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High Frequency Measures of Informed Trading and The Microstructure of Stock and Option Markets

The Regulation and Operation of Modern Financial Markets

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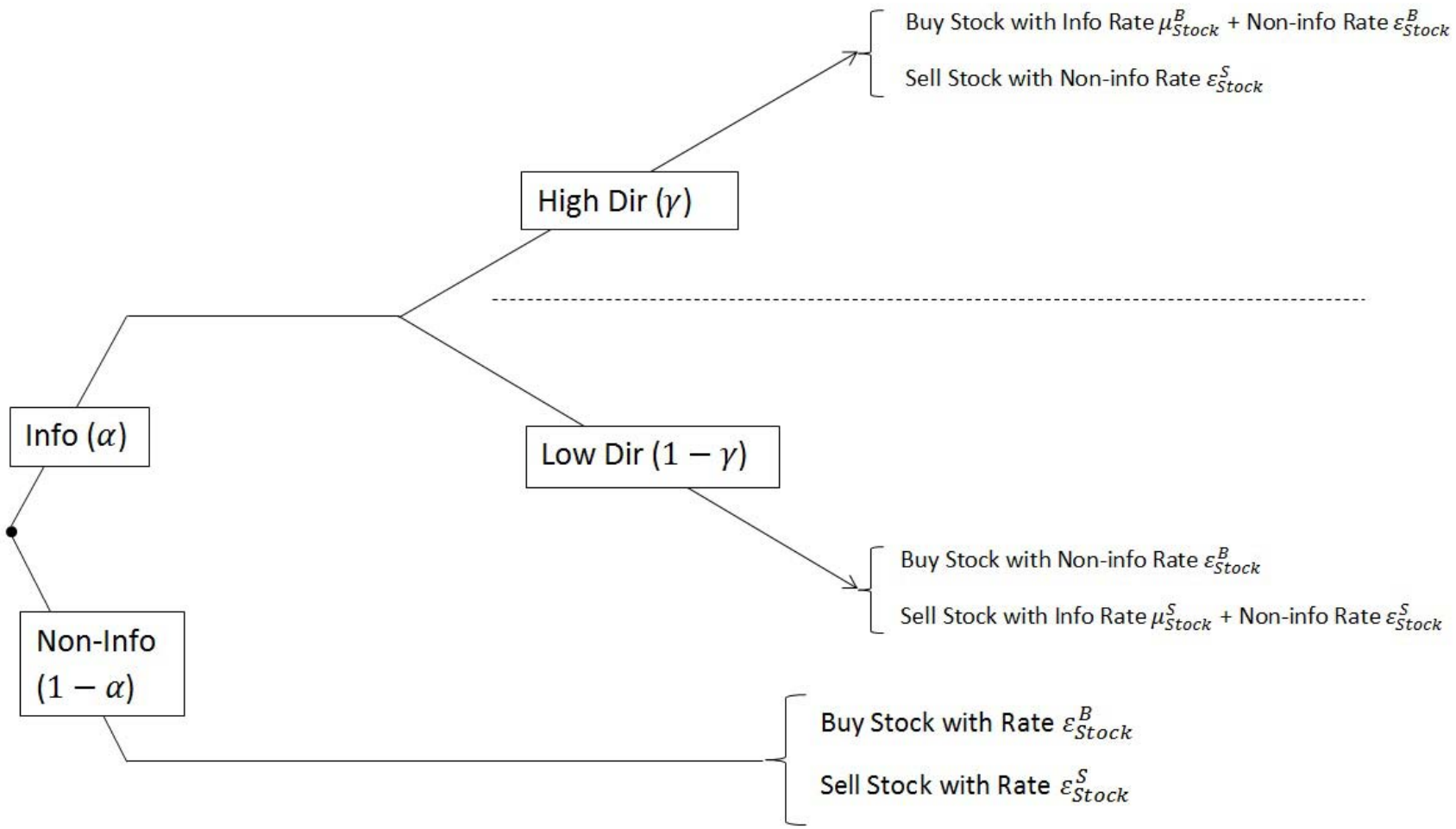
Motivation

- Traders play a crucial role in price discovery and efficiency of securities markets
  - Informed
  - Uninformed (Noise, Liquidity)
  - Stock Market- Extensive research
    - Price discovery and microstructure in the presence of informed and uninformed traders about the future *direction* of the stock
    - Impact of traders on market microstructure, price discovery, quality, and efficiency
    - Role of intermediaries and Market Structures
- Options Market
  - Some research on directional-informed trading
    - Strategies – splitting trading between stock and option markets
    - Hedging by option market makers
  - Relatively little research on the effects of volatility-informed traders on stock and option markets
  - High frequency measures of informed trading

Our Goal

- Trading Model for Stock and Options
- High Frequency Measures of Informed Directional and Volatility Trading
- Estimation Methodology
- Validation
- Application
  - Market Microstructure
    - Determinants of Stock and Option Bid-Ask Spread
  - Informed Trading Around Earnings Announcements

