Information Arrival, News Sentiment, Volatilities and Jump Risk of Intraday Stock Returns

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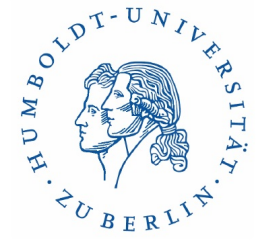


Return and Information Arrival

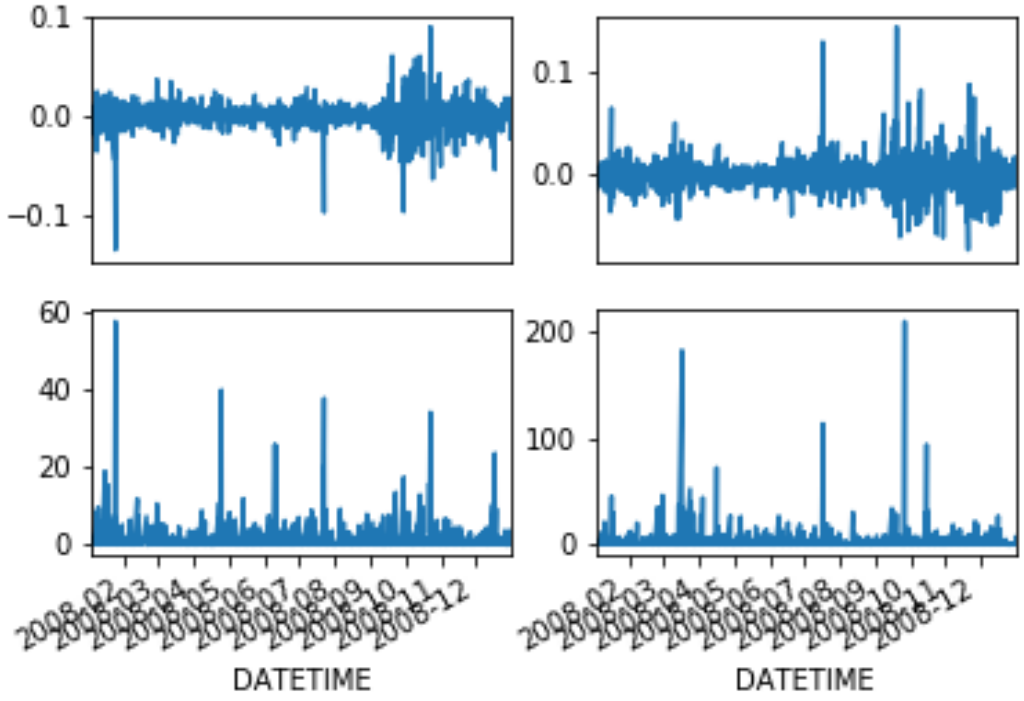
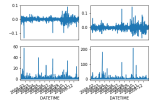


Figure 1: Time series of returns (upper) and information arrival (lower) for AAPL (left) and JPM (right)



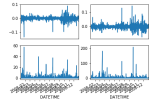
Important Information

Source: MIT Faculty Webpage

"$\cdots$ the 'abnormal' vibrations in price are due to the arrival of important new information about the stock that has more than a marginal effect on price"

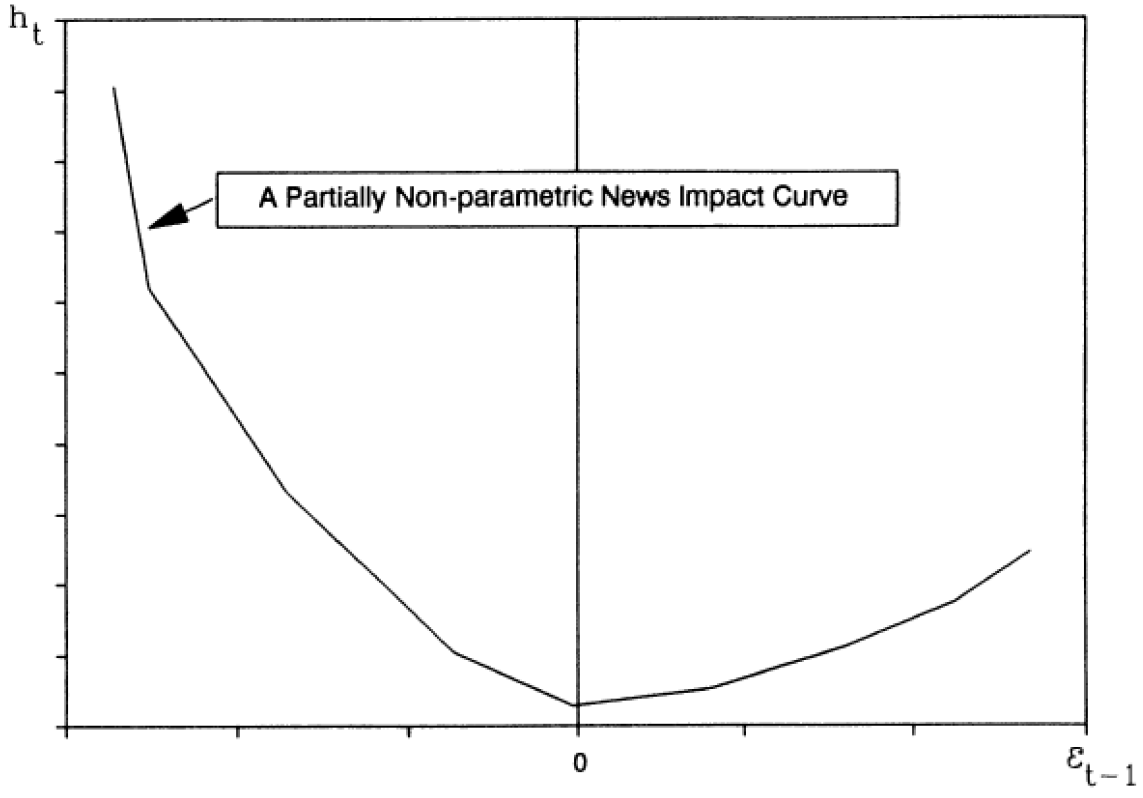
"Usually, such information will be specific to the firm and possibly its industry"

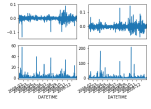
Robert C. Merton, 1976



News & Volatility

Engle and Ng (1993, JF)

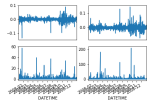




Volatility & News

Kalev and Duong (2011, The Handbook of News Analytics in Finance)

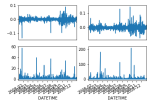
- EGARCH model with news variable
- Reduce of volatility persistence by inclusion of news information
- Consistent with the mixture of distribution hypothesis



News & Jumps

Maheu and Mccurdy (2004, JF)

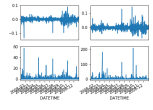
- GARCH-jump model with latent news process
- Abnormal news such as earnings surprises cause jumps
- Evidence of asymmetric effects of return innovations



Jumps & News

Lee and Mykland (2008, RFS)

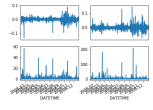
- Nonparametric test (jump arrival times, realized jump sizes and jump directions)
- Ignore misclassification due to high frequency (HF) data
- 3-month 15-min HF data for WMT, IBM, GE and S&P 500 index
- Individual stock jumps associated with prescheduled earnings announcements and other firm-specific news events; S&P 500 index jumps related to general market news announcements
- Suggest different pricing models for individual equity options v.s. index options



Jumps & News

Lahaye, Laurent and Neely (2011, JAE)

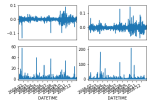
- 4 USD exchange rates (FEX), 3 stock index futures, 1 bond futures, gold prices
- Some surprises create jumps while others don't
- Propensity of surprises creating jumps differs across asset classes
- For stocks and bond futures: payroll announcements
- For FEX: trade related news



Jumps & News Disapproved

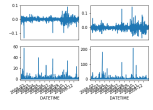
Bajgrowicz, Scaillet and Treccani(2016, MS)

- Disapprove relations between jumps and news
- Spurious detection problem in jump test
- News associated with bursts of volatility instead of jumps



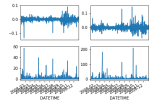
Research Questions

- Jump included in volatility modeling?
- News included explicitly?
- How news affecting the return processes?



