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INFORMATION SHARE IN OPTIONS MARKETS: THE ROLE OF VOLUME, VOLATILITY, AND EARNINGS ANNOUNCEMENTS

by

Lenaye Harris

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of the requirements for the degree

of

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in

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Approved:

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ABSTRACT

Information Share in Options Markets:

The Role of Volume, Volatility, and Earnings Announcements

by

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Utah State University, 2013

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I find no significant difference in the level of information share attributed to the option market when using put data as opposed to call data. In a 12-day sample of 14 S&P 500 stocks, trading volume in the options market increased significantly on the day of an earnings announcement, but, although some securities showed dramatic increases in option information share, no sample-wide consistently signed difference was found around earnings announcements. Companies with higher stock trading volume tend to exhibit higher information share in the options market. Implied price volatility is somewhat correlated with higher information share in options, but its significance shrinks when jointly evaluated with volume.

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INTRODUCTION

The modern world is both increasingly interconnected and increasingly diversified. Commodities and securities can be traded in a variety of different formats – futures, derivatives, etc. – on many different exchanges, all at the same time. Central to the idea of market efficiency is the concept of a common implicit efficient price amongst these many markets. The value of each instrument, regardless of its format, should be linked to the fundamental value of the underlying asset. If prices are indeed efficient, then the prices of the various instruments should never diverge for an extended period of time; the question is, does movement towards the efficient price originate in one market more than the others?

In the early 1990s, researchers explored links between spot and futures markets, dominant and satellite markets, and stock and options markets by regressing the leads and lags of one return against the leads and lags of another in order to determine which market moved first. First movers were thought to control information flow and lead price discovery in their own market and the markets of related securities. In regards to options markets, researchers overwhelmingly found stock prices to lead option prices.[1]

Hasbrouck (1995) felt that lead-lag models were misspecified and developed a new measure of price discovery: information share. Like the lead-lag models, Hasbrouck's information share does not attempt to derive the implicit efficient price, but rather to identify which market moves first to drive the system towards equilibrium. He used a vector error correction model to specify market cointegration, inverted the model to a vector moving average, and decomposed the resulting covariance matrix to quantify the proportions of "efficient price innovation variance" attributed to each

[1]For a detailed list of general lead-lag studies see Hasbrouck (1995), 1176-1177. For a list of lead-lag studies and other early research on price discovery between options markets and equity markets, see Chakravarty et al (2004).

market. Hasbrouck's original model dealt only with price discovery between the New York Stock Exchange and regional U.S. equity markets, but his methods have since been applied to derivative securities.

Gonzalo and Granger (1995) developed an alternative to information share, called Component Share, but most studies have followed Hasbrouck's information share approach. Czerwonko et al (2012) found that, under more precise inversion methods, information share and component share yielded almost identical results.

Chakravarty, Gulen, and Mayhew (2004) applied Hasbrouck's measure of information share to the options market. They aimed to reconcile theory – that informed investors would necessarily be drawn to the leverage opportunities presented in the options markets – with the existing literature, which failed to find evidence of option prices leading stock prices. In contrast to lead-lag studies which based their analysis on short-term data, Chakravarty, Gulen, and Mayhew used intraday ticks for 60 firms over five years. They estimated a 17-18% information share for options markets, on average, with greater information share in out-of-the-money options, compared to at-the-money or in-the-money options.

In contrast to Hasbrouck's information share, Muravyev, Pearson, and Broussard (2013) analyzed disagreements between the stock price implied by put-call parity in the options market and the observed trading price, using three years of intraday data for 39 liquid U.S. stocks and options. In the event of a price disagreement, they found no change in stock price behavior, but rather that option prices adjust to resolve disagreements. As a result, despite the statistical significance of information share, Muravyev, Pearson, and Broussard claim it has little economic significance. The authors further question the current relevance of Chakravarty, Gulen, and Mayhew (2004) because their data pre-dated the decimalization of the options market in the year 2000, citing a paper by Holowczak, Simaan, and Wu (2006) that, using 2002 data, found estimates for information share lower than 17%.

Muravyev, Pearson, and Broussard (2012) also checked pricing disagreements around earnings announcements. They found no significant difference in the changes to stock quotes in the two days leading up to an announcement, and concluded that option markets do not play a greater role in price discovery immediately before an earnings announcement.

Czerwonko et al (2012) claim that information share is higher in the options market than the 17% reported by Chakravarty, Gulen, and Mayhew (2004). They note that lower liquidity and wider bid-ask spreads in options markets add excess noise to the inversion of option quotes to implied stock prices and create a downward bias in information share. The authors further criticize Chakravarty, Gulen, and Mayhew's lagged implied volatility method as imprecise; adding a statistical averaging technique to smooth the volatility parameters greatly increases the resulting information share. In addition, Czerwonko et al used stochastic volatility dynamics to derive implied prices and found that, under their techniques, information share in options markets was double Chakravarty, Gulen, and Mayhew's estimate.

