Too-Systemic-To-Fail

What Option Markets Imply About Sector-wide Government Guarantees

B. Kelly H. Lustig S. Van Nieuwerburgh

Chicago Booth UCLA Anderson NYU Stern

October 29, 2011
BU & Boston Fed Macro-Finance Conference

Too Systemic To Fail

- Understanding systemic risk in financial sector
  1. How to measure?
  2. How to mitigate?
- Solutions to (2) may distort prices/allocations $\Rightarrow$ Feeds back into (1)
- Important to detect and measure such distortions (cfr. systemic risk regulation efforts currently under way)

Systemic Risk Measurement: Options Prices

- Option prices reflect tail risks, ought to be very informative about bailout effects for equity
- One can insure lower tail of financial sector in two ways:
  - Insuring the index (reflects aggregate tail risk)
  - Insuring each element of the index (idiosyncratic and aggregate downside tail risk) - the *basket*

$$\boxed{r_j = r_{index} + \epsilon_j}$$

- If the total amount insured is the same, then difference in the cost of insurance, the basket-index put spread, is informative about:
  1. Degree of underlying idiosyncratic vs. systematic risk (esp. tail)
  2. Government guarantees that potentially affect this risk

This Paper (1): New Empirical Facts

- "Identifying" government guarantees
  - Return correlations among financial stocks increase sharply during financial crisis
  - Financial index puts surprisingly **cheap**: Basket-index put spread increased dramatically
  - Important effects of debt guarantees on value of equity
- A standard option pricing model without bailout guarantee has difficulty reconciling these facts:
  - Increase in correlation would **raise** the index option price relative to the individual options, **lowering** the basket-index spread.
  - This is what we find for **call** options for all sectors of the economy, but not for **put** options, especially in **financial** sector.
  - Explaining rising put spread would require large increase in **idiosyncratic** relative to aggregate (tail) risk $\Rightarrow$ counter-factual decrease in stock return correlations

This Paper (2): Model of Systemic Risk with Bailouts

- Instead, facts are consistent with presence of a **collective bailout guarantee** for the financial sector
  - Bailout: floor under the equity value of the financial sector
  - Government truncates the distribution of **sector-wide tail** risk
  - But does not eliminate any **idiosyncratic tail** risk
- Fits individual and index option and stock price data over 2003-2009
- Explains why OTM index put options were **cheap** during the crisis relative to individual puts
- Disentangles parameters governing systemic risk from those about gov't guarantees
- Model implies large portion of financial sector equity value ($\sim$50%) due to collective bailout guarantee

Data: Options on ETFs (1999-2009)

- Exchange-traded options (CBOE) on 9 iShares sector ETFs and on the S&P 500 ETF
  - Nine sector ETFs have no overlap and cover the entire S&P 500
  - Options on ETFs trade like individual options, are physically settled, and have an American-style exercise feature
  - Financial sector index ETF: $\sim$90 firms from banking, insurance, and real estate
- OptionMetrics Vol Surface: European put and call option **prices** and **implied volatilities** for all 9 sectors and all 500 stocks in the S&P500
  - Interpolated options constant maturity and moneyness. We focus primarily on TTM ≤ 1 year and $\Delta = 20$
  - Adjusted for American feature
- Calculate **realized volatility** of index and individual stock returns, as well as **realized correlations** between individual stock returns

Basket-Index Put Spread

- One can insure lower tail of financial sector in two ways:
  - Insuring the index (reflects aggregate tail risk)
  - Insuring each element of the index (idiosyncratic and aggregate downside tail risk) - the *basket*

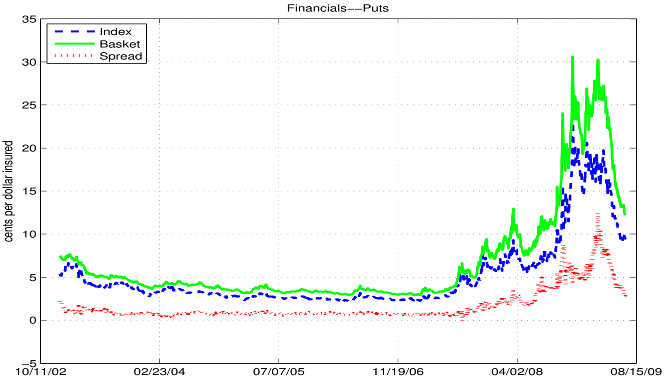
$$\text{cost per dollar insured} = \frac{\text{cost of insurance}}{\text{\$ amount insured}}$$

- Cost per dollar insured for **basket versus index**:

$$\frac{\sum_{j=1}^{N_F} s_j Put_F^j}{\sum_{j=1}^{N_F} s_j K_j} - \frac{Put_F^{index}}{\sum_{j=1}^{N_F} s_j K_j}$$

- The basket-index put spread is informative about:
  1. Degree of underlying idiosyncratic vs. systematic risk (esp. tail)
  2. Government guarantees that potentially affect this risk
- Use moneyness of $|\Delta| = 20$ for individual and index options; TTM $=$ 365 days.

