

# Option Pricing of Earnings Announcement Risks

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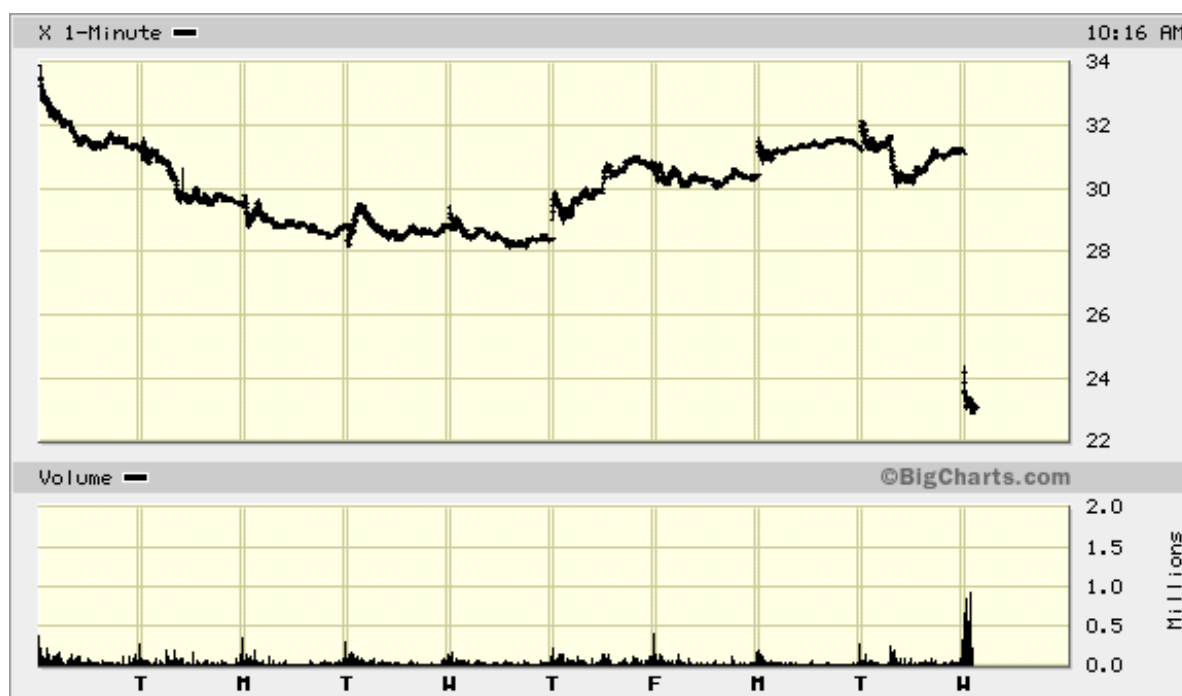