The cited literature focuses on information share in high-volume, highly liquid securities. This paper will test if Chakravarty, Gulen, and Mayhew's information share of 17% in the options market holds among lower-volume securities, particularly after the decimalization of the options market, corresponding to tick size reduction, which began in the year 2000. Additionally, while Chakravarty, Gulen, and Mayhew derived implied stock prices from calls, this paper will calculate information share based on both call and put prices and test for differences in the two measures. The paper will further look for anomalies in information share surrounding earnings announcements and check for correlations between security characteristics and information share.

CONCEPTS AND NUMERICAL METHODS

A. *Common Implicit Efficient Price*

Assume there is a common implicit efficient price underlying each security and all derivatives of that security. Let this efficient price be denoted as EP and follow a random walk. The stock price, S, follows this efficient price with some degree of error:

$$S_t = EP_t + \epsilon_t \tag{2.1}$$

The call price, C, or any other option price is a function of the stock price and volatility, among other parameters.[2] The implied price can be found by inverting this option pricing function.

$$C_t = f(EP_t, \sigma) \tag{2.2}$$

$$IP_t = f^{-1}(C_t, \sigma) \tag{2.3}$$

B. *Implied Volatility and Implied Stock Price*

Unlike the other option pricing parameters, volatility is not directly observable. Implied volatility can be calculated by inverting the option pricing formula and inputting the observed stock price.

$$\hat{\sigma} = f^{-1}(C_t, S_t) \tag{2.4}$$

For tautological reasons, this implied volatility cannot be used to calculate the implied efficient price because re-inputting implied volatility in the inverted formula will necessarily yield the previously-inputted observed stock price.

$$f^{-1}(C_t, \hat{\sigma}) = S_t \tag{2.5}$$

[2]Standard parameters for any option pricing method include the strike price, the risk-free rate, time to maturity, and the dividend discount rate, in addition to the underlying stock price and volatility.

Chakravarty et al (2004) use a 30-minute lagged volatility to calculate the implied stock price. This eliminates the potential tautological error, while still allowing for intraday changes in volatility.[3]

$$IP_t = f^{-1}(C_t, \hat{\sigma}_{t-30m}) \tag{2.6}$$

By way of the Newton-Raphson method, the Black Scholes formula for option pricing can be used to back out implied volatility and, after lagging implied volatility by 30 minutes, to calculate the implied stock price.[4]

$$C(S, K, \sigma, r, \tau, \delta) = Se^{-\delta T}N(d_1) - Ke^{-rT}N(d_2) \tag{2.7}$$

$$\text{where} \quad d_1 = \frac{ln(S/K) + (r - \delta + \frac{1}{2}\sigma^2)T}{\sigma\sqrt{T}} \quad \text{and} \quad d_2 = d_1 - \sigma\sqrt{T}$$

C. Information Share

The efficient price underlying a security and its derivatives takes the form of a random walk.

$$EP_t = EP_{t-1} + u_t \tag{2.8}$$

The goal of information share is to identify the contribution of each market (whether two different equity markets, futures markets, options markets, etc.) to the variance of the random walk. The first step is to form a vector of the observed stock

[3]See Chakravarty et al (2004) 1253-54 for detailed justification of the 30-minute lag. Czerwonko et al (2012) find that simple lagged implied volatility without a smoothing mechanism, such as taking the median volatility over a five-minute moving window, reduces information share by almost half of its "true" value. Further downward bias arises from the microstructure noise in the stock price and the noise inherent in using the midpoint of the wide option bid-ask spread as a proxy for option price.

[4]Although Black Scholes is strictly a formula for pricing European options, it has been adopted for ease of calculation. Details about the timing of option dividends, and potential profitable early exercise, are provided in the Data section.

price and the implied stock price.

$$p_t = \begin{bmatrix} S_t \\ IP_t \end{bmatrix} = \begin{bmatrix} EP_t + \epsilon_{S,t} \\ EP_t + \epsilon_{IP,t} \end{bmatrix} \tag{2.9}$$

Since both the stock price, S_t, and the implied price from the options market, IP_t, rely on EP_t, which is a random walk and thus integrated of order 1, the price vector is nonstationary. Normally, taking first differences would solve this problem and allow the use of OLS; however, since S_t and IP_t are cointegrated, meaning they cannot diverge from each other without bound, the assumptions necessary for OLS do not hold. A vector error correction model (VECM) of first differences will, however, accurately account for the cointegration:

$$\Delta p_t = \phi_1 \Delta p_{t-1} + \cdots \phi_m \Delta p_{t-m} + \beta(z_{t-1} - \mu) + e \tag{2.10}$$

where z_{t-1} is the lagged difference between the two prices $(S_{t-1} - IP_{t-1})$ and μ is the mean error, or the long-run average discrepancy between the two markets.

