



# **Informed Trading around Merger Announcements: An Empirical Test Using Transaction Volume and Open Interest in Options Market**

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## **Abstract**

This paper provides empirical evidence on the level of trading activity in the stock options market prior to the announcement of a merger or an acquisition. Our analysis shows that there is a significant increase in the trading activity of call and put options for companies involved in a takeover prior to the rumor of an acquisition or merger. This result is robust to both the volume of option contracts traded and the open interest. The increased trading suggests that there is a significant level of informed trading in the options market prior to the announcement of a corporate event. In addition, abnormal trading activity in the options market appears to lead abnormal trading volume in the equity market. This finding supports the hypothesis that the options market plays an important role in price discovery.

*Keywords:* acquisitions, mergers, options, open interest, trading volume

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## **1. Introduction**

The estimated dollar value of U.S. targets acquired in 1999 was over one trillion dollars. The hectic pace of mergers and acquisition transactions in the 1990s

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has rekindled interest in the study of these activities by regulators and academics. The Securities and Exchange Commission (SEC) has expressed concern about the trading behavior of potentially well-informed investors surrounding these acquisitions. In fact, in September of 1996 the SEC sued unidentified buyers of Duracell International Corp. options, accusing these individuals of trading on the basis of insider information about the Gillette Co.'s pending acquisition of Duracell.<sup>1</sup> A more recent article reports that the rumor of the takeover of Sun Microsystems by IBM originated when a major institutional trader executed an enormous buy order for speculative out-of-the-money calls.<sup>2</sup>

From an informed trader's perspective, there are advantages to trading in the options market as opposed to the stock market. As Black (1975) first suggested, the options market provides a low cost and efficient means for informed traders to profit from their information. He argues that the higher leverage available in the options market might motivate informed traders to trade options rather than stocks.<sup>3</sup> Cox and Rubinstein (1985) argue that the cost of trading in options is often lower than the cost of making a series of trades to replicate the payoffs such options offer. Diamond and Verrecchia (1987) show that trading in options can mitigate restrictions on short sales. Stephan and Whaley (1990) note that because the options market offers low transaction costs and high financial leverage, both liquidity traders and informed traders will be attracted to it. Advantages to trading in the options market include the limited nature of risk in options investment relative to stocks, no uptick rule regarding short-sales, and the high leverage position provided by options.

The literature suggests that the options market plays an important role in impounding information into security prices. For example, Manaster and Rendleman (1982) show that the options market leads the stock market in price discovery. Anthony's 1988 empirical evidence indicates that trading in call options leads trading in the underlying shares. Sheikh and Ronn (1994) show that informed trading in options makes the order flow in the options market informative about the value of the underlying asset. Easley, O'Hara, and Srinivas (1998) find empirical evidence that the options markets are venues for information-based trading and that option trades convey information about future stock price movements. Their model shows that informed traders often prefer the options market because it offers a higher expected payoff and may allow them to hide their trades.

Researchers also argue that because the options market attracts informed traders, the informational content of the underlying asset prices increases. Cao (1999) shows that increased trading opportunities from derivatives increases the incentive for traders to acquire private information. As a result, the amount of information collected is

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<sup>1</sup> The merger was announced on September 12, 1996, and Duracell's stock price went up by 18% on that day. The alleged illegal trades, purchases of call options on Duracell stock, occurred two days prior.

<sup>2</sup> Dow Jones News Service, August 5, 1998.

<sup>3</sup> To a certain degree, higher leverage position in stocks can be obtained through margin trading.

increased. Similarly, Kumar, Sarin, and Shastri (1998) argue that the marginal benefit of becoming informed after the introduction of options is greater given the superiority of options as a speculative vehicle. The benefits result in a greater information search by traders, which improves the efficiency of the underlying market.

Although informed traders are likely to be attracted to the options market as it offers several advantages, it not clear that informed traders would always trade in the options market. For instance, given the thinness in options relative to the underlying equity, trades made in options market are relatively more transparent. In the Easley, O'Hara, and Srinivas (1998) model, there are certain conditions, such as very low liquidity in the options market, where informed traders will only use stocks. Thus, the level of informed trading in options market vis-à-vis equity market is an empirical question. An examination of the level of trading activity preceding a major informational event such as an acquisition is likely to provide an important avenue for understanding the relative intensity of informed trading in the equity and options markets preceding such events.