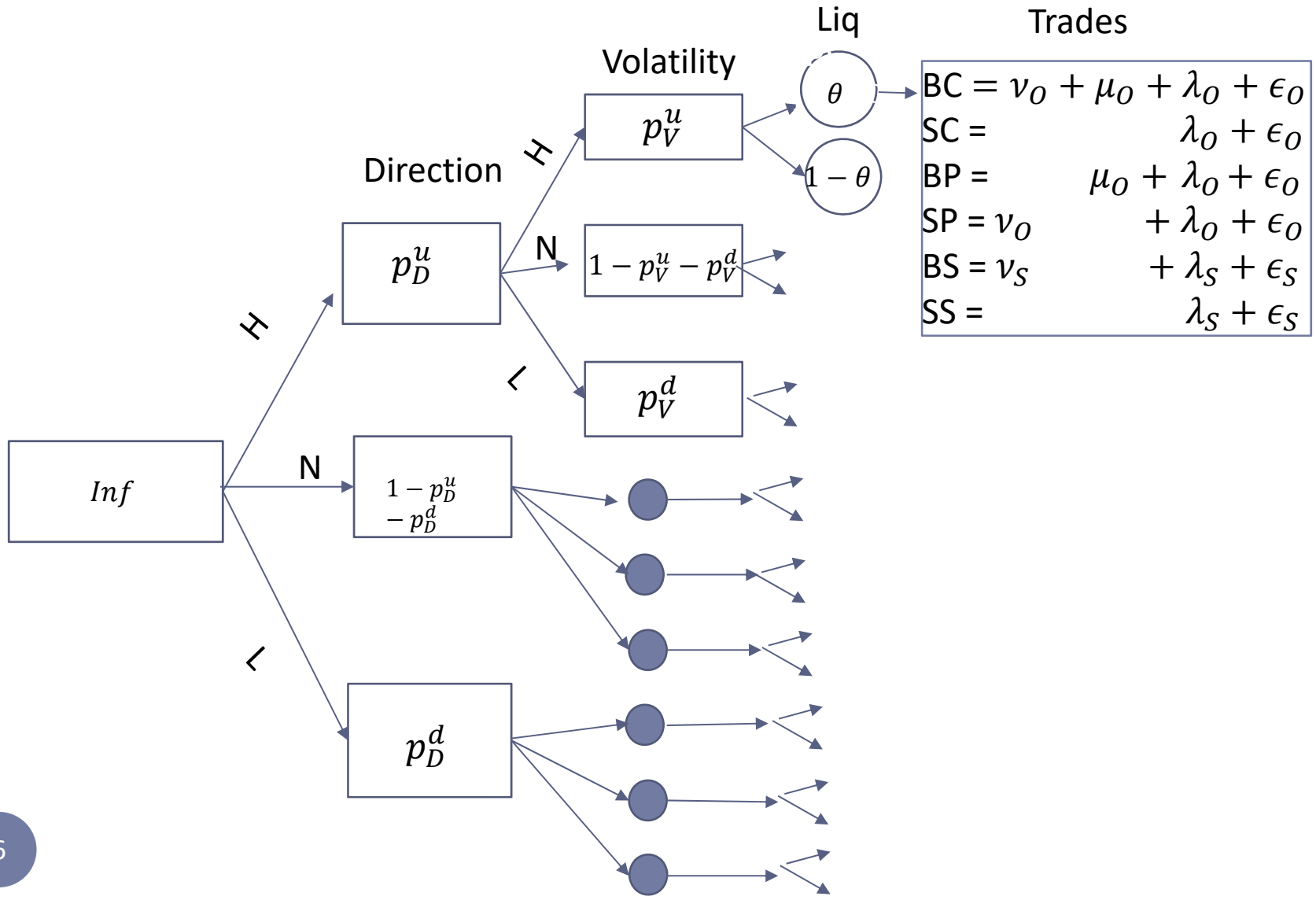
PIN Model (EKOP, 1996)



OSPIN Model- Trader Arrival Rates

1. All arrival rates are Poisson and independent
2. $Noise \sim \epsilon_S, \epsilon_O$
3. $Liquidity \sim \lambda_S, \lambda_O$
4. $Informed - Direction \sim \nu_S, \nu_O$
5. $Informed - Volatility \sim \mu_O$
6. $Prob = \{p_D^u, p_D^d, p_V^u, p_V^d, \theta\}$

OSPIN Model –Information States



Estimation

- Parameters:
  - $\Theta = \{\nu_O, \mu_O, \lambda_O, \epsilon_{O,} \nu_S, \lambda_S, \epsilon_{S,} p_D^u, p_D^d, p_V^u, p_V^d, \theta\}$
- Data:
  - Time interval $\Delta t \rightarrow \Omega = \{BC, SC, BP, SP, BS, SS\}$
- Maximize Log Likelihood to obtain $\widehat{\Theta}$
- Dir → H, Vol → H, High Liq

		Vol Up
Pr	Liq. Pr	p_V^u
p_D^u	θ	$\gamma_{BC} = \epsilon_o + \lambda_o + \nu_o + \mu_o$
		$\gamma_{SC} = \epsilon_o + \lambda_o$
		$\gamma_{BP} = \epsilon_o + \lambda_o + \nu_o + \mu_o$
		$\gamma_{SP} = \epsilon_o + \lambda_o$
		$\gamma_{BS} = \epsilon_s + \lambda_s + \mu_s$
		$\gamma_{SS} = \epsilon_s + \lambda_s$

$$l_{HHH} = \frac{1}{BC!\,SC!\,BP!\,SP!\,BS!\,SS!} p_D^u p_V^u [e^{-\gamma_{BC}} {\gamma_{BC}}^{BC}] [e^{-\gamma_{SC}} {\gamma_{SC}}^{SC}] [e^{-\gamma_{BP}} {\gamma_{BP}}^{BP}] [e^{-\gamma_{SP}} {\gamma_{SP}}^{SP}] [e^{-\gamma_{BS}} {\gamma_{BS}}^{BS}] [e^{-\gamma_{SS}} {\gamma_{SS}}^{SS}]$$

OSPIN Measures

- Informed trading, $i = \{D, V, L\}, m = \{O, S\}$

$$\Pr(\pi_i^m | \widehat{\Theta}) = \frac{E(\pi_i^m | \widehat{\Theta})}{E(\pi^m | \widehat{\Theta})}$$

Example: Pr of Volatility Informed Trading (H+L)

$$\pi_V^O = \frac{2(p_V^u + p_V^d)\mu_O}{2[2\epsilon_O + 2\theta\lambda_O + (p_V^u + p_V^d)\mu_O + (p_D^u + p_D^d)\nu_O}$$

High Frequency Measures of Informed Trading

- ML method requires a large number of observations
- Monthly (30-minute) data
  - OSPIN estimates are the average over a month.
- To study Informed trading around an event such as earnings announcements would require higher frequency (daily or higher)
- Use posterior likelihood conditional on OSPIN model parameter estimates.

$$\widehat{\Theta} = \{\nu_O, \mu_O, \lambda_O, \epsilon_{O,} \nu_S, \lambda_S, \epsilon_{S,} p_D^u, p_D^d, p_V^u, p_V^d, \theta\}$$

$$\Omega_{\delta t} = \{BC_{\delta t}, SC_{\delta t}, BP_{\delta t}, SP_{\delta t}, BS_{\delta t}, SS_{\delta t}\}$$

$$\varphi_{s,\delta t} = \frac{\{l_{s,\delta t}|\hat{\theta}, \Omega_{\delta t}\}}{\sum_{s=1}^{18}\{l_{s,\delta t}|\hat{\theta}, \Omega_{\delta t}\}}$$

