Original Article

Differential information in option volume and stock volume

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ABSTRACT We find that option volumes and stock volumes contain differential information in the setting of the final forecasted stock price. For situations in which the forecasted stock price is expected to increase, the upper bound may be established by call buy volumes and the lower bound by put sell volumes. With implicit stock price decreases, we find bounds based on call sell volumes and put buy volumes. Other limits are imposed by the information contained in short sale volumes and the exercise price. Within these limits, market makers use the information contained in stock buy and sell volumes to determine future stock bid and ask quotes.

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INTRODUCTION

Informed traders in the stock and options markets forecast the future value of stock with a view toward capturing profits. The forecasted value of the stock, also known as the implicit stock price,¹ is a probabilistic estimate of the

future stock price based on actual historical prices. We add to the literature on informed trading by proposing a theory that differentiates between the information contained in option and stock volumes in the setting of stock prices and empirically validating this theory

at merger announcement and completion. We contend that it is the *motivations* of each type of informed trader that separately influence the flow of information into prices.

THE BASIC THEORY

The role of options and stock in predicting implicit prices

We propose that the option market sets upper and lower limits for the implicit stock price. If implicit stock prices are expected to increase, informed options traders will engage in call buying or put selling. The option market's chief benefit is that it offers the potential for upside gain with minimal investment, as risk is cut off at the strike price. For call buy trades, the profit earned = $[-A_c + (V - X)]\theta$,¹ where A_c = call ask price, X = strike price, V = implicit stock price for stock price increases and θ = number of shares controlled by the option. For put sell trades, profit = $-B_p$,¹ where B_p = put bid price for the put seller if the put is not exercised as it would not be with rising prices. If at least some call buyers expect the implicit price to increase, they will continue to purchase calls at successively higher prices until $A_c = V - X$, when the cost of the call is exactly offset by the gain from the price increase, or no further profits may be earned. Market makers set an upper bound by increasing ask quotes to the stock price corresponding to the final call ask price. For the lower limit, put buyers will continue to purchase puts, until they realize that stock prices are going to continue to increase or the puts will never be exercised. The stock bid price corresponding to this final put bid price will be the lower limit.

For implicit price decreases, the implicit stock price may descend below the strike price. The

option market has the two profit-making strategies of call selling and put buying. Call selling offers a profit of B_c ,¹ B_c = call bid price if the call is not exercised as it would not be with falling prices. When prices descend slightly below the strike price, the upper limit = X , the strike price. The lower limit will be the price corresponding to the final call sell trade. If prices descend substantially below the strike price, put buying becomes profitable with a profit of $[(X - \underline{V}) - A_p]\theta$,¹ $\underline{V}$ = implicit stock price for stock price decreases, with the underlying stock ask price corresponding to the final put ask price being the lower limit of the implicit stock ask price.

Once the market maker has established the end points for V or $\underline{V}$, he or she wishes to accurately set stock quotes. The liquidity of the stock market suggests that the overall volume of trading will be higher than the option market. There will be many more trades of large size. The market maker may observe the ask prices of large stock buy trades and select those that cluster at a certain ask price as the level to which a stock ask quote must be increased. We apply this theory to trading situations at merger announcement and completion.

Categorization of mergers by method of payment

Mitchell *et al*² categorized merger transactions into cash and stock mergers. Cash mergers occur when an acquirer purchases a target firm for cash, releasing a positive signal. Stock mergers occur when an acquirer exchanges stock with the target firm, releasing a negative signal. Merger arbitrageurs short the acquirer stock in stock mergers to purchase the target stock in an attempt to guarantee deal completion. Upon

successful completion, a negative signal emerges on cash acquirers and a negative signal on stock acquirers. Deal failure is the inability of merger arbitrageurs to guarantee merger completion.