In this study, we examine the trading behavior of informed traders in the options and equity market prior to the rumor of a takeover. Specifically, we analyze the put and call options volume and open interest for a sample of 33 companies that announced a merger or an acquisition. We find evidence of increased volume and open interest for both puts and calls prior to the rumor of a merger or acquisition. Increases in volume suggest trading by informed traders. Increases in open interest suggest that informed traders adopt strategies that involve taking a position in target company's stock as opposed to liquidating previously established positions. Overall, our results suggest that there is information in the option volume and open interest regarding pending corporate events. We also find that open interest increases are concentrated in out-of-the-money options with maturities of less than 60 days. This suggests that the informed trader is more likely to trade in options that offer a higher leveraged position with lower costs. We also show that the runup in option volume precedes the runup in equity volume, which is consistent with the options market playing an important role in price discovery.

The paper proceeds as follows. Section 2 provides a brief review of the relevant literature. Section 3 outlines the specific trading strategies informed traders might take and the effect of such strategies on the trading activity in the options market. Section 4 describes the sample and the methodology. Section 5 presents the results and discusses the implications of these results. The last section concludes the paper.

## **2. Prior literature**

The presence of informed traders who trade prior to the announcement of a merger is well documented in the equity market. Much of the literature in the equity market has focused on the presence of illegal insider trading. To illustrate, Keown and Pinkerton (1981) find significant positive abnormal returns 12 days prior to takeover announcement, which they attribute to illegal trading on inside information

prior to the takeover. Similarly, Dennis and McConnell (1986) document significant abnormal returns prior to merger announcements.

However, it is often very difficult to clearly identify insider trading activity. Meulbroek (1992) argues that most pre-merger trading by insiders is not reported. Thus, she examines unreported insider trades that were later prosecuted by the SEC. However, this is not a complete solution since the SEC most likely does not detect and prosecute all insider trading. Chakravarty and McConnell (1997) analyze the trading of a confessed inside trader in Carnation's stock prior to Nestle's 1984 acquisition of Carnation. Based on several empirical tests, they are unable to distinguish between the price effects of an insider's purchase and a non-insider's purchase. These papers seem to suggest that it is difficult to distinguish the pre-bid price run-up in the equity market due to insider informed trading from that due to non-insider informed trading.

An alternative to the insider trading explanation for the price run-up of targets prior to takeover announcements could be that the market anticipated these announcements. Jarrell and Poulsen (1989) present some evidence in support of this anticipation hypothesis. They show that there is a higher pre-announcement run-up for those targets about which there was a media speculation. Such a price run-up prior to the actual announcement results in an increased cost for the acquiring firm.

While the distinction between insider trading versus market anticipation theory has been the subject of great debate in the literature on equity trading, distinguishing between the two in the options market is even more problematic. In fact, Cao, Chen, and Griffin (1999) argue that it is infeasible to identify insider trading with options data. Arnold, Erwin, Nail, and Bos (2000) try to distinguish between insider and informed trading in the options market prior to a takeover by analyzing call options for a sample of tender offers. Their analysis relies on the assumption that insiders know the exact price and exact timing information. However, the authors admit that for non-tender offers such information is most likely not known with certainty, including whether the merger will actually occur. Their results, based on an analysis of specific contracts insiders would prefer, suggest insider trading. However, they cannot truly reject the presence of non-insider informed traders since it is possible that the non-insider informed traders also have exact information. Schwert (1996) notes another difficulty. Insider trading can result in a canceled offer. He points out that a bidder who sees a target price runup might postpone or cancel a planned bid. Given these difficulties, we focus simply on informed trading prior to the rumor of a merger or an acquisition instead of trying to identify insider trading.<sup>4</sup>

While there are advantages to trading in the options market for informed traders, not many researchers have examined such trading surrounding a corporate event.

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<sup>4</sup> Given the uncertainty about the exact price, the announcement date, the medium of exchange, and the likelihood of success of the offer, we believe that the pre-announcement trading in the options market should only be attributed to informed trading. In a few cases we were able to identify insider trading activity based upon published reports of investigation of such activities.