Challenges

- Specification of jump models
- Microstructure noise of HF data
- Quantification of information content



Outline

1. Motivation ✓
2. Jumps-News Modeling
3. News Analytics
4. Empirical Evidence
5. Conclusion

EGARCH-Jump-News Model 1 (GJNJ)

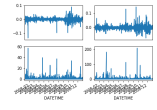
$$r_t = \varepsilon_{1,t} + \varepsilon_{2,t} \tag{1}$$

$$\varepsilon_{1,t} = \sqrt{h_t} z_t, z_t \sim N(0,1) \tag{2}$$

$$\varepsilon_{2,t} = J_t - \mathrm{E}[J_t|\Phi_{t-1}] = \sum_{k=1}^{n_t} Y_{t,k} - \theta\lambda_t, Y_{t,k} \sim \mathrm{N}(\theta, \delta^2) \tag{3}$$

$$\begin{aligned} \log(h_t) = \omega &+ (\alpha + \alpha_j \mathrm{E}[n_{t-1}|\Phi_{t-1}])(|z_{t-1}| - \mathrm{E}\,|z_{t-1}|) \\ &+ (\alpha_a + \alpha_{a,j} \mathrm{E}[n_{t-1}|\Phi_{t-1}])z_{t-1} + \beta \log(h_{t-1}) \end{aligned} \tag{4}$$

$$\lambda_t = \lambda_0 + \rho\lambda_{t-1} + \eta_n N_t + \eta_s \log Sent_t \tag{5}$$



EGARCH-Jump-News Model 2 (GJNG)

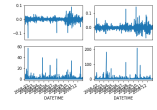
$$r_t = \varepsilon_{1,t} + \varepsilon_{2,t} \tag{6}$$

$$\varepsilon_{1,t} = \sqrt{h_t} z_t, z_t \sim N(0,1) \tag{7}$$

$$\varepsilon_{2,t} = J_t - \mathrm{E}[J_t|\Phi_{t-1}] = \sum_{k=1}^{n_t} Y_{t,k} - \theta\lambda_t, Y_{t,k} \sim \mathrm{N}(\theta, \delta^2) \tag{8}$$

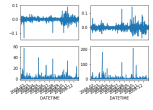
$$\begin{aligned} \log(h_t) = {} & \omega + (\alpha + \alpha_j \,\mathrm{E}[n_{t-1}|\Phi_{t-1}])(|z_{t-1}| - \mathrm{E}\,|z_{t-1}|) \\ & + (\alpha_a + \alpha_{a,j}\,\mathrm{E}[n_{t-1}|\Phi_{t-1}])z_{t-1} + \beta \log(h_{t-1}) \\ & + \eta_n N_t + \eta_s \log Sent_t \end{aligned} \tag{9}$$

$$\lambda_t = \lambda_0 + \rho\lambda_{t-1} + \gamma\xi_{t-1} \tag{10}$$



EGARCH-Jump-News Model (Cont.)

- drift part assumed to be zero due to the high frequency data used
- N_t number of all relevant news at time t, exogenous variable
- $sent_t = \frac{\sum_{i=1}^{k_t} rel_{it} neg_{it}}{\sum_{j=1}^{k_t} rel_{jt} pos_{jt}}$ with k_t the number of relevant news at time t, $rel_{it}, neg_{it}, pos_{it} \in [0, 1]$ the score of relevance, positiveness and negativeness of i_{th} news at time t, exogenous variable
- $\xi_{t-1} = \mathrm{E}[n_{t-1}|\Phi_{t-1}] - \lambda_{t-1}$ jump intensity residual
- $\mathrm{Var}(r_t|\Phi_{t-1}) = \mathrm{Var}(\varepsilon_{1,t}|\Phi_{t-1}) + \mathrm{Var}(\varepsilon_{2,t}|\Phi_{t-1}) = h_t + \lambda_t(\delta^2 + \theta^2)$



Likelihood Function

- Conditioning on j jumps occurring the conditional density of returns is normal,

$$f(r_t|n_t = j, \Phi_{t-1}) = \frac{1}{\sqrt{2\pi(h_t + j\delta^2)}} \exp\{-\frac{(r_t - \mu + \theta\lambda_t - \theta j)^2}{2(h_t + j\delta^2)}\}$$

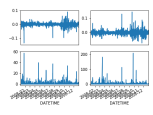
- Integrating out the number of jumps,

$$f(r_t|\Phi_{t-1}) = \sum_{j=0}^{\infty} f(r_t|n_t = j, \Phi_{t-1}) \, \mathrm{P}(n_t = j|\Phi_{t-1})$$

$$\mathrm{P}(n_t = j|\Phi_{t-1}) = \frac{\exp(-\lambda_t)\lambda_t^j}{j!}$$

- Ex post probability of j jumps,

$$\mathrm{P}(n_t = j|\Phi_t) = \frac{f(r_t|n_t = j, \Phi_{t-1}) \, \mathrm{P}(n_t = j|\Phi_{t-1})}{f(r_t|\Phi_{t-1})}$$



Maximum Likelihood Estimation

- Truncate maximum number of jumps at each time interval as 1,

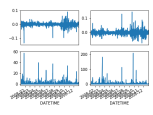
$$f(r_t|\Phi_{t-1}) = f(r_t|n_t = j, \Phi_{t-1})\,\mathrm{P}(n_t = 0|\Phi_{t-1}) + f(r_t|n_t = 1, \Phi_{t-1})\,\mathrm{P}(n_t = 0|\Phi_{t-1})$$

- Maximize likelihood function, estimate the parameters Γ

$$\Gamma = \arg\max_{\Gamma} \sum_t \log\{f(r_t(\Gamma)|\Phi_{t-1})\}$$

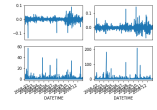
$$\Gamma = (\omega, \alpha, \alpha_j, \alpha_a, \alpha_{a,j}, \beta, \lambda_0, \rho, \eta_n, \eta_s, \theta, \delta)\,GJNJ$$

$$\Gamma = (\omega, \alpha, \alpha_j, \alpha_a, \alpha_{a,j}, \beta, \eta_n, \eta_s, \lambda_0, \rho, \gamma, \theta, \delta)\,GJNG$$



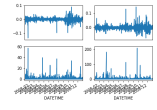
EGARCH Model with Normal Innovation (GN)

$$
\begin{aligned}
r_t &= \varepsilon_t \\
\varepsilon_t &= \sqrt{h_t} z_t, z_t \sim \mathsf{N}(0,1) \\
\log(h_t) &= \omega + \alpha(|z_{t-1}| - \mathsf{E}\,|z_{t-1}|) + \alpha_a z_{t-1} + \beta \log(h_{t-1})
\end{aligned}
$$



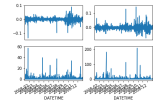
EGARCH-News Model with Normal Innovation (GNN)

$$
\begin{aligned}
r_t &= \varepsilon_t \\
\varepsilon_t &= \sqrt{h_t} z_t, z_t \sim \mathsf{N}(0,1) \\
\log(h_t) &= \omega + \alpha(|z_{t-1}| - \mathsf{E}\,|z_{t-1}|) + \alpha_a z_{t-1} \\
&\quad + \beta \log(h_{t-1}) + \eta_n N_t + \eta_s \log Sent_t
\end{aligned}
$$



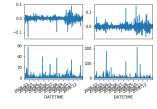
EGARCH Model with skew-t Innovation (GT)

$$
\begin{aligned}
r_t &= \varepsilon_t \\
\varepsilon_t &= \sqrt{h_t} z_t, z_t \sim \text{skewt}(\nu, \lambda) \\
\log(h_t) &= \omega + \alpha(|z_{t-1}| - \text{E}\,|z_{t-1}|) + \alpha_a z_{t-1} + \beta \log(h_{t-1})
\end{aligned}
$$



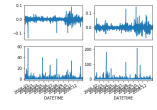
EGARCH-News Model with skew-t Innovation (GNT)

$$
\begin{aligned}
r_t &= \varepsilon_t \\
\varepsilon_t &= \sqrt{h_t} z_t, z_t \sim \text{skewt}(\nu, \lambda) \\
\log(h_t) &= \omega + \alpha(|z_{t-1}| - \text{E}\,|z_{t-1}|) + \alpha_a z_{t-1} \\
&\quad + \beta \log(h_{t-1}) + \eta_n N_t + \eta_s \log Sent_t
\end{aligned}
$$



EGARCH-Jump Model (GJ)

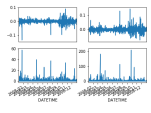
$$
\begin{aligned}
r_t &= \varepsilon_{1,t} + \varepsilon_{2,t} \\
\varepsilon_{1,t} &= \sqrt{h_t} z_t, z_t \sim \mathsf{N}(0,1) \\
\varepsilon_{2,t} &= J_t - \mathsf{E}[J_t|\Phi_{t-1}] = \sum_{k=1}^{n_t} Y_{t,k} - \theta\lambda_t, Y_{t,k} \sim \mathsf{N}(\theta, \delta^2) \\
\log(h_t) &= \omega + \alpha(|\varepsilon_{t-1}| - \mathsf{E}\,|\varepsilon_{t-1}|) + \alpha_a \varepsilon_{t-1} + \beta \log(h_{t-1}) \\
\lambda_t &= \lambda_0 + \rho\lambda_{t-1} + \gamma\xi_{t-1}
\end{aligned}
$$



