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Measuring the impact of option market activity on the stock market: Bivariate point process models of stock and option transactions ☆

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Abstract

I apply the bivariate Autoregressive Conditional Duration model of Engle and Lunde [2003. Trade and quotes: a bivariate point process. Journal of Financial Econometrics 1, 159–188] to stock and option market transactions. The first model uses option trades and stock trades. Shocks to option trade/option trade durations have a significant impact on option trade/stock trade durations. Higher implied volatility, larger stock and option market order imbalances, larger stock trades, larger spreads, smaller depths in the stock market and faster trading in the stock and option markets are all associated with faster trading in both markets. In the second model, option trade/option trade timing leads option trade/stock quote timing and several information-related stock and option market covariates impact the expected inter-market event durations.

JEL classification: G14; C32; C41

Keywords: Autoregressive conditional duration; Informed trading

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1. Introduction

Black (1975) claimed ‘‘Options trading is where the action is in the securities markets these days.’’ It still is today. Options provide leverage to informed traders and speculators seeking to benefit from variations in the underlying price, and allow equity market specialists to hedge their inventory exposure, portfolio managers to insure against negative events, and speculators to bet on swings in volatility. Uninformed liquidity traders might obtain a lower cost position in the options market. Perhaps the most important advantage of listed options is that they allow informed traders to hide their intentions (Anand and Chakravarty, 2007).

Can option market makers detect informed trading quickly enough to protect their inventory? If so, what variables should they monitor: trade size, signed volume, trade frequency or all of these? Early detection of suspect trading activity could permit the option market maker to widen his spread quickly and/or adjust his midquote, thereby discouraging informed traders. Equity market participants face similar challenges. Should the equity market maker monitor the same variables as the option market maker? Or are option market variables redundant? In the perfect derivative hedge model of Cho and Engle (1999) the costs of trading with better informed traders are naturally equilibrated as liquidity (and traders) flow between markets. This pooling equilibrium, with informed traders and liquidity providers utilizing both markets, adds another level of complexity, especially when market makers can hedge only imperfectly.

Recent research has begun to answer some of these questions. Easley et al., 1998 demonstrate that informed traders sometimes choose to trade in the option market first. Chakravarty et al., 2004 show that the information shares for options averaged around 20 percent in the late 1980s and early 1990s.[1] Since the information share is measured at the end of the trading day, the method could determine when it might have been useful to monitor the option market. But it is probably less helpful on an intraday basis. Anand and Chakravarty (2007) employ a similar technique to show that stealthy traders prefer to maintain their advantage by trading at-the-money calls and matching their order size with contract liquidity: medium sized trades for liquid contracts and small trades for less liquid contracts. Participants in both markets might benefit from monitoring activity in these contracts.

This paper applies the bivariate autoregressive conditional duration (ACD) model of Engle and Lunde (2003) to transaction level data from the stock and option markets. With option trades as the censoring process, the model measures the impact of option trade timing on stock market transactions. The model includes transaction variables such as volume, quoted spread and option contract details and assesses their impact on expected duration, providing a more complete understanding of the relations between the trade process variables and trade timing. In contrast to the vector autoregression models of Easley et al., 1998 and the price discovery work of Chakravarty et al., 2004, the ACD model permits inference regarding the impact of specific intraday trade characteristics on the relations between stock and option market activity.

The first bivariate ACD model employs option trades and stock trades. For the forty firms considered in this study, there is considerable evidence that option trade/option trade

[1]Easley, O’Hara and Srinivas (1998) and Chakravarty, Gulen and Mayhew (2004) provide several additional references on earlier empirical studies of information flow between option and stock markets.

timing leads option trade/stock trade timing (intra-market trade timing leads inter-market trade timing). However, this lead is not significantly correlated with average option trade information shares. Several information-related covariates exert a significant impact on trade timing. Higher implied volatility, larger stock and option market order imbalances, larger stock trades, larger spreads, smaller depths in the stock market and faster trading in the stock and option markets are all associated with shorter option trade/option trade durations and shorter option trade/stock trade durations. The second bivariate ACD model uses option trades and stock quote revisions. In this model, option trade/option trade timing leads option trade/stock quote timing and this lead is modestly correlated with option trade information shares. Several information-related stock and option market covariates impact the expected inter-market event durations.

A brief overview of the econometric model, estimation and specification testing is presented in Section 2. Data and variable construction are described in Section 3. Section 4 discusses the results of two applications of the bivariate ACD model and Section 5 concludes the paper. The Appendix contains a glossary of covariates.

2. Bivariate autoregressive duration models

2.1. Economic motivation

In market microstructure theory, equity market participants include informed traders, liquidity traders and market makers. Informed traders aim to maintain their advantage by spreading their trades over time (Kyle, 1985) or trading when liquidity is highest (Admati and Pfleiderer, 1988). Market makers and other liquidity traders discern the presence of informed traders by monitoring order flow characteristics such as price, volume and trade frequency. This view of liquidity and informed trader dynamics has considerable empirical support. Hasbrouck (1991) shows that signed stock volume contains information about future returns, Engle and Russell (1998) show that inter-trade duration is inversely related to information flow and stock price volatility and Dufour and Engle (2000) find that shorter trade durations are associated with faster quote adjustment to stock trades.

Option market microstructure models also recognize the interplay between informed and liquidity traders. Back (1993) extends Kyle's (1985) asymmetric information model to include a call option. Biais and Hillion (1994) derive a model where option spreads are a function of informed trading and John et al., 2000 show that option spreads are positively related to informed trading and leverage. Easley et al., 1998 frame the informed trader's dilemma in terms of a tradeoff between leverage and liquidity in the two markets. One general conclusion is that the addition of an option market extends the range of strategies available to the informed trader, thereby adding an additional level of complexity to the market makers' tasks. All of the models acknowledge the potential impact of informed trading on market making costs in both markets, suggesting that information-related variables could be useful indicators in the option market as well.

But traders use listed options for a variety of reasons unrelated to private information. Short straddles and strangles profit when price remains unchanged and many spreads are often a pure play on time-varying volatility. These trades could impact the option market maker without affecting the equity market or could merely be misinterpreted as informed. Empirical models of stock and option markets must control for these types of trades before ascribing trade frequency or signed volume to informed trading. The bivariate ACD model is ideally suited to the task because characteristics of individual transactions are permitted to influence the inter-market dynamics.

2.2. Econometric model

The bivariate duration process is $\{(X_i \tilde{Y}_i)\}$, $i = 1,\ldots,N$, where X_i is the forward option trade duration and $\tilde{Y}_i$ is the observed forward stock trade or quote revision duration. The joint density for each observation is the product of a marginal density and a conditional density

$$p(X_i, \tilde{Y}_i|\Im_{i-1};\omega) = g(X_i|\Im_{i-1};\omega_j) f(\tilde{Y}_i|X_i, \Im_{i-1};\omega_k), \tag{1}$$

where $\Im_{i-1}$ is the information available at time $i-1$, $g(\bullet|\Im_{i-1};\omega_j)$ is the marginal option trade density and $f(\bullet|X_i,\Im_{i-1};\omega_k)$ is the conditional stock trade or quote revision density. Parameterization of g follows an exponential linked ACD model:

$$\ln(\psi_i) = \alpha + \gamma\xi_{i-1} + \delta\ln(\psi_{i-1}) + \boldsymbol{\beta}'\mathbf{Z}_{i-1}, \tag{2}$$

with ψ the expected forward option trade duration and ξ the forward option trade duration relative to expected. Explanatory variables are contained in $\mathbf{Z}$. Parameterization of the conditional density is slightly more complicated:

$$\begin{aligned}\ln(\varphi_i) = \mu &+ \delta_1(\tilde{Y}_{i-1}/\varphi_{i-1}) + \rho\ln(\varphi_{i-1})\\ &+ \delta_2(\tilde{Y}_{i-1}/\varphi_{i-1})\mathrm{DUM}_{i-1} + \tau_1(\xi_i) + \tau_2(\xi_{i-1}))\\ &+ \tau_3\ln(\psi_{i-1}) + \boldsymbol{\eta}'\mathbf{Z}_{i-1},\end{aligned} \tag{3}$$

with ξ and ψ defined in the marginal Eq. (2). φ is the expected forward stock transaction duration and $\varepsilon(=\tilde{Y}/\varphi)$ is the forward stock transaction duration relative to expected. DUM indicates censoring.