Some notable exceptions include Jayaraman and Shastri (1993), who study the behavior of implied volatility surrounding announcements of dividend increases. They find some evidence of informed trading surrounding the announcement of unlabeled dividend increases. Also, Jayaraman, Mandelker, and Shastri (1991) and Levy and Yoder (1993) examine the behavior of option implied standard deviations (ISDs) around merger and acquisition announcements. Their findings suggest that increasing stock return volatility signals anticipated corporate announcements. However, informed trading in the options market may lead trading in the equity market.

Amin and Lee (1997) document evidence supporting informed trading in options market surrounding earnings announcement. They find an increase in buying activity prior to positive earnings announcements. However, since typically earnings announcement dates are known in advance, it is quite likely that a part of the pre-announcement trading activity in the options market could be explained by some amount of anticipatory trading by speculators/experienced traders. Schachter (1988) finds a decrease in open interest in the options market prior to quarterly earnings announcements. Wilson (1996) examines options volume and open interest around dividend ex-dates and finds evidence of abnormal volume the week before an ex-date.

Cao, Chen, and Griffin (1999) explore informed trading in the options market prior to takeover announcements. They show a significant increase in call volume prior to takeovers. While their study is similar in spirit to ours, there are some notable differences. The focus of their paper is generally on how informed trading in the options market affects the stock market prior to a merger as well as trading profits. Also, they focus primarily on call options. Our study focuses on both call and put options, since bullish strategies exist for both. Arnold, Erwin, Nail, and Bos (2000) only analyze call option volume for cash tender offers. Unlike our study, neither Cao, Chen, and Griffin (1999) nor Arnold, Erwin, Nail, and Bos (2000) examine changes in open interest surrounding takeovers.

In the stock market, it is common to see volume increases before the announcement of a merger (e.g., Pound and Zeckhauser, 1990; Arshadi and Eysell, 1993; Schwert, 1996; and Arshadi, 1998). However, the concept of open interest is unique to the derivatives markets. Since open interest in listed options is endogenous, an analysis of changes in open interest surrounding the acquisition announcement is likely to provide additional insights about informed trading. Option contracts can be traded without a change in open interest. In contrast, changes in open interest require contracts to be traded, except in the case of expirations. An analysis of both volume and open interest allows us to empirically explore whether informed traders trade more (volume) and how such trading affects the number of contracts outstanding (open interest). Such an issue cannot be addressed using data from the equity market. Further, Chen, Cuny, and Haugen (1995) use open interest to proxy for an investor's willingness to be in the market. They use index futures contracts to test their theoretical model. In the context of our paper, open interest may indicate whether traders are willing to stay in the market of the target company. To the

extent that informed traders are uncertain about the merger details, they may have motivation to hold outstanding contracts.

Other studies have begun to recognize the value of analyzing open interest. For example, Bessembinder and Seguin (1993) use open interest as a proxy for market depth in their analysis of futures markets. Longstaff (1995) argues that as open interest increases, so does the liquidity. This reduces the costs of trading and makes it easier to hide trades. Bessembinder, Chan, and Seguin (1996) use open interest in the futures market as a proxy for divergences of traders' opinions. Leisen and Judd (2000) use a stochastic volatility model to isolate the factors driving option demand in equilibrium. In their model, demand is identical to open interest whereas volume is identical to changes in demand over time. In addition to the academic literature, the financial press also emphasizes the importance of open interest. To illustrate, Friedman (1998) notes that many traders view an increase in open interest as an indication of accumulation by the "smart money".

### 3. Trading strategies

It is quite intuitive why informed traders would purchase call options prior to the announcement of an acquisition or merger. Purchasing a call represents a bullish strategy as investors are predicting an upward movement in the stock price. However, this is not the only means for informed traders to utilize information about a pending takeover in the options market. In fact, Cao, Chen, and Griffin (1999) outline other possible strategies. Specifically, they note that the following are all bullish strategies for the informed trader:

- (i) Purchasing a call option
- (ii) Shorting a put option
- (iii) Purchasing the stock and shorting a call option
- (iv) Closing a previous short call position
- (v) Closing a previous long put position
- (vi) Establishing a bullish call spread (short a call with a higher strike price and buy a call with a lower strike price)
- (vii) Establishing a bullish put spread (buy a put with a lower strike price and short a put with a higher strike price)
- (viii) Establishing a bullish calendar spread (short a short-term call and purchase a longer-term call)

While it is not possible to identify the exact strategy, the results of such activities will be reflected in either the volume of option contracts traded or the open interest, or both. To illustrate, buying a call or shorting a put increases both the daily trading volume and the open interest. However, closing a position will only be reflected in the open interest.