Snippet of TRNA

Date/Time	Comp	Source	Item Type	Item Genre	Headline	Relv	Prev Sentmt	Pos	Neut	Neg	1st Ment Loc	Total Sent	# of Cos	# of wds/ tkns	Tot-wds/ tkns	Broker Action	Price/MKT commentary	Item Ct	Lkd Ct	Topic Codes	Other Comp
01/05/2009 10:42:00.699	C	RTRS	ARTICLE	INTERVIEW	INTERVIEW-Philippines seeks underwriters for bond issue	0.35	-1	0.39	0.16	0.46	9	12	5	117	319	UNDEFINED	UNDEFINED	0	0	PH EMRG ASIA GVD DBT FRX ISU HYD FIN BNK INVS US DFIN CH BANK FUND MEVN BSVC FINS CEEU EUROPE WEU LEN RTRS	LEHMQ. PK C.N CSGN.VX UBSN.VX JPM.N
01/05/2009 13:02:12.042	C	RTRS	ALERT	NOT DEFINED	Deutsche Bank DEUTSCHE BANK CUTS CITIGROUP <C.N> 2010 SHR VIEW BY $0.40 TO $0.75	1	-1	0.06	0.13	0.82	1	1	2	14	14	DOWN-GRADE	UNDEFINED	9	2	DBT MTG DRV CORPD USC LOA BACT RES RESF RCH BANK BSVC FINS US BNK FUND LEN RTRS DFIN FIN	BAC.N C.N
01/08/2009 21:12:49.798	C	RTRS	ARTICLE	US STOCKS SNAPSH	US STOCKS SNAPSHOT-S&P 500, Nasdaq up; Dow off on Wal-Mart	0.20	-1	0.08	0.13	0.79	2	13	7	97	215	UNDEFINED	COMMENTARY	51	2	US STX FIN NEWS SOFW DPR ENT SFWR HARW HDWR SWIT TECH COMP TEEQ LEN RTRS FUND BNK DEPT RET CYCS SHOP RETA DFIN FINS	.DJI .SPX .IXIC MSFT.O AAPL.O WMT.N C.N
01/09/2009 20:57:02.200	C	BSW	ARTICLE	NOT DEFINED	Robert E. Rubin Announces His Retirement from Citi <C.N>	0.23	-1	0.42	0.28	0.30	19	51	1	400	1576	UNDEFINED	UNDEFINED	61	6	BACT BNK DFIN FIN FINS MNGISS NEWR US LEN	C.N.

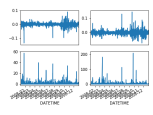
Source: Thomson Reuters Webpage



TRNA Database Coverage

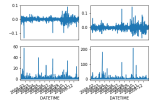
	Item	Coverage	Percentage
Equities	All companies	34,037	100%
	Active companies	32,719	96.1%
	Inactive companies	1,318	3.9%
Regions	Americas	14,785	43.4%
	APAC	11,055	32.5%
	EMEA	8,197	24.1%

Table 1: Coverage of equities and regions of TRNA

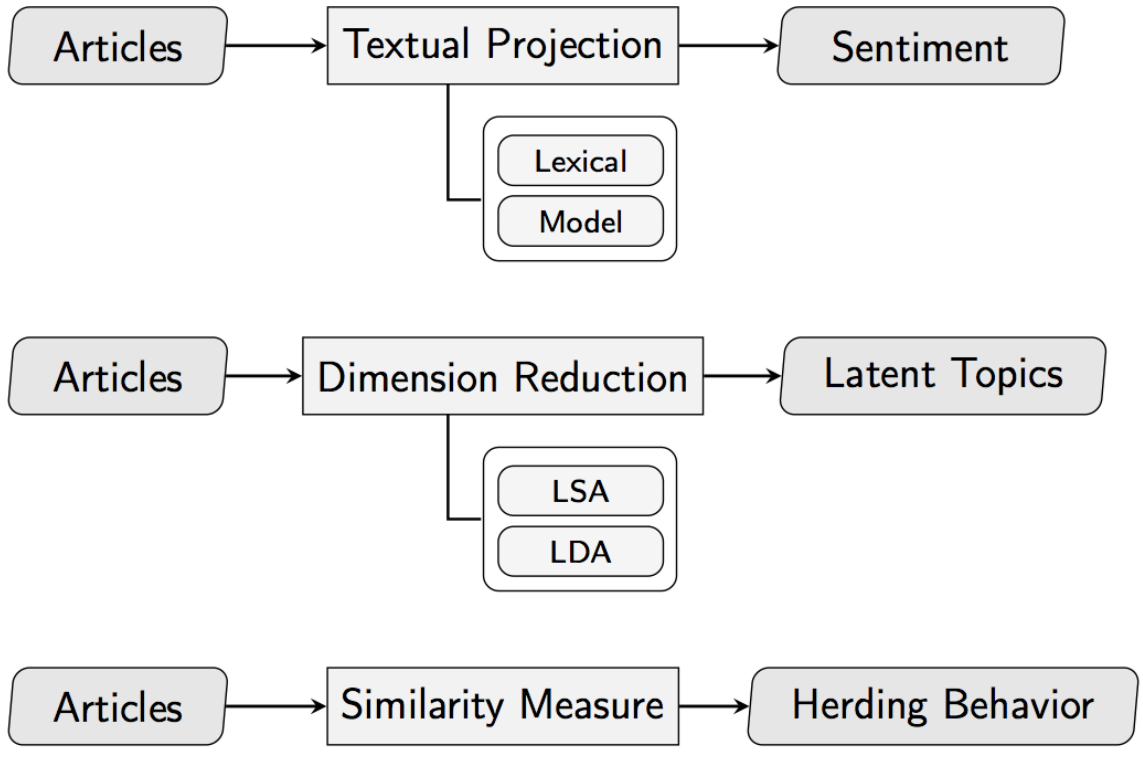


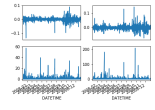
Important Variables in TRNA

- news source: publisher of the news
- headline
- relevance of news item to an asset
- number of sent wds/tkn
- sentiment classfication: POS, NEU, NEG
- novelty: comparison with news in the last 12 hours, 24 hours, 3 days, 5 days or 7 days
- LNKD_CNTs: counts of linked articles
- volume and the corresponding ITEM_CNTs



Textual Analytics





Unsupervised Projection

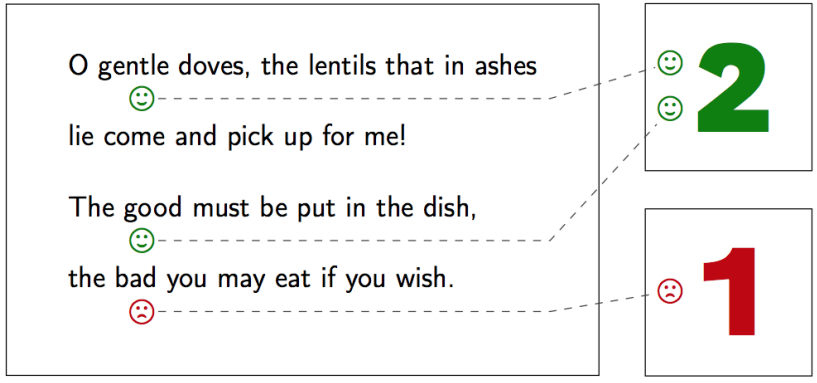
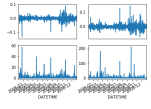


Figure 2: Example of Text Numerisization

- Many texts are numerisized via lexical projection
- Goal: Accurate values for positive and negative sentiment



LEXALYTICS

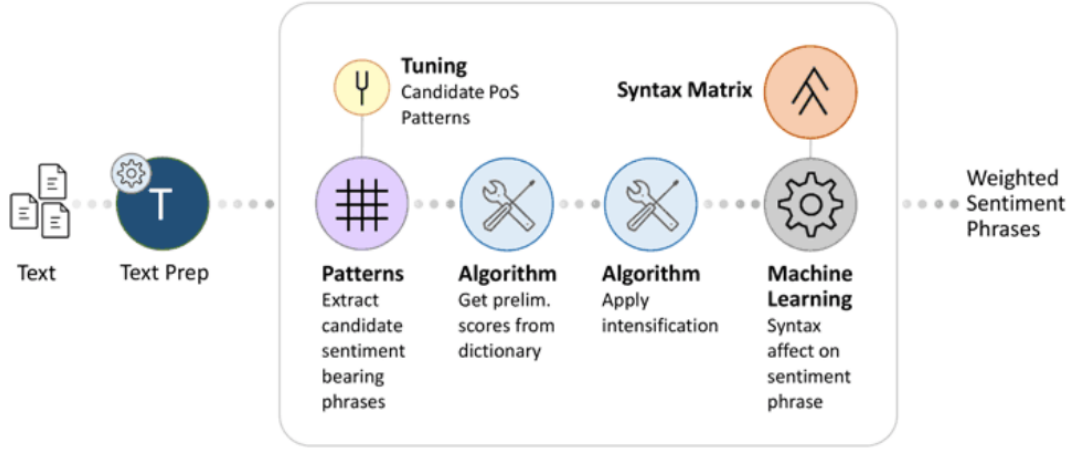
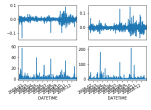


Figure 3: large dictionary of sentiment bearing phrases

(source: lexalytics sentiment analysis)