Cash acquirers at announcement with at-the-money calls

There are two relevant stock prices: the implicit, forecasted price and the actual price. By definition, the implicit stock price is constrained to remain near the exercise price for at-the-money calls. Call buy traders pursue profit-making by purchasing small volumes of calls in the expectation of capitalizing on incremental increases in the implicit stock price. An individual call buy trade may contain minimal information, and thus market makers will need to examine multiple call buy trades using the partial information contained in all of their call volumes to determine the next stock ask quote. Given that these option trades may occur consecutively, a certain length of time may elapse before market makers may establish a stock ask quote. Once the quote is determined, the next stock trade occurs at a higher actual trade price. This actual trade price becomes the upper limit for a particular interval of time. With successive rounds of trading, increasing call buy volumes should progressively increase call ask quotes, except that as the implicit price of the stock cannot increase beyond the exercise price, information in the last call buy trade cannot be used to increase stock ask quotes to the maximum extent. Therefore, the upper limit will remain temporary as of the end of the merger announcement period. The exercise price is the lower limit for at-the-money options.

Stock trades provide final actual stock prices. At any particular point in time, market makers examine five stock buy trades with volumes of 500, 550, 700, 780 and 800. They impose the constraint that the trades must have stock prices within the limits set by the last option trade. If the trade with volume of 700 falls outside of these limits, it will be excluded. They use the information in each of the remaining stock buy volumes to raise ask quotes to different levels, so that subsequent stock purchases occur at a range of stock prices.

Cash acquirers at announcement with in-the-money calls and out-of-the-money puts

If the current actual stock price is greater than exercise price, as for in-the-money calls and out-of-the-money puts, both the upper and lower limits will be set by option trades. The upper limit set in a particular round of trading rises to a higher level in each successive round of trading. Call premiums increase until the penultimate round of trading in which the call premium is marginally less than the gain from purchasing call options. The next call volume will contain complete information about the highest level of the implicit stock price at which the gain from purchasing calls will be exactly offset by the call premium, so that informed traders have no further incentive to purchase calls. Market makers will increase stock ask quotes based on this single call volume, so that the next stock purchase price will be the final upper limit.

In contrast, the lower limit will be based on incremental price projections contained in put sell trades. The volume in each put sell trade suggests a slight increase in the implicit stock

price. Given the thin trading of put options, market makers will have to examine put sell trades over a longer time interval than call buy trades to obtain sufficient information to raise stock bid quotes. Once all of the available information has been incorporated into stock bid quotes, the final, stable lower limit will be established at the next stock sale price.

Cash acquirers at announcement with out-of-the-money calls and in-the-money puts

If the current actual stock price is less than the exercise price as for out-of-the-money call options and in-the-money put options, both call buying and put selling will be inherently unprofitable strategies. By definition, for an out-of-the-money call, the stock price must be less than the exercise price, or call purchases must end just before the implicit stock price reaches the exercise price. As this increment is known, it is possible that the last call buy trade volume will contain information that permits the market maker to raise stock ask quotes to the level at which the stock price is marginally below the exercise price. A stable upper limit will be formed followed by final actual trade prices being determined by stock volumes. However, as the lower limit will be very far below the strike price, or will be highly unprofitable to put sellers, we fail to see any value in put sale volumes reflecting information about very low implicit stock prices.

Stock acquirers at successful completion with in-the-money calls

It is unlikely that any put selling will occur with price reversal being a weaker motivation to trade than merger announcement. Only

in-the-money options will trade, as neither at-the-money options nor out-of-the-money options will be sufficiently profitable to attract risk-taking options traders. As with implicit price increases at merger announcement, a stable upper limit will be formed, followed by stock buy trades that set final stock purchase prices.

Stock acquirers at announcement with at-the-money calls

When the implicit stock price descends just below the strike price, at-the-money calls become informative in setting the lower bound (the upper bound is the exercise price), as their volumes predict the extent of minimal implicit price reduction below the strike price. Market makers are able to reduce stock bid quotes to the level at which the next stock sale occurs slightly below the earlier sales price. By definition, the actual stock price approximates the exercise price, so that the last call sell trade cannot reflect the reduction in implicit stock price to reach the full extent of downward price movement in an environment of freely falling prices. Call sell volumes set an unstable lower limit on at-the-money options.

