

# Internet appendix to

## Is There Price Discovery in Equity Options?

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### 1. Introduction

This appendix reports additional results that supplement the results in Muravyev, Pearson, and Broussard (2012). Specifically, it includes: (a) a figure showing the frequency of primary sample disagreement events throughout the sample period; (b) detailed stock-by-stock results for the one-minute evaluation period that underlie the one-minute evaluation period results in Table 2 of Muravyev, Pearson, and Broussard (2012); (c) the results of quantile regressions explaining quote changes at various quantiles during the disagreement events; (d) the results of quantile regressions explaining signed volume at various quantiles during the disagreement events; and (e) results for signed volume during the various subsamples of disagreement events for which results on quote changes are presented in Section 6 of Muravyev, Pearson, and Broussard (2012).

### 2. Frequency of Primary Sample Disagreement Events.

The primary sample disagreements occur on average more than twice per stock, per day. Figure A1 shows smoothed estimates of the average numbers of  $\{P>IP\}$ -type (the solid red line) and  $\{IP>P\}$ -type events (the dashed blue line) per stock per day. The estimates are constructed by counting the total (across stocks) number of events per day, dividing by the number of stocks and ETF's in the sample on that day, and then smoothing the resulting time series by taking a 30-

day moving average. The disagreement frequency falls from about four per day in the beginning of the sample period to less than one per day at the end, with an overall average of more than two per stock per day. There are two possible drivers for the trend in the frequency of disagreement events. First, volatility as measured by the VIX was falling steadily from 25% in April 2003 to 12% in October 2006. Next, improvements in technology may have made it easier for option market makers to avoid price disagreements.

### 3. Detailed Stock-by-Stock Results for the One-Minute Evaluation Period

Table A1 presents the average quote changes during disagreement events and matched control events for each stock in the sample, using an evaluation period of one minute. These detailed stock-by-stock results underlie the summary results for the one-minute evaluation period in Table 2 of Muravyev, Pearson, and Broussard (2012). The left-hand half of Table A1 presents the average changes in the option-implied bid, option-implied ask, and stock midpoint for both the treatment and control samples separately for each stock or ETF for the {P>IP}-type disagreements. In the treatment sample, the average changes in the option-implied bid are positive for every stock and ETF. The across-stock average of the stock-by-stock average changes in the implied bid is 4.8 cents, and the minimum of the average changes across stocks is 2.4 cents. For the control sample, the average changes in the implied bids are smaller for every stock and ETF, with the largest being 0.7 cents and the average being only 0.3 cents. The average changes in the implied ask quotes are also positive for every stock in the treatment sample, with the average of the stock-by-stock averages change being 8.1 cents and the minimum across stocks being 3.3 cents, respectively. For the control sample, the implied ask increases by an average of 2.7 cents, reflecting some spread widening.<sup>1</sup> Thus, the average difference in the implied ask quote between the treatment and control samples is 5.4 cents, larger than the initial mispricing. This average difference of 5.4 cents is also large relative to the average price of less than two dollars for the at-the-money for call and put options that appear in the sample.<sup>2</sup>

If the stock followed the options, the average change in the stock midpoints in the

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<sup>1</sup> Disagreements are more likely to occur when the option-implied bid-ask spread is smaller than average. Because the option-implied bid-ask spread is used in identifying the matching observations in the control sample, the control sample includes observations of smaller than average option-implied bid-ask spread, and some spread widening is to be expected.

<sup>2</sup> Through the put-call parity relationship  $S = C - P + PV(K)$ , the change in the option-implied stock price  $S$  is equal to the change in the difference between the call and put prices  $C - P$ .

treatment sample would be negative, and less than the corresponding average changes for the control sample. Inconsistent with this hypothesis, the average changes in the stock midpoint are slightly positive for most stocks, with an overall average of 0.1 cents, and in all cases are greater than or equal to the average changes in the stock midpoint in the control sample. Together with the corresponding results for the option-implied quotes, these results imply that for the {P>IP}-type disagreements the options follow the stock and the stock does not follow the options.