The VECM is inverted to a vector moving average model (VMA) by initiating a series of unit shocks to each of the variables and computing the impulse response.

$$\Delta p_t = e_t + \theta_t e_{t-1} + \theta_2 e_{t-2} + \cdots \tag{2.11}$$

Summing the moving average coefficient matrices yields ψ, which can be combined with the variance of the VMA, Ω, to calculate $\psi\Omega\psi'$, the total variance of the changes in implicit efficient price. Since the price innovations in the stock and options markets are likely correlated, the matrix is not diagonal and there is no precise measure of information share. One method of reducing correlation is taking a shorter observation interval; for one-second intervals, however, this is not practical.

Instead, triangularization of the covariance matrix allows calculation of upper and lower bounds of information share for each market.[5]

[5]See Chakravarty et al (2004), 1243-1244. For a detailed explanation of the derivation of and theory behind information share see Hasbrouck (1995), 1182-1184. For application of VECM and information share to more than two securities, see Hasbrouck (2007), 100-102. Specific calculations were accomplished using SAS code provided by Joel Hasbrouck on his website http://people.stern.nyu.edu/jhasbrou/Research/WorkingPaperIndex.htm#PriceDisovery.

DATA

My analysis is based on 12 trading days worth of data for 14 S&P 500 stocks. I wanted to analyze prominent securities with a wealth of available data without restricting the sample to only the most actively-traded options.[6] The 14 companies were each scheduled to issue earnings announcements on 27 February 2013. Second-by-second bid and ask quotes were obtained from Bloomberg for each trading day from 21 February 2013 to 8 March 2013. When multiple quotes were observed in a given second, only the last quote was used. I replaced missing observations with the most recent, and hence prevailing, quote, and calculated the midpoint of the bid-ask spread to represent the option value.[7]

The first set of option data includes the most near-term at-the-money (ATM) option for each security, with the appropriate ATM strike reevaluated daily. For some securities, the same option fulfilled this requirement over the entire sample period. For others, however, different options were tracked each day and as a result, option prices cannot be lagged interday to fill in missing observations. Option volume is much smaller than that of the underlying stock; it is not uncommon for the option market to be open for several seconds or even several minutes before a series of bid-ask quotes is posted. Since this option information is missing, and cannot be interpolated from previous-day prices, implied volatility and the implied stock price cannot be calculated for those time intervals, thus requiring the exclusion of the initial observed stock prices from analysis. The first few minutes of the trading day potentially contain a large flow of information; excluding this data could significantly bias estimates of information share. Furthermore, because I use a strict 30-minute lagged volatility to

[6]Chakravarty et al (2004) uses the 60 options most actively traded on the CBOE. I chose to include less-actively traded options in order to test the effect of liquidity on information share.

[7]The bid-ask spread in the options market is generally wider than that of the equity market. Czerwonko et al (2012) note that using the midpoint of a wide spread to obtain the implied stock price adds noise and mprecision to information share calculations.

compute the implied stock price, the missing observations result in additional missing observations 30 minutes later. To check this concern, the second set of option data consists of second-by-second tick data for the near-term median-strike (MS) option over the period; tracking a single option allows the interday lag of option prices.

Most of the stocks in the sample pay quarterly, discrete dividends. For ease of calculation, however, dividends were treated as continuous, according to the yearly rates quoted on Bloomberg.[8]

Table 1 reports characteristics for each of the firms included in the sample. Market capitalization was taken from Google Finance. Implied volatility is listed according to the 30-day implied volatility for at-the-money options reported by Bloomberg on 8 March 2013, the last day of the sample. Volume measures for the stock and options represent the total number of units traded over the 12-day sample, according to Bloomberg's record of second-by-second trades.

Although quotes were obtained second-by-second, Hasbrouck's method calculates daily information share; all analysis performed on information share is conducted at time intervals no finer than the daily level.

[8]In a few cases, stocks either paid a dividend during the sample period or realized an ex-dividend date, which may pose problems with my simplifying assumptions and use of the Black Scholes formula. Stocks paying dividends during the sample period include TJX (3/7/13), LTD (3/8/13), and CPP (3/8/13). Stocks holding an ex-dividend date during the period include JOY (2/28/13), and HNZ (2/21/13).