Stock acquirers at announcement with out-of-the-money calls and in-the-money puts

When short selling starts driving implicit prices down to a minimum, trading on out-of-the-money calls and in-the-money puts commences. Call sell volumes with predictions of slight reductions in implicit stock prices form the new upper limit. Call sellers gain premiums from modest reductions in the implicit stock price. In each round of trading, they benefit from incremental implicit price reductions, with

the final marginal reduction being realized in the last round of trading, suggesting the formation of a stable upper limit.

Short sale volumes indicate an urgent need by merger arbitrageurs for stock that is rapidly losing value in order to raise funds that permit the purchase of target stock. This need surpasses the profit-making desire of put buyers, thereby setting a limit that is lower than the limit set by put buying. Short selling explains all of the demand for lower priced stock set forth by the negative signal from stock acquirers at merger announcement.²

Cash acquirers at successful completion

The motivation to trade is divestment of stock before the rapid reduction of implicit prices to a minimum, assuming that informed traders actually own the stock. It is doubtful whether bounds will be set by option trades, though some stock prices will be set before the stock is divested. Market makers will examine stock volumes, reducing stock bid quotes so that stock sales will occur at a variety of lower prices.

Target stock at deal failure

When merger arbitrageurs purchase the target stock at merger announcement, they guarantee the stock against deal failure. Deal failure is the failure of this insurance function, resulting in rapid declines in the target stock to a minimum. Accordingly, merger arbitrageurs (who own the target stock) shift to a put buying strategy in which they gain in each round of trading as the implicit price continues to decline below the strike price. The lower bound will be formed by the last put buy trade.

DATA COLLECTION AND ANALYSIS

We constructed a list of cash and stock mergers announced in 2005 and either completed or cancelled in 2005 or 2006 from Factset Mergerstat.³ The sample consisted of a total of 113 mergers, with 77 cash mergers and 36 stock mergers. We used a proprietary database to obtain intraday option volumes. The database provided intraday option volumes, bid and ask quotes, and trade prices. We regressed directional option volume, stock volume and short sale volume for each day during the merger announcement period and closing period.

We tested whether a particular limit was the final, stable limit. If the option volume had a contemporaneous effect on prices, the limit was deemed stable; if not, that is, if the volume affected stock price changes in a later lag, information in multiple trades was needed to reach the upper limit or to prove that an unstable, upper limit subject to revision was present.

RESULTS

All results reported in this section are shown in Table 1 (Panels A–G).

Cash acquirers at announcement with at-the-money call options

Call buy volume on at-the-money options set an unstable upper limit on Day –1, which was revised on Day 0, but did not completely explain stock price changes. Final stock prices were set on Day +1. On Day –1, market makers increased stock prices in response to call buy volume approximately 30–35 min after the occurrence of each trade so that call buy volume significantly influenced stock

Table 1: Regressions of stock price changes on directional volume

<i>Variable</i>	(1) <i>Day -1</i>	(2) <i>Day 0</i>	(3) <i>Day 1</i>
<i>Panel A: Implicit stock price increases on cash acquirers with at-the-money calls and stock at announcement</i>			
Call buy volume	-0.002	-0.019	0.040
Call buy volume - Lag 1	-0.005	-0.006	0.015
Call buy volume - Lag 2	0.011	0.016	0.062
Call buy volume - Lag 3	-0.045	0.073*	-0.031
Call buy volume - Lag 4	-0.069*	-0.016	0.038
Call buy volume - Lag 5	0.025	0.005	0.019
Call buy volume - Lag 6	0.096**	0.005	-0.055
Call buy volume - Lag 7	0.107***	-0.041	0.040
Call buy volume - Lag 8	0.026	-0.021	0.026
Call buy volume - Lag 9	-0.001	-0.013	0.040
Stock buy volume	-0.059	0.039	0.117**
Stock buy volume - Lag 1	0.023	0.094*	0.124**
Stock buy volume - Lag 2	0.006	0.032	0.063
Stock buy volume - Lag 3	-0.011	0.052	0.092*
Stock buy volume - Lag 4	0.021	0.105*	0.024
Stock buy volume - Lag 5	-0.044	0.068	0.011
Stock buy volume - Lag 6	0.059	0.048	0.072
Stock buy volume - Lag 7	0.015	0.065	0.156***
Stock buy volume - Lag 8	0.023	0.046	0.151***
Stock buy volume - Lag 9	0.010	-0.010	0.004
<i>N</i>	693	615	615
<i>R</i> ²	0.19	0.11	0.21
<i>Panel B: Implicit stock price increases on cash acquirers with in-the-money calls, out-of-the-money puts and stock at announcement</i>			
Call buy volume	0.110***	-0.005	0.044
Call buy volume - Lag 1	-0.038	-0.015	0.047
Call buy volume - Lag 2	-0.040	-0.029	0.017
Call buy volume - Lag 3	0.020	-0.026	0.023
Call buy volume - Lag 4	-0.011	-0.053	0.012
Call buy volume - Lag 5	0.007	-0.043	0.001
Call buy volume - Lag 6	-0.039	-0.016	0.040
Call buy volume - Lag 7	-0.041	-0.053	0.011
Call buy volume - Lag 8	-0.079*	-0.091*	0.002
Call buy volume - Lag 9	-0.041	-0.095*	-0.007

