# On the Relative Pricing of Long-Maturity Index Options and Collateralized Debt Obligations

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# Overview

This paper jointly price long-dated S&P 500 index options and CDO tranches of corporate debt

- Investigate a structural model of market and firm-level dynamics in order
- Identify market dynamics from index option prices
- Identify idiosyncratic dynamics from the term structure of credit spreads.

Findings:

- All tranches can be well predicted out-of-sample before the crisis.
- During the crisis, the model can capture senior tranche prices only if we allow for the possibility of a catastrophic jump.
- Thus, senior tranches are nonredundant assets that provide a unique window into pricing of catastrophic risk.

# Background

- Widely argued: risks of subprime mortgages have been dramatically underestimated by market participants since it's a new market
- Yet other securitized portfolios of other major asset classes have also experienced the dramatic shortfall
- Many observers wonder that there was a significant flaw in the pricing methodology used by the Street to evaluate the prices of these securitized products
- **Were the CDOs mispriced?**

# Prior Study By CJS

- *Co val, Jurek, and Stafford (CJS, 2009) i*nvestigate the pricing of CDO tranches created from investment grade bonds portfolios.

  a> systematic component:

    Combine firm-level beta with market dynamics

  b> idiosyncratic component: *(Similar to Non-systematic risk)*

    The vol. is normally distributed and calibrated from equity returns

  c> Merton's (1974) structural model of default:

    Bond defaults at 5 year maturity if firm value falls below barrier

- They found out that senior tranches prices are too low *(Agents have ignored the attached systematic risk during purchase)* and junior tranches prices are too high.

# Improvements

- Specify a dynamic structural model which provides state prices for all maturities
- Specify the default event as the first time firm value drops below the default boundary, instead of limiting default to occur only at maturity

  - Take into account differences in the default timing > Impact cash flow
- CJS calibrate their model to match only 5 year CDX spread, while this paper calibrate for the entire term structure.

  - Why does calibration on shorter horizon CDX index spreads matter?

    a> Contains default timing and idiosyncratic component

    b> Defaults are backloaded without this calibration approach

    c> Increase the % of idiosyncratic risk, otherwise too fat-tailed *

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# Models

A Joint Structural Model for Equity Index Options and CDO Tranches

- A. Market Dynamics for Pricing S&P 500 Options

  - A common approach: local volatility model

  - Use a parametric dynamic model to "extrapolate" for senior tranche

    The volatility surface would be consistent (arbitrage free)

    Able to obtain the state price density for all strikes and all maturities

    Specifically, a "SVCJ" model but allows for 2 stochastic vol. factors

  - Follow a joint-Markov affine jump-diffusion process

# Models

*Given its affine dynamics, the (log) index return process has an exponential affine characteristic function. Therefore, European option prices can be solved by applying the fast Fourier transformation (FFT)*

- **A. Market Dynamics for Pricing S&P 500 Options**

*V and Theta are 2 variance variables*

*Market portfolio value*

*Catastrophic jump*

*Standard jump*

$$\frac{dM_t}{M_t} = (r-\delta)\,dt + \sqrt{V_t}\,dw_1^Q + \sqrt{\theta_t}\,dw_2^Q + (e^y - 1)\,dq - \bar{\mu}_y \lambda^Q\,dt + (e^{y_C} - 1)\left(dq_C - \lambda_C^Q\,dt\right), \quad (1)$$

$dw_j^Q$ $(j = 1, 2, 3, 4)$ are independent Brownian motions and $dq$ is a jump process with constant jump intensity $\lambda^Q$.

$$dV_t = \kappa_V(\bar{V} - V_t)\,dt + \sigma_V\sqrt{V_t}\left(\rho_1\,dw_1^Q + \sqrt{1-\rho_1^2}\,dw_3^Q\right) + y_V\,dq, \quad (2)$$

*Jump sizes of the variance state variables have exponential distributions*

$$y_V \sim \exp(1/\mu_V)$$

$$d\theta_t = \kappa_\theta(\bar{\theta} - \theta_t)\,dt + \sigma_\theta\sqrt{\theta_t}\left(\rho_2\,dw_2^Q + \sqrt{1-\rho_2^2}\,dw_4^Q\right) + y_\theta\,dq. \quad (3)$$

$$y_\theta \sim \exp(1/\mu_\theta)$$

*Compensator for the jump:*

$$\bar{\mu}_y = \mathrm{E}^Q\left[e^y\right] - 1 = e^{\mu_y + \frac{1}{2}\sigma_y^2} - 1.$$

# Models

- **B. Firm Dynamics and Structural Default Model**

$$\frac{dA_t}{A_t} + \delta_A dt - r\,dt = \beta\left(\sqrt{V_t}\,dw_1^Q + \sqrt{\theta_t}\,dw_2^Q + (e^y - 1)\,dq - \bar{\mu}_y \lambda^Q dt\right)$$
$$+ (e^{y_C} - 1)\left(dq_C - \lambda_C^Q dt\right) + \sigma_i\,dw_i + (e^{y_i} - 1)\left(dq_i - \lambda_i^Q dt\right). \quad (5)$$

*Systematic jump* *Idiosyncratic jump*

- **Beta, which denotes the loading of each firm's asset return dynamics on the market (excess) return, is a constant**

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# Models

- **B. Firm Dynamics and Structural Default M**
- Specify that default occurs the first time firm value falls below a default threshold Ab. Therefore, default arrival time for the typical firm i with asset dynamics Ai(t) is:

$$\tau_i = \inf\{t \ : \ A_i(t) \leq A_B\}.$$

- Also denote that, upon default, the debt holder recovers remaining asset value (1 — L)Ab, where L is loss rate

# Models

- **C. Basket CDS Index**
- The paper uses data on synthetic CDO tranches based on the Dow Jones CDX North American Investment Grade Index (CDX.IG)
- To determine the index spread, the present value of cash flows that go to the protection buyer (the "protection leg") and protection seller (the "premium leg") are set equal to each other
- The values of these two cash flow legs are obtained by computing the following expectations (assuming a one dollar total notional):

# Models

- **C. Basket CDS Index**

$$V_{\text{idx, prem}}(S) = S\,\mathrm{E}^Q\left[\sum_{m=1}^{M} e^{-rt_m}(1 - n_{t_m})\,\Delta + \int_{t_{m-1}}^{t_m} e^{-ru}(u - t_{m-1})\,dn_u\right], \quad (7)$$

$$V_{\text{idx, prot}} = \mathrm{E}^Q\left[\int_0^T e^{-rt}\,dL_t\right]. \quad (8)$$

$$n_t = \frac{1}{N}\sum_i \mathbf{1}_{\{\tau_i \le t\}}$$

the time interval $\delta = 0.25$

$$L_t = \frac{1}{N}\sum_i \mathbf{1}_{\{\tau_i \le t\}}\,[1 - R_i(\tau_i)], \quad (9)$$

*Cumulative loss*

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# Models

- **D. CDO Tranches Spread**
- The "attachment points" for different tranches are :

  0-3% (Equity tranche); 3-7% (mezzanine);

  7-10%, 10-15%, and 15-30% (senior); 30-100% (super senior)
- The buyer of protection of a particular L-U% tranche makes periodic premium payments (corresponding to the remaining tranche notional times the tranche spread) until the contract expires. In return, she receives protection payments if cumulative losses in the underlying CDX index exceed L%.
- Payments stop when cumulative losses in the underlying portfolio exceed U%, after which the tranche notional is exhausted and the contract ends.

