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

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October 21, 2011

*First draft: February 15, 2011. We thank Mikhail Chernov, Peter Christoffersen, John Cochrane, George Constantinides, Itamar Drechsler, Darrell Duffie, Willie Fuchs, Ralph Koijen, Martin Lettau, Matteo Maggiore, Marc Martos-Vila, Pascal Maenhout, Ian Martin, Robert McDonald, Thomas Philippon, Richard Roll, Mark Rubenstein, Stephen Ross, Rene Stulz, Ingrid Werner and seminar participants at SITE, Chicago Booth, the University of Southern California, the University of California at Berkeley, Los Angeles, the University of Toronto, the University of Utah, Tulane University, the Federal Reserve Bank of San Francisco, the Stanford University economics and finance departments, NYU Stern finance, the NYU-Maryland conference on systemic risk, the CMY macro-finance conference, and the NYU conference in honor of Thomas Sargent for comments and suggestions.

Abstract

During the crisis, the cost of a basket of individual out-of-the-money put options on all stocks in the financial index increased in relation to the cost of the index put option. 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 12.5 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. We argue that the government's collective guarantee partially absorbs financial sector-wide tail risk, which lowers index put prices but not individual put prices, and hence can explain the basket-index spread. A single factor model with a maximum sector-wide loss rate of 55% replicates the dynamics of the basket-index spread. Investors in option markets price in a substantial collective government bailout guarantee in the financial sector, which puts a floor on the equity value of the financial sector as a whole, but not on the value of the individual firms. The guarantee makes put options on the financial sector index cheap relative to put options on its member banks.

Keywords: systemic risk, government bailout, too-big-to-fail, option pricing models, disaster models, financial crisis
JEL codes: G12, G13, G18, G21, G28, E44, E60, H23

1 Introduction

During the financial crisis, out-of-the-money (OTM) put options on the financial sector index became cheaper relative to individual put options on these same firms, suggesting that there was markedly less tail risk in the financial index than in the stock prices of financial firms that make up the index. At the same time, the correlation among financial stocks increased sharply. These two findings present a novel challenge to standard option pricing models. We argue that government support for the financial sector contributed to the apparent "leakage" of sector-wide talk risk in index option prices.

The anticipation of future government intervention when the entire financial sector is at risk could depress the price of OTM index put options. The downward pressure on individual options is smaller than that on index options because the failure of a single firm may not be sufficient to trigger government intervention. The anticipation effect also makes index put prices less informative about the true amount of aggregate tail risk, confounding measurement of systemic risk. We provide direct and indirect evidence that a sector-wide bailout guarantee was in part responsible for the divergence of individual and index put prices in the financial sector during the recent crisis.

We start by comparing the cost of a basket of single-name options on all of the firms in the index to the cost of the index option. The difference between the cost of a basket of OTM put options and a moneyness-matched index put option on financial firms reaches 12 to 15 cents per dollar insured in March 2009, or 70% to 89% of the cost of the index option. Before the onset of the crisis, the spread never exceeded 2.5 cents per dollar insured. This increase in the basket-index put spread is much larger for the financial sector than for any other sector. Only the consumer discretionary spending sector experienced increases in the basket-index spread of noticeable magnitude. This sector includes the automotive industry, which also benefitted from a government bailout of large auto makers during the financial crisis period.

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 mid-2007 to mid-2009 crisis should have raised the price of OTM index options, relative to the price of a basket of individual options with the same moneyness. This is indeed what we find for call options in all sectors of the economy. In contrast, the cost of the basket of individual puts soars relative to the cost of the index put for the financial sector. To replicate this increase in the basket-index spread for OTM put options, the standard option model would have to assume a large increase in idiosyncratic risk relative to aggregate risk, but this would counter-factually imply a sharp decrease in stock return correlations.

Typically, index options are considered expensive because their prices consistently exceed values implied by standard models (Bondarenko, 2003). Driessen, Maenhout, and Vilkov (2009) argue that this is because index options provide a valuable hedge against increases in correlations, which

deteriorate the stand-in investor's investment opportunity set, giving rise to a negative correlation risk premium. This is because index volatility rises when correlations increase *ceteris paribus*, thus index option prices rise as well. It also makes index options expensive relative to individual name options, which do not hedge against correlation. We find that index put options in the financial sector are different. They are always less expensive than those for other sectors, and they become especially cheap during the crisis. While the actual correlations in the financial sector increase from 0.45 pre-crisis to 0.65 during the crisis, the implied correlations, extracted from OTM financial index put options, decline from 0.60 to 0.57. Realized correlations in non-financial sectors also rise, but their implied correlations behave opposite to those of financials. The higher basket-index put spread in the financial sector and the higher correlations cannot reasonably be attributed to a lower correlation risk premium for financials. If anything, economic logic suggests that the correlation risk premium for financials should be higher than that of any other sector, and that it should have increased during the crisis.

A collective government guarantee for the financial sector can explain the puzzle.[1] We model the government's collective bailout guarantee as a left-tail truncation of the distribution of the common component of financial sector equity, while the idiosyncratic component of individual bank equity is not truncated. To illustrate the basic idea, consider two OTM put options, one on the index and one on a representative individual stock. Assume that they share the same strike price which is below the index bailout threshold. An increase in the volatility of aggregate shocks over the non-truncated region will increase the correlation among stock returns. It will also increase put prices of individual stocks because there is a higher chance that the stock price will fall below the threshold, but without triggering a sector-wide bailout. However, it has no effect on the index put price.

Consistent with this absorption of sector-wide tail risk, the government's guarantee of the sector flattened the well-documented volatility skew for deep OTM put options on the financial sector index. We do not find similar effects on the volatility skew in other sectors of the economy.

Furthermore, a careful study of the evolution of the put spread for the financial index lends direct support to our government guarantee hypothesis. The spread increases on average by 1.61 cents (27%) in the first five days after government announcements that increase the probability of a bailout, while it decreases on average 0.85 cents (13%) after announcements that have the opposite effect. The largest increase in the spread (60%) was registered in the first five days after the U.S. Congress approved the TARP bailout.

A simple single-factor option pricing model lends indirect support to the presence of a government guarantee because it shows that a guarantee is a necessary ingredient to account for the dynamics of the basket-index put spread over our sample. Matching the rise in the basket-index

[1] Schneider and Tornell (2004), Acharya and Yorulmazer (2007), and Farhi and Tirole (2009) explore collective government guarantees in theoretical settings.

spread quantitatively requires a government bailout that truncates the sector-wide equity return at a 55% loss. By comparing the bailout-adjusted and the standard bailout-free Black-Scholes cost of an option-based hedge against a financial sector crash, we obtain a dollar estimate of the value of the government guarantee for the financial sector. According to this estimate, the government support to banks' equity was $0.65 billion before mid-2007 and rose to $42.44 billion between mid-2007 and mid-2009. It peaked well over $150 billion.

There are only two other industries that experienced noticeable increases in the basket-index spreads during the crisis: the consumer discretionary sector and the materials sector. The consumer discretionary sector was highly exposed to aggregate tail risk. Discretionary spending of U.S. consumers experienced the largest post-war decrease during the last quarter of 2008. One major component of this sector is car manufacturers (Ford and GM) and auto parts suppliers, but it also includes other businesses with substantial direct and indirect banking and real estate exposure. The latter is also true for many firms in the materials sector. It is conceivable that this sector would benefit more than other sectors when the collective guarantee for banks kicks in. Of course, the auto industry also benefited directly from a federal government bailout.

We investigate and rule out four other potential alternative explanations for the sharp rise in the basket-index spread during the crisis. First, we confront the fact that individual and index return volatilities rose dramatically during the crisis. This, by itself, could generate an increase in the basket-index spread. We use a simple Black-Scholes model to compute an adjusted basket-index spread that controls for this effect. This explains only a small portion of the spread divergence that we identify. We also consider mispricing due to capital constraints, counter-party risk, and short sale restrictions. A trade that takes advantage of the basket-index spread does not tie up significant capital and occurs through exchanges with a clearing house in the middle. These option positions are marked-to-market daily and ultimately guaranteed by the AAA-rated Options Clearing Corporation. The short sale ban was in place only for a very short time, applied equally to individual and index options, and market makers were exempted from it. We study liquidity differences among different types of options (index versus individual, puts versus calls, or financial firms versus non-financials), and argue that several of the facts are inconsistent with a liquidity explanation. Third, we consider and rule out a decline (in absolute value) in the price of correlation risk.

Our work connects to various strands of the literature. First, it is linked to the problem of measuring systemic risk in the financial sector.[2] Our findings point to a fundamental complication to the problem of measuring systemic risk from market prices. All else equal, the basket-index spread for OTM put options would be a 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

[2]See Acharya, Pedersen, Philippon, and Richardson (2010); Adrian and Brunnermeier (2010); Brownless and Engle (2010); Huang, Zhou, and Zhu (2011) for recent advances in systemic risk measurement.

that benefit from an implicit or explicit collective guarantee, an *increase* in the basket-index spread may occur when systemic risk peaks and the collective bailout guarantee is more likely to kick in. This is what we observed in the financial sector and, to a lesser extent, in the broader economy during the 2007-2009 crisis. Hence, the anticipation of future government intervention, which depends on future prices, is embedded in market prices today and makes them less informative about the true nature of tail risk. This feedback mechanism from anticipated corrective action to market prices echoes the problem of a board of directors looking at share prices to fire a CEO in the presence of rational investors anticipating this behavior (Bond, Goldstein, and Prescott, 2010). A similar situation arises in the context of a central bank setting interest rates via a Taylor rule, which depends on expected inflation, when agents form expectations about inflation in part based on the central bank's policy rule.

Economic downturns that follow in the wake of financial crises are deep and persistent.[3] Governments seek to mitigate the risk and repercussions of financial disasters by providing implicit and explicit guarantees to financial institutions that are deemed integral to the stability of the financial system. The size and the effect of these too-systemic-to-fail government guarantees remain highly uncertain and intensely researched. There are a number of papers that measure the impact of these guarantees on the total value of the firm. Lucas and McDonald (2006, 2010) take an option-based approach to valuing the government guarantees extended to Fannie Mae and Freddie Mac. Veronesi and Zingales (2010) use CDS data to measure the value of government bailouts to bondholders and stockholders of the largest financial firms from the Paulson plan. They estimate that this plan increased the total value of the banks balance sheet by $131 billion.

Our paper focuses exclusively on equity. Equity options markets are uniquely suited to gauge the market's perception of too-systemic-to-fail guarantees. Since guarantees only kick in during a financial crisis, their effect should be most visible in the prices of assets that mostly reflect tail risk, like put options. We find that investors price in substantial government bailout guarantees for the financial sector as a whole. In principle, bailouts of bondholders and other creditors do not imply that the value of equity is protected. However, there may be massive uncertainty about the resolution regime in practice, especially for large financial institutions. As a result, collective guarantees tend to benefit shareholders as well because the government is aware that bankruptcy costs start well before the value of bank equity actually hits zero.

Our evidence of a large collective equity bailout guarantee in the financial sector suggests a substantial reduction the cost of capital for systemically risky financial firms. This is consistent with the historical evidence from bank stock returns. Gandhi and Lustig (2010) quantify the effect of too-big-to-fail on the cost of equity capital of large banks by analyzing stock returns on size-sorted bank portfolios. They find that large banks have risk-adjusted returns that are 5% per annum lower than those of the smallest banks, and they attribute this difference to the implicit

[3]See, for example, Reinhart and Rogoff (2009).

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-to-fail by the Comptroller of the Currency in 1984, and negative wealth effects for those banks that were not included. Since we find strong evidence of ex-ante subsidies to shareholders, our results imply 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 the financial sector and in all other non-financial sectors in Section 3. Section 4 corrects the basket-index spread for changes in volatility with the help of a simple Black-Scholes model. Section 5 introduces a bailout guarantee into this single factor model, and shows that this model is able to account for the observed basket-index spread dynamics. A technical contribution of the paper is to derive option prices in the presence of a bailout guarantee in closed-form. Section 6 finds direct evidence for our collective government guarantee hypothesis in the events of the 2007-2009 crisis. Section 7 studies and rules out three potential alternative explanations: mispricing, liquidity, and fluctuations in the price of correlation risk. The last section concludes. Technical details are relegated to a separate appendix.

2 Defining the Basket-Index Spread

Two potential ways to insure equity in the financial sector are to insure each financial institution or to insure the financial sector index. In this section we propose a comparison of these two insurance schemes that is useful for identifying investors' perceptions of government guarantees.

We focus on a traded sector index i comprised of different stocks j. $Index_i$ denotes the share price level of the index. The dollar cost of the index, i.e., the total market cap of all the firms in the index, is given by $Index_i^{\$} = \sum_{j=1}^{N_i} s_j S_j$, where N_i is the number of different stocks that constitute index i, while S_j and s_j are the price per share and number of shares outstanding, respectively, for stock j in index i. The index price is a constant fraction $1/scale_i$ of the total market value of its constituent stocks, where $scale_i = \frac{Index_i^{\$}}{Index_i}$. 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. Similar notation applies for calls.

The basket of put options provides insurance against both common and idiosyncratic stock price crashes, while the index put option only insures states of the world that prompt a common crash. The difference between the costs of these insurance schemes is informative about the relative importance of aggregate and idiosyncratic risks, and is also informative about sector-wide government guarantees. We study two different ways of comparing basket and index options.

Δ-Matched Basket The first approach ensures that the index and the individual options have the same option Δ.[4] 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, we choose the number of index options with strike K such that the total dollar amount insured by the index (denoted $K^{index_i,\$}$) is equal to the dollar amount insured by the basket:

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

The advantage of this approach is that both the index and individual options in the basket have the same moneyness. However, no-arbitrage does not bound the basket-index spread at zero from below.