The log likelihood of the specification in Eq. (1) is

$$\begin{aligned}L(\omega; X, \tilde{Y}) = \Sigma_i[&\ln g(X_i|\Im_{i-1};\omega_j)\\ &+ \ln f(\tilde{Y}_i|X_i, \Im_{i-1};\omega_k)].\end{aligned} \tag{4}$$

The first term is maximized by choosing ω_j, followed by the second term conditional on the first. The parameter estimates are then used as starting points for maximization of the joint function.

The assumption of exponential densities results in estimation of a quasi-likelihood function. Tests for excess dispersion of the residuals can determine the appropriateness of the QMLE distribution assumption. Engle and Russell (1998) propose a test of the exponential: under the null hypothesis of exponential errors, residual variance should equal one. Residual autocorrelations and squared autocorrelations test the specification of the mean equations.

3. Data and variables

The transaction data for this study are extracted from the NYSE Trade and Quote (TAQ) database and the Berkeley Options database for the period from January 1 to June 30, 1995. The sample consists of the 40 NYSE-listed firms with the most option trading activity during the six month period. For stock quotes, the following are deleted: negative bid or ask price, negative bid or ask depth, negative bid-ask spread, spreads greater than \$2, consecutive quotes with the bid or ask increasing by more than 10% and quotes out of sequence or reported with errors. With the exception of the depth filter, option quotes receive similar treatment. Also, a few incidents of zero-bid option quotes and their associated trades are dropped. Stock and option trades are deleted if they are recorded out of sequence or with errors, if consecutive trade prices increase by more than 10% or if the price or volume is negative.[2]

The option trade sample contains both put and call contracts of all maturities and strike prices. Quotes are moved forward one second. Henker and Wang (2006) show that the Lee and Ready (1991) "five second rule" is not appropriate for matching quotes and trades in TAQ data. Option quotes receive similar treatment. The first transaction of the day in each market and all transactions occurring after 4:00 p.m. are omitted. Prior to covariate construction, sample sizes ranged from 2,841 to 141,767 transactions. The duration variables are constructed in a manner consistent with the Engle and Lunde (2003) model. For the option trade/stock trade model, every option trade has two associated durations: the time from the previous option trade to the current option trade (the forward option trade duration, X) and the time from the previous option trade to the next stock trade (the forward stock trade duration, Y). If Y exceeds X, then the observation is censored, the variable $\tilde{Y}$ (the observed forward stock trade duration) takes a value equal to the minimum of Y and X, and a dummy variable, DUM, takes a value of one. A similar construction applies to the option trade/equity quote revision model. Some summary statistics are presented in Table 1.

For the option trade/equity trade model, additional exogenous duration variables include the mean of the ten most recent option trade durations (level_oodur), the mean of the ten most recent stock trade durations (level_ssdur), and the time between the option trade that initiated the current duration and the previous stock trade (tslst). For the option trade/equity quote model, additional variables include level_oodur, the mean of the ten most recent quote revision durations (level_qqdur), and the time between the option trade that initiated the current duration and the previous quote revision (tslqr). All durations, including X, Y, and $\tilde{Y}$ are scaled by 30 seconds. Each equation also includes six time-of-day dummy variables to model the diurnal pattern in durations. The dummy variables, T1,…, T6 take the value of one if the duration was initiated between the hours of 10:00–11:00,…, 15:00–16:00.

The choice of explanatory variables is informed by previous studies of asymmetric information in microstructure theory and practice. Biais et al., 2005 provide a review of market microstructure theory and Hasbrouck (1994) reviews some empirics. In these models, periods of increased information flow are characterized by higher trading volume, wider spreads and smaller depths. Stock volume is defined as: stock_vol = (stock trade size/100)$^{1/2}$, and option volume as: option_vol = (option trade size)$^{1/2}$. An additional exogenous option (stock) market variable is the absolute value of the cumulated signed volume for the last ten transactions, option_imbalance (stock_imbalance). Hasbrouck (1991, 1994) finds that trade sign exhibits positive autocorrelation when information

[2]A web appendix contains a table of the sample firms and some summary statistics for the raw data. Also included is a detailed exposition of the data handling procedures from initial extraction from the databases to final estimation of the models. An example dataset is available along with the Eviews and SAS code. See www.huizenga.nova.edu/collver/documents/Web%20Appendix%20B.pdf.

Table 1
Summary statistics for transaction variables

Variable	Mean	Range	
Panel A: Option trades			
Number of option trades	16100	1612	140258
Average forward option/option duration	256	19.51	676
Average option volume	13.83	7.89	20.77
Average time S.L.S.T.	90.92	28.55	197
% Buy	41.93	33.10	51.01
% Sell	36.22	28.99	46.42
% Midquote	21.85	9.35	31.15
Panel B: Stock trades			
Average observed forward option/stock duration	222	15.60	600
% Censored	44.40	27.14	67.74
Average stock volume	31.46	13.82	59.03
% Buy	42.37	30.34	59.88
% Sell	37.17	25.84	53.23
% Midquote	20.08	6.09	43.50
Panel C: Stock quotes			
Average time S.L.Q.R.	177	29.63	1600
Average observed forward option/QR duration	222	15.95	623
% Censored	49.30	29.76	74.51

The table presents the mean, minimum and maximum of the average trade variable value for each firm. Average forward option-option trade duration is the average time (in seconds) between two consecutive option trades. Average option volume is in number of contracts. Average time S.L.S.T. is the average time from the option trade that initiated a duration and the stock trade that occurred immediately before that option trade. For the option trades, call purchases and put sales are designated "buys" and call sales and put purchases are "sells." The average observed forward option/stock duration is the average time between an option trade and the subsequent event. If the next event is an option trade, then the duration is censored. Average stock volume is in round lots. Average time S.L.Q.R. is the average time from the option trade that initiated a duration and the quote revision that occurred immediately before. The average observed forward option trade/qr duration is the average time between an option trade and the subsequent event. If the next event is an option trade, then the duration is censored.

trading is more prominent. Periods of increased information flow are associated with a succession of buys or sells. Engle and Lunde (2003) term this phenomenon order imbalance.

The cumulated signed volume variables require a method for classifying stock and option trades. I adopt the midpoint rule of Lee and Ready (1991).[3] Since signed volume is used as an indicator of a trade's impact on the specialist's order book, trades that are at the midquote are considered crossed trades and assigned a 0. For option trades, call purchases and put sales are assigned a value of 1, call sales and put buys are assigned a value of -1 and the remaining indeterminate trades are assigned a value of 0. Table 1 provides some summary statistics for the trade classification procedure. The signed volume variables are created from the product of the trade sign and the appropriate volume. Finally, trades that occur at the same time in the same market are aggregated.

[3]I do not employ their tick test. Savickas and Wilson (2003) report that the quote rule correctly signs 88.65% of individual equity option trades.

Stock quote revision variables include the change in the relative spread (100∗ln(ask/bid)) from the most recent stock quote to the prevailing stock quote (delta_relative_spread_s), the average of ten lagged spreads (level_relative_spread_s), the change in depth (ask size plus bid size) from the most recent stock quote to the prevailing stock quote (delta_depth), and the average of ten lagged depths (level_depth). A large quoted spread in either market is indicative of a higher perceived probability of information based trades. A small quoted depth in the stock market is also associated with informed trading.