# Models

- **D. CDO Tranches Spread**

The tranche loss as a function of the cumulative losses ($L_t$) in the portfolio underlying the tranche is[20]

$$T_j(L_t) \equiv T_{K_{j-1},K_j}(L_t) = \max[\min(L_t, K_j) - K_{j-1}, 0]$$
$$= \max[L_t - K_{j-1}, 0] - \max[L_t - K_j, 0]. \quad (10)$$

The initial value of the protection leg on tranche $j$ is

$$\text{Prot}_j(0, T) = \text{E}^Q\left[\int_0^T e^{-rt}\, dT_j(L_t)\right]. \quad (11)$$

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# Models

- **D. CDO Tranches Spread**

In terms of the tranche spread $S_j$, the initial value of the premium leg on tranche $j$ (except for the equity and super-senior tranches) is

$$\text{Prem}_j(0, T) = S_j \text{E}^Q \left[ \sum_{m=1}^{M} e^{-rt_m} \int_{t_{m-1}}^{t_m} du(K_j - K_{j-1} - T_j(L_u)) \right]. \qquad (12)$$

(12) could be used as IV of the premium leg of Equity Tranche while it's a full-running premium; another common approach (Upfront premium U):

$$\text{Prem}_1(0, T) = UK_1 + 0.05\text{E}^Q \left[ \sum_{m=1}^{M} e^{-rt_m} \int_{t_{m-1}}^{t_m} du(K_1 - K_0 - T_1(L_u)) \right]. \quad (13)$$

Finally, the super-senior tranche premium is specified by

$$\text{Prem}_6(0, T) = S_6 \text{E}^Q \left[ \sum_{m=1}^{M} e^{-rt_m} \int_{t_{m-1}}^{t_m} du(K_6 - K_5 - n_u R - T_6(L_u)) \right]. \qquad (14)$$

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# Data

- 1- and 5-year S&P 500 European option implied volatilities
- The CDX North American Investment Grade Index spreads from 1 to 5 years
- Tranche spreads written on this index for 3- and 5-year maturities
- Every 6 months (on March 21 and September 21), a new on-the-run CDX series will be introduced
- Distinguish two subperiods: the "precrisis" period (September 21, 2004 to September 20, 2007) and the "crisis" period (September 21, 2007 to September 20, 2008). The precrisis period includes data from on-the-run series 3-8, whereas our crisis period includes data from on-the-run series 9 and series 10.

# Calibrations

- A. Calibration on Market Dynamics
- Use a closed-form expression to minimize the relative root mean square error (RMSE) between model prices and observed prices by searching over both parameters and latent state variables (V,Theta).
- B. Calibration of Firm Dynamics
- The paper estimates the firm-specific parameters of the asset dynamics in equation (5)

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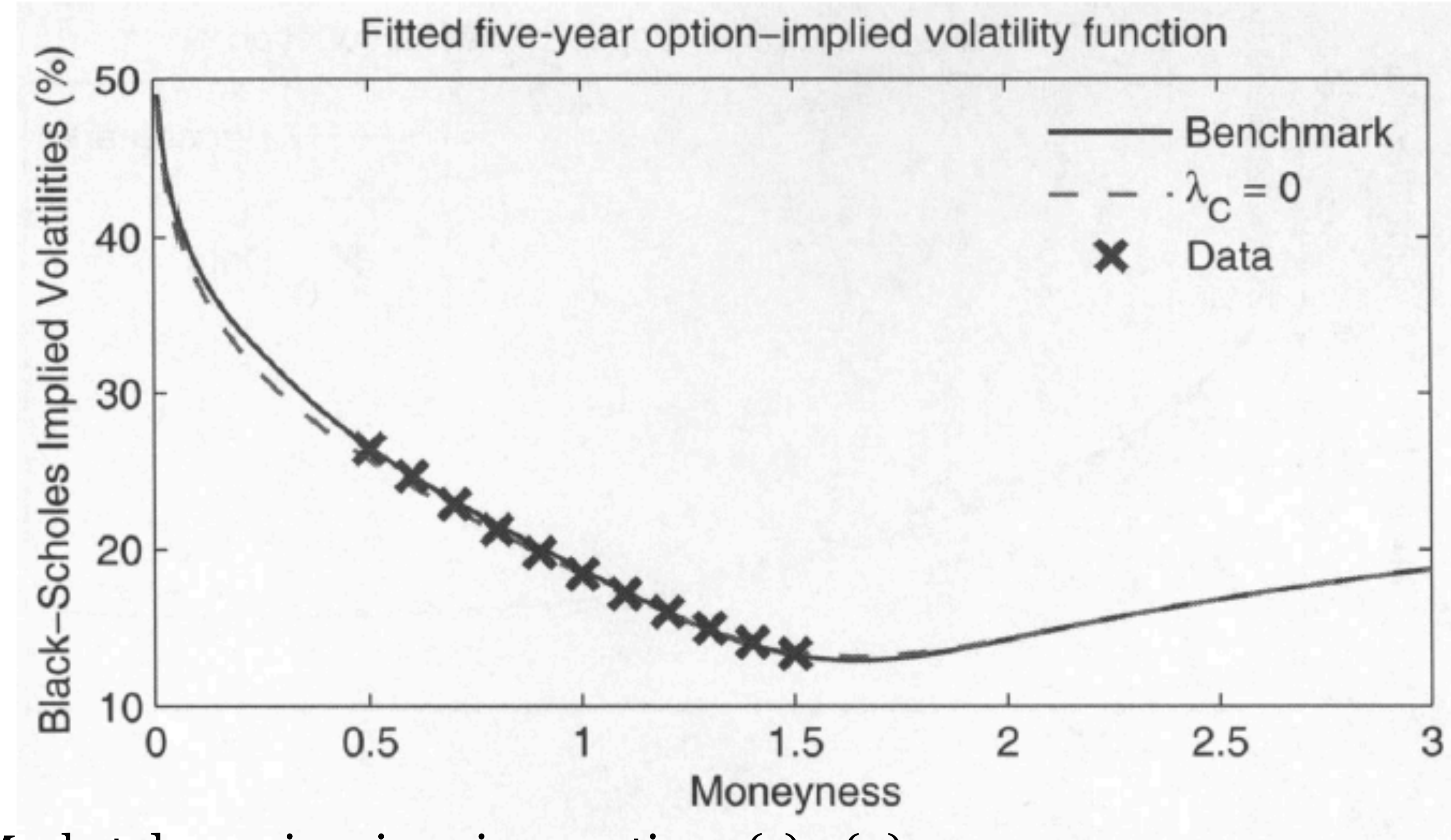
# Calibrations

**Table I**
**Calibrated Parameters of Market Dynamics**

This table reports the calibrated parameters of the market dynamics given in equations (1), (2), and (3), and following the calibration procedure decribed in Section II.B.