Most of these trading strategies are likely to result in an increase in the trading volume. Thus, one would expect the volume of option contracts traded

to increase if informed traders were acting on their information prior to the announcement of a takeover. However, the impact on open interest is less clear. The outlined strategies can either increase or decrease the open interest. Given that virtually all studies to date examining the information content of trading in the options market have ignored open interest, this makes our study unique. Open interest is endogenous because the investors themselves write the contracts. Thus, changes in open interest may provide new insights with regard to information processing. For example, if volume increases and open interest increases, this suggests that informed traders implement bullish trading strategies that increase the number of outstanding contracts. If volume increases and open interest remains unchanged or decreases, this may suggest that informed traders are not willing to stay in the market of the target company or that closing positions offset or exceeded new positions. While the effect on open interest is essentially an empirical question, Friedman's (1998) hypothesis suggests that an increase in open interest reflects informed trading.

It is also possible to hypothesize about the types of option contracts that informed traders would prefer. For example, Leisen and Judd (2000) note that deep out-of-the-money options provide the greatest leverage and are thus the best suited for traders to profit from superior information. Easley, O'Hara, and Srinivas (1998) develop a microstructure model where an informed trader is more likely to trade in out-of-the-money call and put options as they present a higher leveraged position. Additionally, the informed trader is more likely to trade in options closer to maturity as they are likely to carry a lower time premium. While the Easley, O'Hara, and Srinivas (1998) model shows more specific preferences for informed traders, it is difficult to empirically test the model. They test their model with transaction data, allowing them to classify trade volume as long call volume, short call volume, long put volume, and short put volume. Since we do not have access to such data, we examine the basic premise of the model, which is that informed traders will prefer out-of-the-money options with short-term maturity.<sup>5</sup>

## **4. Data and methodology**

### **4.1. Data**

We identify a large sample of companies that had publicly traded options prior to merging or being acquired. The options trading data are obtained from the Chicago Board of Options Exchange (CBOE). Our sample period consists

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<sup>5</sup> Arnold, Erwin, Nail, and Bos (2000) use the Easley, O'Hara, and Srinivas (1998) model to identify the one optimal insider contract. They assume that insiders know the exact pricing and timing information of the takeover.

Table 1

**Sample selection**

This table provides the details of our sample selection. We start with the list of top one hundred acquisitions each year, published in *Mergers & Acquisitions* in the following year. Since the annual list of top hundred acquisitions in 1996 was not published at the time of data collection, we used four quarterly lists of major acquisitions for 1996. As we are interested only in firms with options traded, we exclude those acquisitions in which options on acquired firm are not traded. Since our data is for CBOE, we then exclude those acquisitions with options traded on an exchange other than CBOE. Subsequently, we exclude any partial acquisitions or acquisitions in which only a unit was acquired, and any acquisitions for which data is missing on the CBOE data file. Our final sample consists of a total of 33 firms.

Number of acquisitions initially included based on <i>Mergers &amp; Acquisitions</i>	1,271
Subtract: Acquisitions in which options on acquired firm are not traded	931
Acquisitions remaining	340
Subtract:	
Acquisitions with options traded on an exchange other than CBOE	218
Partial acquisitions or acquisitions in which only a unit was acquired	68
Missing data on the CBOE data file	21**
Final sample	33

\*\* One-third (7) of these are acquisitions in 1986, the first year for which CBOE has options trading data available.

of 1986 through 1996. We choose 1986 as the starting year of the sample period since this is the first full year for which the data are available from the CBOE.<sup>6</sup>

Table 1 shows the details of our sample selection process. For each of the years in our sample period, we identify the top one hundred acquisitions by purchase price. This list is published annually in *Mergers & Acquisitions*. Since we are interested only in the acquisitions of companies on which options were traded, we use *Value Line Options* to shortlist such acquisitions. From *Value Line Options*, we then identify the exchange on which the options were traded for each of the short-listed acquisitions. Since we have the data for options traded on CBOE only, we exclude the acquisitions of companies whose options were traded on an exchange other than CBOE. From the remaining acquisitions, we further exclude those in which less than 100% interest was acquired or not all the units were acquired. Our resulting sample consists of 33 acquisitions.

