MAE	GSE	NO
FIFTH THIRD BANCORP	NON-IB	NO
FREDDIE MAC	GSE	NO
GOLDMAN SACHS GROUP INC	IB	YES
HARTFORD FINANCIAL SERVICES	NON-IB	NO
JPMORGAN CHASE & CO	IB	YES
KEYCORP	NON-IB	YES
LEHMAN BROTHERS HOLDINGS INC	IB	NO
LINCOLN NATIONAL CORP	NON-IB	NO
MBIA INC	NON-IB	NO
MERRILL LYNCH &CO	IB	NO
METLIFE INC	NON-IB	YES
MARSH & MCLENNEN COMPANIES INC	NON-IB	NO
MORGAN STANLEY	IB	YES
BANK ONE	NON-IB	NO
PROGRESSIVE CORP	NON-IB	NO
PNC FINANCIAL SERVICES GROUP INC	NON-IB	YES
PRUDENTIAL FINANCIAL INC	NON-IB	NO
REGIONS FINANCIAL CORP	NON-IB	YES
CHARLES SCHWAB CORP	NON-IB	NO
SALLIE MAE	GSE	NO
SUNTRUST BANKS INC	NON-IB	YES
STATE STREET CORP	NON-IB	YES
TORCHMARK CORP	NON-IB	NO
UNUM GROUP	NON-IB	NO
US BANCORP	NON-IB	YES
WACHOVIA CORP	IB	NO
WELLS FARGO & COMPANY	NON-IB	YES
WASHINGTON MUTUAL INC	NON-IB	NO

Table 3: **Estimation of credit spread-to-equity semi-elasticities.** This table reports the results from estimating the equation $\Delta CDS_{i,t} = c + (\beta_0 + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E + \beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, and $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, Skewness for both samples and Fundingrisk for financial firms in addition. $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The equation is estimated separately for financial and non-financial firms using OLS and firm fixed effects. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level. Risk-sensitive hedge ratio reports the p-value of an F-Test of the joint null hypothesis of all risk measure coefficients being zero.

Panel A: Results for financial firms

	(1) Δ CDS	(2) Δ CDS	(3) Δ CDS	(4) Δ CDS
r^E	-92.48***	-101.6***	-108.7***	-91.71***
	(10.50)	(12.70)	(14.17)	(10.53)
$r^E \cdot Leverage$	-30.90	-49.16**	-58.86***	-31.12
	(23.59)	(22.37)	(20.20)	(23.60)
$r^E \cdot Volatility$	-19.64***			-17.42*
	(6.29)			(9.47)
$r^E \cdot Skewness$		-11.93**		-2.29
		(5.65)		(8.66)
$r^E \cdot Fundingrisk$			-5.81	-2.63
			(5.96)	(6.47)
Risk-sensitive hedge ratio	0.00	0.00	0.01	0.00
Observations	15,722	15,722	15,722	15,722
R^2	0.221	0.219	0.217	0.221
Controls for market liquidity	yes	yes	yes	yes
Controls for aggregate risk	yes	yes	yes	yes

Panel B: Results for non-financial firms

	(1) Δ CDS	(2) Δ CDS	(3) Δ CDS
r^E	-110.5***	-129.1***	-108.9***
	(7.16)	(7.08)	(6.83)
$r^E \cdot Leverage$	-32.44**	-52.52***	-30.79**
	(13.10)	(8.89)	(12.37)
$r^E \cdot Volatility$	-43.63***		-36.23***
	(6.98)		(7.66)
$r^E \cdot Skewness$		-34.74***	-20.35***
		(5.38)	(6.02)
Risk-sensitive hedge ratio	0.00	0.00	0.00
Observations	56,780	56,780	56,780
R^2	0.248	0.244	0.249
Controls for market liquidity	yes	yes	yes
Controls for aggregate risk	yes	yes	yes

Table 4: **Estimation of bailout probabilities for financial firms across firm types.** This table reports the results from estimating the equation $\Delta CDS_{i,t} = c + (1 - \sum_j PB_j D_{i,j}) \cdot (\beta_0 + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E + \beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, Skewness, and Fundingrisk. $D_{i,j}$ are financial sector dummy variables, including government-sponsored enterprises (GSE), systemically important banks (SIB), and investment banks (IB). $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The equation is estimated using non-linear least squares. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level.