LEXALYTICS

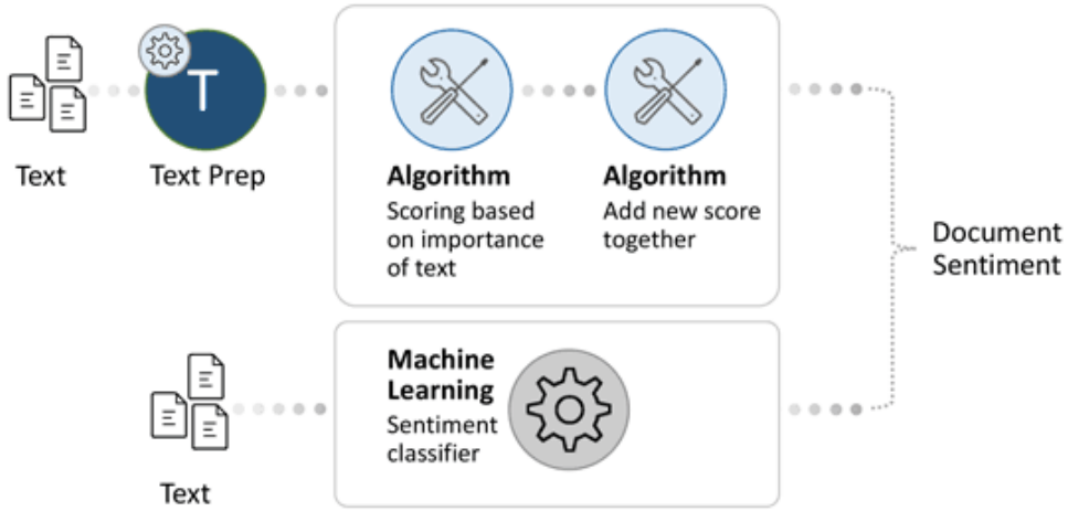
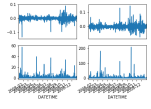


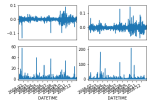
Figure 4: document or entity sentiment computation

(source: lexalytics sentiment analysis)



Data

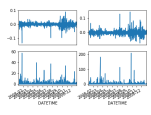
- stock price data: TAQ database (TZ: EST)
- news data: Thomson Reuters News Analytics (TRNA) (TZ: GMT)
- DJIA 30 constituents
- 2008.01.01 - 2008.12.31 (crisis time) & 2013.01.01 - 2013.12.31 (most recent data available)
- frequency:
  - stock price : tick-by-tick
  - news data: milliseconds



Stock Data Cleaning Procedures

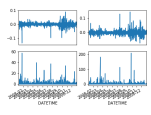
Barndorff-Nielsen, Hansen, Lunde and Shephard (2009, Econometrics Journal) and Brownlees and Gallo (2006, CSDA) and Daily TAQ Client Specification (2.2a)

1. Keep entries from 9:30 to 16:00 (trading hours)
2. Delete entries with transaction price equal to 0 (input errors)
3. Retain entries originating from a single exchange (each stock's listed exchange)
4. Delete entries with corrected trades (trade with a correction indicator, CORR $\neq 0$)
5. Delete entries with abnormal sale condition (trades where COND has a letter code, except for 'E' and 'F')



Stock Data Cleaning Procedures

6. Use last previous price to resample into 15-min frequency data, except for the the opening price and closing price and therefore the price at time point for example, 10:00 is the last tick price during [9:45:00, 9:59:59]
7. Aggregate the volume during each interval (e.g. SIZE at time 10:00 is the trading volume from 9:45:00 to 9:59:59)
8. To consider overnight effect or opening hour effect, retain data and add instrument variable for the first 15-minute iterval as comparison



Time Series of Returns

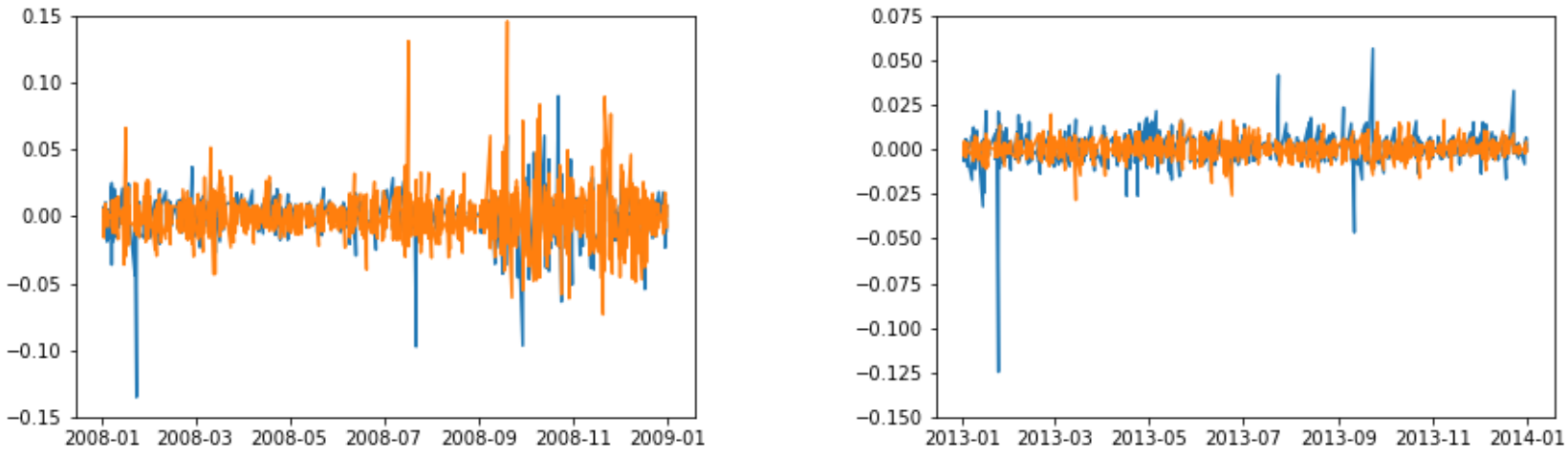
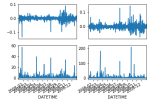


Figure 5: High frequency return for stock AAPL and JPM in 2008 (left panel) and 2013 (right panel)



News Flows of DJIA Stocks

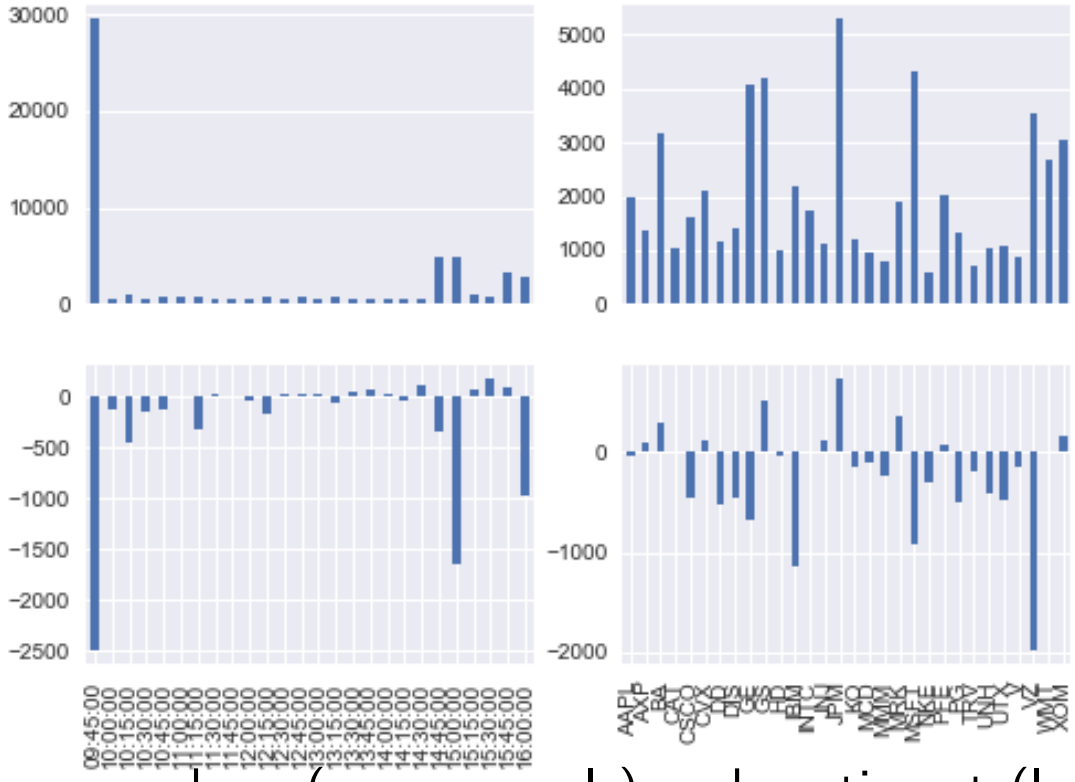
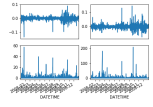


Figure 6: News numbers (upper panels) and sentiment (lower panels) by timestamp (left panels) and by stock (right panels) in 2008