| | Precrisis | | | | | | Crisis | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $\lambda_C = 0$ | | $\lambda_C > 0$ | |
| Parameter | Series 3 | Series 4 | Series 5 | Series 6 | Series 7 | Series 8 | Series 9 | Series 10 | Series 9 | Series 10 |
| $\kappa_V$ | 4.316 | 4.800 | 4.836 | 3.980 | 2.178 | 0.877 | 4.886 | 5.001 | 4.323 | 4.815 |
| $\bar{V}$ | 0.0018 | 0.0042 | 0.0046 | 0.0054 | 0.0057 | 0.0036 | 0.0015 | 0.0015 | 0.0012 | 0.0013 |
| $\sigma_V$ | 0.2961 | 0.274 | 0.2732 | 0.2666 | 0.2422 | 0.3296 | 0.2578 | 0.2613 | 0.2715 | 0.2531 |
| $\rho_1$ | −0.48 | −0.48 | −0.48 | −0.48 | −0.48 | −0.48 | −0.48 | −0.48 | −0.48 | −0.48 |
| $\mu_V$ | 0.0503 | 0.0504 | 0.0491 | 0.0425 | 0.0736 | 0.0284 | 0.046 | 0.0458 | 0.0844 | 0.0618 |
| $\kappa_\theta$ | 0.00130 | 0.0012 | 0.0012 | 0.0015 | 0.0015 | 0.00050 | 0.0012 | 0.0012 | 0.0012 | 0.0012 |
| $\bar{\theta}$ | 0.0068 | 0.0056 | 0.0057 | 0.0044 | 0.0055 | 0.0057 | 0.0044 | 0.004 | 0.0041 | 0.0049 |
| $\sigma_\theta$ | 0.00068 | 0.00074 | 0.00075 | 0.00075 | 0.00075 | 0.00069 | 0.00080 | 0.00081 | 0.00073 | 0.00072 |
| $\rho_2$ | 0.00032 | 0.00034 | 0.00034 | 0.00033 | 0.00027 | 0.00039 | 0.00035 | 0.00035 | 0.00036 | 0.00036 |
| $\mu_\theta$ | 0.0668 | 0.0668 | 0.0667 | 0.0484 | 0.0281 | 0.0208 | 0.0647 | 0.0652 | 0.0221 | 0.0355 |
| $\mu_y$ | −0.3816 | −0.3834 | −0.3796 | −0.5038 | −0.2883 | −0.4723 | −0.4439 | −0.4415 | −0.4584 | −0.4369 |
| $\sigma_y$ | 0.0167 | 0.0173 | 0.0171 | 0.0177 | 0.0205 | 0.0231 | 0.0177 | 0.0178 | 0.0175 | 0.0171 |
| $\lambda$ | 0.0886 | 0.1089 | 0.1179 | 0.0847 | 0.1598 | 0.0991 | 0.1726 | 0.1828 | 0.192 | 0.1496 |
| RMSE ($\lambda_C = 0$) | 2.27% | 1.01% | 0.92% | 1.28% | 0.78% | 2.77% | 1.94% | 0.93% | | |
| RMSE | 2.27% | 1.68% | 0.92% | 1.38% | 0.82% | 2.30% | | | 1.86% | 1.74% |

# Calibrations




Market dynamics given in equations (1)—(3) are calibrated to match 1- and 5-year option prices on June 15, 2005 (the pre-crisis)

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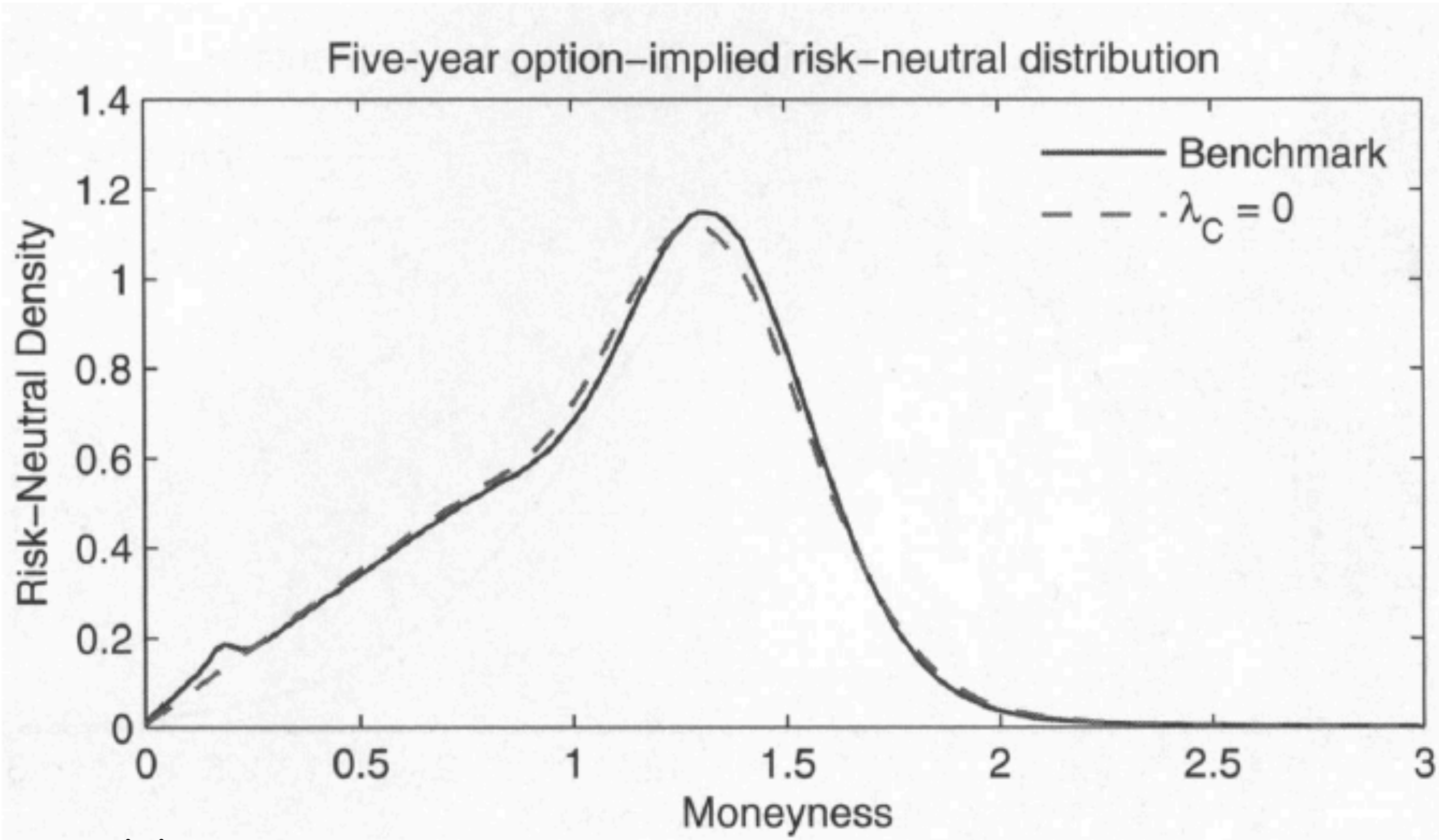
# Calibrations