Some option trade variables are constructed from the preceding quotes for matching contracts. Potential information related variables include the relative spread (relative_spread_o = ln(ask/bid)), the change in the relative spread (delta_relative_spread_o) and the average of ten lagged spreads (level_relative_spread_o). Several implied volatility variables are also constructed from matching contract quotes. I use a 100 step binomial model with discrete dividends to calculate implied volatility. Actual dividends, obtained from the CRSP daily files, are used as a proxy for expected dividends. The risk-free rate is interpolated from the two monthly US dollar LIBOR rates closest to option maturity. The mean implied volatility (IV) from the most recent quotes for the same contract type and maturity (ivsmile_avg) controls for the level of implied volatility. While periods of higher volatility are typically associated with informed trading, high levels of implied volatility could attract some volatility traders to the option market. The slope of the smile (ivsmile_slope) is a linear approximation calculated as the difference in implied volatilities between the highest and lowest strikes divided by the dollar difference in strikes. Larger IV slopes could proxy for jump risk in the underlying (Pan, 2002). They also provide incentives for spread traders. Similar variables are constructed for the maturity structure of IV (ivterm_avg and ivterm_slope).

Moneyness is defined as the ratio of stock price to strike price (strike price/stock price) for calls (puts). Black (1975) suggests that informed traders might prefer the leverage afforded by out-of-the-money options. However, at-the-money options are subject to the most gamma risk. Delta hedgers are likely to trade these contracts more frequently, especially when they approach expiry. Other liquidity traders are likely to use these more actively traded at-the-money options. Of course informed traders may use the liquidity provided by at-the-money contracts to conceal their intentions (Anand and Chakravarty, 2007). These incentives suggest that trade frequencies may increase in both markets when the stock price approaches the strike price. To capture this effect, a second variable, moneyness2, is constructed as the absolute value of (1-moneyness). A third variable, max_pain2 = moneyness2*(indicator for the last week of expiry), controls for the potential strike price pegging phenomena that might have been common during the sample period. Table 2 provides some summary statistics for the covariates.[4]

4. Model results

4.1. The option trade/equity trade model

The left panel of Table 3 contains a summary of estimates from Eq. (2): the option trade/option trade equation for all option trades.[5] Both δ (the AR parameter) and γ (the surprise

[4]Firm-level summary statistics for the trade variables (Table 1) and covariates (Table 2) are available in a web appendix: www.huizenga.nova.edu/collver/documents/Web%20Appendix%20A.pdf.

[5]The individual parameter estimates for each firm are available upon request.

Table 2
Summary statistics for covariates

Covariate	Mean	Range	
Panel A: Option trade/equity trade model			
option_vol	3.01	2.38	3.50
option_imbalance	60.5	28.2	102.6
level_oodur	8.20	0.65	20.37
relative_spread_o	19.3	7.6	28.7
delta_relative_spread_o	4.60	0.84	8.90
level_relative_spread_o	13.33	4.87	22.12
moneyness	0.998	0.969	1.071
max_pain2	0.0188	0.0092	0.0327
ivterm_avg	0.337	0.159	0.593
ivsmile_avg	0.479	0.271	0.783
ivterm_slope	−0.267	−0.703	−0.113
ivsmile_slope	−0.0197	−0.0767	0.0091
tslst	3.03	0.95	6.57
stock_vol	3.99	2.91	5.76
stock_imbalance	18169	7523	40005
delta_depth	21.00	0.34	149.46
level_depth	413	49	1326
delta_relative_spread_s	0.0079	−0.0154	0.0475
level_relative_spread_s	0.467	0.194	0.999
level_ssdur	2.69	0.82	6.11
Panel B: Option trade/equity quote model			
option_vol	3.00	2.38	3.53
option_imbalance	60.5	28.3	103.5
level_oodur	8.22	0.65	20.39
relative_spread_o	19.1	7.6	28.5
delta_relative_spread_o	4.46	0.80	8.72
level_relative_spread_o	13.3	4.9	22.1
moneyness	0.997	0.969	1.059
max_pain2	0.0182	0.0091	0.0326
ivterm_avg	0.333	0.158	0.593
ivsmile_avg	0.477	0.270	0.788
ivterm_slope	−0.270	−0.734	−0.114
ivsmile_slope	−0.0199	−0.0786	0.0094
tslqr	5.91	0.99	53.33
stock_vol	4.49	3.22	6.76
stock_imbalance	19516	7800	46482
delta_depth	18.13	0.49	145.60
level_depth	413	49	1322
delta_relative_spread_s	−0.0077	−0.0458	0.0111
level_relative_spread_s	0.466	0.194	0.995
level_qqdur	3.22	0.94	7.21

This table presents the mean, minimum and maximum of the average covariate value for each firm.
The definition of each covariate is provided in Appendix A: Glossary of covariates.

term) are positive and significant with δ in excess of 0.8 for most firms. Also, stationarity conditions are satisfied with δ significantly less than one for all firms. These results are consistent with earlier studies that also find high persistence in trading intensity. The coefficient for ivsmile_avg is negative and significant for a majority of firms suggesting that

Table 3
Estimate summary for the marginal option trade equation, option trade/equity trade model

		All option trades				At-the-money call trades			
	Variable	Mean	t-stat	+@ 5%	−@ 5%	Mean	t-stat	+@ 5%	−@ 5%
	α (constant)	0.2906	3.53	13	6	0.0957	0.48	7	8
	ψ_{i-1}	0.8079	26.84	40	0	0.6409	19.27	38	0
	ξ_{i-1}	0.0861	29.09	40	0	0.0924	18.87	37	0
$(\times 10^{-2})$	option_vol$_{i-1}$	0.3194	1.74	9	9	1.0500	3.43	14	8
$(\times 10^{-4})$	option_imbalance$_{i-1}$	−0.7495	−2.60	2	13	−1.8329	−3.16	2	12
$(\times 10^{-2})$	level_oodur$_{i-1}$	0.1434	1.37	16	15	0.4549	5.56	23	5
$(\times 10^{-3})$	relative_spread_o$_{i-1}$	0.1170	0.65	13	2	1.7948	3.33	15	1
$(\times 10^{-3})$	delta_relative_spread_o$_{i-1}$	0.2569	2.07	4	0	0.2967	0.75	5	4
$(\times 10^{-3})$	level_relative_spread_o$_{i-1}$	0.1285	0.32	4	6	2.3428	2.13	13	4
$(\times 10^{-1})$	max_pain2 $_{i-1}$	0.0667	0.11	10	7	3.1963	0.89	12	7
	ivterm_avg$_{i-1}$	−0.1188	−1.62	4	13	−0.0474	−0.16	8	11
$(\times 10^{-1})$	ivsmile_avg$_{i-1}$	−0.4893	−4.81	0	26	−0.2077	−0.68	4	9
$(\times 10^{-1})$	ivterm_slope$_{i-1}$	−0.1136	−1.06	3	4	0.3450	0.87	12	4
	ivsmile_slope$_{i-1}$	−0.1186	−1.39	9	5	0.0650	0.40	10	2
$(\times 10^{-1})$	moneyness$_{i-1}$	−0.9390	−2.21	3	8	3.4909	1.99	13	6
$(\times 10^{-2})$	tslst$_{i-1}$	0.9732	7.78	38	0	1.5093	7.32	29	0
$(\times 10^{-2})$	stock_vol$_{i-1}$	−0.4911	−7.44	0	30	−0.8048	−4.76	3	27
$(\times 10^{-4})$	stock_imbalance$_{i-1}$	−0.5587	−5.29	0	21	−1.0586	−3.75	1	16
$(\times 10^{-4})$	delta_depth$_{i-1}$	−0.4849	−1.43	3	7	−0.1384	−0.26	2	8
$(\times 10^{-1})$	delta_relative_spread_s$_{i-1}$	0.1717	1.03	4	6	0.3062	0.82	7	4
$(\times 10^{-1})$	level_relative_spread_s$_{i-1}$	−0.8425	−2.28	6	14	−2.0344	−2.83	6	13
$(\times 10^{-1})$	level_ssdur$_{i-1}$	0.2883	7.29	40	0	0.6005	8.78	37	0
$(\times 10^{-4})$	level_depth$_{i-1}$	−0.6497	−2.92	1	23	−0.6359	−0.98	3	9
	T1$_{i-1}$	0.1113	5.82	36	0	0.2169	3.48	31	2
	T2$_{i-1}$	0.1671	6.13	39	0	0.3513	5.39	34	2
	T3$_{i-1}$	0.1946	5.92	40	0	0.4034	6.40	35	2
	T4$_{i-1}$	0.1643	5.45	40	0	0.3231	5.37	34	2
	T5$_{i-1}$	0.1292	5.67	38	0	0.2344	4.39	30	2
	T6$_{i-1}$	0.0340	3.57	16	0	0.0329	0.65	13	4