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 strike prices K_j $(j = 1, 2, \ldots, N_i)$ for individual stocks in the index to match a certain Δ. Second, we choose the strike price of the index options $K^{index_i,\$}$ such that the strike price of the index (in dollars) equals the share-weighted sum of the individual strike prices as in equation (1). Third, we choose a strike price for the index K such that the total dollar cost of insurance equals $K^{index_i,\$}$:

$$K^{index_i,\$} = K \times scale_i.$$

The advantage of strike-matching 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.[5] The disadvantages are that the Δ of the index option can differ from the moneyness of the option basket and that this approach is computationally more involved.[6]

[4] The Δ of an option is the derivative of the option price with respect to the underlying asset price. While put options have negative Δ, we use the convention of taking the absolute value, so that all Δs are positive. Δ measures the moneyness of an option, with low values such as 20 indicating OTM options and high values such as 80 indicating in-the-money (ITM) options. Short-dated at-the-money (ATM) forward options have a Δ approximately equal to 50.

[5] This is because the payoffs at maturity satisfy the following inequality: $\sum_{j=1}^{N_i} s_j \max(K_j - S_{T,j}, 0) \geq \max(K^{index_i,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}, 0)$. This implies that $\sum_{j=1}^{N_i} s_j \max(K_j - S_{T,j}, 0) \geq K^{index_i,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}$, which also means that $\sum_{j=1}^{N_i} s_j \max(K_j - S_{T,j}, 0) \geq \max(K^{index_i,\$} - \sum_{j=1}^{N_i} s_j S_{T,j}, 0)$, because the left hand side is non-negative. Since the payoff from the option basket exceeds that of the index option, its cost must be weakly higher as well.

[6] Since data are on a discrete grid of Δs, different option Δs can satisfy this condition on consecutive days. To avoid oscillation in the basket price, we set a given sector's basket Δ equal to the mode of the day-by-day best Δ match for that sector. Allowing for oscillation introduces noise, but has no qualitative effect on our findings.

Cost Per Dollar Insured To compare prices across time, sectors, and between puts and calls, we define the cost per dollar insured (cdi) as the ratio of the price of the basket/index option divided by its strike price: $Put_{cdi,i}^{basket} = \frac{Put_i^{basket}}{\sum_{j=1}^{N_i} s_j K_j}$ and $Put_{cdi,i}^{index} = \frac{scale \times Put_i^{index}}{\sum_{j=1}^{N_i} s_j K_j}$. No arbitrage implies that the cost of basket insurance exceeds the cost of index insurance, $Put_{cdi,i}^{basket} \geq Put_{cdi,i}^{index}$, if we construct the index strike to match the share-weighted strike price.

We define the basket-index put spread per dollar insured as: $Put_i^{spread} = Put_{cdi,i}^{basket} - Put_{cdi,i}^{index}$. Call spreads are defined analogously.

Other recent studies have similarly examined the relative pricing of derivative securities. Coval, Jurek, and Stafford (2009) compare the prices of CDX tranches to those of index options prior to and during the financial crisis, and they conclude that CDX tranches are overpriced relative to index options.[7] Driessen, Maenhout, and Vilkov (2009), Carr and Wu (2009) and Schurhoff and Ziegler (2011) also study prices of index versus individual options.

3 Measuring the Basket-Index Spread

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

3.1 Data

We use daily option data from January 1, 2003 until June 30, 2009. Index option prices are on the nine SPDR sector exchange-traded funds (ETFs) and on the S&P500 ETF, traded on the CBOE.[8] As ETFs trade like stocks, options on these products are similar to options on an individual stock. Options on ETFs are physically settled and have an American-style exercise feature. The nine sector ETFs conveniently have no overlap and collectively span the entire S&P500. Appendix A contains more details and lists the top 40 holdings in the financial sector ETF.[9] We also use individual option data for all 500 stocks in the S&P500. The OptionMetrics Volatility Surface provides daily European put and call option prices that have been interpolated over a grid of time-to-maturity (TTM) and option Δ, and that are adjusted to account for the American option

[7] Note that a comparison of single-name CDS and the CDX (modulo changes in the index composition through defaults) index is different because the cost of a basket of credit default swaps has to be equal to the CDX index to rule out arbitrage opportunities.

[8] SPDRs are a large family of ETFs traded in the United States, Europe, and Asia-Pacific and managed by State Street Global Advisors.

[9] Our sample length is constrained by the availability of ETF option data. For the financial sector (but not for all non-financial sectors), we are able to go back to January 1999. The properties of our main object of interest, the basket-index put spread for financials, do not materially change if we start in 1999.

feature of the raw option data. The European style of the resulting prices allows us to compare them to the option prices we later compute in our model. Interpolated prices allow us to hold maturity and moneyness constant over time and across underlyings. Constant maturity options are available at various intervals between 30 and 730 days to maturity and at values of (absolute) Δ ranging from 20 to 80. We focus primarily on options with 365 days to maturity and Δ of 20. Implied volatility data are from the interpolated implied volatility surface of OptionMetrics. We use CRSP for returns, market capitalization, and number of shares outstanding for sector ETFs and individual stocks. We calculate realized volatility of index and individual stock returns, as well as correlations between individual stock returns from CRSP return data. Our database changes as the index composition of the S&P500 changes. Whenever a firms gets added or deleted from the S&P500 and hence from its sector ETF, we also drop it from the individual option data base so as to maintain consistency between the composition of the option basket and the index option.[10]

3.2 Main Facts

Δ-Matched Basket Panel I in Table I provides summary statistics for the basket-index spread per dollar insured using the Δ-matched approach and setting $\Delta = 20$. Columns (1)-(2) report results for the financial sector. Columns (3)-(4) report results for a value-weighted average of the eight non-financial sectors. Columns (5)-(6) report the differences in the spread between the financial and non-financial sectors. All spreads are reported in cents per dollar insured. An increase in the spread between the basket and the index means index options become 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).

Over the full sample, the mean spread for OTM puts is 1.69 cents per dollar in the financial sector and 1.11 cents in the non-financial sectors. The basket-index spread for OTM calls are an order of magnitude smaller than those for puts: 0.24 cents for financials and 0.21 cents for non-financials. Put spreads are more volatile than call spreads: 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. The largest basket-index put spread for financials is 12.46 cents per dollar, recorded on March 6, 2009. It represents 70% of the cost of the index option on that day. On that same day, the difference between the spread for financials and non-financials peaks at 9.07 cents per dollar insured. The largest basket-index put spread for non-financials is 4.13 cents per dollar, recorded on November 21, 2008. In contrast, the largest basket-index call spread is only 0.49 cents for financials and 0.36 cents for non-financials.

[10] Our results remain unchanged when we focus on the subset of firms that remain in the financial sector index throughout our sample.

The bottom third of Panel I focuses 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. 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). Put spread volatility increases in the crisis, especially for financials, whose standard deviation rises from 0.20 pre-crisis to 2.39 during the crisis. Non-financial put spread volatilities increase from 0.44 to only 0.90. OTM call spreads 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).

The top panel of Figure 1 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 the basket-index put spread (dotted line) for the entire sample. Before the crisis, the put spread is essentially constant and very small, less than 1 cent per dollar. During the crisis, it increases as the index option gradually becomes cheaper relative to the basket of put options. 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 dollar of insurance. The basket index spread also becomes more volatile.

The bottom panel of Figure 1 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).[11] We find essentially the same results for call spreads in all other sectors.

Figure 2 compares the put spread of financials and non-financials over time (the dotted lines from the previous figure). For non-financials (solid line), the basket-index spread remains very low until October 2008. For financials (dashed line) on the other hand, the put spread starts to widen in August 2007 (the asset-backed commercial paper crisis), spikes in March 2008 (the collapse of Bear Stearns), and then spikes further 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 increases from the summer of 2007 to October 2008, falls until the end of 2008, and increases dramatically from January to March 2009. The main take-away is that none of the eight non-financial sectors has anywhere close to the large put spread increase in the financial sector. Section 6 provides a detailed interpretation of this pattern based on crisis-related government announcements.

[11] This negative number refers to the Δ-matched spread and does not violate no-arbitrage. Recall that the zero lower bound only holds for the strike-matched basket-index spread.

Strike-Matched Baskets Panel II in Table I reports results for our second approach constructing the basket-index spread in which the index strike price is matched to the share-weighted strike of the basket. Here, no-arbitrage implies that the basket-index spreads are non-negative. Essentially, we see the same pattern as with the Δ-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. By fixing Δ as the crisis unfolds, the first approach studied put contracts with lower strike prices during the crisis, and hence it looked at options with lower prices. This tends to lower the basket-index spreads. Put differently, individual options in the second approach have higher Δs 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 minima reported are all positive, which means the no-arbitrage constraint is satisfied.

3.3 The Effect of Time-To-Maturity

Panel III of Table I studies the cost of insurance when the TTM 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 TTM. Yet we observe the same patterns as in Panel I. We limit our discussion to Panel III; the strike-matched results in Panel IV are similar.

Starting with the basket-index spread for puts on financials, we find an average of 0.62 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 (that is, 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 2.46 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 0.16 cents pre-crisis to an average of 0.10 cents during the crisis, a slower rate than for longer-dated options.

For non-financials, the put spread increases by a factor of 1.8 (from 0.13 before the crisis to 0.23 cents during the crisis). This is larger than the increase for long-dated puts of 1.7 times when taking into account the shorter time interval. The call spread for non-financials increases slightly during the crisis (from 0.11 to 0.14 cents), while it falls for longer-dated options (from 0.25 to 0.11 cents).

3.4 The Effect of Moneyness

Table II reports the cost of insurance for the basket versus the index as a function of moneyness (Δ). It follows the format of Table I, and the first panel is identical in both tables. While option prices are naturally higher when options are closer to being in the money (ITM), it turns out that basket-index spreads also increase in moneyness. 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 $\Delta = 50$. Similarly, the proportional decrease in call spreads is larger for OTM than for ATM options. For non-financials, the put spread increase during the crisis is much smaller and decreases in moneyness. The difference in the put spread between financials and non-financials (reported in column 5) increases only marginally during the crisis, from 2.22 cents at $\Delta = 20$ to 2.37 cents per dollar at $\Delta = 50$. Since option prices are higher for high-Δ options, the financials minus non-financials put spreads are much larger in percentage terms for OTM options. The percentage spread, measured as the basket-index spread divided by the cost of the financial index put, is 37% for $\Delta = 20$ puts during the crisis but only by 26% for $\Delta = 50$. Similarly, the maximum percentage put spread falls from 81% to 52% as moneyness increases from $\Delta = 20$ to $\Delta = 50$. For call options on financials, the largest percentage spreads are in the pre-crisis sample. Finally, we see a decrease in average percentage spreads during the crisis for non-financials.

3.5 Bid-Ask Spread

To ensure that the increase in the basket-index put spread is not solely due to wider bid-ask spreads during the crisis, we reconstruct an alternative basket-index spread series using raw option price quotes rather than the interpolated volatility surface provided by OptionMetrics. To do so, we buy the index option at the ask price and sell individual options at their bid prices, each day.[12] Because the cost of basket insurance is calculated using the bottom of the quote range and the cost of index insurance uses the top of the quote range, the bid-ask-adjusted put spread will be narrower than the spread calculated from midquotes. We find that the resulting "net of transaction costs" (Δ-matched) basket-index put spread has very similar dynamics than our main series. The correlation between the two is 0.88 (0.90) over the entire (crisis) sample. The average spread increases fivefold

[12]On each day, we find the XLF option with TTM closest to 365; we also find two index puts with Δ closest to 20 (one above, one below), and form a portfolio of these such that the portfolio has Δ of 20. We do the same for each individual stock in the index. We drop all options with zero bids or otherwise missing information. Often a stock has only one option near $\Delta = 20$. If the option $\Delta \leq 40$, we include it. This effectively means that in some cases we use individual stock options with Δ as large as 40 (rarely are the lone options with absolute $\Delta \leq 20$). Because these closer-to-the-money options are more expensive, they will bias the put spread downward, hence this is conservative.

from 0.52 cents per dollar pre-crisis to 2.45 cents per dollar during the crisis, while the maximum spread increases from 3.29 to 11.53 cents per dollar insured. We postpone an extended discussion of the liquidity of the options under study to Section 7.3.

3.6 Sector Analysis

Table III compares the basket-index spread for all nine sectors of the S&P500. The only other industries which experienced significant increases in the basket-index spreads during the crisis were the consumer discretionary sector and the materials sector. Discretionary spending of U.S. consumers experienced the largest post-war decrease during the last quarter of 2008. One major component of this sector is car manufacturers (Ford and GM) and parts suppliers (e.g., Goodyear and Johnson Controls), but it also includes retail, home construction (e.g., D. R. Horton and KB Home), hotels (e.g., Marriott and Harrah's) and other businesses with substantial direct and indirect real estate exposure. The basket-index spread peaked at 9 cents per dollar insured for this industry. The average increased from 1.84 cents to 3.28 cents per dollar insured. It is conceivable that this sector benefits more than other sectors when the collective guarantee for the financial sector kicks in. The auto industry also benefited directly from a federal government bailout in November-December 2008. The materials sector ETF has similarly large exposure to businesses benefitting from government guarantees. Examples include US Steel, whose large customers include the transportation and construction industries, and Weyerhaeuser, which produces building materials and operates a large real estate development segment.

3.7 Bending the Implied Volatility Skew

Another indicator of the relative costs of index and basket insurance on the financial sector is the difference in their implied volatility skew. The volatility skew plots implied volatilities of options as a function of option moneyness. The top panel of Figure 3 shows the difference between the implied volatility skew for the financial sector put basket and the index put skew. During the crisis (circles), the difference between the implied volatility of the basket and that of the index reaches a maximum of 11.5% for $\Delta = 20$, and gradually decreases to 9% for $\Delta = 50$. This evidence is consistent with the presence of a government guarantee which effectively bends the implied volatility skew for index put options much more than for individual options in the financial sector. Intuitively, this downward sloping pattern arises because a government guarantee has a larger relative impact on index put prices with lower strike prices. In the pre-crisis sample (squares), the basket-index skew spread was essentially flat across moneyness. The same flatness arises for the basket-index skew spread in non-financial sectors, both pre-crisis (diamonds) and during the crisis (stars). Finally, the bottom panel of Figure 3 plots the implied volatility skew spread inferred from calls. Here we see the exact opposite pattern. During the crisis, the financial sector basket-index

skew spread for calls actually has a positive slope (circles). This is because OTM index call options were substantially more expensive relative to the basket, while the prices of ATM index calls were much further from the basket price. This is consistent with elevated aggregate tail risk during the crisis and high return correlations, exactly what we would expect to see (including for puts) in the absence of a bailout guarantee.

