Full-distribution event studies

Justin Wolfers (Wharton, NBER)
Eric Zitzewitz (Stanford GSB)

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Main idea

• Option prices imply a state price density (SPD)
  – SPD: \( s(x) = \text{price of security worth } \$1 \text{ if stock price } = \$x \text{ at some future date} \)
  – SPDs in turn imply a probability density for the future value of the underlying stock

• For an event that introduces uncertainty, one can “subtract” (actually, deconvolve) the pre and post-event distributions to recover the distribution of the uncertainty introduced
  – Can do same for event that resolves uncertainty
Potential applications

• Fields
  – Law and economics
  – IO
  – Financial economics
  – Positive political economy
  – Macroeconomic effects of policies

• Incremental contribution over traditional approach
  – Understand importance of considering different scenarios
  – Correct for any distortion of prices due to risk premia and increased or decreased uncertainty
  – Estimate size of atom at/near zero (i.e. probability that event = non-event)
  – Estimate time frame for resolution of uncertainty
Issues with event studies

Defining “events”
• Event window
• Pre and post-event beliefs
• Event => info re: other issues

Interpreting market prices
• Market inefficiency
• Risk premia
• Belief aggregation

Interpreting market movements around event
• “Average” event effect vs. range of possibilities
• Distortions due to low-probability events
• Price moves for other reasons during window
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Resolving uncertainty

• The Bernanke nomination was "an elimination of uncertainty -- one element that helps," said Paul Cherney of Cherney Market Analysis, Inc. "I don't know that it was a surprise to anybody."
Related literature

- Estimating SPDs
  - Theory: Arrow (1971), Breeden and Litzenberger (1978)
  - Non-parametric: Ait-Sahalia and Lo (1998)
- Event effects on option prices
  - Price discovery in stocks vs. options: Chao, Chen, and Griffin (2003)
  - Earnings and macro announcements: Berber and Brandt (2003), Dubinsky and Johannes (2005)
- Full-distribution prediction market-based analysis
  - Leigh, Wolfers, and Zitzewitz (2003), Wolfers and Zitzewitz (2005)
Estimating a SPD from options

Option value

Long 1 Call at strike price $K - e$

$K - e$  

Stock price at expiry
Estimating a SPD from options

Long 1 Call at strike price \( K - e \)
Short 1 Call at strike price \( K \)
Estimating a SPD from options

Option value

Long 1 Call at strike price $K - e$
Short 2 Calls at strike price $K$
Long 1 Call at strike price $K + e$
H = Forward price of a call option on a future with strike price K

\[ H(K) = \int_{K}^{\infty} (x - K)s(x)\,dx \]

An option’s “delta” = price of forward contract paying $1 if stock price > $K at expiry

\[ -\frac{dH}{\partial K} = \int_{K}^{\infty} s(x)\,dx \]

An option’s “gamma” = \( s(K) \) = Price of forward contract paying $1 if stock price = $K at expiry

\[ \frac{d^2H}{\partial K^2} = s(K) \]
Estimating an event effect distribution (EED)

1. Estimate pre and post-event SPDs
2. Calculate pre and post-event PDFs:
   \[ f(x) = \frac{s(x)}{E[u'(w) | x]} \]
3. Deconvolve distributions to recover incremental uncertainty introduced by event (i.e., find \( g(e) \) that satisfies below for every \( x \))
   \[ f_{post}(x) = \int f_{pre}(x - e) g(e) \, de \]
Methodological choices

• Approach for estimating $H(K)$ [and $H''(K)$]
  – Parametric vs. semi-parametric vs. non-parametric
  – Fit $H(K)$ or $H''(K)$?
  – What to assume about tails

• Adjust post distribution for elapsed time?