This table reports the estimation results from the option trade equation: $\ln(\psi_i) = \alpha + \gamma\xi_{i\ -1} + \delta\ln(\psi_{i-1}) + \boldsymbol{\beta}'\mathbf{Z}_{i-1}$. The first sample is composed of all option trades (40 firms) and the second sample is restricted to near term at-the-money calls (38 firms). ψ is the expected forward option trade duration and ξ is the forward option trade duration relative to expected. Explanatory variables in **Z** are defined in Appendix A. The number of parameters significant at 5% are two-tailed tests of the null hypothesis $\beta = 0$. The test for δ is a one tailed test of $\delta = 1$. Standard errors for individual parameters employ the robust QMLE covariance matrix (Bollerslev and Wooldridge, 1992).

higher levels of implied volatility are associated with increased option trading intensities (shorter durations). None of the other option trade covariates are significant for a majority of the firms.

The positive and significant coefficients on tslst and level_ssdur indicate that faster trading in the stock market is associated with faster trading in the option market. The negative and significant coefficient on stock_vol for thirty firms suggests that large stock trades are followed by shorter durations in the option market. Easley and O'Hara (1987) provide a model in which large trades are indicative of informed trading. Informed traders optimally choose to trade quickly on their private information, resulting in faster markets. The coefficient on the measure of stock market trade imbalance (stock_imbalance) is negative on average and significant for twenty-one of the firms. For these firms, increased trade imbalance in the stock market leads to decreased expected option trade duration. Hasbrouck (1994) finds positive and significant autocorrelations for trade sign. Informed traders are willing to trade at the bid or ask to facilitate a quick transaction. If NYSE specialists lay off risk in the option market, then faster option trading would be positively associated with lagged stock volume, stock market order imbalance and stock market trade timing. This is exactly what the option trade equation shows.

However, the coefficient for level_depth is negative and significant for a majority of firms. Increased liquidity in the stock market is associated with shorter option trade durations. This observation contrasts with the informed trading interpretation of the other stock market variables. But stock volume, trade frequency and, to some extent, order imbalance are determined by the actions of stock traders. Depth is determined by specialists and limit order traders. If liquidity providers in the stock market can hedge cheaply in the option market, as in Cho and Engle (1999), then equity market depth might not adjust quickly to the presence of informed traders. None of the other equity spread or depth variables are significant, on average.

Impact multipliers provide an assessment of the economic significance of changes in the covariates. Coefficients in Eq. (2) represent the percentage change in the expected option trade/option trade duration due to a change in the covariate. For each covariate, z_i, the short run impact multiplier is given by: $\mathrm{SRIM}_i = [(Q3(z_i)/Q1(z_i))-1]^*\beta_i$, and the long run impact multiplier is $\mathrm{SRIM_i}/(1-\delta)$. The short run impact multiplier is the product of the parameter estimate and the percentage change in the covariate when it moves from the 25th percentile to the 75th percentile of the distribution. For JNJ, the short run impact multiplier for the ivsmile_avg variable is given by $0.5587*-0.1369 = -7.65\%$. The average option trade/option trade duration for JNJ is 209 seconds. A jump from the first quartile to the third quartile results in an increase in implied volatility of about 56% which translates into a decrease in expected option trade duration of $0.0765*209$ or about 16 seconds for the next trade. The long run impact is −17.7% or a decrease of 37 s for JNJ. The long run impact multipliers for ivsmile_avg are presented in Fig. 1. The percentage short (long) run impact for ivsmile_avg ranges from −9.1 to 1.8 (−61.4 to 25.6). Fig. 2 presents the impact multipliers for some of the other statistically significant covariates. The long run impact of an increase in stock volume appears to be economically significant for many firms. In contrast, order imbalance and average depth in the stock market appear to exert minimal economic influence on expected option trade duration in this model.

Ljung-Box tests of the option trade/option trade durations (X_i) and standardized residuals (ξ_i) with 15 lags show that the exponential ACD(1,1) does a good job of reducing the autocorrelation in the option trade/option trade duration series.[6] However 82.5% of the firms still exhibit excess autocorrelation. The standard deviations of the residuals are all in excess of one. While the assumption of an exponential distribution may be theoretically incorrect, the use of quasi-maximum likelihood estimation with corrected standard errors is still appropriate.

The left panel of Table 4 contains a summary of estimates from Eq. (3): the option trade/stock trade equation for all option trades. While the AR parameter is positive and significant for most firms, it is much smaller than in the option trade/option trade duration equations. The surprise term, δ_1, is positive and significant for most firms, but the term on the censored durations, δ_2, is significant less frequently. The positive and significant coefficient on tslst indicates that shorter backward recurrence times to stock trades are

[6]The individual residual tests for each firm from all of the models are in the web appendix.

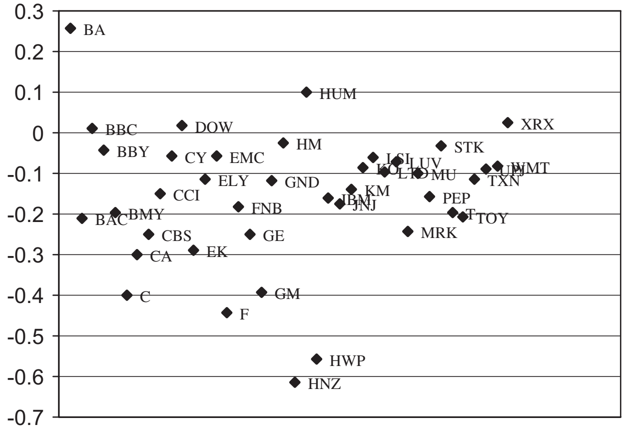

Fig. 1. Long run impact multipliers for ivsmile_avg; option trade equation, option trade/equity trade model. The long run impact multiplier is given by $[(Q3(z_i)/Q1(z_i))–1]*\beta_i/(1-\delta)$, with $z_i =$ ivsmile_avg. The numerator is the product of the parameter estimate and the percentage change in ivsmile_avg when it moves from the 25th percentile to the 75th percentile of the distribution.