The right-hand half of the table presents the corresponding average quote changes for the {IP>P}-type disagreements. The average changes in the option-implied bid and ask are now negative and less than the corresponding average changes in the control sample for every stock and ETF, implying that in this case also the options follow the stocks. (Recall that for the {IP>P}-type disagreements the option-implied stock prices exceed the actual stock prices, so that if the options follow the stock the average changes in the option-implied bid and ask prices will be negative.) The overall average change in the implied bid is  $-7.7$  cents, close to the magnitude of the overall average change in the implied ask of 8.1 cents for the {P>IP}-type disagreements, and the overall average change in the implied bid is  $-4.6$  cents, close to the magnitude of the overall average change in the implied bid of 4.8 cents for the {P>IP}-type disagreements. The overall average change in stock prices is zero and less than the overall average change in the control sample, inconsistent with the hypothesis that the stocks follow the options. Overall, this table produces strong evidence that if prices disagree, the options market adjusts to eliminate mispricing, and the stock market does not adjust. It seems worth emphasizing that the average changes in the option prices are large, and typically larger than the extent of the disagreement, while the average change in stock prices are close to zero. To the extent that the average changes in stock prices are non-zero, the stock prices move to widen the disagreement rather than reduce it.<sup>3</sup>

#### **4. Quantile Regressions of Quote Changes**

The regressions (3)-(5) in Muravyev, Pearson, and Broussard (2012) and the results in Tables 2 and 3 of that paper and the results in Table A1 of this appendix allow for statistical inference about only the average and conditional average effects of the disagreement. We

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<sup>3</sup> The 3 cent change in the stock midpoint for MMM for the {IP>P}-type events is based on only 384 disagreement events (see Table 1), and is about equal to the average bid-ask spread for MMM. (MMM was the highest price stock in our sample and the only stock in our sample with a spread consistently above one cent.)

provide evidence that the distributional shifts apparent in Figure 3 of Muravyev, Pearson, and Broussard (2012) are statistically significant by estimating quantile regressions analogous to (3)-(5) of Muravyev, Pearson, and Broussard (2012) for the implied bid, implied ask, and actual stock midpoint for both the  $\{P>IP\}$  and  $\{IP>P\}$ -type disagreements. We report results only for specifications that include the vector of control variables  $X$ , and use the same control variables used in the conditional mean regressions for which results were reported in Table 3 of Muravyev, Pearson, and Broussard (2012). Because the quantile regressions are more demanding of the data and some of the stocks have relatively few events due to their early departures from the sample, we estimate the quantile regression for a pooled sample that combines the events for the 39 different stocks and ETFs.

Table A2 presents the coefficient estimates and standard errors for the disagreement dummy in regressions for the 10%, 30%, 50%, 70%, and 90% quantiles, for the various regression models and both disagreement types. For the  $\{P>IP\}$ -type disagreements (the left-hand side of the table) the option-implied bid and ask are below the actual stock price, and increases in the implied ask are necessary to eliminate the disagreement. For the implied ask regressions the coefficient on the dummy variable is at least 0.05 (five cents) for all except the 10% quantile. In the implied bid regressions the coefficient on the dummy variable is at least 0.05 (five cents) for all except the 30% quantile. The reported standard errors are very small and in many cases zero; they are based on 100 bootstrap iterations, and in many cases the same coefficient estimate is obtained in all 100 iterations.

For the  $\{IP>P\}$ -type disagreements (the right-hand side of the table) the option-implied bid and ask are above the actual stock price and we focus on changes in the implied bid. For these regressions the coefficient on the dummy variable is less than or equal to  $-0.05$  for all except the 90% quantile, and again bootstrapped standard errors are either zero or close to zero. In the implied ask regressions the dummy coefficient is  $-0.05$  or smaller at all except the 70% quantiles. These results are consistent with the shifts in the distributions shown visually in Panels A, B, D, and E of Figure 3 of Muravyev, Pearson, and Broussard (2012), and demonstrate that the distribution shifts in those panels are statistically significant.

In contrast, the quantile regressions for changes in the stock price provide no evidence that the stock follows the options. For both the  $\{P>IP\}$  and  $\{IP>P\}$ -type disagreements the estimated coefficient on the dummy is either zero or close to zero at most of the quantiles. To the

extent that the estimated dummy coefficients are different from zero, they indicate that during the disagreement events at some quantiles the actual stock price continues moving away from the option-implied stock prices, not toward them. This finding is consistent with the distributions of changes in stock prices shown in Panels C and F of Figure 3 of Muravyev, Pearson, and Broussard (2012).