Table 1 *continued*

<i>Variable</i>	(1) <i>Day - 1</i>	(2) <i>Day 0</i>	(3) <i>Day 1</i>
Put sell volume	0.020	0.079★	-0.025
Put sell volume - Lag 1	-0.024	0.031	-0.059
Put sell volume - Lag 2	0.005	0.048	-0.038
Put sell volume - Lag 3	-0.017	0.048	-0.029
Put sell volume - Lag 4	0.257***	0.007	-0.003
Put sell volume - Lag 5	0.175**	0.036	0.020
Put sell volume - Lag 6	-0.007	-0.071↑	0.019
Put sell volume - Lag 7	-0.026	-0.032	0.003
Put sell volume - Lag 8	-0.029	-0.009	-0.005
Put sell volume - Lag 9	0.018	0.006	-0.066↑
Stock buy volume	-0.014	-0.045	0.038
Stock buy volume - Lag 1	0.056	-0.047	0.086↑
Stock buy volume - Lag 2	0.002	-0.002	-0.067
Stock buy volume - Lag 3	-0.001	0.036	0.060
Stock buy volume - Lag 4	0.035	0.074	-0.112★
Stock buy volume - Lag 5	-0.014	0.035	-0.040
Stock buy volume - Lag 6	0.056	0.014	-0.016
Stock buy volume - Lag 7	0.039	0.062	-0.052
Stock buy volume - Lag 8	0.091★	0.087	0.054
Stock buy volume - Lag 9	-0.012	-0.014	-0.090
<i>N</i>	615	538	615
<i>R</i> ²	0.22	0.10	0.14

<i>Variable</i>	(1) <i>Day - 1</i>	(2) <i>Day 0</i>
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Panel C: Implicit stock price increases on cash acquirers with out-of-the-money calls and stock at announcement

Call buy volume	0.081**	0.009
Call buy volume - Lag 1	-0.056	-0.005
Call buy volume - Lag 2	-0.068★	0.044
Call buy volume - Lag 3	0.002	-0.012
Call buy volume - Lag 4	-0.029	0.025
Call buy volume - Lag 5	-0.003	-0.004
Call buy volume - Lag 6	-0.045	0.027
Call buy volume - Lag 7	-0.031	0.022
Call buy volume - Lag 8	-0.065★	-0.012
Call buy volume - Lag 9	-0.045	0.112**

Table 1 *continued*

<i>Variable</i>	(1) <i>Day - 1</i>	(2) <i>Day 0</i>
Stock buy volume	0.002	0.066
Stock buy volume – Lag 1	0.071	–0.091
Stock buy volume – Lag 2	–0.010	–0.101
Stock buy volume – Lag 3	–0.044	0.135**
Stock buy volume – Lag 4	0.015	0.108
Stock buy volume – Lag 5	–0.034	0.055
Stock buy volume – Lag 6	0.045	–0.060
Stock buy volume – Lag 7	0.040	0.038
Stock buy volume – Lag 8	0.091*	0.016
Stock buy volume – Lag 9	–0.007	0.049
<i>N</i>	615	616
<i>R</i> ²	0.18	0.08