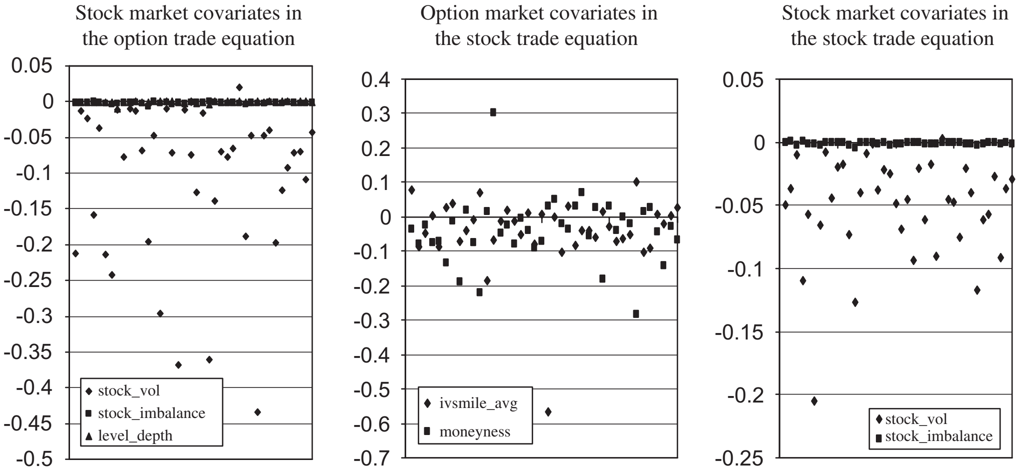

Fig. 2. Long run impact multipliers for the option trade/equity trade model. The long run impact multiplier is given by $[(Q3(z_i)/Q1(z_i))–1]*\beta_i/(1-\delta)$. The numerator is the product of the parameter estimate and the percentage change in the covariate when it moves from the 25th percentile to the 75th percentile of the distribution.

associated with faster inter-market trade timing. The positive coefficient on level_ssdur confirms this observation.

The stock volume covariates are significant for more firms in the option trade/stock trade equation than for the option trade/option trade equation. The negative and significant coefficient on stock_vol for 36 firms suggests that large stock trades are followed by shorter inter-market durations. The coefficient on the measure of stock market

Table 4
Estimate summary for the conditional stock trade equation, option trade/equity trade model

	Variable	All option trades				At-the-money call trades			
		Mean	*t*-stat	+ @ 5%	− @ 5%	Mean	*t*-stat	+ @ 5%	− @ 5%
	μ (constant)	0.2776	2.96	18	12	−0.0820	−0.38	7	15
	φ_{i-1}	0.5836	16.03	39	0	0.3972	11.62	38	0
	ε_{i-1}	0.1140	15.81	39	0	0.0957	14.19	35	0
	ε_{i-1}*DUM$_{i-1}$	0.0286	2.35	19	4	−0.0227	−0.89	9	8
	ξ_i	0.4339	27.70	40	0	0.5321	32.75	38	0
	ξ_{i-1}	−0.1737	−12.24	0	39	−0.1128	−7.38	1	31
	ψ_{i-1}	0.0155	2.69	24	7	0.0081	4.90	28	5
$(\times 10^{-3})$	option_vol$_{i-1}$	−0.3410	−0.24	10	18	9.5130	2.93	16	8
$(\times 10^{-4})$	option_imbalance$_{i-1}$	−0.8713	−2.83	5	14	−2.1679	−3.66	2	17
$(\times 10^{-2})$	level_oodur$_{i-1}$	0.4585	3.20	29	6	0.6803	7.56	31	4
$(\times 10^{-3})$	relative_spread_o$_{i-1}$	0.0255	0.10	18	8	1.2839	3.53	14	2
$(\times 10^{-3})$	delta_relative_spread_o$_{i-1}$	0.2987	1.97	16	6	0.3765	1.06	13	7
$(\times 10^{-3})$	level_relative_spread_o$_{i-1}$	0.0029	0.01	15	9	2.7098	2.39	21	7
$(\times 10^{-1})$	max_pain2 $_{i-1}$	0.6064	0.75	18	10	4.6465	1.01	17	11
	ivterm_avg$_{i-1}$	−0.1105	−1.29	10	20	0.2330	0.69	14	12
$(\times 10^{-1})$	ivsmile_avg$_{i-1}$	−0.2864	−3.05	7	22	−0.1275	−0.37	12	10
$(\times 10^{-1})$	ivterm_slope$_{i-1}$	−0.1063	−0.84	13	13	0.7530	1.57	18	7
	ivsmile_slope$_{i-1}$	−0.1061	−1.02	11	18	0.0415	0.24	12	6
	moneyness$_{i-1}$	−0.2043	−3.37	8	25	0.1875	0.94	13	12
$(\times 10^{-1})$	tslst$_{i-1}$	0.1876	10.01	40	0	0.2619	11.42	37	0
$(\times 10^{-2})$	stock_vol$_{i-1}$	−0.8198	−9.69	0	36	−1.0903	−6.21	2	31
$(\times 10^{-3})$	stock_imbalance$_{i-1}$	−0.0896	−6.14	0	34	−0.1360	−5.37	0	25
$(\times 10^{-5})$	delta_depth$_{i-1}$	0.0823	0.03	16	9	6.1875	1.04	11	10
$(\times 10^{-1})$	delta_relative_spread_s$_{i-1}$	0.1757	0.64	13	13	0.1479	0.46	10	7
	level_relative_spread_s$_{i-1}$	−0.1605	−3.51	9	23	−0.2824	−3.23	7	20
$(\times 10^{-1})$	level_ssdur$_{i-1}$	0.5266	8.68	40	0	0.8392	8.96	37	0
$(\times 10^{-4})$	level_depth$_{i-1}$	−0.7998	−3.24	6	28	−0.7137	−1.10	9	9
	T1$_{i-1}$	0.1430	6.77	38	0	0.2355	4.24	30	1
	T2$_{i-1}$	0.2156	8.21	39	0	0.4180	6.91	35	1
	T3$_{i-1}$	0.2574	7.59	40	0	0.4922	7.74	35	1
	T4$_{i-1}$	0.2263	7.39	40	0	0.4092	6.64	34	1
	T5$_{i-1}$	0.1856	6.94	40	0	0.3133	5.70	33	1
	T6$_{i-1}$	0.0686	5.74	30	2	0.0785	1.42	18	3

This table reports the estimation results from the stock trade equation: $\ln(\varphi_i) = \mu + \delta_1(\tilde{Y}_{i-1}/\varphi_{i-1}) + \rho\ln(\varphi_{i-1}) + \delta_2(\tilde{Y}_{i-1}/\varphi_{i-1})\mathrm{DUM}_{i-1} + \tau_1(\xi_i) + \tau_2(\xi_{i-1}) + \tau_3\ln(\psi_{i-1}) + \boldsymbol{\eta}'\mathbf{Z}_{i-1}$. The first sample is composed of all option trades (40 firms) and the second sample is restricted to near term at-the-money calls (38 firms). ψ is the expected forward option trade duration and ξ is the forward option trade duration relative to expected. φ is the expected forward stock trade duration and $\varepsilon(=\tilde{Y}/\varphi)$ is the forward stock trade duration relative to expected. DUM indicates censoring. Explanatory variables in **Z** are defined in Appendix A. The number of parameters significant at 5% are two-tailed tests of the null hypothesis $\beta = 0$. Standard errors for individual parameters employ the robust QMLE covariance matrix (Bollerslev and Wooldridge, 1992).

trade imbalance is negative, on average, and significant for 34 firms, suggesting that increased trade imbalance in the stock market leads to decreased expected inter-market trade duration. A few of the option trade covariates are significant. Faster trading in the option market, higher implied volatilities and increased moneyness are all associated with shorter times between option trades and stock trades. Impact multipliers are calculated in a manner similar to that of the option trade equation. Fig. 2 presents the impact multipliers for some of the significant covariates. Stock volume, option moneyness and implied volatility all appear to exert significant economic impact on option trade/stock trade duration for many firms.