News Flows of DJIA Stocks

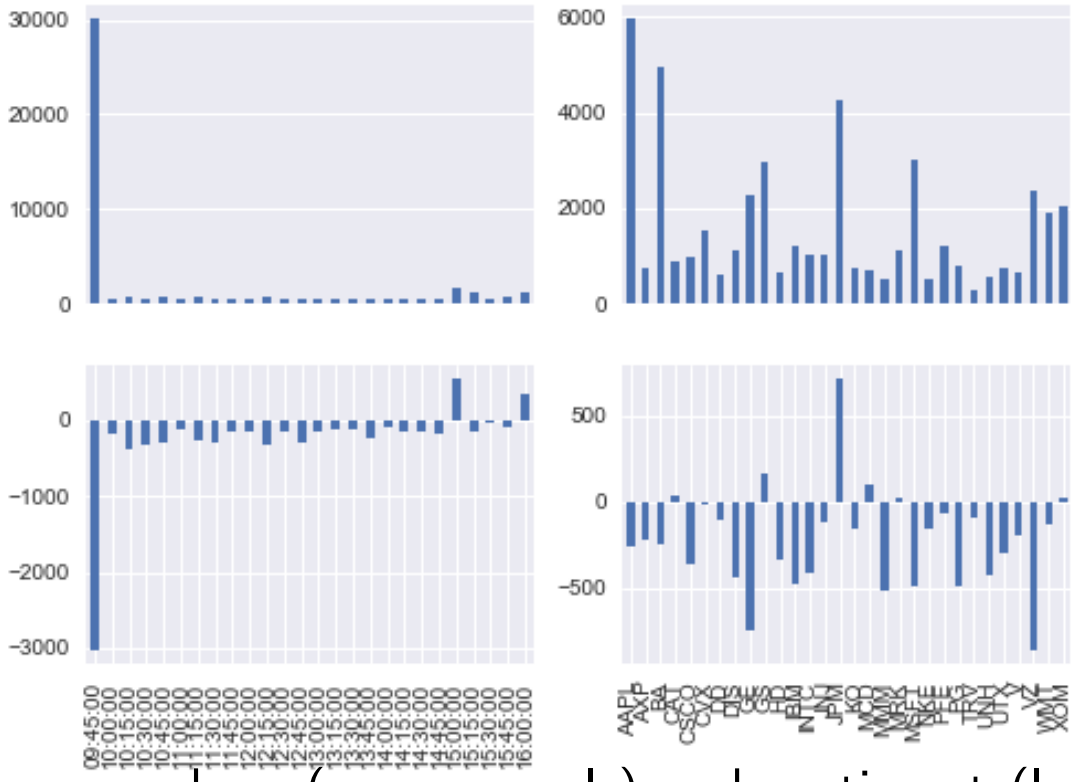
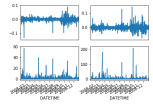


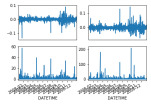
Figure 7: News numbers (upper panels) and sentiment (lower panels) by timestamp (left panels) and by stock (right panels) in 2013



Estimated Parameters for AAPL in 2008

para	*GJNJ*	*GJNG*	*GN*	*GNN*	*GT*	*GNT*	*GJ*
				2008			
ω	−10.7501	−7.7866	0.0078	−2.1791	−0.0570	−1.4418	−7.6536
α	0.2037	0.1964	0.0286	0.5481	0.0787	0.4449	0.2206
α_j	0.2373	0.2043					0.1712
α_a	−0.0391	0.0026	−0.0329	−0.0431	−0.0331	−0.0509	−0.1103
α_{aj}	−0.0598	0.0105					0.0398
β	0.0253	0.3021	0.9989	0.7920	0.9945	0.8642	0.3081
λ_0	0.6310	0.0949					0.1091
ρ	−0.0154	0.3099					0.2381
γ		0.0807					0.1952
η_n	0.2483	0.1968		0.2055		0.1187	
η_s	−0.0351	0.0859		0.0336		0.0102	
θ	−0.0001	−0.0009					0.0002
δ	0.0184	0.0120					0.0170
LL	24526	24819	24197	24774	25120	25178	24501

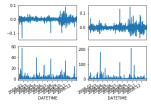
Table 2: Parameter estimations (all parameters are significant at 5% significance level)



Estimated Parameters for AAPL in 2013

para	*GJNJ*	*GJNG*	*GN*	*GNN*	*GT*	*GNT*	*GJ*
				2013			
ω	−12.4387	−8.8891	−4.0784	−5.6851	−3.0815	−4.3835	−8.7640
α	0.0562	0.0328	0.6133	0.3231	0.3536	0.3820	0.0281
α_j	0.0666	0.0802					0.0537
α_a	0.0129	0.0370	−0.2251	−0.0331	−0.0618	−0.0316	0.0007
α_{aj}	0.0007	−0.0082					0.0152
β	0.0285	0.3161	0.6320	0.5437	0.7478	0.6523	0.3014
λ_0	0.0709	0.1138					0.0920
ρ	−0.0442	0.3059					0.3030
γ		0.0967					0.2006
η_n	0.0465	0.1788		0.2036		0.1543	
η_s	−0.0315	0.0923		0.0347		0.0256	
θ	0.0005	0.0003					0.0002
δ	0.0092	0.0043					0.0096
LL	30312	30635	28309	30375	30453	30855	30165

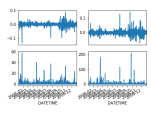
Table 3: Parameter estimations (parameters in red cell are not significant at 5% significance level)



Estimated Parameters for JPM in 2008

para	*GJNJ*	*GJNG*	*GN*	*GNN*	*GT*	*GNT*	*GJ*
				2008			
ω	−5.4291	−5.5060	−0.0151	−1.7891	0.0577	−1.1994	−5.2758
α	0.1764	0.2165	0.0814	0.4612	0.1141	0.4262	0.2137
α_j	0.1276	0.2107					0.1680
α_a	0.0164	0.0200	−0.0061	0.0176	−0.0160	0.0243	−0.0114
α_{aj}	0.0457	0.0139					0.0006
β	0.4881	0.4936	0.9976	0.8214	0.9939	0.8824	0.5073
λ_0	0.0605	0.0954					0.0539
ρ	0.5239	0.5114					0.4926
γ		0.1087					0.1515
η_n	0.0549	0.2038		0.0930		0.0479	
η_s	−0.0395	−0.0461		0.0286		−0.0071	
θ	0.0011	0.0009					0.0026
δ	0.0159	0.031					0.0205
LL	23015	23238	22835	23000	23533	23605	23129

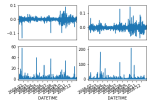
Table 4: Parameter estimations (all parameters are significant at 5% significance level)



Estimated Parameters for JPM in 2013

para	*GJNJ*	*GJNG*	*GN*	*GNN*	*GT*	*GNT*	*GJ*
				2013			
ω	−12.8466	−9.0220	−4.3583	−5.7129	−2.7187	−4.4859	−9.0078
α	0.0737	0.0755	0.3707	0.3802	0.3407	0.3920	0.0211
α_j	0.1126	0.0768					0.0823
α_a	−0.0499	−0.0099	−0.0237	−0.0534	−0.0128	−0.0349	0.0391
α_{aj}	0.0284	−0.0065					−0.0051
β	−0.0002	0.3142	0.6372	0.5505	0.7823	0.6499	0.3205
λ_0	0.2180	0.1064					0.1077
ρ	0.0102	0.2934					0.2928
γ		0.0953					0.1997
η_n	0.1476	0.1411		0.2424		0.1825	
η_s	−0.0372	0.1033		0.0009		0.0024	
θ	−0.0002	0.0000					−0.0001
δ	0.0039	0.0038					0.0052
LL	31155	31601	30505	31407	31522	31795	31372

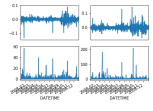
Table 5: Parameter estimations (parameters in red cell are not significant at 5% significance level)



GN v.s. GNN

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
AAPL	✓	✓	✓	✓	✓	✓
AXP	✓	✗	✓	✓	✗	✓
BA	✓	✓	✓	✓	✓	✓
CAT	✓		✓	✓	✗	✓
CSCO	✓	✗	✓	✓	✗	✓
CVX	✓	✗	✓	✓	✓	✓
DD	✓	✗	✓	✓	✗	✓
DIS	✓	✗	✓	✓	✗	✓
GE	✓		✓	✓	✗	✓
GS	✓	✓	✓	✓		✓
HD	✓	✓	✓	✓	✗	✓
IBM	✓	✗	✓	✓	✗	✓
INTC	✓	✗	✓	✓	✗	✓
JNJ	✓	✗	✓	✓	✗	✓
JPM	✓	✓	✓	✓		✓

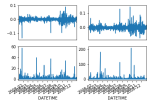
Table 6: Significance of news variables and likelihood ratio test of DJIA stocks, positive and negative are significant at 5%



GN v.s. GNN (Cont.)