• Asset pricing model for $E[u'(w)|x]$
  For individual stocks, $w$ doesn’t vary much with $x$

• Adjust for aggregate market movements
  – Mean shift
  – Adjust for changes in aggregate market PDF

• Approach for estimating $g(e)$
  – Two vs. three step method
  – Para vs. semi vs. non-parametric
  – If non-parametric, smoothing technique
Methodological choices for today

• Approach for estimating $H(K)$
  – Parametric: Fit double integral of skew-t distribution for $H(K)$

• Adjust post distribution for elasped time?
  – No

• Asset pricing model for $E[u'(w)|x]$ 
  – Risk neutrality

• Adjust for aggregate market movements
  – No

• Approach for estimating $g(e)$
  – Three step, semi/non-parametric: estimate pre and post PDFs semi-parametrically, then find $g(e)$ that optimizes combination of fit and smoothness
Fitting $H''(K)$

Merck Jan 2006 SPD, Sep 30, 2004

State prices

- Fitting $H''(K)$
- Fitting $H(K)$
- Prices of state space triangles

![Graph showing state prices and fitting curves](image-url)
Fitting $H(K)$

Merck Jan 2006 options, Sep 30, 2004

- Fit of $H(K)$
- Fit of $H''(K)$
- Option midpoints

The diagram shows a graph with the Y-axis labeled "Put option price" and the X-axis labeled "Strike price." The graph includes three lines:
- A dashed line representing the fit of $H(K)$
- A solid line representing the fit of $H''(K)$
- A series of points representing option midpoints.

The graph illustrates the relationship between strike price and put option price, with the fitted curves and data points indicating how the option prices are spread across different strike prices.
Methodological choices (2)

• Use out-of-the-money options only
  – In-the-money options more sensitive to non-synchronous trading

• Convert American option prices to European options on futures using implied volatilities calculated by OptionMetrics

• Loss function for non-parametric fits:

\[
\sum_{k \in K} [f_{\text{post}}(k) - \hat{f}_{\text{post}}(k)]^2 + M \max \left\{ \frac{e_{\min}}{\max[g(e)]}, m \right\}
\]
Merck SPD 9/29 and 9/30
Merck Jan 2006 SPD, 9/29 and 9/30, 2004

State price

Stock price (log scale)
Merck pulls Vioxx on 9/30/2004

- Announces studies reveal higher heart attack and stroke rates in patients taking Vioxx
  - “Voluntarily” withdraws Vioxx from market
- Loses Vioxx sales (11% of 2004H1 sales)
- Cuts 2004 earnings guidance by 19%
- In 2004Q2 earnings report, stated it was investigating new patient populations for Vioxx
  => news about Vioxx unexpected
- Stock declines 27% to $33
EEDs for different expiry dates

![Graph showing the effect on log stock price for different expiry dates.]
Merck SPDs for Nov 2004
Bank of America: 9/2 to 9/4/2003

Effect on Log stock price (Jan 2005)

Jan 2004

Jan 2005
Marsh McLennan settlements with SEC

- November 12, 2003 settlement (Jan 2005 expiry)
- April 8, 2004 settlement (Jan 2005 expiry)
Microsoft breakup overturned

Uncertainty removed by Microsoft breakup being overturned (June 28, 2001)
Limitations

• Requires multiple options to be liquidly traded
  – Large cap stocks
  – Futures (equity, financial, commodities)
• Better for large events
  – Especially for individual stocks
• Difficult to apply to events that simultaneously introduce and resolve uncertainty
  – E.g., event moving probability of lawsuit from 50 to 100%
Open issues

• Better SPD estimation
  – Skew-t vs. non-parametric densities
  – Treatment of tails

• Better EED estimation

• “Standard errors”/robustness
  – To noise (e.g., bid-ask bounce) in option prices
  – To methodological choices, especially about tails
Epilogue: Bernanke and bond prices

PDF of uncertainty from Fed chairmanship

10-year bond futures (Dec 2005 expiry)
Bernanke and bond prices

PDF of uncertainty from Fed chairmanship

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