Ljung-Box tests of the option trade/stock trade durations ($\tilde{Y}_i$), and standardized residuals (ε_i), with 15 lags show that the exponential ACD(1,1) does a good job of reducing the autocorrelation in the option trade/stock trade duration series. However 65% of the firms still exhibit excess autocorrelation. Except for LTD, the standard deviations of the residuals are all less than one.

Eq. (3) allows for tests of the existence of a lead from option trade timing to stock trade timing. The parameter on ξ_i, τ_1, measures the immediate impact of a shock to option trade/option trade duration on expected option trade/stock trade duration. This parameter is positive and significant for all firms suggesting that these two inter-trade durations are highly correlated. However, the impact of ξ_{i-1} on expected option trade/stock trade duration is negative, significant and a little less than half of the impact of ξ_i. A distributed lag relation exists between $\ln(\varphi_i)$ and ξ_i. The total lag 1 effect is measured by $\rho * \tau_1 + \tau_2$ and $(\tau_1 + \tau_2)/(1-\rho)$ measures the long run impact. The lag 1 effect ranges from 0.012 (IBM) to 0.104 (KO), and, the long run effect is positive for all forty firms. Overall, positive (negative) shocks to option trade/option trade durations result in increased (decreased) expected option trade/stock trade durations.

But there is little indication that the distributed lag effects are associated with informed trading. The correlations between the lag 1 effect and average (median) option information shares calculated for each firm are 0.434 (0.433) and the correlations between the long run effect and average (median) option information shares are 0.003 (0.024). The information shares are calculated for option trades and stock trades following the methods of Chakravarty et al., 2004.[7] Only near term at-the-money call option trades are used for the calculation. A more direct comparison involves these information shares and the distributed lag effects obtained from an ACD model of stock trades and near term at-the-money call option trades.

Parameter estimate summaries for this model are provided in the right panels of Tables 3 and 4. There are a few notable differences between the models of all option trades and the thinned point process of near term at-the-money call trades. The ivsmile_avg coefficient is no longer significant, but level_oodur is positive and significant in the option trade equation. The ivsmile_avg coefficient is also no longer significant in the stock trade equation. Increased spreads (level_relative_spread_o) for near term at-the-money calls are associated with longer option trade durations and longer inter-market durations. These particular contracts are known to attract informed traders. Wider spreads in these contracts, especially when trading is slow, could warn the equity market specialist of informed trading in the option market.

The correlations between the lag 1 effect obtained from the ACD model of the thinned point process and average (median) option information shares calculated for each firm are 0.222 (0.200) and the correlations between the long run effect and average (median) option information shares are 0.099 (0.122). Overall, there is little indication that the distributed lag effects derived from the ACD models are related to informed trading in the option market. However, the lagged effects and information shares are firm-level averages from approximately six months of data. It is possible that these statistics exhibit higher

[7]Due to data sparseness, information shares are calculated for only 34 firms. Complete details and summary tables are in the web appendix.

correlations on a daily basis. Unfortunately, there are too few option trades to estimate daily ACD models.

4.2. The option trade/equity quote model

A quote revision is the conditional event in the option trade/equity quote model. The left panel of Table 5 contains a summary of estimates from Eq. (2): the option trade/option trade equation for all option trades. The results are similar to those obtained from the marginal option trade equation of the option trade/equity trade model. The positive and significant coefficient on tslqr indicates that shorter backward recurrence times to quote revisions are associated with faster trading in the option market. The positive and significant coefficient on level_qqdur for a majority of firms provides more evidence on the

Table 5
Estimate summary for the marginal option trade equation, option trade/equity quote model

		All option trades				At-the-money call trades			
	Variable	Mean	t-stat	+ @ 5%	− @ 5%	Mean	t-stat	+ @ 5%	− @ 5%
	α (constant)	0.3057	3.45	15	6	0.3184	1.74	10	6
	ψ_{i-1}	0.8637	27.68	36	0	0.7067	19.48	38	0
	ξ_{i-1}	0.0808	28.10	40	0	0.0907	13.29	36	1
$(\times 10^{-2})$	option_vol$_{i-1}$	−0.1311	−1.08	3	16	0.6696	2.11	11	9
$(\times 10^{-4})$	option_imbalance$_{i-1}$	−0.3898	−2.12	4	10	−1.5452	−3.17	2	9
$(\times 10^{-3})$	level_oodur$_{i-1}$	0.3091	0.35	11	19	3.9195	4.47	21	6
$(\times 10^{-3})$	relative_spread_o$_{i-1}$	0.0227	0.13	12	3	1.3172	2.89	10	1
$(\times 10^{-3})$	delta_relative_spread_o$_{i-1}$	0.3076	2.01	7	2	0.2455	0.63	6	3
$(\times 10^{-3})$	level_relative_spread_o$_{i-1}$	0.5481	1.17	10	7	2.1963	1.90	12	6
$(\times 10^{-1})$	Max_pain2$_{i-1}$	0.5081	0.92	11	5	4.9059	1.42	12	8
	ivterm_avg$_{i-1}$	−0.1419	−2.04	6	14	0.0952	0.31	6	11
$(\times 10^{-1})$	ivsmile_avg$_{i-1}$	−0.3430	−3.48	1	18	−0.1654	−0.46	6	11
$(\times 10^{-1})$	ivterm_slope$_{i-1}$	−0.1595	−1.61	5	9	0.4220	1.11	9	4
	ivsmile_slope$_{i-1}$	−0.1265	−1.35	7	6	−0.0090	−0.05	8	4
	moneyness$_{i-1}$	−0.1136	−2.36	3	12	0.0584	0.37	9	9
$(\times 10^{-2})$	tslqr$_{i-1}$	0.2621	5.02	31	0	0.7170	5.02	26	0
$(\times 10^{-2})$	stock_vol$_{i-1}$	−0.2141	−3.51	0	25	−0.4901	−2.51	1	17
$(\times 10^{-4})$	stock_imbalance$_{i-1}$	−0.4796	−3.63	0	25	−0.8851	−3.37	1	18
$(\times 10^{-4})$	delta_depth$_{i-1}$	0.2457	1.18	4	3	0.4495	0.65	10	3
$(\times 10^{-1})$	delta_relative_spread_s$_{i-1}$	−0.1465	−0.89	1	10	−0.1472	−0.28	5	11
	level_relative_spread_s$_{i-1}$	−0.1218	−3.58	2	18	−0.2483	−3.14	3	13
$(\times 10^{-2})$	level_qqdur$_{i-1}$	0.8900	4.18	26	1	2.1761	4.85	26	0
$(\times 10^{-4})$	level_depth$_{i-1}$	−0.7054	−2.96	1	25	−1.3692	−1.99	2	13
	T1$_{i-1}$	0.1023	5.26	38	0	0.2307	4.97	32	1
	T2$_{i-1}$	0.1591	4.98	40	0	0.3641	6.38	34	1
	T3$_{i-1}$	0.1826	4.84	40	0	0.4178	7.69	36	0
	T4$_{i-1}$	0.1596	4.64	40	0	0.3615	6.63	36	1
	T5$_{i-1}$	0.1212	4.58	38	0	0.2673	5.95	33	1
	T6$_{i-1}$	0.0306	3.40	20	1	0.0620	1.54	18	3

This table reports the estimation results from the option trade equation: $\ln(\psi_i) = \alpha + \gamma\xi_{i-1} + \delta\ln(\psi_{i-1}) + \boldsymbol{\beta}'\mathbf{Z}_{i-1}$. The first sample is composed of all option trades (40 firms) and the second sample is restricted to near term at-the-money calls (38 firms). ψ is the expected forward option trade duration and ξ is the forward option trade duration relative to expected. Explanatory variables in **Z** are defined in Appendix A. The number of parameters significant at 5% are two-tailed tests of the null hypothesis $\beta = 0$. The test for δ is a one tailed test of $\delta = 1$. Standard errors for individual parameters employ the robust QMLE covariance matrix (Bollerslev and Wooldridge, 1992).