Data

- OPRA - Options transactions data including signed trade direction - 2011
- OptionMetrics – Option Greeks, Implied Volatility, Realized Volatility, Option Volume
- TAQ – stock transactions data
- CRSP – Stock volume, market cap , shares outstanding
- Top 200 stock and options on them based on option volume in 2010
- Six groups by moneyness and maturity
- Use 30 minute interval for Δt
- Aggregate the total CB,CS,PB,PS for each group for the options on each stock and BS,SS
- Use 4-week period (260 observations) for estimation

MC Simulation

Table 1: MC Simulation: N(OBS)=250, FIRMS=200, Months =12

Sim/Est	Par	$Mean$	se_{mean}	$P25$	$Median$	$P75$
Sim	p_V^u	0.118	0.0005	0.098	0.117	0.139
Est	p_V^u	0.120	0.0005	0.104	0.119	0.135
Sim	p_V^d	0.088	0.0004	0.071	0.086	0.104
Est	p_V^d	0.104	0.0005	0.088	0.103	0.118
Sim	p_D^u	0.089	0.0004	0.075	0.087	0.105
Est	p_D^u	0.083	0.0004	0.069	0.082	0.096
Sim	p_D^d	0.092	0.0003	0.079	0.093	0.104
Est	p_D^d	0.094	0.0004	0.080	0.094	0.108
Sim	θ	0.202	0.0006	0.180	0.203	0.227
Est	θ	0.187	0.0012	0.164	0.180	0.199
Sim	ϵ_s	1000	6.3	738	1023	1273
Est	ϵ_s	992	2.5	993	1006	1018
Sim	λ_s	1467	5.9	1228	1452	1709
Est	λ_s	1499	1.6	1462	1504	1544
Sim	ν_s	1103	4.4	910	1088	1286
Est	ν_s	1115	2.0	1054	1116	1176
Sim	ϵ_c	25	0.06	23	25	28
Est	ϵ_c	25	0.02	25	25	25
Sim	ϵ_p	15	0.06	13	15	18
Est	ϵ_p	15	0.02	15	15	15
Sim	λ_o	62	0.44	43	60	80
Est	λ_o	59	0.09	57	59	61
Sim	ν_o	40	0.12	36	40	46
Est	ν_o	40	0.04	39	40	41
Sim	μ_o	30	0.06	28	30	32
Est	μ_o	30	0.03	30	30	31

MC Simulation - OSPIN

Table 2: MC Simulation- Simulated and Estimated PIN Measures

Sim/Est	PIN	$Mean$	se_{mean}	$P25$	$Median$	$P75$
Sim	π_S^D	0.075	0.0005	0.055	0.071	0.089
Est	π_S^D	0.073	0.0003	0.064	0.071	0.079
Sim	π_S^L	0.222	0.0014	0.170	0.218	0.266
Est	π_S^L	0.206	0.0016	0.181	0.196	0.213
Sim	π_O^D	0.094	0.0004	0.080	0.092	0.105
Est	π_O^D	0.094	0.0003	0.085	0.093	0.103
Sim	π_O^V	0.080	0.0003	0.066	0.078	0.092
Est	π_O^V	0.090	0.0003	0.081	0.090	0.099
Sim	π_O^L	0.308	0.0016	0.238	0.311	0.377
Est	π_O^L	0.285	0.0008	0.262	0.283	0.305

Trade Summary

Table 3: Stock and Option Trade Summary (All)

Panel A: Number of Trades

Variable	Mean	STD	p25	Median	p75
BS	1593	1911	569	1030	1893
SS	1604	1931	571	1034	1905
BC	41	165	4	11	32
BP	28	112	2	7	21
SC	37	148	4	11	30
SP	24	98	2	6	18

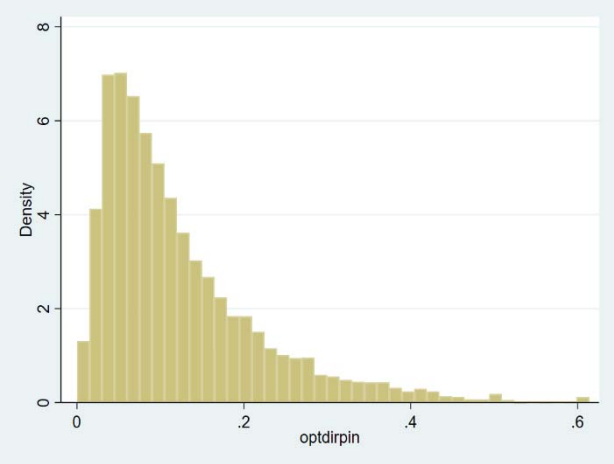
Correlations (ALL)

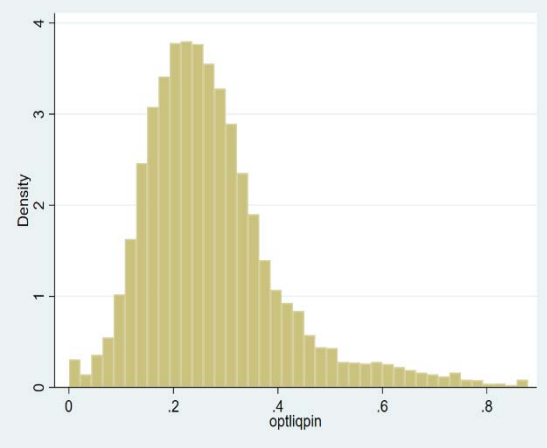
	BS	SS	BC	BP	SC	SP
BS	1.00					
SS	0.87	1.00				
BC	0.46	0.40	1.00			
BP	0.37	0.42	0.46	1.00		
SC	0.45	0.44	0.62	0.46	1.00	
SP	0.40	0.38	0.46	0.56	0.48	1.00