Table 1: Stock Characteristics and Information Share for ATM Options

Ticker	Market Cap	Imp Vol	Stock *Volume (M)*	Call *Volume*	Put *Volume*	Stock IS *Min*	Stock IS *Max*	Call IS *Min*	Call IS *Max*	Put IS *Min*	Put IS *Max*
TGT	44.16	15.05	82.46	10,335	15,507	0.788	0.981	0.014	0.110	0.002	0.144
NRG	8.52	19.29	46.08	8,513	2,484	0.913	0.969	0.004	0.029	0.025	0.068
JOY	6.03	31.70	29.66	3,932	8,920	0.710	0.965	0.010	0.186	0.013	0.194
TJX	34.12	16.47	56.58	9,501	6,398	0.897	0.969	0.016	0.066	0.009	0.048
JCP	3.4	60.88	246.95	15,745	31,991	0.615	0.974	0.016	0.267	0.006	0.261
LTD	13.32	21.59	38.96	847	821	0.922	0.972	0.007	0.036	0.014	0.058
PLL	7.43	15.05	6.64	319	59	0.954	0.982	0.005	0.018	0.010	0.034
MYL	11.32	17.63	72.74	2,907	243	0.761	0.962	0.002	0.061	0.025	0.221
MNST	8.22	39.17	26.98	4,039	7,237	0.849	0.968	0.004	0.063	0.020	0.101
DLTR	10.55	24.42	50.34	5,757	5,108	0.887	0.952	0.013	0.054	0.028	0.075
AES	9.25	18.58	77.22	266	129	0.905	0.933	0.045	0.071	0.012	0.036
HNZ	23.17	3.14	51.56	866	178	0.938	0.955	0.026	0.039	0.012	0.032
CNP	10.21	19.10	41.76	507	125	0.949	0.959	0.024	0.037	0.008	0.024
LUK	6.72	118.08	45.64	185	281	0.909	0.940	0.038	0.072	0.013	0.033

Stock volume represents the total number of shares traded in the ATM sample across the 12-day sample period, and is reported in millions. Option volume is in units. Implied volatility was taken from Bloomberg's report for 30-day implied volatility for at-the-money options on 3/8/2013, which is the last day of the sample. Market capitalization was taken from Google Finance on 5 April 2013, and is reported in billions. The information share bounds listed are the average for each stock over the 12-day time period.

RESULTS

Table 2: Information Share for ATM Options

	Stock		**Call**		**Stock**		**Put**	
Date	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
21-Feb	0.937	0.983	0.017	0.063	0.913	0.979	0.021	0.087
22-Feb	0.934	0.982	0.018	0.066	0.915	0.984	0.016	0.085
25-Feb	0.940	0.992	0.007	0.060	0.901	0.967	0.033	0.099
26-Feb	0.920	0.968	0.032	0.080	0.901	0.975	0.025	0.099
27-Feb	0.932	0.981	0.019	0.068	0.877	0.968	0.032	0.123
28-Feb	0.893	0.952	0.048	0.107	0.882	0.980	0.020	0.118
1-Mar	0.952	0.997	0.003	0.048	0.894	0.982	0.018	0.106
4-Mar	0.909	0.965	0.035	0.091	0.908	0.984	0.016	0.092
5-Mar	0.948	0.987	0.013	0.052	0.888	0.983	0.017	0.112
6-Mar	0.898	0.975	0.025	0.102	0.907	0.965	0.035	0.093
7-Mar	0.914	0.977	0.023	0.086	0.929	0.979	0.021	0.071
8-Mar	0.920	0.985	0.015	0.080	0.902	0.979	0.021	0.098
Average	**0.925**	**0.979**	**0.021**	**0.075**	**0.901**	**0.977**	**0.023**	**0.099**

Table 3: Information Share for MS Options

	Stock		**Call**		**Stock**		**Put**	
Date	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
21-Feb	0.947	0.995	0.005	0.053	0.920	0.990	0.010	0.080
22-Feb	0.932	0.985	0.015	0.068	0.934	0.983	0.017	0.066
25-Feb	0.923	0.984	0.016	0.077	0.924	0.983	0.017	0.076
26-Feb	0.939	0.987	0.013	0.061	0.897	0.976	0.024	0.103
27-Feb	0.950	0.989	0.011	0.050	0.887	0.970	0.030	0.113
28-Feb	0.863	0.949	0.051	0.137	0.932	0.979	0.021	0.068
1-Mar	0.927	0.983	0.017	0.073	0.962	0.990	0.010	0.038
4-Mar	0.889	0.963	0.037	0.111	0.929	0.979	0.021	0.071
5-Mar	0.956	0.992	0.008	0.044	0.924	0.978	0.022	0.076
6-Mar	0.941	0.992	0.008	0.059	0.926	0.978	0.022	0.074
7-Mar	0.945	0.982	0.018	0.055	0.945	0.989	0.011	0.055
8-Mar	0.929	0.980	0.020	0.071	0.965	0.990	0.010	0.035
Average	**0.928**	**0.982**	**0.018**	**0.072**	**0.929**	**0.982**	**0.018**	**0.071**

Table 4: Joint Information Share for ATM Options

	Stock		**Call**		**Put**	
Date	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
21-Feb	0.869	0.961	0.016	0.081	0.010	0.089
22-Feb	0.876	0.971	0.011	0.075	0.009	0.082
25-Feb	0.856	0.961	0.006	0.073	0.030	0.110
26-Feb	0.841	0.947	0.032	0.099	0.011	0.105
27-Feb	0.876	0.968	0.013	0.068	0.010	0.086
28-Feb	0.805	0.935	0.035	0.098	0.018	0.137
1-Mar	0.882	0.980	0.002	0.053	0.011	0.093
4-Mar	0.823	0.953	0.030	0.116	0.012	0.093
5-Mar	0.884	0.980	0.008	0.047	0.008	0.089
6-Mar	0.852	0.967	0.010	0.087	0.020	0.087
7-Mar	0.863	0.965	0.018	0.082	0.011	0.079
8-Mar	0.856	0.966	0.011	0.073	0.018	0.089
Average	**0.857**	**0.963**	**0.016**	**0.079**	**0.014**	**0.095**