Pre-Crisis

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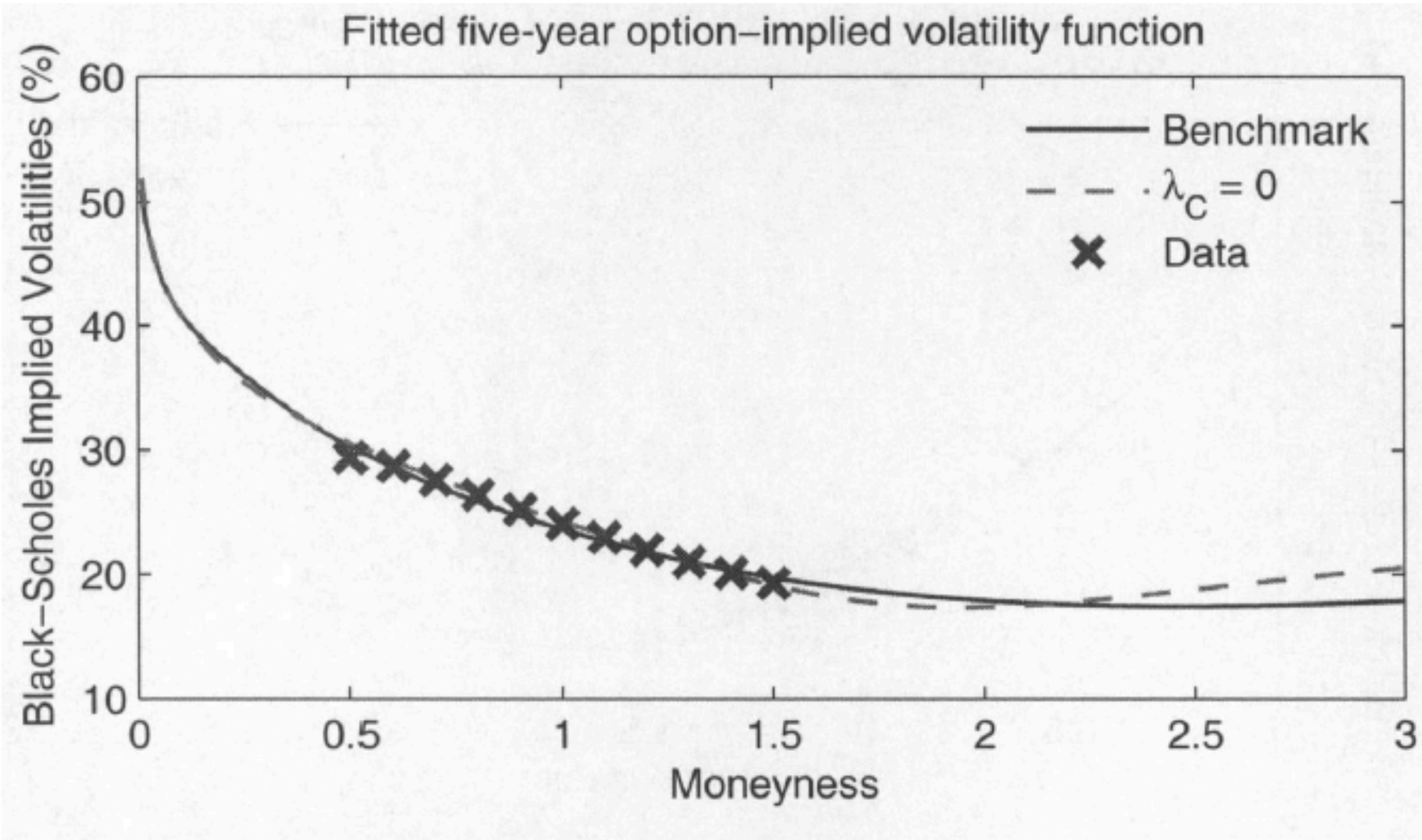
# Calibrations




Crisis

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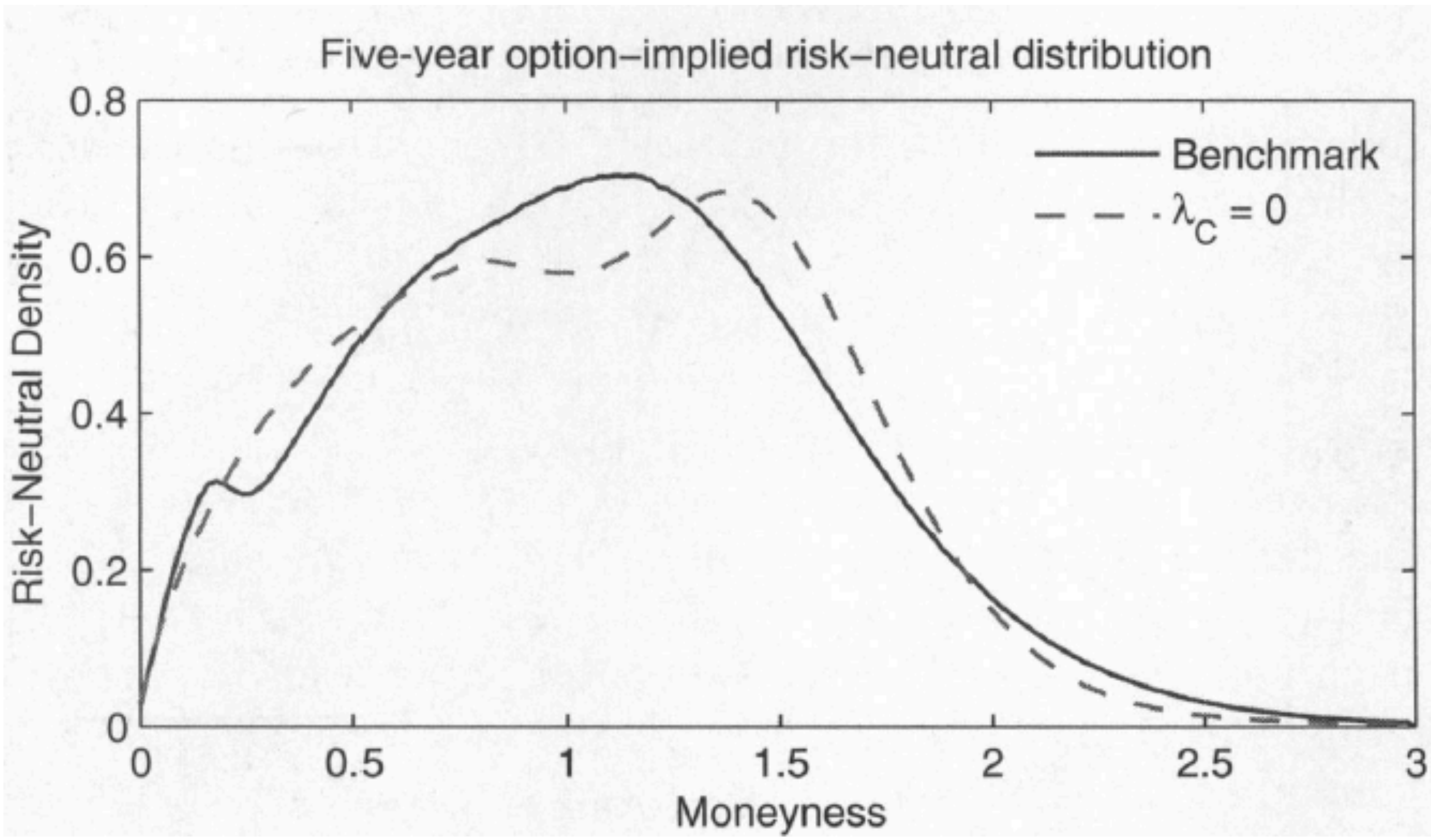
# Calibrations




Crisis

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# Calibrations

**Table II**

**Average Firm Asset Value Statistics**

This table presents key aggregate statistics of collateral firms, risk-free rate, and S&P 500 index dividend yield for the 6-month period that a given series is on-the-run. Estimates other than asset beta are annualized and reported in percentage terms.