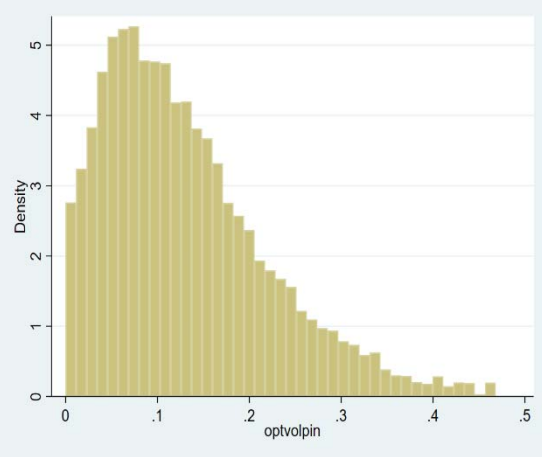
Covariances

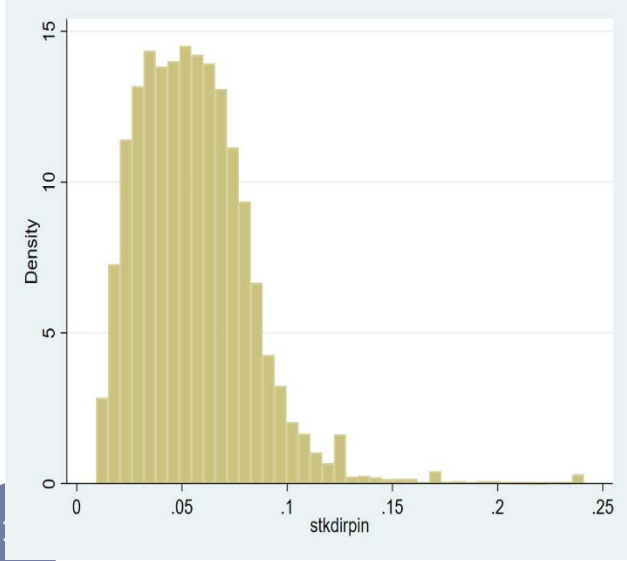
$$\sigma_{BC,SC} = \sigma_{BP,SP} = \lambda_O^2\theta(1-\theta) - \mu_O^2 p_V^d p_V^u - \nu_O^2 p_D^d p_D^u$$

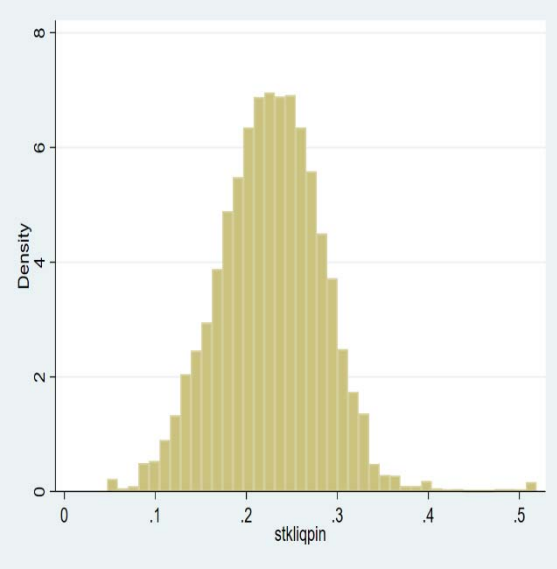
OSPIN – Distribution of Estimates











OSPIN by Moneyness and Maturity

Table 5: OSPIN Estimates by Moneyness and Maturity

	ALL		OTM		ATM		ITM		≤30 Days		>30 Days	
Par	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
p_V^u	0.18	0.20	0.08	0.08	0.06	0.07	0.06	0.07	0.25	0.22	0.18	0.16
p_V^d	0.07	0.10	0.05	0.06	0.03	0.04	0.04	0.05	0.11	0.12	0.12	0.13
p_D^u	0.06	0.05	0.07	0.05	0.05	0.04	0.09	0.07	0.07	0.05	0.07	0.05
p_D^d	0.07	0.05	0.08	0.06	0.06	0.05	0.09	0.07	0.08	0.06	0.08	0.06
θ	0.21	0.07	0.22	0.09	0.23	0.08	0.22	0.11	0.21	0.07	0.21	0.07
ϵ_S	1134	891	1075	863	1091	862	1006	887	1131	889	1132	887
λ_S	1748	1366	1696	1418	1698	1349	1510	1491	1755	1379	1759	1378
ν_S	1597	1536	2009	2580	2377	2751	1653	2427	1549	1523	1541	1483
ϵ_O	46.52	117.47	2.27	5.81	21.40	77.63	1.01	3.56	29.81	83.23	23.09	48.44
λ_O	61.75	139.17	7.57	15.44	34.26	95.59	3.64	10.04	44.70	105.05	29.22	64.84
ν_O	69.85	128.45	14.98	26.52	64.50	109.58	5.87	12.26	46.00	83.13	33.03	42.13
μ_O	61.45	105.63	18.62	32.49	71.36	130.01	8.41	16.76	38.59	70.74	30.37	37.96

OSPIN by MV and Moneyness

Table 6: OSPIN Model Probabilities by Market Value Quintile and Moneyness

Quintile	Desc.	OSPIN	ATM		ITM		OTM	
			Mean	Std	Mean	Std	Mean	Std
1(Small)	*StkDir*	π_S^D	0.062	0.027	0.072	0.046	0.072	0.033
	StkLiq	π_S^L	0.236	0.052	0.191	0.091	0.214	0.066
	OptDir	π_O^D	0.137	0.053	0.263	0.127	0.232	0.102
	OptVol	π_O^V	0.121	0.054	0.136	0.106	0.196	0.102
	OptLiq	π_O^L	0.303	0.074	0.460	0.190	0.351	0.153
2	*StkDir*	π_S^D	0.055	0.022	0.068	0.044	0.064	0.028
	StkLiq	π_S^L	0.234	0.054	0.203	0.092	0.215	0.067
	OptDir	π_O^D	0.118	0.049	0.243	0.136	0.222	0.097
	OptVol	π_O^V	0.113	0.053	0.132	0.108	0.195	0.097
	OptLiq	π_O^L	0.305	0.068	0.449	0.194	0.344	0.135
3	*StkDir*	π_S^D	0.048	0.022	0.066	0.035	0.060	0.028
	StkLiq	π_S^L	0.248	0.049	0.201	0.083	0.228	0.061
	OptDir	π_O^D	0.096	0.047	0.223	0.122	0.192	0.090
	OptVol	π_O^V	0.097	0.051	0.127	0.098	0.169	0.089
	OptLiq	π_O^L	0.295	0.058	0.420	0.180	0.311	0.124
4	*StkDir*	π_S^D	0.042	0.021	0.066	0.040	0.050	0.021
	Stkliq	π_S^L	0.250	0.050	0.209	0.081	0.232	0.059
	OptDir	π_O^D	0.077	0.042	0.203	0.116	0.162	0.085
	OptVol	π_O^V	0.089	0.049	0.129	0.092	0.158	0.077
	OptLiq	π_O^L	0.294	0.057	0.389	0.161	0.295	0.111
5 (Large)	*StkDir*	π_S^D	0.037	0.020	0.054	0.030	0.048	0.021
	StkLiq	π_S^L	0.264	0.048	0.228	0.073	0.247	0.057
	OptDir	π_O^D	0.051	0.029	0.158	0.100	0.114	0.067
	OptVol	π_O^V	0.056	0.035	0.117	0.084	0.128	0.073
	OptLiq	π_O^L	0.285	0.050	0.336	0.146	0.283	0.095