#### **4. Quantile Regressions Explaining Signed Volume During the Disagreement Events**

Table A3 provides additional evidence about signed volume during the disagreement events by presenting coefficient estimates from quantile regressions predicting signed volume during both the  $\{P>IP\}$  and  $\{IP>P\}$ -type disagreements, based on a 60-second evaluation period. We use a pooled sample that combines both the treatment and control samples for all stocks, and capture the effect of the disagreement with a dummy variable  $D$  that takes the value of one for the disagreement events. As with the previous quantile regressions predicting quote changes, we report results for a specification includes the vector of control variables  $X$ .

Table A3 presents the coefficient estimates and asymptotic  $t$ -statistics for the disagreement dummy in regressions for the 10%, 30%, 50%, 70%, and 90% quantiles of delta-signed volume in all options, delta-signed volume in just the call-put pair that triggered the disagreement, and signed volume in the underlying stock. For the  $\{P>IP\}$ -type disagreements (the left-hand side of the table), the regressions for signed delta-equivalent volume in all options shows that the disagreement causes large increases in volume at the 70% and 90% quantiles. The effects of the disagreement at the 70% and 90% quantile are 2,580 and 7,480 share equivalents. The effect at the median is 950 delta-equivalent shares. This effect at the median implies that more than half of the disagreement events display signed volume in the direction that will tend to push prices to close the disagreement. Delta-equivalent volume in the call-put pair that triggered the disagreement is 1,000 and 3,740 shares at the 70% and 90% quantiles, and 210 shares at the median. For the  $\{IP>P\}$ -type disagreements (the right-hand side of the table) the delta-equivalent volumes are negative, and the 30% and 10% quantiles correspond to the 70% and 90% quantiles of the  $\{P>IP\}$ -type disagreements. For these regression the effects at the 30% and 10% quantiles are similar the effects are found at the 70% and 90% quantiles for the  $\{P>IP\}$ -type disagreements.

This finding that the effect of the disagreement on signed delta-equivalent option volume is highly skewed is unsurprising because there is no reason to expect that it will always be

profitable to trade on or “arbitrage” the disagreement. However, when trading on the disagreement is profitable, one expects arbitrageurs to trade large numbers of options.

Turning to the quantile regressions for signed volume in the underlying stocks, the coefficients at the 10% and 90% percentiles have opposite signs, indicating that the disagreement events are associated with greater dispersion in signed volume. At the median, for the {P>IP}-type disagreements, the disagreement event increases stock signed volume by about 210 shares relative to the control events, consistent with the stock volume results in Table 6 of Muravyev, Pearson, and Broussard (2012) and inconsistent with significant arbitrage selling of the stock. For the {IP>P}-type disagreements, at the median the disagreement event decreases stock signed volume by about 30 shares. This result is similar to that in Table 6 of Muravyev, Pearson, and Broussard (2012), where the difference in medians was also small, though in Table 6 the effect of the disagreement was slightly positive rather than slightly negative.

To summarize, signed option volume in the direction that tends to eliminate the disagreements occurs in more than half of the disagreement events. In a significant fraction of the events, the delta-equivalent signed option volume is large, consistent with “arbitrage” trading exploiting mispricing during the disagreement events. There is no evidence of unusual signed volume in the underlying stocks. For stocks, the increase in signed volume is small and, if anything, is in a direction that increases mispricing.

## **5. Results for Signed Volume in the Subsamples Used in Robustness Tests**

Table A4 contains results for signed volume in the subsamples used in robustness tests discussed in Section 6 of Muravyev, Pearson, and Broussard (2012).

Column 2 of Table A4 shows the estimates of the coefficient on the disagreement dummy in regressions explaining signed volume for the subset of disagreement events that are initiated by the options market. The point estimates in column 2 of both Panels A and B indicate volume in the direction that tends to close the disagreements, consistent with the full sample results, though the magnitudes are not as large as in the full sample and in the results for “All Options” in Panel B the point estimate is small and not significantly different from zero. The weaker evidence of option market volume tending to close the disagreements is unsurprising, because it is likely that at least some of these disagreements were caused by signed option volume in a direction that tended to open the disagreement. If any of this volume carries over into the disagreement period it will tend to offset “arbitrage” trades in the direction that tends to close the

disagreement.