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
KO	✓		✓	✓		✓
MCD	✓		✓	✓	✓	✓
MMM	✓		✓	✓		✓
MRK	✓	✓	✓	✓		✓
MSFT	✓		✓	✓	✓	✓
NKE	✓		✓	✓	✓	✓
PFE	✓		✓	✓	✓	✓
PG	✓		✓	✓		✓
TRV	✓		✓	✓	✓	✓
UNH	✓		✓	✓		✓
UTX	✓	✓	✓	✓		✓
V	✓		✓	✓		✓
VZ	✓	✓	✓	✓		✓
WMT	✓	✓	✓	✓	✓	✓
XOM	✓		✓	✓	✓	✓

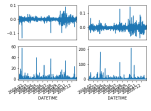
Table 7: Significance of news variables and likelihood ratio test of DJIA stocks - continued



GT v.s. GNT

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
AAPL			✓			✓
AXP			✓			✓
BA			✓			✓
CAT			✓			✓
CSCO			✓			✓
CVX			✓			✓
DD			✓			✓
DIS			✓			✓
GE			✓			✓
GS			✓			✓
HD			✓			✓
IBM						✓
INTC			✓			✓
JNJ			✓			✓
JPM			✓			✓

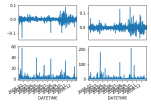
Table 8: Significance of news variables and likelihood ratio test of DJIA stocks



GT v.s. GNT (Cont.)

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
KO	✓		✓	✓		✓
MCD	✓	✓	✓	✓		✓
MMM	✓		✓	✓		✓
MRK	✓		✓	✓		✓
MSFT	✓		✓	✓	✓	✓
NKE	✓		✓			✓
PFE	✓		✓	✓	✓	✓
PG	✓		✓	✓		✓
TRV	✓		✓	✓		✓
UNH	✓		✓	✓		✓
UTX			✓	✓		✓
V	✓		✓	✓		✓
VZ	✓	✓	✓	✓		✓
WMT	✓	✓	✓	✓	✓	✓
XOM	✓		✓	✓	✓	✓

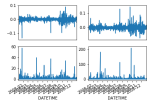
Table 9: Significance of news variables and likelihood ratio test of DJIA stocks - continued



GJ v.s. GJNJ

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
AAPL			✓			✓
AXP						✓
BA						✓
CAT						
CSCO						✓
CVX						✓
DD						✓
DIS						✓
GE						✓
GS			✓			✓
HD						✓
IBM						✓
INTC						✓
JNJ						✓
JPM						

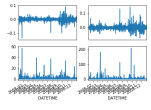
Table 10: Significance of news variables and likelihood ratio test of DJIA stocks



GJ v.s. GJNJ (Cont.)

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
KO						
MCD						
MMM						
MRK						✓
MSFT						
NKE						
PFE						
PG						✓
TRV						
UNH						
UTX						
V						✓
VZ						
WMT						✓
XOM						✓

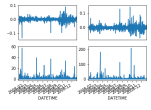
Table 11: Significance of news variables and likelihood ratio test of DJIA stocks - continued



GJ v.s. GJNG

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
AAPL			✓			✓
AXP			✓			
BA			✓			✓
CAT			✓			✓
CSCO			✓			✓
CVX			✓			✓
DD			✓			✓
DIS			✓			✓
GE			✓			✓
GS			✓			✓
HD			✓			✓
IBM			✓			✓
INTC			✓			✓
JNJ			✓			✓
JPM			✓			✓

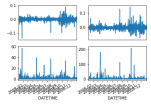
Table 12: Significance of news variables and likelihood ratio test of DJIA stocks



GJ v.s. GJNG (Cont.)

stock	2008 significant η_n	2008 significant η_s	2008 LR test	2013 significant η_n	2013 significant η_s	2013 LR test
KO			✓			✓
MCD			✓			
MMM			✓			✓
MRK			✓			✓
MSFT			✓			✓
NKE			✓			✓
PFE			✓			✓
PG			✓			✓
TRV						✓
UNH			✓			✓
UTX			✓			✓
V						✓
VZ			✓			✓
WMT			✓			✓
XOM			✓			✓

Table 13: Significance of news variables and likelihood ratio test of DJIA stocks - continued



Significance of Jump Parameters - GJ

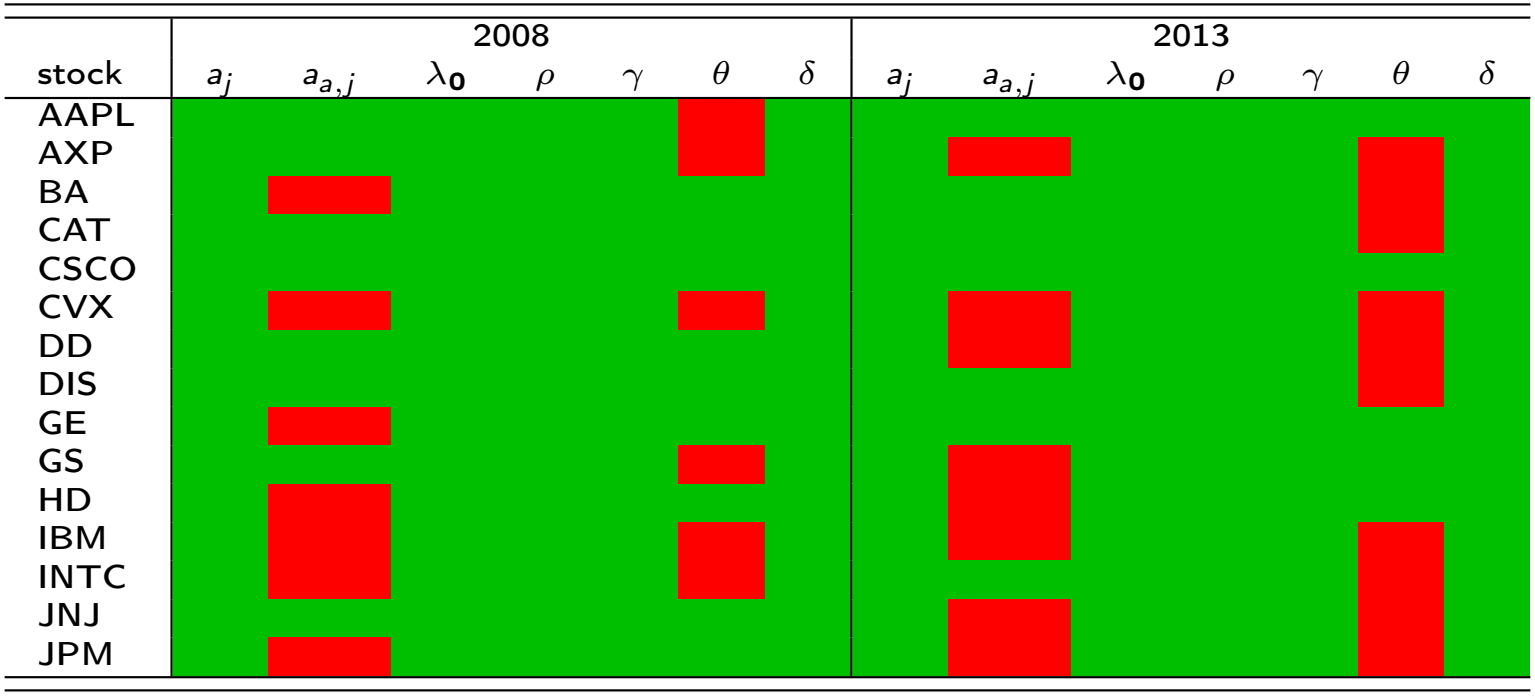
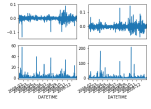


Table 14: Significance of jump parameters - GJ model



Significance of Jump Parameters - GJ (Cont.)