Table 5: Joint information Share for MS Options

	Stock		**Call**		**Put**	
Date	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
21-Feb	0.883	0.977	0.008	0.066	0.010	0.082
22-Feb	0.888	0.966	0.008	0.067	0.014	0.068
25-Feb	0.861	0.964	0.011	0.086	0.017	0.088
26-Feb	0.873	0.966	0.012	0.073	0.010	0.092
27-Feb	0.870	0.965	0.006	0.056	0.018	0.099
28-Feb	0.864	0.942	0.037	0.092	0.012	0.058
1-Mar	0.928	0.980	0.005	0.044	0.010	0.037
4-Mar	0.889	0.969	0.015	0.066	0.011	0.053
5-Mar	0.891	0.973	0.009	0.067	0.009	0.062
6-Mar	0.896	0.977	0.006	0.059	0.013	0.063
7-Mar	0.918	0.981	0.013	0.050	0.005	0.044
8-Mar	0.906	0.972	0.015	0.061	0.009	0.038
Average	**0.889**	**0.969**	**0.012**	**0.066**	**0.011**	**0.066**

A. *Information Share from Calls and Puts*

Table 2 reports the mean daily bounds of information share between stocks and ATM options for each of the 12 days in the sample. The last row of the table shows a higher average maximum bound for put information share than for call information share. Statistically, however, this difference is not significant (p-value = 0.0723). Furthermore, the difference disappears in a sample of MS options, as shown in Table 3.

Table 3 reports mean daily information share bounds between stocks and MS options for the same period. Unlike the ATM options, this data set always includes the first seconds of trading data for each day. The last row of Table 3 shows no difference between the maximum bound of information share for calls and puts; both range between 1.8% and 7.2%. Thus, the data implies a maximum option information share of 7.2%, a measure which is robust to put or call price calculations in samples of ATM options and MS options.

Table 4 shows a similar discrepancy when evaluating the joint information share between calls, puts, and stocks. In this case, calls and puts were treated as separate markets, potentially contributing information share to each other and to the stock market. Looking at the last row of the table, puts seem to have a higher maximum information share than stocks (9.5% compared to 7.9%). As in the two-market case, however, the difference is not statistically significant and disappears when considering MS options. The last row of Table 5 reports an average information share range of 1.2% to 6.6% for calls and a range of 1.1% to 6.6% for puts. Thus, each option market contributes at most 6.6% to information share.

B. *Volume and Earnings Announcements*

This section sets information share aside and considers only changes in trading volume on the day of, and day before, an earnings announcement.

Table 6: Volume Around Earnings Announcements

The dependent variables are: stock volume (regression 1), option volume (regression 2), call volume (regression 3), and put volume (regression 4). Stock volume is the total number of shares of stock traded on any given day; call volume and put volume follow the same pattern. EA is a dummy variable representing 27 February 2013, the day of the earnings announcement. P-values are reported in parentheses.

	Stock Volume	*Option Volume*	*Call Volume*	*Put Volume*
	1	**2**	**3**	**4**
Intercept	5,139,066	369.49	324.10	414.88
	(0.000)	(0.000)	(0.000)	(0.000)
EA	728,457	680.44	662.19	698.69
	(0.542)	(0.001)	(0.002)	(0.049)
R^2	0.001	0.033	0.059	0.0231

Table 6 reports changes in average stock volume, option volume (combined call and put volume), call volume, and put volume on an earnings announcement date. Although stock volume shows no significant difference from the mean on the day of the announcement, option volume exhibits a significant increase. Call volume almost triples (from 324 to 946) and put volume more than doubles (from 415 to 1,113). The data seems to suggest that, with the influx of information occurring at an earnings announcement, additional, and potentially informed, investors are more likely to turn to the options market than the stock market. Although not reported in the table, all four cases show no significant change in volume on the day before the earnings announcement, or the day after.

C. Information Share around Earnings Announcements

Section A examined the maximum bound of option information share and found equal contributions from puts and calls. Section B found that option trading volume increased on the day of an earnings announcement. This section will address changes in daily information share surrounding an earnings announcement, checking if the increase in option trading volume is correlated with a change in information share. The sample covers 21 February to 8 March, with earnings announced on 27 February.

Table 7: Stocks Exhibiting Change in Information Share near Earnings Announcements

Reported results come from regressing the maximum bound of information share for calls or puts on the dummy variable representing the day of an earnings announcement, or the day before. The coefficients listed represent the difference from the mean option information share on the listed day for the given security. P-values are reported in parentheses.