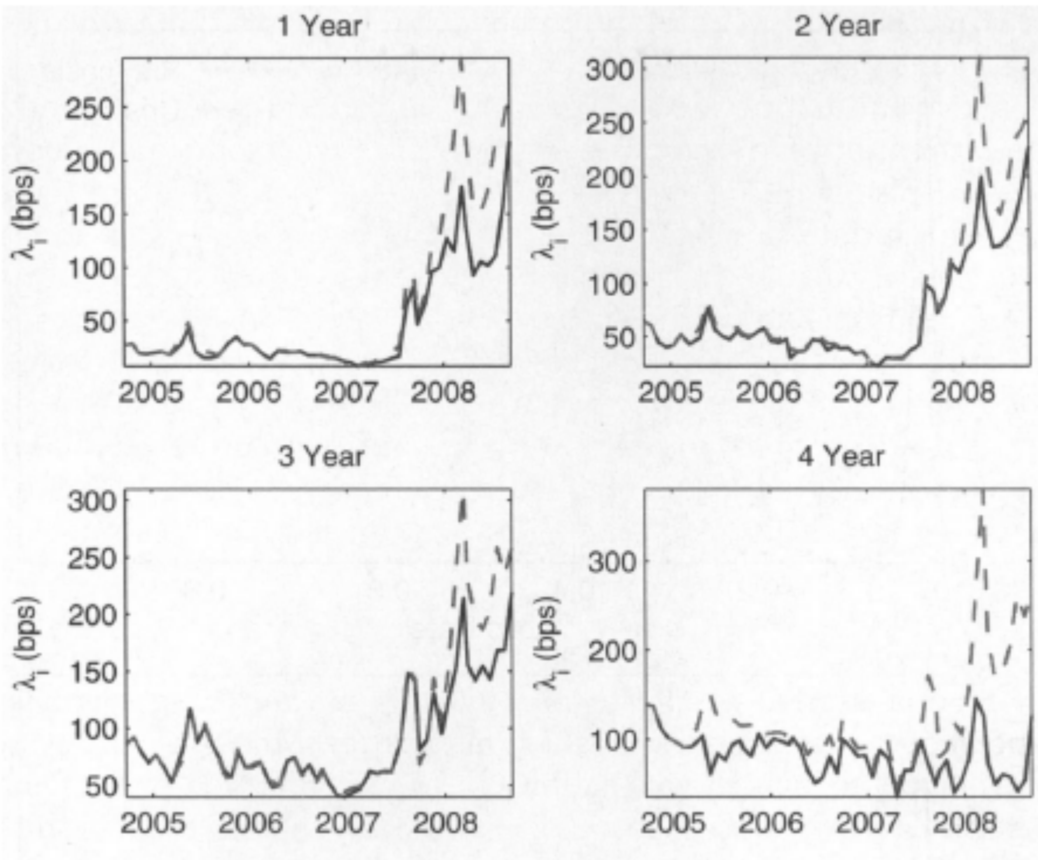
| Series | Period | Asset Beta | Idiosyncratic Asset Volatility | Leverage Ratio | Payout Ratio | Risk-Free Rate | S&P 500 Div. Yield |
|---|---|---|---|---|---|---|---|
| 3 | 9/2004–3/2005 | 0.56 | 19.2 | 37.3 | 1.87 | 1.81 | 1.64 |
| 4 | 3/2005–9/2005 | 0.57 | 18.7 | 36.3 | 2.37 | 2.88 | 1.78 |
| 5 | 9/2005–3/2006 | 0.60 | 19.0 | 33.4 | 2.73 | 3.90 | 1.92 |
| 6 | 3/2006–9/2006 | 0.61 | 18.9 | 32.9 | 3.04 | 4.75 | 2.00 |
| 7 | 9/2006–3/2007 | 0.62 | 19.1 | 32.2 | 3.08 | 5.08 | 1.95 |
| 8 | 3/2007–9/2007 | 0.61 | 18.8 | 31.7 | 3.06 | 4.83 | 2.00 |
| 9 | 9/2007–3/2008 | 0.64 | 18.4 | 30.6 | 2.64 | 2.95 | 2.08 |
| 10 | 3/2008–9/2008 | 0.66 | 17.9 | 28.8 | 2.43 | 1.87 | 2.14 |

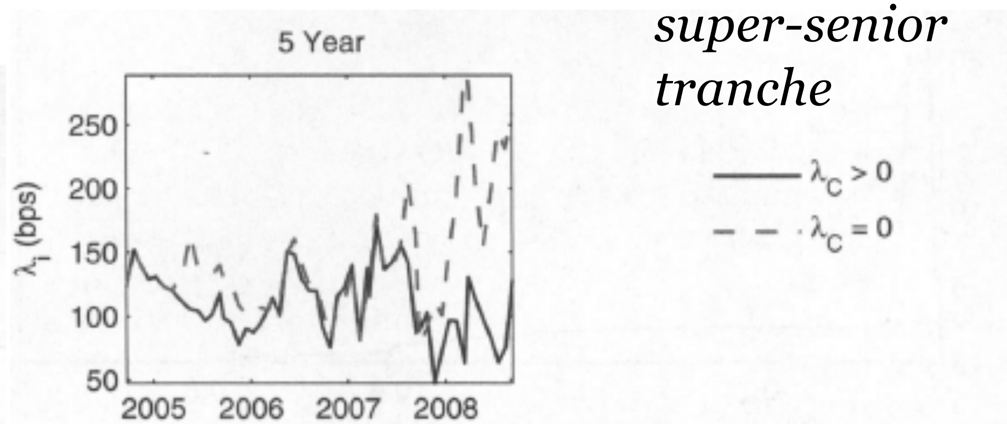
- The relative contribution of systematic and idiosyncratic risk to total risk shifted progressively during this period, with the fraction of total risk due to systematic risk increasing steadily as the crisis unfolded.
- As the proportion of systematic risk increases, loss distribution becomes more fat tailed *