	Δ CDS
Part A: Estimated probability of bailout	
Government-sponsored enterprises (PB_{GSE})	0.88***
	(0.05)
Systemically important banks (PB_{SIB})	0.55*
	(0.19)
Investment banks (PB_{IB})	-0.85**
	(0.27)
Part B: Credit spread-to-equity semi-elasticity parameters	
β_0	-89.93***
	(14.51)
$\beta_{Leverage}$	12.53
	(23.81)
$\beta_{Volatility}$	-29.37***
	(9.78)
$\beta_{Skewness}$	-7.62
	(9.38)
$\beta_{Fundingrisk}$	5.18
	(5.54)
Controls for market liquidity	yes
Controls for aggregate risk	yes
Observations	16,497
R^2	0.228

Table 5: **Estimation of bailout probabilities for financial firms across different time periods.** This table reports the results from estimating the equation $\Delta CDS_{i,t} = c + (1 - \sum_T PB_T D_{t,T}) \cdot (\beta_0 + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E + \beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, Skewness, and Fundingrisk. $D_{t,T}$ are mutually exclusive time series dummies, including the period from September 2007 to March 2008 ($ABCP$), the period from March 2007 to September 2008 (BSC), the period from September 2008 to June 2009 (LEH), the period from June 2009 to July 2010 ($DF - A$), and the period after July 2010 ($DF - S$). $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The equation is estimated using non-linear least squares. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level. Part C reports p-values of F-tests on the equality of estimated bailout probabilities across adjacent time periods.

	Δ CDS
Part A: Estimated probability of bailout	
Asset backed commercial paper crisis (PB_{ABCP})	0.26
(August 2007 - March 2008)	(0.17)
Rescue of Bear Stearns (PB_{BSC})	0.57***
(March 2008 - September 2008)	(0.11)
Failure of Lehman Brothers (PB_{LEH})	0.81***
(September 2008 - June 2009)	(0.06)
Announcement and negotiation of Dodd-Frank (PB_{DF-A})	0.59***
(June 2009 - July 2010)	(0.12)
Signing of the Dodd-Frank and thereafter (PB_{DF-S})	0.08
(July 2010 - September 2014)	(0.26)
Part B: Credit spread-to-equity semi-elasticity parameters	
β_0	-105.26***
	(24.09)
$\beta_{Leverage}$	-71.40
	(57.50)
$\beta_{Volatility}$	-109.30
	(33.91)
$\beta_{Skewness}$	-16.89
	(12.76)
$\beta_{Fundingrisk}$	-49.46***
	(17.10)
Part C: Equality of bailout probabilities (p-values)	
$PB_{ABCP} = PB_{BSC}$	0.002***
$PB_{BSC} = PB_{LEH}$	0.003***
$PB_{LEH} = PB_{DF-A}$	0.005***
$PB_{DF-A} = PB_{DF-S}$	0.003***
Controls for market liquidity	yes
Controls for aggregate risk	yes
Observations	16,095
R^2	0.250

Table 6: **Estimation of bailout probabilities for non-financial firms across different time periods.** This table reports the results from estimating the equation $\Delta CDS_{i,t} = c + (1 - \sum_T PB_T D_{t,T}) \cdot (\beta_0 + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E + \beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, and Skewness. $D_{t,T}$ are mutually exclusive time series dummies, including the period from September 2007 to March 2008 ($ABCP$), the period from March 2007 to September 2008 (BSC), the period from September 2008 to June 2009 (LEH), the period from June 2009 to July 2010 ($DF-A$), and the period after July 2010 ($DF-S$). $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The equation is estimated using non-linear least squares. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level. Part C reports p-values of F-tests on the equality of estimated bailout probabilities across adjacent time periods.

	Δ CDS
Part A: Estimated probability of bailout	
Asset backed commercial paper crisis (PB_{ABCP})	0.08
(August 2007 - March 2008)	(0.14)
Rescue of Bear Stearns (PB_{BSC})	0.09
(March 2008 - September 2008)	(0.12)
Failure of Lehman Brothers (PB_{LEH})	0.49***
(September 2008 - June 2009)	(0.06)
Announcement and negotiation of Dodd-Frank (PB_{DF-A})	-0.08
(June 2009 - July 2010)	(0.15)
Signing of the Dodd-Frank and thereafter (PB_{DF-S})	-0.26*
(July 2010 - September 2014)	(0.16)
Part B: Credit spread-to-equity semi-elasticity parameters	
β_0	-86.09***
	(9.90)
$\beta_{Leverage}$	-16.96
	(13.45)
$\beta_{Volatility}$	-60.84***
	(11.93)
$\beta_{Skewness}$	-26.52***
	(6.13)
Part C: Equality of bailout probabilities (p-values)	
$PB_{ABCP} = PB_{BSC}$	0.952
$PB_{BSC} = PB_{LEH}$	0.000***
$PB_{LEH} = PB_{DF-A}$	0.000***
$PB_{DF-A} = PB_{DF-S}$	0.032**
Controls for market liquidity	yes
Controls for aggregate risk	yes
Observations	57,355
R^2	0.266