Column 3 shows the results for the subset of disagreement events that occur in the two trading days prior to earnings announcements. The point estimates for signed option volume in this subsample are very similar to those for the full sample, though the  $t$ -statistics are smaller because of the smaller sample size.

Column 4 headed “Pre-Event Return  $>0.3\%$ ” shows the conditional average signed volume for the subset of disagreement events for which the return (for the  $\{P>IP\}$ -type events) or its negative (for the  $\{IP>P\}$ -type events) during the two minutes prior to the beginning of the disagreement event exceeded 0.3%. The estimates for signed volume for this subsample are very similar to those for the full sample.

Column 5 shows that signed delta-equivalent option volume during disagreement events was larger in this subsample than in the full sample, which is unsurprising given the increase in option trading volume during the sample period.

Column 6 explores whether the results are different during periods of high option volume by looking at the subsample of price disagreement events that occurred on days in which option trading volume exceeded the 80<sup>th</sup> percentile of daily option trading volume for that underlying stock. They are not—the results for signed option volume during this subsample are similar to those in the full sample.

Column 7 explores the possibility that the results might be different following order imbalances in the stock market by examining the subset of events for which the ratio of the signed stock market volume (or its negative, for the  $\{IP>P\}$ -type events) to total stock volume in the two minutes preceding the event exceeds 0.5. The results show that signed option volume in this subsample is also similar to that in the full sample. The point estimates for signed stock volume differ from those in the full sample, but are insignificant.

Columns 8, 9, and 10 show results for the subsamples in which both the call and put prices used in the put-call parity are “trade confirmed,” both the call and put prices are “quote confirmed,” and for the combined case in which the call and put prices are either “trade confirmed” or “quote confirmed.” In each case, we also use only correspondingly confirmed control observations. The coefficients for signed option volume are much larger than in the full sample case, with the coefficients for signed option volume in the disagreement pairs being more than two times larger than in the full sample case in Column 1.

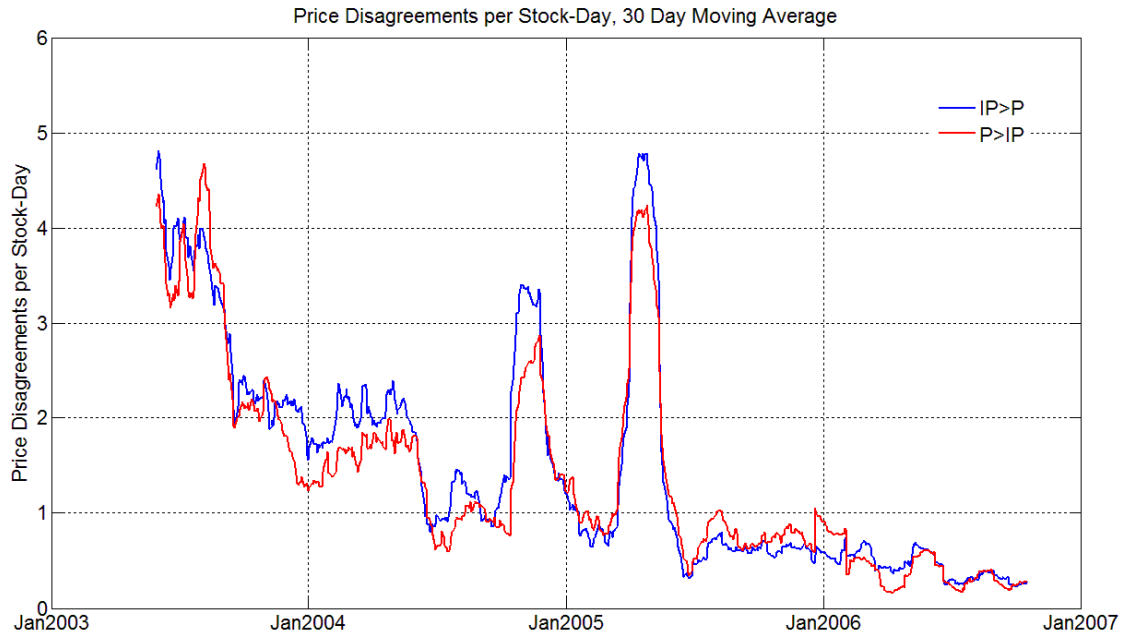
Column 11 headed “>10 sec duration” considers the subsample of treatment events in which the option-implied quotes that triggered the disagreement do not change for at least 10 seconds after the event is triggered. For this subsample the pair of options that triggered the disagreement shows slightly less signed volume than does the full sample, while in this subsample signed volume in all options is greater than in the full sample.