# Calibrations

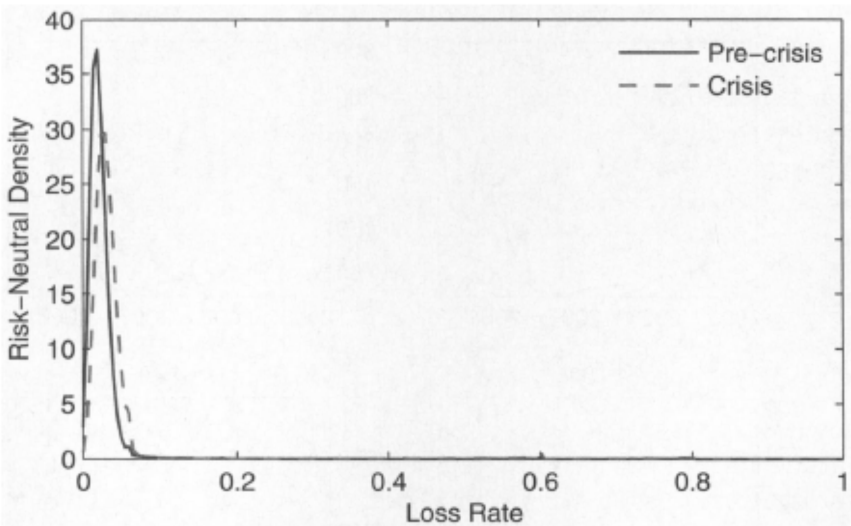
## Idiosyncratic jump-risk intensities

*Lambda: with/without catastrophic risk fitted to super-senior tranche*



# Results



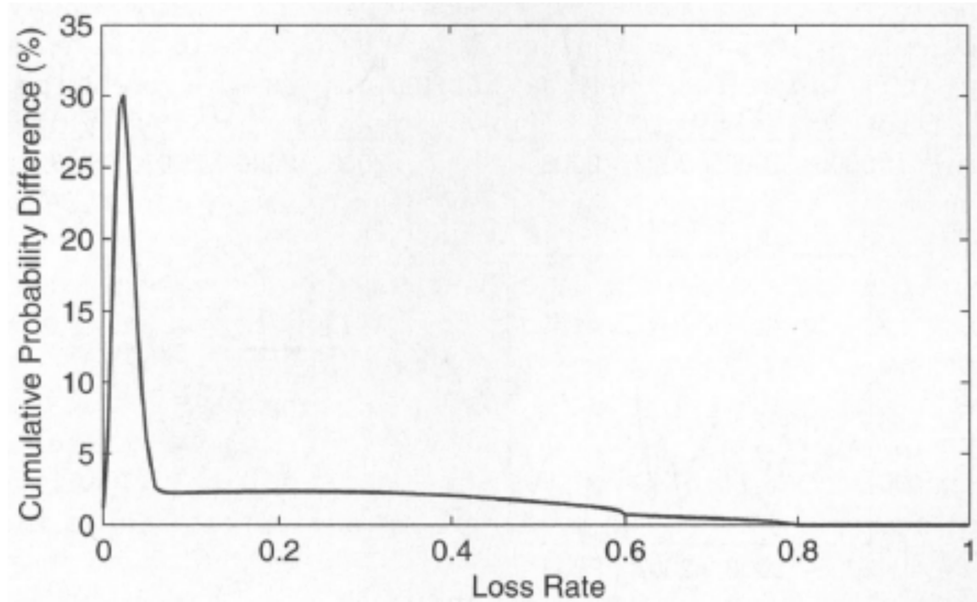




**Figure 4. Risk-neutral loss density.** The upper panel shows the risk-neutral loss density for the precrisis and crisis periods. The crisis period has higher expected losses and a less-peaked distribution due to a larger proportion of risk being systematic. The lower panel shows the difference in the cumulative loss distributions for the crisis and precrisis periods.

- Left hand side plots a representative risk-neutral loss density pre-crisis and during it.
- Right hand side is the difference between the two cumulative distributions.
- The risk-neutral loss density has fatter tails during the crisis

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# Results

## Average Tranches Spreads Results

**Table III**

**Historical and Model-Estimated Average Tranche Spreads**

This table presents historical and model-estimated average tranche spreads over the period September 2004 to September 2007 for three models: i) benchmark, ii) benchmark without catastrophic jump ($\lambda_C = 0$), and iii) benchmark without either catastrophic jump or idiosyncratic jumps ($\lambda_C = 0$, $\lambda_i = 0$). For comparison, we also report the results of CJS when available.

Actual Value

CJS Value

| | 5-Year Tranche | | | | | | | 3-Year Tranche | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–3% | 3–7% | 7–10% | 10–15% | 15–30% | 30–100% | 0–3% Upfrt | 0–3% | 3–7% | 7–10% | 10–15% | 15–30% | 30–100% | 0–3% Upfrt |
| | Precrisis | | | | | | | Precrisis | | | | | | |
| Data | 1,496 | 117 | 28 | 14 | 7 | 4 | 0.34 | 968 | 20 | 8 | 3 | 2 | 1 | 0.11 |
| Benchmark | 1,495 | 78 | 26 | 18 | 12 | 4 | 0.34 | 959 | 10 | 4 | 3 | 2 | 1 | 0.11 |
| $\lambda_C = 0$ | 1,668 | 104 | 20 | 12 | 5 | 0 | 0.38 | 1,007 | 10 | 3 | 2 | 1 | 0 | 0.12 |
| $\lambda_C = \lambda_i = 0$ | 659 | 223 | 133 | 89 | 42 | 4 | 0.06 | 286 | 84 | 49 | 32 | 15 | 1 | −0.06 |
| Coval | 914 | 267 | 150 | 87 | 28 | 1 | na | | | | | | | |
| | Crisis | | | | | | | Crisis | | | | | | |
| Data | 2,584 | 451 | 237 | 127 | 64 | 35 | 0.53 | 2,793 | 364 | 168 | 87 | 48 | 23 | 0.43 |
| Benchmark | 3,592 | 409 | 106 | 90 | 81 | 32 | 0.65 | 3,558 | 220 | 52 | 50 | 48 | 23 | 0.53 |
| $\lambda_C = 0$ | 5,502 | 1,122 | 205 | 53 | 22 | 3 | 0.77 | 5,258 | 540 | 24 | 10 | 5 | 1 | 0.66 |
| $\lambda_C = \lambda_i = 0$ | 1,020 | 523 | 375 | 286 | 174 | 26 | 0.19 | 635 | 295 | 205 | 153 | 90 | 12 | 0.03 |
| | Full Sample | | | | | | | Full sample | | | | | | |
| Data | 1,834 | 221 | 93 | 49 | 25 | 13 | 0.40 | 1,536 | 127 | 58 | 29 | 16 | 8 | 0.21 |
| Benchmark | 2,147 | 181 | 50 | 41 | 33 | 12 | 0.43 | 1,768 | 75 | 19 | 18 | 17 | 8 | 0.24 |
| $\lambda_C = 0$ | 2,861 | 421 | 77 | 24 | 10 | 1 | 0.50 | 2,329 | 175 | 10 | 4 | 2 | 0 | 0.29 |
| $\lambda_C = \lambda_i = 0$ | 771 | 317 | 208 | 150 | 83 | 11 | 0.10 | 394 | 150 | 97 | 70 | 38 | 5 | −0.03 |

Lambda c = 0, no catastrophic jumps; idiosyncratic jumps calibrated to match the 1-, 2-, 3-, 4-, and 5-year CDX index spreads;
Lambda c,i = 0, catastrophic jumps; no idiosyncratic jumps; default boundary calibrated to match only the 5-year CDX index.