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## US Steel on Tuesday

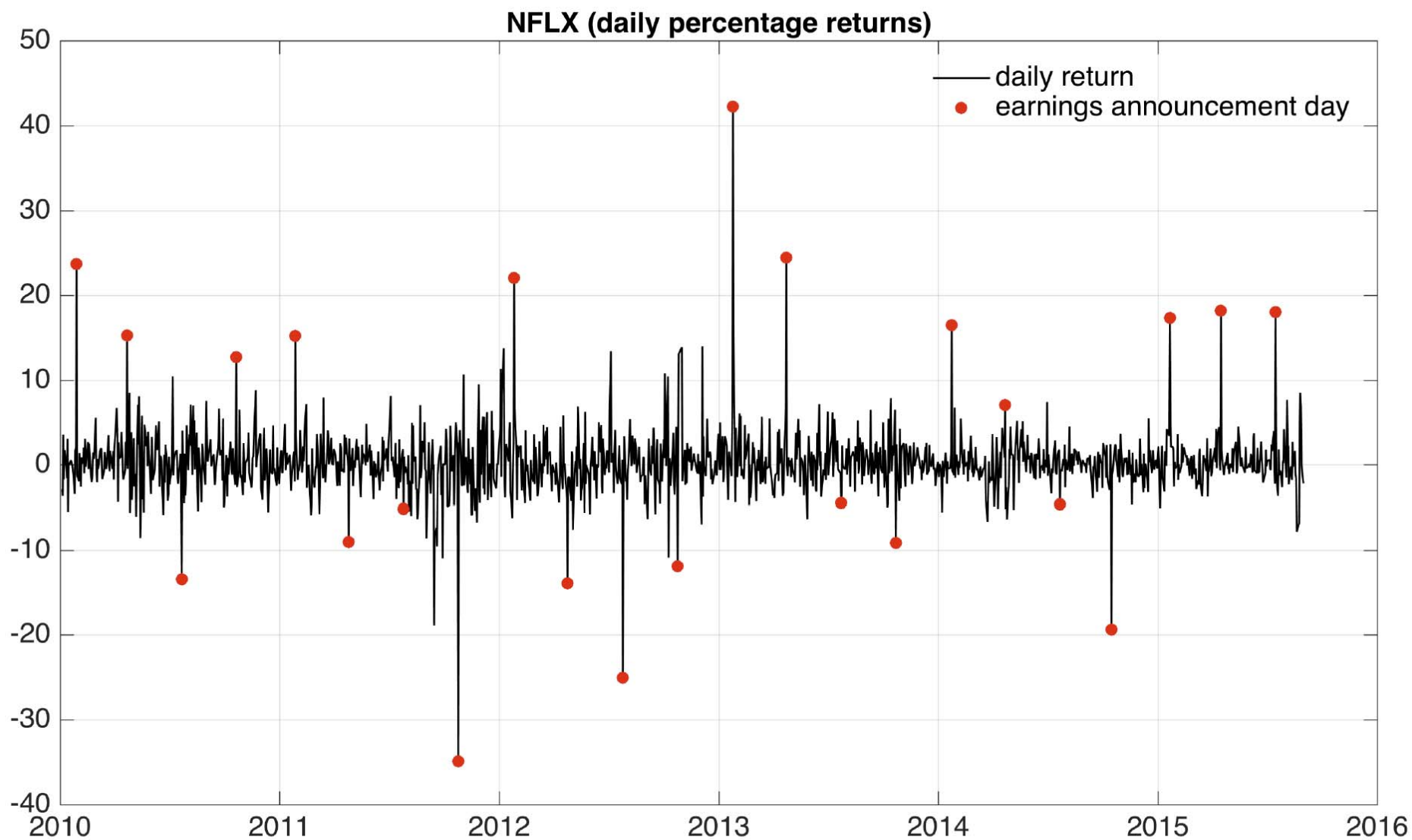
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- *“US Steel is diving after reporting a loss for the first quarter of 2017 on Tuesday. The adjusted \$0.83 per share loss was far below analysts expectations of earnings of \$0.35 per share. Additionally, the company whiffed on revenues, generating \$2.73 billion versus expectations of \$2.95 billion.”*