## **Reference**

Muravyev, Dimitriy, Neil D. Pearson, and John P. Broussard. 2012. Is There Price Discovery in Equity Options? Working Paper, University of Illinois at Urbana-Champaign and Rutgers University-Camden.

**Figure A1.** Frequency of primary sample disagreement events per stock per day. The figure presents a smoothed estimate of the average number of events per day per stock during the sample period. The estimate of the number of events per day is constructed by counting the total (across stocks) number of events per day, dividing by the number of stocks in the sample on that day, and then smoothing the resulting time series by taking a 30-day moving average. The red line is the smoothed estimate of the number of  $\{P>IP\}$ -type events in which the actual price exceeds the option-implied stock price, while the blue line is the smoothed estimate of the number of  $\{IP>P\}$ -type events.



**Table A1.** Mean quote changes in the disagreement and control samples. For each stock and ETF, the table presents the mean changes (in cents) of the option-implied bid quote, option-implied ask quote, and actual stock midpoint for the disagreement and the control samples, for both the {P>IP}-type and {IP>P}-type disagreements. The evaluation period is set to one minute. The averages in the last row are equal-weighted averages of the stock/ETF averages. The units of all variables are cents. Ticker symbols indicated with \* dropped before the end of the sample period.

Ticker	{P > IP}-Type Disagreements						{IP > P}-Type Disagreements					
	Treatment Sample			Control Sample			Treatment Sample			Control Sample		
	Implied Bid	Implied Ask	Stock Midpoint	Implied Bid	Implied Ask	Stock Midpoint	Implied Bid	Implied Ask	Stock Midpoint	Implied Bid	Implied Ask	Stock Midpoint
AIG	6.1	11.4	-0.4	0.7	4.2	-0.4	-11.4	-5.9	0.4	-4.0	-0.3	0.5
AMAT	4.4	6.1	0.2	0.2	1.9	-0.1	-5.8	-4.3	-0.2	-2.1	-0.3	0.0
AMGN	5.9	10.5	-0.1	-0.1	3.4	-0.8	-10.4	-5.5	0.3	-3.7	0.2	0.7
AMR	3.7	7.5	0.3	0.2	2.6	-0.1	-6.6	-2.9	0.4	-3.0	-0.2	-0.1
AMZN	5.5	10.0	0.5	0.1	3.5	-0.5	-9.5	-4.9	-0.1	-3.3	0.1	0.7
AOL*	4.3	6.7	-0.8	0.5	1.0	-0.2	-4.7	-4.4	-0.7	-1.6	-0.1	-0.2
BMJ	4.5	6.7	-0.2	0.5	1.8	0.2	-5.7	-4.1	-0.4	-1.9	-0.2	-0.2
BRCM	4.6	9.3	-0.1	-0.1	3.3	-0.6	-9.3	-4.6	0.0	-3.4	0.2	0.6
C	4.6	7.1	0.4	0.4	2.7	0.1	-6.4	-4.2	-0.2	-2.4	0.0	0.1
COF	6.7	12.3	-0.1	0.6	4.4	-0.4	-12.3	-6.4	0.8	-4.1	-0.4	0.5
CPN*	2.4	3.3	0.4	0.1	1.0	0.3	-4.8	-3.2	-1.2	-0.9	0.0	-0.1
CSCO	4.8	5.9	0.2	0.3	1.6	-0.3	-6.1	-5.2	-0.3	-1.7	-0.5	0.2
DELL	4.4	6.7	0.1	0.2	2.2	-0.3	-6.8	-4.6	-0.4	-2.3	-0.2	0.3
DIA	5.2	15.6	-0.1	0.7	5.3	0.2	-14.5	-4.6	-0.2	-5.8	-1.2	-0.7
EBAY	6.5	12.2	0.3	0.2	4.6	-0.6	-11.7	-5.9	0.4	-4.3	0.3	1.1
EMC	4.2	5.3	0.0	0.3	1.2	0.1	-4.5	-4.3	-0.4	-1.5	-0.1	-0.1
F	3.5	5.5	-0.1	0.3	1.2	-0.1	-5.3	-3.3	-0.6	-0.9	-0.2	0.1
GE	4.3	5.6	0.0	0.5	1.6	0.2	-5.6	-4.8	-0.5	-1.6	-0.5	-0.2
GM	4.1	7.7	0.3	0.7	2.8	0.0	-7.2	-3.6	-0.2	-2.6	-0.3	0.2
HD	4.3	6.8	0.1	0.5	2.8	0.1	-6.8	-4.6	-0.3	-2.6	-0.3	0.0
IBM	6.4	10.7	-0.9	0.4	4.2	-0.1	-11.3	-6.6	0.2	-3.9	-0.2	0.2
INTC	4.7	5.3	0.1	0.4	1.5	-0.3	-5.8	-5.0	-0.1	-1.7	-0.7	0.3
JPM	4.1	6.3	0.0	0.2	2.4	0.1	-6.4	-4.2	-0.4	-2.3	-0.1	0.0
KLAC	4.8	9.8	-0.2	-0.3	4.0	-0.7	-10.2	-4.9	0.2	-4.0	0.2	0.7
MMM	7.0	14.1	-0.3	0.7	5.5	-0.2	-11.9	-4.5	3.0	-4.7	0.2	0.6
MO	5.2	10.4	0.3	0.4	2.9	-0.2	-9.3	-5.5	-0.1	-3.1	-0.4	-0.1
MSFT	4.5	5.3	0.1	0.4	1.4	-0.4	-5.3	-4.6	-0.1	-1.4	-0.6	0.3

