Too-Systemic-To-Fail: What Option Markets Imply About Sector-wide Government Guarantees*

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Abstract

Investors in option markets perceive the financial sector to be too-systemic-to-fail. They price in a substantial collective government bailout guarantee, which puts a floor on the value of the financial sector as a whole, but not on its individual members. The guarantee makes put options on the financial sector index cheap relative to put options on its member banks. The basket-index put spread rises fourfold from 0.8 cents per dollar insured before the financial crisis to 3.8 cents during the crisis for deep out-of-the-money options. The spread peaks at 12 cents per dollar, or 70% of the value of the index put. The rise in the put spread cannot be attributed to an increase in idiosyncratic risk because the correlation of stock returns increased during the crisis. Sector-wide tail risk, partially absorbed by the government's collective guarantee for the financial sector, lowers the index put prices but not the individual put prices, and hence can explain the basket-index spread. A structural model quantitatively matches these facts and indicates that as much as half of the value of the financial sector during the crisis. The model solves the problem of how to measure systemic risk in a world where the government distorts market prices.

1 Introduction

As the world recovers from the financial crisis and legislation is passed to prevent a repeat of the events that unfolded between mid-2007 and mid-2009, observers fear that one problem has not gone away: too-systemic-to-fail. The head of the Troubled Asset Relief Program program Neil Barofsky testified before the U.S. Congress that the financial sector has become even more concentrated than before the crisis and that markets continue to perceive financial firms as too systemically risky to be let go in a crisis. In this paper, we argue that options markets are uniquely suited to gauge the market's perception of too-systemic-to-fail government guarantees. We find that investors price in substantial government bailout guarantees.

Specifically, we document that during the financial crisis, there was markedly less aggregate tail risk priced in put options on the financial sector index than in the individual put option prices on all the stocks that make up that financial sector index. This leakage of aggregate tail risk at the sector level is consistent with investors' perception of a strong collective bailout guarantee for the financial sector. By putting a floor under the equity value of the financial sector, the government eliminates part of the sector-wide tail risk. But it does not eliminate idiosyncratic tail risk. That explains why out-of-the-money index put options were cheap during the crisis, relative to the basket of individual put options. We use the difference between the cost of a basket of options and an index option to estimate the size of the guarantee extended to the financial sector during the crisis. The dollar value of the collective equity bailout guarantee, inferred from the basket-index spread for one-year out-the-money put options, is plotted in figure 1 against the market cap of the financials. It peaks at $139 billion on October 13, 2008, implying that the government provided guarantees worth 10.5% of the financial index's market value that day. We argue below that this is a conservative estimate and that the collective bailout guarantee accounts for as much as half of the market value of the financial sector.

Absent bailout guarantees, the high basket-index spread in the financial sector is puzzling. Standard option pricing logic suggests that the dramatic increase in the correlation of stock returns during the crisis should raise the price of the out-of-the-money index options relative to the price of a basket of individual options with the same moneyness. This is exactly what we find when we focus on index call options for all sectors of the economy. In contrast, the cost of the basket of individual stock puts soars relative to the cost of the index puts for the financial sector. Moreover, this increase in the basket-index put spread is much larger for the financial sector than for any other sector index. The basket-index spread for out-of-the-money put options on the financial sector index reaches a maximum of 12 cents per dollar insured in March 2009, or 80% of the cost of the index put. To generate the increase in the basket-index spread for out-of-the-money put options, the standard option model would have to assume a large increase in idiosyncratic tail risk, which would counter-factually lead to a decrease in stock return correlations.

A collective bailout guarantee for the financial sector can explain these facts. Intuitively, the government's collective bailout guarantee truncates the distribution of the total equity value of the financial sector, but not that of the individual stocks in the sector. Consider an out-of-the-money index put option with a strike price below the bailout bound. An increase in the volatility of aggregate shocks will increase the correlation among stock returns, it will increase the put prices of individual stocks, but it does not affect the index put price. Only a model with a bailout guarantee can simultaneously generate a high put spread and an increase in correlation between stocks. Furthermore, a careful read of the evolution of the put spread for the financial index lend support to the presence of a collective bailout guarantee. Each large, adverse shock to the financial sector during our sample increases the basket-index spread (e.g., the Bear Stearns rescue, the failure of Lehman Brothers). These same shocks simultaneously lower the ratio of implied volatility to realized volatility for out-of-the-money put index options.

We use a calibrated dynamic asset pricing model with rare events to study the impact of sector-wide bailout guarantees on individual and index option prices. To model the asset pricing impact of financial crises, we use a version of the Barro-Rietz asset pricing model with a time-varying probability of rare disasters and with two sources of priced risk: normal risk and financial disaster risk. In the model, the collective bailout bounds the aggregate equity loss rate for the financial sector in a disaster, but not for individual firms in the sector. We model the financial crisis as an increased probability of a financial disaster. First, we show that this (state-of-the-art) structural model without bailout guarantees cannot explain the joint stock and option moments for the financial sector, discussed above. Second, we show that a model with bailout guarantee can. Third, we use the structural parameters of the model to infer the effect of the bailout option on financial firms' expected return, their cost of capital, and the overall dollar size of the government subsidy implied by the bailout guarantee.

We investigate and rule out three other potential alternative explanations: mispricing (violations of the law of one price) during the crisis, liquidity differences across index and individual options, put and call options, and financial and non-financial sector options, and a smaller price of correlation risk (in absolute value) during the crisis. As pointed out by Driessen, Maenhout, and Vilkov (2009), index options provide a hedge against increases in correlations, which constitute a deterioration in the investment opportunity set, because their prices rise when correlations increase. Individual options do not have this feature. The observed pattern would then imply that the average investor was less eager to hedge against such deteriorations during the crisis. This is implausible. Moreover, a decrease in the correlation risk premium would also increase call spreads in the financial sector, which is counter-factual. More plausibly, the price of correlation risk increased (in absolute value) during the crisis, and leads our constant correlation risk price model to understate the true bailout guarantee.

Our paper contributes to the growing literature on tail risk measurement and how this risk is priced. In recent work, Kelly (2009) uses the cross-section of stock returns to construct a measure of tail risk. Backus, Chernov, and Martin (2011) use option prices to make inference about the size and frequency of consumption disasters. Our work uses the relative valuation of sector and stock-specific option prices to distinguish between firm-specific and aggregate tail risk. We find that there was less aggregate tail risk priced in index option markets during the crisis than there would have been absent a bailout option.

Our work contributes to the important task of measuring systemic risk in the financial sector (for example, see Acharya, Pedersen, Philippon, and Richardson, 2010; Adrian and Brunnermeier, 2010, for novel ways of measuring systemic risk). Our results provides a cautionary note on the difficulties of systemic risk measurement when governments distort market prices by providing bailout guarantees. The basket-index spread for out-of-the-money put options would be natural measure of systemic risk: the *smaller* the basket-index spread in a sector, the larger the amount of systemic risk in that sector. However, in sectors that benefit from a collective bailout guarantee, an *increase* in the basket-index spread occurs when systemic risk peaks and the collective bailout guarantee kicks in. This is what we observed in the financial sector, and to a lesser extent, in the broader economy, during the 2007-2009 crisis. A structural model like ours is needed to undo the effect of the government's distortions on measures of systemic risk.

Other studies have measured the size of guarantees on the cost of bank credit. Recently, Giglio (2010) and Longstaff, Arora, and Gandhi (2009) infer joint default probabilities for banks from the pricing of counter-party risk in credit default swap markets. We focus exclusively on the equity side, and we find evidence of a large collective equity bailout guarantee in the financial sector. Consistent with our findings, Gandhi and Lustig (2010) quantify the effect of too-big-too fail on the cost of equity capital of large banks by analyzing stock returns on size-sorted bank portfolios. They find that large banks yield risk-adjusted returns that are 500 basis points per annum lower than those of the smallest banks, and they attribute this difference to the implicit guarantee for large banks. In a seminal paper on this topic, O'Hara and Shaw (1990) document large positive wealth effects for shareholders of banks who were declared too big too fail by the Comptroller of the Currency in 1984, and negative wealth effects for those banks that were not included.[1] Since we find strong evidence of ex ante subsidies to shareholders, this implies that there are even larger subsidies to other creditors of large banks.

The rest of the paper is organized as follows. After defining index and basket put and call spreads and their relationship in Section 2, we document their empirical behavior in Section 3 in the financial sector and in all other non-financial sectors. Section 4 finds supporting evidence

[1] A number of events have been important in creating and sustaining the too-big-too fail perception in the market. Among these are the FDIC's intervention to prevent the failure of Continental Illinois National Bank in 1984, Federal Deposit Insurance Corporation Improvement Act of 1991, and the Federal Reserve's intervention in 1998 to save LTCM. While the FDICIA limits the protection of creditors, it provides a systemic risk exception.

for our collective bailout hypothesis in the events in the 2007-2009 crisis. Section 5 develops a structural asset pricing model which features a time-varying probability of financial disasters. A technical contribution of the paper is to derive option prices in the presence of a bailout option. Section 6 calibrates the model and shows that it is able to account for the observed option and return data, but only when a bailout guarantee is present. Section 7 studies and rules out three potential alternative explanations: mispricing, liquidity, and time-varying price of correlation risk. The last section concludes.

2 Cost of Basket of Options and Index Option Prices

We focus on a traded sector indices i comprised of different stocks j. $Index$ denotes the level of the index as traded. The dollar cost of the index, i.e., the total market cap of all the firms in the index, is given by $Index^{\$} = \sum_{j=1}^{N_i} s_j S_j$, where N_i is the number of different stocks that constitute index i and s_j denotes the number of shares of stock j in the index i. We use Put_i^{basket} to denote the price of a basket of put options on all stocks: $Put_i^{basket} = \sum_{j=1}^{N_i} s_j Put_j$. We use Put_i^{index} to denote the price of a put option on the sector index. Similarly, we use $Call_i^{basket}$ to denote the price of a basket of call options on all stocks in the sector index and $Call_i^{index}$ to denote the price of a call option on the index. We study two different ways of comparing basket and index options.

Delta-matched Basket The first approach ensures that the index and the individual options have the same option Δ.[2] First, we choose strike prices $K_j, j = 1, 2, \ldots, N_i$ for individual stocks to match the targeted Δ level. Second, we choose the strike price K for the index to match that same Δ. Third, taking K from the previous step, we choose $K^{index,\$}$ such that the total amount

[2]The Delta of an option is the derivative of the option price with respect to the underlying asset price. While put options have negative Deltas, we use the convention of taking the absolute value, so that all delta's are positive. Delta measures the moneyness of an option, with low values such as 20 indicating out-of-the-money options and high values such as 80 indicating in-the-money options. At the money options have a Delta of 50.

insured by the basket and the index option strategies is the same:

$$K^{index,\$} = scaling \times K = \sum_{j=1}^{N_i} s_j K_j.$$

The advantage of this approach is that both the index and basket options have the same moneyness. The disadvantage, as we explain below, is that no-arbitrage does nut put bounds on the basket-index spread.

Strike-matched Basket The second approach ensures that the strike price on the index matches the share-weighted strike of the basket. First, we choose all the strike prices $K_j, j = 1, 2, \ldots, N_i$ for individual stocks that are part of the index to match a certain Δ. Second, we choose the strike price of the index options $K^{index,\$}$ (in billions) such that the strike price of the index (in dollars) equals the share-weighted sum of the individual strike prices:

$$K^{index,\$} = \sum_{j=1}^{N_i} s_j K_j.$$

Third, we choose a strike price for the index K such that the total dollar cost of insurance equals $K^{index,\$}$:

$$K^{index,\$} = K \times \frac{Index^{\$}}{Index}.$$

The advantage of this approach is that the cost of the basket has to exceed the cost of the index option by no arbitrage, which bounds the basket-index spread below from zero. The disadvantages are that the moneyness and Δ of the index option can be substantially different from the moneyness of the basket options and that this approach is computationally more involved.[3]

No-Arbitrage Basket-Index Relationship We compare the cost of the index option and the basket of options under the second approach. At expiration, the payoff of the basket of options is:

[3]Since we are on a discrete grid in the data for Δ's, we occasionally jump back and forth between deltas that satisfy this on consecutive days. To avoid oscillation in the basket price, we determine the best basket Δ on each day and for each sector and redo the basket price calculation for that delta, which is set equal to the mode of day-by-day delta series.

$Put^{basket}_{T,i} = \sum_{j=1}^{N_i} s_j max(K_j - S_{T,j}, 0)$. We can compare this payoff to the payoff from the index put option: $Put^{index}_{T,i} = \max(K^{index,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}, 0)$, where the strike price in dollars of the index is the weighted strike price of the underlying stocks in the basket $K^{index,\$} = \sum_{j=1}^{N_i} s_j K_j$.

Proposition 1. *The cost of the basket of put options has to exceed the cost of the index put option:*

$$Put^{basket}_{T,i} \geq Put^{index}_{T,i}. \tag{1}$$

Proof. The payoffs at maturity satisfy the following inequality: $\sum_{j=1}^{N_i} s_j max(K_j - S_{T,j}, 0) \geq max(K^{index,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}, 0)$, First note that, for each j, $s_j max(K_j - S_{T,j}, 0) \geq s_j(K_j - S_{T,j})$. This implies that $\sum_{j=1}^{N_i} s_j max(K_j - S_{T,j}, 0) \geq K^{index,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}$. However, this also means that $\sum_{j=1}^{N_i} s_j max(K_j - S_{T,j}, 0) \geq max(K^{index,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}, 0)$, because the left hand side is non-negative. □

To get some intuition, note the following. If the payoff from the basket of put option is zero, then the index put option has a zero payoff too:

$$Put^{basket}_{T,i} = 0 \Rightarrow Put^{index}_{T,i} = 0,$$

because

$$K_j - S_{T,j} < 0 \textit{ for all } j \Rightarrow K^{index,\$} - \sum_{j=1}^{N_i} s_j S_{T,j} < 0.$$

This follows from the definition of $K^{index,\$}$ However, the reverse is clearly not true.

$$K^{index,\$} - \sum_{j=1}^{N_i} s_j S_{T,j} < 0. \nRightarrow K_j - S_{T,j} < 0 \textit{ for all } j.$$

Consider out-of-the money put options. The basket of put options provides insurance against states of the world in which there are large declines in the price of any individual stock, including declines that affect many stocks simultaneously. The index put option only provides insurance in those states of the world that prompt common declines in stock prices. Hence the difference

$Put^{basket}_{T,i} - Put^{index}_{T,i}$ between these two put prices is the cost of insurance against large declines in individual stock prices but not in the overall index. Hence, the basket-index spread is non-negative. The same inequality applies to the basket of calls and the call on the index.[4]

Cost Per Dollar Insured To be able to compare prices across baskets, we define the cost per dollar insured (cdi) as the ratio of the price of the basket/index option divided by its strike price: $Put^{basket}_{cdi,i} = \frac{Put^{basket}_i}{\sum_{j=1}^{N_i} s_j K_j}$ and $Put^{index}_{cdi,i} = \frac{Put^{index}_i}{\sum_{j=1}^{N_i} s_j K_j}$. From equation (1), we know that the cost of basket insurance exceeds the cost of index insurance: $Put^{basket}_{cdi,i} \geq Put^{index}_{cdi,i}$ if we construct the index strike to match the share-weighted strike price. We define the basket-index put spread per dollar insured as: $Put^{spread}_i = Put^{basket}_{cdi,i} - Put^{index}_{cdi,i}$. $Call^{basket}_{cdi,i}$ and $Call^{spread}_i$ are defined analogously.

Basket-index Spread The ΔPut^{spread}_F is the difference in the basket-index spread for financials (Put^{spread}_F) and the entire S&P 500 ($Put^{spread}_{S\&P}$)

$$\Delta Put^{spread}_F = Put^{spread}_F - Put^{spread}_{S\&P}.$$

$\Delta Call^{spread}_F$ is defined analogously. We sometimes refer to the basket-index put (call) spread simply as the put (call) spread.

3 The Basket-Index Spread in the Data

This section documents our main stylized facts.

3.1 Data

We use exchange-traded options on the nine iShares sector exchange-traded funds (ETF) and on the S&P500 ETF. The CBOE trades options on ETFs. As ETFs trade like stock, options on these products are similar to options on individual stock. Options on ETFs are physically settled and

[4]This property is unique to equity options. In the case of credit default swaps, the cost of a basket of credit default swaps has to be equal to the CDX index to rule out arbitrage opportunities.

have an American-style exercise feature. The nine sector ETFs have the nice feature that they have no overlap and collectively cover the entire S&P500. Appendix A.1 contains more details and lists the top 40 holdings in the financial sector ETF. We also use individual option data for all 500 stocks in the S&P500. The OptionMetrics Volatility Surface provides European put and call option prices that have been interpolated over a grid of time-to- expiration and option delta, and that perform a standard adjustment to account for the American option feature of the raw option data. The European style of the resulting prices allows us to compare them to the European-style options we compute in our structural model later. Interpolated prices allow us to hold maturity and moneyness constant over time and across underlyings. The constant maturity options are available at various intervals between 30 and 730 days and at grid points for (absolute) Δ ranging from 20 to 80. We use CRSP for the returns, the market capitalization, and the number of outstanding shares for the sector ETFs and the individual stocks. Our database changes as the index composition of the S&P500 changes. We focus primarily on options with 365 days to maturity and on Δ of 20. We obtain implied volatility data from the interpolated implied volatility surface data of OptionMetrics. We calculate realized volatility of index and individual stock returns, as well as correlations between individual stock returns from the CRSP return data.

3.2 Delta-matched Basket

This section describes the moments in the data for the basket-index option spread. We find that out-of-the-money put options on the index were cheap during the financial crisis, relative to the individual stock options, while out-of-the-money index calls were relatively expensive. This pattern is much more pronounced for the financial sector than for the other non-financial sectors.

Panel I in Table I provides summary statistics for the basket-index spread per dollar insured, for the approach where we fix the Δ for the index and the individual options at 20. Columns (1)-(2) report results for the financial sector. Columns (3)-(4) report results for the non-financial sector. Columns (5)-(6) report the differences in the spread between the financial and non-financial sector. All results are reported in cents per dollar. An increase in the spread between the basket and the index means index options are cheaper relative to the individual options. We report statistics for three samples: the entire sample (top panel, January 2003 until June 2009), the pre-crisis sample (middle panel, January 2003 until July 2007), and the crisis sample (bottom panel, August 2007 until June 2009).

We start by discussing the full sample. Over the entire sample, the mean spread for out-of-the-money (OTM) puts is 1.69 cents per dollar in the financial sector, compared to 1.10 cents per dollar in the non-financial sector. The same numbers for OTM calls are an order of magnitude smaller: 0.23 cents for financials and 0.20 cents for non-financials (value-weighted average across all non-financial sectors). The standard deviation of the basket-index spread over time is 1.89 cents for puts compared to only 0.16 cents for calls in the financial sector. Hence, there is much more volatility in the call-based spreads. The largest recorded put-based basket-index spread in our sample for financials is 12.45 cents per dollar. This spread was recorded in March 6, 2009 and represents 70% of the cost of the index option. On that same day, the difference between the spread for financials and non-financials peaks at 9.07 cents per dollar insured. The largest recorded put-based basket-index spread for non-financials in our sample is 4.1 cents per dollar on November 21 2008. The largest basket-index spread for calls is only 0.49 cents for financials and 0.36 cents for non-financials. Both are an order of magnitude smaller for puts, but the financial sector's call spread is still substantially above that of the non-financial sectors.

The bottom half of Panel I focusses exclusively on the crisis subsample. The mean spread backed out from OTM puts is 3.79 cents per dollar for financials and 1.57 for non-financials. Hence, while there is an across-the-board increase in the put spread from pre-crisis to crisis, the increase is much more pronounced for financials (4.7 times versus 1.7 times). The put spread volatility increases in the crisis, especially for financials: from 0.20 pre-crisis to 2.39 during the crisis. For non-financials the increase is much less dramatic from 0.44 to 0.90. A very different pattern emerges for OTM call spreads. They are substantially lower in the crisis than in the pre-crisis period. The crisis call spread is 0.06 cents for financials and 0.11 cents for non-financials. The volatility increases only modestly from 0.06 to 0.17 (0.05 to 0.10) for financials (non-financials).