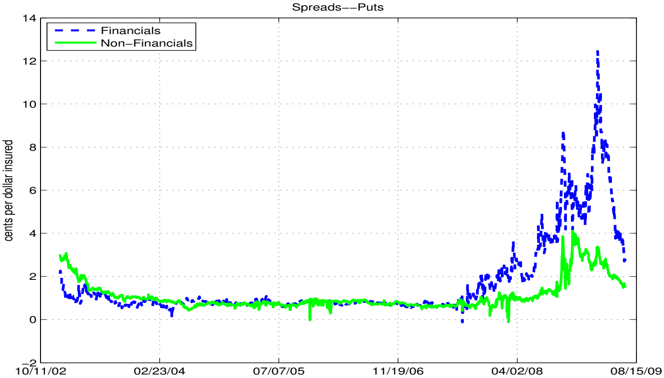
Basket-Index Put Spread



$$\text{Basket-Index Put Spread} = \frac{\sum_{j=1}^{N_F} s_j Put_F^j}{\sum_{j=1}^{N_F} s_j K_j} - \frac{Put_F^{index}}{\sum_{j=1}^{N_F} s_j K_j}$$

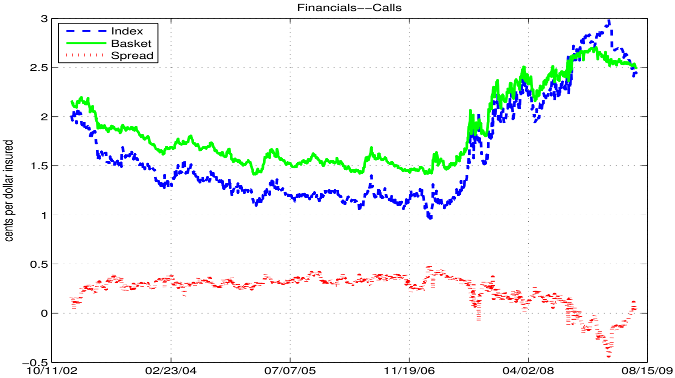
*Moneyness $|\Delta| = 20$ for individual and index options; TTM $= 365$ days.

Financial vs. Non-financial Basket-Index Put Spread



Much higher for financial than non-financial sectors (value-weighted avg)

OTM Call Instead of Put Options



- Basket-index spread for OTM call options goes down
- Same across other sectors

Basket-Index Spreads: Average Effects

Table: Basket-Index Spreads $|\Delta| = 20$, $TTM = 365$

		Financials		Non-financials	
		Puts	Calls	Puts	Calls
Pre-Crisis	mean	**0.81**	0.32	**0.91**	0.25
(Jan 03-Jul 07)	max	**2.27**	0.49	**3.09**	0.36
Crisis	mean	**3.79**	0.06	**1.57**	0.11
(Aug 07- Jun 09)	max	**12.46**	0.37	**4.13**	0.29

- Triple-diff: put - call spreads, crisis - pre-crisis, financial - non-financial firms: **+2.44** (mean), **+9.19** (max)

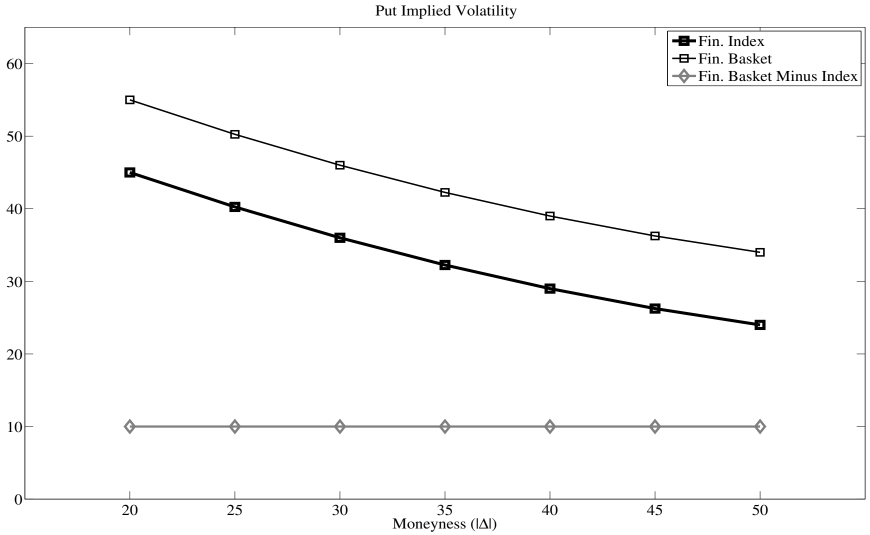
Announcement Effects (1)

- Link basket-index put spread for financials directly to government announcements
- Five "positive" events that *ex-ante* suggest increased likelihood/size of bailout
  - 10/3/2008: Revised bailout plan (TARP) passes the U.S. House
  - 10/6/2008: Term Auction Facility is increased to $900bn
  - 11/25/2008: Term Asset-Backed Securities Loan Facility (TALF) announced
  - 01/16/2009: Treasury, Federal Reserve, and the FDIC Provide assistance to Bank of America
  - 02/02/2009: Federal Reserve announces it is prepared to increase TALF to $1trn.
- Average spread increase: 1.61 cents or 27% in subsequent 5 days