**Table A1** (continued)

Ticker	{P > IP}-Type Disagreements						{IP > P}-Type Disagreements					
	Treatment Sample			Control Sample			Treatment Sample			Control Sample		
	Implied Bid	Implied Ask	Stock Midpoint	Implied Bid	Implied Ask	Stock Midpoint	Implied Bid	Implied Ask	Stock Midpoint	Implied Bid	Implied Ask	Stock Midpoint
MWD*	5.7	10.7	0.6	0.0	3.2	-0.5	-9.2	-4.6	-0.2	-3.5	-0.3	0.0
NXTL*	4.3	6.5	0.3	0.4	2.3	-0.2	-6.7	-4.5	-0.5	-2.2	-0.3	0.2
ORCL	4.1	5.1	-0.2	0.4	1.1	-0.3	-6.2	-4.4	-0.1	-1.1	0.0	0.3
PFE	4.3	6.0	-0.1	0.6	2.2	0.0	-5.3	-3.9	0.1	-2.0	-0.5	0.0
QCOM	5.5	9.5	0.2	0.3	3.5	-0.4	-9.3	-5.2	-0.2	-3.1	0.2	0.8
QLGC	5.1	10.6	0.3	-0.1	3.6	-0.7	-9.9	-4.7	0.3	-4.0	-0.1	0.5
QQQ*	4.5	5.9	0.2	0.6	1.5	0.1	-5.8	-4.6	-0.2	-1.6	-0.7	-0.2
QQQQ	6.1	7.8	0.6	0.7	2.2	0.1	-7.7	-5.8	-0.2	-2.3	-0.6	0.2
SBC*	4.6	6.1	0.2	-0.1	1.8	-0.1	-5.1	-3.3	0.3	-2.0	0.0	0.0
SMH	4.6	7.1	0.5	0.6	3.2	0.4	-7.5	-4.9	-0.8	-3.5	-0.8	-0.4
TYC	4.3	6.8	0.4	0.4	2.4	0.2	-5.4	-3.3	0.1	-2.3	-0.2	-0.1
XLNX	4.6	8.3	0.0	-0.1	3.0	-0.5	-8.5	-4.7	-0.1	-3.2	0.0	0.5
XOM	5.5	8.1	-0.2	0.6	2.7	-0.2	-7.4	-4.7	0.7	-2.6	-0.2	0.5
Average	4.8	8.1	0.1	0.3	2.7	-0.2	-7.7	-4.6	0.0	-2.7	-0.2	0.2

**Table A2.** Estimates of coefficients on the disagreement dummy in quantile regressions explaining quote changes, for various quantiles, using the primary sample. The table presents the coefficient estimates on the disagreement dummy in quantile regressions explaining quote changes in specifications that include a constant, the disagreement dummy, and the three variables used in matching (the option-implied spread and the 2-minute and 10-second pre-event returns), and a fourth control variable equal to the order imbalance in the stock during the 2-minute pre-event period. Each coefficient estimate in the table is from a separate regression for the pooled sample. Only the coefficient for the disagreement dummy is reported. Standard errors (in parentheses) are based on 100 bootstrap iterations. There are 38,979 and 42,045 {P>IP}-type and {IP>P}-type disagreements, respectively. Because each disagreement event is matched to three control events, the total number of observations is four times the number of disagreement events.