Table 2 provides the details of the 33 acquisitions included in our sample. Acquisition details are obtained from *Mergers & Acquisitions*. Rumor, bid and agreement dates are obtained from the *Wall Street Journal* index. The transactions

<sup>6</sup> CBOE was the only options exchange that sold electronic options data at the time that data were collected. Given the difficulties with manual collection and that more than 50% of the trades in options on U.S. equities take place in CBOE, we only include CBOE data. However, we do not anticipate sample selection bias problems with such a limitation, since there is no reason to expect that options listed on other exchanges would exhibit different trading patterns prior to a takeover.



range from \$200 million to \$24.72 billion. In 23 out of 33 cases, the bid date and the rumor date are identical. To be conservative, for the rest of the analysis, we define the comparison and event period based on the rumor date. Using *Lexis/Nexis*, we identify five cases where there was news of investigation of insider trading activities.<sup>7</sup> In Appendix 1, we provide additional details about the allegations of insider trading activities for these companies. In Table 2, we also explore if some options are thinly traded by reporting the mean and median volume for calls and puts prior to the rumor of a takeover. As expected, more puts are thinly traded than calls. If lower liquidity makes it more difficult for informed traders to hide their transactions, they may not be able to take advantage of their information in these options. However, this also suggests that including all companies in our sample may understate the significance of informed trading in companies whose options are more liquid.

#### 4.2. Methodology

To measure the abnormal level of option trading volume for each target company, we use a comparison period approach.<sup>8</sup> We define the benchmark period as –140 to –41 days relative to the rumor date. Because of the wide variation in the number of option contracts traded daily, we use a logarithmic transformation of the volume. We define  $V_{i,t}$  to be  $\ln(1 + \text{Number of call options on company } i \text{ traded on day } t)$ . We compute the benchmark volume as  $\bar{V}_i = \frac{1}{100} \sum_{t=-140}^{t=-41} V_{i,t}$ . We define

two alternative event periods, which we call the pre-rumor periods. One is from –10 to –1 and the other is from –30 to –1. We compute the pre-rumor period volume as  $\bar{V}_i = \frac{1}{10} \sum_{t=-10}^{t=-1} V_{i,t}$  and  $\bar{V}_i = \frac{1}{30} \sum_{t=-30}^{t=-1} V_{i,t}$ . To test the significance of difference in call options trading volume between benchmark and event periods, we perform standard t-test. Our analysis of put options volume as well as call and put options open interest follows the same approach.

For the purposes of sub-sample analysis, we divide call options into two groups based on time-to-expiration and moneyness. The first group consists of short-term out-of-the-money options, which we define as options with maturity less than 60 days and stock to exercise price ratio less than one. The second group consists of the remaining options. We similarly divide put options into two groups. Out-of-the-

<sup>7</sup> The SEC did not confirm investigation in all cases.

<sup>8</sup> This approach is essentially the same as the approach used by Cao, Chen, and Griffin (1999), Schachter (1988), and Amin and Lee (1997). Our main results are robust to the methodology of Ajinkya and Jain (1989) and Sanders and Zdanowicz (1992) as illustrated later in Table 8. However, we focus on results based on a comparison approach since this approach has been used in the literature with both options volume and open interest data. The Ajinkya and Jain (1989) and Sanders and Zdanowicz (1992) approach has been used primarily for stock volume analyses.

Table 2

## Sample details

This table provides the details of the acquisitions included in our sample. Our sample period is 1986 through 1996. The 33 acquisitions included in the sample are identified using *Mergers & Acquisitions* and *Value Line Options*. Rumor, bid and agreement dates are obtained from the *Wall Street Journal* index. Acquisition details are obtained from *Mergers & Acquisitions*. Mean (median) call and put volumes are the average (median) number of contracts traded during the benchmark period. The benchmark period is defined as days -140 through -41, with the day of the first rumor regarding an acquisition being day 0. The trading volume data are from *CBOE*. Five of the sample companies for which there was news of investigation of insider trading activities are in bold. The relevant details for these five companies are included in Appendix 1.