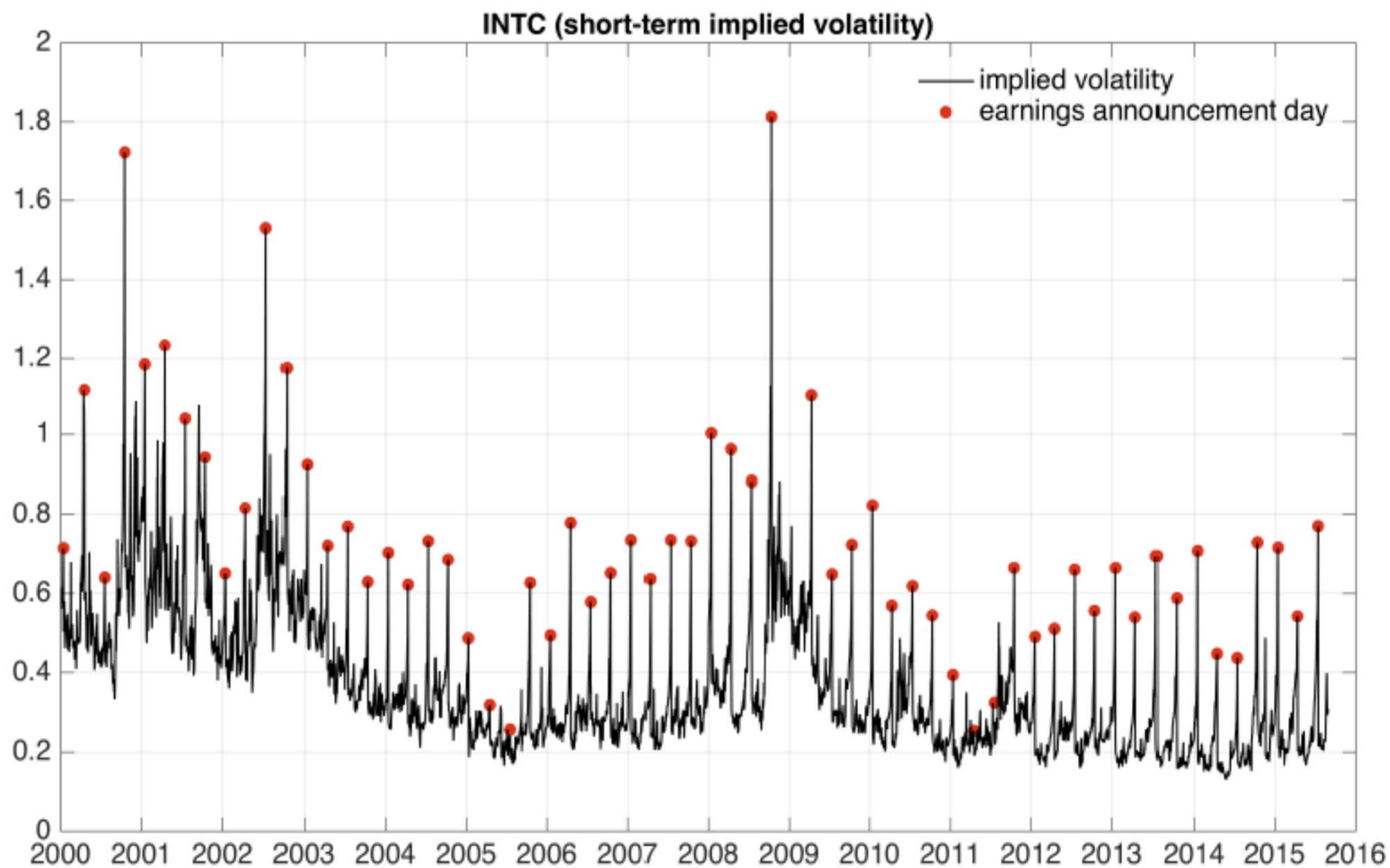


# Earnings announcements matter. A lot.

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# Earnings announcements are priced in options



# This paper

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- Extend traditional models to incorporate earnings announcements, use options to learn from options about earnings induced price volatility, to understand how earning risks are priced in options and to study their information content.
  
- Contributions:
  1. Models: Build stochastic volatility models incorporating earnings announcements.
  2. Impact: document earnings announcements have a first order impact on option prices (extending early work by Patell and Wolfson)
  3. Estimates: estimate and characterize earnings induced price volatility, both in the time series and cross-section.
  4. Information and pricing: understand the predictive content of earnings volatilities and earnings jump risk premia.
  5. Calibrate formal stochastic volatility option pricing models to understand the relative importance of earnings announcements.

\*\*\* Laboratory to understand predictable events, but results apply to many other events like such as macro economic announcements. Suggests a different view of 'volatility:' a sequence of important predictable events.