Stock Descriptive Statistics

Table 7: Stock Descriptive Summary

Variable	Units	Mean	STD	25p	50P	75p
Market Cap (MCAP)	$ Billion	45	55	13	26	169
Price (PRC)	$	66	74	31	47	72
Volume (VOL)	Millions/D	2.55	5.89	0.71	1.25	2.26
Number of Trades (TRD)	Millions/M	1.06	0.87	0.47	0.8	1.35
Intra day Volatility (STD)	%	0.181	0.073	0.127	0.168	0.221
Quoted Spread (QS)	%	0.041	0.031	0.025	0.032	0.046
Realized Spread (RS)	%	0.032	.055	0.014	0.023	0.038
Effective Spread (ES)	%	0.032	0.024	0.02	0.026	0.036
Price Impact(λ)	$\times 10^6$	19.77	314.92	0.64	1.16	2.01
Adverse Selection Spread (AS)	%	0.012	0.025	0.003	0.007	0.014

Option Microstructure- QS

Table 9: Options Spread by MV Quintile (%), N=2389

Panel A - Quoted Spread

	ATM		ITM		OTM	
	Mean	STD	Mean	STD	Mean	STD
MVQ 1(S)	6.98	3.40	3.80	1.80	12.52	4.81
MVQ 2	6.11	2.99	3.18	1.45	11.39	4.38
MVQ 3	4.90	2.15	2.58	1.21	9.83	3.29
MVQ 4	4.35	1.60	2.19	0.89	9.16	2.82
MVQ 5(L)	4.58	1.63	1.68	0.55	9.19	2.97

Determinants of Option Spread

Adverse Selection

- DirPIN
- VolPIN
- Stock PIN

Hedging Costs

- $Intital\ Hedeging: IC = k\Delta S:$
- $Rebalancing: RB = \frac{2\nu k}{\sqrt{2\pi(\delta t)}}$

$(k = relative\ stock\ spread, S = stock\ price, \Delta = option\ delta, \nu = option\ vega)$

Order Processing

- Trading volume

Informed Trading and Microstructure

$$
\begin{aligned}
Opt\_Spread &= \beta_0 + \beta_1(StkPIN) + \beta_2(StkLIQ) + \beta_3(OptDirPIN) + \beta_4(OptVolPIN) \\
&\quad + \beta_5(OptLiq) + \beta_6(StkSprd) + \beta_7(DELTA_{option}) + \beta_8(VEGA_{Option}) + \Gamma(Controls) + \epsilon \\
Stk\_Spread &= \beta_0 + \beta_1(StkPIN) + \beta_2(StkLIQ) + \beta_3(OptDirPIN) + \beta_4(OptVolPIN) \\
&\quad + \beta_5(OptLiq) + \beta_6(OptSprd) + \Gamma(Controls) + \epsilon
\end{aligned}
$$

Price Impact on Stock – Amihud (Intra-day)

VARIABLES	All	OTM	ATM	ITM	MAT < 30	MAT >30
StkDir	9.72e-08***	3.60e-08*	7.69e-08**	5.48e-09	1.10e-07***	1.17e-07**
	(2.746)	(1.923)	(2.342)	(1.014)	(3.018)	(2.215)
StkLiq	3.73e-08**	2.25e-09	2.90e-08***	-6.12e-09	2.86e-08**	3.86e-08**
	(2.575)	(0.366)	(2.746)	(-1.435)	(2.513)	(2.321)
OptDir	-2.27e-08	3.94e-10	-8.96e-10	3.19e-09	-2.97e-08***	-1.69e-08
	(-1.615)	(0.0870)	(-0.123)	(0.962)	(-2.663)	(-1.484)
OptLIq	-2.62e-10	4.34e-10	6.17e-09	2.55e-09	2.88e-10	-3.04e-09
	(-0.0789)	(0.127)	(1.208)	(1.180)	(0.125)	(-0.740)
OptVol	4.24e-10	1.48e-08**	3.06e-09	2.76e-09	4.39e-09	-3.83e-09
	(0.0580)	(2.010)	(0.324)	(0.420)	(1.015)	(-0.844)
Stk-TO	-2.95e-08***	-2.89e-08***	-2.98e-08***	-2.88e-08***	-2.99e-08***	-2.91e-08***
	(-6.612)	(-6.949)	(-6.577)	(-6.678)	(-6.647)	(-6.662)
Volatility	3.04e-05	3.46e-05	3.19e-05	2.86e-05	3.33e-05	3.33e-05
	(0.903)	(1.060)	(0.943)	(0.825)	(0.991)	(0.975)
Constant	4.11e-08***	4.66e-08***	4.05e-08***	5.17e-08***	4.22e-08***	3.94e-08***
	(9.649)	(10.62)	(9.192)	(13.38)	(9.865)	(7.756)
Observations	2,400	2,400	2,400	2,399	2,400	2,400
R-squared	0.944	0.944	0.944	0.943	0.944	0.944
Stock FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
Stock Clustered SE	YES	YES	YES	YES	YES	YES