In the options literature, the variance risk premium, defined as option-implied variance minus expected realized variance of the underlying, offers a separate evaluation of the relative expense of an option position (Carr and Wu, 2009). The literature has shown that the variance risk premium is generally positive for index options, reflecting the fact that they are expensive.[13] For financials, we find that the average implied variance minus realized variance is -0.006 over the full sample. In the pre-crisis sample, this difference is 0.022 (0.047 versus 0.025). However, in the crisis-sample, this difference drops to -0.204 (0.235 versus 0.439). The ratio of the two falls from 1.9 to 0.5. It is yet another important indication that index put options on the financial sector are cheap during the crisis. For non-financials, in contrast, the variance risk premium increases slightly during the crisis (from -0.022 to -0.007). Similarly to puts, call options on financials indicate a large decrease in the variance risk premium from -0.003 to -0.294 in the crisis. The decrease is again smaller for non-financials.[14]

4 A Benchmark Model Without Guarantees

In this section, we write down a simple Gaussian option pricing model without government guarantees. An increase in the level of volatility during the crisis could differentially affect individual and index options and may, in and of itself, lead to an increase in the basket-index spread. A simple model allows us to quantify this effect and to construct an adjusted basket-index spread which takes out this effect. The remaining component is a non-Gaussian skew effect, distinct from the Gaussian volatility level effect. This decomposition is informative about which features of the data can and cannot be explained with a standard Black and Scholes (1973) (henceforth BS) model. While it is well known that the BS model does not accurately price index options (Bondarenko, 2003; Pan, 2002), it is nevertheless an interesting lens through which to study the basket-index spread data, in the same tradition that the BS model is used to study implied volatilities.

[13] Other evidence is that returns on OTM index put options are large and negative, CAPM alphas are large and negative, and Sharpe ratios on put writing strategies are larger than those on the underlying index (see Bondarenko, 2003). Broadie, Chernov, and Johannes (2009) propose a model to explain many features of these returns.

[14] Implied variance is calculated using options with $\Delta = 20$ and $TTM = 365$. To proxy for the day t expected realized variance over the next year, we use the daily realized variance calculated from trading day $t+1$ to $t+252$. The decrease in the variance risk premium during the crisis is qualitatively similar if alternative measures of expected physical variance are used, including GARCH forecasts and backward-looking rolling variances.

4.1 Single-Factor Model

We use a simple single-factor model to price options, similar to the one used by Vasicek (2002) to value loan portfolios. The log of the stock return on an individual stock follows:

$$r^{indiv} = \mu - \lambda J^a + \sigma_d \epsilon,$$

where the shock ϵ is an idiosyncratic shock which is standard normally distributed and i.i.d. over time and across firms. In contrast, the shock J^a is a sector-wide shock, also i.i.d. over time and normally distributed: $J^a \sim \mathcal{N}(0, \delta_r^2)$. We assume that the index is composed of ex-ante identical firms. To take into account the sector concentration, we choose the number of stand-in firms j in sector i on a given day t, N_t^i, to match the inverse of the sum of squared market capitalization weights for the firms present in the financial sector on that day: $N_t^i = (\sum_j \omega_{j,t}^2)^{-1}$. We use $\sigma_{t,i}^{index}$ to denote the volatility of the index return in sector i. The volatility of the index is related to the volatility of the stand-in firm, $\sigma_{t,i}^{indiv}$, in the following way:

$$\sigma_{t,i}^{index} = \sqrt{\frac{N_t + N_t(N_t - 1)\rho_{t,i}}{N_t^2}} \sigma_{t,i}^{indiv}, \tag{2}$$

where $\rho_{t,i}$ is an estimate of the return correlation between individual firms in sector i.

As we did for strike-matched options in the data, we choose an individual option with a strike K_t that delivers a Δ of 20. The same K_t is used for the index option. We then feed in a daily risk-free rate r_t,[15] the strike K_t, the index volatility $\sigma_{t,F}^{index}$, and the individual stock volatility $\sigma_{t,F}^{indiv}$ to compute BS prices for the index option and the basket of options with maturity T equal to one year:

$$Put_{t,i}^{BS,index} = BS(\sigma_{t,i}^{index}, K_t, r_t, T), \text{ and } Put_{t,i}^{BS,basket} = BS(\sigma_{t,i}^{indiv}, K_t, r_t, T). \tag{3}$$

The strike-matched BS basket-index put spread, expressed as a cost per dollar insured, is

$$\frac{Put_{t,i}^{BS,basket}}{K_t} - \frac{Put_{t,i}^{BS,index}}{K_t}.$$

The analysis for call options is analogous.

4.2 Feeding in Index Option-Implied Volatility

In a first exercise, we ask what the BS model implies for the basket-index spread for $\Delta = 20$ put options. In particular, we want to establish that the Black-Scholes model cannot account for the

[15] We also use the yield curve provided by Optionmetrics to estimate the interest rate r for maturity T.

increase in the put spread during the crisis, once we feed in the observed increases in individual and index volatility.

We feed in a daily series for implied volatilities for the index option, $\sigma_{t,F}^{index}$, so that we match daily index put price *by construction*. We also feed in a daily sequence of realized correlations, $\rho_{t,F}$, which together with the index (implied) volatility delivers a daily measure for the volatility of the stand-in individual firm, $\sigma_{t,F}^{indiv}$, via equation (2). Equation (3) then delivers a BS index and basket put option price. We follow the same procedure for the non-financial sectors, as well as for call options.

Thus, this exercise takes into account the dynamics of daily index return volatilities and average pairwise return correlations. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity. As mentioned in the introduction, the crisis was characterized by a substantial increase in the correlation of individual stock returns. The correlation among stocks in the financial sector index increased from 45.9% pre-crisis to 57.9% during the crisis. For non-financials, the full-sample average correlations are lower than for financials: 45.1 versus 51.3%. For non-financials, the correlation increased from 33.7% pre-crisis to 57.1% in the crisis.

Table IV reports BS option put prices. The left half of the table shows results for financials while the right half is for non-financials. Side-by-side we report the BS value and the observed value of the index option (columns 1 and 2), the basket (columns 3 and 4), and the basket-index spread (columns 5 and 6). The last column in each panel reports the difference between the basket-index spread in the data and in the BS model (column 7).

We start by discussing put options on financials in Panel I. While the BS model does a good job matching index option prices by construction, it also matches the cost of basket option and therefore the basket-option spread quite well in the pre-crisis period. In sharp contrast, the BS model fails to match the sharp increase in the price of the basket in the crisis. In the data, the financial sector put spread increases by a factor of 3.4, while in the BS model in only increases by a factor of 1.3. Put differently, the volatility level effect only contributes 1 cent to the more than 4 cent (per dollar insured) increase in the put spread.

Looking at the maximum spread confers the same message: The maximum spread in the data reaches 15.87 cents, while the maximum BS spread is only 8.08 cents. The through-to-peak movement in the basket-index spread is about 7 cents in the BS model and more than 14 cents in the data. The BS model also cannot match the put spread volatility differences between the pre-crisis and the crisis sample. The BS basket-index spread shows similar standard deviation in both episodes, ranging between 1.19 and 6.37 cents before the crisis and between 1.62 and 8.08 cents during the crisis. In the data, the spread only varies between 1.06 and 3.76 cents before the crisis, but fluctuates as between 1.02 and 15.87 cents during the crisis. The standard deviation of

the observed increases from 0.35 pre-crisis to 3.00 during the crisis, while the standard deviation of the BS spread only increases from 0.81 to 1.39.

Column 7 shows that the average gap, defined as the put spread in the data minus that predicted by BS, is -1.34 cents before the crisis. This suggests that index put options are expensive in the data relative to BS pre-crisis, in line with the literature on index options. However, the average gap increases by 3.17 cents to positive 1.83 cents during the crisis. That is, index put options become substantially cheaper during the crisis, relative to the BS benchmark.

Panel II shows the results for the non-financials. During the crisis, the BS put spread falls slightly (column 5), compared to a modest increase in the data (column 6). In the full sample and in each subsample, the difference between the observed put spread for non-financials and its BS-implied value is negative (column 7), and more negative than in the financial sector. That is, non-financial index puts are uniformly more expensive than financial index puts even after controlling for the relative price of a basket of puts, and after controlling for differences in risk via a standard one-factor model. The last column of Table IV reports a difference-in-differences number that captures the differential cost per dollar insured for basket versus the index, financials versus non-financials, and data versus Black-Scholes. On average, financial index put options are 2.29 cents per dollar cheaper during the crisis and 0.71 cents cheaper before the crisis than non-financial index puts after adjusting for basket and BS comparisons. The maximum financial index put discount is 8.12 cents per dollar during the crisis and 3.76 before the crisis. These results are consistent with the existence of a government guarantee for the financial sector.

Figure 4 plots the difference between the actual and BS-implied basket-index spread for the put options on financials (dashed line) and non-financials (solid line). The dotted line plots the difference. The plot shows that the gap between the put spread in the data and BS for financials consistently exceeds that of non-financials, even before the crisis. This implies that financial index puts are consistently cheap relative to both BS and non-financials. During the crisis, the difference between these two widens even further.

4.3 BS-Implied Correlations

The BS model suggests another useful exercise. Instead of feeding in realized correlations and computing the BS-implied basket-index spreads, we can back out the daily implied correlation $\rho_{t,i}$ that equates the (strike-matched) basket-index spread in the BS model to that in the data. As in the previous exercise, the implied volatility for the index is fed in and the implied volatility for the stand-in individual firm is computed from equation (2). The resulting option-implied correlations are a normalized comparison of the prices on the basket of options and the index option. High implied correlations, compared to realized correlations, indicate that index options are relatively expensive.

Table V reports realized correlations, calculated from stock returns, model-implied correlations, and the difference between realized and option-implied correlations. Columns 2-3 use financial sector put options, columns 4 and 5 use financial sector calls, and columns 6-10 are for non-financials. Over the full sample, implied correlations from OTM puts in the financial sector are 8 percentage points lower than actual correlations. Pre-crisis, the realized correlation for financials is 0.45, while the put-implied correlations is 0.60. During the crisis, the realized correlation increases by 20 percentage points to 0.65, while the implied correlation falls by 3 percentage points to 0.57. Thus, their difference decreases by 23 percentage points. Thus, the BS model implies a negative correlation risk premium for financials pre-crisis, which is the expected sign for a correlation risk premium (Driessen, Maenhout, and Vilkov, 2009), but a positive correlation risk premium during the crisis. For calls, we note the opposite pattern. The implied correlations now increase (from 0.51 to 0.67) and the gap between implied and actual correlations remains positive so that the correlation risk premium is negative throughout. For non-financials, reported in the right panel, the implied correlation from put options actually increases from 0.49 to 0.54, but less so than the actual correlations, thus shrinking the gap to an average of 3 percentage points. When viewed through the lens of the BS model, correlation risk premia seem larger in absolute value for non-financials than financials, and even more so during the crisis than pre-crisis. In conclusion, the observed pattern for the basket-index put spread in the financial sector could in principle be consistent with a decrease in the price of correlation risk in absolute value over time. But economic logic suggests that, if anything, the price of correlation risk should have increased in absolute value during the crisis. Furthermore, such an increase would have counter-factual implications for call spreads, which would be predicted to increase as well. The data instead show a decline in call spreads during the crisis. Finally, one would have to be willing to accept a different price of correlation risk on options in different sectors.

Figure 5 plots the implied correlations against the actual correlations (dashed lines). The implied correlation for puts on financials (top left panel) initially increases at the start of the crisis to 0.86 and then gradually declines to a minimum of 0.40 in the midst of the crisis in November 2008. Over the same period, the actual correlation increases from 0.51 to 0.74. Remarkably, the actual and implied correlation are uncorrelated (-0.05) over the entire sample. During the crisis, this correlation drops to -0.25. In contrast, the correlation for calls (top right panel) is 0.93 over the entire sample and 0.68 during the crisis. For non-financials (bottom panels), the implied correlation is remarkably flat during the crisis. The correlation between actual and implied put correlations is 0.48 over the entire sample, much higher than for financials.

We have repeated the same exercise for short-date options with TTM of 30 days, and we find very similar results.

4.4 Forecasting Realized Volatility

Our previous two BS exercises fed in implied volatility for index options. We now briefly consider using forecasts of expected future index return volatility from daily return data instead. Our conclusions remain unchanged: the BS model has tremendous difficulty accounting for the increase in the basket-index put spread observed in the data.