ATM Options			MS Options		
Ticker	**Call**	**Put**	**Ticker**	**Call**	**Put**
On an Earnings Announcement			On an Earnings Announcement		
MYL	0.056		**NRG**		0.257
	(0.036)				(0.000)
			JCP		0.265
					(0.043)
The Day Before			The Day Before		
LUK	0.215	0.063	**MYL**		0.480
	(0.000)	(0.011)			(0.009)

A few select securities exhibit a difference in option market information share on the day of an earnings announcement or the day before, as shown in Table 7. In every case, the change to option information share is positive. The timing of these changes, however, is not consistent across option types, or between ATM and MS data, implying that Table 7 results could be one-time anomalies. Furthermore, the aggregate sample shows no significant difference in information share on the day of the earnings announcement, the day of and the day following, the day of and the two days following, and the day before for both the ATM options data and the MS options data (see Table 8).[9]

Due to the short time frame of this sample, regression analysis may not be the best method for detecting changes in information share around an earnings announcement. Regression results only identify differences relative to the mean, which may not be well specified over 12 days that include an earnings announcement; graphs, on the other hand, can help show relative changes in information share day to day, which, for this short-term sample, may be more informative than differences from the mean. The discrepancies in information share change could also be due to company-specific factors – timing of the earnings announcement, positive or negative news, etc. – making the insignificant results a product of omitted variable bias.

Figure 1: JCP ATM Information Share

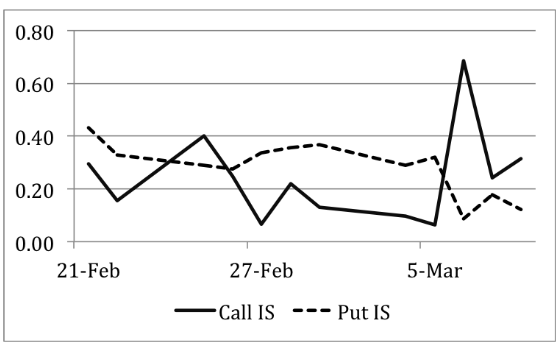
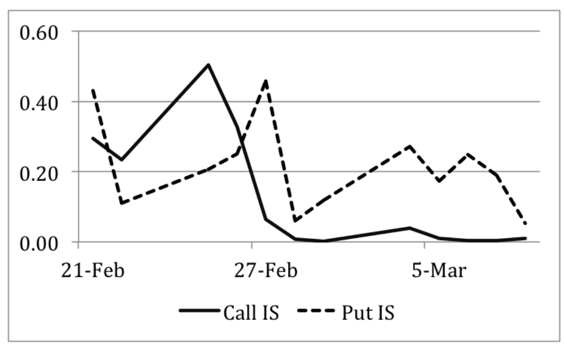


Figure 2: JCP MS Information Share



Although ATM data was inconclusive about changes in information share (as shown in Figure 1), JCP experienced higher-than-average put information share on the day of the earnings announcement in the MS data (see Figure 2). Figure 2 also shows increasing call information share in the days leading up to the earnings announcement followed by a dramatic decrease, none of which was identified by the

[9]Regressions 1 and 2 show that information share for ATM calls is not significantly different from the mean information share (p-value = 0.777 for the day of an Earnings Announcement; p-value = 0.849 for the day before). Although not recorded in Table 8, I also tested for differences for the two-day period beginning the day of an earnings announcement, and for the two-day period beginning the day before. Neither were significant. Regression results for ATM puts, and for MS calls and puts, were also highly insignificant.

regression. To correlate the graphs with market events, at the close of the trading day, JCP reported a loss of 1.95 per share, which was a greater loss than estimated. The stock market had closed at 21.16 and re-opened the next day at 17.87.

Figure 3: NRG ATM Information Share

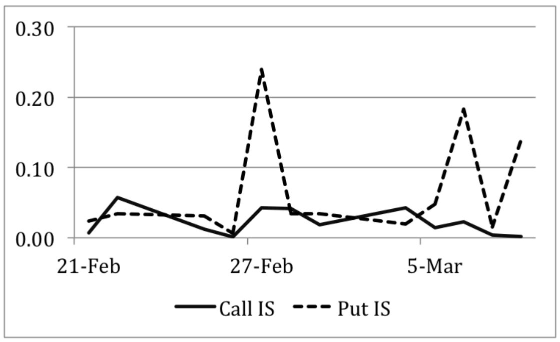
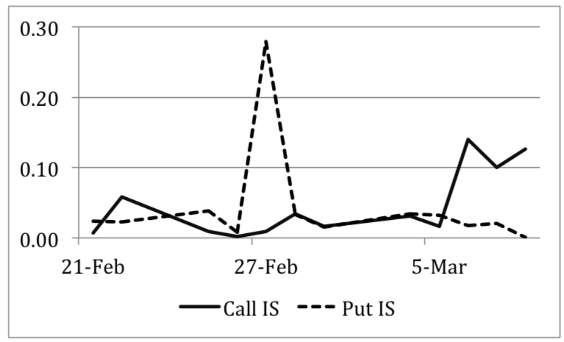


Figure 4: NRG MS Information Share



Regression analysis of NRG found an increase in put information share on the day of the earnings announcement. This anomaly clearly showed up in the MS data (see Table 7 and Figure 4). Although Figure 3 reveals a spike in ATM put information share that is similar to the MS data in both timing and magnitude, regression analysis failed to yield a significant coefficient, likely because a second spike near the end of period raised the average level of information share and made the earnings announcement increase seem insignificant.[10] NRG announced earnings before the market opened, reporting a higher-than-anticipated gain of 0.07 per share. The market opened for NRG only 1 cent off of its closing value, and price fluctuations settled out before the close of day.