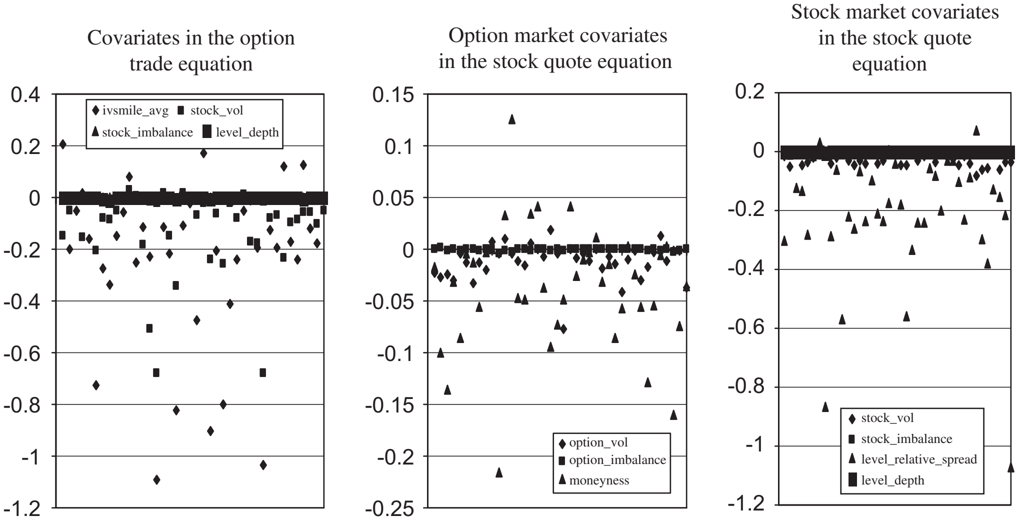

Fig. 3. Long run impact multipliers for the option trade/equity quote model. The long run impact multiplier is given by $[(Q3(z_i)/Q1(z_i))–1]*\beta_i/(1-\delta)$. The numerator is the product of the parameter estimate and the percentage change in the covariate when it moves from the 25th percentile to the 75th percentile of the distribution.

relation between backward recurrence times to quote revisions and option trades. Faster trading in the option market is associated with faster quote revisions in the equity market.

The negative and significant coefficient on stock_vol for 25 firms means that large stock trades are followed by shorter durations in the option market. Again, the insights of Easley and O'Hara (1992) apply: informed traders optimally choose to trade quickly on their private information, resulting in faster markets. Similar to the previous model, the coefficients on stock_imbalance and level_depth are both negative and significant for most firms and similar interpretations apply. The long run impact multipliers are presented in Fig. 3. Stock volume and implied volatility exert the largest economic impact in the option trade equation.

The left panel of Table 6 contains a summary of estimates from Eq. (3): the option trade/stock quote equation for all option trades. While the ρ (AR) parameter is positive and significant for all firms, it is much smaller than in the option trade/option trade duration equations. The surprise term, δ_1, is positive, on average. The term on the censored durations, δ_2, is positive, on average, and significant for 30 firms, suggesting that censoring potentially impacts this equation for these firms. The positive and significant coefficient on tslqr indicates that shorter backward recurrence times to quote revisions in the stock market are associated with faster inter-market option trade/stock quote revision timing. The positive and significant coefficient on level_qqdur confirms this observation.

The coefficient for stock_vol is negative and significant on average, suggesting that large stock trades are followed by shorter inter-market durations. All of the quote-related variables are significant in this equation. The stock_imbalance, delta_relative_spread_s and level_relative_spread_s coefficients are negative and significant for many firms in the sample. Increased order imbalance and wide and increasing spreads are all associated with decreased expected option trade/stock quote durations. And, decreasing depths are also

Table 6
Estimate summary for the conditional stock quote equation, option trade/equity quote model

		All option trades				At-the-money call trades			
	Variable	Mean	*t*-stat	+ @ 5%	- @ 5%	Mean	*t*-stat	+ @ 5%	- @ 5%
	μ (constant)	0.4986	5.56	31	5	0.6117	3.17	18	5
	φ_{i-1}	0.3848	10.87	40	0	0.3300	14.35	36	1
	ε_{i-1}	0.0998	11.67	38	0	0.0994	14.76	37	0
	ε_{i-1}*DUM$_{i-1}$	0.1049	6.01	30	4	0.0696	2.09	19	7
	ξ_i	0.4064	21.74	40	0	0.4820	25.90	38	0
	ξ_{i-1}	−0.0916	−6.32	4	32	−0.0755	−5.99	3	28
	ψ_{i-1}	0.0491	5.86	38	1	0.0227	3.34	30	2
$(\times 10^{-2})$	option_vol$_{i-1}$	−0.6007	−4.86	2	24	0.4064	1.20	13	15
$(\times 10^{-4})$	option_imbalance$_{i-1}$	−0.8584	−3.73	5	20	−2.5069	−3.89	0	16
$(\times 10^{-2})$	level_oodur$_{i-1}$	0.2657	1.42	21	14	0.5467	3.44	27	3
$(\times 10^{-4})$	relative_spread_o$_{i-1}$	−0.7354	−0.33	15	14	4.7571	0.90	17	8
$(\times 10^{-3})$	delta_relative_spread_o$_{i-1}$	0.2310	1.26	13	9	0.4505	1.16	9	8
$(\times 10^{-3})$	level_relative_spread_o$_{i-1}$	0.4523	0.71	18	12	2.3888	1.70	19	8
	max_pain2 $_{i-1}$	0.1575	1.97	19	6	0.6144	1.59	17	10
$(\times 10^{-1})$	ivterm_avg$_{i-1}$	−0.0577	−0.05	14	16	2.1890	0.56	14	14
$(\times 10^{-1})$	ivsmile_avg$_{i-1}$	−0.1063	−1.00	12	13	0.3098	0.74	13	8
$(\times 10^{-2})$	ivterm_slope$_{i-1}$	0.2887	0.17	16	12	7.3696	1.50	17	8
$(\times 10^{-2})$	ivsmile_slope$_{i-1}$	0.6576	0.06	15	13	−0.1280	−0.01	14	6
	moneyness$_{i-1}$	−0.2537	−4.26	4	26	−0.2642	−1.84	6	17
$(\times 10^{-1})$	tslqr$_{i-1}$	0.1607	11.15	40	0	0.1866	8.52	37	0
$(\times 10^{-2})$	stock_vol$_{i-1}$	−0.7485	−9.33	0	35	−0.9571	−5.33	1	31
$(\times 10^{-3})$	stock_imbalance$_{i-1}$	−0.1058	−5.77	0	33	−0.1214	−4.59	3	28
$(\times 10^{-3})$	delta_depth$_{i-1}$	0.3190	9.21	34	1	0.2858	3.61	30	2
	delta_relative_spread_s$_{i-1}$	−0.2420	−6.17	2	30	−0.1935	−3.70	4	24
	level_relative_spread_s$_{i-1}$	−0.4279	−6.84	1	34	−0.4869	−5.59	5	27
$(\times 10^{-1})$	level_qqdur$_{i-1}$	0.2733	8.96	39	0	0.3670	7.03	34	0
$(\times 10^{-4})$	level_depth$_{i-1}$	0.1027	0.21	22	11	−0.7191	−0.78	17	8
	T1$_{i-1}$	0.1599	8.45	38	0	0.2433	3.50	28	2
	T2$_{i-1}$	0.2667	9.18	40	0	0.4306	5.37	33	0
	T3$_{i-1}$	0.3116	9.07	40	0	0.5248	6.46	33	0
	T4$_{i-1}$	0.2812	9.07	40	0	0.4695	5.47	33	0
	T5$_{i-1}$	0.2215	7.83	40	0	0.3599	4.85	31	1
	T6$_{i-1}$	0.1004	7.45	33	0	0.1044	1.48	20	3