Concretely, we forecast index return volatility over the option maturity of one year using a one-year rolling-window estimate, repeated each day. As before, we feed in daily realized correlations and obtain daily individual volatilities from equation (2). We then form option prices from equation (3) and the strike-matched basket-index spread. Table VI reports the results. For financials (left panel), we find that the BS model somewhat underprices both the index put option and the basket of put options. The average basket-index put spread goes up from 2.08 cent pre-crisis to 3.88 cent during the crisis (a factor of 1.8), while in the data the spread increases from 1.71 cent to 5.86 cents (a factor of 3.4). Put differently, the BS-adjusted put spread (data-BS in column 7) increases substantially from pre-crisis to crisis. On average, it goes up by 2.35 cent, the maximum increases by 6.82 cent, and the through-to-peak movement is 11.43 cents which is larger than the comparable 7.77 cent movement in the raw put spread. This confirms our earlier conclusion that individual put options were expensive relative index options, even after accounting for the relative movements in volatility. For non-financials, the BS model fails to generate any increase in the basket-index put spread, while the data show a 1.5 cent increase. The BS-adjusted put spread increases by 1.4, as much as the raw put spread. The last column reports difference-in-differences statistics: data minus Black-Scholes and financial minus non-financials. On average, this statistic increases by 0.94 cents from pre-crisis to crisis while the maximum increases by 4.63 cents. [16]

4.5 Too-Big-To-Fail: Largest Banks

Our main hypothesis considers a too-systemic-to-fail guarantee for the entire financial sector, but not for individual banks. This section briefly considers a milder version of this hypothesis where the largest individual banks also enjoy a too-big-to-fail government guarantee. We find evidence that government guarantees primarily benefit large banks. We focus on a group of 12 large banks, a sample that includes most of the largest U.S. financial institutions and which account for nearly half of the market capitalization of the sector index at the onset of the financial crisis. For each of these financial institutions we estimate an individual return volatility process using the rolling-window approach of the previous section. We then use the BS model of Section 4.1 to compute their put option prices. Table VII reports the difference between the actual and the BS single name put

[16] We also considered a GARCH model to forecast realized index volatility, in particular the asymmetric threshold GARCH(1,1) model of Glosten, Jagannathan, and Runkle (1993). The GARCH model has more difficulties to explain the observed levels of index option prices, but the results for the BS-implied basket-index put spread and therefore for the adjusted put spread are very similar. Detailed results are available upon request.

option prices for nine banks. The first column reports the BS-adjusted cost of the basket including all financials (about 90 firms) as a point of reference. The second column reports the average BS-adjusted put option price for the nine large banks. The last nine columns report each large bank individually. In the pre-crisis period, large banks' OTM put options are 0.52 cents cheaper than the sector average after adjusting for volatility effects via BS (1.32 minus 0.80). During the crisis, large banks become 3.17 cents cheaper than the full sector average (2.13 minus -1.04). Thus, while BS-adjusted put option prices increase during the crisis, they decrease for the large banks. This striking conclusion holds for eight out of the eleven banks.[17]

5 A Benchmark Model With Guarantees

The previous sections showed a large increase in the basket-index put spread for financials relative to non-financials and showed that this spread was not accounted for by relative volatility dynamics. This section will provide indirect evidence for our hypothesis that the government may have played an important role in generating the observed patterns, while the next section will provide direct evidence based on an event study of government announcements. The indirect evidence comes from the fact that the observed basket-index spread dynamics can be accounted for by a simple option pricing model, once a collective government guarantee assumption is added. We extend the simple single-factor model developed in Section 4 and assume that the maximum sector-wide loss rate tolerated by the government is fixed (and common knowledge). While the resulting model still faces substantial challenges in accounting for the level of individual and index option prices, as one might expect from a Black-Scholes type model, it is the simplest model to illustrate the effect of collective bailout guarantees.[18]

5.1 Single Factor Model with Bailout

Log stock returns for the stand-in individual stock follow the same process as in Section 4 with the following exception. The single sector-wide shock is truncated by a government guarantee. This truncation occurs at $\underline{J} < \infty$, and modifies the sector-wide shock:

$$J^a \quad = \quad \min(J^r, \underline{J}), \quad J^r \sim \mathcal{N}(0, \delta_r^2).$$

[17] Two of the three for which BS-adjusted option prices rise are Freddie Mac and Freddie Mae, which actually fail in September 2008. This failure wiped out the equity holders, and the rise in their put prices during the crisis (in this case August 2007-September 2008) reflects the increased probability of a collapse.

[18] The NBER working paper version of our paper considers a model with disasters that matches both option pricing levels and the basket-index spread, but only once a bailout guarantee is introduced. That model requires several auxiliary assumptions which we avoid in the model presented below.

A technical contribution of our paper is to derive a closed-form expression for the bailout-adjusted index put and basket put prices:

$$Put_{t,i}^{Bail,index} = BS^{Bail}(\sigma_{t,i}^{index}, K_t, r_t, T, \mu_{t,i}, \underline{J}), \text{ and } Put_{t,i}^{Bail,basket} = BS^{Bail}(\sigma_{t,i}^{indiv}, K_t, r_t, T, \mu_t, \rho_{t,i}, \underline{J}). \quad (4)$$

Appendix C contains the derivation of the put option prices; it relies on results in Appendix B and on auxiliary lemmas stated in Appendix E. The bailout-adjusted option prices depend on three additional parameters: (i) $\underline{J}$ is the maximum loss tolerated by the government, (ii) $\mu_{t,i}$ is the expected return on the stocks in sector i, and (iii) $\rho_{t,i}$ is the correlation between stocks in sector i. The strike-matched Black-Scholes basket-index spread is defined as before.

5.2 Feeding in Index Option-Implied Volatility

To compute the basket-index spread in the presence of a bailout, we follow the same procedure that we described in Section 4. We feed in option-implied index volatility and realized correlations and use equation (2) to obtain the stand-in firm's volatility. We also need an estimate of the expected return $\mu_{t,i}$. To obtain a model-free, option-based estimate for the expected return (in levels), we use the simple variance swap of idea of Martin (2011).[19] Note that since it is based on options data, our expected return estimate reflects all potential effects of sector-wide guarantees on stock returns. Appendix D discusses the details and shows how expected returns, volatilities, and correlations relate to the structural parameters of the model. The model then delivers a daily put price for the basket and the index via equation (4).

The solid line in Figure 6 plots the basket-index spread in the bailout model (with $\underline{J} = 0.60$) against the observed basket-index spread (dashed line). The key result is that the two series track each other closely. The correlation between them is 0.81 (0.86) over the entire (crisis) sample. The bailout-adjusted basket-index spread peaks at 16.34 cents per dollar insured. It is informative to consider how the put spread in the data (dashed line) relates to the difference between the put spreads from the models with and without a bailout guarantee (dotted line). The correlation between them is 0.67 over the entire sample (0.62 during crisis). While the bailout model misses part of the initial run-up in the basket-index spread after March 2008, it does a remarkable job of explaining the remaining variation.

Table VIII reports the basket-index put spread for the bailout model for different values of the guarantee threshold $\underline{J}$, and compares it to the data. The top panel is for financials, the bottom panel for non-financials. The put spreads in both the data (column 1) and the model (next columns)

[19] Martin (2011) derives a model free notion of implied volatility, $SVIX$, from an equally weighted average of put and call prices at different strikes. He uses $SVIX$ to derive a lower bound on the expected risk premium under weak assumptions. To implement our empirics, we assume the lower bound is satisfied with equality. We separately compute $SVIX$ for financials and for the non-financial sectors.

are adjusted for what is predicted by the simple BS model without bailout. A lower value for $\underline{J}$ makes the government guarantee stronger and eliminates more of the aggregate downside risk; a value of $+\infty$ recovers the model without bailout guarantee. The table shows that the effect of $\underline{J}$ on the put spread is non-monotonic. The price of sector-wide risk has to increase to match the risk premium, which at some point starts to lower the basket-index spread as $\underline{J}$ is lowered further. In the pre-crisis sample, the average spread in the data (in deviation from Black-Scholes) is -1.34 cents. The bailout model struggles to generate much difference with the no-bailout model for most values of $\underline{J}$, and hence fails to account for the fact that index put options are relatively expensive in normal times. However, the real test for the bailout mechanism is the crisis sample. When we choose the maximum loss to be $\underline{J}$ of 0.60 (which implies a maximum loss rate of 51% in levels), the model delivers an BS-adjusted spread of 1.58 cents per dollar, compared to 1.83 cents in the data. The maximum spread is 8.44 cents per dollar, compared to 9.30 cents in the data.

Panel II of Table VIII shows that the effects of a similar-size guarantee are much smaller for non-financials. While the increase in the BS-adjusted put spread is small in the data (1.31 cents), it is smaller still in the model (0.11 cents). Likewise, the maximum put spread the model can generate for any bailout level is 3.7 cents, while the maximum value observed in the data is 4.4 cents. There is not enough volatility in non-financial stock returns to make the guarantee more valuable.[20]

For a given maximum loss rate $\underline{J}$, we can estimate the dollar value of the bailout by computing the cost of obtaining downside insurance for the sector (using index options) with and without the bailout guarantee. The difference is our estimate of the total value of the bailout guarantee. Holding fixed $\underline{J} = 0.60$, the average crisis value of the bailout is \$42.45 bn, compared to \$0.65 bn before the crisis.

6 Government Announcements

In this section, we provide direct evidence that the dynamics of the basket-index spread during the crisis are closely tied to government policy announcements. Under the collective bailout hypothesis, 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 stronger for the financial sector, we expect to see an effect in the relative basket-index spreads of financials relative to non-financials. To link the put spread directly to (the market's perceptions of) the government's bailout actions, we study government announcements during the financial

[20]Rather than using the put option-implied volatility as a measure of index return volatility, we can instead use rolling-window realized volatilities or GARCH-model forecasts to evaluate model-implied spreads, similar to the analysis in Section 4.4. Results are similar to those using implied volatilities, and are available upon request.

crisis of 2007-2009. We focus on significant announcements for which we can determine ex-ante the sign of the effect on the likelihood (and size) of a collective bailout. Our evidence suggests that we spreads respond to government announcements in a manner consistent with the collective bailout hypothesis. Since we report the dynamics BS-adjusted basket-index spreads, the results are not simply picking up volatility effects.

We identify six events that increase the probability of a government bailout for shareholders of the financial sector: (i) July 11, 2008: Paulson requests government funds for Fannie Mae and Freddie Mac (ii) October 3, 2008: Revised bailout plan (TARP) passes the U.S. House of Representatives, (iii) October 6, 2008: The Term Auction Facility is increased to $900bn, (iv) November 25, 2008: The Term Asset-Backed Securities Loan Facility (TALF) is announced, (v) January 16, 2009: Treasury, Federal Reserve, and the FDIC provide assistance to Bank of America, (vi) February 2, 2009: The Federal Reserve announces it is prepared to increase TALF to $1trn. We refer to these as positive announcement dates.

We also identify six negative announcements that (we expect ex-ante to) decrease the probability of a bailout for shareholders: (i) March 3, 2008: Bear Stearns is bought for $2 per share, (ii) September 15, 2008: Lehman Brothers files for bankruptcy, (iii) September 29, 2008: House votes no on the bailout plan, (iv) October 14, 2008: Treasury announces $250bn capital injections, (v) November 7, 2008: President Bush warns against too much government intervention in the financial sector, and (vi) November 13, 2008: Paulson indicates that TARP will not used for buying troubled assets from banks.

First, we consider the following difference-in-differences, data minus Black-Scholes and basket minus index, around announcement dates. We verify that the basket-index spread of financials increases after positive announcement dates relative to the implied Black-Scholes value, and declines after negative announcement dates. Panel I of Figure 7 plots the results. In the five days following a positive announcement we find an average spread increase of 1.62 cents (62%). The five days following a negative announcement experience an average spread decrease of 1.27 cents (39%).

Second, we look at a triple difference: financials minus non-financials, data minus Black-Scholes, and basket-index. Panel II of Figure 7 plots the results for the basket-index put spread (data minus BS) for financials minus the non-financial basket-index spread (data minus BS) around the announcement dates. We find that the basket-index spread increases on average by 0.89 cents (29%) in the first five days following a positive announcement, while it decreases 1.85 cents (28%) in the five days following a negative announcement. The pre-announcement movements suggest that some announcements may be anticipated by the market.

The largest positive effect occurs after the House approves the Emergency Economic Stabilization Act of 2008 (Public Law 110-343) on October 3, which establishes the $700 billion Troubled Asset Relief Program (TARP), raising the spread 47% in the first five days after the announcement. Furthermore, the approval of TARP started a sustained increase in the basket-index spread in the

ensuing period.

Both the failure of Bear Stearns and Lehman Brothers initially reduce the basket-index put spread. The largest negative effect was registered on October 14, 2008 when the U.S. Treasury announced the TARP would be used as a facility to purchase up to $250bn in preferred stock of U.S. financial institutions. The Treasury essentially shifted TARP's focus from purchasing toxic assets to recapitalizing banks, which resulted in dilutions of existing shareholders, driving the spread down by 22% over the next five days. This was the start of a longer decline in the spread that was reinforced by speeches delivered by president Bush and Secretary Paulson in early November. Clearly, there was a fear that bank shareholders would not receive the government bailout they had hoped for.

This decline in the spread was reversed only in early January 2009 when the FDIC, the Fed and the Treasury provided assistance to Bank of America, without diluting existing shareholders. The put spread started its largest increase in the beginning of February and peaked in March.[21]

Markets were gradually reassured that the government was indeed committed to bailing out the financial sector without wiping out equity holders. Our measure of the value of the bailout guarantee suggests that the market was not initially reassured by the TARP program and its implementation, which consisted mostly of cash infusions from sales of preferred shares. Only when the Treasury and the Federal Reserve explicitly announces programs to purchase toxic assets such as mortgage-backed securities does the collective bailout guarantee become valuable.

7 Alternative Explanations

In addition to the volatility effect and the correlation risk premium effect, which we discussed above, this section consider three more alternatives to the collective bailout explanation for the behavior of crisis put spreads: Counter-party risk, mispricing and short sale restrictions, and liquidity on the other hand. We conclude that none are consistent with the patterns in the data.

7.1 Counterparty Credit Risk

The most obvious alternative explanation is counterparty risk. The OTM financial index put options pay off in states of the world in which the financial system is potentially in a meltdown.

[21] On February 10, 2009, Treasury Secretary Geithner announced 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 announced that it was prepared to expand TALF to as much as $1trn and to broaden eligible collateral to include AAA-rated commercial mortgage-backed securities, private-label residential mortgage-backed securities, and other asset-backed securities. The expansion of TALF would be supported by $100bn from TARP. In the last week of February there was discussion of assurances to prop up the banking system, including Fannie Mae and Freddie Mac.