Panel D: Implicit stock price increases on stock acquirers with in-the-money calls and out-of-the-money puts and stock at successful completion

Call buy volume	0.092*	–0.006
Call buy volume – Lag 1	–0.032	0.010
Call buy volume – Lag 2	–0.012	0.028
Call buy volume – Lag 3	0.039	0.041
Call buy volume – Lag 4	–0.026	0.082*
Call buy volume – Lag 5	–0.018	0.049
Call buy volume – Lag 6	0.015↑	0.034
Call buy volume – Lag 7	0.009	0.043
Call buy volume – Lag 8	–0.020	0.055
Call buy volume – Lag 9	0.051	0.056
Put sell volume	0.053	0.025
Put sell volume – Lag 1	0.038	0.024
Put sell volume – Lag 2	0.062	–0.023
Put sell volume – Lag 3	0.023	–0.098*
Put sell volume – Lag 4	0.088	–0.020
Put sell volume – Lag 5	0.011	–0.054
Put sell volume – Lag 6	–0.079	–0.084
Put sell volume – Lag 7	–0.047	–0.043
Put sell volume – Lag 8	0.001	–0.057
Put sell volume – Lag 9	–0.025	0.001

Table 1 *continued*

<i>Variable</i>	(1) <i>Day -1</i>	(2) <i>Day 0</i>
Stock buy volume	0.104★	0.040
Stock buy volume - Lag 1	-0.099★	0.014
Stock buy volume - Lag 2	0.055	-0.021
Stock buy volume - Lag 3	0.013	-0.047
Stock buy volume - Lag 4	-0.026	0.044
Stock buy volume - Lag 5	0.034	0.056
Stock buy volume - Lag 6	0.096★	-0.036
Stock buy volume - Lag 7	-0.071	-0.057
Stock buy volume - Lag 8	0.151***	-0.016
Stock buy volume - Lag 9	0.088	0.018
<i>N</i>	537	537
<i>R</i> ²	0.17	0.11

<i>Variable</i>	(1) <i>Day -1</i>	(2) <i>Day 0</i>	(3) <i>Day 1</i>
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Panel E: Implicit stock price decreases on stock acquirers with at-the-money calls and stock (Day -1) and out-of-the-money calls, puts, short sales, and stock (Day 0 and Day +1) at announcement

Call sell volume	0.130	0.014	0.113★★
Call sell volume - Lag 1	0.267	0.087★	0.057
Call sell volume - Lag 2	0.343	0.048	0.022
Call sell volume - Lag 3	0.090	-0.011	-0.030
Call sell volume - Lag 4	0.014	-0.037	0.140***
Call sell volume - Lag 5	-0.099	-0.064	0.150***
Call sell volume - Lag 6	-0.057	-0.123★★	0.023
Call sell volume - Lag 7	0.058	-0.106★★	0.007
Call sell volume - Lag 8	0.005	-0.062	-0.018
Call sell volume - Lag 9	0.070	-0.055	-0.019
Stock sell volume	0.031	0.085	0.127★★
Stock sell volume - Lag 1	-0.347	0.001	-0.031
Stock sell volume - Lag 2	-0.564★★	-0.033	0.051
Stock sell volume - Lag 3	-0.218	0.130	0.036
Stock sell volume - Lag 4	-0.571★★	-0.004	0.088
Stock sell volume - Lag 5	-0.341	-0.002	0.039
Stock sell volume - Lag 6	-0.216	0.100	0.032
Stock sell volume - Lag 7	-0.032	0.088	-0.010
Stock sell volume - Lag 8	-0.333	-0.006	0.015
Stock sell volume - Lag 9	-0.171	-0.033	0.015