This table reports the estimation results from the stock quote equation: $\ln(\varphi_i) = \mu + \delta_1(\tilde{Y}_{i-1}/\varphi_{i-1}) + \rho\ln(\varphi_{i-1}) + \delta_2(\tilde{Y}_{i-1}/\varphi_{i-1})\mathrm{DUM}_{i-1} + \tau_1(\xi_i) + \tau_2(\xi_{i-1}) + \tau_3\ln(\psi_{i-1}) + \boldsymbol{\eta}'\mathbf{Z}_{i-1}$. The first sample is composed of all option trades (40 firms) and the second sample is restricted to near term at-the-money calls (38 firms). ψ is the expected forward option trade duration and ξ is the forward option trade duration relative to expected. φ is the expected forward stock quote duration and $\varepsilon(=\tilde{Y}/\varphi)$ is the forward stock quote duration relative to expected. DUM indicates censoring. Explanatory variables in $\mathbf{Z}$ are defined in Appendix A. The number of parameters significant at 5% are two-tailed tests of the null hypothesis $\beta = 0$. Standard errors for individual parameters employ the robust QMLE covariance matrix (Bollerslev and Wooldridge, 1992).

associated with smaller inter-market durations. These results might not be particularly surprising in light of the fact that the quotes that appear in the model are defined by an occurrence of an option trade. Fig. 3 presents some long run impact multipliers. Average spread in the stock market exhibits a very large impact on expected option trade/stock quote duration for most firms.

A few option trade covariates are significant as well. Increased option_vol, option_imbalance and moneyness are all associated with shorter option trade/stock quote durations. Fig. 3 presents some long run impact multipliers for the option market covariates. Option volume and moneyness exhibit some economic significance and option market order imbalance does not.

These results provide some indication that option market covariates associated with information-based trading impact the timing from option trades to stock quote revisions. The significance of many information-related stock quote variables indicates that option traders might be hedging asymmetric information risk in the equity market. Cho and Engle (1999) suggest that liquidity is naturally passed from one market to the other if the option market maker can perfectly hedge in the underlying. The fact that information-related covariates from both stock and option markets impact the time between an option trade and a stock quote revision suggests that option market makers are not always able to perfectly hedge their exposure. Therefore, an informed trader's market choice could be very important to the equity specialist.

The lag 1 effect for the option trade/equity quote model ranges from 0.004 (IBM) to 0.117 (UPJ), and, the long run effect is positive for all forty firms. Overall, positive (negative) shocks to option trade/option trade durations result in increased (decreased) expected option trade/quote revision durations. The tests confirm a lead from option trade timing to stock quote revision timing. The correlations between the lag 1 effect and average (median) option information shares are 0.504 (0.553) and the correlations between the long run effect and average (median) option information shares are 0.274 (0.303), somewhat higher than in the option trade/equity trade model.

Estimate summaries for the option trade/equity quote ACD model of stock quotes and near term at-the-money call option trades are provided in the right panels of Tables 5 and 6. The most notable difference in the thinned point process model is the positive and significant impact of level_oodur in both equations. Also, increased spreads (level_relative_spread_o) for near term at-the-money calls are associated with longer inter-market durations. This result confirms a similar finding from the ACD model of near term at-the-money call option trades and stock trades. The correlations between the lag 1 effect obtained from the ACD model of the thinned point process and average (median) option information shares are 0.342 (0.386) and the correlations between the long run effect and average (median) option information shares are 0.211 (0.234). These correlations are lower than those from the model with all option trades.

5. Conclusion

If informed traders are at least temporarily able to hide in the option market, then the timing and characteristics of option trades could provide an early indication to the NYSE specialist. The results of the option trade/stock trade model show that intra-market option trade timing leads inter-market option trade/stock trade timing. Increased implied volatility and moneyness of the option contracts are associated with decreased inter-market trade timing. When the option trade sample is thinned to include only near term at-the-money calls, the impact of these two variables disappears and quoted spreads in the option market exhibit an interesting phenomenon. While faster trading in these option contracts continues to be associated with faster inter-market trading, wider spreads are associated with slower intra- and inter-market trading. If perceived informed trading compels the option market maker to widen his spread then informed trading in the option market is associated with slower trading in both markets.

Engle and Lunde (2003) find that stock trade timing leads some equity quote revisions. The results of the option trade/stock trade model (option trade timing leads stock trade timing) taken with the Engle and Lunde (2003) findings (stock trade timing leads equity quote revision timing) suggest that NYSE specialists could benefit from monitoring option trade frequency, especially during periods of greater perceived information asymmetry. The option trade/equity quote model provides further evidence in support of this point of view. The results of this model suggest that intra-market option trade timing leads inter-market option trade/stock quote revision timing. Moreover, option market covariates typically associated with asymmetric information are statistically significant in the conditional quote revision equation, providing more rigorous support for an information-based lead from option trades to stock quote revisions. When the option trade sample includes only near term at-the-money calls, wider quoted spreads in the option are associated with longer times between option trades and stock quote revisions.

Whether specialists actually monitor the derivatives markets or not is no longer an issue reserved solely for academics. Consolidation of global exchanges, including the merger of NYSE and Archipelago, introduces the potential for side-by-side trading of stocks and options. While such an arrangement has not yet been approved by the SEC, if it were approved, it would not only reduce the marginal costs of monitoring the opposite market, but would redirect the debate on whether NYSE specialists monitor the options markets or not. The question is no longer do specialists monitor the options markets but should they monitor the options markets? If so, when would it be more beneficial to do so? The ACD models of option and stock markets provide some initial answers: specialists should monitor the options markets when option trade intensities, option volumes and option order imbalances increase, and should be especially aware of quoted spreads in contracts favored by informed option traders.

Appendix A. Glossary of covariates

This glossary provides a description of the covariates used in the bivariate ACD models. A web appendix provides detailed variable construction. See http://www.huizenga.nova.edu/collver/documents/Web%20Appendix%20B.pdf.

option_vol: square root of option trade size in number of contracts.
option_imbalance: absolute value of signed option trade size (# of contracts) cumulated over ten trades.
level_oodur: mean of the ten most recent option trade durations (30 seconds).
relative_spread_o: ln(ask/bid) for the most recent option quote.
delta_relative_spread_o: change in relative spread for two consecutive option quotes.
level_relative_spread_o: mean of the ten most recent option quote relative spreads.
moneyness: stock price/strike price (strike price/stock price) for calls (puts).
max_pain2: absolute value of (1-moneyness)*(indicator for expiration week).
ivterm_avg: mean implied volatility from the most recent quotes for the same type (put or call) and strike.
ivsmile_avg: mean implied volatility from the most recent quotes for the same type and maturity.
ivterm_slope: slope of implied volatility from the most recent quotes for the same type and strike.

ivsmile_slope: slope of implied volatility from the most recent quotes for the same type and maturity.
tslst: time from recent stock trade to option trade initializing current duration (30 seconds).
tslqr: time from recent equity quote to option trade initializing current duration (30 seconds).
stock_vol: square root of stock trade size (round lots).
stock_imbalance: absolute value of cumulated signed stock trade size.
delta_depth: change in depth (ask plus bid size) from the equity quote prior to option trade initializing current duration.
level_depth: mean of ten most recent equity quote depths.
delta_relative_spread_s: change in relative spread (100*ln(ask/bid)) for equity quotes.
level_relative_spread_s: mean of ten most recent equity quote relative spreads.
level_ssdur: mean of ten most recent stock trade durations (30 seconds).
level_qqdur: mean of ten most recent equity quote durations (30 seconds).
T1 through T6: hourly dummy variables for each hour from 10:00 AM to 4:00 PM.

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