Stock Proportional Spread

VARIABLES	All	OTM	ATM	ITM	MAT < 30	MAT > 30
StkDir	0.000904*	0.000330	0.000501	0.000182	0.00105*	0.000924
	(1.916)	(1.584)	(1.494)	(1.616)	(1.787)	(1.634)
StkLiq	-0.000114	-9.81e-05	-0.000118	-2.24e-05	-0.000117	-0.000114
	(-1.053)	(-1.054)	(-1.181)	(-0.707)	(-1.639)	(-1.057)
OptDir	-5.19e-05	0.000102**	0.000165**	1.89e-05	-8.94e-05	-3.86e-05
	(-0.577)	(2.266)	(2.269)	(1.563)	(-1.032)	(-0.397)
OptLiq	-1.42e-05	-1.54e-07	6.04e-05	-5.57e-06	1.10e-05	-1.68e-05
	(-0.557)	(-0.00551)	(0.912)	(-0.356)	(0.454)	(-0.579)
OptVol	2.68e-05	-4.56e-05**	6.64e-05	3.43e-05	2.95e-05	2.35e-05
	(0.306)	(-2.085)	(0.796)	(1.204)	(0.745)	(0.371)
Stk TO	-4.69e-05	-4.54e-05	-4.62e-05	-5.19e-05*	-4.95e-05	-4.35e-05
	(-1.450)	(-1.448)	(-1.436)	(-1.821)	(-1.645)	(-1.344)
Stk-Voltility	1.359*	1.333*	1.266*	1.286*	1.382*	1.336*
	(1.928)	(1.848)	(1.751)	(1.757)	(1.971)	(1.887)
Constant	0.000288***	0.000302***	0.000282***	0.000309***	0.000276***	0.000281***
	(4.296)	(4.480)	(3.885)	(4.969)	(4.400)	(4.604)
Observations	2,400	2,400	2,400	2,399	2,400	2,400
R-squared	0.948	0.948	0.948	0.947	0.949	0.948
Stock &n Month FE	YES	YES	YES	YES	YES	YES
Stock Clustered SE	YES	YES	YES	YES	YES	YES

Option Quoted Spread (%)

	OPTION QUOTED SPREAD			
VARIABLES	OTM	ATM	ITM	ALL
StkDir	0.000703	0.0109	-0.00441	0.0114
	(0.00769)	(0.00771)	(0.00473)	(0.00962
StkLiq	-0.00154	0.00214	-0.000254	0.00804*
	(0.00311)	(0.00377)	(0.00128)	(0.00338
OptDir	0.000931	0.0154***	-0.000617	0.00683
	(0.00218)	(0.00339)	(0.00176)	(0.00538
OptLiq	6.03e-05	0.00999***	0.00184***	0.00293
	(0.00177)	(0.00271)	(0.000531)	(0.00255
OptVol	0.01000***	0.00446	0.000626	0.00184
	(0.00134)	(0.00324)	(0.00120)	(0.00322
Stk-Sprd(%)	10.11***	12.55***	-1.052	7.248***
	(2.043)	(1.162)	(1.013)	(0.920)
LN(Opt_Volume)	-0.00148**	-0.00288***	-0.00132***	-0.00248**
	(0.000657)	(0.000456)	(0.000316)	(0.000397
LN(Stk_Volume)	0.00224	0.00339***	0.000621	0.00277**
	(0.00128)	(0.000488)	(0.000546)	(0.000423
IV	-0.0311***	-0.0389***	-0.0226***	-0.0269**
	(0.00750)	(0.00356)	(0.00499)	(0.00280
Delta	-0.0867**	-0.131***	-0.103***	-0.253***
	(0.0287)	(0.0277)	(0.0152)	(0.0303)
Vega	-0.000510**	-0.000429***	-0.000135	-0.000359*
	(0.000175)	(0.000101)	(0.000128)	(0.000103
Observations	2,388	2,394	2,318	2,369
R-squared	0.858	0.935	0.880	0.930

*** p<0.01, ** p<0.05, * p<0.1

Stock&Month FE & Clustered SE & PIN measures > 0

High Frequency Posterior Likelihood of Informed Trading Around Earnings Announcements

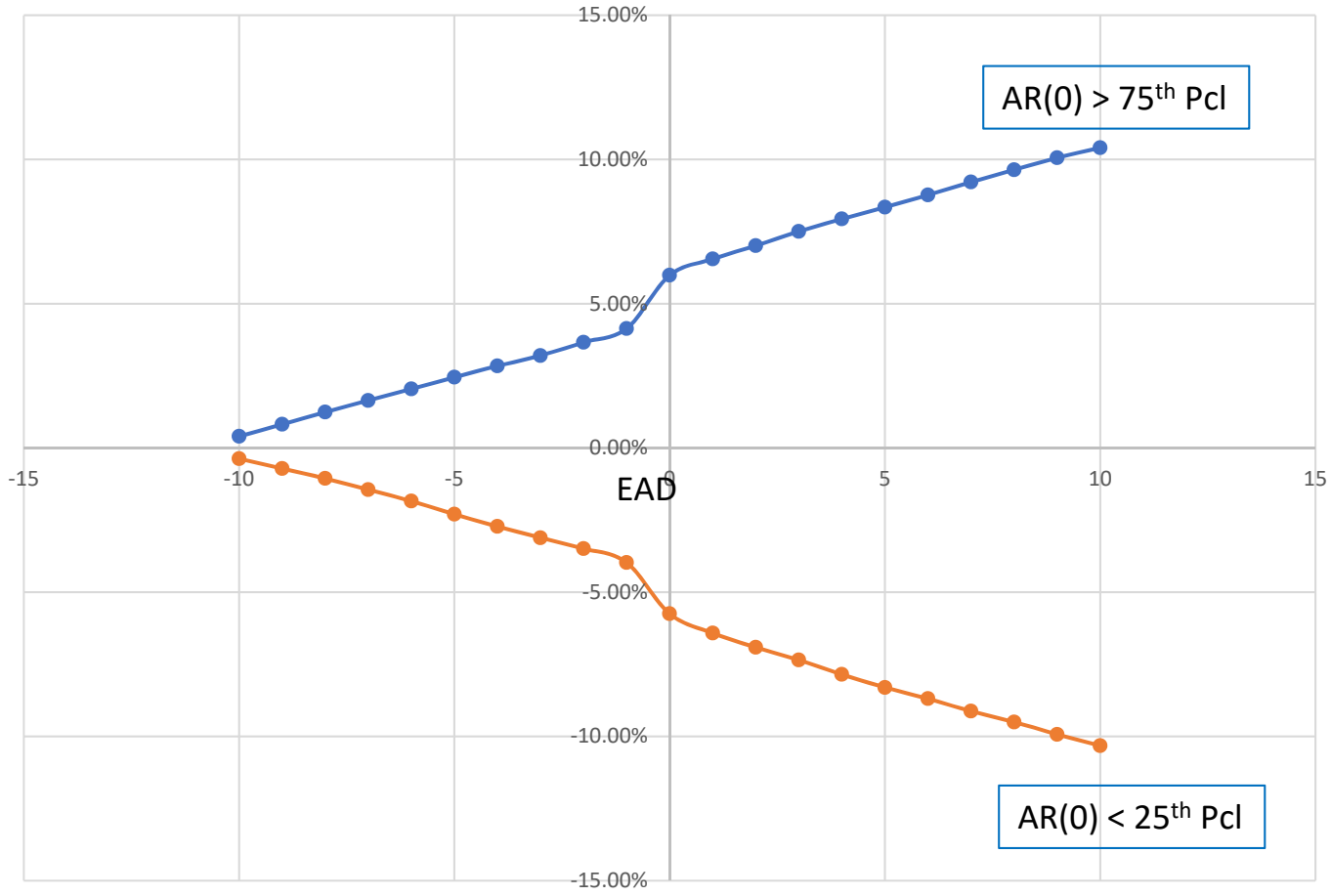
- Estimate the OSPIN model parameters using two-weeks of data before and two weeks of data after the announcement
- Calculate the posterior likelihood for each information metric on a daily basis based on the daily number of trades for the options and the stock by moneyness groups.
- Earnings announcement day, t=0