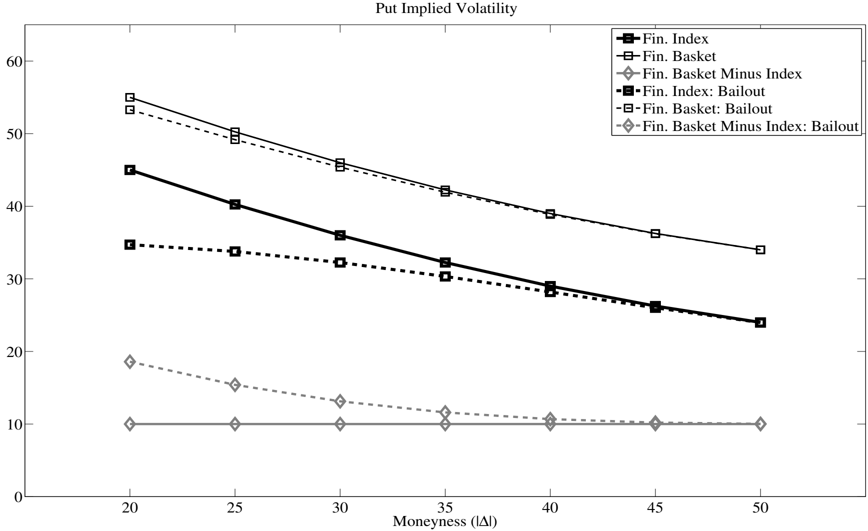
Announcement Effects (2)

- Six "negative" events that ex-ante suggest decreased likelihood/size of bailout
  - 03/3/2008: Bear Stearns is bought for $2 per share
  - 09/15/2008: Lehman Brothers files for bankruptcy
  - 09/29/2008: House votes no on the bailout plan
  - 10/14/2008: Treasury announces $250 billion capital injections
  - 11/07/2008: President Bush warns against too much government intervention in the financial sector
  - 11/13/2008: Paulson indicates that TARP will not used for buying troubled assets from banks
- Average spread decrease: 0.85 cents or 13% in subsequent 5 days