Figure 2 plots the cost of the basket of put options per dollar insured (full line), the cost of the financial sector put index (dashed line), and their difference, the basket-index spread (dotted line) for the entire sample. Before the crisis, the basket-index spread is essentially constant and very small, less than 1 cent per dollar. During the crisis, the index option gradually becomes cheaper relative to the basket of put options and the put spread increases. The cost of the basket occasionally exceeds 30 cents while the cost of the index put rarely rises above 20 cents per dollar. At the start of 2009, the difference exceeds 12 cents per 1$ of insurance. The basket index spread also becomes more volatile. The standard deviation of the spread is 2.39 cents compared to 0.20 pre-crisis. By fixing Δ as the crisis unfolds, we are looking at put contracts with lower strike prices during the crisis, and hence at options with lower prices. This of course tends to lower the basket-index spreads (in cents per dollar insured). If we were to fix the K's instead of Δ, we would obtain larger increases in the basket-index spreads. No other non-financial sector has such a large increase in the put spread during the crisis.

Figure 3 plots the cost per dollar insured of basket and index call options, as well as the call spread. During the crisis, index options become more expensive relative to the basket of call options. In addition, the volatility of the basket-index spread decreases. At some point, the call spread becomes negative (-0.44 cents at the lowest point). Recall that the zero lower bound for the spread only holds for strike-matched and not Delta-matched options, so that this negative number does not present a puzzle. We find essentially the same results for call spreads in all other sectors.

In Figure 4, we compare the put spread of financials and non-financials over time (the dotted lines from the previous two figures). For non-financials (solid line), the basket-index spread remains very low until the Fall of 2008. On the other hand, for financials (dashed line), the put spread starts to widen in the summer of 2007, spikes in March 2008 (the collapse of Bear Stearns), and then spikes even more after the Freddie Mac and Fannie Mae bailouts and the Lehman Brothers bankruptcy in September 2008. After a decline in November and December of 2008, the basket-index spread peaks at 12 cents per dollar in March 2009. The dotted line plots the difference in put spread between the financial sector and non-financial sectors. This difference is positive throughout the crisis, except for a few days in November of 2008. It increase from the summer of 2007 to October 2008, falls until the end of 2008, and increases dramatically from January to March 2009. The next section provides a detailed interpretation of this pattern based on crisis-related government announcements.

3.3 Share-Weighted-Strike-matched Baskets

Panel II in Table I reports results for our second approach to compare basket-index spreads: the index strike matches the share-weighted strike price of the basket. In this case, no-arbitrage implies that the basket-index spreads be non-negative. Essentially, we see the same pattern as with the delta-matching approach. The correlation between these two measures is 0.995. However, the basket-index spreads are larger when we match the share-weighted strike price. The reason is that the higher volatility of individual stock returns leads to a lower (higher) strike price for OTM put (call) options when we match Deltas. Put differently, individual options in the second approach have higher Deltas than index options, which increases spreads.

The average put spread during the crisis is 5.85 cents per dollar for financials (compared to 3.79 cents in Panel I), and the volatility is 3.01 (compared to 2.39). The maximum spread is now 15.87 cents per dollar insured (compared to 12.46). This number represents 89% of the cost of the index put on March 6, 2009 (compared to 70%). On that same day, the difference between the put spread for financials and non-financials peaks at 10.17 cents per dollar. The maximum spread for calls is only 1.27 cents per dollar. The minimums reported are all positive, which means the no-arbitrage constraint is satisfied. Since our results do not seem sensitive to how we perform the basket-index comparison, we report only the Δ-matched basket-index spread results in the remainder of the paper.

3.4 The Effect of Time To Maturity

Panel III of table I studies the cost of insurance when the time to maturity is 30 days instead of 365 days. As we show later, these shorter maturity option contracts are more liquid. Naturally, all basket-index spreads are smaller for shorter-dated options, because the cost per dollar insured increases with the time to maturity. Yet, we observe the same patterns as in Panel I. We limit our discussion to Panel III; the share-weighted-strike results in Panel IV are very similar.

Starting with the basket-index spread for puts on financials, we find an average of 0.61 cents per dollar in the crisis, up from 0.17 cents pre-crisis. This represents an increase by a factor of 3.7, only slightly lower than the 4.7 factor with $TTM = 365$. Per unit of time (relative to the ratio of the square root of maturities), the put spread increase during the crisis is larger for $TTM = 30$ options than for $TTM = 365$ options. The 30 day spread reaches a maximum of 2.45 cents per dollar or 52% of the cost of the index option on that day. The call spread for financials decreases from an average of 0.15 cents pre-crisis to an average of 0.10 cents during the crisis, a slower rate than for longer-dated options. For non-financials, there is an increase in the put spread by a factor of 1.8 (from 0.13 before the crisis to 0.23 cents during the crisis). This is similar to the increase in long-dated puts of 1.8, and larger when taking into account the shorter time interval. The call spread actually increases during the crisis for shorter-dated options (from 0.11 to 0.14 cents), while it falls for longer-dated options (from 0.25 to 0.11 cents). This is the only qualitative feature of the data for which maturity matters.

3.5 The Effect of Moneyness

Table II reports the cost of insurance on basket minus index for different moneyness ($|\Delta|$). It follows the format of Table I, and their Panel I is identical. While option prices are naturally higher when options are closer to being in-the-money, it turns out that spreads also increase in size. However, the proportional increase in the basket-index spread from pre-crisis to crisis is much larger for OTM put options than for at-the-money (ATM) puts.

Starting with financials, options with the lowest moneyness ($\Delta = 20$) see the largest proportional increase in put spread from pre-crisis to crisis. That factor is 4.7 for $\Delta = 20$, 3.5 for $\Delta = 30$, 3.0 for $\delta = 40$, and 2.5 for at-the-money options ($\Delta = 50$). Similarly, the proportional decreases in call spreads are larger for OTM than for ATM options. For non-financials, the put spread increases during the crisis are again much smaller and again decreasing in moneyness. The difference in the put spread between financials and non-financials (reported in column 5) during the crisis increases only marginally from 2.22 cents at $|\Delta = 20|$ to 2.37 cents per dollar at $|\Delta = 50|$. Since ATM option prices are obviously higher for high $|\Delta|$ options, the F-NF put spreads fare much larger in percentage terms for OTM options. To make this point clear, Table III reports the *percentage* spread, measured as the basket-index spread relative to the cost of the index option. For put options on financials, the percentage spread during the crisis is 37% for $|\Delta = 20|$ but only by 26% for $|\Delta = 50|$. Similarly, the maximum percentage put spread falls from 80.5% to 51.7% as moneyness increases. For call options on financials, the largest percentage spreads are in the pre-crisis sample. Finally, we only see large increases in the average percentage spreads for OTM put options with $|\Delta = 20|$ on financials.

3.6 Correlation and Volatility

The crisis was characterized by a substantial increase in the correlation of individual stock returns. Panel I of Tables V and VII reports the average pairwise correlations for financials and non-financials, respectively, computed from daily return data. The correlation for the stocks in the financial sector index is 51.3% on average over the entire sample. This number increased from 44.8% pre-crisis to 57.9% during the crisis. For non-financials, the correlations are lower. The average correlation is 45.1%. This number increased from 33.6% pre-crisis to 57.1% in the crisis. Figure 5 plots these correlations for financials and non-financials. The correlations for financials are invariably higher. We argue below that the increase in correlations during the crisis is evidence that points towards the collective bailout hypothesis.

Panel I of Tables V and VII also reports the realized volatility of individual and index returns in financials and non-financials. Panel I of Tables IV and VI reports option-implied volatilities in financials and non-financials. Over the entire sample, the implied volatility is 2.9 percentage points higher than the realized volatility for financials. In the pre-crisis sample, this difference is 9.8 percentage points (21.7% versus 11.9%). However, in the crisis-sample, this difference shrinks to 4.7 percentage points (48.5% versus 43.8%). The ratio of the two falls from 1.82 to 1.11. In the options literature, the difference between implied volatility and the expectation of realized volatility is called the volatility risk premium. To the extent that the sample average of realized volatility (measured over a long enough sample) is a good proxy of the average conditional expectation of realized volatility, this is evidence that the variance risk premium in financials decreases during the crisis. It is yet another important indication that index put options on the financial sector are cheap during the crisis. In contrast to financials, the volatility risk premium barely decreases for non-financials. The difference between implied volatility and average realized volatility is 9.5 percentage points in the pre-crisis sample compared to 9.1 percentage points during the crisis. Similarly to puts, call options on financials indicate a large decrease in the volatility risk premium from 3.0 percentage points to -6.0 percentage points in the crisis. The decrease is again smaller for non-financials.

Figure 6 shows the difference between put-option-implied and realized volatility for financials (dashed line) and non-financials (solid line). It clearly shows that implied volatility falls below realized volatility during the crisis, and more so in the financial sector than in the non-financial sector. For non-financials, the downward spike in this difference in September 2008 may simply arise because the realization of a disaster leads to a spike in realized volatility. However, for financials, implied volatility is persistently below realized volatility, consistent with our explanation that a collective bailout guarantee makes financial sector put options artificially cheap.

4 Interpreting The Basket-Index Spread During the Crisis

In a financial disaster, the banking sector is insolvent because the sector's asset value drops below the value of all debt issued. Under the collective bailout hypothesis, the government bounds the value of total losses to equity holders in a financial disaster. In principle, bailouts of bondholders and other creditors do not preclude shareholder the value of equity being erased completely. In practice, given the uncertainty about the resolution regime, especially for large financial institutions, the collective bailout does put a lower bound on the value of equity in the financial sector. In the presence of a collective bailout guarantee, an increase in the probability of a financial disaster increases the put basket-index spread because the cost of downside insurance for the entire sector - which is supported by the government- increases by less than the cost of downside insurance for all the stocks in the basket. If the guarantee is specific to the financial sector, we do not expect to see the same pattern in other sectors. In this section, we study salient events during the financial crisis of 2007-2009 from the perspective of our collective bailout hypothesis.

4.1 Financials

Phase I: Onset of the Crisis During the financial crisis, each major negative event rendered index put options on the financials *cheaper* relative to the individual stock options. The dashed line in Figure 7 plots the put spread for financials. The spread starts to go up in August 2007, when the BNP Paribas hedge funds trigger a run in the asset-backed commercial paper market and the financial crisis begins. The spread reaches a first peak of 3.7 cents per dollar on March 17, 2008 after the failure of Bear Stearns. The spread starts to climb again after the failure of Indy Mac on July 11 and it reaches a second peak on July 15 when the Securities Exchange Commission (SEC) issues an emergency order temporarily prohibiting naked short selling in the securities of Fannie Mae, Freddie Mac, and primary dealers at commercial and investment banks. The third major run-up in the spread is initiated by the failure of Lehman Brothers on September 15, 2008. The model's interpretation of these events is that each negative shock increases the probability of a disaster. In the presence of a bailout, an increasing disaster probability increases the put spread.

Phase II: TARP On Sept 25, 2008, the day JP Morgan takes over Washington Mutual, the spread for financials starts a steep increase from 4.1 cents to 8.8 cents on Oct 13. The crisis spreads internationally. They key event is the passing of TARP legislation and its implementation. On Oct 3, Congress passes and President Bush signs into law the Emergency Economic Stabilization Act of 2008 (Public Law 110-343), which establishes the $700 billion Troubled Asset Relief Program (TARP). On Oct 14, the U.S. Treasury Department announces the Troubled Asset Relief Program (TARP) that will purchase capital in financial institutions under the authority of the

Emergency Economic Stabilization Act of 2008. The U.S. Treasury will make available $250 billion of capital to U.S. financial institutions. This facility will allow banking organizations to apply for a preferred stock investment by the U.S. Treasury. Nine large financial organizations announce their intention to subscribe to the facility in an aggregate amount of $125 billion. Moreover, the FDIC creates a new Temporary Liquidity Guarantee Program to guarantee the senior debt of all FDIC-insured institutions and their holding companies, as well as deposits in non-interest-bearing deposit transaction through June 30, 2009.

From the perspective of our model, market participants substantially revise up their probability of a financial disaster in this period. TARP is essentially a collective bailout of the financial sector's equity holders. However, it occurs amidst massive losses in the stock market and initial uncertainty about the exact mission of TARP, whose purpose was only clarified on October 14, 2008.

Phase III: Increased Bailout Uncertainty After October 15, 2008, the put spread stays high but actually declines somewhat from 8.8 cents to 5-6 cents per dollar, and hovers there until the end of January 2009. This period is one of heightened market volatility and uncertainty about the government's commitment to a bailout. On November 9, president Bush speaks out against too much government involvement in resolving the crisis. A November 13 Treasury announcement that TARP would not be used to buy troubled assets from large banks had a negative impact on their share prices. On November 19 and 20, the Dow Jones fell by 870 points to its lowest level in six years (now matching the 50% drop in stocks of the Great Depression). Citibank, which is thought to have $20 billion in toxic assets loses 26% of its market value and other large banks lose around 10%. The decline in the financial sector put spread during this period is consistent with a lower perceived bailout option.

Phase IV: TALF The put spread starts its largest increase between the beginning of February 2009 and peaks in the beginning of March. On February 10, 2010, U.S. Treasury Secretary Timothy Geithner announces a Financial Stability Plan involving Treasury purchases of convertible preferred stock in eligible banks, the creation of a Public-Private Investment Fund to acquire troubled loans and other assets from financial institutions, expansion of the Federal Reserve's Term Asset-Backed Securities Loan Facility (TALF), and new initiatives to stem residential mortgage foreclosures and to support small business lending. The Federal Reserve Board announces that is prepared to expand the Term Asset-Backed Securities Loan Facility (TALF) to as much as $1 trillion and to broaden the eligible collateral to include AAA-rated commercial mortgage-backed securities, private-label residential mortgage-backed securities, and other asset-backed securities. An expansion of the TALF would be supported by $100 billion from the Troubled Asset Relief Program (TARP). In the last week of February there is a lot of language about assurances to prop up the banking system and Fannie Mae and Freddie Mac. Finally, on March 3, just before the spread for financials peaks, the U.S. Treasury Department and the Federal Reserve Board announce the launch of the Term Asset-Backed Securities Loan Facility (TALF). Under the program, the Federal Reserve Bank of New York will lend up to $200 billion to eligible owners of certain AAA-rated asset-backed securities backed by newly and recently originated auto loans, credit card loans, student loans and small business loans that are guaranteed by the Small Business Administration. These events suggest that markets gradually became reassured that the government was indeed committed to bailing out the financial sector. Our measure of the value of the bailout guarantee suggests that the market initially was not reassured by the initial TARP program and its implementation, which consisted mostly of cash infusions from sales of preferred shares. Only when the Treasury and the Fed explicitly announce programs to purchase toxic assets such as MBS does the collective bailout guarantee become really valuable.

4.2 Non-financials

During the financial crisis, as market-wide volatility increased, even the index put options on the non-financials became *cheaper* relative to the individual stock options. The solid line in figure 7 plots the put spread for non-financials during the crisis. The put spread hovers around 1 cent until Lehman Brothers fails in September 2008. After that, it increases to 3.9 cents on October 10, and it reaches a maximum of 4.1 cents on November 21. This suggests that for a brief period, the market was expecting some bailouts in the non-financial sector as well. For example, on November 18, the CEOs of General Motors, Chrysler, and Ford testify before Congress and request access to the TARP for federal loans. This access is later granted on December 19, 2008. That said, the magnitude of the put spread in non-financials is much smaller than in financials. Also speaking to a divergence between the financial and non-financial sector are the different dynamics of their put spreads. The financial put spread increases with every shock that hits the financial sector, not so for the non-financial put spread. Also, the non-financial put spread is strongly positively correlated with the VIX index, an economy-wide measure of implied volatility, while the financial sector put spread is not.

5 Dynamic Asset Pricing Model with Financial Disaster Risk

The critical difference between banks and other non-financial corporations is their heightened exposure to bank runs during financial crises. Traditionally, such runs took place by depositors, but in the modern financial system they took place by other creditors, such as investors in asset-backed commercial paper, repos, money market mutual funds, etc. (see Gorton and Metrick, 2009). This leads us to consider banking panics or financial disasters as a source of aggregate risk. To model the asset pricing impact of financial disasters, we use a version of the Barro (2006); Rietz (1988); Longstaff and Piazzesi (2004) asset pricing model with a time-varying probability of disasters, as developed by Gabaix (2008); Wachter (2008); Gourio (2008). The model features two sources of priced risk: normal risk and financial disaster risk. While non-financial corporations are also subject to these rare events, their exposure is more limited and they do not (or at least much less) enjoy the collective bailout guarantee that supports the financial sector. The model allows us to interpret the financial crisis as an elevated probability of a financial disaster (for pricing purposes), as well as the realization of a financial disaster itself, and to make contact with option pricing facts we document above.

5.1 Environment

Preferences We consider a representative agent with Epstein and Zin (1989) preferences over non-durable consumption flows. For any asset return $R_{i,t+1}$, this agent faces the standard Euler equation:

$$
\begin{aligned}
1 &= E_t\left[M_{t+1}R_{i,t+1}\right], \\
M_{t+1} &= \beta^{\alpha}\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{\alpha}{\psi}} R_{a,t+1}^{\alpha-1},
\end{aligned}
$$

where $\alpha \equiv \frac{1-\gamma}{1-\frac{1}{\psi}}$, γ measures risk aversion, and ψ is the elasticity of inter-temporal substitution (EIS). The log of the stochastic discount factor (SDF) $m = \log(M)$ is given by:

$$
m_{t+1} = \alpha \log\beta - \frac{\alpha}{\psi}\Delta c_{t+1} + (\alpha - 1)r_{a,t+1}.
$$

All lowercase letters denote logs. We note and use later that $\frac{\alpha}{\psi} + 1 - \alpha = \gamma$.

Uncertainty There is a time-varying probability of a disaster p_t. This probability follows an I-state Markov chain. Let Π be the $1 \times I$ steady-state distribution of the Markov chain and $\mathcal{P}$ the $I \times 1$ grid with probability states. The mean disaster probability is $\Pi\mathcal{P}$. The Markov chain is uncorrelated with all other consumption and dividend growth shocks introduced below. However, the volatility of Gaussian consumption and dividend growth risk potentially varies with the Markov state. This allows us to capture more Gaussian risk in bad states, associated with high disaster probabilities.

In state $i \in \{1, 2, \ldots, I\}$, the consumption process (Δc_{t+1}) is given by a standard Gaussian component and a disaster risk component:

$$
\begin{aligned}
\Delta c_{t+1} &= \mu_c + \sigma_{ci}\eta_{t+1}, \quad \text{if no disaster} \\
\Delta c_{t+1} &= \mu_c + \sigma_{ci}\eta_{t+1} - J_{t+1}^{c}, \quad \text{if disaster,}
\end{aligned}
$$

where η is a standard normal random variable, and J^c is a Poisson mixture of normals governing the size of the consumption drop (jump) in the disaster state. We adopt Backus, Chernov, and Martin (2011)'s model of consumption disasters. The random variable J^c is a Poisson mixture of normal random variable; the number of jumps is n with probability $e^{-\omega}\frac{\omega^j}{j!}$. Conditional on n, J^c is normal with mean $(n\theta_c)$ and variance $n\delta_c^2$. Thus, the parameter ω (jump intensity) reflects the average number of jumps, θ_c the mean jump size, and δ_c the dispersion in jump size.[5] Finally, we allow for heteroscedasticity in the Gaussian component of consumption growth: σ_{ci} depends on the Markov state i.

Individual Dividends in Financial Sector In state $i \in \{1, 2, \ldots, I\}$, the dividend process of an individual bank is given by:

$$\begin{aligned}
\Delta d_{t,t+1} &= \mu_d + \phi_d \sigma_{ci} \eta_{t+1} + \sigma_{di} \epsilon_{t+1}, \quad \text{if no disaster} \\
\Delta d_{t,t+1} &= \mu_d + \phi_d \sigma_{ci} \eta_{t+1} + \sigma_{di} \epsilon_{t+1} - J^d_{t+1} - J^a_{t+1}, \quad \text{if disaster}
\end{aligned}$$

where ϵ_{t+1} is standard normal and i.i.d. across time. It is the sum of an idiosyncratic and an aggregate component, which we introduce in the calibration below. The term $\exp\left(-J^d_{t+1} - J^a_{t+1}\right)$ can be thought of as the recovery rate in case the rare event is realized. The remaining fraction $1 - \exp\left(-J^d_{t+1} - J^a_{t+1}\right)$ of the dividend gets wiped out in a disaster. The loss rate varies across banks; it has an idiosyncratic component J^i and a common component J^a. The idiosyncratic jump component J^d_{t+1} is a Poisson mixture of normals that are i.i.d. across time and banks, but with common parameters $(\omega, \theta_d, \delta_d)$. We set $\theta_d = 0$, which implies that the idiosyncratic jump is truly idiosyncratic; during a disaster the average jump in any stock's log dividend growth is $-E[J^a]$.