Acquired Company	Option Symbol	Acquirer	Price (\$ mil.)	Rumor Date	Bid Date	Agreement Date	Call Volume		Put Volume	
							Mean	Median	Mean	Median
ADT Ltd.	ADT	Republic Industries Inc.	4,490.0	960701	960701	960701	142	20	36	0
ALC Communications	ALC	Frontier Corp.	1,884.1	950410	950410	950410	192	25	24	0
Alexander & Alexander Svcs.	AAL	Aon Corp.	1,230.0	960919	961211	961211	59	5	7	0
Blockbuster Entertainment	BV	Viacom Inc.	7,971.1	930929	930929	940823	2,449	703	1,003	136
<b>Boatmen's Bancshares</b>	<b>BTQ</b>	<b>NationsBank Corp.</b>	<b>8,700.0</b>	<b>960528</b>	<b>960829</b>	<b>960902</b>	<b>311</b>	<b>63</b>	<b>72</b>	<b>1</b>
Bruno's	BRQ	Kohlberg, Kravis, Roberts & Co.	1,150.0	950420	950420	950518	380	100	36	0
Caremark International	CK	MedPartners/Mullikin Inc.	2,500.0	960513	960514	960514	176	45	84	10
Cheyenne Software	CYE	Computer Associates International	1,200.0	961007	961007	961007	7,524	1,929	1,361	311
Cleanse	CZ	Hoechst AG.	2,723.5	861103	861103	861103	432	146	215	74
Continental Bank	CBK	BankAmerica Corp.	2,162.0	940130	940130	940130	468	90	92	13
<b>Diamond Shamrock</b>	<b>DRM</b>	<b>Ultramar Corp.</b>	<b>1,350.0</b>	<b>960923</b>	<b>960923</b>	<b>960923</b>	<b>39</b>	<b>5</b>	<b>5</b>	<b>0</b>
Dreyfus	DRY	Mellon Bank	1,848.3	931111	931206	931206	25	0	28	0
First Boston	FBC	CS First Boston Inc.	1,677.4	880828	880828	881009	715	185	108	20
First Chicago	FNB	Erger NBD Bancorp.	5,295.6	950416	950712	950712	937	289	214	50
Freeport-McMoRan Gold	FTX	Minorco SA	704.9	900220	900220	900220	204	46	57	10
Global Natural Resources	GNR	Seagull Energy Corp.	600.0	960722	960722	960722	38	0	4	0
<b>Grumman Corp.</b>	<b>GQ</b>	<b>Northrop Corp.</b>	<b>2,104.0</b>	<b>940307</b>	<b>940307</b>	<b>940404</b>	<b>52</b>	<b>5</b>	<b>44</b>	<b>0</b>
IVAX Corp.	IVX	Bergen Brunswig Corp.	1,650.0	961110	961110	961110	1,562	454	598	149

(continued)

Table 2

## Sample details (continued)

Acquired Company	Option Symbol	Acquirer	Price (\$ mil.)	Rumor Date	Bid Date	Agreement Date	Call Volume		Put Volume	
							Mean	Median	Mean	Median
<b>MCI Communications</b>	<b>MCQ</b>	<b>British Telecommunications PLC</b>	<b>20,880.0</b>	<b>961103</b>	<b>961103</b>	<b>961103</b>	<b>1,346</b>	<b>492</b>	<b>432</b>	<b>95</b>
Medical Care America	MRX	Columbia/HCA Healthcare Corp.	875.6	931025	931025	940523	483	712	288	50
MFS Communications	MQF	WorldCom Inc.	12,400.0	960825	960825	960825	727	154	171	20
Norton	NRT	Compagnie de Saint-Gobain SA	1,833.0	900315	900315	900425	209	20	77	0
NWA	NWA	Wings Holdings Inc.	3,759.6	890223	890330	890619	1,313	338	195	30
Owens-Illinois	OI	Kohlberg, Kravis, Roberts & Co.	3,688.0	861211	861211	870210	1,181	330	82	20
Paramount Communications	PCI	Viacom Inc.	9,600.0	930908	930912	940215	2,010	813	246	82
Payless Cashways	PCX	PCL Acquisition Corp.	908.8	880519	880626	880700	119	31	10	0
Pet	PT	Grand Metropolitan PLC.	2,610.0	941205	950109	950109	1,367	403	158	44
RJR Nabisco	RJR	Kohlberg, Kravis, Roberts & Co.	24,716.9	881020	881020	881200	3,422	1,427	1,288	383
Santa Fe Pacific Gold Corp.	GLD	Homestake Mining Co.	2,300.0	961205	961205	961208	258	69	119	20
Syntex	SYN	Roche Holding Ltd.	5,307.2	931219	940502	940502	3,598	1,537	1,823	619
Telebit	TQT	Cisco Systems Inc.	200.0	960722	960722	960722	342	109	29	0
Ventritex	VEQ	St. Jude Medical Inc.	501.0	961023	961023	961023	515	147	87	20
Viacom International	VIA	National Amusements Inc.	3,299.1	860916	860916	870304	3,000	1,000	539	132