Table 1 *continued*

<i>Variable</i>	(1) <i>Day - 1</i>	(2) <i>Day 0</i>	(3) <i>Day 1</i>
Put buy volume	—	-0.020	-0.021
Put buy volume - Lag 1	—	0.008	-0.032
Put buy volume - Lag 2	—	-0.072	-0.006
Put buy volume - Lag 3	—	-0.021	-0.030
Put buy volume - Lag 4	—	-0.071	0.080
Put buy volume - Lag 5	—	-0.052	0.030
Put buy volume - Lag 6	—	-0.038	0.014
Put buy volume - Lag 7	—	-0.017	0.068
Put buy volume - Lag 8	—	-0.051	0.030
Put buy volume - Lag 9	—	-0.055	0.025
Short sale volume	—	0.028	0.076
Short sale volume - Lag 1	—	-0.107	0.084
Short sale volume - Lag 2	—	-0.063	0.194***
Short sale volume - Lag 3	—	-0.048	0.065
Short sale volume - Lag 4	—	-0.027	0.053
Short sale volume - Lag 5	—	0.036	0.154**
Short sale volume - Lag 6	—	0.001	-0.044
Short sale volume - Lag 7	—	0.110	0.098
Short sale volume - Lag 8	—	-0.013	-0.646
Short sale volume - Lag 9	—	-0.038	0.077
<i>N</i>	147	537	536
<i>R</i> ²	0.39	0.25	0.26

<i>Variable</i>	(1) <i>Day - 1</i>	(2) <i>Day 0</i>
<i>Panel F: Implicit stock price decreases on cash acquirers with out-of-the-money calls, puts and stock at successful completion</i>		
Call sell volume	-0.044	-0.021
Call sell volume - Lag 1	-0.196	-0.052
Call sell volume - Lag 2	-0.181	-0.004
Call sell volume - Lag 3	0.135	0.056
Call sell volume - Lag 4	-0.181	0.071 ↑
Call sell volume - Lag 5	-0.103	0.060
Call sell volume - Lag 6	-0.250	-0.003
Call sell volume - Lag 7	-0.008	-0.021
Call sell volume - Lag 8	-0.176	-0.006
Call sell volume - Lag 9	-0.172	0.007

Table 1 *continued*

<i>Variable</i>	(1) <i>Day -1</i>	(2) <i>Day 0</i>
Put buy volume	-0.150	0.019
Put buy volume - Lag 1	-0.310	0.015
Put buy volume - Lag 2	-0.987	0.002
Put buy volume - Lag 3	-1.163	-0.007
Put buy volume - Lag 4	-1.589	0.031
Put buy volume - Lag 5	-2.176	0.025
Put buy volume - Lag 6	-1.600	0.074
Put buy volume - Lag 7	-1.243	-0.013
Put buy volume - Lag 8	-0.593	0.024
Put buy volume - Lag 9	0.198	-0.034
Stock sell volume	-0.251	0.092
Stock sell volume - Lag 1	-0.339	-0.042
Stock sell volume - Lag 2	0.075	0.053
Stock sell volume - Lag 3	0.286	0.033
Stock sell volume - Lag 4	0.325	0.044
Stock sell volume - Lag 5	-0.733	0.023
Stock sell volume - Lag 6	-0.815	-0.062
Stock sell volume - Lag 7	-1.163	-0.089
Stock sell volume - Lag 8	-0.830	-0.038
Stock sell volume - Lag 9	-0.450	-0.128**
<i>N</i>	69	538
<i>R</i> ²	0.11	0.23

Panel G: Implicit stock price decreases on target stock at deal failure

Call sell volume	-0.031	0.050
Call sell volume - Lag 1	-0.046	0.073
Call sell volume - Lag 2	-0.025	0.022
Call sell volume - Lag 3	0.052	0.069
Call sell volume - Lag 4	0.085	-0.004
Call sell volume - Lag 5	0.037	0.008
Call sell volume - Lag 6	0.176*	0.012
Call sell volume - Lag 7	-0.038	0.016
Call sell volume - Lag 8	-0.135*	-0.034
Call sell volume - Lag 9	-0.074	0.124**