Quantile:	{P > IP}-Type Disagreements					{IP>P}-Type Disagreements				
	10%	30%	50%	70%	90%	10%	30%	50%	70%	90%
Implied Bid	4.8 (0.01)	0.0 (0.0)	5.0 (0.0)	7.5 (0.0)	5.6 (0.06)	-5.0 (0.04)	-5.1 (0.01)	-10.0 (0.0)	-5.0 (0.0)	0.0 (0.0)
Implied Ask	0.0 (0.0)	5.0 (0.0)	10.0 (0.0)	5.3 (0.01)	6.7 (0.04)	-5.0 (0.0)	-7.5 (0.0)	-5.0 (0.0)	0.0 (0.0)	-4.7 (0.0)
Actual Stock Midpoint	-0.2 (0.01)	0.1 (0.0)	0.3 (0.0)	1.0 (0.0)	1.6 (0.01)	-1.4 (0.01)	-1.0 (0.0)	-0.4 (0.0)	-0.2 (0.0)	0.3 (0.01)

**Table A3.** Estimates of the coefficient on the disagreement dummy in quantile regressions explaining signed volume, for various quantiles, using the primary sample. The table presents the coefficient estimates on the disagreement dummy in quantile regressions explaining delta-equivalent signed volume (for the options) or signed volume (for the stock) in specifications that include a constant, the disagreement dummy, and the three variables used in matching (the option-implied spread and the 2-minute and 10-second pre-event returns), and a fourth control variable equal to the order imbalance in the stock during the 2-minute pre-event period. Only the coefficient for disagreement dummy is reported, and each cell in the table is from a separate regression for the pooled sample using an evaluation period of one minute. Signed volume in the underlying stocks is based on the Lee and Ready (1991) algorithm, while a version of the quote rule is used to estimate the direction of options trades. The delta-equivalent volume is computed using the estimates of signed option volume and the options deltas from Option Metrics. “All Options” include all option pairs for a given underlying stock, while the “Disagreement Pair” includes only volume in the option pair that triggered the disagreement event. The columns headed “Mean” and “Median” report the mean and median, respectively, of the 39 stock-by-stock values. The columns headed “4-th”, and “36-th” report the 4-th and 36-th largest of the signed volumes for the 39 stocks. The units are round lots of 100 shares, so that “1” means 100 shares. Standard errors (in parentheses) are based on 100 bootstrap iterations. There are 38,979 and 42,045 {P>IP}-type and {IP>P}-type disagreements, respectively. Because each disagreement event is matched to three control events, the total number of observations is four times the number of disagreement events.

Quantile:	{P>IP}-Type Disagreements					{IP>P}-Type Disagreements				
	10%	30%	50%	70%	90%	10%	30%	50%	70%	90%
All Options	-3.8 (0.09)	0.7 (0.01)	9.5 (0.02)	25.8 (0.05)	74.8 (0.19)	-74.1 (0.19)	-23.9 (0.05)	-8.9 (0.02)	-0.6 (0.0)	2.3 (0.08)
Disagreement Pair	-2.9 (0.02)	0.0 (0.0)	2.1 (0.01)	10.0 (0.01)	37.4 (0.09)	-36.1 (0.07)	-9.9 (0.01)	-2.2 (0.01)	0.0 (0.0)	3.3 (0.02)
Stock	-84.1 (0.55)	-13.1 (0.11)	2.1 (0.07)	15.0 (0.13)	49.4 (0.43)	-42.6 (0.40)	-10.4 (0.11)	-0.3 (0.06)	12.7 (0.11)	59.6 (0.45)