[10]This demonstrates one weakness of a 12-day data set - a few outliers have the power to eliminate otherwise significant results.

Figure 5: MYL ATM Information Share

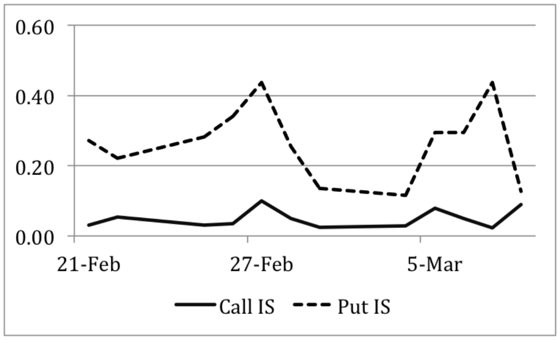
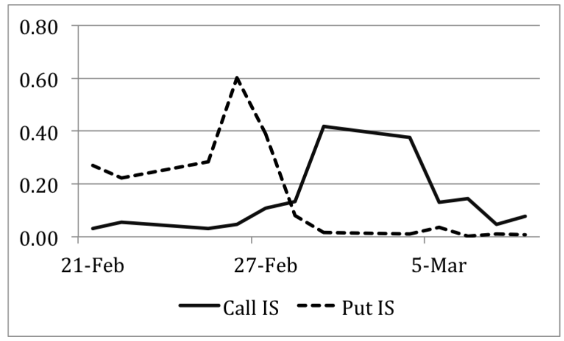


Figure 6: MYL MS Information Share



MYL reported a small positive surprise at the close of the trading day; the price jumped from 28.57 to 29.34 when the market opened the next morning. Regression results in Table 7 show different information share changes for MYL across the two data sets: an increase in call information share on the day of the announcement for ATM data, and an increase in put information share the day before for MS data. Figures 5 and 6 reconcile these differences, revealing a spike in put information share near the announcement for ATM data and an increase in call information share following the announcement for MS data.

Figure 7: LUK ATM Information Share

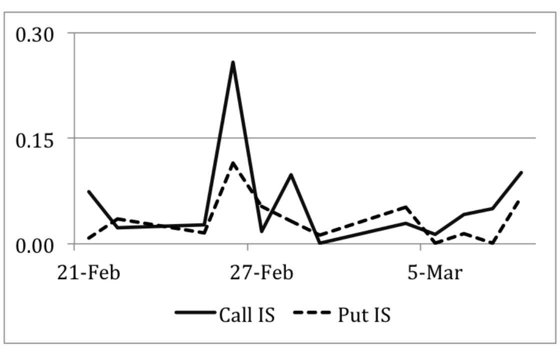
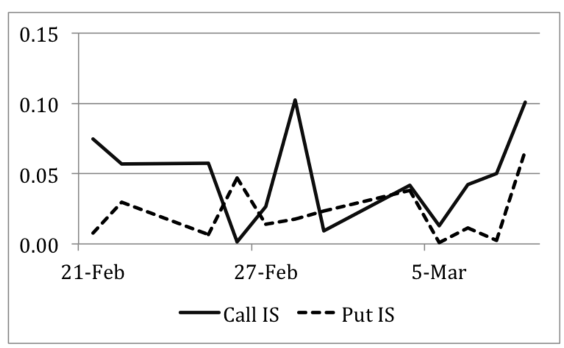


Figure 8: LUK MS Information Share



LUK is another example of a security that exhibited anomalies around earnings announcements in both the ATM and MS data which were not identified through regression analysis due to other data anomalies. The market events for LUK are different than the other securities in the sample. Although LUK was scheduled to release earnings on 27 February, the company reported a positive surprise in their earnings two days early, near the close on 25 February. Then, on 28 February, LUK announced their quarterly cash dividend and confirmed a merger with JEF to take place the following day.[11]

Figure 7 shows a large increase in call information share on 27 February (the day before the merger announcement); put information share also increases, but not as dramatically. Figure 8 shows a similar spike in call information share on 28 February (the day of the merger announcement), as well as a mild increase in put information share on the 27th. The overall level of information share is higher in the ATM data, but the patterns of information share change are similar for the two data sets.[12]

D. *Security Characteristics and Information Share*

Table 1 lists all of the securities represented in the sample along with characteristics such as market capitalization, implied volatility, trading volume, and the three-way information share between calls, puts, and the underlying stock. JCP easily has the highest volume in both the stock market and the options markets, and also reports the highest possible information share values for the options markets. Regression results support this correlation. Regressions 3 and 4 in Table 8 show call volume and stock volume, respectively, to be positively and significantly correlated with information share in the option market (call volume estimate = 2.95e-05, p-value = 0.003; stock volume estimate = 6.14e-09, p-value = 0.000). Regression 5 clarifies that, when both call volume and stock volume are included in the regression, the significance of call volume disappears (p-value = 0.504). There is a high degree of

[11] Even though LUK did not report earnings on 27 February as scheduled, they were not excluded from the sample because of the other large informational events occurring in roughly the same period.