If these contracts are not honored in these states of the world, that could generate a basket-index spread increase for put options on financial firms, more so than for other firms.

All of the options traded on the CBOE are cleared by the Options Clearing Corporation, which also is the ultimate guarantor of these contracts. The writer of an option is subject to margin requirements that exceed the current market value of the contract by a margin that provides a cushion to cover two-day market risk. These margins are exempt from bankruptcy clawbacks. The positions are marked-to-market on a daily basis. During the crisis, there were intra-day margin calls as well. In addition, the OCC has a clearing fund. The size of the clearing fund is directly tied to the volume of transactions. This clearing fund was only tapped once after the crash of 1987, and the amount was small. The clearing fund was not used during the recent financial crisis, even though the volume of transactions set a new record. S&P has consistently given the OCC a AAA rating since 1993. So, counterparty risk seems limited, but we cannot completely rule this out.

However, if counter-party credit risk is the driver of the basket-index spread, then the percentage effects should be much larger for shorted-dated options. Given that these contracts are marked-to-market every day, the effect of counter-party credit risk on a one-year option is of order $\sigma\sqrt{1/250}$ rather than σ, because after one day more margin is posted if the index declines enough during the day, and the contract is collateralized again. However, we find that the basket-index spreads roughly increase with the square root of the maturity of the contract. For example, for the strike-matched index with Δ of 20, the average basket-index spread during the crisis is 5.85 cents per dollar at $TTM = 365$, while it is 4.69 cents per dollar after multiplying the $TTM = 30$ spread by $\sqrt{12}$. If anything, the effect on the basket-index spread for one-year options is larger.

Finally, the dynamics of the basket-index spread are inconsistent with a counter-party credit risk explanation. Announcements that increase the likelihood of a bailout increased the basket-index spread, while negative announcements decreased the basket-index spread. The counterparty credit risk explanation would obviously predict the opposite effect. Moreover, it seems hard to argue that the likelihood of a complete meltdown of the financial system was highest in March 2009, when the basket-index spread peaked.

7.2 Mispricing, Cost of Hedging and short-sale restrictions

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 corporate bond yields and 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 index options and the cost of the basket does not require substantial 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 (which we address above) and the cost of hedging.

Single name options and index options have different costs of hedging. Since single name options are hedged with cash market transactions while the index options are hedged using futures since these are available and very liquid. A future contract on the financial sector (Financial SPCTR future) was traded on the CME, but not for other sectors. Hedging using cash transactions is more expensive than using futures. This affects put options more than call options since shorting a stock accrues additional costs (and these costs can be larger in times of crisis). The difference in the cost of hedging should affect financials more than other sectors because there were no futures on most other sectors (more on this below), and because the short squeeze (the difficulty of shorting stocks) was concentrated in financials. Therefore the benefit of available futures contracts on the financials index compared to cash trading was bigger than in other sectors.

In fact, there were explicit short sale restrictions on financial sector stocks. A short sale ban could push investors to express their bearish view by buying put options instead of shorting stocks. Market makers or other investors may find writing put options more costly when such positions cannot be hedged by shorting stock. The SEC imposed a short sale ban from September 19, 2008 until October 8, 2008 which affected 800 financial stocks. From July 21, 2008 onwards, there was a ban on *naked* short-selling for Freddie Mac, Fannie Mae, and 17 large banks. However, exchange and over-the-counter option market makers where exempted from both SEC rules so that they could continue to provide liquidity and hedge their positions during the ban. Both the short window of the ban compared to the period over which the put spread increased and the exemption for market makers make the short sale ban an unlikely explanation for our findings. Furthermore, we show that the financial index options are cheap, even without the option basket benchmark. The implied volatility declines relative to realized volatility for financial index put options, but not for other index put options.

Finally, our analysis of implied volatility on index options has established that these index options are cheap during the crisis even when comparing implied and realized volatility. This comparison does not rely at all on single name option prices, which may be more subject to mispricing, because of the higher cost of hedging.

7.3 Liquidity

Another potential alternative explanation of our findings is that index put options are more liquid than individual options, and that their relative liquidity rose during the financial crisis. The same explanation must also apply to call options. We now argue that these liquidity facts are an unlikely explanation for our findings, often pointing in the opposite direction.

Table IX reports summary statistics for the liquidity of put options on the S&P 500 index, sector indices (a value-weighted average across all 9 sectors), the financial sector index, all individual stock options (a value-weighted average), and individual 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 OTM ($\Delta < 20$) to deep ITM ($\Delta > 80$), while the rows report a range of option maturities. We separately report averages for the pre-crisis and crisis periods. 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 bid-ask and volume numbers understate the degree of liquidity. However, absent arbitrage opportunities across trading locations, the option prices in our database do reflect this additional liquidity.

Deep OTM put options with $\Delta < 20$ have large spreads, and volume is limited. OTM puts with Δ between 20 and 50 still have substantial option spreads. For 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 7.0% 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 decrease 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 firms' options.[22] At the same time, volume and open interest for long-dated OTM puts increased. For example, volume increased from 400 to 507 contracts 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. During the crisis, trade in 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. The absolute increase in liquidity of financial sector index puts during the crisis and the relative increase versus individual put options suggests that index options should have become more expensive, not cheaper during the crisis.

[22] Absolute bid-ask spreads 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.

Short-dated put options (with maturity less than 10 days) are more liquid than long-dated options; they experience a larger increase in trade during the crisis. We verified above that our results are robust across option maturities.

Table X reports the same liquidity statistics for calls. Calls and puts are similarly liquid yet display very different basket-index spread behavior. Finally, the increase in the basket-index spread during the crisis is also present in shorter-dated options, which are more liquid. All these facts suggest that illiquidity is an unlikely candidate.

8 Conclusion

We uncover new evidence from option prices that suggests the government absorbs aggregate tail risk by providing a sector-wide bailout guarantee to the financial sector. In doing so, the government subsidizes the private insurance against financial sector systemic risk. In turn, this effectively bends down the implied volatility skew for index put options on the financial sector, and causes the spread between financial index puts and a basket of individual bank puts to diverge. These effects are clearly visible in options prices during the 2007-2009 financial crisis.

A simple, single factor model helps us to understand whether fluctuations in the basket-index put spread may be attributed to changing risk exposure, or if something more is needed. The standard model fares poorly in explaining the sharp increase in the financial sector put spread during the crisis. We also show that a modification of the canonical model that truncates downside risk in the financial sector does a much better job explaining crisis put spread behavior. These results are consistent with the interpretation hypothesis that the government provides a collective bailout guarantee to the banking sector.

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Table I: Basket-Index Spreads on Out-of-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: Δ-Matched $TTM = 365$							Panel II: 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
	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
	max	2.269	0.487	3.090	0.359	0.953	0.198	0.870	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
	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: Δ-Matched, $TTM = 30$							Panel IV: 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
	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
	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
	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 strike price. 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. Δ is 20. In the top half of the table, time-to-maturity is 365 days, in the bottom half it is 30 days. Panel I uses Δ-matching to construct the basket-index spread and Panel II uses strike-matching (see Section 2).

Table II: Summary Statistics 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
		$\Delta = 20$							$\Delta = 30$						
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
	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
	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
	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
		$\Delta = 40$							$\Delta = 50$						
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
	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
	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
	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, using Δ-matching. Numbers reported are in cents per dollar of strike price. 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.

Table III: Basket-Index Spreads on Out-of-the-Money Options in Other Sectors

		Put Spread		
Sector		Full Sample	Pre-Crisis	Crisis
Financials	mean	1.69	0.81	3.80
	max	12.46	2.27	12.46
Consumer Disc.	mean	2.27	1.84	3.28
	max	9.02	4.67	9.02
Materials	mean	1.69	1.18	2.91
	max	7.70	2.95	7.70
Technology	mean	1.95	1.68	2.59
	max	6.68	4.13	6.68
Healthcare	mean	1.40	1.09	2.13
	max	5.95	3.78	5.95
Industrials	mean	1.81	1.65	2.19
	max	4.73	3.74	4.73
Consumer Staples	mean	1.35	1.15	1.84
	max	5.91	2.52	5.91
Utilities	mean	0.63	0.53	0.86
	max	4.10	2.56	4.10
Energy	mean	0.95	0.89	1.07
	max	3.47	3.41	3.47

This table reports the average basket-index put spread in the cost of insurance per dollar insured for the nine S&P 500 sector ETFs. Numbers reported are in cents per dollar of the strike price. 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. Δ is 20, time to maturity is 365 days and spreads are calculated using Δ-matched options. Sectors are listed in descending order by mean crisis spread.

Table IV: Black-Scholes Put Option Prices when Feeding in Implied Volatility

		Financials							Non-Financials							Diff
		Index		Basket		Basket-Index Spread			Index		Basket		Basket-Index Spread			Spread
		(1) BS	(2) data	(3) BS	(4) data	(5) BS	(6) data	(7) data-BS	(1) BS	(2) data	(3) BS	(4) data	(5) BS	(6) data	(7) data-BS	data-BS
Full	mean	4.13	5.15	7.48	8.08	3.34	2.94	−0.41	2.60	3.87	6.87	6.56	4.27	2.69	−1.59	1.18
	max	26.30	26.45	34.20	33.77	8.08	15.87	9.30	11.10	12.15	14.94	19.25	6.82	7.58	4.29	8.12
Pre-Crisis	mean	2.09	3.15	5.14	4.86	3.06	1.71	−1.34	1.74	3.06	6.06	5.32	4.32	2.26	−2.06	0.71
	max	5.86	6.65	9.18	9.22	6.37	3.76	1.47	4.15	5.10	9.05	9.65	6.82	4.57	0.52	3.76
Crisis	mean	9.01	9.91	13.04	15.77	4.03	5.86	1.83	4.65	5.81	8.82	9.51	4.17	3.70	−0.47	2.29
	max	26.30	26.45	34.20	33.77	8.08	15.87	9.30	11.10	12.15	14.94	19.25	5.60	7.58	4.29	8.12

This table reports summary statistics for basket and index put prices, comparing the Black-Scholes model predictions to the observed data. Numbers reported are in cents per dollar of strike price. 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. Δ is 20. We choose the index option with the same weighted average strike as the individual options. We use implied volatilities for the index and the realized correlations to back out the implied volatility for the individual stocks. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity.

Table V: Correlations implied by Black-Scholes

		Financials					Non-Financials				
			Puts		Calls			Puts		Calls	
		Actual	Implied	Spread	Implied	Spread	Actual	Implied	Spread	Implied	Spread
Full	mean	0.51	0.59	0.08	0.56	0.05	0.39	0.51	0.11	0.31	-0.08
	max	0.74	0.84	0.36	0.79	0.18	0.75	0.71	0.38	0.48	0.01
Pre-Crisis	mean	0.45	0.60	0.15	0.51	0.06	0.34	0.49	0.15	0.28	-0.06
	max	0.73	0.78	0.36	0.70	0.18	0.57	0.65	0.38	0.41	0.01
Crisis	mean	0.65	0.57	-0.08	0.67	0.03	0.52	0.54	0.03	0.38	-0.14
	max	0.74	0.84	0.22	0.79	0.15	0.75	0.71	0.28	0.48	-0.00

This table compares realized correlations to Black-Scholes implied correlations from put and call options. The implied correlation is chosen such that the basket-index spread in the data equals the Black-Scholes basket-index spread. 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. Δ is 20. We choose the index option with the same strike as the individual options. We use implied volatilities for the index. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity.

Table VI: Black-Scholes Put Option Prices when Feeding in Implied Volatility

		Financials							Non-Financials							Diff
		Index		Basket		Basket-Index Spread			Index		Basket		Basket-Index Spread			Spread
		BS	data	BS	data	BS	data	data-BS	BS	data	BS	data	BS	data	data-BS	data-BS
Full	mean	3.92	5.15	6.53	8.08	2.61	2.94	0.32	2.04	3.87	4.90	6.56	2.86	2.69	−0.17	0.50
	max	25.52	26.45	33.34	33.77	8.53	15.87	8.35	7.14	12.15	13.15	19.25	6.25	7.58	5.55	6.17
Pre-Crisis	mean	1.46	3.15	3.54	4.86	2.08	1.71	−0.37	1.44	3.06	4.29	5.32	2.85	2.26	−0.59	0.22
	max	4.86	6.65	7.89	9.22	4.71	3.76	1.53	4.34	5.10	8.69	9.65	4.81	4.57	0.96	1.73
Crisis	mean	9.76	9.91	13.64	15.77	3.88	5.86	1.98	3.46	5.81	6.34	9.51	2.88	3.70	0.82	1.16
	max	25.52	26.45	33.34	33.77	8.53	15.87	8.35	7.14	12.15	13.15	19.25	6.25	7.58	5.55	6.17

This table reports summary statistics for basket and index put prices, comparing the Black-Scholes model predictions to the observed data. Numbers reported are in percent of the strike price. 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. Δ is 20. We choose the index option with the same weighted average strike as the individual options. We use a-one year backward looking window forecast for index return volatilities and the realized correlations to back out the implied volatility for the individual stocks. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity.

Table VII: Observed Minus Black-Scholes Put Option Prices for Largest Banks

		Basket	Big 12	C	AIG	BoA	JP	$Wells$	$Wach$	GS	$Amex$	MS	$Merrill$	Fannie	Freddie
Pre-Crisis	mean	1.32	0.80	0.64	0.93	0.31	0.53	0.99	0.78	0.93	0.71	0.74	0.94	1.03	1.09
	max	4.33	3.49	2.65	2.96	3.93	3.75	3.22	3.29	2.91	3.33	3.82	3.54	4.36	4.09
Crisis	mean	2.13	−1.04	−1.68	−1.49	−6.85	−0.21	0.09	−6.81	0.21	2.27	−4.85	0.36	2.81	3.68
	max	14.53	19.94	27.88	18.45	40.42	13.83	15.62	15.30	17.49	18.83	26.66	11.10	15.66	18.09

This table reports the difference between the actual and the BS price put option price (per dollar insured). Numbers reported are in cents per dollar of strike price. 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. Δ is 20. We choose the index option with the same weighted average strike as the individual options. We use a one-year-ahead GARCH-based forecast for stock return volatilities. Rolling volatilities are estimated from daily returns using a one year backward looking window. The cost of the basket is computed as described in Section 4.1. Data for Wachovia and Merrill Lynch end in December 2008. data for freddie Mac and Fannie Mae end in September 2008. For these four firms, the reported averages for the crisis period end at these times.