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# Results

## Average Tranches Spreads Results

**Table IV**

**Historical and Model-Estimated Average Term Structure of CDX Index Spreads**

This table presents historical and model-estimated average CDX index spreads for the period September 2004 to September 2007 for three different models: i) benchmark, ii) benchmark without catastrophic jump ($\lambda_C = 0$), and iii) benchmark without either catastrophic jump or idiosyncratic jumps ($\lambda_C = 0$, $\lambda_i = 0$).

| | 1-Year | 2-Year | 3-Year | 4-Year | 5-Year |
|---|---|---|---|---|---|
| Data | 14 | 20 | 27 | 35 | 44 |
| Benchmark | 13 | 20 | 27 | 35 | 44 |
| $\lambda_C = 0$ | 14 | 21 | 27 | 36 | 44 |
| $\lambda_C = \lambda_i = 0$ | 1 | 7 | 18 | 31 | 44 |

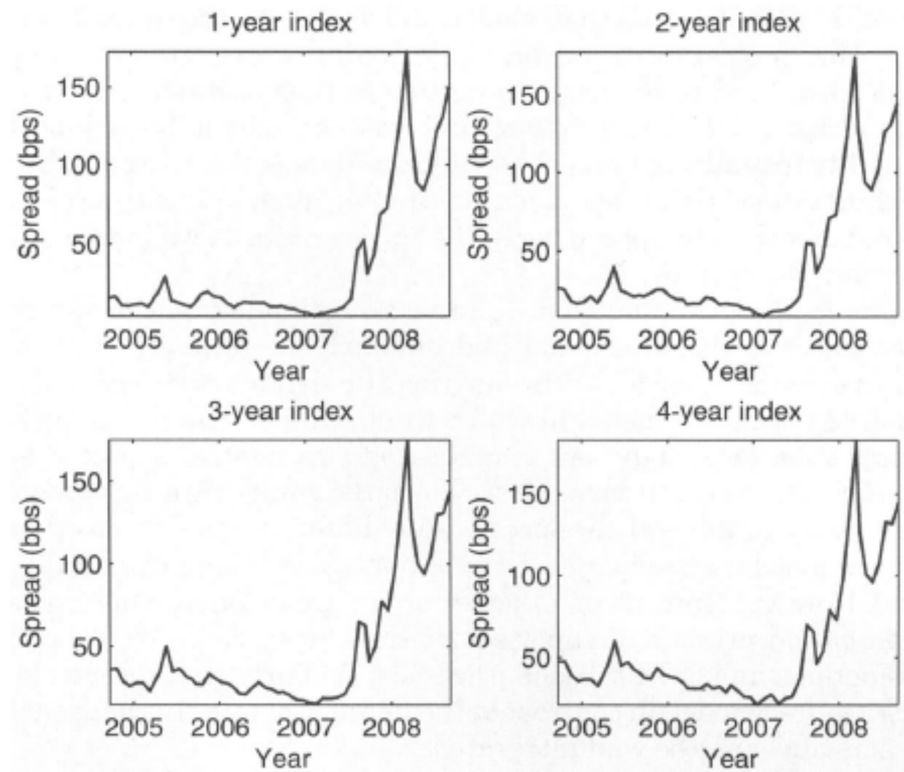
SD: 2.7%

SD: 6.8%

- Without both jumps, the expected loss has the "Backloading" problem which suggests that the buyer of equity protection pays too much premium for too long
- Also, adding idiosyncratic jumps lowered the standard deviation from 6.8% to 2.7%

# Results

## Time Series of Tranches Spreads



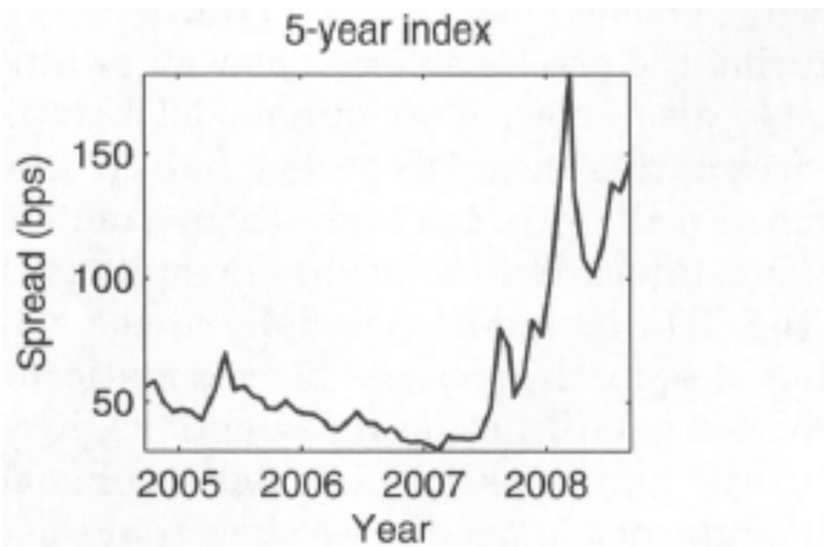
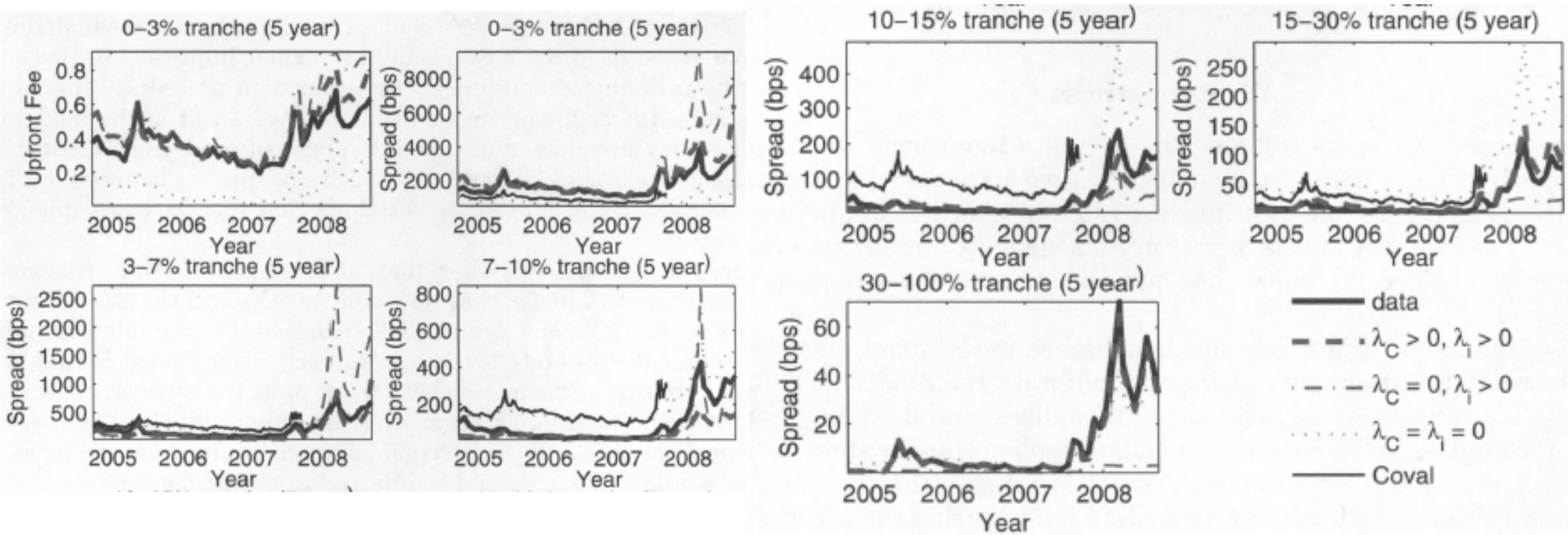




**Figure 5. Time series of CDX indices.** Historical time series of spreads for the 1-year, 2-year, 3-year, 4-year, and 5-year CDX indices. Our benchmark model is calibrated to perfectly match these time series.