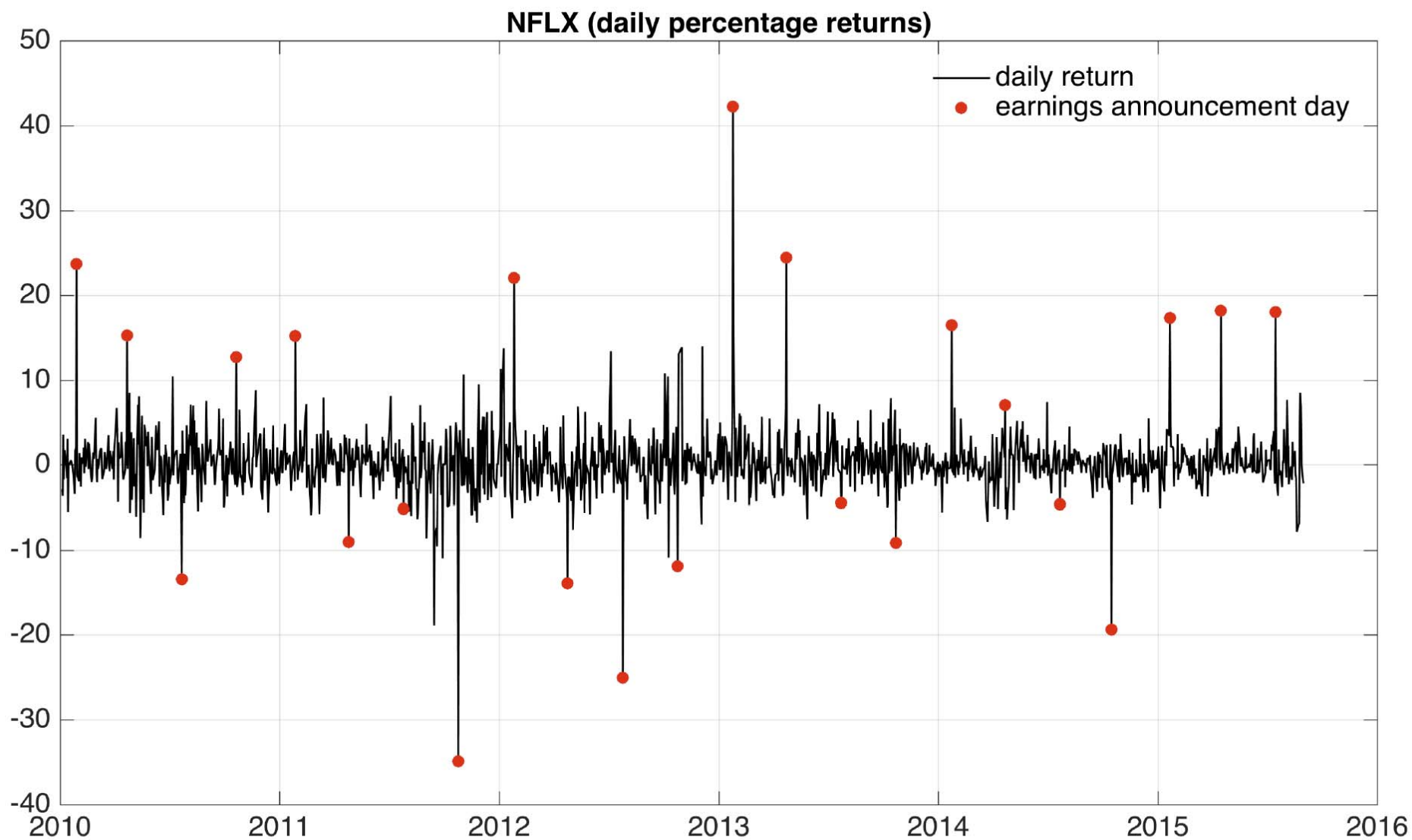
## Earnings announcements

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- Every quarter, firms are required by the SEC to report “earnings.” These almost always occur outside of trading hours (BMO or AMC)
  - These announcements include accounting information (income & cash flow statements, balance sheet, etc.) but also informal “soft” information, forecasts, and often Q&A with management.
- Major determinant of asset return volatility.
  - E.g., 20% of Google’s total volatility occurs on the 4 days after earnings.
  - Related to many interesting return anomalies: e.g., post-earnings announcement drift.

# Earnings announcements matter.

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# Incorporating earnings announcement risks

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- Consider first a simple model for intuition
  - Let  $N_t^d$  count the number of earnings announcements prior to time  $t$ .
  - $Z_j$  is the random jump size induced by an EAD at time  $t_j$ :  $Z_j \sim N(\mu_j, \sigma_j^2)$

$$\frac{dS_t}{S_t} = \mu dt + \sqrt{\sigma^2} dW_t^S + d \left( \sum_{j=1}^{N_t^d} (e^{Z_j} - 1) \right)$$

- Notables
  - Arrival times are fully predictable. Volatility as a sequence of events.
  - One shot event: hard to learn about jumps from P-measure (1 data point)
  - Can add stochastic volatility, random jumps (we do).
  - Return volatility on day of/after EAD:  $\sigma^2/252 + \sigma_j^2$ .
  - Earnings ‘jump’ is a reduced form model of earnings information.  
Standard accounting regression:

$$Z_j = \alpha + \beta(E_j - \hat{E}_j) + \varepsilon_j$$



# Option pricing

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- Option prices: equity prices are log-normal, thus Black-Scholes like formula holds.
- For an option expiring in T days, where  $t < t_j < t + T$ , the annualized implied volatility (IV) at time t is