Guarantee and Implied Volatility Skew: Hypothesis



Guarantee and Implied Volatility Skew: Hypothesis



Implied Volatility Skew for Puts: Basket Minus Index

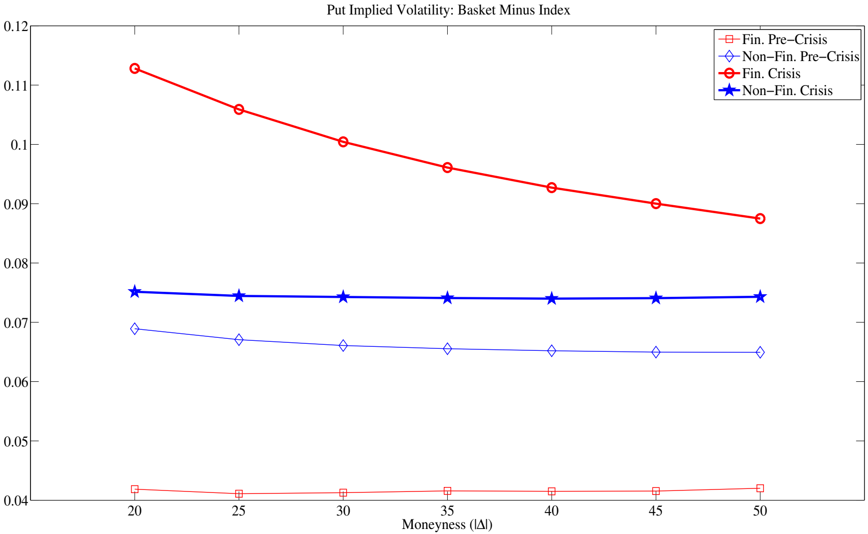


Figure: Implied Vol Skew Inferred from Puts

Implied Volatility Skew for Calls: Basket Minus Index

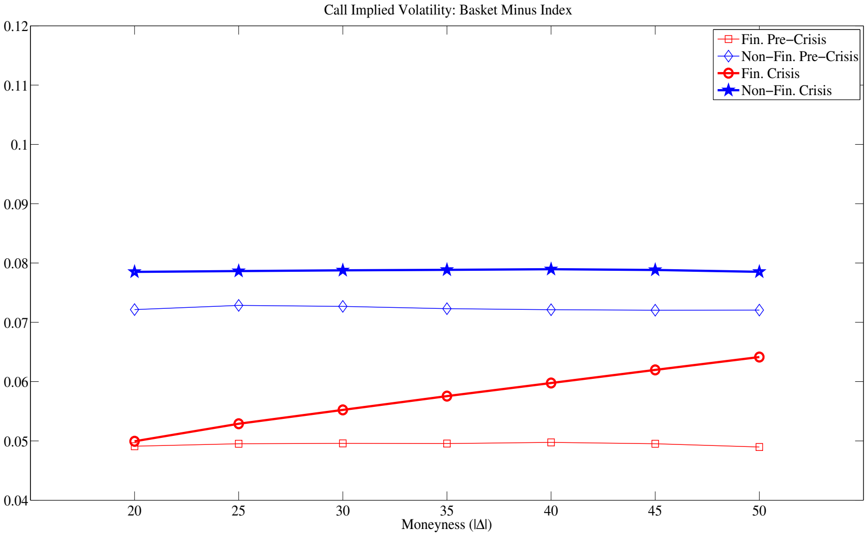


Figure: Implied Vol Skew Inferred from Calls

Additional Empirical Facts

Volatility

- VRP = Implied Vol – Realized Vol
- Typically has strong positive correlation with ERP
- Fin: VRP = 9.8% pre-crisis, 4.7% crisis
- Non-Fin: VRP = 9.8% pre-crisis, 9.1% crisis

Time to Maturity

- Spreads are smaller for shorter-dated options (though larger per unit time); we observe the same patterns as above

Moneyness

- Spreads are larger for ATM options (though smaller proportional change during crisis); we observe the same patterns as above

Alternative Explanations

- **Mispricing**
  - Several violations of law-of-one-price in financial markets during crisis
  - Less plausible as explanation for basket-index spread dynamics: no capital needed, no counter-party risk, why only in puts on financials?
- **Liquidity**
  - Financial sector index options more liquid than other sector's index options, and more liquid relative to individual options
  - Liquidity of financial sector index options increased more during the crisis than in other sectors, and relative to individual options
  - No differential liquidity between puts and calls
- Decrease (in absolute value) in **price of correlation risk**
  - Economically implausible
  - Would lead to counter-factual increase in call spreads

Why Do We Need a Model?

- Empirics have many moving parts (equity prices, volatilities, correlations, put and call prices, moneyness, bailout, before and after crisis); model helps to disentangle effects
- Need *structural* model that starts from cash flows and preferences because stock returns themselves reflect the bailout, not just options
- Model builds further credibility to bailout explanation
  - Model without bailout cannot explain observed option prices
  - Model *with* bailout can
- Use calibrated model to quantify effect of bailout on banks' stock prices

Model: Preferences and Endowments

- Epstein-Zin: log stochastic discount factor m:

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

  where $\gamma = \text{RA}$, $\psi = \text{EIS}$, and $\alpha \equiv \frac{1-\gamma}{1-\frac{1}{\psi}}$.

- Time-varying probability of a financial disaster p_t, where p_t follows an I-state Markov chain.

- In state $i \in \{1, 2, \ldots, I\}$, consumption growth process is*

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

*η is Gaussian, σ_{ci} depends on Markov state i, J^c is consumption drop in disaster

Financial Disasters: Dividends

- in state $i \in \{1, 2, \ldots, I\}$, dividend process of an individual bank is:

$$\begin{aligned} \Delta d_{t+1}^{ND} &= \mu_d + \phi_d \sigma_{ci} \eta_{t+1} + \sigma_{di} \epsilon_{t+1} \\ \Delta d_{t+1}^{D} &= \mu_d + \phi_d \sigma_{ci} \eta_{t+1} + \sigma_{di} \epsilon_{t+1} - J_{t+1}^{d} - J_{t+1}^{a} \end{aligned}$$

  where ϵ_{t+1} is Gaussian and i.i.d. across time, σ_{di} depends on Markov state i

- Loss rate in disaster state $J_{t+1}^{d} + J_{t+1}^{a}$ (can vary across banks)
  1. Has an **idiosyncratic** component J^d
  2. Has a **sector-wide** component J^a.

Collective Government Bailout

- Collective government guarantee puts floor $\underline{J}$ on aggregate losses of financial sector in a disaster
- The **common** component of the loss rate is the minimum of the maximum industry-wide loss rate $\underline{J}$ and the actual realized aggregate loss rate J^r:

$$J_t^a = \min(J_t^r, \underline{J})$$

  - The **no-bailout** case: $\underline{J} \to +\infty$, so that $J^a = J^r$.

Disasters, Bailouts and Prices

- Disaster jumps are Poisson mixtures of normal random variables
- Derive prices of equity and bonds
- How to price options in the presence of a bailout guarantee?
- Put price is weighted average of a Gaussian and a disaster component:

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

- We provide analytic formula in presence of bailout (assuming European exercise)

Calibration

Preferences

- $\gamma = 10$, $\psi = 3$, and $\beta = .96$
- Generates ERP and option prices while matching short rate before/during crisis

Consumption

- Avg growth absent disasters: $\mu_c = 2.21\%$, avg disaster growth drop: $\theta_c = 6.5\%$. Implies unconditional mean of 1.37%
- Gaussian growth vol: $\sigma_c(1) = 0.35\%$ in pre-crisis sample, increasing to $\sigma_c(2) = 0.7\%$ in crisis, disaster vol: $\delta_c = 3.5\%$. Implies unconditional cons. gr. volatility of 0.92%

Dividends

- Avg growth absent disasters: $\mu_d = 8\%$, leverage: $\phi_d = 3$
- Avg of one jump during a disaster: $\omega = 1$, idiosyncratic jump risk: $\theta_d = 0$
- Remaining 5 dividend parameters to match option and returns: $\Theta = (\sigma_d, \underline{J}, \theta_r, \delta_r, \delta_d)$