Table VIII: Actual vs. Bailout Basket-Index Spreads: Implied Volatility

		Data minus BS	Bailout minus BS								
	$\underline{J}$		0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	∞
Part I: Financials											
Full	mean	−0.41	0.62	0.67	0.60	0.55	0.46	0.31	0.17	0.09	0.00
	max	9.30	2.87	4.82	6.86	7.98	8.44	10.46	9.95	6.67	0.00
Pre-Crisis	mean	−1.34	0.76	0.30	0.04	−0.01	−0.01	−0.00	−0.00	−0.00	0.00
	max	1.47	1.39	2.22	1.10	0.28	0.01	−0.00	−0.00	−0.00	0.00
Crisis	mean	1.83	0.30	1.54	1.92	1.86	1.58	1.05	0.59	0.29	0.00
	max	9.30	2.87	4.82	6.86	7.98	8.44	10.46	9.95	6.67	0.00
Part II: Non-financials											
Full	mean	−1.09	0.63	0.64	0.28	0.10	0.02	−0.00	−0.01	−0.01	0.00
	max	4.46	1.60	3.16	3.70	3.23	3.27	2.06	0.90	0.32	0.00
Pre-Crisis	mean	−1.48	0.59	0.33	0.04	−0.01	−0.01	−0.01	−0.00	−0.00	0.00
	max	0.97	1.00	1.83	0.83	0.17	−0.00	−0.00	−0.00	−0.00	0.00
Crisis	mean	−0.17	0.73	1.38	0.85	0.38	0.11	0.01	−0.02	−0.02	0.00
	max	4.46	1.60	3.16	3.70	3.23	3.27	2.06	0.90	0.32	0.00

This table reports summary statistics for the BS-adjusted basket-index put spread in the data and in the model with bailouts. Numbers reported are in percent of the strike price. 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. Δ is 20. We choose the index option with the same weighted average strike as the individual options. We use implied volatilities for the index and the realized correlations to back out the implied volatility for the individual stocks. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity.

Table IX: 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* $\leq$ 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* $\leq$ 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* $\leq$ 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* $\leq$ 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* $\leq$ 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* $\leq$ 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 X: 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* $\leq$ 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* $\leq$ 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* $\leq$ 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* $\leq$ 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* $\leq$ 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* $\leq$ 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.

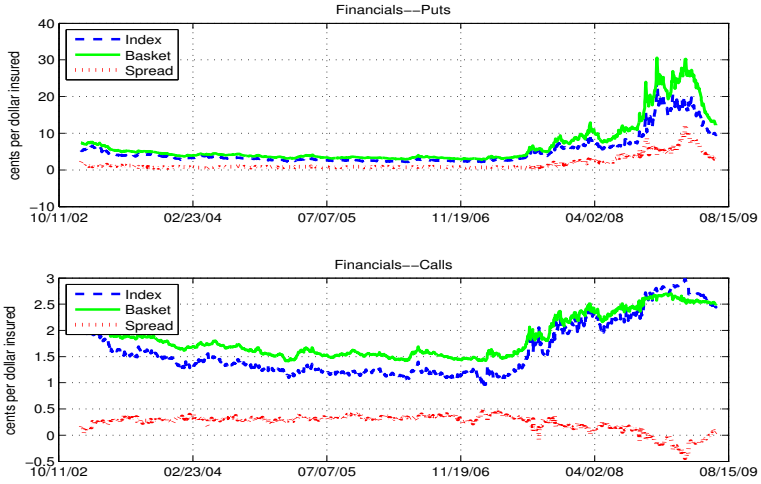


Figure 1: Cost Per Dollar Insured - Financial Sector

The dashed (full) line shows the cost per dollar insured for the index $Call^{index}_{cdi,f}$(basket, $Call^{basket}_{cdi,f}$). The dotted line plots their difference. Δ is 20. Time to maturity is 365 days. We choose the index option with the same Δ as the individual options. The top panel looks at puts. The bottom looks at calls.

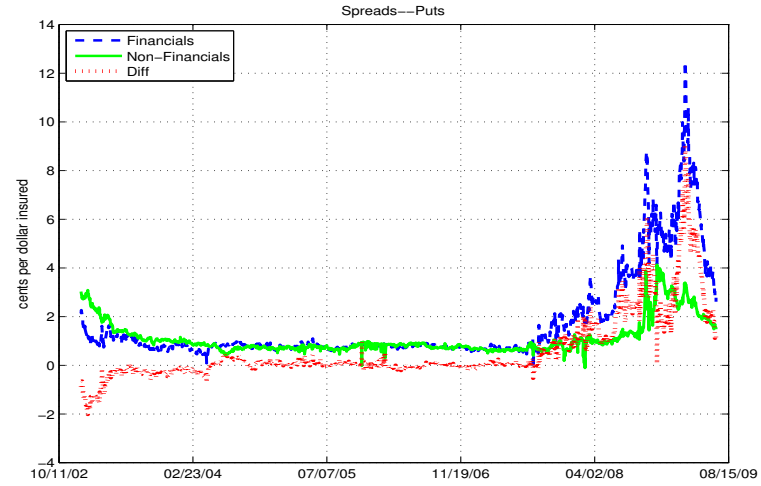


Figure 2: Basket-Index Spread in Cost Per Dollar Insured Inferred from Puts

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

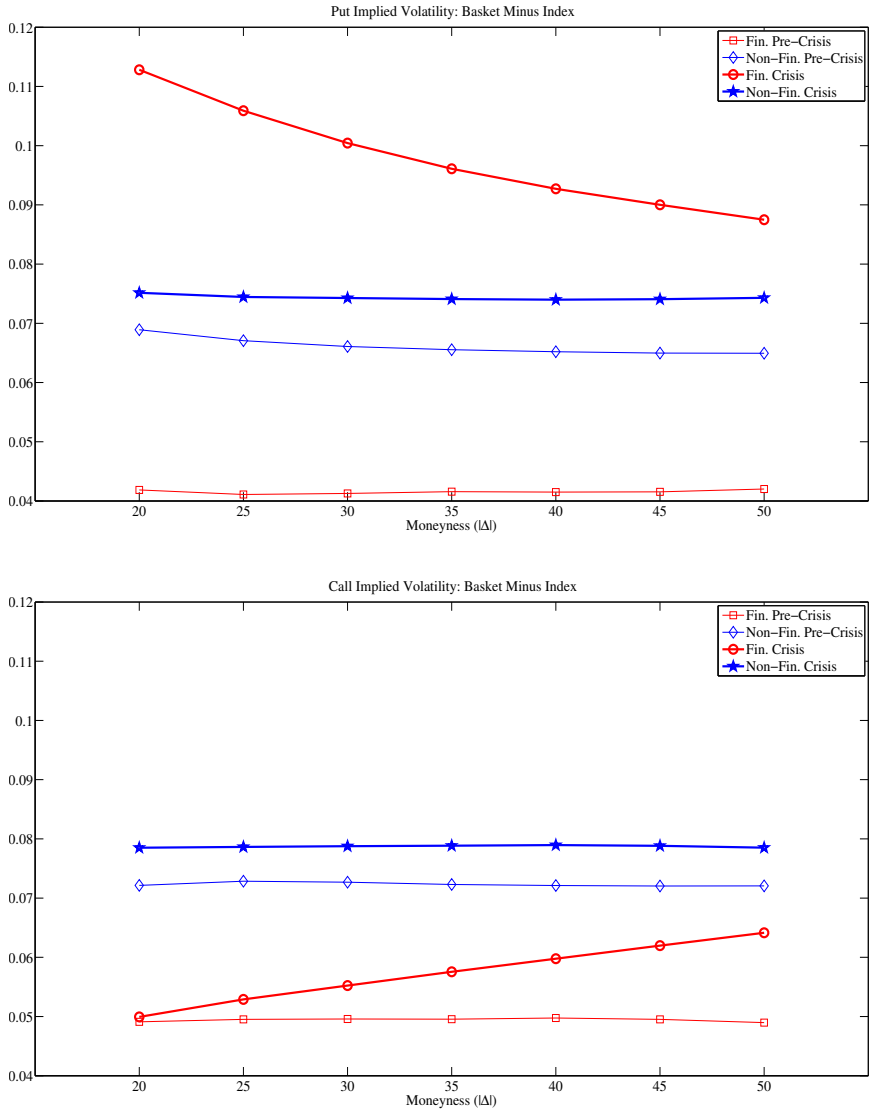


Figure 3: Implied Volatility Skew Inferred from Calls

The figure plots the average implied volatility difference (basket minus index) inferred from puts (top panel) and calls (bottom panel) for financials and non-financials against moneyness. The pre-crisis sample covers 1/2003-7/2007. The crisis sample covers 8/2007-6/2009.

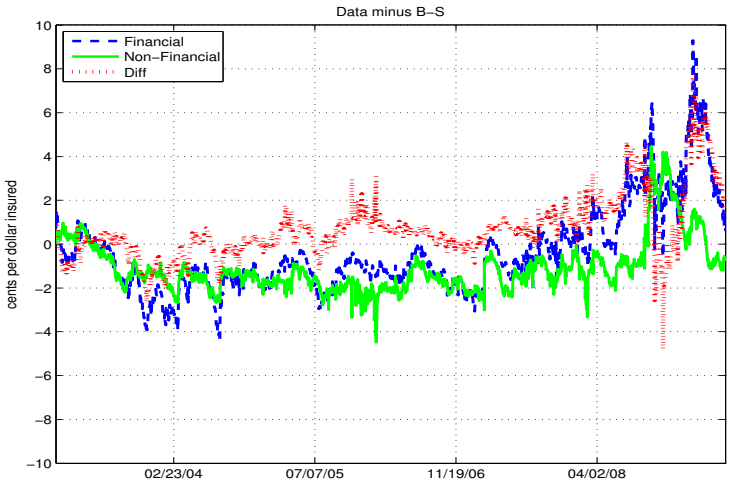


Figure 4: Actual Minus Black-Scholes Basket-Index Spreads on Put Options: Implied Vol

The dashed (full) line shows the actual minus Black-Scholes basket-index put spread for the financials (non-financials). The dotted line plots their difference. Δ is 20. Time to maturity is 365 days. We choose the index option with the same strike as the individual options.

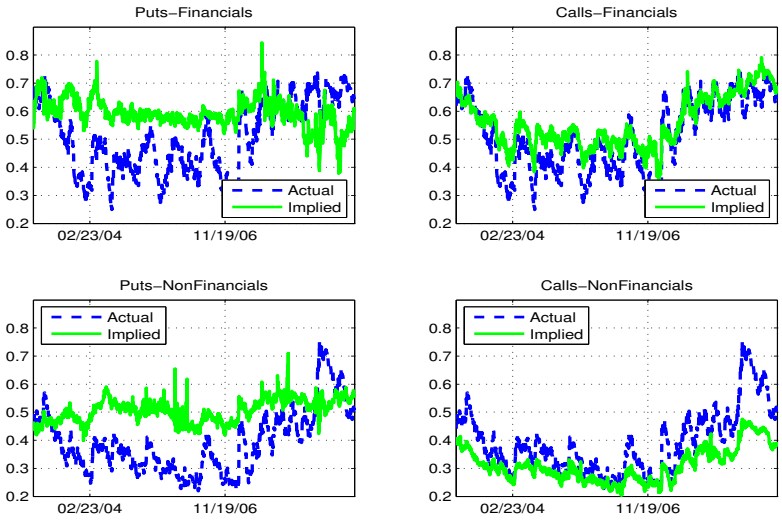


Figure 5: Actual vs Black-Scholes Implied Correlations

The dashed (full) line shows the actual (Black-Scholes-implied) correlations the financials (top panel) and non-financials (bottom panel). Δ is 20. Time to maturity is 365 days. We choose the index option with the same strike as the individual options. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity.

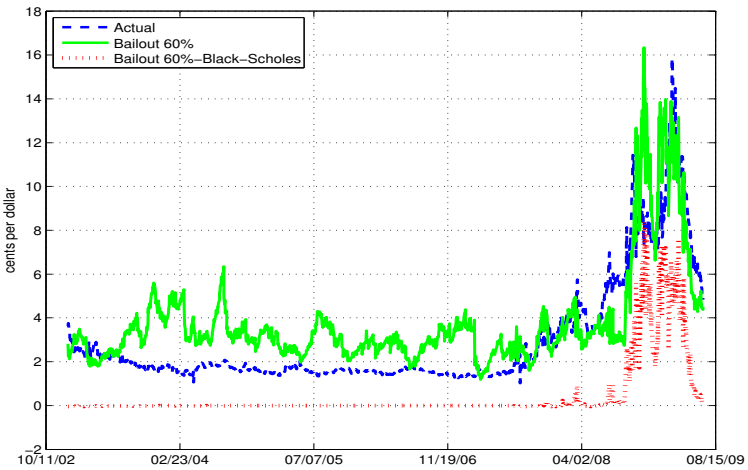
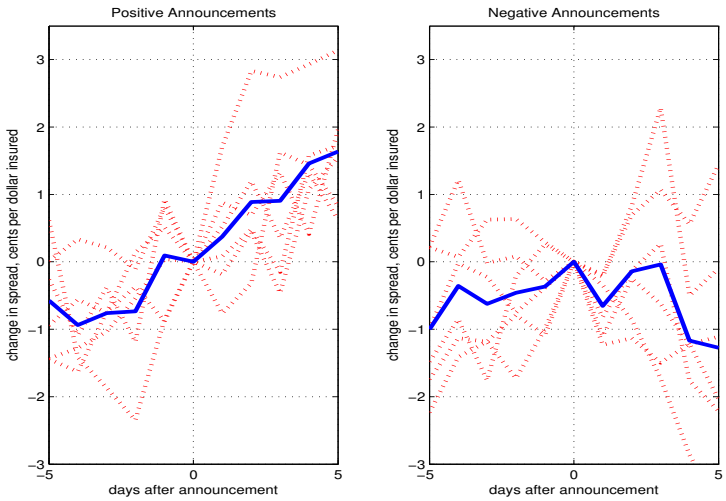


Figure 6: Basket-Index Put Spreads: Model with Bailout

The dashed line shows the observed basket-index put spread for financials. The dashed line plots the same object for the single-factor model with bailouts. The dotted line plots the difference between the basket-index put spreads for the single-factor model with bailout minus that implied by the single-factor model without bailout guarantee. Δ is 20 and time to maturity is 365 days. We choose the index option with the same strike as the individual options. We use the implied volatility for the index and the realized correlations to back out the implied volatility for the individual stocks. Daily pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95. Pairwise correlations within the sector are then averaged each day, weighted by the pairs' combined market equity.