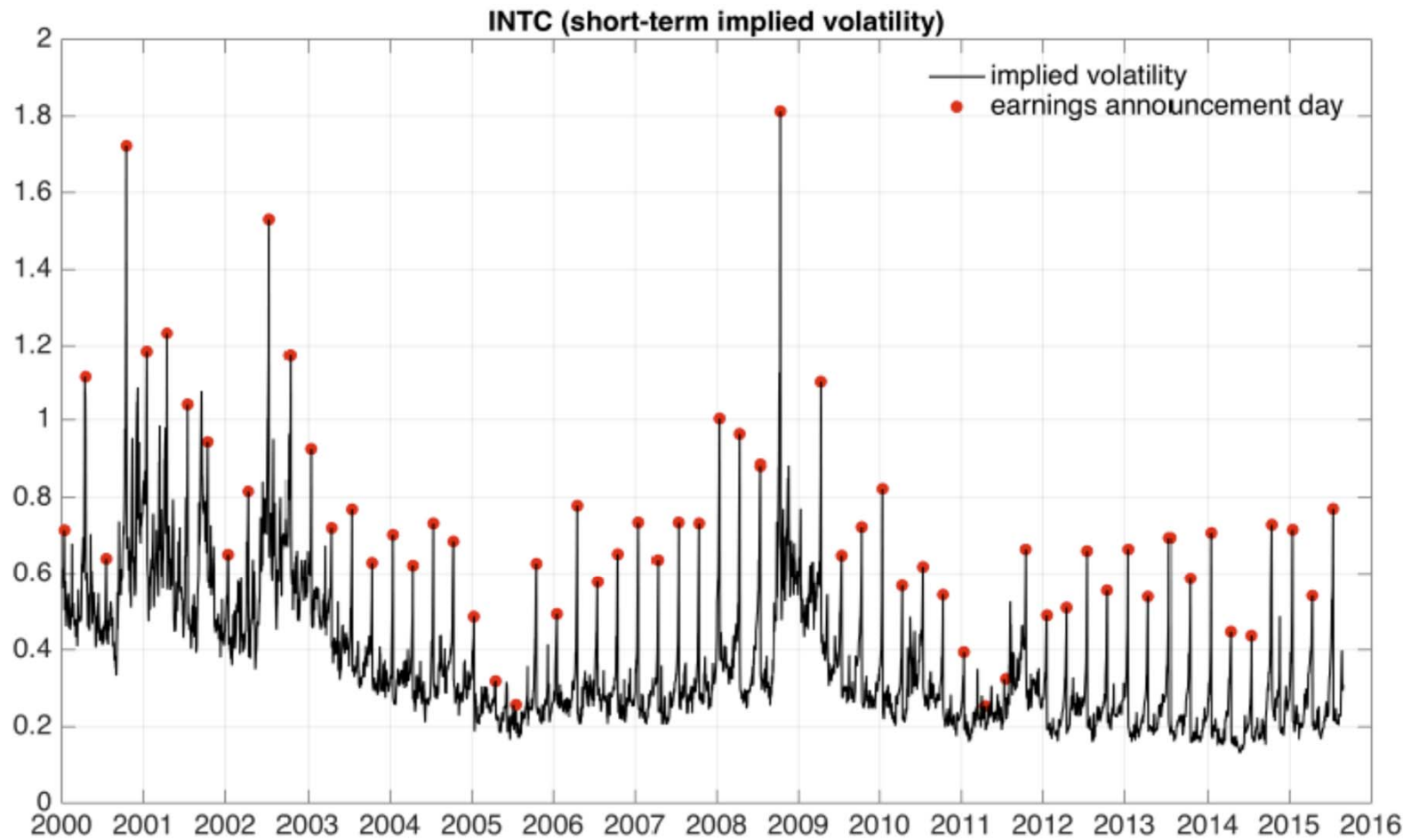
$$\sigma_{t,T}^2 = \sigma^2 + \frac{(\sigma_j^Q)^2}{T}$$

- Option pricing implications
  - IV's increase prior to earnings announcements.
  - IV falls discontinuously after an earnings announcement
  - The term structure of IV decreases with maturity (negatively sloped term structure)

\*\*\* The first two of these were noted by PW (1979, 1985). They worked in volatilities instead of variances.

## General patterns are easily confirmed (formal tests in paper)

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## How to extract/estimate EAD price jump volatility?

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- The simple model provides a number of ways to estimate EAD volatility. Two primary approaches:

1. Compare pre and post announcement volatility (time series)

$$\sigma_{t_j^-, T}^2 = \sigma^2 + \frac{(\sigma_j^Q)^2}{T} \text{ and } \sigma_{t_j^+, T}^2 = \sigma^2$$

2. Use the term structure of implied volatility (term structure)

$$\sigma_{t, T_1}^2 = \sigma^2 + \frac{(\sigma_j^Q)^2}{T_1} \text{ and } \sigma_{t, T_2}^2 = \sigma^2 + \frac{(\sigma_j^Q)^2}{T_2}$$

- Like an ‘implied’ earnings price jump volatility estimator. In the paper
  - Discuss how stochastic volatility affects estimators: minor impact, largely robust.
  - Argue term structure is more robust and less noisy than time series (though empirically highly correlated).