[12] Graphical analysis of other securities would likely yield more interesting anomalies. However, for the purposes of this paper, analysis is restricted to the four securities showing earnings announcement anomalies in the regressions.

collinearity between the two measures of volume, but stock volume is a much more powerful predictor of information share than option volume.

The other strong predictor of information share, as reported in Table 8, is volatility in the option market. Regression 7 shows a significant, positive correlation between option volatility and call information share (estimate = 6.97e-04; p-value = 0.010). The significance of volatility diminishes, however, when stock volume is included in Regression 8 (p-value = 0.069). Volatility is insignificant when regressed on put information share for the ATM data.

To test for robustness, I regressed maximum call information share on the interaction term for volume on an earnings announcement day. The results were insignificant for both stock volume (p-value = 0.822) and call volume (p-value = 0.787). I also regressed the same dependent variable on the interaction term for volume the day before an earnings announcement. Again, the results were insignificant for stock volume (p-value = 0.456) and call volume (p-value = 0.981). Running the same regressions for maximum put information share also failed to yield significant results.

Market capitalization is not a significant predictor of information share in the options market, as can be seen in Table 1. TJX, for example, has ten times the market capitalization of JCP, but less than a quarter of the trading volume, and a much smaller proportion of information share in the options markets. The insignificance of market capitalization is also demonstrated econometrically in Regression 6 of Table 8 (estimate = -6.97e-04; p-value = 0.299).

Table 8: Regression: Stock Characteristics on Maximum ATM Call Information Share

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Intercept	0.076	0.075	0.064	0.043	0.043	0.085	0.054	0.031
	(0.000)	0.000	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.006)
EA	-0.008							
	(0.777)							
BEFORE		0.005						
		(0.849)						
Call Volume			2.95e-05		7.17e-06			
			(0.003)		(0.504)			
Stock Volume				6.14e-09	5.71e-09			5.75e-09
				(0.000)	(0.000)			(0.000)
Mktcap						-6.97e-04		
						(0.299)		
Volatility							6.97e-04	4.69e-04
							(0.010)	(0.069)
R^2	0.0005	0.0002	0.0518	0.1430	0.1454	0.0065	0.0390	0.1601

The dependent variable is the upper bound of information share for the implied stock price derived from call options. EA is a dummy variable set to 1 for the the day of an earnings announcement (27 February 2013). BEFORE is a dummy variable set to 1 for the day before an earnings announcement (26 February 2013). P-values are reported in parentheses below their respective coefficients.

CONCLUSIONS

Following Chakravarty, Gulen, and Mayhew (2004), I derive implied stock prices using 30-minute lagged implied volatility and the midpoint of bid-ask quotes for near-term, at-the-money and near-the-money calls and puts. I apply Hasbrouck's (1995) methodology to calculate bounds of information share between stocks and calls, stocks and puts, and stocks, puts, and calls. These measures help quantify proportions of price discovery occurring between stock and options markets.

I find a statistically significant proportion of information share in the options market, with a maximum bound of 7.2%. This is lower than Chakravarty, Gulen, and Mayhew's estimate of 17%, likely due to the intervening decimalization of the options market and to sample-specific characteristics, such as my inclusion of lower-volume stocks, and the comparatively short time horizon of my sample.

I find no significant difference for information share derived from put prices as opposed to that derived from call prices. Although implied price volatility seems to be correlated with higher option information share, most of its influence can be explained by controlling for volume.

Information share in the option market tends to be higher for more frequently traded stocks. High option volume also predicts increased option information share, but not as strongly. These correlations hold across different securities, but they may not explain day-to-day differences. Although options experience high volume on the day of an earnings announcement, sample-wide there is no statistical evidence of increased option information share the day of an earnings announcement. There is also, however, no significant change in stock market volume on the day of an announcement, which may explain the lack of change in information share.

The sample-wide insignificance of earnings announcements on option share is not conclusive. Several of the securities in the sample did exhibit significant, positive changes in option information share in the period surrounding an earnings announcement. Other securities seem to reveal an increase in option information share when viewed graphically, although they failed econometric tests for significance. A longer time period would help to better estimate the mean information share and, subsequently, better detect deviations from the mean. Additionally, a sample including more securities would better determine if higher option information share at an announcement is an exception, or the rule.

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