Panel I: Difference-in-differences (data minus Black-Scholes and basket minus index)



Panel II: Triple Difference (financials minus non-financials, data minus Black-Scholes, and basket-index)

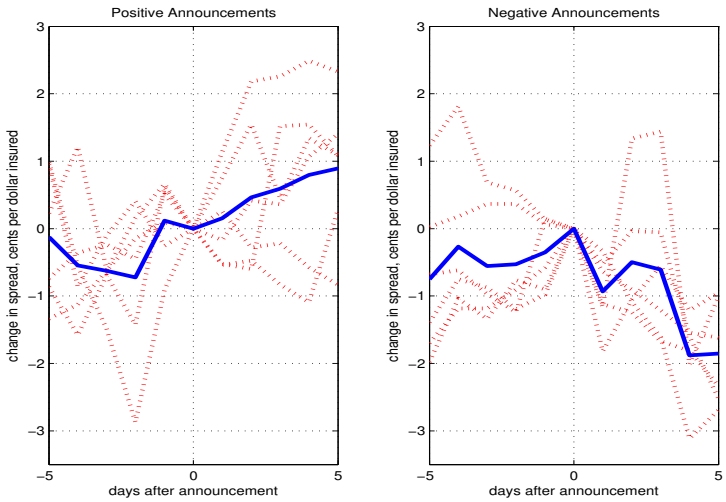


Figure 7: Basket-Index Spread Event Study Around Government Announcements

Panel I shows the basket-index spread difference-in-differences (data minus Black-Scholes and basket minus index) around announcement dates. Panel II shows the basket-index spread triple difference (financials minus non-financials, data minus Black-Scholes, and basket-index) around announcement dates. Figures on the left and right show responses to positive and negative announcements, respectively. In each figure, the solid line shows the average spread response over all announcements, and the dotted lines show the responses to each individual announcement. Spreads use options with $\Delta = 20$ and $TTM = 365$, and are constructed using strike-matching. BS basket-index spreads are computed using the implied index volatility.

Separate Appendix–Not for Publication

A Data Appendix

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 A reports the XLF holdings before and after the crisis.

B Appendix Gaussian Model

B.1 Individual Firm returns

An individual bank j's stock return is given by

$$\begin{aligned} r^j &= \mu^j - \lambda^j J^a + \sigma\epsilon^j, \\ J^a &= \min(J^r, \underline{J}), \quad J^r \sim \mathcal{N}(\theta_r, \delta_r^2) \end{aligned}$$

where the shock ϵ^j is an idiosyncratic shock which is standard normally distributed and i.i.d. over time and across firms. In contrast, the shock J^a is an aggregate shock, also i.i.d. over time. The common shock is truncated by a government bailout for $\underline{J} < \infty$. The shocks J^r and ϵ^j are orthogonal; ϵ^j is uncorrelated with the SDF. The process J^r is correlated with the SDF; define $\sigma_{m,J} = Cov(m, J^r)$ and

$$\beta_J = \frac{Cov(m, J^r)}{Var(J^r)} = \frac{\sigma_{m,J}}{\delta_r^2}.$$

Below we will use the fact that, since m and J^r are bivariate normal, which implies that:

$$E[m|J^r] = E[m] + \beta_J(J^r - \theta_r), \text{ and } V[m|J^r] = V[m] - \beta_J\sigma_{m,J}.$$

See Lemma 4 at the end of this appendix.

We are interested in computing the variance of returns and the covariance between a pair of returns. This will allow us to compute the volatility of returns and the correlation of returns. Two auxiliary results turn out to be useful:

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

and

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

The variance of returns is:

$$Var[r^j] = E[\left(r^j\right)^2] - \left[E[r^j]\right]^2 = \sigma^2 + (\lambda^j)^2 \sigma_a^2$$

Similarly, mean returns are given by:

$$E[r^j] = \mu^j - \lambda^j \theta_a.$$

Note that if there is no bailout guarantee, $\theta_a = \theta_r$ and $\sigma_a^2 = \delta_r^2$, so that

$$Var[r^j] \equiv \sigma_{nb}^2 = \sigma^2 + (\lambda^j)^2 \delta_r^2 \quad E[r^j] = \mu^j - \lambda^j \theta_r$$

The covariance of a pair of different firms' returns (r^1, r^2) is:

$$Cov[r_i^1, r_i^2] = E[r^1 r^2] - [E[r^1] E[r^2] = \lambda^1 \lambda^2 \sigma_a^2,$$

Define

$$\chi = \theta_r + \sigma_{m,J}.$$

In order to get the equity risk premium for an individual stock, start from the Euler equation:

$$\begin{aligned} 1 &= E\left[\exp\left(m + \mu^j - \lambda^j J^a + \sigma \epsilon^j\right)\right] \\ &= \exp\left(\mu^j + .5\sigma^2\right) E\left[\exp\left(m - \lambda^j J^a\right)\right] \\ &= \exp(\mu^j) \left\{E\left[\exp\left(m - \lambda^j J^r\right) 1_{(J^r < \underline{J})}\right] + E\left[\exp\left(m - \lambda^j \underline{J}\right) 1_{(J^r > \underline{J})}\right]\right\} \\ &= \exp\left(\mu^j + .5\sigma^2\right) \left\{\Psi(1, -\lambda^j; m, J^r) \Phi\left(\frac{\underline{J} - \chi + \lambda^j \delta_r^2}{\delta_r}\right) + \exp(-r^f - \lambda^j \underline{J}) \Phi\left(\frac{\theta_r - \underline{J}}{\delta_r}\right)\right\} \text{ by Lemma 1} \\ &= \exp\left(\mu^j - r^f + .5\sigma^2\right) \\ &\quad \times \left\{\exp\left(-\lambda^j \chi + .5(\lambda^j)^2 \delta_r^2\right) \Phi\left(\frac{\underline{J} - \chi + \lambda^j \delta_r^2}{\delta_r}\right) + \exp(-\lambda^j \underline{J}) \Phi\left(\frac{\theta_r - \underline{J}}{\delta_r}\right)\right\} \end{aligned}$$

which implies that the expected return equals:

$$\mu^j = r^f - .5\sigma^2 - \log\left\{\exp\left(-\lambda^j \chi + .5(\lambda^j)^2 \delta_r^2\right) \Phi\left(\frac{\underline{J} - \chi + \lambda \delta_r^2}{\delta_r}\right) + \exp(-\lambda^j \underline{J}) \Phi\left(\frac{-\underline{J}}{\delta_r}\right)\right\}. \quad (5)$$

In the no-bailout case, $\underline{J} \to +\infty$, and the equity risk premium (including Jensen term) becomes $\mu_{nb}^j - r^f + .5\sigma_{nb}^2 = \lambda^j \chi$.

B.2 Aggregation to Sector

We construct the value-weighted portfolio return of all stocks, the index, with portfolio weights w.

$$r^{index} = \mu^{index} - J^a + \sigma^{index} \epsilon^{index},$$

where ϵ^{index} is i.i.d. standard Normal, $w'\lambda = 1$, where $\mu^{index} = w'\mu^j$, and where

$$\sigma^{index} = \sqrt{w'\sigma\sigma'w} \approx 0$$

If the number of firms is large and the weights are equal across firms, the last term equals zero. Note that we do not need to set it equal to zero.

Next, assume that diversification is complete so that $r^{index} = \mu^{index} - J^a$, and solve for μ^{index} from the Euler equation for the index return:

$$\begin{aligned} 1 &= E\left[\exp\left(m + \mu^{index} - J^a\right)\right] \\ &= \exp(\mu^{index})\left\{\Psi(1,-1;m,J^r)\Phi\left(\frac{\underline{J} - \chi + \delta_r^2}{\delta_r}\right) + \exp(-r^f - \underline{J})\Phi\left(\frac{\theta_r - \underline{J}}{\delta_r}\right)\right\} \text{ by Lemma 1} \\ &= \exp\left(\mu^{index} - r^f\right)\left\{\exp\left(-\chi + \frac{\delta_r^2}{2}\right)\Phi\left(\frac{\underline{J} - \chi + \delta_r^2}{\delta_r}\right) + \exp(-\underline{J})\Phi\left(\frac{\theta_r - \underline{J}}{\delta_r}\right)\right\} \end{aligned}$$

which implies

$$\mu^{index} = r^f - \log\left\{\exp\left(-\chi + \frac{\delta_r^2}{2}\right)\Phi\left(\frac{\underline{J} - \chi + \delta_r^2}{\delta_r}\right) + \exp(-\underline{J})\Phi\left(\frac{\theta_r - \underline{J}}{\delta_r}\right)\right\}. \tag{6}$$

In the no-bailout case, this gives $\mu_{nb}^{index} = r^f - \frac{\delta_r^2}{2} + \chi$.

C Valuing Options

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

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

where the strike price K is expressed as a fraction of a dollar (that is, $K = 1$ is the ATM option). The option value in state i on stock j is:

$$Put^j = E\left[M(K - R^j)^+\right] = -E\left[\exp\left(m + r^j\right)1_{k>r^j}\right] + KE\left[\exp\left(m\right)1_{k>r^j}\right] = -V_1 + V_2$$

We now compute this in terms of the underlying structural parameters. Define $\tilde{r} = \mu + \sigma\epsilon$ and $r = \tilde{r} - \lambda\min(J^r, \underline{J})$, where we omit the dependence on j for ease of notation. Our derivation below exploits the normality of m and $\tilde{r}$, which are conditionally uncorrelated.

First term V_1

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

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

$$\begin{aligned}
V_{11} &= E\left[\exp\left(m+\tilde{r}-\lambda J^r\right)1_{k>r}1_{J^r<\underline{J}}\right] \\
&= E\left[E\left\{\exp\left(m+\tilde{r}-\lambda J^r\right)1_{k+\lambda J^r>\tilde{r}}|J^r\right\}1_{J^r<\underline{J}}\right] \\
&= E\left[E\left\{\exp\left(m+\tilde{r}\right)1_{k+\lambda J^r>\tilde{r}}|J^r\right\}\exp\left(-\lambda J^r\right)1_{J^r<\underline{J}}\right] \\
&= E\left\{E[\exp(m)|J^r]E[\exp(\tilde{r})1_{k+\lambda J^r>\tilde{r}}|J^r]E[\exp\left(-\lambda J^r\right)1_{J^r<\underline{J}}|J^r]\right\} \\
&= E\left\{\exp\left(E[m|J^r]+.5V[m|J^r]\right)E[\exp(\tilde{r})1_{k+\lambda J^r>\tilde{r}}|J^r]\exp\left(-\lambda J^r\right)1_{J^r<\underline{J}}\right\} \\
&= E\left\{\exp\left(E[m]+\beta_J(J^r-\theta_r)+.5V[m]-.5\beta_J\sigma_{m,J}\right)E[\exp(\tilde{r})1_{k+\lambda J^r>\tilde{r}}|J^r]\exp\left(-\lambda J^r\right)1_{J^r<\underline{J}}\right\} \\
&= \Psi(1;m)\exp\left(-\beta_J\theta_r-.5\beta_J\sigma_{m,J}\right)E\left\{E[\exp(\tilde{r})1_{k+\lambda J^r>\tilde{r}}|J^r]\exp\left(\left[\beta_J-\lambda\right]J^r\right)1_{J^r<\underline{J}}\right\} \\
&= \Psi(1;m)\Psi(1;\tilde{r})\exp\left(-\beta_J\theta_r-.5\beta_J\sigma_{m,J}\right)E\left\{\Phi\left(\phi_0+\phi_1 J^r\right)\exp\left(\left[\beta_J-\lambda\right]J^r\right)1_{J^r<\underline{J}}\right\} \text{ by Lemma 1} \\
&= \Psi(1;m)\Psi(1;\tilde{r})\exp\left(-\beta_J\theta_r-.5\beta_J\sigma_{m,J}+.5\left[\beta_J-\lambda\right]^2\delta_r^2+\left[\beta_J-\lambda\right]\theta_r\right) \\
&\quad\times\Phi\left(\frac{\phi_0-t_1}{\sqrt{1+\phi_1^2\delta_r^2}}\,,\frac{\underline{J}-t_2}{\delta_r}\,;\rho\right) \text{ by Lemma 2} \\
&= \Psi(1;m)\Psi(1;\tilde{r})\exp\left(.5\lambda^2\delta_r^2-\lambda[\sigma_{m,J}+\theta_r]\right)\Phi\left(\frac{\phi_0-t_1}{\sqrt{1+\phi_1^2\delta_r^2}}\,,\frac{\underline{J}-t_2}{\delta_r}\,;\rho\right)
\end{aligned}$$

where $\phi_1=\frac{\lambda}{\sigma}$, $\phi_0=\frac{\phi_1}{\lambda}\left(k-\mu-\sigma^2\right)$, $t_2=\theta_r+\sigma_{m,J}-\lambda\delta_r^2$, $t_1=-\phi_1 t_2$, and $\rho=\frac{-\phi_1\delta_r}{\sqrt{1+\phi_1^2\delta_r^2}}$. We have used fact that m and J^r are jointly normal to calculate the conditional moments $E[m|J^r]$ and $V[m|J^r]$, as discussed above.