## Simple, robust event risk estimators

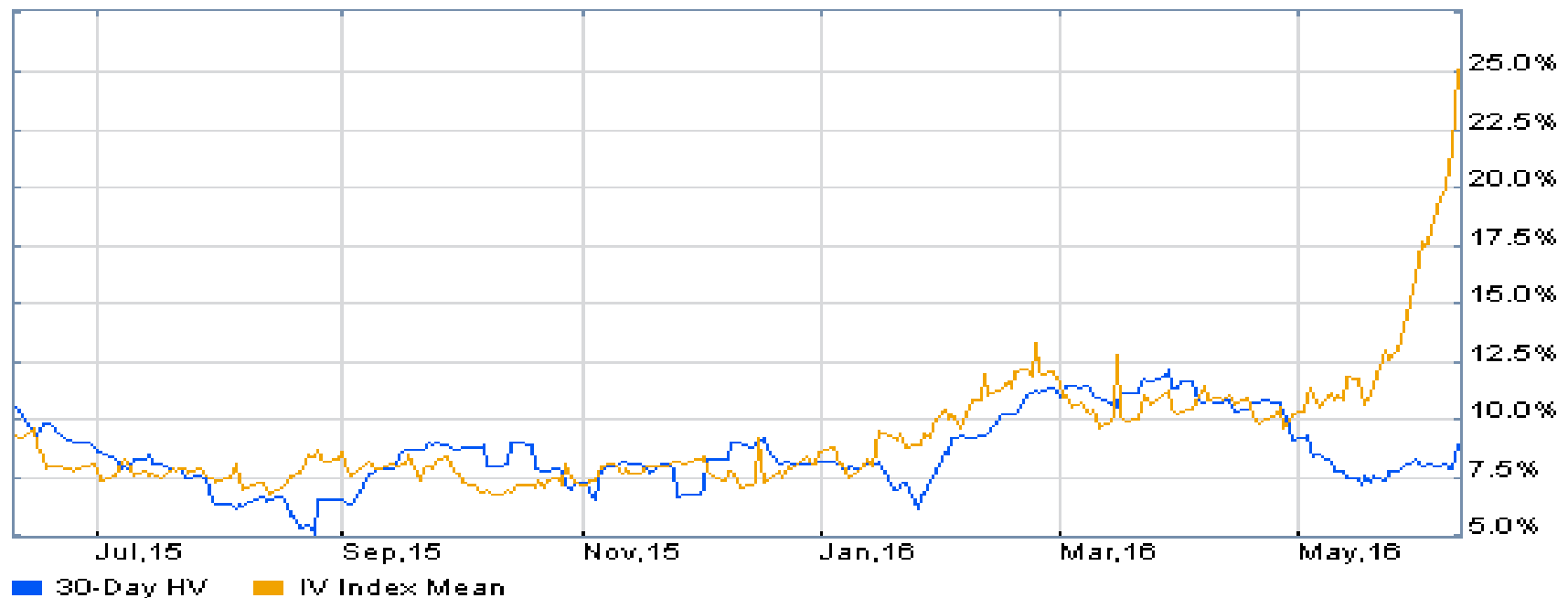
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- An advantage of these estimators are their simplicity: don't need a formal SV model, etc. Can apply to any event.
- Brexit

## Simple, robust event risk estimators

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- Brexit: GBP/USD implied volatilities the day prior to Brexit
  - 1 month: 28.21%, 2 months: 21.51%
  - Term structure estimator:  $\sigma_j^Q = 7.5\%$
  - Spot GBP/USD dropped 10% the next day.

**FXB:Daily 1 Year Volatility Chart ( 3 months | 6 months | 1 Year )**  
[IV Index Call](#) | [IV Index Put](#) | [IV Index Call & Put](#) | [IV Index Mean](#)



# Data

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- Standard data sources
  - OptionMetrics post 2000. Close prices, careful to average call and put prices to avoid synchronicity issues
  - EADs: Thomson Reuters, IBES, and Compustat (manually search disagreements on LexisNexis).
  
- Screens
  - Select 50 most actively traded firms by option \$ volume each year.
  - Slightly unbalanced panel.

## Results: earnings jump volatility estimates

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- In the paper, we report firm specific and pooled estimates. A few representative firms:

Table: Average  $\sigma_j^Q$  (ex-ante estimator, by firm)