Collective Bailout Option The key feature of the model is the presence of the collective bailout option which puts a floor $\underline{J}$ on the losses of the banking sector. The aggregate component of the loss rate is the minimum of the maximum industry-wide loss rate $\underline{J}$ and the actual realized aggregate

[5] Note that when J^c is activated, we have already conditioned on a disaster occurring. Therefore, the parameter ω is not the disaster frequency but rather the mean of the number of jumps, conditional on a disaster. There is a non-zero probability $e^{-\omega}$ of zero jumps in the disaster state. In what follows we normalize ω to 1.

loss rate J^r:

$$J^a_{t+1} = \min(J^r_{t+1}, \underline{J})$$

We model J^r as a Poisson mixture of normals with parameters $(\omega, \theta_r, \delta_r)$. For simplicity, we assume that the jump intensity is perfectly correlated among the three jump processes (J^c, J^i, J^r), but the jump size distributions are independent. We can think of the no-bailout case as $\underline{J} \to +\infty$, so that $J^a = J^r$.

5.2 Valuing Stocks

Valuing the Consumption Claim We start by valuing the consumption claim. We log-linearize the total wealth return $R^a_{t+1} = \frac{W_{t+1}}{W_t - C_t} = \frac{WC_{t+1}}{WC_t - 1}\frac{C_{t+1}}{C_t}$ as follows: $r_{a,t+1} = \kappa^c_0 + wc_{t+1} - \kappa^c_1 wc_t + \Delta c_{t+1}$ with linearization constants:

$$\kappa^c_1 = \frac{e^{\overline{wc}}}{e^{\overline{wc}} - 1} \tag{2}$$

$$\kappa^c_0 = -\log\left(e^{\overline{wc}} - 1\right) + \kappa^c_1 \overline{wc}. \tag{3}$$

The wealth-consumption ratio differs across Markov states. Let wc_i be the log wealth-consumption ratio in Markov state i. Then, the mean log wealth-consumption ratio can be computed using the stationary distribution:

$$\overline{wc} = \sum_{i=1}^{I} \Pi_i wc_i. \tag{4}$$

Note that the linearization constants κ^c_0 and κ^c_1 depend on $\overline{wc}$.

Consider the investor's Euler equation for the consumption claim: $E_t[M_{t+1}R^a_{t+1}] = 1$. This investor's Euler equation can be decomposed as follows:

$$1 = (1 - p_t)E_t[\exp(\alpha \log \beta - \frac{\alpha}{\psi}\Delta c^{ND}_{t+1} + \alpha r^{ND}_{a,t+1})] + p_t E_t[\exp(\alpha \log \beta - \frac{\alpha}{\psi}\Delta c^{D}_{t+1} + \alpha r^{D}_{a,t+1})],$$

where ND (D) denotes the Gaussian (disaster) component of consumption growth, dividend growth or returns. We define "resilience" for the consumption claim as:

$$H_t^c = 1 + p_t \left(E_t \left[\exp \left\{ (\gamma - 1) J_{t+1}^c \right\} \right] - 1 \right).$$

Because the wealth-consumption ratio is not affected by the disaster -wealth and consumption fall by the same fraction-, we can write the Euler equation as:

$$1 = H_t^c E_t \left[\exp \left\{ \alpha \log \beta - \frac{\alpha}{\psi} \Delta c_{t+1}^{ND} + \alpha r_{a,t+1}^{ND} \right\} \right].$$

Using the log linearization for the total wealth return, the Euler equation can be restated as follows:

$$1 = \exp(h_t^c) E_t \left[\exp \left\{ \alpha \log \beta - \frac{\alpha}{\psi} (\mu_c + \sigma_{ci} \eta_{t+1}) + \alpha (\kappa_0^c + wc_{t+1} - \kappa_1^c wc_t + \Delta c_{t+1}^{ND}) \right\} \right].$$

Resilience takes a simple form in our setting:

$$\begin{aligned} h_t^c &\equiv \log(H_t^c) = \log\left(1 + p_t \left[\exp\left\{\bar{h}^c\right\} - 1\right]\right), \\ \bar{h}^c &\equiv \log E_t \left[\exp\left\{(\gamma - 1) J_{t+1}^c\right\}\right] = \omega \left(\exp\left\{(\gamma - 1)\theta_c + .5(\gamma - 1)^2 \delta_c^2\right\} - 1\right), \end{aligned}$$

where we used the cumulant-generating function to compute $\bar{h}^c$. It is now clear that resilience only varies with the probability of a disaster p_t. Therefore, it too is a Markov chain. Denote by h_i^c the log resilience in Markov state i.

Solving the Euler equation for the consumption claim amounts to solving for the log wealth-consumption ratio in each state i. We obtain the following system of I equations, which can be solved for $wc_i,\ i = 1, \dots I$:

$$1 = \exp(h_i^c) \exp \left\{ \alpha (\log \beta + \kappa_0^c) + (1 - \gamma) \mu_c - \alpha \kappa_1^c wc_i + \frac{1}{2} (1 - \gamma)^2 \sigma_{ci}^2 \right\} \sum_{j=1}^{N} \pi_{ij} \exp \left\{ \alpha wc_j \right\}.$$

Taking logs on both sides we get the following system of equations which can be solved in conjunction with (2), (3), and (4):

$$0 = h_i^c + \alpha(\log\beta + \kappa_0^c) + (1-\gamma)\mu_c - \alpha\kappa_1^c wc_i + \frac{1}{2}(1-\gamma)^2\sigma_{ci}^2 + \log\sum_{j=1}^{N}\pi_{ij}\exp\left\{\alpha wc_j\right\}.$$

Valuing the Dividend Claim We log-linearize the stock return on bank i $R_{t+1}^d = \frac{P_{t+1}+D_{t+1}}{P_t} = \frac{PD_{t+1}+1}{PD_t}\frac{D_{t+1}}{D_t}$ as follows: $r_{d,t+1} = \kappa_0^d + \kappa_1^d pd_{t+1} - pd_t + \Delta d_{t+1}$, with the linearization constants:

$$\kappa_1^d = \frac{e^{\overline{pd}}}{1+e^{\overline{pd}}}, \tag{5}$$

$$\kappa_0^d = \log(1+e^{\overline{pd}}) - \kappa_1^d\overline{pd}. \tag{6}$$

Consider the investor's Euler equation for asset, $E_t[M_{t+1}R_{t+1}^d] = 1$, which can be decomposed as follows:

$$\begin{aligned} 1 &= (1-p_t)E_t\left[\exp(\alpha\log\beta - \frac{\alpha}{\psi}\Delta c_{t+1}^{ND} + (\alpha-1)r_{a,t+1}^{ND} + r_{d,t+1}^{ND})\right] \\ &\quad + p_t E_t\left[\exp(\alpha\log\beta - \frac{\alpha}{\psi}\Delta c_{t+1}^{D} + (\alpha-1)r_{a,t+1}^{D} + r_{d,t+1}^{D})\right] \end{aligned}$$

If we define "resilience" for the dividend claim as:

$$H_t^d = 1 + p_t\left(E_t\left[\exp\left\{\gamma J_{t+1}^c - J_{t+1}^d - J_{t+1}^a\right\}\right] - 1\right),$$

then the Euler equation simplifies to:

$$1 = H_t^d E_t\left[\exp\left\{\alpha\log\beta - \frac{\alpha}{\psi}\Delta c_{t+1}^{ND} + (\alpha-1)r_{a,t+1}^{ND} + r_{d,t+1}^{ND}\right\}\right].$$

To compute the resilience term, we proceed as before:

$$\begin{aligned} h_t^d &\equiv \log\left(1 + p_t\left(\exp\left\{\bar{h}_d\right\} - 1\right)\right), \\ \bar{h}_d &\equiv \log E_t\left[\exp\left\{\gamma J_{t+1}^c - J_{t+1}^d - J_{t+1}^a\right\}\right]. \end{aligned}$$

By using the independence of the three jump processes, conditional on a given number of jumps, we can simplify the last term to:

$$\begin{aligned} \bar{h}_d &= \log\left(\sum_{n=0}^{\infty} \frac{e^{-\omega}\omega^n}{n!} e^{n(\gamma\theta_c + .5\gamma^2\delta_c^2)} e^{n(-\theta_d + .5\delta_d^2)}\right. \\ &\quad \left. \times \left\{e^{n(-\theta_r + .5\delta_r^2)}\Phi\left(\frac{\underline{J} - n\theta_r + n\delta_r^2}{\sqrt{n}\delta_r}\right) + e^{-\underline{J}}\Phi\left(\frac{n\theta_r - \underline{J}}{\sqrt{n}\delta_r}\right)\right\}\right). \end{aligned}$$

The derivation uses Lemma 1 in the technical appendix. The last expression, while somewhat complicated-looking, is straightforward to compute. In the no-bailout case ($\underline{J} \to +\infty$), the last exponential term reduces to $e^{n(-\theta_r + .5\delta_r^2)}$. The dynamics of h_t^d are fully determined by the dynamics of p_t, which follows a Markov chain. Denote by h_i^d the resilience in Markov state i.

Solving the Euler equation for the dividend claim amounts to solving for the log price-dividend ratio in each state i, pd_i. We can solve the following system of N equations for pd_i:

$$\begin{aligned} pd_i &= h_i^d + \alpha \log\beta - \gamma\mu_c + (\alpha - 1)\left(\kappa_0^c - \kappa_1^c wc_i\right) + \kappa_0^d + \mu_d + \frac{1}{2}(\phi_d - \gamma)^2\sigma_{ci}^2 + \frac{1}{2}\sigma_{di}^2 \\ &\quad + \log\left(\sum_{j=1}^{N} \pi_{ij} \exp\left\{(\alpha - 1)wc_j + \kappa_1^d pd_j\right\}\right), \end{aligned}$$

together with the linearization constants in (5) and (6), and the mean pd ratio:

$$\overline{pd} = \sum_j \Pi_j pd_j. \qquad (7)$$

Equity Risk Premium An important object is the equity risk premium, the expected excess log stock return adjusted for a Jensen inequality term.

$$-Cov(m,r) \quad = \quad \gamma\phi_d\sigma_{ci}^2 - \zeta_{m,i} + \gamma Cov(J^d, J^c) + \gamma Cov(J^a, J^c),$$

Appendix B.3 derives the various terms as a function of the structural parameters. The first term represents the standard Gaussian equity risk premium, the second term reflect compensation for the risk that emanates from the Markov switches, while the last two terms are the pure compensation for disaster risk. Since we will normalize θ_d to zero, the second term is zero. Hence, the third term is the disaster risk premium. It depends on the risk aversion coefficient, the probability of a disaster, and how much aggregate consumption and financial sector dividends fall in a disaster. The latter depends on θ_r as well as on the bailout guarantee, $\underline{J}$. Absent the bailout guarantee, the disaster risk premium would be $\gamma p_i(2-p_i)\theta_c\theta_r$, which is higher than with the guarantee.

5.3 Valuing Options

The main technical contribution of the paper is to price options in the presence of a bailout guarantee.

Options on Individual Banks We are interested in the price per dollar invested in a put option (cost per dollar insured) on a bank stock. For simplicity, we assume that the option has a one-period maturity and is of the European type. We denote the put price by Put:

$$Put_t = E_t\left[M_{t+1}\left(K - R_{t+1}\right)^+\right] = (1-p_t)Put_t^{ND} + p_t Put_t^{D},$$

where the strike price K is expressed as a fraction of \$1; for example $K = 1$ is the at-the-money option. The put price is the sum of a disaster component and a non-disaster component. We derive both components next.

Conditional on no disaster Conditional on no disaster in the next period, we are back to the familiar Black-Scholes world (with Epstein-Zin preferences). The option value in state i is:

$$\begin{aligned} Put_i^{ND} &= E\left[M^{ND}(K - R^{ND})^+\right] \\ &= -E\left[\exp\left(m^{ND} + r^{ND}\right) 1_{k > r^{ND}}\right] + KE\left[\exp\left(m^{ND}\right) 1_{k > r^{ND}}\right] \end{aligned}$$

We condition on a Markov state transition from state i in the current period to state j in the next one. Then, the log SDF and log return are bivariate normally distributed; see Appendices B.2 and B.3. Application of Lemma 1 in Appendix B.1 leads to the familiar Black-Scholes value of a put option:

$$Put_{ij}^{ND} = -\Psi(1,1;m^{ND},r^{ND})\Phi(d_{ij} - \sigma_{ri}) + Ke^{-r_{ij}^{f,ND}}\Phi(d_{ij}), \tag{8}$$

where $d_{ij}^{ND} = \frac{k - \mu_{rij} - \sigma_{m,r}}{\sigma_{ri}}$, where $k = \log(K)$, μ_{rij} is the mean log stock return conditional on a transition from i to j and no disaster, σ_{ri} the volatility of the log stock return in state i, σ_{mr} the covariance of log return and log SDF, and where $\Psi(a,b;x,y) = \exp\left(a\mu_x + b\mu_y + \frac{a^2\sigma_x^2}{2} + \frac{b^2\sigma_y^2}{2} + ab\rho_{xy}\sigma_x\sigma_y\right)$ is the bivariate normal moment-generating function of x and y evaluated at (a,b). We have used the fact that $\Psi(1,0;m^{ND},r^{ND}) = \exp(\mu_{mj} + .5\sigma_m^2) = \exp(-r_{ij}^{f,ND})$, where $r_{ij}^{f,ND}$ is the risk-free rate in Markov state i, conditional on a transition to state j and conditional on no disaster. As an aside, if there were no disaster state, then $\Psi(1,1;m^{ND},r^{ND}) = 1$.[6] Since we conditioned on a particular transition to state j, we still have to average over all such transitions to obtain the no-disaster option price in state i:

$$Put_i^{ND} = \sum_{j=1}^{I} \pi_{i,j} Put_{ij}^{ND}.$$

[6]This would follow immediately from the fact the no-disaster return would satisfy the Euler equation. We would then have that $\mu_r = r^{f,ND} - \sigma_{m,r} - .5\sigma_r^2$ with $-\sigma_{m,r} = \gamma\phi\sigma_{ci}^2$ as the familiar Gaussian equity risk premium. Equation (8) would then collapse to the standard Black-Scholes formula, with $d^{ND} = \frac{k - r^{f,ND} + .5\sigma_r^2}{\sigma_r}$.

Conditional on a disaster Conditional on having a disaster, the formulae become a lot more involved because of the presence of a bailout option. Backus, Chernov, and Martin (2011) derive option prices in a setting similar to ours, but one that does not have the bailout option. In their setting, Black-Scholes can be applied because log returns are a Poisson mixtures of normals, so that they are normally distributed conditional on a given number of jumps. Option prices are then simply weighted-averages of Black-Scholes values, weighted by the Poisson probability of a given number of jumps. In the presence of the bailout option, log stock returns are no longer normally distributed; They contain a term $J^a = min(J^r, \underline{J})$, where J^r is normal conditional on a given number of jumps; J^a is not normal. A technical contribution of the paper is to show that we can still obtain closed-form expressions for the put option price. The result hinges on repeated application of Lemmas 1 and 2, stated in Appendix B.1. The details of the derivation are relegated to Appendix B.4.

We start by conditioning on a Markov state transition from state i to state j and we condition on n jumps to the three jump processes (J^c, J^i, J^r). The option value is

$$\begin{aligned} Put^D_{ijn} &= E\left[M^D(K - R^D)^+\right] \\ &= -E\left[\exp\left(m^D + r^D\right) 1_{k>r^D}\right] + KE\left[\exp\left(m^D\right) 1_{k>r^D}\right], \\ &= -Put^D_{ijn1} + Put^D_{ijn2}. \end{aligned}$$

We define the random variable $\tilde{r} = r^{ND} - J^d$. Log returns in the disaster state are $r^D = \tilde{r} - J^a$. The appendix derives the following expressions for the two terms in the put price:

$$\begin{aligned} Put^D_{ijn1} &= \Psi(1,1;m^D,\tilde{r})\left\{e^{n(-\theta_r + .5\delta_r^2)}\Phi\left(\frac{k - \mu_{rj} + n\theta_i - \sigma^2_{\tilde{r}} - \sigma_{m^D,\tilde{r}} + n(\theta_r - \delta_r^2)}{\sqrt{\sigma^2_{\tilde{r}} + n\delta_r^2}}, \frac{\underline{J} - n\theta_r + n\delta_r^2}{\sqrt{n}\delta_r}; \rho\right)\right. \\ &\quad \left. + e^{-\underline{J}}\Phi\left(\frac{\underline{J} + k - \mu_{rj} + n\theta_i - \sigma^2_{\tilde{r}} - \sigma_{m^D,\tilde{r}}}{\sigma_{\tilde{r}}}\right)\Phi\left(\frac{n\theta_r - \underline{J}}{\delta_r\sqrt{n}}\right)\right\} \qquad (9) \\ Put^D_{ijn2} &= Ke^{-r^{f,D}_{ijn}}\left\{\Phi\left(\frac{k - \mu_{rj} + n\theta_i - \sigma_{m^D,\tilde{r}} + n\theta_r}{\sqrt{\sigma^2_{\tilde{r}} + n\delta_r^2}}, \frac{\underline{J} - n\theta_r}{\sqrt{n}\delta_r}; \rho\right)\right. \\ &\quad \left. + \Phi\left(\frac{\underline{J} + k - \mu_{rj} + n\theta_i - \sigma_{m^D,\tilde{r}}}{\sigma_{\tilde{r}}}\right)\Phi\left(\frac{n\theta_r - \underline{J}}{\delta_r\sqrt{n}}\right)\right\} \qquad (10) \end{aligned}$$

We note that $\Psi(1,0;m^D,\tilde{r}) = e^{-r^{f,D}_{ijn}}$, where $r^{f,D}_{ijn}$ is the risk-free rate conditional on a disaster realization, n jumps, and a Markov transition from state i to j. The correlation coefficient is:

$$\rho = -\frac{\sqrt{n}\delta_r}{\sqrt{\sigma_r^2 + n\delta_i^2 + n\delta_r^2}}.$$

Note that equations (9) and (10) are entirely in terms of the structural parameters of the model. Thus, we essentially obtain closed-form solutions for the option prices.

Finally, we sum over the various jump events and Markov states j to obtain the disaster option price in state i:

$$Put_i^D \quad = \quad \sum_{j=1}^{I} \pi_{i,j} \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} \left(-Put^D_{ijn1} + Put^D_{ijn2}\right). \tag{11}$$

Special case: no bailout option We verify that the above put price collapses to the simpler case of no bailout options, that is $J^a = J^r$. This is the case as $\underline{J} \to +\infty$. Appendix B.4 shows that option prices are Poisson-mixtures of the Black-Scholes expressions in (8), except that the mean and volatility of returns are (risk-neutrally) adjusted for the jumps and that the jump intensity used in the counterpart of equation (11) is increased from the physical intensity to account for risk aversion: $\omega^* = \omega \exp\left(\gamma\theta_c + .5\gamma^2\delta_c^2\right)$. This risk-neutrality adjustment is also taking place in our more general model with bailout options, but it is implicit in the $\Psi(\cdot)$ terms.