Next, we turn to V_{12}:

$$\begin{aligned}
V_{12} &= E\left[\exp\left(m+\tilde{r}-\lambda\underline{J}\right)1_{k>r}1_{J^r>\underline{J}}\right] \\
&= \exp(-\lambda\underline{J})E\left\{E[\exp(m)|J^r]1_{J^r>\underline{J}}\right\}E[\exp(\tilde{r})1_{k+\lambda\underline{J}>\tilde{r}}] \\
&= \exp(-\beta_J\theta_r-.5\beta_J\sigma_{m,J}-\lambda\underline{J})\Psi(1;m)\Psi(1;\tilde{r})\Phi\left(\frac{\lambda\underline{J}+k-\mu-\sigma^2}{\sigma}\right)E\left[\exp(\beta_J J^r)1_{J^r>\underline{J}}\right] \\
&= \exp(-\lambda\underline{J})\Psi(1;m)\Psi(1;\tilde{r})\Phi\left(\frac{\lambda\underline{J}+k-\mu-\sigma^2}{\sigma}\right)\left[1-\Phi\left(\frac{\underline{J}-\theta_r-\sigma_{m,J}}{\delta_r}\right)\right] \text{ by Lemma 1} \\
&= \exp(-\lambda\underline{J})\Psi(1;m)\Psi(1;\tilde{r})\Phi\left(\frac{\lambda\underline{J}+k-\mu-\sigma^2}{\sigma}\right)\Phi\left(\frac{-\underline{J}+\theta_r+\sigma_{m,J}}{\delta_r}\right)
\end{aligned}$$

Second term V_2

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

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

$$\begin{aligned}
V_{21} &= KE\left[\exp\left(m\right)1_{k>r}1_{J^r<\underline{J}}\right] \\
&= KE\left[E\left\{\exp\left(m\right)1_{k+\lambda J^r>\tilde{r}}|J^r\right\}1_{J^r<\underline{J}}\right] \\
&= K\Psi(1;m)\exp\left(-\beta_J\theta_r-.5\beta_J\sigma_{m,J}\right)E\left[\Phi\left(\phi_0+\phi_1 J^r\right)\exp\left(\beta_J J^r\right)1_{J^r<\underline{J}}\right] \text{ by Lemma 1} \\
&= K\Psi(1;m)\Phi\left(\frac{\phi_0-t_1}{\sqrt{1+\phi_1^2\delta_r^2}}\,,\frac{\underline{J}-t_2}{\delta_r}\,;\rho\right) \text{ by Lemma 2}
\end{aligned}$$

where $\phi_1 = \frac{\lambda}{\sigma_d}$, $\phi_0 = \frac{\phi_1}{\lambda}(k-\mu)$, $t_2 = \theta_r + \sigma_{m,J}$, $t_1 = -\phi_1 t_2$, $\rho = \frac{-\phi_1\delta_r}{\sqrt{1+\phi_1^2\delta_r^2}}$.

Finally, we turn to V_{22}:

$$\begin{aligned}
V_{22} &= KE\left[\exp(m)\,1_{k>r}1_{J^r>\underline{J}}\right] \\
&= KE\left[\exp(m)\,1_{k+\lambda\underline{J}>\tilde{r}}1_{J^r>\underline{J}}\right] \\
&= KE\left\{E[\exp(m)|J^r]1_{J^r>\underline{J}}\right\}E\left[1_{k+\lambda\underline{J}>\tilde{r}}\right] \\
&= K\exp(-\beta_J\theta_r - .5\beta_J\sigma_{m,J})\Psi(1;m)\Phi\left(\frac{\lambda\underline{J}+k-\mu}{\sigma}\right)E\left[\exp(\beta_J J^r)1_{J^r>\underline{J}}\right] \\
&= K\Psi(1;m)\Phi\left(\frac{\lambda\underline{J}+k-\mu}{\sigma}\right)\left[1-\Phi\left(\frac{\underline{J}-\theta_r-\sigma_{m,J}}{\delta_r}\right)\right] \text{ by Lemma 1} \\
&= K\Psi(1;m)\Phi\left(\frac{\lambda\underline{J}+k-\mu}{\sigma}\right)\Phi\left(\frac{-\underline{J}+\theta_r+\sigma_{m,J}}{\delta_r}\right).
\end{aligned}$$

Combining Terms Note that $\Psi(1;m) = \exp(-r_t^f)$ and that $\Psi(1;\tilde{r}) = \exp(\mu_r + .5\sigma^2)$ which is the expected log stock return adjusted for a Jensen term. Note that the Jensen term only involves the idiosyncratic risk. The correlation coefficient is $\rho = \frac{-\lambda\delta_r}{\sqrt{\sigma^2+\lambda^2\delta_r^2}}$. Recall the definitions:

$$\chi = \theta_r + \sigma_{m,J} \quad \text{and} \quad \sigma_{nb}^2 = \sigma^2 + \lambda^2\delta_r^2.$$

Combining the four terms, we get that the put price on an individual stock is given by (dependence on j suppressed):

$$\begin{aligned}
Put &= -\exp(\mu - r^f + .5\sigma^2)\left\{\exp\left(-\lambda\chi + .5\lambda^2\delta_r^2\right)\Phi\left(\frac{k-\mu+\lambda\chi-\sigma_{nb}^2}{\sigma_{nb}}\,,\frac{\underline{J}-\chi+\lambda\delta_r^2}{\delta_r}\,;\rho\right)\right. \\
&\quad \left.+\exp(-\lambda\underline{J})\Phi\left(\frac{k-\mu-\sigma^2+\lambda\underline{J}}{\sigma}\right)\Phi\left(\frac{-\underline{J}+\chi}{\delta_r}\right)\right\} \\
&\quad +K\exp(-r_t^f)\left\{\Phi\left(\frac{k-\mu+\lambda\chi}{\sigma_{nb}}\,,\frac{\underline{J}-\chi}{\delta_r}\,;\rho\right)+\Phi\left(\frac{k-\mu+\lambda\underline{J}}{\sigma}\right)\Phi\left(\frac{-\underline{J}+\chi}{\delta_r}\right)\right\}
\end{aligned} \tag{7}$$

Comparison with Black-Scholes To compare with Black-Scholes, set $\underline{J} = +\infty$. This implies, along with $\mu_{nb}^j - r^f + .5\sigma_{nb}^2 = \lambda^j\chi$, that

$$Put = -\Phi\left(\frac{k-r^f-.5\sigma_{nb}^2}{\sigma_{nb}}\right) + K\exp(-r_t^f)\Phi\left(\frac{k-r^f+.5\sigma_{nb}^2}{\sigma_{nb}}\right).$$

Hence, our expression collapses to the standard Black-Scholes price for a put option in the absence of a bailout guarantee.

The Index The index option price is a simple case of the general option pricing formula with $\mu^j = \mu^{index}$, $\lambda^j = 1$ and with $\sigma^j = \sigma^{index}$. Under the additional assumption that $\sigma^{index} = 0$, the derivation simplifies somewhat. The variable $\tilde{r}$ is then no longer a random variable, but a constant. The four terms

of the put option formula become

$$\begin{aligned}
V_{11}^{index} &= \exp\left(\mu^{index} - r^f + .5\delta_r^2 - \chi\right)\left\{\Phi\left(\frac{\underline{J} - \chi + \delta_r^2}{\delta_r}\right) - \Phi\left(\frac{\mu^{index} - k - \chi + \delta_r^2}{\delta_r}\right)\right\} \\
V_{12}^{index} &= \exp(\mu^{index} - r^f - \underline{J})\Phi\left(\frac{-\underline{J} + \chi}{\delta_r}\right) \\
V_{21}^{index} &= K\exp(-r^f)\left\{\Phi\left(\frac{\underline{J} - \chi}{\delta_r}\right) - \Phi\left(\frac{\mu^{index} - k - \chi}{\delta_r}\right)\right\} \\
V_{22}^{index} &= K\exp(-r^f)\Phi\left(\frac{-\underline{J} + \chi}{\delta_r}\right)
\end{aligned}$$

Combining terms,

$$\begin{aligned}
Put^{index} = &-\exp\left(\mu^{index} - r^f\right)\left\{\exp\left(.5\delta_r^2 - \chi\right)\left[\Phi\left(\frac{\underline{J} - \chi + \delta_r^2}{\delta_r}\right) - \Phi\left(\frac{\mu^{index} - k - \chi + \delta_r^2}{\delta_r}\right)\right]\right. \\
&\left. + \exp(-\underline{J})\Phi\left(\frac{-\underline{J} + \chi}{\delta_r}\right)\right\} + K\exp(-r^f)\Phi\left(\frac{k - \mu_r^{index} + \chi}{\delta_r}\right)
\end{aligned}$$

Note that this formula only holds if $\mu^{index} < k + \underline{J}$. If instead $\mu^{index} > k + \underline{J}$, then $Put^{index} = 0$.

D How to operationalize

E How to operationalize

We need each of the inputs to formula (7). The six-step procedure below is for a given bailout level $\underline{J}$.

First, and without loss of generality, we set $\theta_r = 0$, which makes J^r a mean-zero shock. Also, the formula requires a zero-coupon risk-free rate r^f which is readily available in the OptionMetrics data at daily frequency.

Second, we can recover estimates for σ_{nb} and δ_r from the variance of an individual stock return,

$$(\sigma^j)^2 = (\lambda^j)^2\sigma_a^2 + \sigma^2,$$

and from the variance of the index return,

$$(\sigma^{index})^2 = \sigma_a^2 + w'\sigma_d\sigma_d'w \approx \sigma_a^2,$$

where w are the weights of the stocks in the index. When the number of firms is large and index components are about equally weighted, the last term is approximately zero. These two variances can be estimated at a daily frequency.

Third, abstracting from heterogeneity in λ, the correlation between two stocks in the index is $\rho(r^k, r^j) = \frac{\lambda^2\sigma_a^2}{\lambda^2\sigma_a^2 + \sigma^2}$. The correlation should be estimated over the same (rolling) window as the individual and aggregate variance. Now, we can back out an estimate for λ and σ_d^2 from the correlation, the variance of the individual return and the variance of the index return. We have $\sigma_d^2 = \sigma_r^2 - (\lambda^j)^2\sigma_a^2$ and $\lambda = \frac{\sigma_r\sqrt{\rho_{i,j}}}{\sigma_a}$.

Fourth, the moments of the aggregate truncated shock derived above imply the following non-linear

equation, which we can solve based on observables to arrive at an estimate for the jump variance δ_r:

$$\sigma_a^2 = \delta_r^2\Phi\left(\frac{\underline{J}}{\delta_r}\right) - \delta_r\underline{J}\phi\left(\frac{\underline{J}}{\delta_r}\right) + \underline{J}^2\Phi\left(\frac{-\underline{J}}{\delta_r}\right) - \delta_r^2\phi\left(\frac{\underline{J}}{\delta_r}\right)^2 - \underline{J}^2\Phi\left(\frac{-\underline{J}}{\delta_r}\right)^2 + 2\delta_r\underline{J}\phi\left(\frac{\underline{J}}{\delta_r}\right)\Phi\left(\frac{-\underline{J}}{\delta_r}\right).$$

Finally, we must estimate the expected log index return. To do so, we rely on the equity risk premium lower bound derived in Martin's (2011) simple variance swap framework. He shows that the following bound obtains under weak assumptions:

$$\exp(r^f)E[\exp(r^{index}) - \exp(r^f)] \geq SVIX^2.$$

For our estimate, we assume that this bound holds with equality. Next, we make the Jensen inequality adjustment

$$\log E[\exp(r^{index})] = \mu^{index} + .5\sigma_a^2. \tag{8}$$

This relationship is exact in the absence of a bailout ($\underline{J} = \infty$), but when J^a is truncated normality is violated and the equality in (8) is an approximation. The expected return based on $SVIX$ and the previously discussed inputs is then calculated as

$$\mu^{index} = \log\left(\frac{SVIX^2}{exp(r^f)} + exp(r^f)\right) - \frac{\sigma_a^2}{2}.$$

Our calculation of $SVIX$ for this step uses financial sector index options with $TTM = 30$. Our construction follows Martin (2011), which effectively forms an equally weighted portfolio of index calls and puts with varying strikes.

F Auxiliary Lemmas

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*

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

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 $\Gamma = E[\exp(ax+by)1_{d<y<c}]$, then:

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

□

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

$$E\left[\Phi\left(b_0+b_1x\right)\exp\left(ax\right)1_{x<c}\right] = \Phi\left(\frac{b_0-t_1}{\sqrt{1+b_1^2\sigma_x^2}}\ ,\frac{c-t_2}{\sigma_x}\ ;\rho\right)\exp(z_1) \tag{9}$$

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 $t_1 = -b_1t_2$, $t_2 = a\sigma_x^2 + \mu_x$, $s_1 = -.5$, $s_2 = -.5b_1$, $s_3 = -.5b_1^2 - \frac{1}{2\sigma_x^2}$, 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

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

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*

$$E[Z1_{Z<b}] = \mu\Phi - \sigma\phi, \tag{10}$$
$$E[Z^2 1_{Z<b}] = \left(\sigma^2 + \mu^2\right)\Phi - \sigma(b+\mu)\phi \tag{11}$$

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:

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

□

Table A: 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 96 companies. This table reports the relative market capitalizations of the top 40 holdings of the index.