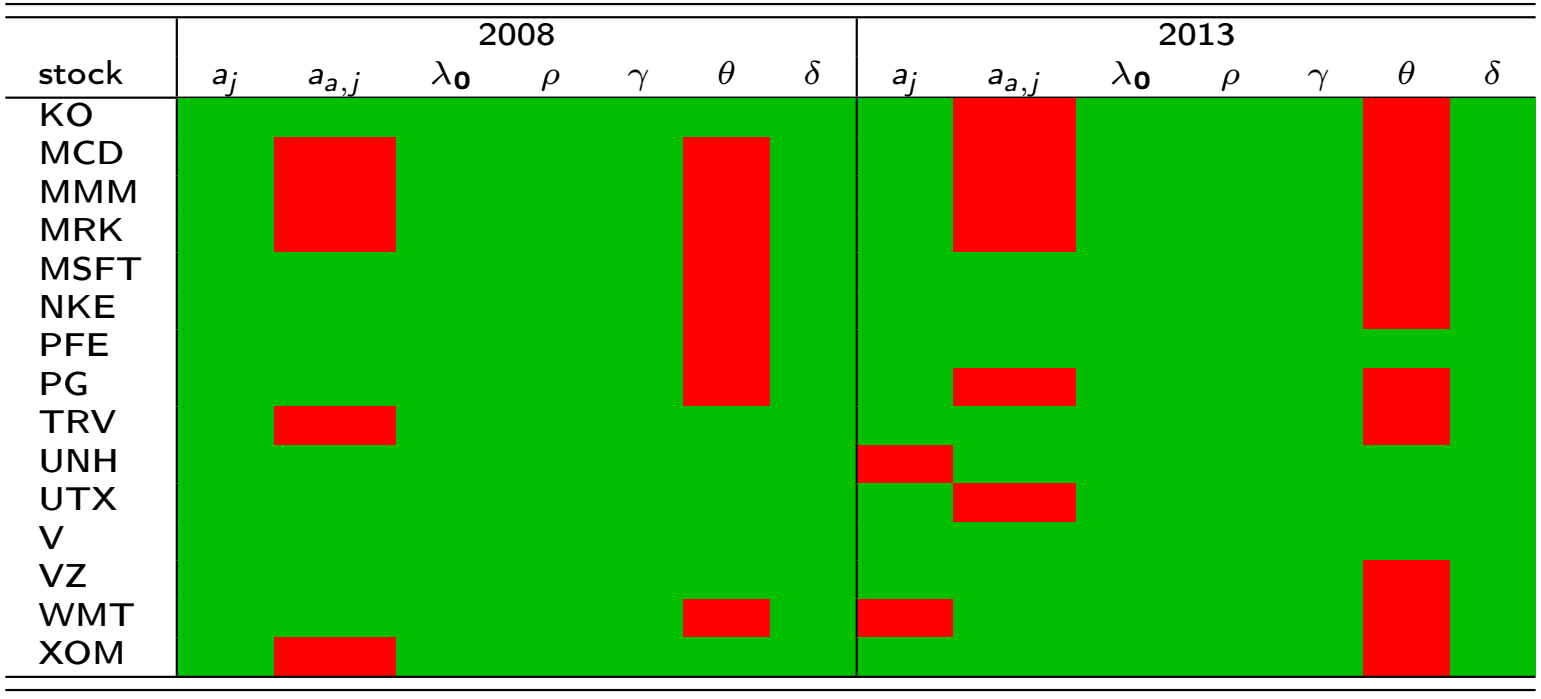
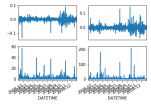


Table 15: Significance of jump parameters - GJ model - continued



Significance of Jump Parameters - GJNJ

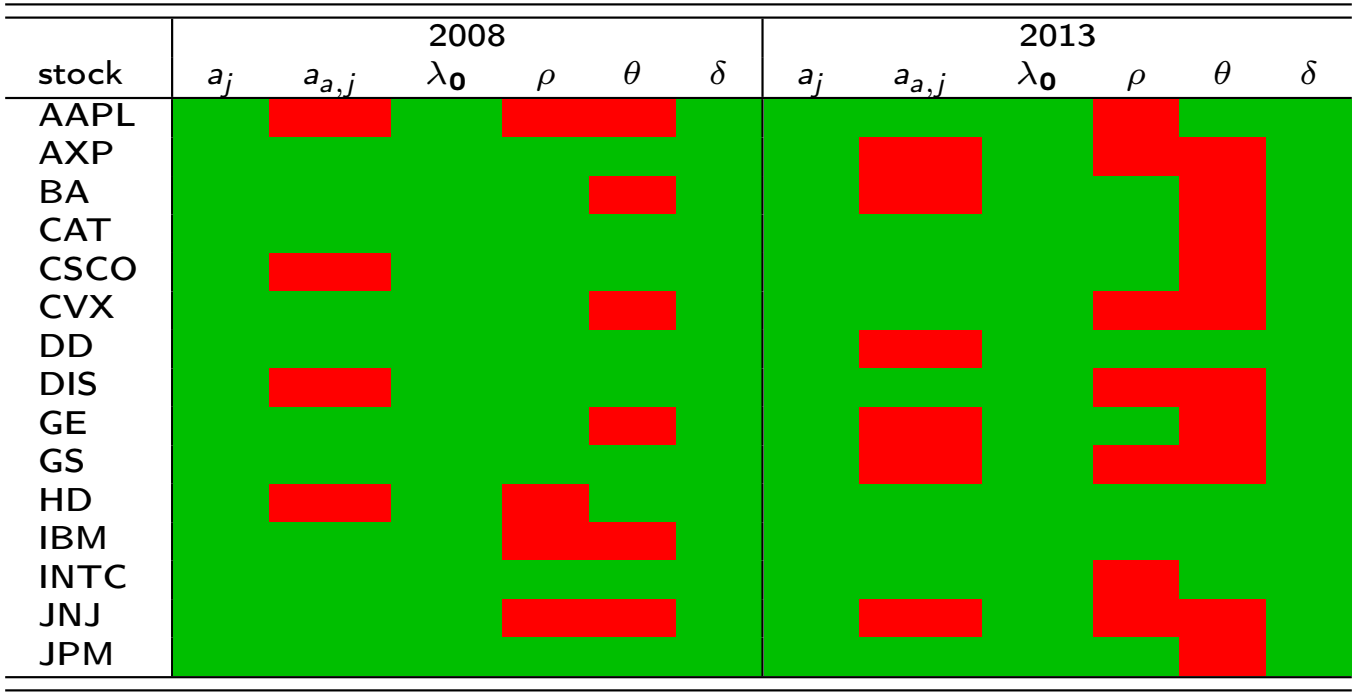
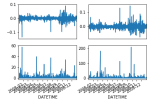


Table 16: Significance of jump parameters - GJNJ model



Significance of Jump Parameters - GJNJ (Cont.)

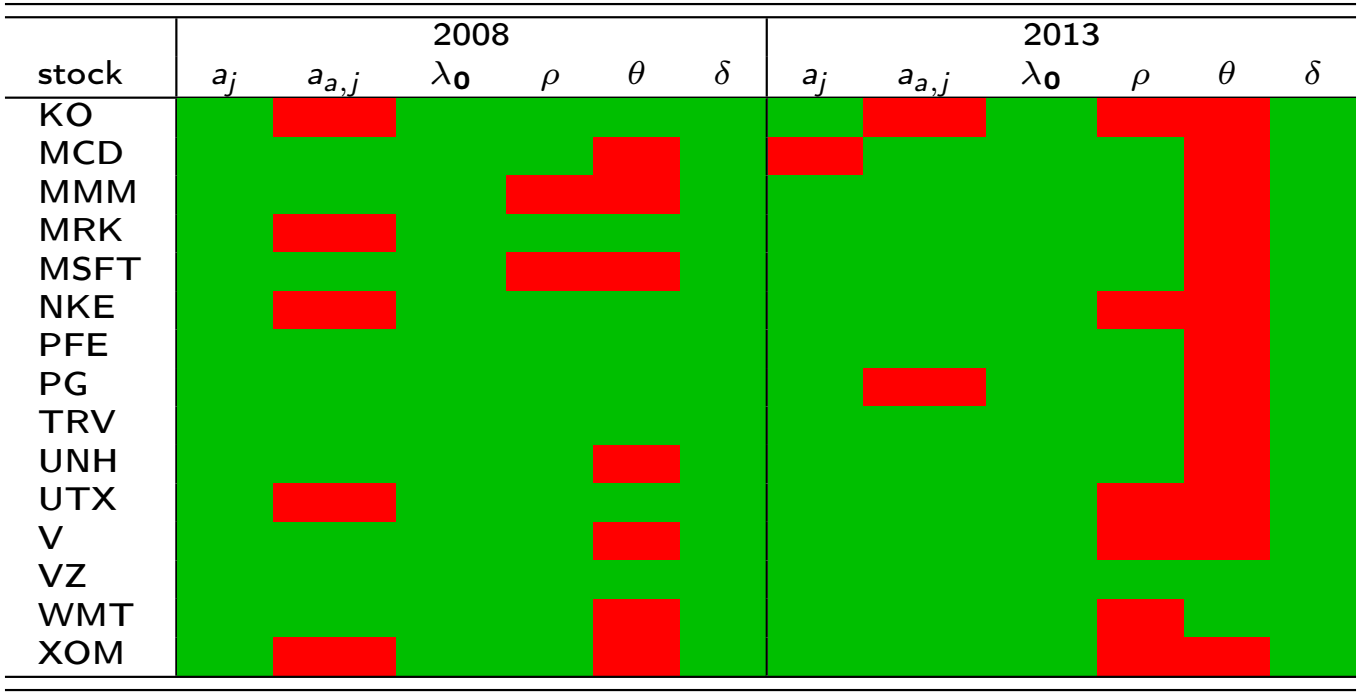
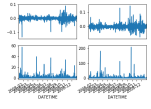


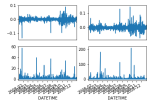
Table 17: Significance of jump parameters- GJNJ model -continued



Significance of Jump Parameters - GJNG

stock	2008 a_j	2008 $a_{a,j}$	2008 λ_0	2008 ρ	2008 γ	2008 θ	2008 δ	2013 a_j	2013 $a_{a,j}$	2013 λ_0	2013 ρ	2013 γ	2013 θ	2013 δ
AAPL														
AXP														
BA														
CAT														
CSCO														
CVX														
DD														
DIS														
GE														
GS														
HD														
IBM														
INTC														
JNJ														
JPM														

Table 18: Significance of jump parameters - GJNG model



Significance of Jump Parameters - GJNG (Cont.)