**Table A4.** Signed volume in various subsamples. Panels A and B show coefficient estimates for the {P>IP} and {IP>P}-type disagreement events, respectively. In each panel, each column reports the coefficient estimates on the disagreement dummy and the associated *t*-statistics (in parentheses) for regressions of either the delta-equivalent signed option volume in a set of options or the signed stock volume on a constant and the disagreement dummy for a separate subsample identified by the column heading. The results in the rows labeled “All Options” use as the left-hand side variable the total delta-equivalent signed volume in all option pairs for a given underlying stock. The results in the rows labeled “Disagreement Pair” use only the delta-equivalent signed option volume for the option pair that triggered the disagreement event, while the rows labeled “Stock” use the signed volume in the underlying stock. In each subsample, all observations are pooled together and a single regression is estimated. The table also reports the median disagreement duration, in seconds, and the number of treatment sample events. Because each disagreement event is matched with three control events, the total number of observations is four times the number of treatment events. The evaluation period is 30 seconds, and the *t*-statistics are based on White heteroscedasticity-consistent standard errors.

The various subsamples are identical to those used in Table 11. As in Table 11, results for the full sample are provided in column 1 for comparison.

Panel A: {P>IP}-Type Disagreements

	1	2	3	4	5	6	7	8	9	10	11
	Full Sample	Option-Initiated	2 Pre-Earnings days	Pre-Event Return >0.3%	Year >2004	Option Volume > 80 <sup>th</sup> %-tile	Pre-Event Order Imbalance	Trade Conf.	Exch. Conf.	Trade or Exch.	>10 Sec. Duration
All Options	26.3 (12.0)	18.6 (4.3)	17.6 (2.1)	24.1 (4.2)	35.3 (6.5)	30.0 (9.7)	25.6 (4.8)	67.9 (8.1)	49.9 (3.7)	44.5 (8.2)	31.2 (11.4)
Disagreement Pair	12.6 (18.3)	8.7 (4.9)	16.6 (4.1)	9.8 (6.7)	20.2 (13.7)	14.3 (13.1)	14.2 (6.5)	42.4 (12.8)	36.5 (9.4)	28.0 (16.6)	15.1 (13.9)
Stock	-16.5 (-3.6)	-37.9 (-2.8)	-8.2 (-0.6)	-27.1 (-3.0)	-22.3 (-2.5)	-36.9 (-3.9)	10.7 (0.6)	-23.6 (-1.5)	-24.6 (-1.2)	-22.0 (-2.4)	-1.3 (-0.2)
Median Duration	8.0	5.1	5.8	5.0	3.4	6.5	15.0	17.7	9.4	8.9	30.3
No. of Treatment Events	38,979	4,745	1,517	10,161	12,868	10,095	4,916	5,402	4,228	13,734	17,765

**Table A4** (continued)

## Panel B: {IP&gt;P}-Type Disagreements

	1	2	3	4	5	6	7	8	9	10	11
	Full Sample	Option- Initiated	2 Pre- Earnings Days	Pre-Event Return < -0.3%	Year >2004	Option Volume > 80 <sup>th</sup> %-tile	Pre-Event Order Imbalance	Trade Conf.	Exch. Conf.	Trade or Exch.	>10 Sec. Duration
All Options	-25.7 (-13.7)	-1.6 (-0.3)	-23.8 (-4.7)	-25.1 (-10.2)	-44.0 (-9.8)	-20.1 (-5.0)	-23.4 (-2.8)	-68.2 (-7.3)	-64.3 (-9.1)	-47.1 (-11.0)	-26.1 (-9.9)
Disagreement Pair	-12.9 (-12.0)	-5.7 (-2.6)	-11.4 (-6.0)	-9.7 (-10.1)	-22.0 (-7.4)	-10.7 (-8.7)	-12.2 (-7.0)	-44.3 (-6.7)	-31.5 (-12.7)	-27.5 (-9.8)	-13.3 (-15.2)
Stock	5.0 (1.1)	7.0 (0.5)	31.0 (2.5)	9.1 (1.4)	4.4 (0.6)	-0.8 (-0.1)	49.0 (1.9)	19.5 (0.9)	4.5 (0.3)	8.6 (0.9)	4.9 (0.6)
Median Duration	7.9	5.1	6.1	5.1	3.2	6.4	16.0	16.8	9.4	9.1	30.6
No. of Treatment Events	42,045	4,714	1,487	11,344	13,832	10,706	3,807	6,154	4,714	15,141	19,045