Table 7: **Evolution of bailout probabilities for SIBs and investment banks.** This table reports the results from estimating the equation $\Delta CDS_{i,t} = c+(1-\sum_j \sum_T D_{i,j,t,T})\cdot(\beta_0+\sum_{j=1}^{k} \beta_j X_{i,t}^j)\cdot r_{i,t}^E+\beta_Z \cdot Z_{i,t}+\epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, Skewness, and Fundingrisk. $D_{i,j,t,T}$ is dummy variable that is one if firm i belongs to firm type j and the observation at time t belongs to period T, and zero otherwise. The periods are defined from September 2007 to March 2008 ($ABCP$), from March 2007 to September 2008 (BSC), from September 2008 to June 2009 (LEH), from June 2009 to July 2010 ($DF-A$), and after July 2010 ($DF-S$). The sample is restricted to firm types SIB (systemically important banks) and IB (investment banks). $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The equation is estimated using non-linear least squares. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level.

		(1) Δ CDS		(2) Δ CDS
Part A: Estimated probability of bailout				
Asset backed commercial paper crisis ($PB_{ABCP,type}$) (August 2007 - March 2008)	SIB	0.00 (0.27)	IB	0.04 (0.24)
	Non-SIB	0.30* (0.16)	Non-IB	0.38** (0.15)
Rescue of Bear Stearns ($PB_{BSC,type}$) (March 2008 - September 2008)	SIB	0.63*** (0.13)	IB	0.35* (0.16)
	Non-SIB	0.57*** (0.11)	Non-IB	0.60*** (0.11)
Failure of Lehman Brothers ($PB_{LEH,type}$) (September 2008 - June 2009)	SIB	0.83*** (0.05)	IB	0.77*** (0.06)
	Non-SIB	0.80*** (0.07)	Non-IB	0.83*** (0.06)
Announcement of Dodd-Frank ($PB_{DF-A,type}$) (June 2009 - July 2010)	SIB	0.64*** (0.13)	IB	0.56*** (0.18)
	Non-SIB	0.58*** (0.12)	Non-IB	0.61*** (0.12)
Signing of the Dodd-Frank ($PB_{DF-S,type}$) (July 2010 - September 2014)	SIB	0.13 (0.27)	IB	-0.12 (0.32)
	Non-SIB	0.06 (0.25)	Non-IB	0.27 (0.23)
Part B: Credit spread-to-equity semi-elasticity parameters				
β_0		-105.6*** (24.06)		-107.5*** (24.64)
$\beta_{Leverage}$		-68.84 (53.78)		-31.83 (56.32)
$\beta_{Volatility}$		-111.70*** (33.06)		-125.10*** (38.29)
$\beta_{Skewness}$		-18.27 (11.89)		-19.98 (12.99)
$\beta_{Fundingrisk}$		-50.72*** (18.21)		-19.89 (15.16)
Controls for market liquidity		yes		yes
Controls for aggregate Risk		yes		yes
Observations		16,095		16,095
R^2		0.251		0.254

Table 8: **Estimation of bailout probabilities for financial firms with time-varying volatility.** This table reports the results from estimating the equation $\Delta CDS_{i,t} = c + (1 - \sum_T PB_T D_{t,T}) \cdot (\beta_0 + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E + \beta_{IV} \cdot D_{t,T} \cdot \Delta IV_{i,t} + \beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, Skewness, and Fundingrisk. $D_{t,T}$ are mutually exclusive time series dummies, including the period from September 2007 to March 2008 ($ABCP$), the period from March 2007 to September 2008 (BSC), the period from September 2008 to June 2009 (LEH), the period from June 2009 to July 2010 ($DF-A$), and the period after July 2010 ($DF-S$). We further include interactions of $D_{t,T}$ with the change in the implied equity volatility $\Delta IV_{i,t}$. $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The equation is estimated using non-linear least squares. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level.