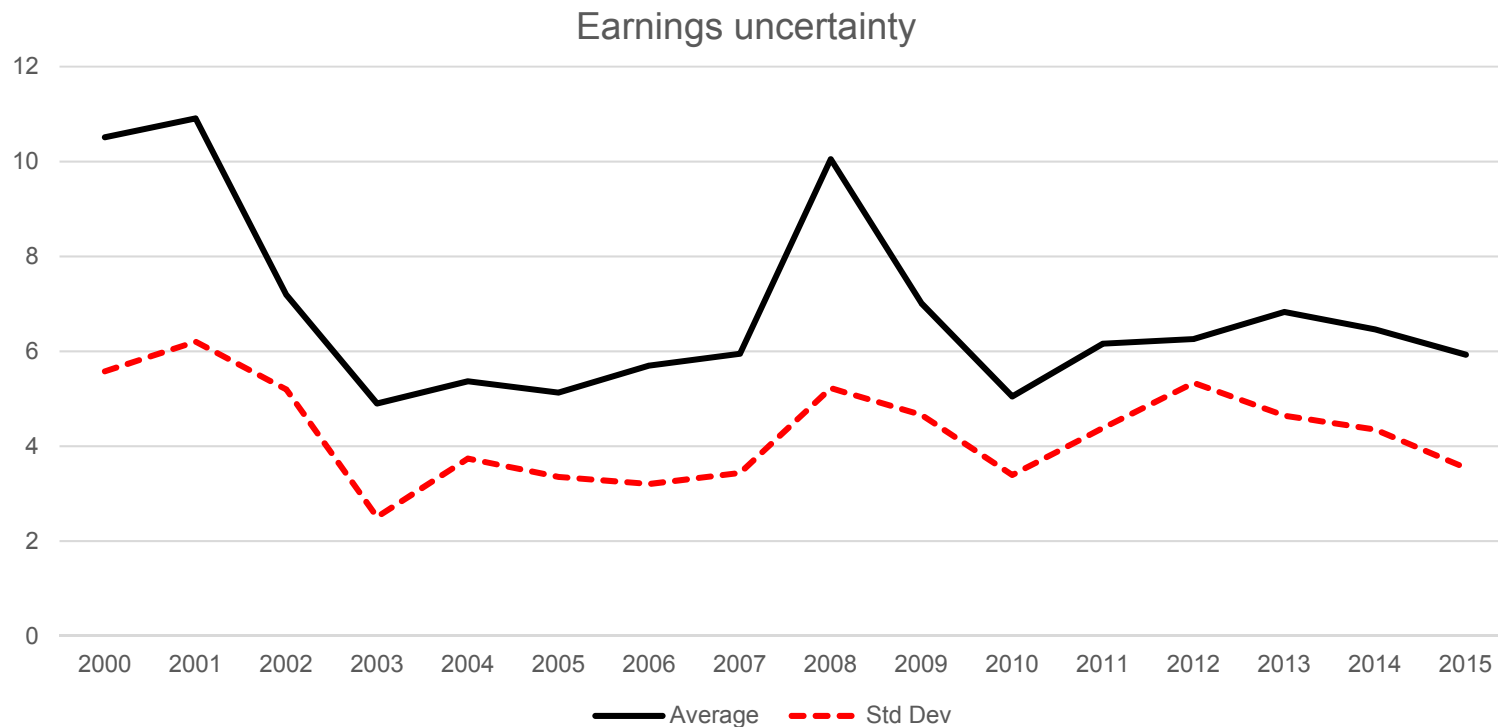
Term	Mean	Median	Std Error	25%	75%	Obs
AAPL	8.83	8.49	0.40	7.08	9.76	52
AMZN	12.06	11.06	0.49	9.49	13.94	64
IBM	5.68	5.02	0.30	4.49	6.15	64
INTC	7.04	6.27	0.36	5.31	7.66	63
NFLX	14.92	13.98	0.91	11.25	18.39	28
WMT	3.26	3.30	0.15	2.60	3.57	52

- Notes
  - Strong time series variation: Apple's std. deviation about 3%.
  - Magnitudes: largely determined by transparency of firm: firms whose earnings are more easily discerned have lower volatility. E.g., WMT vs. NFLX.
  - Correlation with time series estimator: across firms, 93%.

## Time series behavior

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- Earnings uncertainty and cross-sectional dispersion increases in recessions



- Significantly correlated with CAPM betas: systematic components.



## Results: Predictive information in options

- Are options informative about future realized volatility?
  - Cross-sectional correlation at firm level: 85%. Highly informative.
  - Correlations are at maximally expected levels given normal noise in 1-day realized volatility.
- Pooled
  - Significant, no evidence that analyst dispersion is informative.

$$|r_j| = \alpha + \sum \beta_i \text{Predictor}_i + \text{Error}$$

	Model (1)		Model (2)		Model (3)		Model (4)	
Panel A – Dependent variable: absolute EAD return								
Constant	0.01	(3.69)	0.05	(13.66)	0.02	(4.09)	0.01	(1.85)
EAD Vol	0.58	(11.42)					0.50	(7.02)
IBES DV			0.82	(1.15)			-0.45	(-0.72)
					0.09	(11.73)	0.03	(4.31)
$R^2$ (%)	28.47		0.17		15.28		29.68	

IBES: analyst dispersion, DV: diffusive volatility

# Variance risk premiums

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- Strong evidence for macro market variance and jump risk premia:
  - Indices, long term bonds, FX markets, commodity markets (intuitively,  $IV-RV > 0$ ).
  - Hard to tell if volatility or jump risk.
  - Evidence for earnings announcement volatility jump premium?
- Why volatility premia for individual firm volatilities?
  - Capital constrained intermediaries
  - Systematic components: strong correlation between  $\sigma_j^Q$  and CAPM  $\beta$ . (similar reason why positive announcement premia at firm level)
- Consider multiple measures of variance risk premia
  - Compare  $\sigma_j^Q$  to various measures of  $\sigma_j^P$ .
  - Standardized realized returns by option implied volatility
  - Compute announcement day straddle returns