Table 1 *continued*

<i>Variable</i>	(1) <i>Day -1</i>	(2) <i>Day 0</i>
Put buy volume	-0.044	0.001*
Put buy volume - Lag 1	-0.017	0.001 ↑
Put buy volume - Lag 2	-0.019	0.009
Put buy volume - Lag 3	0.016	0.002***
Put buy volume - Lag 4	0.044	0.001*
Put buy volume - Lag 5	0.110	0.001
Put buy volume - Lag 6	0.115	0.001
Put buy volume - Lag 7	0.050	0.001
Put buy volume - Lag 8	-0.034	0.001
Put buy volume - Lag 9	-0.012	0.001
Stock sell volume	0.019	0.056
Stock sell volume - Lag 1	0.005	-0.014
Stock sell volume - Lag 2	-0.007	0.070
Stock sell volume - Lag 3	0.033	0.095
Stock sell volume - Lag 4	-0.014	0.039
Stock sell volume - Lag 5	0.003	0.103
Stock sell volume - Lag 6	0.092	-0.028
Stock sell volume - Lag 7	0.029	0.044
Stock sell volume - Lag 8	-0.079	0.043
Stock sell volume - Lag 9	-0.058	-0.002
<i>N</i>	293	381
<i>R</i> ²	0.29	0.35

$P < 0.05$, $\uparrow P < 0.06$, $**P < 0.01$, $***P < 0.001$.

price changes in the sixth and seventh lags ($\beta = 0.09601$, $P < 0.01$, and $\beta = 0.1070$, $P < 0.001$, Table 1, Panel A, Column (1)). No lower bound was formed by option trading as, by definition, the exercise price is the lower bound for at-the-money options. On Day 0, at-the-money calls showed a revised, though not firm, upper bound with call buy volume significantly explaining stock price changes in the third lag ($\beta = 0.0733$, $P < 0.05$, Table 1, Panel A,

Column (2)). No revision of upper bounds occurred on Day +1, with call buy volume failing to explain the variation in stock price changes in nine lags. Final stock prices were established at a variety of trading volumes based on the upper limit of the preceding day. They included contemporaneous effects of stock buy volume on stock price changes ($\beta = 0.1167$, $P < 0.01$, Table 1, Panel A, Column (3)), Lag 1 effects ($\beta = 0.1236$, $P < 0.01$, Table 1, Panel A, Column (3)),

Lag 3 effects ($\beta = 0.0921$, $P < 0.05$, Table 1, Panel A, Column (3)), Lag 7 effects ($\beta = 0.1558$, $P < 0.001$, Table 1, Panel A, Column (3)), and Lag 8 effects ($\beta = 0.1513$, $P < 0.001$, Table 1, Panel A, Column (3)).

Cash acquirers at announcement with in-the-money call options and out-of-the-money put options

On Day -1 , market makers adjusted stock ask quotes upwards to form a firm upper limit at the next stock trade price. Call buy volume significantly influenced stock price changes contemporaneously ($\beta = 0.1096$, $P < 0.001$, Table 1, Panel B, Column (1)). Next, market makers observed put sell trades, increasing stock prices to form a new, unstable lower bound in 20 min from the time of trade, with put sell volume significantly explaining stock price changes in the fourth lag ($\beta = 0.2572$, $P < 0.001$, Table 1, Panel B, Column (1)). Once the limits were established, market makers set final prices in 40 min from time of trade, with stock purchase volume significantly affecting stock price changes in the eighth lag ($\beta = 0.0913$, $P < 0.05$, Table 1, Panel B, Column (1)). On Day 0, market makers revised the lower bound with put sell volume significantly influencing stock price changes contemporaneously, suggesting that a final lower bound had been reached ($\beta = 0.079$, $P < 0.05$, Table 1, Panel B, Column (2)). This was followed by the establishment of final prices by stock buy volumes, which influenced stock price changes marginally in the first lag on Day $+1$ ($\beta = 0.086$, $P < 0.06$, Table 1, Panel B, Column (3)).

Cash acquirers at announcement with out-of-the-money call options and in-the-money put options

On out-of-the-money call options with unlikely rise in prices, a stable upper bound was set on Day -1 , immediately after trade with call buy volume influencing stock price changes contemporaneously ($\beta = 0.0814$, $P < 0.01$, Table 1, Panel C, Column (1)). Stock prices were set approximately 40 min later, with stock buy volume significantly influencing stock price changes in the eighth lag ($\beta = 0.0914$, $P < 0.05$, Table 1, Panel C, Column (1)).