$$APL_t = PL_t - PL_{t+10}$$

$$CAL_{-10} = APL_{-10}$$

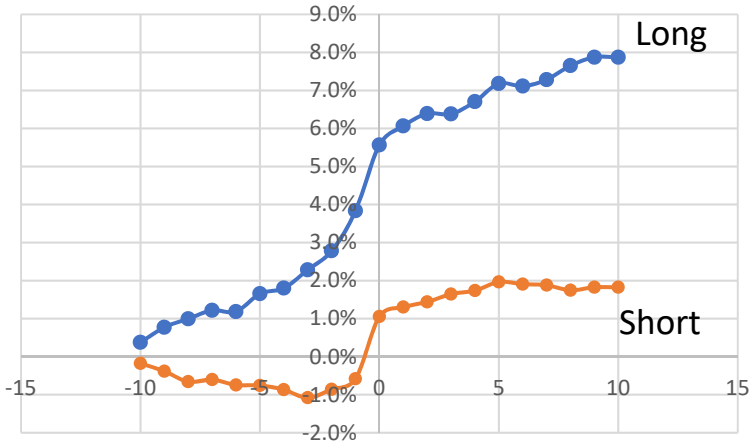
$$CAL_t = CAL_{t-1} + APL_t, \{t \in (-9\ to + 10)\}$$