Disaster Probabilities

- Frequency of financial disasters in U.S. since 1800 (Reinhart and Rogoff 2009): $p_{ss} = 13\%$
- Markov states: $I = 2$, "pre-crisis" (Jan 03-Jul 07) and "crisis" (Aug 07-June 09)
- Probability of a financial disaster: 7% in state 1, 28% in state 2
- Crisis = elevated probability of financial diasaster (and realization)

Matching Moments with Bailout Option

- Search over Θ to match 12 moments:
- Option prices: 4 put + 4 call price moments, $\Delta = 20$, TTM=365
  - basket-index spread: basket price and index price
  - in state 1 = pre-crisis average (Jan 03-Jul 07) and in state 2 = crisis average (Aug 07-Jun 09)
- Return correlation and volatility: 4 moments
  - volatility of individual stock returns, correlation among pairs of individual stock returns, volatility of index return
  - in state 1 = pre-crisis average (Jan 03-Jul 07) and in state 2 = crisis average (Aug 07-Jun 09)

Parameters

Param	Governs	Value
σ_d	gaussian idiosyncratic risk	0.150
δ_d	dispersion of idiosyncratic tail risk	0.516
$\underline{J}$	maximum log aggregate loss rate	0.921
θ_r	untruncated mean log aggregate loss rate	0.815
δ_r	dispersion of aggregate tail risk	0.550
θ_a	truncated mean log aggregate loss rate	0.465

- Enough aggregate tail risk (after bailout) to make all options expensive enough
- Enough idiosyncratic tail risk to make individual options more expensive than index options
- Cannot be too much idiosyncratic tail risk or else counter-factually imply very low correlation during a crisis. We return to this point

Model With Bailouts: Option Prices and Stock Returns

Cost Per Dollar Insured (in cents)

	Puts			**Calls**		
	Basket	Index	Spread	Basket	Index	Spread
			Data			
			Option Prices			
pre-crisis	4.0	3.2	0.8	1.6	1.3	0.3
crisis	13.7	9.9	**3.8**	2.4	2.3	**0.1**
			Model with Bailout			
			Option Prices			
pre-crisis	4.3	4.1	0.3	1.5	1.2	0.4
crisis	13.7	9.9	**3.8**	2.5	2.3	**0.2**

Percentage Return Volatility and Correlation

	Index	**Individual Stocks**	
	Volatility	Volatility	Correlation
		Data	
pre-crisis	11.9	18.1	45.8
crisis	43.8	72.9	57.6
		Model with Bailout	
pre-crisis	19.2	26.7	42.3
crisis	31.9	44.5	51.1

No Bailout: Option Prices and Stock Returns

- We set $\underline{J} = +\infty$, and re-search over Θ. Best match: very high idiosyncratic volatility, low aggregate volatility
- We match the put spread in pre-crisis and crisis as well as the return volatility moments, but...
- Main problem: Model implies a massive decrease in return correlation from 44% to 27% instead of an increase from 44% to 57%
- Model implies an increase in call spread instead of decrease

Cost of Capital Implications

- Equity risk premium for the financial sector index is
  - 4.7% per year in the pre-crisis
  - rises to 14.0% during the crisis
- Absent collective bailout, equity risk premium would be twice as large
  - 8.9% per year in the pre-crisis
  - rises to 28.0% during the crisis
- Massive reduction in the cost of capital for systemically risky financial firms
- Consistent with empirical evidence in Gandhi and Lustig (2010)
- Bailout guarantee accounts for **half of the true value** of the financial sector

Conclusion

- New legislation wrestles with how to best measure systemic risk
- Market prices are distorted by guarantees
- Proposed structural model to disentangle true exposure from observed exposure in prices
- Results suggest massive propping up of bank sector *equity*

EXTRA SLIDES

Calibration Non-Financials

- Recalibrate Θ for the non-financial sector
- **No bailout** and much less idiosyncratic and aggregate tail risk
- Manage to match all put spread, call spread, volatility, and correlation moments
- $diff^3$: put - call spreads, crisis - pre-crisis periods, financial vs. non-financial firms: **+2.44** (data), **+2.32** (model)
- Suggests bailout guarantee only necessary for financial sector
- However, matching spike in put spread in Nov-Dec 2008 may require 3-state model with bailout

Robustness

- Gaussian benchmark to illustrate that disaster model is necessary to fit the data
- Estimate parameters to best fit not only return and $\Delta = 20$ put prices, but also $\Delta = 30, 40, 50$ put prices
- Three-state model to capture notion that crisis became more severe in September 2008-March 2009
- Heterogeneity: larger banks have bigger implicit subsidy of cost of capital than smaller banks, ceteris paribus

Mechanics of Collective Bailout: Simple Example

- Collective bailout implies that individual stock return r^i is:

$$r^i = \underbrace{max(\underline{J}, r^{index})}_{\textbf{sector-wide}} + \underbrace{e^i}_{\textbf{idiosyncratic}}$$