Options on the Financial Sector To aggregate from the individual firms to the index, use a generic set of index weights $w_j, j = 1, \cdots, N_i$ for the sector i's constituents, where $\sum_{j=1}^{J} w_j = 1$. We assume that all individual firms in an index face the same dividend growth parameters (ex-ante identical except for size w_j). Assuming in the model that all stocks initially trade at \$1, the one-period dividend growth rate of the index in the model is given by:

$$\Delta d^{index} = \sum_{j=1}^{J} w_j \delta d^j.$$

The weights allow us to take into account a finite number of index constituents as well as sector concentration, as measured by $\sqrt{(\sum w_i^2)}$. The Gaussian dividend growth shock ϵ, which is not priced, has standard deviation σ_{di}. We assume that a fraction ξ_d of its variance is aggregate, with the remainder being idiosyncratic. It follows that the Gaussian variance of the index is given by

$$\sigma_{di}^{index} = \sigma_{di}\sqrt{(\xi_d + \sum_{j=1}^{N_i} w_j^2(1-\xi_d)}$$

The gains from diversification make the Gaussian variance of the index lower than that of its constituents. Similarly, the idiosyncratic tail risk of the financial sector index is much lower than that of any individual stock:

$$\delta_d^{index} = \delta_d\sqrt{\sum_{j=1}^{N_i} w_j^2}$$

and $\theta_d^{index} = \theta_d = 0$. The growth rate of the sector's dividends is then given by:

$$\begin{aligned}\Delta d_{t,t+1}^a &= \mu_d + \phi_d\sigma_{ci}\eta_{t+1} + \sigma_d^{index}\epsilon_{t+1}, \quad \text{if no disaster} \\ \Delta d_{t,t+1}^a &= \mu_d + \phi_d\sigma_{ci}\eta_{t+1} + \sigma_d^{index}\epsilon_{t+1} - J_{t+1}^{d,index} - J_{t+1}^a, \quad \text{if disaster}\end{aligned}$$

Since $J^{d,index}$ has mean zero, $\exp\left(-J_{t+1}^a\right)$ is the recovery rate of the index in case the rare event is realized.

6 Quantitative Implications

The goal of this section is threefold. First, we argue that a (state-of-the-art) structural model with bailout guarantees can explain the pattern in option prices and stock returns we document in the previous section. Second, we show that a model without bailout guarantee cannot. Third, we use the structural parameters of the model to infer the effect of the bailout option on financial firms' expected return, their cost of capital, and the overall dollar size of the government subsidy implied by the bailout guarantee.

6.1 Parameter Choices

We calibrate the model at the annual frequency to match it up with option prices with one-year maturity.

Disaster probabilities We set the number of Markov states I equal to 2 and treat the first state as the pre-crisis state and the second state as the crisis state. We define a *financial crisis* as a period of elevated probability of a financial disaster. Our sample is 78 months long and 23 of these months are a crisis, or 29.5% of the months. We choose the elements of the transition probability matrix to match the 29.5% fraction of the time in a crisis and to obtain that, conditional on being in a crisis, the expected length of a crisis is 2 years, the length of the crisis in the data. This leads us to set $\pi_{11} = .79$ and $\pi_{22} = .50$. We set the probability of a financial disaster equal to 7% in state 1 and 28% in state 2. This gives a steady state financial disaster probability of $p_{ss} = 13\%$, matching the historical frequency of financial disasters in the U.S. since 1800; see Reinhart and Rogoff (2009).

Consumption We set μ_c equal to real per capita total consumption growth during the pre-crisis period, which is 2.21% in our sample. Coincidentally, that is also the average over the full 1951-2010 sample. Unconditional average consumption is $\mu_c - p_{ss}\theta_c$ in the model. We choose $\theta_c = .065$ to match average annual real consumption growth of 1.37% over our 2003-2009 sample. That means that annual consumption drops 4.3% (2.2-6.5%) in real terms in a disaster. This 4.2% consumption drop (in levels) is close to the 5.9% annual consumption drop during a typical financial crisis in developed economies, as reported in Reinhart and Rogoff (2009).[7] We choose $\sigma_c(1) = .0035$ to match the standard deviation of real per capita consumption growth (annualized from overlapping quarterly data) of 0.35% in the pre-crisis period. We set $\delta_c = .035$ to allow for some non-trivial dispersion around the size of the consumption disaster and we allow for a doubling of Gaussian consumption risk to $\sigma_c(1) = .0070$. This delivers an unconditional consumption growth volatility of 0.92% per year given all other parameters. This is close to the observed volatility of 0.81% in our

[7]Reinhart and Rogoff find that the (worldwide) average financial crisis is associated with a 35.5% fall in GDP over six years. Barro and Ursua (2008) find that consumption disasters are typically of the same magnitude as GDP contractions during crises.

sample and exactly matches the 0.92% in the 1951-2010 sample. Seen from the model's perspective and interpreting the period 2007-2009 as the realization of a disaster, the observed consumption growth rate of -0.7% (or 2.9% lower than in the non-disaster state) was one standard deviation above the mean growth rate in disasters.

Preferences We set the coefficient of relative risk aversion equal to 10 and the inter-temporal elasticity of substitution equal to 3. The combination of a high risk aversion and a high EIS allows us to simultaneously generate a meaningful equity risk premium and a low risk-free rate. The high risk aversion will also be necessary to match the high out-of-the-money put prices observed during the crisis. We set the subjective time discount factor $\beta = .9555$. The unconditional real risk-free rate that results is 2.44% per year. It is 3.43% in state 1 and 0.07% in state 2, reflecting the additional precautionary savings motive when a disaster is more likely. This compares to an observed average yield on a one-period zero coupon government bond of 0.66% in the pre-crisis period and 0.05% in the crisis period, after subtracting realized inflation. Lowering average interest rates, as well as the difference between the interest rates in state 1 and 2, is possible if we further increase the EIS, while simultaneously increasing the time discount factor. We opt not to do this because the EIS is already high. Furthermore, we need strictly positive interest rates in both states in order to be able to compute implied volatilities from put prices in matlab. Our parameter choices are a compromise that still delivers the low interest rate environment of our sample period. The unconditional volatility of the risk-free rate is low at 1.54% per annum, matching the 1.59% volatility in our sample.

Dividends Next, we calibrate the parameters that govern the dividend growth rate of the firms in the financial sector. The mean growth rate of any firm, and therefore of the index, is $\mu_d = .08$ in order to match the high observed dividend growth rate on the financial sector index in the pre-crisis period. We set $\phi_d = 3$, a standard choice for the leverage parameter. This delivers a negligible Gaussian equity risk premium $\gamma \phi_d \sigma_c^2$ of 4 basis points in state 1 and 15 basis points in state 2. The entire equity risk premium in the model reflects compensation for disaster risk.

The key objects of the model are the parameters that govern the Gaussian and especially the tail risk. We use a representative set of index weights for the financial sector index constituents (that of 04/09/2010, 79 firms on that day) for w_j where $\sum_{j=1}^{J} w_j = 1$. The concentration metric $\sqrt{(\sum w_i^2)}$ measures concentration is 0.22 for the financial sector (on that day). This measure would only be half as large (0.11) if all 79 firms had equal size. We keep σ_d constant across Markov states in our benchmark calibration for simplicity. We recall that $\omega = 1$, which implies that the average number of jumps during a disaster is one, and that $\theta_d = 0$, which implies that the idiosyncratic jump is truly idiosyncratic. These are best thought of as sensible normalizations. The parameters that remain to be calibrated are $\Theta = (\sigma_d, \xi_d, \underline{J}, \theta_r, \delta_r, \delta_d)$. Together these parameters determine the equity risk premium, the volatility of dividend growth and returns at the individual and index level, the pairwise correlation between stock returns, and all option prices. It is the parameters in Θ that we vary between our benchmark calibrations with and without bailout.

6.2 Economy with bailout guarantee

In a first exercise, we ask whether we can match average prices on deep out-of-the-money puts and calls ($\Delta = 20$, TTM=365) on the financial sector index, the basket of financial stocks, and their spread in both the pre-crisis (state 1 in the model) and the crisis period (state 2). Simultaneously, we are interested in matching the correlation between return pairs and the volatility of the index returns in both states. That is 16 moments. Our benchmark calibration for the financial sector sets

$$\Theta^F = (\sigma_d, \xi_d, \underline{J}, \theta_r, \delta_r, \delta_d) = (0.15, 0, 0.921, 0.815, 0.55, 0.516).$$

Because the disaster probability is modest in state 1, Gaussian risk is what mostly drives the standard deviation of the index and the correlation among stocks in that state. The choice $\xi_d = 0$ implies that all the unpriced Gaussian dividend growth risk is idiosyncratic. This creates relatively more idiosyncratic risk, increasing the basket-index spread for both calls and puts in both states 1 and 2. It also allows us to lower the pairwise return correlation (by increasing σ_d), without causing much of an increase in the volatility of the index return. The choice $\sigma_d = .15$ allows us to match the 43% pairwise correlation between stock returns in the pre-crisis period. It generate a financial index return volatility of 19%, which is reasonably close to the 12% in the pre-crisis period.

We choose a high value for the aggregate tail risk parameter $\theta_r = .815$ as well as a high dispersion $\delta_r = .55$. That means that, absent bailout options, the financial sector would suffer a return drop of 81.5% or 55.7% in levels, with a wide confidence interval around it. However, the bailout option $\underline{J}$ substantially limits the losses for the index. The mean loss θ_a, which takes into account the bailout, is 46.5% or 37.2% in levels. At the same time, there is substantial idiosyncratic tail risk $\delta_d = .516$, meaning that some firms fare a lot better than others in a financial disaster. Importantly, the bailout only applies to the aggregate and not the idiosyncratic tail risk. Our parameters are such that there is enough residual aggregate tail risk (after the bailout) to make all options expensive enough, and enough idiosyncratic tail risk to make basket options more expensive than index options. However, there cannot be too much idiosyncratic tail risk or else the pairwise correlation of stock returns would fall from state 1 to state 2, because it would be very low in a crisis. We come back to the point in the next subsection.

As Panel B of Table IV shows, our model is able to quantitatively account for the observed option prices. It matches the put basket and index prices in the crisis (state 2) perfectly. It also generates about the right level for put prices in the pre-crisis period (state 1), but it understates the put spread in state 1. In any case, the model is able to account for a large run-up in the put spread between the pre-crisis period and the crisis period. In the model, this run-up is caused by a four-fold increase in the probability of a financial disaster. Similarly, the model generates about the right prices for deep out-of-the-money call options. In particular, it captures the feature of the data that the call spread decreases from the pre-crisis to the crisis period. The model slightly overstates the call spreads. The option-implied volatility from the put index increases from 31.2% pre-crisis to 46.7% in the crisis inside the model. The latter number is only slightly above the model's realized index volatility in a disaster of 46.4%. The difference between option-implied and realized volatility shrinks substantially during the crisis: from 12% to 0.3%. In the data, the pattern is the same with implied volatility 9.8% above realized volatility pre-crisis and 4.7% in the crisis.

Panel B of Table V shows that the model also generates an increase in the volatility of index returns, thanks to the large amount of aggregate tail risk. Finally, the model generates a substantial increase in the pairwise correlation of returns from pre-crisis to crisis. While it still understates the rise in the data, the increase is important and goes hand in hand with the bailout option. Intuitively, in state 1 the correlation mostly reflects Gaussian risk and the Gaussian correlation is low because all ϵ shocks are idiosyncratic. Because of the substantial amount of aggregate tail risk -relative to the idiosyncratic tail risk-, the correlation between returns in the disaster state is higher (40% versus 16% in the non-disaster state). Since state 2 gives the disaster state more weight, the correlation rises from state 1 to 2. Absent bailout, this amount of aggregate tail risk would lead to option prices that are too high.

The large amount of idiosyncratic Gaussian and tail risk deliver individual stock returns that are volatile: 27% in the pre-crisis and 44.5% in the crisis. Conditional on a disaster, individual stock return volatility is 69.5%, not unlike the observed 72.9% realized volatility of individual financial firms during the crisis period. Implied volatility from the put basket is 61.3% during the crisis in the model, substantially below realized volatility of 69.5%. The same is true in the data, where implied volatility is 59.5%, below the realized volatility of 72.9%.

6.3 Economy without bailout guarantee

Having shown that we can match the option prices of interest in the presence of a bailout guarantee, we now show that the bailout guarantee is essential. To that end, we set $\underline{J} = +\infty$, and search over the remaining parameters of Θ to best match the 16 moments of interest. We find the best match for:

$$\Theta^{NB} = (\sigma_d, \xi_d, \underline{J}, \theta_r, \delta_r, \delta_d) = (0.15, .628, +\infty, 0.2825, 0.25, 0.65).$$

This calibration features a higher level of idiosyncratic tail and a much lower level of aggregate tail risk. The aggregate dividend falls 25% during a disaster, with substantially less dispersion around it. It also has a lower level of Gaussian tail risk because 2/3 of the ϵ shocks are now common across firms.

As Panel C of Table IV shows, the model without bailout guarantee matches put option prices in the crisis equally well. It also does a reasonably good job matching put prices in the pre-crisis period, but understating the put spread just like the model with bailouts. The match for call prices is worse than for the model with bailouts. In particular, this model shows a negative call spread in the pre-crisis which rises during the crisis. The opposite is true in the data. The implied volatility from basket calls and puts is about the same, while it is much lower for calls than for puts in the data. The latter again reflects the high degree of idiosyncratic tail risk in this calibration.

The main problem with this calibration, however, is that the correlation between stock returns goes *down* in the crisis, as can be seen in Panel C of Table V. The reason is that correlations between stocks are very low during disasters in this model because idiosyncratic tail risk is high while aggregate tail risk is low. To match the pre-crisis correlation, the model must make most of the Gaussian risk systematic. This decline in correlation is a highly counter-factual and undesirable feature of the model without bailouts. Another related issue is that the idiosyncratic tail risk is so high that price-dividend ratio of individual stocks blows up (it is 225,602 in levels while the one for the index is a reasonable 19).

6.4 Non-Financial Sectors

Next, we ask whether the model can explain the options prices and return moments for the non-financial sectors. We documented smaller increase in put spreads during the crisis, as repeated in the top panel of Table VI. Table VII also shows a much smaller increase in the volatility of individual stock and index returns for on-financials than for financials. Volatilities are higher in the pre-crisis than for financials, but substantially lower during the crisis. Also return correlations are lower, but increase to the same high level as for financials, implying a stronger increase. Matching these return facts necessitates a recalibration of the dividend growth parameters for the non-financial sector. All other parameters stay at their benchmark values. We choose

$$\Theta^{NF} = (\sigma_d, \xi_d, \underline{J}, \theta_r, \delta_r, \delta_d) = (0.17, 0.14, \infty, 0.219, 0.15, 0.23).$$

This calibration features no bailout option, substantially less idiosyncratic and aggregate tail risk, and slightly more unpriced Gaussian risk, a larger fraction of which is aggregate. This allows us to match the return volatility and correlation moments well, as shown in Panel B of Table VII. The option prices in Panel B of Table VI also provide a good match to the put prices in the crisis. They generate the 1.6 cents put spread of the data. They also generate a large increase in the put spread from pre-crisis to crisis. The model also captures the decline in the call spread that we found in the data, but overstates OTM call price levels and spreads somewhat. Overall, these results suggests that, to a first-order approximation, it is appropriate to think of the bailout guarantee as being confined to the financial sector.

6.5 Cost of Capital and Systemic Risk Measurement

Finally, we use the model's parameters to gauge the effect of the bailout option on the cost of capital of financial firms and to compute a measure of the total value of the subsidy implied by the collective bailout guarantee.

The benchmark model's equity risk premium for the financial sector index is 4.7% per year in the pre-crisis and rises to 14.0% during the crisis. The bailout guarantee plays an important role in keeping the equity risk premium down. Without it, and holding all other parameters constant, the equity risk premium would be exactly twice as large. We conclude that option prices tell us that the bailout option substantially reduces the cost of capital for systemically risky financial firms. Similarly, we find that the price-dividend ratio in the model with bailout guarantees is 49.5% lower pre-crisis (in state 1) and 61% lower in the crisis state (state 2) than it would be absent guarantee. This implies that the bailout guarantee accounts for fully half of the value of the financial sector when calibrated to our sample.

Our model also enables us to measure systematic risk in the presence of a bailout guarantee.

In particular, our calibration of the financial sector model with bailout guarantees delivers the aggregate amount of aggregate tail risk is that the financial sector takes on. Absent guarantees, the average financial firm would suffer a return fall of 55.7% in a financial disaster, compared to 37.2% with guarantees. The guarantee also affects the higher-order moments of the recovery distribution. The high and variable aggregate tail risk would presumably incur much higher (systemic) regulatory capital charges if detected and measured properly. The structural model allows us to do so.

7 Alternative Explanations

We consider three alternative explanations to collective bailout options: mispricing, liquidity, and time-varying correlation risk premia. We conclude that none is consistent with the patterns in the data.

7.1 Mispricing

Recent research has documented violations of the law of one price in several segments of financial markets during the crisis. In currency markets, violations of covered interest rate parity have been documented (see Garleanu and Pedersen, 2009). In government bond markets, there was mispricing between TIPS, nominal Treasuries and inflation swaps (see Fleckenstein, Longstaff, and Lustig, 2010). Finally, in corporate bond markets, large arbitrage opportunities opened up between CDS spreads and the CDX index and between the corporate bond yields and the CDS (see Mitchell and Pulvino, 2009)). A few factors make the mispricing explanation a less plausible candidate for our basket-index put spread findings.

First, trading on the difference between the cost of the index options and the cost of the basket does not require capital, unlike some of these other trades (CDS basis trade, TIPS/Treasury trade). Hence, instances of mispricing in the options basket-index spread due to capital shortages are less likely to persist (see Mitchell, Pedersen, and Pulvino, 2007; Duffie, 2010).

Second, if we attribute our basket-index spread findings to mispricing, we need to explain the divergence between put and call spreads. This asymmetry rules out most alternative explanations, except perhaps counter-party risk. The state of the world in which the entire financial sector, or the whole economy, is at risk is the state of the world in which OTM index put options pay off. However, these are exchange traded options and hence are cleared through a clearing house; no clearing house has ever failed. All options transactions on the CBOE are cleared by the Options Clearing Corporation (OCC). The OCC is the first clearinghouse to receive Standard & Poor's (S&P) highest credit rating. Hence, these options are very unlikely to be affected by counterparty default risk.

Finally, our analysis of implied volatility on index options has established that these index options are cheap during the crisis even when comparing implied to realized volatility. This comparison does not rely on individual option prices, which may be less liquid and hence more likely to be subject to mispricing.

7.2 Liquidity

Table VIII report summary statistics for the liquidity of *put* options on the S&P500, sector indices (a value-weighted average across all 9 sectors), the financial sector index, all individual stock options (a value-weighted average), and financial stock options. The table reports daily averages of the bid-ask spread in dollars, the bid-ask spread in percentage of the midpoint price, trading volume, and open interest. The columns cover the full range of moneyness, from deep out-of-the-money ($\Delta < 20$) to deep in-the-money ($\Delta > 80$), while the rows report a range of option maturities. We separately report averages for the pre-crisis period (January 2003 until July 2007) and the crisis period (August 2007 until March 2009). It is worth pointing out that a substantial fraction of trade in index options takes place in over-the-counter markets, which are outside our database. Hence, these numbers overstate the degree of illiquidity. Absent arbitrage opportunities across trading locations, prices in our database do reflect this additional liquidity.

Deep OTM put options with $|\Delta|$ less than 20 have large spreads, and volume is limited. We do not use these prices. OTM puts with $|\Delta|$ between 20 and 50 still have substantial option spreads. For the long-dated OTM puts (maturity in excess of 180 days), the average pre-crisis spread is

5.5% for the S&P 500, 12.8% for the sector options, 10.8% for the financial sector options, 6.8% for all individual stock options, and 7% for individual stock options in the financial sector. Financial sector index options appear, if anything, more liquid than other sector index options. The liquidity difference between index and individual put options is smaller for the financial sector than for the average sector.

Interestingly, during the crisis, the liquidity of the options appears to increase. For long-dated OTM puts, the spreads decreased from 5.5 to 4.7% for S&P 500 options, from 12.8 to 7.8% for sector options, from 10.8% to 4.5% for financial sector options, from 6.8 to 5.5 % for all individual options, and from 7.0% to 5.8% for financial firm's options.[8] At the same time, volume and open interest for long-dated OTM puts increased. For example, volume increased from 400 to 507 for the S&P 500 index options, from 45 to 169 for the sector options, from 287 to 1049 for financial index options, and from 130 to 162 for individual stock options in the financial sector. Short-dated put options (with maturity less than 10 days) are much more liquid than long-dated options; they experience a much larger increase in trade during the crisis. We verify below that our results are robust across maturities. During the crisis, trade in the OTM financial sector put options invariably exceeds not only trade in the other sector OTM put options but also trade in the OTM S&P 500 options.

Long-dated in-the-money options have somewhat smaller percentage bid-ask spreads but somewhat lower volume than out-of-the-money put options, in both subsamples. Table IX reports the same liquidity statistics for calls. There is no marked difference between puts and calls.