# Results

## Time Series of Tranches Spreads

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# Robustness

**Table V**

**Robustness Analysis**

This table reports tranche spreads for six different models that relax some of the simplifying assumptions made for our benchmark model. In addition, we report the data and our benchmark model estimates. Results are presented for three representative days chosen to correspond to the 25th, median, and 75th percentile of the level of the CDX index in our sample. The six extensions of the benchmark model are described in detail in Section IV.

| | 5-Year Tranche | | | | | | | 3-Year Tranche | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–3% | 3–7% | 7–10% | 10–15% | 15–30% | 30–100% | 0–3% Upfrt | 0–3% | 3–7% | 7–10% | 10–15% | 15–30% | 30–100% | 0–3% Upfrt |
| | 25% Precrisis | | | | | | | 25% precrisis | | | | | | |
| Data | 1,266 | 114 | 22 | 10 | 4 | 2 | 0.29 | 799 | 9 | 3 | 2 | 1 | 0 | 0.08 |
| Benchmark | 1,234 | 54 | 19 | 14 | 8 | 2 | 0.27 | 613 | 6 | 3 | 3 | 2 | 0 | 0.03 |
| Dynamic capital structure | 1,230 | 55 | 22 | 15 | 9 | 2 | 0.27 | 608 | 6 | 4 | 3 | 2 | 0 | 0.03 |
| SVCJ | 1,201 | 56 | 23 | 16 | 10 | 2 | 0.26 | 587 | 11 | 7 | 5 | 3 | 0 | 0.02 |
| Stochastic short-term rate | 1,295 | 58 | 20 | 14 | 8 | 2 | 0.29 | 636 | 5 | 3 | 2 | 1 | 0 | 0.04 |
| Industry correlations | 1,177 | 90 | 23 | 16 | 10 | 3 | 0.25 | 630 | 7 | 3 | 2 | 1 | 0 | 0.03 |
| Financials and industrials | 1,286 | 53 | 17 | 11 | 7 | 2 | 0.29 | 621 | 5 | 3 | 2 | 2 | 0 | 0.03 |
| Correct for cash holding | 1,277 | 48 | 14 | 11 | 8 | 2 | 0.29 | 620 | 3 | 2 | 2 | 1 | 0 | 0.03 |
| | Median Precrisis | | | | | | | Median precrisis | | | | | | |
| Data | 1,571 | 110 | 26 | 13 | 6 | 3 | 0.36 | 1,021 | 9 | 3 | 2 | 1 | 0 | 0.13 |
| Benchmark | 1,579 | 81 | 24 | 16 | 10 | 3 | 0.37 | 978 | 6 | 3 | 2 | 1 | 0 | 0.12 |
| Dynamic capital structure | 1,561 | 81 | 27 | 18 | 11 | 3 | 0.36 | 972 | 6 | 3 | 2 | 1 | 0 | 0.12 |
| SVCJ | 1,543 | 81 | 26 | 18 | 11 | 3 | 0.36 | 940 | 14 | 8 | 6 | 3 | 0 | 0.11 |
| Stochastic short-term rate | 1,579 | 80 | 23 | 16 | 10 | 2 | 0.37 | 994 | 6 | 3 | 2 | 1 | 0 | 0.12 |
| Industry correlations | 1,457 | 121 | 25 | 17 | 11 | 3 | 0.33 | 998 | 15 | 3 | 2 | 1 | 0 | 0.12 |
| Financials and industrials | 1,589 | 76 | 20 | 14 | 9 | 3 | 0.37 | 965 | 5 | 2 | 2 | 1 | 0 | 0.12 |
| Correct for cash holding | 1,606 | 71 | 16 | 12 | 8 | 2 | 0.37 | 994 | 3 | 1 | 1 | 1 | 0 | 0.12 |
| | 75% Precrisis | | | | | | | 75% precrisis | | | | | | |
| Data | 1,639 | 122 | 36 | 18 | 9 | 4 | 0.38 | 986 | 25 | 9 | 4 | 3 | 1 | 0.12 |
| Benchmark | 1,585 | 92 | 28 | 20 | 14 | 5 | 0.38 | 913 | 8 | 4 | 3 | 2 | 1 | 0.11 |
| Dynamic capital structure | 1,568 | 92 | 30 | 21 | 14 | 5 | 0.38 | 913 | 9 | 5 | 3 | 2 | 1 | 0.11 |
| SVCJ | 1,555 | 94 | 31 | 23 | 15 | 4 | 0.37 | 875 | 16 | 10 | 7 | 4 | 1 | 0.10 |
| Stochastic short-term rate | 1,582 | 90 | 29 | 21 | 14 | 5 | 0.38 | 956 | 7 | 4 | 2 | 1 | 0 | 0.12 |
| Industry correlations | 1,495 | 143 | 29 | 20 | 13 | 5 | 0.35 | 962 | 16 | 4 | 3 | 2 | 1 | 0.12 |
| Financials and industrials | 1,608 | 87 | 24 | 17 | 12 | 5 | 0.39 | 943 | 7 | 4 | 3 | 2 | 1 | 0.11 |
| Correct for cash holding | 1,614 | 82 | 21 | 17 | 13 | 5 | 0.39 | 921 | 5 | 3 | 2 | 2 | 1 | 0.11 |

# Summary

Writers demonstrate the importance of calibrating the model to match the entire term structure of CDX index spreads (timing of expected defaults, idiosyncratic dynamics)

Jumps must be added to idiosyncratic dynamics to explain credit spreads at short maturities.

Super-senior tranche is not a redundant security, it provides window into the market's crash-risk expectation and risk aversion.

Overall, contrast to the conclusions of CJS (2009), the writers conclude that S&P 500 options prices and CDX tranche spreads can be well captured within an arbitrage-free framework. In that sense, these two markets appear to be well integrated

# Discussions

The model will require some probability of a catastrophic event that would not be directly inferred from option data (No enough options with the strikes in the relevant range)*

The model did not perform well in data during crisis, the size/allowance of the catastrophic risk could be increased to absorb the change

The model could be further improved by calibrating other tranches data rather than pricing them out-of-sample

* Sang Byung Seo and Jessica A. Wachter, 2016, “Do rare events explain CDX tranche spreads?”

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# Thank you!