- Compare two put options with same strike $K < \underline{J}$
  1. on the sector-wide return $max(\underline{J}, r^{index})$
  2. on the individual stock r^i

- Effect of an increase in **sector-wide volatility** of returns:
  1. Increase in correlation of returns r^i; more common variation over non-truncated region
  2. No effect on the price of the OTM sector put
  3. Positive effect on the price of the OTM individual put; more prob mass on outcomes r^i lower than K

- Not true without the bailout guarantee

Financial Sector Index: Top 20 Holdings of XLF

	12/30/2010		07/30/2007	
	Name	Weight	Name	Weight
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**	8.02
4	Berkshire Hathaway B	7.52	JPMorgan Chase & Co	7.25
5	Bank Of America Corp.	7.3	Wells Fargo & Co	5.44
6	Goldman Sachs Group Inc.	4.66	**Wachovia** Corp	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**	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**	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

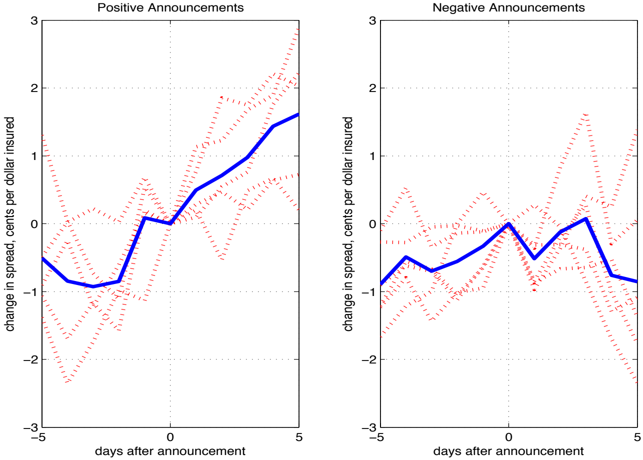
Basket-Index Spreads for Short-dated Options

Table: Basket-Index Spreads $|\Delta| = 20$, $TTM = 30$

		Financials		Non-financials	
		Puts	Calls	Puts	Calls
Pre-Crisis	mean	**0.170**	0.155	**0.129**	0.105
	min	-0.072	-0.227	-0.831	-0.103
	max	**0.376**	0.270	**0.511**	0.240
Crisis Sample	mean	**0.617**	0.100	**0.228**	0.144
	min	-0.150	-0.312	-0.139	-0.202
	max	**2.458**	0.272	**0.651**	0.238

- $diff^3$: crisis vs. pre-crisis, puts vs. calls, financials vs. non-financials: **+0.44** (mean), **+1.94** (max)

Basket-Index Spread around Announcements



Improving Correlation Fit in Financial Sector

		benchm	**altern**	*levels b*	*levels a*
σ_d	Gaussian risk	0.150	**0.150**		
δ_d	dispersion of idiosyncratic tail risk	0.516	**0.390**		
$\underline{J}$	maximum aggregate loss rate	0.921	**0.840**	60.2%	56.8%
θ_r	untruncated mean aggregate loss rate	0.815	**0.950**	55.7%	61.3%
δ_r	dispersion of aggregate tail risk	0.550	**0.710**		
θ_a	truncated mean aggregate loss rate	0.465	**0.430**	37.2%	35.0%

Alternative calibration leads to **same 50% reduction in value** and increase in risk premium when bailout guarantee is removed.

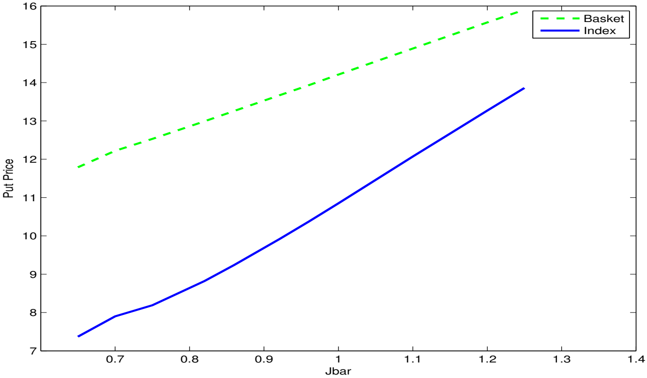
Fixing Correlation: Return Moments

	Index	Individual Stocks	
	Volatility	Volatility	Correlation
		Data	
pre-crisis	11.9	18.1	45.8
crisis	43.8	72.9	57.6
		Model without Bailout	
pre-crisis	17.9	24.7	45.8
crisis	31.5	39.7	58.7
disaster realization	*44.2*	*59.8*	*51.2*

Fixing Correlation: Option Moments

	Puts			Calls		
	Basket	Index	Spread	Basket	Index	Spread
			Data			
			Option Prices			
pre-crisis	4.0	3.2	0.8	1.6	1.3	0.3
crisis	13.7	9.9	3.8	2.4	2.3	0.1
			Model with Bailout			
pre-crisis	3.9	3.7	0.2	1.4	1.0	0.4
crisis	11.7	8.8	2.9	2.3	2.1	0.2