These liquidity facts are an unlikely explanation for our findings, often pointing in the opposite direction. Calls and puts are similarly liquidity yet display very different basket-index spread behavior. The relative increase in liquidity during the crisis of financial sector index versus individual options suggests that index options should have become more expensive, not cheaper during the crisis. Finally, the increase in the basket-index spread during the crisis is also (and even more strongly) present in shorter-dated options, which are more liquid. All three facts suggest that

[8]Absolute bid-ask spread increase during the crisis but this is explained by the rise in put prices during the crisis. Absolute bid-ask spreads increase by less than the price.

illiquidity is an unlikely candidate.

7.3 Time-Varying Price of Correlation Risk

Index put options are typically considered to be expensive. Returns on index put options are large and negative: -90% per month for deep out-of-the-money put options (see Bondarenko, 2003). CAPM alphas are large and negative as well, and the Sharpe ratios on put writing strategies are larger than those on the underlying index. However, this does not imply these options are mispriced (see Broadie, Chernov, and Johannes, 2009). Stochastic volatility models and models with jumps can explain many features of these returns.

Index options are also typically expensive relative to individual stock options. Driessen et al. (2009) attribute this to a negative correlation risk premium. The value of the index option increases when correlations of the basket constituents increase. Index options provide investors with a hedge against the increase in correlation, which constitutes a deterioration in the investment opportunity set. A related stylized fact is that the implied index volatility is always higher than the expected realized index volatility, but the implied volatilities for individual stocks are not significantly higher than their expected realized volatilities. These features arise form models with (i) a zero risk price for idiosyncratic variance risk and (ii) a negative risk price for correlation risk.

We showed that the patterns for financial sector put options during the crisis were exactly the opposite. Implied volatility is often lower than the realized volatility for the index but not for the individual stocks during the crisis, and the index put option decreases in price relative to the individual options despite an increase in return correlations. These patterns for puts could in principle be consistent with a decrease in the price of correlation risk (in absolute value) over time. But, if anything, one would expect the price of correlation risk to increase in absolute value during the crisis. Furthermore, such a decreased price of correlation risk would have counter-factual implications for call spreads, which would be predicted to increase as well. The data show a decline in the call spread during the crisis instead.

8 Conclusion

The financial crisis brought the problem of government guarantees front and center. Underpriced mortgage guarantees charged by Freddie Mac and Fannie Mae, mispriced deposit guarantees by the FDIC, and implicit too-big-to-fail guarantees to Citibank, AIG, and other large complex financial institutions all distorted the financial sector's capital allocation during the Great Moderation and let to an unparalleled build-up of risk. The worst financial disaster since the Great Depression ensued in 2007-2009. Financial authorities worldwide are passing new legislation to prevent a repeat of these events. An important question they face is how to best measure systemic risk. Most proposals under investigation rely on market prices. One important message of our paper is that measuring systemic risk is inherently difficult when the government provides (implicit) too-big-to-fail guarantees to the financial system.

We propose a structural model that can disentangle true exposure to aggregate tail risk from exposure implied by market prices. Our model identifies the magnitude of the collective bailout guarantee to the financial sector from the difference between the price of a basket of put options on individual financial firms and the price of a put option on the financial sector index. It ascribes the increase in the put spread to an increased probability of a financial disaster. During such periods, there is an increase in the relative amount of aggregate versus idiosyncratic tail risk, which helps to explain the increased return correlation between stocks. Put spreads can only rise because of a collective bailout guarantee which makes index options artificially cheap. Our model calibration suggests that the government's backstop massively reduced the cost-of-capital to the financial sector over our 2003-2009 sample. The massive amount of aggregate tail risk the sector takes on would lead to a fifty percent reduction in its market value if the guarantee were taken away.

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A Construction of Index Strike

A.1 Sector SPDR

The S&P 500 Index is an unmanaged index of 500 common stocks that is generally considered representative of the U.S. stock market. The Select Sector SPDR Trust consists of nine separate investment portfolios (each a Select Sector SPDR Fund or a Fund and collectively the Select Sector SPDR Funds or the Funds). Each Select Sector SPDR Fund is an index fund that invests in a particular sector or group of industries represented by a specified Select Sector Index. The companies included in each Select Sector Index are selected on the basis of general industry classification from a universe of companies defined by the Standard & Poor's 500 Composite Stock Index (S&P 500). The nine Select Sector Indexes (each a Select Sector Index) upon which the Funds are based together comprise all of the companies in the S&P 500. The investment objective of each Fund is to provide investment results that, before expenses, correspond generally to the price and yield performance of publicly traded equity securities of companies in a particular sector or group of industries, as represented by a specified market sector index. The financial sector's ticker is XLF. Table X reports the XLF holdings before and after the crisis.

B Option Pricing Derivations

B.1 Auxiliary Lemmas

We state and prove two important lemmas which are invoked repeatedly to derive the option prices.

Lemma 1. *Let $x \sim N(\mu_x, \sigma_x^2)$ and $y \sim N(\mu_y, \sigma_y^2)$ with $Corr(x, y) = \rho_{xy}$. Then*

$$E[\exp(ax + by)1_{c>y}] = \Psi(a, b; x, y)\Phi\left(\frac{c - \mu_y - b\sigma_y^2 - a\rho_{xy}\sigma_x\sigma_y}{\sigma_y}\right) \tag{12}$$

where $\Psi(a, b; x, y) = \exp\left(a\mu_x + b\mu_y + \frac{a^2\sigma_x^2}{2} + \frac{b^2\sigma_y^2}{2} + ab\rho_{xy}\sigma_x\sigma_y\right)$ is the bivariate normal moment-generating function of x and y evaluated at (a, b).

Proof. Lemma 1 First, note that $x|y \sim N\left(\mu_x + \frac{\rho_{xy}\sigma_x}{\sigma_y}[y - \mu_y], \sigma_x^2(1 - \rho_{xy}^2)\right)$, therefore

$$E[\exp(ax)|y] = Q\exp\left(\frac{a\rho_{xy}\sigma_x}{\sigma_y}y\right)$$

where $Q = \exp\left(a\mu_x - \frac{a\rho_{xy}\sigma_x\mu_y}{\sigma_y} + \frac{a^2\sigma_x^2(1-\rho_{xy}^2)}{2}\right)$. Denote $\Gamma = E[\exp(ax+by)1_{c>y}]$, then:

$$\begin{aligned}
\Gamma &= E[E\{\exp(ax)|y\}\exp(by)1_{c>y}] \\
&= QE\left[\exp\left(y\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b\right\}\right)1_{c>y}\right] \\
&= Q\int_{-\infty}^{c}\exp\left(y\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b\right\}\right)dF(y) \\
&= Q\int_{-\infty}^{c}\exp\left(y\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b+\frac{\mu_y}{\sigma_y^2}\right\}-\frac{y^2}{2\sigma_y^2}-\frac{\mu_y^2}{2\sigma_y^2}\right)\frac{dy}{\sigma_y\sqrt{2\pi}} \\
&\quad \text{Complete the square} \\
&= Q\exp\left(\frac{\sigma_y^2}{2}\sigma_y\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b\right\}^2+\mu_y\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b\right\}\right)\int_{-\infty}^{c}\exp\left(-\frac{\left[y-\sigma_y^2\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b+\frac{\mu_y}{\sigma_y^2}\right\}\right]^2}{2\sigma_y^2}\right)\frac{dy}{\sigma_y\sqrt{2\pi}} \\
&\quad \text{Substitute } u = \frac{y-\sigma_y^2\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b+\frac{\mu_y}{\sigma_y^2}\right\}}{\sigma_y},\ du\sigma_y = dy \\
&= \exp\left(a\mu_x+\frac{a^2\sigma_x^2(1-\rho_{xy}^2)}{2}+\frac{\sigma_y^2}{2}\left\{\frac{a\rho_{xy}\sigma_x}{\sigma_y}+b\right\}^2+b\mu_y\right)\Phi\left(\frac{c-b\sigma_y^2-a\rho_{xy}\sigma_x\sigma_y-\mu_y}{\sigma_y}\right)
\end{aligned}$$

□

Lemma 2. *Let $x \sim N(\mu_x, \sigma_x^2)$, then*

$$E\left[\Phi\left(b_0+b_1x\right)\exp\left(ax\right)1_{x<c}\right] = \Phi\left(\frac{b_0-t_1}{\sqrt{1+b_1^2\sigma_x^2}}\ ,\frac{c-t_2}{\sigma_x}\ ;\rho\right)\exp(z_1) \tag{13}$$

where $t_1 = -b_1t_2$, $t_2 = a\sigma_x^2+\mu_x$, $z_1 = \frac{a^2\sigma_x^2}{2}+a\mu_x$, $\rho = \frac{-b_1\sigma_x}{\sqrt{1+b_1^2\sigma_x^2}}$, and $\Phi(\cdot\ ,\cdot\ ;\rho)$ is the cumulative density function (CDF) of a bivariate standard normal with correlation parameter ρ.

Proof. Lemma 2 Denote $\Omega = E\left[\Phi\left(b_0 + b_1 x\right)\exp\left(ax\right)1_{x<c}\right]$, then:

$$\begin{aligned}
\Omega &= \int_{-\infty}^{c}\int_{-\infty}^{b_0+b_1x}\exp\left(ax\right)dF(v)dF(x) \\
&= \int_{-\infty}^{c}\int_{-\infty}^{b_0+b_1x}\exp\left(ax - \frac{v^2}{2} - \frac{\left[x-\mu_x\right]^2}{2\sigma_x^2}\right)\frac{dv\ dx}{\sigma_x 2\pi} \\
&\quad \text{Substitute } v = u + b_1 x,\ dv = du \\
&= \int_{-\infty}^{c}\int_{-\infty}^{b_0}\exp\left(ax - \frac{(u+b_1x)^2}{2} - \frac{\left[x-\mu_x\right]^2}{2\sigma_x^2}\right)\frac{du\ dx}{\sigma_x 2\pi} \\
&= \int_{-\infty}^{c}\int_{-\infty}^{b_0}\exp\left(-\frac{u^2}{2} - x^2\left(\frac{1}{2\sigma_x^2} + \frac{b_1^2}{2}\right) - b_1ux + 0u + x\left(a + \frac{\mu_x}{\sigma_x^2}\right) - \frac{\mu_x^2}{2\sigma_x^2}\right)\frac{du\ dx}{\sigma_x 2\pi} \\
&\quad \text{Complete the square in two variables using Lemma 3} \\
&= \int_{-\infty}^{c}\int_{-\infty}^{b_0}\exp\left\{\begin{pmatrix} u-t_1 \\ x-t_2\end{pmatrix}'\begin{pmatrix} s1 & s2 \\ s2 & s3\end{pmatrix}\begin{pmatrix} u-t_1 \\ x-t_2\end{pmatrix} + z_1\right\}\frac{du\ dx}{\sigma_x 2\pi} \\
&= \int_{-\infty}^{c}\int_{-\infty}^{b_0}\exp\left(-\frac{1}{2}(U-T)'(-2S)(U-T) + z_1\right)\frac{du\ dx}{\sigma_x 2\pi}
\end{aligned}$$

where $U = (u, x), T = (t_1, t_2), -2S = \begin{pmatrix} 1 & b_1 \\ b_1 & b_1^2 + \frac{1}{\sigma_x^2}\end{pmatrix}, (-2S)^{-1} = \begin{pmatrix} 1 + b_1^2\sigma_x^2 & -b_1\sigma_x^2 \\ -b_1\sigma_x^2 & \sigma_x^2\end{pmatrix}$. This is the CDF for $U \sim N(T, (-2S)^{-1})$. Let $w_1 = \frac{u-t_1}{\sqrt{1+b_1^2\sigma_x^2}}$, $w_2 = \frac{x-t_2}{\sigma_x}$, and $\Sigma = \begin{pmatrix} 1 & \rho \\ \rho & 1\end{pmatrix}$ with $\rho = \frac{-b_1\sigma_x}{\sqrt{1+b_1^2\sigma_x^2}}$. We have that $W' = (w_1, w_2) \sim N(0, \Sigma)$. Also, $du = dw_1\sqrt{1+b_1^2\sigma_x^2}$ and $dx = dw_2\sigma_x$.

$$\begin{aligned}
\Omega &= \exp(z_1)\left\{\int_{-\infty}^{\frac{c-t_2}{\sigma_x}}\int_{-\infty}^{\frac{b_0-t_1}{\sqrt{1+b_1^2\sigma_x^2}}}\exp\left(-\frac{1}{2}W'\Sigma^{-1}W\right)\frac{dw_1\ dw_2}{2\pi\sqrt{1-\rho^2}}\right\}\sqrt{1+b_1^2\sigma_x^2}\sqrt{1-\rho^2} \\
&= \Phi\left(\frac{b_0-t_1}{\sqrt{1+b_1^2\sigma_x^2}}, \frac{c-t_2}{\sigma_x}; \rho\right)\exp(z_1)
\end{aligned}$$

where we used that $\sqrt{1+b_1^2\sigma_x^2}\sqrt{1-\rho^2} = 1$, and where completing the square implies $t_1 = -b_1 t_2$, $t_2 = a\sigma_x^2 + \mu_x$, $s_1 = -.5$, $s_2 = -.5b_1$, $s_3 = -.5b_1^2 - \frac{1}{2\sigma_x^2}$, and $z_1 = \frac{a^2\sigma_x^2}{2} + a\mu_x$ by application of Lemma 3. □

Lemma 3. *Bivariate Complete Square*

$$Ax^2 + By^2 + Cxy + Dx + Ey + F = \begin{pmatrix} x-t_1 \\ y-t_2\end{pmatrix}'\begin{pmatrix} s_1 & s_2 \\ s_2 & s_3\end{pmatrix}\begin{pmatrix} x-t_1 \\ y-t_2\end{pmatrix} + z_1$$

where

$$\begin{aligned} t_1 &= -(2BD - CE)/(4AB - C^2) \\ t_2 &= -(2AE - CD)/(4AB - C^2) \\ s_1 &= A \\ s_2 &= C/2 \\ s_3 &= B \\ z_1 &= F - \frac{BD^2 - CDE + AE^2}{4AB - C^2} \end{aligned}$$

The following lemma will be useful in deriving the variance and covariances of stock returns.

Lemma 4. *Let $Z \sim N(\mu, \sigma^2)$ and define $\phi = \phi\left(\frac{b-\mu}{\sigma}\right)$ and $\Phi = \Phi\left(\frac{b-\mu}{\sigma}\right)$. Then*

$$E[Z1_{Z<b}] = \mu\Phi - \sigma\phi, \quad (14)$$

$$E[Z^2 1_{Z<b}] = \left(\sigma^2 + \mu^2\right)\Phi - \sigma(b + \mu)\phi \quad (15)$$

Proof.

$$E[Z1_{Z<b}] = E[Z|Z<b]Pr(Z<b) = \left(\mu - \frac{\sigma\phi}{\Phi}\right)\Phi = \mu\Phi - \sigma\phi$$

The second result is shown similarly:

$$\begin{aligned} E[Z^2 1_{Z<b}] &= E[Z^2|Z<b]Pr(Z<b) \\ &= (Var[Z^2|Z<b] + E[Z|Z<b]^2)Pr(Z<b) \\ &= \left(\sigma^2 - \frac{\sigma(b-\mu)\phi}{\Phi} - \sigma^2\frac{\phi^2}{\Phi^2} + \left[\mu - \frac{\sigma\phi}{\Phi}\right]^2\right)\Phi \\ &= \left(\sigma^2 + \mu^2\right)\Phi - \sigma(b+\mu)\phi \end{aligned}$$

□

B.2 Dividend Growth and Return Variance and Covariance

Recall that dividend growth in state i today is

$$\begin{aligned} \Delta d_i &= (1 - p_i)\Delta d_i^{ND} + p_i \Delta d_i^{D}, \\ \Delta d_i^{ND} &= \mu_d + \phi_d \sigma_{ci}\eta + \sigma_{di}\epsilon, \\ \Delta d_i^{D} &= \mu_d + \phi_d \sigma_{ci}\eta + \sigma_{di}\epsilon - J^d - J^a \end{aligned}$$

where the shock $\epsilon = \sqrt{\xi_d}\epsilon^a + \sqrt{1-\xi_d}\epsilon^i$ is the sum of a common shock and an idiosyncratic shock, both of which are standard normally distributed and i.i.d. over time. Stock returns in state i today and assuming a transition to state j next period are:

$$\begin{aligned} r_i &= (1-p_i)r_i^{ND} + p_i r_i^D, \\ r_i^{ND} &= \mu_{rij} + \phi_d \sigma_{ci}\eta + \sigma_{di}\epsilon, \\ r_i^D &= \mu_{rij} + \phi_d \sigma_{ci}\eta + \sigma_{di}\epsilon - J^d - J^a, \\ \mu_{rij} &= \mu_d + \kappa_0^d + \kappa_1^d pd_j - pd_i, \\ J^a &= \min(J^r, \underline{J}) \end{aligned}$$

We are interested in computing the variance of dividend growth rates, the variance of returns and the covariance between a pair of returns. This will allow us to computet he volatility of returns and the correlation of returns.

Applying Lemma 4 to the J^a process and conditioning on n jumps, this lemma implies that

$$\begin{aligned} E[J^a|n] &= E[\min(J^r, \underline{J})|n] \\ &= E[J^r 1_{(J^r<\underline{J})}|n] + \underline{J}E[1_{(J^r \geq \underline{J})}|n] \\ &= n\theta_r \Phi\left(\frac{\underline{J} - n\theta_r}{\sqrt{n}\delta_r}\right) - \sqrt{n}\delta_r \phi\left(\frac{\underline{J} - n\theta_r}{\sqrt{n}\delta_r}\right) + \underline{J}\Phi\left(\frac{n\theta_r - \underline{J}}{\sqrt{n}\delta_r}\right), \end{aligned}$$

and

$$\begin{aligned} E[J^{a2}|n] &= E[\min(J^r, \underline{J})^2|n] \\ &= E[J^{r2} 1_{(J^r<\underline{J})}|n] + \underline{J}^2 E[1_{(J^r \geq \underline{J})}|n] \\ &= \left(n\delta_r^2 + n^2\theta_r^2\right)\Phi\left(\frac{\underline{J} - n\theta_r}{\sqrt{n}\delta_r}\right) - \sqrt{n}\delta_r(\underline{J} + n\theta_r)\phi\left(\frac{\underline{J} - n\theta_r}{\sqrt{n}\delta_r}\right) + \underline{J}^2\Phi\left(\frac{n\theta_r - \underline{J}}{\sqrt{n}\delta_r}\right). \end{aligned}$$

Note that the corresponding moments for the J^d process are:

$$\begin{aligned} E[J^d|n] &= n\theta_d \\ E[J^{d^2}|n] &= n\delta_d^2 + n^2\theta_d^2 \end{aligned}$$

We now average over all possible realizations of the number of jumps n to get:

$$\begin{aligned} E[J^d] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} E[J^d|n] = \theta_d, \\ E[J^{d^2}] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} E[J^{d^2}|n] = \delta_d^2 + 2\theta_d^2, \\ E[J^a] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} E[J^a|n] \equiv \theta_a, \\ E[J^{a2}] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} E[J^{a2}|n], \\ E[J^d J^a] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} n\theta_d E[J^a|n], \\ E[J^{d,1}J^{d,2}] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} (n\theta_d)(n\theta_d) = 2\theta_d^2 \end{aligned}$$

where we used our assumption that $\omega = 1$, which implies that $\sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} n = 1$ and $\sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} n^2 = 2$. The last but one expression uses the fact that the two jumps are uncorrelated, conditional on a given number of jumps. The last expression computes the expectation of the product of the idiosyncratic jumps for two different stocks. Note that the correlation between these two idiosyncratic jump processes is zero if and only if $\theta_d = 0$, an assumption we make in our calibration.

The variance of dividend growth of a firm can be computed as follows

$$\begin{aligned} Var[\Delta d_i] &= (1-p_i)E[\left(\Delta d_i^{ND}\right)^2] + p_i E[\left(\Delta d_i^{D}\right)^2] - \left[(1-p_i)E[\Delta d_i^{ND}] + p_i E[\Delta d_i^{D}]\right]^2, \\ &= (1-p_i)\left[\mu_d^2 + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2\right] \\ &\quad + p_i \left[\mu_d^2 + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2 + E[{J^d}^2] + E[{J^a}^2] + 2E[J^d J^a] - 2\mu_d(E[J^d] + E[J^a])\right] \\ &\quad - \left[(1-p_i)\mu_d + p_i[\mu_d - E[J^d] - E[J^a]]\right]^2, \\ &= \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2 + p_i(\delta_d^2 + 2\theta_d^2 + E[{J^a}^2] + 2E[J^d J^a]) - p_i^2(\theta_d + \theta_a)^2 \end{aligned}$$

Similarly, mean dividend growth is given by $E[\Delta d_i] = \mu_d - p_i(\theta_d + \theta_a)$. If $\theta_d = 0$, as we assume, mean dividend growth is simply $\mu_d - p_i\theta_a$.