Stock acquirers at successful completion

We have theorized that for stock mergers at successful completion, the impetus for trading is price reversal, which is a weaker motivation to trade than the expectation of future implicit price increases owing to the ability to purchase target stock for cash. Therefore, both upper and lower bounds may not be achieved. Final stock prices may be established based on a single bound. On in-the-money calls, a firm upper bound was set on Day -1 with call buy volume significantly influencing stock price changes contemporaneously ($\beta = 0.0919$, $P < 0.05$, Table 1, Panel D, Column (1)). No lower limit is set by put sell trades. Final stock prices depend entirely on the upper limit and are finalized immediately after the establishment of the upper limit as stock buy volume explains stock price changes contemporaneously ($\beta = 0.1035$, $P < 0.05$, Table 1, Panel D, Column (1)). No revision of limits or setting of final stock prices occurred on Day 0, as put sell volumes and stock purchase volumes failed to significantly explain

stock price changes in all nine lags (see Table 1, Panel D, Column (2)).

Stock acquirers at announcement with at-the-money call options

It was expected that as the implicit stock price descended below the strike price, call sell volume would set a new lower limit on at-the-money call options. That first occurred on Day 0, when call sell volume decreased stock prices in the first lag ($\beta = 0.0873$, $P < 0.05$, see Table 1, Panel E, Column (2)). This limit was less than stable with a 5-min interval between option trades and stock price changes.

Stock acquirers at announcement with out-of-the-money call options and in-the-money put options

On Day +1, market makers used call sell volumes to reduce stock bid quotes to a final upper limit (call sell volume explained stock price changes contemporaneously ($\beta = 0.1134$, $P < 0.01$, Table 1, Panel E, Column (3))). Ten minutes later, they examined short sale volume to reduce stock bid quotes further to a lower limit (short sale volume influenced stock price changes in the second lag ($\beta = 0.1940$, $P < 0.001$, Table 1, Panel E, Column (3))). They set final stock prices with stock sale volume reducing stock price changes contemporaneously ($\beta = 0.127$, $P < 0.01$, Table 1, Panel E, Column (3))). This is the only specification of a lower limit by short selling, and it does not appear to be final, with a 10-min lapse between the short sale trade and stock bid quote reduction to set the lower limit. Perhaps the lower limit set by short interest volumes is the final, stable lower limit.

Cash acquirers at successful completion

The negative signal on cash mergers owing to price reversal did not yield any setting of upper limits by call sell volume or lower limits by put buy volume, presumably because price reversal of the implicit stock price did not provide a sufficiently strong impetus for trading and because owners of acquirer stock in cash mergers divested themselves of stock with downward sloping demand well in advance of deal completion (see Table 1, Panel F, Columns (1) and (2)).

Target stock at deal failure

On Day -1, as a free fall in target stock prices commenced, market makers examined call sell volume, reducing stock bid quotes so that a new upper bound was formed 25 min after a call sell trade ($\beta = 0.1756$, $P < 0.05$, Table 1, Panel G, Column (1)). On Day 0, a firm lower bound was established with put buy volume affecting stock price changes contemporaneously ($\beta = 0.0011$, $P < 0.05$, Table 1, Panel G, Column (3))). No final stock prices were established.

CONCLUSIONS

We have demonstrated that the information contained in option volume and stock volumes is complementary in that option volumes set bounds and stock volumes set final, actual stock prices for both positive and negative signals on acquirer stock and target stock at deal failure during merger announcement and completion. If this information is complete in forecasting the maximum or minimum level of implicit stock prices, then final, stable, upper and lower limits have been reached. It follows that in cases in which the exercise price sets an artificial limit

(as with at-the-money options), the information contained in the last option trade will reflect the expectation of maximum upward or downward movement in the stock price. Such limits will be unstable. The inclusion of short sale volumes in the establishment of lower bounds for in-the-money puts with implicit stock price decreases below the exercise price yielded a lower, less stable limit than that created by the last put buy trade. This may be the result of inability of short sale data to reflect all of the downward price pressure. Yet another reason may be short sale restrictions, which lead to fewer short sale transactions and failure

of short volumes to reflect all of the information about future reductions in the implicit stock price.

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