Collective Bailout Guarantee and Put Prices

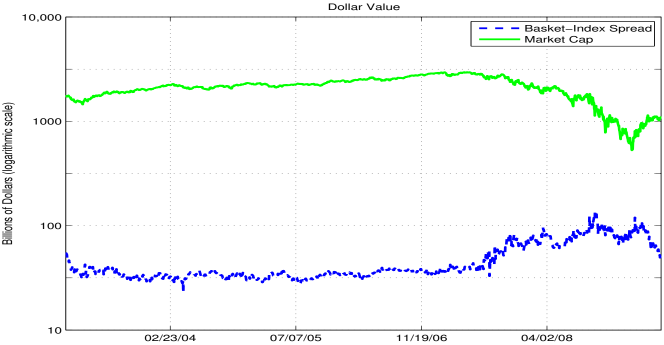


Elasticity of put price to $\underline{J}$: 10.8 for index vs. 6.9 for individual option

Gaussian model

- Disaster probability is zero in state 1 and 2
- Crank up consumption risk: $\sigma_c(1) = 0.01$ and $\sigma_c(2) = 0.05$
- Set $\sigma_d(1) = 0.133$, $\sigma_d(2) = 0.698$, $\xi_d(1) = .705$, $\xi_d(2) = 0.315$ to match individual and index volatility in pre-crisis and crisis
- Implies huge put spread in crisis (7.8) but zero put spread pre-crisis. Call spreads go up.
- **Return correlation goes down from 84% pre-crisis to 37% crisis!**

Dollar Value of Basket-Index Spread



- Dollar value of the basket-index spread guarantee peaks at $139 billion on October 13, 2008
- 10.5% of overall market capitalization of financial sector

Fitting Put Spreads Across Moneyness

Parameters: $\sigma_d(1) = 0.145$, $\sigma_d(2) = 0.30$, $\xi_d(1) = 0$, $\xi_d(2) = 0.30$, $\delta_d = 0.36$, $\underline{J} = 0.79$, $\theta_r = 1.28$, and $\delta_r = 0.95$.

	Moments in Data								
	Puts Delta = 20			**Puts Delta = 30**			**Puts Delta = 40**		
	Basket	Index	Spread	Basket	Index	Spread	Basket	Index	Spread
pre-crisis	4.0	3.2	0.8	5.8	4.6	1.2	7.7	6.1	1.6
crisis	13.7	9.9	3.8	17.8	13.4	4.4	21.6	16.7	4.9
	Puts Delta = 50					**Return moments**			
	Basket	Index	Spread			Index vol	Indiv vol	Indiv Correl	
pre-crisis	9.8	7.7	2.1			11.9	18.1	45.8	
crisis	25.5	20.1	5.4			43.8	72.9	57.5	
	Moments in Model with Bailout; change Gaussian risk								
	Basket	Index	Spread	Basket	Index	Spread	Basket	Index	Spread
pre-crisis	3.7	3.6	0.1	5.3	4.9	0.3	8.0	6.1	1.8
crisis	12.3	8.9	3.4	16.4	13.0	3.4	20.4	16.3	4.1
	Puts Delta = 50					**Return moments**			
	Basket	Index	Spread			Index vol	Indiv vol	Indiv Correl	
pre-crisis	12.8	8.2	4.6			17.2	23.5	45.6	
crisis	24.4	19.1	5.3			35.1	46.2	53.4	
disaster real						*46.6*	*62.9*	*51.4*	

Removing bailout: ERP increases from 4.0% to 13.1% in state 1 and from 12.1% to 42.9% in state 2

Heterogeneity: Large vs. Small Banks

Common parameters: $\underline{J} = 0.84$, $\theta_r = 0.95$, and $\delta_r = 0.71$
Big 12 parameters: $\lambda_d = 1.21$, $\sigma_d(1) = 0.11$, $\sigma_d(2) = 0.09$, $\delta_d = 0.50$

Small bank parameters: $\lambda_d = 0.93$, $\sigma_d(1) = 0.18$, $\sigma_d(2) = 0.20$, $\delta_d = 0.32$

	Put prices		**Call prices**		**Returns**	
	basket	spread	basket	spread	indiv vol	correl
			Data Big 12			
pre-crisis	4.0	0.8	1.6	0.3	17.0	57.0
crisis	14.5	4.6	2.4	0.1	84.7	59.4
			Model Big 12			
pre-crisis	4.6	0.9	1.3	0.2	26.3	57.1
crisis	14.5	5.7	2.4	0.3	45.9/*72.3*	63.0/*50.6*
			Data small banks			
pre-crisis	4.0	0.9	1.7	0.3	24.6	38.7
crisis	12.8	2.9	2.4	0.0	44.9	57.6
			Model small banks			
pre-crisis	3.7	0.0	1.5	0.5	25.4	38.7
crisis	10.6	1.9	2.3	0.2	38.8/*55.1*	54.4/*53.1*

Removing bailout: ERP increases by 12% points for big 12 and 9% points for small banks

Solving for Wealth

Result

We solve the following system of N equations for wc_i:

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

Resilience of the consumption claim is:

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

Solving for Bank Prices

Result

We solve the following system of N equations for pd_i:

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

together with the linearization constants and the mean pd ratio:

$$
\overline{pd} = \sum_j \Pi_j pd_j .
$$

No Bailout: Option Prices and Stock Returns

- We set $\underline{J} = +\infty$, and re-search over Θ. Best match: high idios. vol. low agg. vol.