The variance of returns can be derived similarly, with the only added complication that we need to take into account state transitions from i to j that affect the mean return μ_{rij}.

$$\begin{aligned} Var[r_i] &= (1-p_i)E[\left(r_i^{ND}\right)^2] + p_i E[\left(r_i^{D}\right)^2] - \left[(1-p_i)E[r_i^{ND}] + p_i E[r_i^{D}]\right]^2, \\ &= (1-p_i)\left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij}^2 + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2\right] \\ &\quad + p_i\left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij}^2 + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2 + E[{J^d}^2] + E[{J^a}^2] + 2E[J^d J^a] - 2\sum_{j=1}^{I} \pi_{ij}\mu_{rij}(E[J^d] + E[J^a])\right] \\ &\quad - \left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij} - p_i(E[J^d] + E[J^a])\right]^2, \\ &= \zeta_{ri} + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2 + p_i(\delta_d^2 + 2\theta_d^2 + E[{J^a}^2] + 2E[J^d J^a]) - p_i^2(\theta_d + \theta_a)^2, \end{aligned}$$

where

$$\zeta_{ri} \equiv \sum_{j=1}^{I} \pi_{ij}\mu_{rij}^2 - \left(\sum_{j=1}^{I} \pi_{ij}\mu_{rij}\right)^2,$$

is an additional variance term that comes from state transitions that affect the price-dividend ratio. The volatility of the stock return is the square root of the variance.

Finally, the covariance of a pair of returns (r^1, r^2) in state i is:

$$
\begin{aligned}
Cov[r_i^1, r_i^2] &= (1-p_i)E[r_i^{1,ND} r_i^{2,ND}] + p_i E[r_i^{1,D} r_i^{2,D}] \\
&\quad - \left[(1-p_i)E[r_i^{1,ND}] + p_i E[r_i^{1,D}]\right]\left[(1-p_i)E[r_i^{2,ND}] + p_i E[r_i^{2,D}]\right], \\
&= (1-p_i)\left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij}^2 + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2\xi_d\right] \\
&\quad + p_i\left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij}^2 + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2\xi_d + E[J^{d,1}J^{d,2}] + E[J^{a2}] + 2E[J^d J^a] - 2\sum_{j=1}^{I}\pi_{ij}\mu_{rij}(\theta_d+\theta_a)\right] \\
&\quad - \left(\sum_{j=1}^{I}\pi_{ij}\mu_{rij}\right)^2 - p_i^2(\theta_a+\theta_d)^2 + 2\sum_{j=1}^{I}\pi_{ij}\mu_{rij}(\theta_d+\theta_a), \\
&= \zeta_{ri} + \phi_d^2\sigma_{ci}^2 + \sigma_{di}^2\xi_d + p_i(2\theta_d^2 + E[J^{a2}] + 2E[J^d J^a]) - p_i^2(\theta_d+\theta_a)^2,
\end{aligned}
$$

where we recall that ξ_d is the fraction of the variance of the Gaussian ϵ shock that is common across all stocks. The correlation between two stocks is the ratio of the covariance to the variance (given symmetry).

B.3 Equity Risk premium

By analogy with the derivations above, we have

$$
\begin{aligned}
E[J^c] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} E[J^c|n] = \theta_c, \\
E[J^d J^c] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} (n\theta_d)(n\theta_d) = 2\theta_c\theta_d, \\
E[J^a J^c] &= \sum_{n=1}^{\infty} \frac{e^{-\omega}\omega^n}{n!} n\theta_c E[J^a|n]
\end{aligned}
$$

We also have

$$
\begin{aligned}
m^{ND} &= \mu_{mij} - \gamma\sigma_{ci}\eta, \\
m^D &= \mu_{mij} - \gamma\sigma_{ci}\eta + \gamma J^c, \\
\mu_{mij} &= \alpha\log\beta + (\alpha-1)(\kappa_0^c + wc_j - \kappa_1^c wc_i) - \gamma\mu_c,
\end{aligned}
$$

The equity risk premium is $-Cov(m, r)$, which can be derived similarly to the covariance between two returns. In particular:

$$\begin{aligned}
Cov[m_i, r_i] &= (1-p_i)E[m_i^{ND} r_i^{ND}] + p_i E[m_i^D r_i^D] \\
&\quad - \left[(1-p_i)E[m_i^{ND}] + p_i E[m_i^D]\right] \left[(1-p_i)E[r_i^{ND}] + p_i E[r_i^D]\right], \\
&= (1-p_i)\left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij}\mu_{mij} - \gamma\phi_d\sigma_{ci}^2\right] \\
&\quad + p_i\left[\sum_{j=1}^{I} \pi_{ij}\mu_{rij}\mu_{mij} - \gamma\phi_d\sigma_{ci}^2 - \gamma E[J^d J^c] - \gamma E[J^a J^c] + \gamma\sum_{j=1}^{I}\pi_{ij}\mu_{rij}\theta_c - \sum_{j=1}^{I}\pi_{ij}\mu_{mij}(\theta_d+\theta_a)\right] \\
&\quad - \left[\sum_{j=1}^{I}\pi_{ij}\mu_{mij} + p_i\gamma\theta_c\right]\left[\sum_{j=1}^{I}\pi_{ij}\mu_{rij} - p_i(\theta_d+\theta_a)\right] \\
&= \zeta_{mi} - \gamma\phi_d\sigma_{ci}^2 - p_i\gamma(2\theta_d\theta_c + E[J^d J^a]) + p_i^2\gamma\theta_c(\theta_d+\theta_a),
\end{aligned}$$

where

$$\zeta_{mi} \equiv \sum_{j=1}^{I}\pi_{ij}\mu_{rij}\mu_{mij} - \left(\sum_{j=1}^{I}\pi_{ij}\mu_{rij}\right)\left(\sum_{j=1}^{I}\pi_{ij}\mu_{mij}\right).$$

B.4 Option Pricing in the Disaster State

We condition on the disaster state occurring in the next period, on a transition from state i to state j and on a known number of jumps n for the jump variables. Later we will average over the possible values for each. The put option value in this state is:

$$\begin{aligned}
Put_{ijn}^D &= E\left[M^D(K-R^D)1_{K>R^D}\right] \\
&= -E\left[\exp\left(m^D + r^D\right)1_{k>r^D}\right] + KE\left[\exp\left(m^D\right)1_{k>r^D}\right] \\
&= -Put_{ijn1}^D + Put_{ijn2}^D.
\end{aligned}$$

We now develop the two terms. For ease of notation, let $V_1^D = Put_{ijn1}^D$ and $V_2^D = Put_{ijn2}^D$.

Recall that $\tilde{r} = r^{ND} - J_i$ and $r^D = \tilde{r} - min(J^r, \underline{J})$. Our derivation below exploits the normality of the following two random variables:

$$\begin{aligned}
m^D &= \mu_{mj} - \gamma\sigma_{ci}\eta + \gamma J_c \sim N(\mu_m + \gamma n\theta_c, \sigma_m^2 + \gamma^2 n\delta_c^2) \\
\tilde{r} &= \mu_{rj} + \phi\sigma_{ci}\eta + \sigma_{di}\epsilon - J^i \sim N(\mu_{rj} - n\theta_i, \sigma_{\tilde{r}}^2) \\
\sigma_{\tilde{r}}^2 &= \sigma_r^2 + n\delta_i^2, \quad \sigma_{m^D,\tilde{r}} = \sigma_{m,r} = -\gamma\phi\sigma_{ci}^2
\end{aligned}$$

First term V_1^D

$$\begin{aligned}
V_1^D &= E\left[\exp\left(m^D + r^D\right)1_{k>r^D}1_{J^r<\underline{J}}\right] + E\left[\exp\left(m^D + r^D\right)1_{k>r^D}1_{J^r>\underline{J}}\right] \\
&= E\left[\exp\left(m^D + r^{ND} - J_i - J^r\right)1_{k>r^D}1_{J^r<\underline{J}}\right] + E\left[\exp\left(m^D + r^{ND} - J_i - \underline{J}\right)1_{k>r^D}1_{J^r>\underline{J}}\right] \\
&= V_{11}^D + V_{12}^D
\end{aligned}$$

The first term V_{11}^D can be solved as follows:

$$\begin{aligned}
V_{11}^D &= E\left[\exp\left(m^D + \tilde{r} - J^r\right) 1_{k>r^D} 1_{J^r<\underline{J}}\right] \\
&= E\left[E\left\{\exp\left(m^D + \tilde{r} - J^r\right) 1_{k+J^r>\tilde{r}} | J^r\right\} \mid 1_{J^r<\underline{J}}\right] \\
&= E\left[E\left\{\exp\left(m^D + \tilde{r}\right) 1_{k+J^r>\tilde{r}} | J^r\right\} \exp\left(-J^r\right) 1_{J^r<\underline{J}}\right] \\
&= \Psi(1,1;m^D,\tilde{r}) E\left[\Phi\left(\phi_0 + \phi_1 J^r\right) \exp\left(-J^r\right) 1_{J^r<\underline{J}}\right] \quad \text{by Lemma 1} \\
&= \Psi(1,1;m^D,\tilde{r}) \exp(z_1) \Phi\left(\frac{\phi_0 - t_1}{\sqrt{1+\phi_1^2 n\delta_r^2}}, \frac{\underline{J} - t_2}{\sqrt{n}\delta_r}; \rho\right) \quad \text{by Lemma 2}
\end{aligned}$$

where $\phi_1 = \frac{1}{\sigma_{\tilde{r}}}$, $\phi_0 = \phi_1\left(k - \mu_{rj} + n\theta_i - \sigma_{\tilde{r}}^2 - \sigma_{m^D,\tilde{r}}\right)$, $t_2 = n(\theta_r - \delta_r^2)$, $t_1 = -\phi_1 t_2$, $\rho = \frac{-\phi_1\sqrt{n}\delta_r}{\sqrt{1+\phi_1^2 n\delta_r^2}}$, and $z_1 = \frac{n\delta_r^2}{2} - n\theta_r$.

Next, we turn to V_{12}^D:

$$\begin{aligned}
V_{12}^D &= E\left[\exp\left(m^D + r^{ND} - J_i - \underline{J}\right) 1_{k>r^D} 1_{J^r>\underline{J}}\right] \\
&= \exp(-\underline{J}) E\left[\exp\left(m^D + \tilde{r}\right) 1_{k+\underline{J}>\tilde{r}}\right] \Phi\left(\frac{n\theta_r - \underline{J}}{\delta_r\sqrt{n}}\right) \\
&= \Psi(1,1;m^D,\tilde{r}) \exp(-\underline{J}) \Phi\left(\frac{\underline{J} + k - \mu_{rj} + n\theta_i - \sigma_{\tilde{r}}^2 - \sigma_{m^D,\tilde{r}}}{\sigma_{\tilde{r}}}\right) \Phi\left(\frac{n\theta_r - \underline{J}}{\delta_r\sqrt{n}}\right) \quad \text{by Lemma 1}
\end{aligned}$$

Second term V_2^D

$$\begin{aligned}
V_2^D &= KE\left[\exp\left(m^D\right) 1_{k>r^D}\right] \\
&= KE\left[\exp\left(m^D\right) 1_{k>r^D} 1_{J^r<\underline{J}}\right] + KE\left[\exp\left(m^D\right) 1_{k>r^D} 1_{J^r>\underline{J}}\right] \\
&= V_{21}^D + V_{22}^D
\end{aligned}$$

The first term V_{21}^D can be solved as follows:

$$\begin{aligned}
V_{21}^D &= KE\left[\exp\left(m^D\right) 1_{k>r^D} 1_{J^r<\underline{J}}\right] \\
&= KE\left[E\left\{\exp\left(m^D\right) 1_{k+J^r>\tilde{r}} | J^r\right\} 1_{J^r<\underline{J}}\right] \\
&= K\Psi(1,0;m^D,\tilde{r}) E\left[\Phi\left(\phi_0 + \phi_1 J^r\right) 1_{J^r<\underline{J}}\right] \quad \text{by Lemma 1} \\
&= K\Psi(1,0;m^D,\tilde{r}) \Phi\left(\frac{\phi_0 - t_1}{\sqrt{1+\phi_1^2 n\delta_r^2}}, \frac{\underline{J} - t_2}{\sqrt{n}\delta_r}; \rho\right) \quad \text{by Lemma 2}
\end{aligned}$$

where $\phi_1 = \frac{1}{\sigma(\tilde{r})}$, $\phi_0 = \phi_1\left(k - \mu_{rj} + n\theta_i - \sigma_{m^D,\tilde{r}}\right)$, $t_2 = n\theta_r$, $t_1 = -\phi_1 t_2$, $\rho = \frac{-\phi_1\sqrt{n}\delta_r}{\sqrt{1+\phi_1^2 n\delta_r^2}}$, and $z_1 = 0$. Because $z_1 = 0$, $\exp(z_1) = 1$, and we have dropped that term from the expression.

Finally, we turn to V_{22}^D:

$$\begin{aligned}
V_{22}^D &= KE\left[\exp\left(m^D\right)1_{k>r^D}1_{J^r>\underline{J}}\right] \\
&= KE\left[\exp\left(m^D\right)1_{k+\underline{J}>\tilde{r}}1_{J^r>\underline{J}}\right] \\
&= KE\left[\exp\left(m^D\right)1_{k+\underline{J}>\tilde{r}}\right]\Phi\left(\frac{n\theta_r-\underline{J}}{\delta_r\sqrt{n}}\right) \\
&= K\Psi(1,0;m^D,\tilde{r})\Phi\left(\frac{\underline{J}+k-\mu_{rj}+n\theta_i-\sigma_{m^D,\tilde{r}}}{\sigma_{\tilde{r}}}\right)\Phi\left(\frac{n\theta_r-\underline{J}}{\delta_r\sqrt{n}}\right) \quad \text{by Lemma 1}
\end{aligned}$$

B.5 Option Pricing Absent Bailout Guarantees

Absent bailout options (NB), $J^a = J^r$, and we obtain substantial simplification to the general formula. This special case arises as $\underline{J} \to +\infty$. In that case, the second terms of equations (9) and (10) are zero. In both first terms, the bivariate CDF simplifies to a univariate CDF.

$$\begin{aligned}
Put_{ijn}^{D,NB} &= -\Psi(1,1;m^D,\tilde{r})e^{n(-\theta_r+.5\delta_r^2)}\Phi\left(d_{jn}^{NB}-\sqrt{\sigma_r^2+n(\delta_i^2+\delta_r^2)}\right)+K\Psi(1,0;m^D,\tilde{r})\Phi\left(d_{jn}^{NB}\right) \\
&= -\exp\left(\mu_{mj}+\mu_{rj}+.5\sigma_m^2+.5\sigma_r^2+\sigma_{m,r}+n(\gamma\delta_c-\theta_i-\theta_r)+.5n(\gamma^2\delta_c^2+\delta_i^2+\delta_r^2)\right) \\
&\quad \times\Phi\left(d_{jn}^{NB}-\sqrt{\sigma_r^2+n(\delta_i^2+\delta_r^2)}\right)+K\exp\left(\mu_{mj}+.5\sigma_m^2+n\gamma\delta_c+.5n\gamma^2\delta_c^2\right)\Phi\left(d_{jn}^{NB}\right) \\
&= \exp\left(n\gamma\delta_c+.5n\gamma^2\delta_c^2\right)\left\{-\Psi(1,1;m^{ND},r^{ND})\exp\left(n(-\theta_i-\theta_r)+.5n(\delta_i^2+\delta_r^2)\right)\right. \\
&\quad \left.\times\Phi\left(d_{jn}^{NB}-\sqrt{\sigma_r^2+n(\delta_i^2+\delta_r^2)}\right)+Ke^{-r_{ij}^{f,ND}}\Phi\left(d_{jn}^{NB}\right)\right\}
\end{aligned}$$

with

$$d_{jn}^{NB}=\frac{k-\mu_{rj}+n(\theta_i+\theta_r)-\sigma_{m^D,\tilde{r}}}{\sqrt{\sigma_r^2+n\delta_i^2+n\delta_r^2}}$$

This equation is the counter-part of the Black-Scholes formula in equation (8), except that the mean and volatility of returns are adjusted for the jumps. Indeed, absent bailout options, log returns are normally distributed conditional on a given number of jumps n. We note that the expression for d^{NB} is in terms of the moments of the risk-neutral distribution of log returns. In particular, the risk-neutral mean is

$$\mu_{rj}^*=\mu_{rj}-n(\theta_i+\theta_r)-(-\sigma_{m^D,\tilde{r}}).$$

Thus the risk-neutral mean of the jump size equals the physical mean ($\theta_i^*=\theta_i$ and $\theta_r^*=\theta_r$), which follows from the fact that the jump sizes of the J^r and the J^i processes are independent of those of aggregate consumption J^c. The risk-neutral variance of log returns is equal to the physical variance, as usual ($\sigma_r^*=\sigma_r$, $\delta_i^*=\delta_i$ and $\delta_r^*=\delta_r$). The risk-neutral jump intensity is increased from the physical one as follows: $\omega^*=\omega\exp\left(\gamma\theta_c+.5\gamma^2\delta_c^2\right)$. To see this, note that the term $\exp\left(n\gamma\delta_c+.5n\gamma^2\delta_c^2\right)$, which factors out of the put price, can be folded into the Poisson weights when we sum over all possible number of jumps as in equation (11):

$$\sum_{n=1}^{\infty}\frac{e^{-\omega}\omega^n}{n!}\exp\left(n(\gamma\theta_c+.5\gamma^2\delta_c^2)\right)\cdots=\sum_{n=1}^{\infty}\frac{e^{-\omega^*}\omega^{*n}}{n!}\cdots$$

We recover the formulae of Backus, Chernov, and Martin (2011).