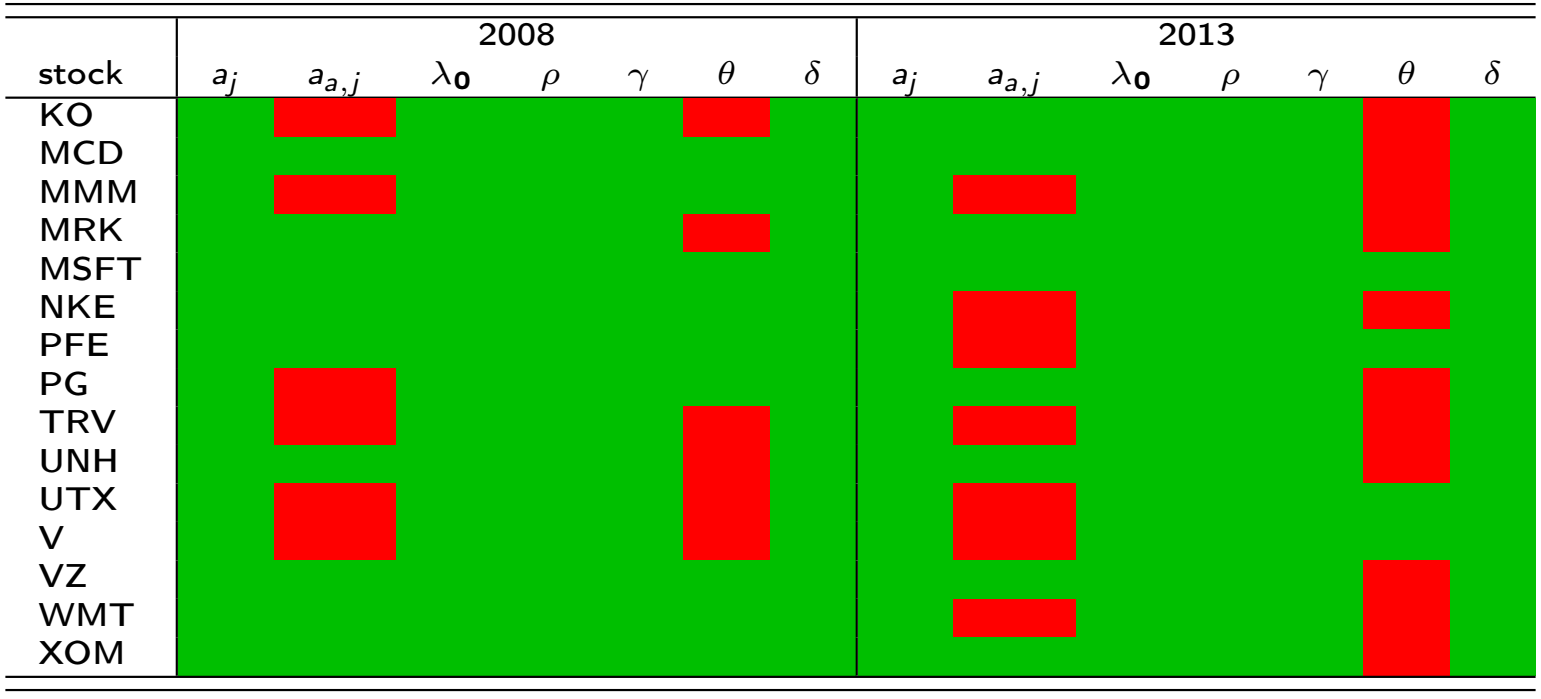
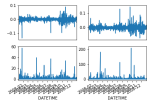


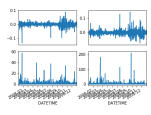
Table 19: Significance of jump parameters - GJNG model- continued



Maximum Likelihood of All 7 Models - 2008

model	GJNJ	GJNG	GN	GNN	GT	GNT	GJ
AAPL	24526	24819	24197	24774	25120	25178	24501
AXP	23304	23578	22965	23206	23870	23888	23459
BA	26302	26586	25803	26289	27014	27081	26451
CAT	25457	25699	25477	25549	26240	26248	25661
CSCO	25663	25861	25499	25765	26171	26196	25675
CVX	25960	26208	26306	26347	26829	26838	26132
DD	26139	26383	25960	26309	26828	26847	26211
DIS	26528	26729	26626	26731	27306	27326	26653
GE	25750	26209	25250	26153	26772	26813	25943
GS	23320	23717	23530	23716	24227	24244	23168
HD	24726	24923	24430	24483	25171	25184	24793
IBM	27137	27400	27257	27374	27907	27909	27189
INTC	25752	25969	25356	25779	26213	26259	25792
JNJ	29936	30359	30305	30575	31027	31093	30208
JPM	23015	23238	22835	23000	23533	23605	23129

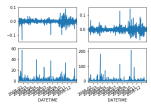
Table 20: Best model fitting for DJIA stocks in 2008



Maximum Likelihood of All 7 Models - 2008 (Cont.)

model	GJNJ	GJNG	GN	GNN	GT	GNT	GJ
KO	28722	28977	28254	28697	29439	29455	28849
MCD	27531	27769	27295	27673	28179	28220	27583
MMM	27636	27775	27693	27740	28274	28287	27726
MRK	26216	26644	24854	26206	26847	26974	26355
MSFT	26650	26958	26430	26897	27169	27316	26768
NKE	26030	26188	25585	25966	26564	26572	26088
PFE	27635	27887	27658	27799	28387	28439	27769
PG	29031	29329	29050	29197	29842	29860	29157
TRV	25174	25311	25193	25297	25858	25906	25392
UNH	24898	25200	24011	25752	25636	25751	25068
UTX	27029	27270	26844	26929	27758	27776	27194
V	25899	26029	25969	30274	31640	31684	26171
VZ	26244	26591	25899	26376	26730	26928	26373
WMT	27680	27921	27543	27747	28271	28330	27767
XOM	26333	26606	26637	26663	27185	27193	26439

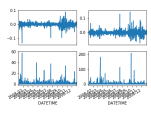
Table 21: Best model fitting for DJIA stocks in 2008 - continued



Maximum Likelihood of All 7 Models - 2013

model	GJNJ	GJNG	GN	GNN	GT	GNT	GJ
AAPL	30312	30635	28309	30375	30453	30853	30165
AXP	32419	32402	30959	31719	32464	32609	32417
BA	31837	31804	29805	31647	31871	32303	31782
CAT	32053	32264	30765	31663	32253	32428	32107
CSCO	31124	31403	28117	31040	31373	31633	31051
CVX	33229	33571	32655	33131	33540	33692	32879
DD	32471	32609	31531	31963	32633	32735	32462
DIS	32296	32330	31209	31928	32339	32487	32225
GE	32540	32821	31280	32522	32733	32975	32500
GS	30840	30854	29802	30777	30920	31201	30754
HD	32106	32143	31105	31648	32234	32347	32079
IBM	33252	33033	31523	33196	33423	33680	32985
INTC	31359	31567	30181	31266	31545	31743	31325
JNJ	33882	34026	33093	33690	34028	34200	33817
JPM	31155	31601	30505	31407	31522	31795	31372

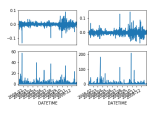
Table 22: Best model fitting for DJIA stocks in 2013



Maximum Likelihood of All 7 Models - 2013 (Cont.)

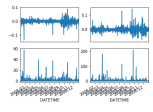
model	GJNJ	GJNG	GN	GNN	GT	GNT	GJ
KO	32910	33057	31906	32530	33126	33255	32995
MCD	34345	34411	32977	33738	34534	34698	34418
MMM	33800	34030	32671	33335	34039	34144	33830
MRK	32305	32490	31614	32395	32590	32809	32295
MSFT	31347	31644	29293	31522	31613	32005	31245
NKE	31771	31955	30039	31599	32051	32206	31810
PFE	32174	32352	31410	32197	32390	32604	32226
PG	33180	33380	31730	33051	33389	33574	33193
TRV	33495	33592	32147	32849	33601	33677	33426
UNH	31567	31762	30190	31322	31770	31933	31567
UTX	32824	32975	31919	32365	33048	33196	32969
V	31748	31770	30589	31420	31958	32099	31763
VZ	32356	32468	31057	32216	32486	32721	32237
WMT	33467	33859	32533	33532	33815	34026	33637
XOM	33643	33773	32671	33543	33665	33897	33539

Table 23: Best model fitting for DJIA stocks in 2013 - continued



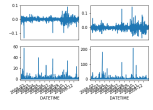
Conclusions

- News variables as to be explicitly included into modeling of financial returns
- Amount of relevant news to each large US stock positively related to return volatility
- News sentiment performing indefinite but significant effect on volatility modeling in most cases
- Taking jumps into consideration, news affecting stock behavior through GARCH channel (GJNG) performing better than the one through jump channel (GJNJ)



Conclusions (Cont.)

- Modeling jump process separately not as profitable as simpler GARCH with innovation distribution capable to capture fat tails, e.g. skew-t distribution
- GNT as the best candidate in describing 15-min high frequency stock behaviors of large US companies
- No significant difference between 2008 and 2013



Information Arrival, News Sentiment, Volatilities and Jump Risk of Intraday Stock Returns

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