Cost Per Dollar Insured (in cents)

	Puts			Calls		
	Basket	Index	Spread	Basket	Index	Spread
			Data			
			Option Prices			
pre-crisis	4.0	3.2	0.8	1.6	1.3	0.3
crisis	13.7	9.9	**3.8**	2.4	2.3	0.1
			Model without Bailout			
			Option Prices			
pre-crisis	3.8	3.4	0.4	1.5	1.6	-0.1
crisis	13.7	9.9	**3.8**	2.6	2.3	0.3

Percentage Return Volatility and Correlation

	Index	Individual Stocks	
	Volatility	Volatility	Correlations
		Data	
pre-crisis	11.9	18.1	44.8
crisis	43.8	72.9	57.5
		Model without Bailout	
pre-crisis	18.7	26.0	43.8
crisis	28.7	44.4	**35.8**
disaster realization	*42.8*	*76.7*	*26.7*

Calibration Non-Financials

		F	**NF**	*levels F*	*levels NF*
σ_d	Gaussian risk	0.150	**0.170**		
δ_d	dispersion of idiosyncratic tail risk	0.516	**0.230**		
$\underline{J}$	maximum aggregate loss rate	0.921	$+\infty$	60.2%	$+\infty$
θ_r	untruncated mean aggregate loss rate	0.815	**0.219**	55.7%	19.7%
δ_r	dispersion of aggregate tail risk	0.550	**0.150**		
θ_a	truncated mean aggregate loss rate	0.465	**0.219**	37.2%	19.7%

NF sector: no bailout and much less idiosyncratic and aggregate tail risk

Non-Financials

- *diff*^{3}: put - call spreads, crisis - pre-crisis periods, financial vs. non-financial firms: **+2.44** (data), **+2.32** (model)

Cost per dollar insured (in cents)

	Puts			Calls		
	Basket	Index	Spread	Basket	Index	Spread
			Data			
			Option Prices			
pre-crisis	4.3	3.4	0.9	1.8	1.5	0.3
crisis	7.9	6.3	1.6	2.2	2.0	0.1
			Model without Bailout			
			Option Prices			
pre-crisis	2.8	2.3	0.5	1.5	0.9	0.6
crisis	7.9	6.3	1.6	2.0	1.6	0.4

Percentage Return Volatility and Correlation

	Index	**Individual Stocks**	
	Volatility	Volatility	Correlations
		Data	
pre-crisis	12.2	21.5	33.7
crisis	25.1	35.1	56.8
		Model without Bailout	
pre-crisis	12.7	20.7	33.2
crisis	19.9	27.7	48.2
	28.7	*39.5*	*50.1*

Pairwise Return Correlations

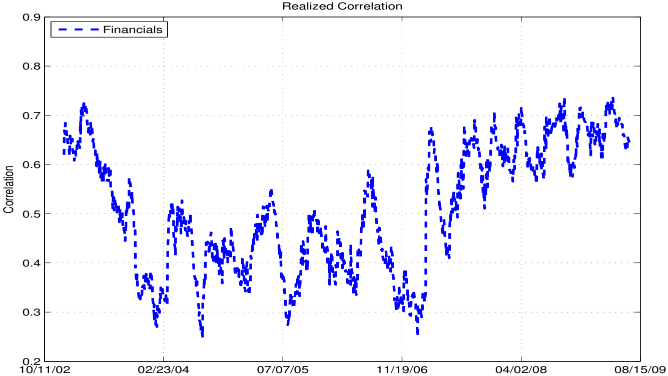


Figure: Realized Equity Return Correlations

Daily market-cap weighted pairwise conditional correlations for stocks are estimated using the exponential smoother with smoothing parameter 0.95.

Implied-Realized Volatility

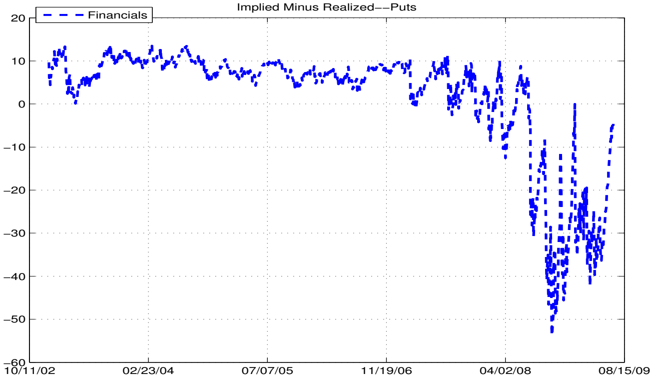


Figure: Implied minus Realized Vol Inferred from Puts

Realized volatilities for each sector are defined as daily conditional volatilities and are estimated by exponential smoothing with smoothing parameter 0.95.

Pricing Stocks

Definition

Resilience (risk-neutral recovery rate) is defined as:

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

- Stand-in investor's Euler equation for bank stock is:

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