Table I: Basket-Index Spreads on Out-f-the-Money Options

		Financials		Non-financials		F Minus NF			Financials		Non-financials		F Minus NF		
		Puts	Calls	Puts	Calls	Puts	Calls	P Minus C	Puts	Calls	Puts	Calls	Puts	Calls	P Minus C
		Panel I: Delta-matched $TTM = 365$							Panel II: Share-weighted Strike Matched $TTM = 365$						
Full Sample	mean	1.693	0.238	1.106	0.208	0.588	0.030	0.558	2.936	0.990	2.686	2.019	0.250	-1.029	1.279
	std	1.891	0.157	0.686	0.094	1.435	0.100	1.506	2.516	0.100	1.076	0.246	1.693	0.194	1.846
	min	-0.133	-0.437	-0.122	-0.253	-1.899	-0.498	-1.732	1.019	0.632	1.265	1.663	-2.031	-1.943	-0.887
	max	12.458	0.487	4.128	0.359	9.070	0.440	9.568	15.872	1.273	7.579	2.754	10.168	-0.709	12.111
Pre-Crisis	mean	0.810	0.315	0.911	0.249	-0.098	0.067	-0.165	1.710	0.951	2.259	1.896	-0.549	-0.945	0.396
	std	0.197	0.056	0.442	0.052	0.335	0.052	0.326	0.345	0.070	0.587	0.128	0.329	0.085	0.269
	min	0.078	2.593	3.265	-0.033	-1.899	0.942	1.410	1.061	2.322	4.070	1.265	-2.031	0.942	1.943
	max	2.269	5.462	8.090	3.090	0.953	2.082	2.201	3.763	5.097	9.651	4.567	0.444	2.082	3.101
Crisis	mean	3.792	0.055	1.572	0.111	2.220	-0.057	2.277	5.851	1.082	3.702	2.313	2.149	-1.230	3.379
	std	2.393	0.166	0.904	0.100	1.705	0.130	1.791	3.006	0.101	1.274	0.206	2.076	0.230	2.253
	min	-0.133	-0.437	-0.122	-0.253	-0.538	-0.498	-0.740	1.019	0.632	1.776	1.867	-1.203	-1.943	-0.223
	max	12.458	0.370	4.128	0.285	9.070	0.440	9.568	15.872	1.273	7.579	2.754	10.168	-0.709	12.111
		Panel III: Delta-matched, $TTM = 30$							Panel IV: Share-weighted Strike Matched, $TTM = 30$						
Full Sample	mean	0.302	0.139	0.158	0.116	0.145	0.023	0.122	0.683	0.430	0.576	0.559	0.107	-0.129	0.236
	std	0.334	0.064	0.136	0.054	0.274	0.085	0.302	0.612	0.156	0.251	0.156	0.414	0.076	0.405
	min	-0.150	-0.312	-0.831	-0.202	-0.415	-0.433	-0.424	0.170	-0.010	-0.529	0.241	-0.385	-0.613	-0.207
	max	2.458	0.272	0.651	0.240	1.865	0.324	2.031	3.977	1.081	1.976	1.308	2.663	0.204	2.777
Pre-Crisis	mean	0.170	0.155	0.129	0.105	0.042	0.051	-0.009	0.400	0.352	0.476	0.483	-0.076	-0.131	0.055
	std	0.063	0.054	0.110	0.052	0.119	0.072	0.095	0.074	0.047	0.137	0.070	0.118	0.071	0.090
	min	-0.072	-0.227	-0.831	-0.103	-0.316	-0.347	-0.424	0.170	0.535	0.948	-0.529	-0.385	0.236	0.636
	max	0.376	0.270	0.511	0.240	0.996	0.324	0.869	0.757	1.710	2.257	0.947	0.860	0.954	1.384
Crisis Sample	mean	0.617	0.100	0.228	0.144	0.389	-0.044	0.434	1.360	0.618	0.814	0.743	0.546	-0.126	0.671
	std	0.476	0.071	0.163	0.048	0.367	0.077	0.386	0.782	0.165	0.297	0.151	0.527	0.085	0.518
	min	-0.150	-0.312	-0.139	-0.202	-0.415	-0.433	-0.185	0.245	0.159	0.359	0.361	-0.181	-0.613	-0.014
	max	2.458	0.272	0.651	0.238	1.865	0.253	2.031	3.977	1.081	1.976	1.308	2.663	0.204	2.777

This table reports summary statistics for the basket-index spread in the cost of insurance per dollar insured. Numbers reported are in cents per dollar of the underlying. The full sample covers 1/2003-6/2009. The pre-crisis sample covers 1/2003-7/2007. The crisis sample covers 8/2007-6/2009. $|\Delta|$ is 20. In the top panel, Time to maturity is 365 days. In Panel I, we choose the index option with the same Δ as the individual options. In Panel II, we choose the index option with the same share-weighted strike price as the basket.

Table II: Summary Stats for Spreads on Options sorted by Moneyness

		Financials		Non-financials		F Minus NF			Financials		Non-financials		F Minus NF		
		Puts	Calls	Puts	Calls	Puts	Calls	P Minus C	Puts	Calls	Puts	Calls	Puts	Calls	P Minus C
		$\lvert\Delta\rvert = 20$							$\lvert\Delta\rvert = 30$						
Full	mean	1.693	0.238	1.106	0.208	0.588	0.030	0.558	2.133	0.459	1.514	0.421	0.621	0.039	0.582
	std	1.891	0.157	0.686	0.094	1.435	0.100	1.506	2.030	0.289	0.761	0.155	1.507	0.201	1.646
	min	-0.133	-0.437	-0.122	-0.253	-1.899	-0.498	-1.732	0.227	-1.036	-0.023	-0.285	-2.214	-1.186	-1.839
	max	12.458	0.487	4.128	0.359	9.070	0.440	9.568	14.090	0.843	5.345	0.683	11.002	0.789	11.691
Pre-Crisis	mean	0.810	0.315	0.911	0.249	-0.098	0.067	-0.165	1.193	0.593	1.292	0.489	-0.096	0.104	-0.201
	std	0.197	0.056	0.442	0.052	0.335	0.052	0.326	0.293	0.105	0.480	0.084	0.338	0.106	0.290
	min	0.078	2.593	3.265	-0.033	-1.899	0.942	1.410	0.227	0.101	-0.023	0.269	-2.214	-0.442	-1.839
	max	2.269	5.462	8.090	3.090	0.953	2.082	2.201	2.454	0.843	3.762	0.683	1.483	0.342	1.308
Crisis	mean	3.792	0.055	1.572	0.111	2.220	-0.057	2.277	4.370	0.142	2.042	0.258	2.328	-0.116	2.444
	std	2.393	0.166	0.904	0.100	1.705	0.130	1.791	2.573	0.336	1.006	0.165	1.807	0.277	2.007
	min	-0.133	-0.437	-0.122	-0.253	-0.538	-0.498	-0.740	0.479	-1.036	0.307	-0.285	-0.520	-1.186	-0.577
	max	12.458	0.370	4.128	0.285	9.070	0.440	9.568	14.090	0.753	5.345	0.577	11.002	0.789	11.691
		$\lvert\Delta\rvert = 40$							$\lvert\Delta\rvert = 50$						
Full	mean	2.581	0.763	1.968	0.702	0.615	0.062	0.553	3.083	1.161	2.487	1.079	0.599	0.083	0.516
	std	2.085	0.452	0.789	0.229	1.558	0.350	1.794	2.131	0.649	0.836	0.344	1.619	0.546	1.969
	min	0.522	-1.743	0.029	-0.241	-2.825	-2.154	-2.213	0.486	-2.770	0.348	-0.322	-4.086	-3.579	-2.737
	max	14.287	1.406	5.450	1.303	9.231	0.927	11.385	15.589	2.178	6.021	2.254	9.959	1.300	13.513
Pre-Crisis	mean	1.620	0.957	1.740	0.791	-0.116	0.167	-0.283	2.114	1.403	2.262	1.184	-0.145	0.221	-0.365
	std	0.305	0.175	0.519	0.152	0.441	0.191	0.378	0.328	0.278	0.586	0.266	0.514	0.277	0.394
	min	0.522	0.093	0.029	0.367	-2.825	-0.908	-2.213	0.586	0.375	0.348	0.173	-4.086	-1.349	-2.737
	max	2.955	1.406	4.771	1.303	2.033	0.584	1.705	4.015	2.178	5.895	2.254	2.290	1.187	1.734
Crisis	mean	4.867	0.303	2.511	0.490	2.356	-0.188	2.544	5.387	0.586	3.019	0.830	2.368	-0.244	2.613
	std	2.655	0.563	1.022	0.243	1.855	0.489	2.215	2.748	0.877	1.069	0.380	1.946	0.820	2.546
	min	0.643	-1.743	0.325	-0.241	-0.734	-2.154	-0.469	0.486	-2.770	0.719	-0.322	-1.287	-3.579	-1.246
	max	14.287	1.294	5.450	0.984	9.231	0.927	11.385	15.589	2.084	6.021	1.594	9.959	1.300	13.513

This table reports summary statistics for the basket-index spread in the cost of insurance per dollar insured. Numbers reported are in cents per dollar insured. The full sample covers 1/2003-6/2009. The pre-crisis sample covers 1/2003-7/2007. The crisis sample covers 8/2007-6/2009. We choose the index option with the same Δ as the individual options.

Table III: Percentage Basket-Index Spreads on Options with Varying Moneyness

		Financials		Non-financials	
		Puts	Calls	Puts	Calls
		$\|\Delta\| = 20$			
Full Sample	mean	29.69%	18.41%	25.23%	13.70%
	std	9.38%	11.95%	7.45%	7.09%
	max	80.53%	51.73%	64.48%	27.34%
Pre-Crisis Sample	mean	26.67%	24.68%	26.04%	16.91%
	std	5.78%	6.80%	7.47%	4.94%
	max	43.71%	51.73%	64.48%	0.36%
Crisis Sample	mean	36.86%	3.47%	23.28%	6.05%
	std	12.04%	7.46%	7.02%	5.38%
	max	80.53%	20.97%	44.97%	16.81%
		$\|\Delta\| = 30$			
Full Sample	mean	28.22%	19.29%	24.16%	14.97%
	std	7.66%	12.03%	5.73%	6.80%
	max	68.84%	48.15%	54.68%	28.54%
Pre-Crisis Sample	mean	26.84%	25.47%	25.19%	18.18%
	std	6.19%	7.09%	5.50%	4.46%
	max	44.00%	48.15%	54.68%	0.68%
Crisis Sample	mean	31.50%	4.41%	21.67%	7.25%
	std	9.61%	7.62%	5.48%	4.98%
	max	68.84%	22.08%	37.75%	18.57%
		$\|\Delta\| = 40$			
Full Sample	mean	27.99%	19.72%	24.27%	15.35%
	std	7.17%	11.91%	5.23%	6.46%
	max	57.82%	51.69%	50.85%	29.28%
Pre-Crisis Sample	mean	27.87%	25.69%	25.67%	18.29%
	std	6.78%	7.46%	4.96%	4.54%
	max	47.14%	51.69%	50.85%	1.30%
Crisis Sample	mean	28.22%	5.39%	20.89%	8.29%
	std	8.04%	7.57%	4.23%	4.68%
	max	57.82%	23.14%	33.41%	19.69%
		$\|\Delta\| = 50$			
Full Sample	mean	28.17%	19.49%	24.73%	15.52%
	std	7.26%	11.35%	5.42%	6.41%
	max	51.71%	55.53%	51.46%	29.75%
Pre-Crisis Sample	mean	29.02%	24.93%	26.49%	18.21%
	std	7.13%	7.62%	5.03%	4.92%
	max	47.47%	55.53%	51.46%	2.24%
Crisis Sample	mean	26.11%	6.43%	20.48%	9.07%
	std	7.19%	7.53%	3.69%	4.73%
	max	51.71%	24.35%	32.70%	21.26%

This table reports summary statistics for the basket-index spread. Numbers reported are in percent of the cost of the index put. The full sample covers 1/2003-6/2009. The pre-crisis sample covers 1/2003-7/2007. The crisis sample covers 8/2007-6/2009. $|\Delta|$ is 20. We choose the index option with the same Δ as the individual options.

Table IV: Option Prices in Model and Data

The table reports option prices and implied volatility for the financial sector index, for its constituents, and pairwise correlations between the stocks in the financial sector index.

	Puts			Calls		
	Basket	Index	Spread	Basket	Index	Spread
			Panel I: Data			
			Option Prices			
pre-crisis	4.0	3.2	0.8	1.6	1.3	0.3
crisis	13.7	9.9	3.8	2.4	2.3	0.1
			Implied Vol			
pre-crisis	25.9	21.7	4.2	19.8	14.9	4.9
crisis	59.5	48.5	11.0	42.8	37.8	5.0
			Panel II: Model with Bailout			
			Option Prices			
pre-crisis	4.3	4.1	0.3	1.5	1.2	0.4
crisis	13.7	9.9	3.8	2.5	2.3	0.2
pre-crisis	34.1	31.2	2.9	17.4	11.0	6.5
crisis	61.3	46.7	14.6	35.0	24.1	10.9
			Panel III: Model without Bailout			
			Option Prices			
pre-crisis	3.8	3.4	0.4	1.5	1.6	-0.1
crisis	13.7	9.9	3.8	2.6	2.3	0.3
			Implied Vol			
pre-crisis	32.2	29.2	3.0	17.7	18.2	-0.5
crisis	62.9	48.6	14.3	61.0	27.7	33.3

Table V: Return Moments in Model and Data

The table reports realized volatility for the financial sector index, for its constituents, and pairwise correlations between the stocks in the financial sector index. The crisis numbers for the model represent the unconditional moment in state 2, taking disasters into account probabilistically. The number *in italic* for the model report the moments in state 2 of the model *conditional* on a disaster realization.

	Index	**Individual Stocks**	
	Volatility	Volatility	Correlations
		Panel I: Data	
pre-crisis	11.9	18.1	44.8
crisis	43.8	72.9	57.5
		Panel II: Model with Bailout	
pre-crisis	19.2	26.7	42.3
crisis	31.9	44.5	51.1
	46.4	*69.5*	*40.7*
		Panel III: Model without Bailout	
pre-crisis	18.7	26.0	43.8
crisis	28.7	44.4	35.8
	42.8	*76.7*	*26.7*

Table VI: Option Prices in Model and Data in Non-Financial Sector

The table reports option prices and implied volatility for the non-financial sector index, for its constituents, and pairwise correlations between the stocks in the financial sector index.

	Puts			Calls		
	Basket	Index	Spread	Basket	Index	Spread
			Panel I: Data			
			Option Prices			
pre-crisis	4.3	3.4	0.9	1.8	1.5	0.3
crisis	7.9	6.3	1.6	2.2	2.0	0.1
			Implied Vol			
pre-crisis	28.6	21.7	6.9	23.2	15.9	7.3
crisis	41.7	34.2	7.5	32.1	24.3	7.8
			Panel II: Model without Bailout			
			Option Prices			
pre-crisis	2.8	2.3	0.5	1.5	0.9	0.6
crisis	7.9	6.3	1.6	2.0	1.6	0.4
			Implied Vol			
pre-crisis	27.1	22.4	4.7	17.0	8.4	8.6
crisis	42.6	35.6	7.0	25.1	20.0	5.1

Table VII: Return Moments in Model and Data in Non-financial Sector

The table reports realized volatility for the financial sector index, for its constituents, and pairwise correlations between the stocks in the non-financial sector index. The crisis numbers for the model represent the unconditional moment in state 2, taking disasters into account probabilistically. The number *in italic* for the model report the moments in state 2 of the model *conditional* on a disaster realization.

	Index	**Individual Stocks**	
	Volatility	Volatility	Correlations
		Panel I: Data	
pre-crisis	12.2	21.5	33.6
crisis	25.1	35.1	57.1
		Panel II: Model without Bailout	
pre-crisis	12.7	20.7	33.2
crisis	19.9	27.7	48.2
	28.7	*39.5*	*50.1*

Table VIII: Liquidity in Puts

	$0 \leq \|\Delta\| < 20$				$20 \leq \|\Delta\| < 50$				$50 \leq \|\Delta\| < 80$				$80 \leq \|\Delta\| < 100$			
	Spr. ($)	Spr. (%)	Vol.	O.I.	Spr. ($)	Spr. (%)	Vol.	O.I.	Spr. ($)	Spr. (%)	Vol.	O.I.	Spr. ($)	Spr. (%)	Vol.	O.I.
Pre-Crisis Sample	**10 Days < *TTM* ≤ 90 Days**															
S&P 500	0.450	80.5%	1072	15783	1.295	9.4%	2219	16594	1.821	5.8%	693	6807	1.959	3.7%	93	3138
All Sector SPDRs	0.133	150.5%	80	3205	0.141	35.0%	867	7606	0.167	13.7%	269	3221	0.239	7.9%	26	339
Financial SPDR	0.096	142.3%	187	10494	0.109	30.9%	1791	19708	0.125	12.4%	502	7907	0.182	7.0%	44	689
Indiv. Stocks	0.088	106.3%	169	5447	0.106	13.2%	836	9225	0.152	6.2%	473	5990	0.230	3.1%	76	1550
Fin. Indiv. Stocks	0.095	103.5%	142	4534	0.116	13.4%	691	7667	0.169	6.4%	380	4888	0.254	3.3%	65	1288
	90 Days < *TTM* ≤ 180 Days															
S&P 500	0.701	56.3%	373	18107	1.719	6.9%	1242	22052	1.982	3.4%	198	5962	2.076	1.5%	14	1949
All Sector SPDRs	0.141	96.0%	21	1132	0.156	19.0%	163	3057	0.198	8.7%	40	1258	0.273	6.3%	3	118
Financial SPDR	0.103	71.0%	103	4307	0.119	16.8%	452	13713	0.142	7.6%	96	3891	0.182	4.9%	16	347
Indiv. Stocks	0.094	72.4%	66	4326	0.133	8.1%	278	7760	0.196	4.3%	123	4622	0.242	2.3%	21	1138
Fin. Indiv. Stocks	0.103	68.4%	56	3445	0.147	8.3%	229	6509	0.216	4.4%	103	3565	0.271	2.5%	18	807
	180 Days < *TTM* ≤ 365 Days															
S&P 500	1.067	33.7%	237	12015	2.093	5.5%	400	10895	2.185	2.6%	52	2837	2.174	1.1%	4	1359
All Sector SPDRs	0.130	60.6%	9	857	0.156	12.8%	45	1290	0.203	6.8%	10	593	0.273	4.7%	2	129
Financial SPDR	0.095	47.5%	24	2448	0.105	10.8%	287	7823	0.139	5.6%	53	3313	0.188	4.0%	4	128
Indiv. Stocks	0.103	55.3%	52	4432	0.156	6.8%	170	6880	0.224	3.8%	65	4040	0.255	2.1%	15	1208
Fin. Indiv. Stocks	0.112	49.8%	48	3782	0.174	7.0%	130	5582	0.247	3.9%	50	2972	0.278	2.2%	11	756
Crisis Sample	**10 Days < *TTM* ≤ 90 Days**															
S&P 500	1.120	61.7%	1369	14797	2.663	9.4%	2652	18992	2.974	4.5%	871	14305	3.033	2.4%	120	9284
All Sector SPDRs	0.087	59.4%	667	8801	0.130	11.8%	2849	20540	0.226	6.9%	963	12846	0.388	4.8%	72	3724
Financial SPDR	0.042	24.7%	4422	52042	0.054	6.5%	12983	88367	0.107	4.4%	4336	56684	0.206	3.7%	376	19916
Indiv. Stocks	0.108	55.5%	344	5590	0.153	7.9%	1170	9400	0.244	4.5%	529	6857	0.481	2.9%	87	2404
Fin. Indiv. Stocks	0.126	56.2%	296	4390	0.181	8.1%	1041	8047	0.288	4.6%	452	5741	0.516	3.0%	83	2435
	90 Days < *TTM* ≤ 180 Days															
S&P 500	1.723	35.2%	568	16641	3.003	6.2%	1147	18511	3.179	2.8%	212	12697	3.255	1.3%	25	7625
All Sector SPDRs	0.112	31.1%	209	4218	0.184	8.1%	527	8681	0.286	4.9%	162	5310	0.407	3.6%	17	1598
Financial SPDR	0.055	18.7%	1421	24285	0.079	5.3%	3012	49466	0.159	4.0%	1008	28769	0.227	3.0%	129	8338
Indiv. Stocks	0.133	38.2%	119	4640	0.214	5.5%	339	7705	0.318	3.2%	115	4908	0.492	2.2%	15	1593
Fin. Indiv. Stocks	0.154	37.9%	106	3405	0.253	5.6%	301	6235	0.376	3.3%	94	4085	0.536	2.2%	16	1637
	180 Days < *TTM* ≤ 365 Days															
S&P 500	2.402	22.3%	272	12355	3.409	4.7%	507	13293	3.538	2.1%	60	7814	3.593	1.1%	8	5226
All Sector SPDRs	0.177	22.1%	57	1693	0.300	7.8%	169	3428	0.410	4.8%	50	3257	0.474	3.3%	44	1818
Financial SPDR	0.057	12.9%	238	7318	0.089	4.5%	1049	19391	0.170	3.5%	300	13661	0.219	2.4%	121	6042
Indiv. Stocks	0.186	30.4%	69	2713	0.294	5.5%	173	5372	0.423	3.1%	55	3653	0.623	2.2%	9	1269
Fin. Indiv. Stocks	0.208	30.6%	54	1984	0.338	5.8%	162	4654	0.474	3.3%	47	3529	0.630	2.3%	9	1459

The full sample covers 1/2003-6/2009. The pre-crisis sample covers 1/2003-7/2007. The crisis sample covers 8/2007-6/2009. The stats reported for individual and sector options are value-weighted.