CAR Around Earnings Announcements

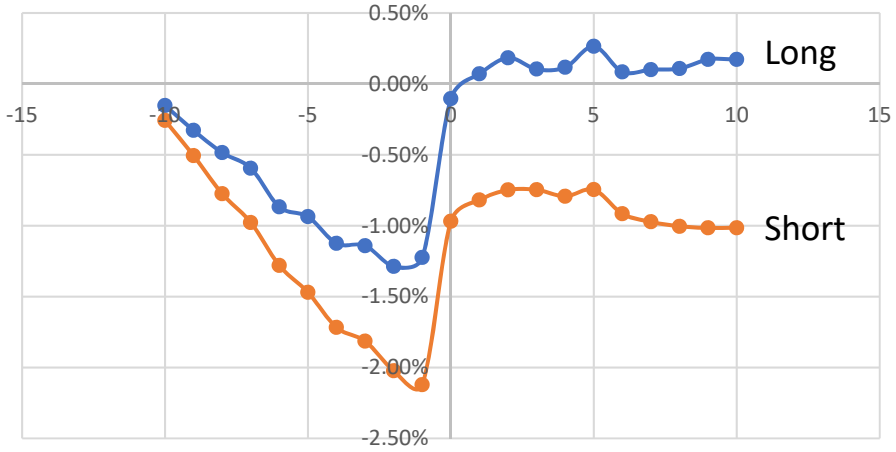


CAL-Direction Traders Around Earnings Announcements |AR(0) > 75th Pcl

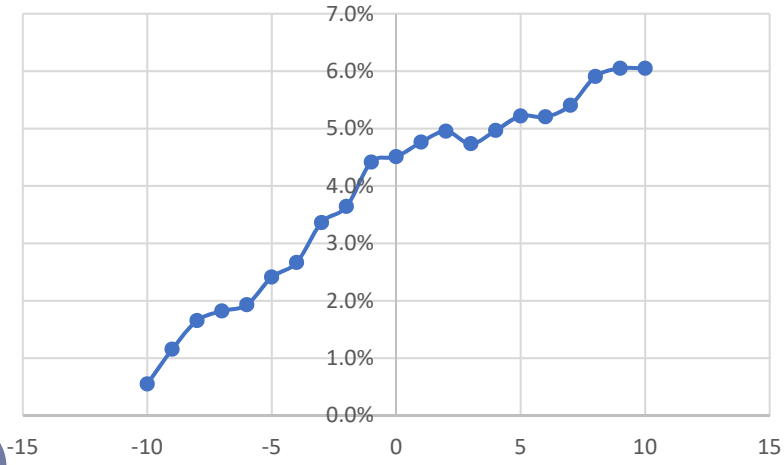
Cumulative Abnormal Likelihood - OPTDIR



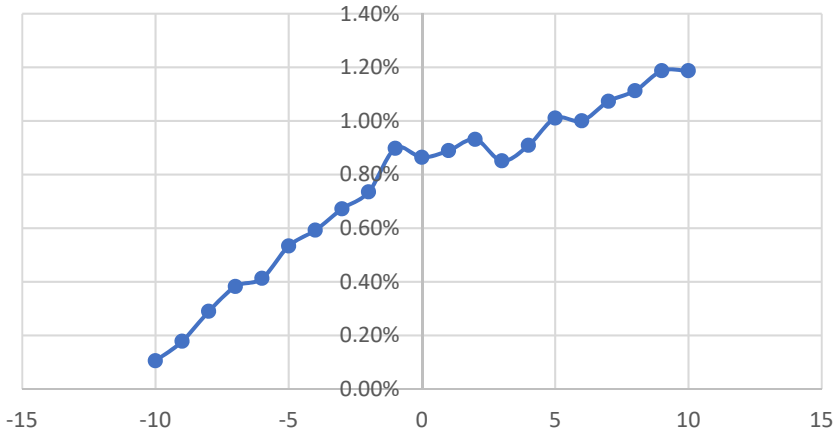
Cumulative Abnormal Likelihood - STKDIR



Net Long Option

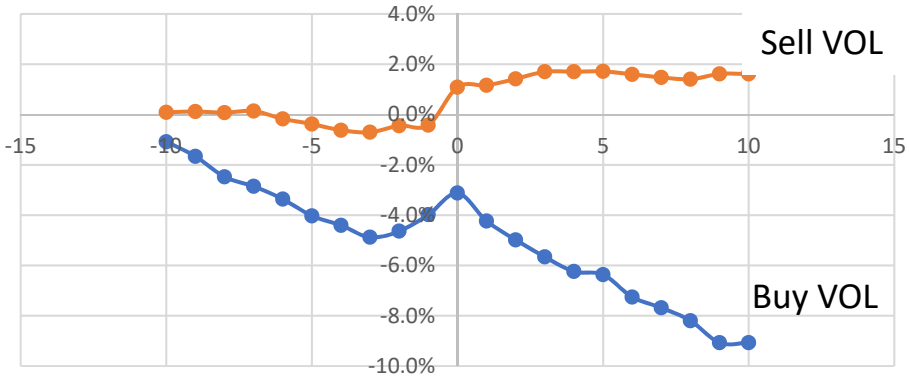


Net Long Stock

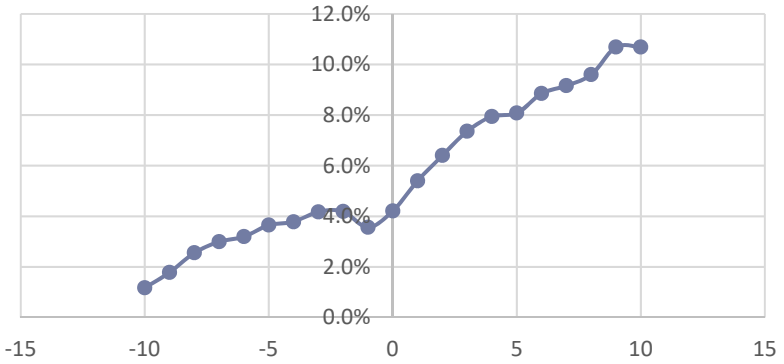


CAL- Volatility Traders Around Earnings Announcements

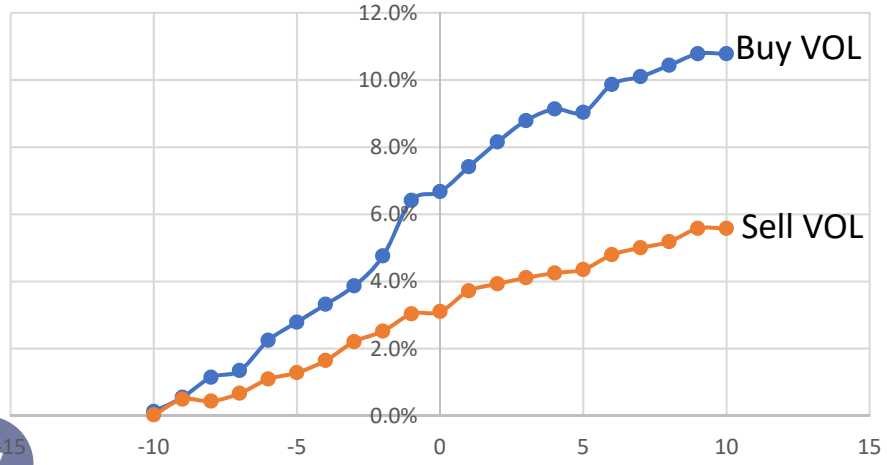
AR(0) > 75th Pcl (large Positive)



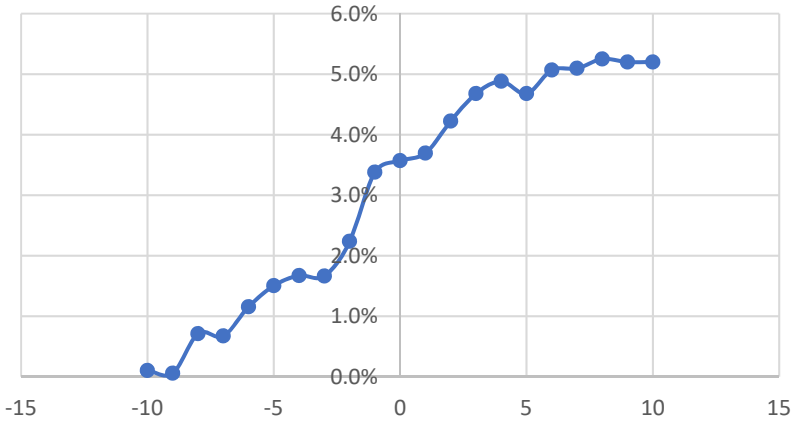
Net Short



AR(0) < 25th Pcl (large Negative)



Net Long VOL



Conclusions

- Trading model that incorporates both stock and options markets
  - Estimation
  - Probability of informed direction and volatility trading
- Estimates of high frequency likelihood of informed trading on both markets
  - Likelihood of informed trading is significantly higher a several days prior to announcement in the options markets for ATM options
- Future research
  - Relation between our metrics and other metrics that are used:
    - PUT/CALL ratios
    - OTM/Total volume