	Δ CDS
Part A: Estimated probability of bailout	
Asset backed commercial paper crisis (PB_{ABCP})	0.43***
(August 2007 - March 2008)	(0.14)
Rescue of Bear Stearns (PB_{BSC})	0.73***
(March 2008 - September 2008)	(0.07)
Failure of Lehman Brothers (PB_{LEH})	0.85***
(September 2008 - June 2009)	(0.05)
Announcement and negotiation of Dodd-Frank (PB_{DF-A})	0.59***
(June 2009 - July 2010)	(0.12)
Signing of the Dodd-Frank and thereafter (PB_{DF-S})	0.13
(July 2010 - September 2014)	(0.22)
Part B: Credit spread-to-equity semi-elasticity parameters	
β_0	-95.34***
	(21.67)
$\beta_{Leverage}$	-27.08
	(61.34)
$\beta_{Volatility}$	-110.50***
	(32.35)
$\beta_{Skewness}$	-34.57
	(17.34)
$\beta_{Fundingrisk}$	-14.44*
	(27.64)
Part C: Coefficients of $\Delta Volatility$	
Control Period	77.78***
(before August 2007)	(26.43)
Asset backed commercial paper crisis	221.80***
(August 2007 - March 2008)	(40.70)
Rescue of Bear Stearns	251.9***
(March 2008 - September 2008)	(59.52)
Failure of Lehman Brothers	232.8***
(September 2008 - June 2009)	(34.55)
Announcement and negotiation of Dodd-Frank	233.7***
(June 2009 - July 2010)	(53.27)
Signing of the Dodd-Frank and thereafter	75.36
(July 2010 - September 2014)	(52.16)
Controls for market liquidity	yes
Controls for aggregate risk	yes
Observations	16,497
R^2	0.267

Table 9: **Estimation of bailout probabilities based on two-stage OLS regressions.** This table reports the results of a two-stage OLS regression approach. In the first stage, we estimate in the pre-crisis period the equation $\Delta CDS_{i,t} = c + (\beta_0 + \sum_{j=1}^{k} \beta_j X_{i,t}^j) \cdot r_{i,t}^E + +\beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$, where $\Delta CDS_{i,t}$ is the change in the CDS spread, $r_{i,t}^E$ is the equity return, and $X_{i,t}^j$ are individual risk measures, including Leverage, Volatility, Skewness, and Fundingrisk. $Z_{i,t}$ are control variables including aggregate risk factors, i.e. the 10-year treasury rate, the slope of the treasury rate, the change in the VIX index and Moody's corporate BBB-spread, as well as market liquidity control variables, i.e the change in the ten year swap spread as well as the level and change of the stock specific Amihud (2002) ratio. The estimated coefficients $\widetilde{\beta_0}$ and $\widetilde{\beta_j}$ are then used to predict the fundamental credit spread-to-equity semi-elasticity $\widehat{\beta}_{CS,E}$ over the whole sample period. In the second stage, we estimate the equation $\Delta CDS_{i,t} = c + (1 - \sum_T PB_T D_{t,T}) \cdot \widehat{\beta}_{CS,E} \cdot r_{i,t}^E + +\beta_Z \cdot Z_{i,t} + \epsilon_{i,t}$. The regression was estimated for the financial sample using OLS and fixed effects. The standard errors are clustered at the firm level and reported in parentheses. * (**,***) means that the estimated parameter is significant at the 10%(5%,1%) level.

	Δ CDS
Part A: Estimated probability of bailout (estimated in stage two)	
Asset backed commercial paper crisis (PB_{ABCP})	0.42***
(August 2007 - March 2008)	(0.10)
Rescue of Bear Stearns (PB_{BSC})	0.68***
(March 2008 - September 2008)	(0.03)
Failure of Lehman Brothers (PB_{LEH})	0.83***
(September 2008 - June 2009)	(0.03)
Announcement and negotiation of Dodd-Frank (PB_{DF-A})	0.74***
(June 2009 - July 2010)	(0.05)
Signing of the Dodd-Frank and thereafter (PB_{DF-S})	0.38***
(July 2010 - September 2014)	(0.06)
Part B: Credit spread-to-equity semi-elasticity parameters (estimated in stage one)	
β_0	-123.93***
	(20.42)
$\beta_{Leverage}$	-121.34***
	(41.17)
$\beta_{Volatility}$	-159.76***
	(59.32)
$\beta_{Skewness}$	-9.48
	(23.38)
$\beta_{Fundingrisk}$	84.31***
	(24.32)
Part C: Equality of bailout probabilities (p-values)	
$PB_{ABCP} = PB_{BSC}$	0.011**
$PB_{BSC} = PB_{LEH}$	0.004***
$PB_{LEH} = PB_{DF-A}$	0.006***
$PB_{DF-A} = PB_{DF-S}$	0.000***
Controls for market liquidity	yes
Controls for aggregate risk	yes
Observations	16,095
R^2	0.235

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