Table IX: Liquidity in Calls

	$0 \leq \|\Delta\| < 20$				$20 \leq \|\Delta\| < 50$				$50 \leq \|\Delta\| < 80$				$80 \leq \|\Delta\| < 100$			
	Spr. ($)	Spr. (%)	Vol.	O.I.	Spr. ($)	Spr. (%)	Vol.	O.I.	Spr. ($)	Spr. (%)	Vol.	O.I.	Spr. ($)	Spr. (%)	Vol.	O.I.
Pre-Crisis Sample								**10 Days < TTM ≤ 90 Days**								
S&P 500	0.405	96.9%	1002	11990	1.204	10.3%	1598	12885	1.836	5.3%	930	11351	2.006	1.9%	71	3476
All Sector SPDRs	0.123	169.3%	23	745	0.135	42.3%	262	2970	0.160	14.3%	187	2790	0.236	7.4%	16	931
Financial SPDR	0.081	177.4%	22	1497	0.107	38.2%	512	6477	0.129	13.4%	311	6428	0.183	6.7%	28	1995
Indiv. Stocks	0.077	140.7%	203	5916	0.100	14.6%	1430	14839	0.144	6.1%	928	11702	0.229	3.1%	186	3840
Fin. Indiv. Stocks	0.083	138.1%	179	4926	0.110	15.1%	1145	11640	0.160	6.2%	738	9123	0.252	3.3%	142	3189
								90 Days < TTM ≤ 180 Days								
S&P 500	0.592	85.7%	301	10160	1.662	8.2%	703	17315	1.983	3.0%	364	13038	2.049	1.1%	22	3148
All Sector SPDRs	0.134	122.8%	8	434	0.154	24.1%	59	1481	0.195	9.1%	50	1365	0.282	5.9%	4	306
Financial SPDR	0.085	94.5%	12	1012	0.120	22.2%	134	4566	0.148	8.1%	109	3734	0.214	5.0%	7	748
Indiv. Stocks	0.082	112.2%	77	4798	0.122	9.5%	512	11756	0.187	4.5%	262	8052	0.251	2.4%	34	2248
Fin. Indiv. Stocks	0.089	111.2%	60	3468	0.136	9.9%	395	8320	0.207	4.6%	187	5686	0.279	2.5%	26	1567
								180 Days < TTM ≤ 365 Days								
S&P 500	0.872	50.0%	113	6705	2.001	6.9%	249	10021	2.198	2.3%	106	7283	2.224	0.9%	11	1200
Sector SPDRs	0.121	89.4%	3	455	0.151	17.2%	23	1070	0.204	7.0%	19	825	0.270	4.8%	2	258
Financial SPDR	0.088	64.8%	7	493	0.108	15.1%	48	2362	0.139	5.8%	45	2548	0.198	3.7%	3	497
Indiv. Stocks	0.090	93.6%	51	5189	0.143	8.5%	259	9021	0.215	4.1%	147	6730	0.271	2.2%	23	2363
Fin. Indiv. Stocks	0.096	96.1%	40	3962	0.158	8.9%	207	6783	0.238	4.3%	109	5349	0.292	2.3%	16	1877
Crisis Sample								**10 Days < TTM ≤ 90 Days**								
S&P 500	0.705	118.6%	580	10797	2.497	11.4%	1857	16012	2.968	4.3%	1047	9846	3.047	1.8%	50	2157
All Sector SPDRs	0.080	103.7%	390	7908	0.121	14.1%	3386	19642	0.211	7.2%	1552	11705	0.350	4.6%	98	2581
Financial SPDR	0.037	47.7%	3007	52259	0.050	8.5%	17312	93957	0.097	4.8%	8020	56259	0.178	4.0%	628	19025
Indiv. Stocks	0.094	96.6%	341	6754	0.141	9.5%	1623	11596	0.230	4.8%	838	7407	0.446	3.1%	103	2423
Fin. Indiv. Stocks	0.110	93.6%	293	5739	0.169	10.0%	1362	9587	0.263	4.9%	754	6157	0.490	3.3%	104	1742
								90 Days < TTM ≤ 180 Days								
S&P 500	1.067	97.4%	183	10138	2.913	8.8%	637	12846	3.167	3.0%	326	4394	3.219	1.3%	13	912
All Sector SPDRs	0.099	81.2%	109	4741	0.168	10.8%	480	7791	0.278	5.6%	219	3878	0.394	3.6%	19	702
Financial SPDR	0.051	50.3%	749	25321	0.077	8.2%	2916	42929	0.139	4.4%	1193	18780	0.219	3.5%	107	3391
Indiv. Stocks	0.118	75.5%	100	5023	0.197	7.5%	460	9358	0.299	3.9%	216	5972	0.496	2.5%	25	1818
Fin. Indiv. Stocks	0.136	73.9%	93	4523	0.236	7.9%	375	7207	0.350	4.1%	181	4543	0.537	2.7%	19	1269
								180 Days < TTM ≤ 365 Days								
S&P 500	1.625	66.6%	62	8211	3.420	7.7%	237	8752	3.500	2.5%	126	4713	3.485	1.1%	5	510
All Sector SPDRs	0.151	63.6%	45	2964	0.280	11.6%	162	4348	0.411	5.8%	77	2034	0.507	3.8%	6	431
Financial SPDR	0.054	35.2%	154	8949	0.088	7.5%	836	18346	0.151	4.1%	480	11201	0.207	3.0%	18	1960
Indiv. Stocks	0.159	62.1%	57	4033	0.274	8.0%	210	5991	0.395	4.2%	118	3886	0.609	2.8%	14	891
Fin. Indiv. Stocks	0.170	63.9%	54	4381	0.311	8.6%	190	5345	0.451	4.5%	103	3124	0.630	3.1%	13	702

The full sample covers 1/2003-6/2009. The pre-crisis sample covers 1/2003-7/2007. The crisis sample covers 8/2007-6/2009. The stats reported for individual and sector options are value-weighted.

Table X: Top 40 Holdings of the Financial Sector Index XLF

	12/30/2010		07/30/2007	
	Name	Weighting	Name	Weighting
1	JPMorgan Chase & Co.	9.01	CITIGROUP INC	11.1
2	Wells Fargo & Co.	8.86	BANK OF AMERICA CORP	10.14
3	Citigroup Inc.	7.54	AMERICAN INTERNATIONAL GROUP I	8.02
4	BERKSHIRE HATHAWAY B	7.52	JPMORGAN CHASE & Co	7.25
5	Bank of America Corp.	7.3	WELLS FARGO & Co NEW	5.44
6	Goldman Sachs Group Inc.	4.66	WACHOVIA CORP 2ND NEW	4.35
7	U.S. BANCORP	2.82	GOLDMAN SACHS GROUP INC	3.71
8	American Express Co.	2.44	AMERICAN EXPRESS CO	3.35
9	MORGAN STANLEY	2.25	MORGAN STANLEY DEAN WITTER & C	3.25
10	MetLife Inc.	2.21	MERRILL LYNCH & Co INC	3.11
11	Bank of New York Mellon Corp.	2.04	FEDERAL NATIONAL MORTGAGE ASSN	2.81
12	PNC Financial Services Group Inc.	1.75	U S BANCORP DEL	2.51
13	Simon Property Group Inc.	1.6	BANK OF NEW YORK MELLON CORP	2.32
14	Prudential Financial Inc.	1.56	METLIFE INC	2.15
15	AFLAC Inc.	1.45	PRUDENTIAL FINANCIAL INC	2
16	Travelers Cos. Inc.	1.39	FEDERAL HOME LOAN MORTGAGE COR	1.83
17	State Street Corp.	1.27	TRAVELERS COMPANIES INC	1.63
18	CME Group Inc. Cl A	1.18	WASHINGTON MUTUAL INC	1.61
19	ACE Ltd.	1.15	LEHMAN BROTHERS HOLDINGS INC	1.59
20	Capital One Financial Corp.	1.06	ALLSTATE CORP	1.56
21	BB&T Corp.	1	C M E GROUP INC	1.46
22	Chubb Corp.	0.99	CAPITAL ONE FINANCIAL CORP	1.41
23	Allstate Corp.	0.93	HARTFORD FINANCIAL SVCS GROUP	1.4
24	Charles Schwab Corp.	0.93	SUNTRUST BANKS INC	1.35
25	T. Rowe Price Group Inc.	0.89	STATE STREET CORP	1.28
26	Franklin Resources Inc.	0.87	A F L A C INC	1.23
27	AON Corp.	0.82	P N C FINANCIAL SERVICES GRP I	1.11
28	EQUITY RESIDENTIAL	0.81	REGIONS FINANCIAL CORP NEW	1.02
29	Marsh & McLennan Cos.	0.81	LOEWS CORP	1.02
30	SunTrust Banks Inc.	0.8	FRANKLIN RESOURCES INC	1.01
31	Ameriprise Financial Inc.	0.78	SCHWAB CHARLES CORP NEW	0.98
32	PUBLIC STORAGE	0.77	B B & T CORP	0.98
33	Vornado Realty Trust	0.74	FIFTH THIRD BANCORP	0.98
34	Northern Trust Corp.	0.73	CHUBB CORP	0.97
35	HCP Inc.	0.73	S L M CORP	0.97
36	Progressive Corp.	0.71	SIMON PROPERTY GROUP INC NEW	0.93
37	Loews Corp.	0.67	ACE LTD	0.91
38	Boston Properties Inc.	0.66	NATIONAL CITY CORP	0.82
39	Host Hotels & Resorts Inc.	0.64	COUNTRYWIDE FINANCIAL CORP	0.81
40	FIFTH THIRD BANCORP	0.64	LINCOLN NATIONAL CORP IN	0.79

This table reports the XLF weights on 12/30/2010 and 07/30/2007. On 12/30/2010, there were 81 companies in XLF; on 07/30/2007, there were 92 companies. This table reports the relative market capitalizations of the top 40 holdings of the index.

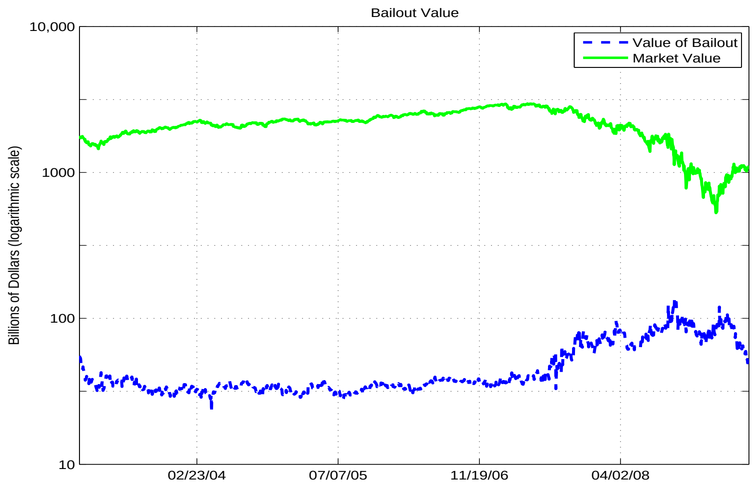

Figure 1: Dollar Value of the Equity Bailout Guarantee for the Financial Sector

The dashed (full) line shows the dollar value of the equity bailout guarantee inferred from the basket-index spreads for puts. $|\Delta|$ is 20. Time to maturity is 365 days. We choose the index options with the same Δ as the individual options.

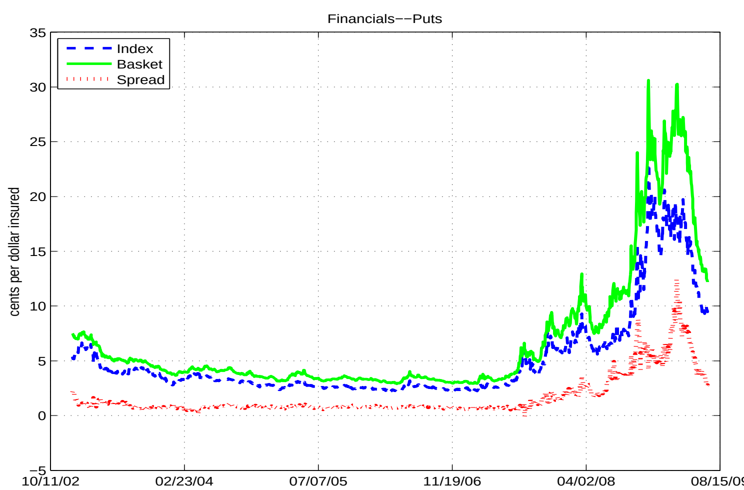

Figure 2: Cost Per Dollar Insured Inferred from Puts - Financial Sector

The dashed (full) line shows the cost per dollar insured for the index $Put_{cdi,F}^{index}$ (basket, $Put_{cdi,F}^{basket}$). The dotted line plots their difference. $|\Delta|$ is 20. Time to maturity is 365 days. We choose the index option with the same Δ as the individual options.

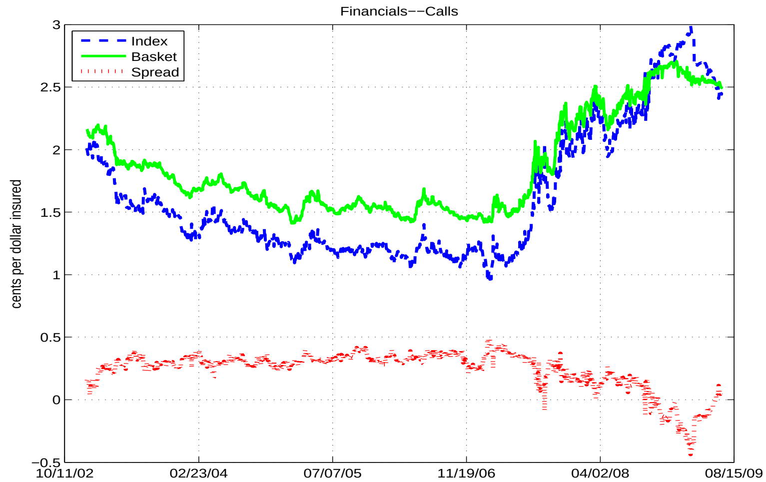

Figure 3: Cost Per Dollar Insured Inferred from Calls - Financial Sector

The dashed (full) line shows the cost per dollar insured for the index $Call_{cdi,F}^{index}$(basket, $Call_{cdi,F}^{basket}$). The dotted line plots their difference. $|\Delta|$ is 20. Time to maturity is 365 days. We choose the index option with the same Δ as the individual options.

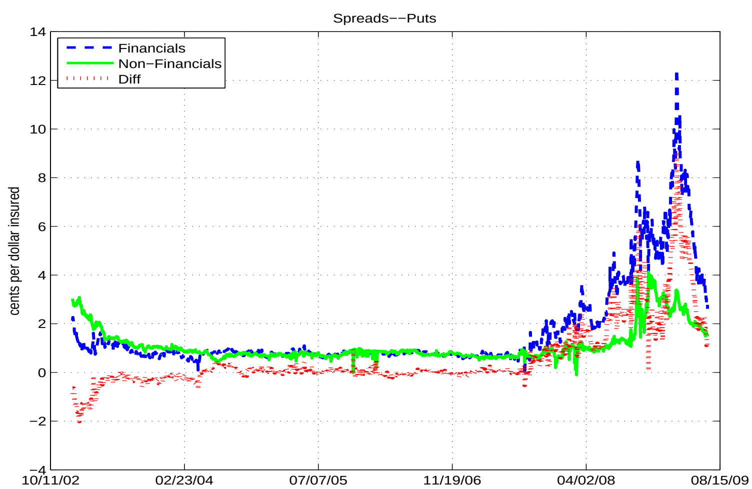

Figure 4: Basket-Index Spread in Cost Per Dollar Insured Inferred from Puts

The dashed (full) line shows the difference in the cost per dollar insured for the index $Put_{cdi,i}^{basket} - Put_{cdi,i}^{index}$ for financials (non-financials). The dotted line plots their difference. $|\Delta|$ is 20. Time to maturity is 365 days. We choose the index option with the same Δ as the individual options.

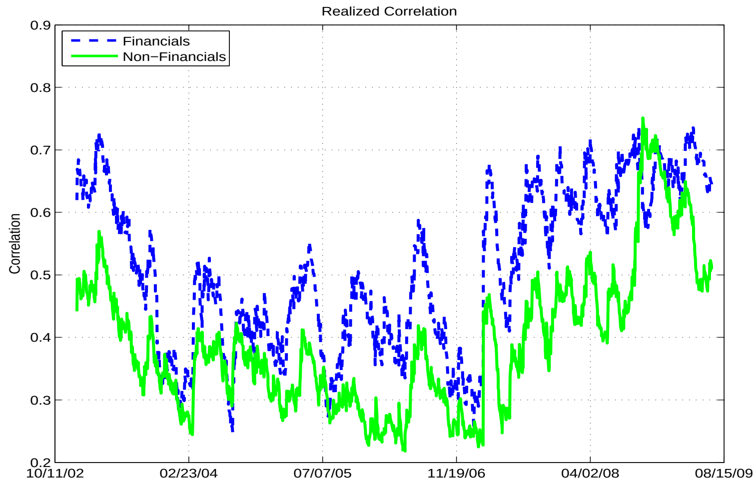

Figure 5: Realized Equity Return Correlations

The dashed (full) line shows the average pairwise correlations within the financial sector (non-financial sectors). Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the financial sector are then averaged each day, weighted by the pairs' combined market equity. To address stocks' entry into and exit from the S&P 500 index during the sample period, a pair's correlation is only included in the average on a given day if both stocks were members of the index that day. To remain comparable to the average pairwise correlation among financial stocks, the non-financials average correlation reflects only correlations between pairs of stocks within the same sector, omitting cross-sector correlations from the average.

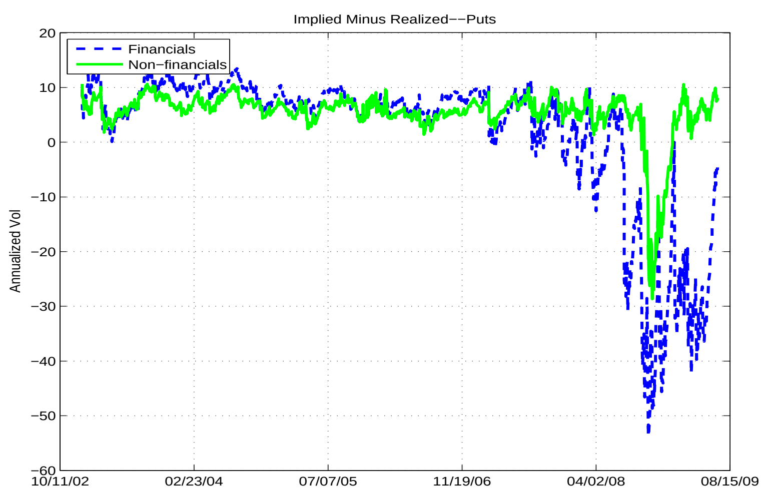

Figure 6: Implied minus Realized Vol Inferred from Puts

The figure shows the implied minus realized volatility difference for financial (dashed line) and non-financial (solid line) S&P sector indices. Realized volatilities for each sector are defined as daily conditional volatilities and are estimated by exponential smoothing with smoothing parameter 0.95. For non-financials, the daily volatility on day t is calculated as the weighted average volatility across non-financial sectors that day with weights based on the total market value of stocks within sectors. Daily implied volatilities are based on options with $|\Delta|$ of 20 and time to maturity of 365 days, and the non-financials number represents a value-weighted average across sectors.

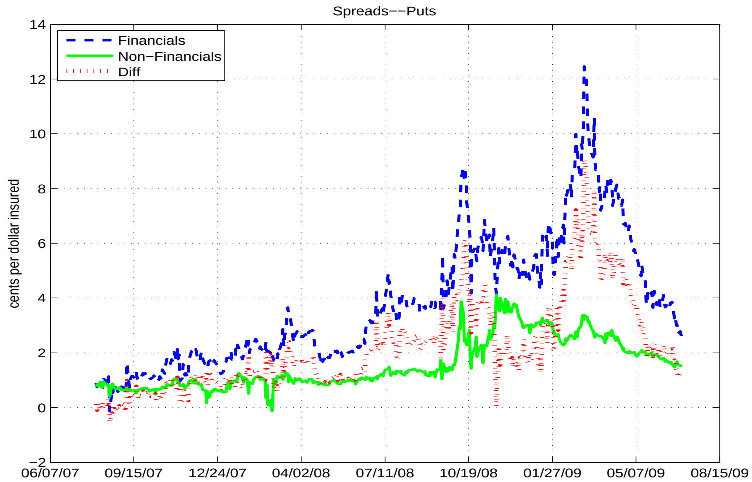

Figure 7: The Put Spread during the Financial Crisis

The dashed (solid) line shows the difference in the cost per dollar insured for the index $Put^{basket}_{cdi,i} - Put^{index}_{cdi,i}$ for financials (non-financials). The bottom line plots the difference.$|\Delta|$ is 20. Time to maturity is 365 days.