## Results: Jump volatility risk premium

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- Uniform evidence that implied EAD jump volatility is greater than subsequent return volatility (Qvol>Pvol)
  - Average standardized returns are less than 1
  - P-Vol is always less than Q-vol (CC-close-to-close)

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Year	Std	P-Vol (CC)	Q-Vol mean	P-Vol (CO)	Q-Vol jump	Q-Vol median
2000 to 2005	0.94	7.63	9.92	6.65	7.46	7.08
2006 to 2010	0.92	7.22	7.74	5.60	6.77	6.15
2011 to 2015	0.91	7.35	6.78	6.60	6.34	5.19
Pooled	0.92	7.42	8.22	6.31	6.87	6.03

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## Straddle returns

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- Straddle returns are highly significant: -8%/EAD.

Idea: If  $\sigma_j^Q > \sigma_j^P$ , then writing straddles around EADs should be profitable.

Table: Straddle returns

Statistic	Data	Bootstrapped Distribution								
		mean	std	1%	5%	25%	50%	75%	95%	99%
Mean	-7.96	-1.51	0.29	-2.17	-1.94	-1.73	-1.52	-1.31	-1.01	-0.82
Median	-10.24	-3.17	0.21	-3.66	-3.50	-3.32	-3.17	-3.01	-2.86	-2.69
Std	27.47	15.01	0.70	13.68	13.97	14.54	14.95	15.28	16.39	17.32
Skewness	1.44	2.27	0.91	1.17	1.40	1.77	2.03	2.44	4.09	5.81
Kurtosis	8.93	21.77	19.64	8.65	9.84	12.92	15.75	20.90	61.27	113.18
t-stat	-13.25	-5.40	1.17	-7.92	-7.12	-6.19	-5.44	-4.60	-3.50	-2.63

## SV option pricing model implications

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- Consider a general SV model

$$dS_t = (\mu - \bar{\lambda}_y \psi_t) S_t dt + \sqrt{V_t} S_t dW_t^s + d \left( \sum_{j=1}^{N_t^d} S_{\tau_{j-}} [e^{Z_j} - 1] \right) + d \left( \sum_{j=1}^{\bar{N}_t} S_{\tau_{j-}} [e^{\bar{Z}_j} - 1] \right),$$

$$dV_t = \kappa_v (\theta_v - V_t) dt + \sigma_v \sqrt{V_t} dW_t^v,$$

- Main question: How important are earnings announcements for pricing the full cross-section of options? Focus on pricing errors.
- Data and calibration approach
  - Focus on 6 most liquid firms. 9 options by moneyness (DOTM, OTM, ATM) and maturity (S/M/L) for 16 years.
  - Computations: 150K numerical inversions for objective function evaluation.

## Option pricing summaries

- Results for Intel
  - SVEJ (SV with earnings jumps) and SVJEJ (SVJ with earnings jumps)

Firm	Category	Model	Days relative to EAD						
			-5	-4	-3	-2	-1	0	1
INTC	all	SV	3.32	3.66	3.72	4.11	3.91	4.55	1.25
		SVEJ	1.82	1.95	1.84	1.93	1.62	2.05	1.20
	short	SV	8.01	8.60	9.10	10.04	6.72	5.53	1.96
		SVEJ	4.34	4.58	4.52	5.27	3.40	2.79	2.00
	medium	SV	2.34	2.56	2.75	3.18	3.62	4.08	1.45
		SVEJ	1.14	1.18	1.21	1.24	1.36	1.65	1.13
	long	SV	2.24	2.51	2.58	3.02	3.93	4.75	1.01
		SVEJ	1.32	1.44	1.35	1.40	1.68	2.22	1.02

Firm	Model	Option Categories						
		All	OTM	ATM	ITM	short	medium	long
INTC	SV	1.88	1.97	1.81	1.85	3.28	1.47	1.49
	SVEJ	1.49	1.55	1.40	1.55	2.70	1.18	1.21
	SVJ	1.82	1.84	1.82	1.81	3.17	1.40	1.46
	SVJEJ	1.48	1.49	1.44	1.52	2.64	1.15	1.21

- Huge conditional improvement around EADs, large overall improvement (15-20%). Far more important than random jumps.

## Conclusions, implications, and future directions

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- Earnings announcements are first order important for option prices, and option prices are highly useful for learning about future earnings induced price volatility.
- Important note of caution: individual firm options are quite different from index options.
  - Many papers are now using option IV's to generate trading strategies for equities. Since much of IV variation loads on EADs, these trading strategies will too
- Event risk is most important at a firm level, but still very important for macroeconomic markets. Other events?
  - Macroeconomic events (FOMC, employment, etc.)
  - Market specific events (crop reports, oil inventory announcements)
  - Political events: Kelly, Pastor, and Veronesi (2015)