money puts are those with stock to exercise price ratio of more than one. Note that the grouping is done on a daily basis throughout the benchmark and event periods. This is important since the moneyness of the options contract will be affected by the pre-rumor stock price runup.

To examine whether abnormal trading activity first manifests itself in the options or equity market, we utilize the methodology advocated by Ajinkya and Jain (1989) and Sanders and Zdanowicz (1992) to perform a day-wise analysis. We begin by defining  $V_{i,t}$  to be  $\ln(1 + \text{Company } i\text{'s volume on day } t)$ , where the volume is call volume, put volume, or stock volume. We then estimate the relation:

$$\Delta V_{i,t} = \alpha + \beta_i \Delta V_{i,t-1} + \varepsilon_{i,t}$$

where  $\Delta V_{i,t} = V_{i,t} - V_{i,t-1}$ , over the benchmark period  $-140$  through  $-41$ . We calculate abnormal volume using standard event study methodology (Brown and Warner 1985) and use the parameter estimates of the above relation to estimate abnormal volume during the pre-rumor period  $-30$  to  $-1$ . For stock volume, we include day-of-the-week dummy variables as in Sanders and Zdanowicz (1992).

## 5. Results

### 5.1. Analysis of call option contracts

In Table 3, we present the results of our analysis of the trading activity of call options prior to the acquisition rumor. We report results both at the individual firm level and at the aggregate level. The results are reported for the log transformed volume variable. Using a pre-rumor period of  $-10$  to  $-1$  days, we find a marked increase in the volume of call options traded. The increase is statistically significant at the 1% level with a t-statistic of 5.56.<sup>9</sup> The result continues to be statistically significant at the 1% level if we use the alternative definition of pre-rumor period as  $-30$  to  $-1$  days. These results strongly indicate that there is a significant increase in trading activity of call options prior to the rumor regarding a possible merger or acquisition. It is also interesting to note that those companies investigated by the SEC generally show a large increase in trading volume.

Focusing on the individual company level, we find that 29 of the 33 companies, i.e., 88% of the sample, have a higher call option trading volume during the pre-rumor period of  $-10$  to  $-1$  days than during the benchmark volume. While the number of such cases declines from 29 to 21 when we use the longer window of  $-30$  to  $-1$  days, it still represents 64% of the sample. In general, the results clearly suggest that there is a surge in trading volume closer to the rumor.

We also examine the open interest surrounding the acquisition announcement. In Table 4, we report the results on call option open interest surrounding the

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<sup>9</sup> We also performed Wilcoxon tests for the medians. The p-value is 0.00.

Table 3

**Call options trading volume**

This table reports the trading volume in call options for the benchmark period and the pre-rumor period for each of the 33 sample firms and the average across these firms. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days –140 through –41. We define two pre-rumor periods: –10 to –1 and –30 to –1. Due to the wide variation in the number of option contracts traded daily, we use a logarithmic transformation of the volume. We define  $V_{i,t}$  to be  $\ln(1 + \text{Number of call options on company } i \text{ traded on day } t)$ . We compute the benchmark volume as  $\bar{V}_i = \frac{1}{100} \sum_{t=-140}^{t=-41} V_{i,t}$ . We compute the pre-rumor period volume as  $\bar{V}_i = \frac{1}{10} \sum_{t=-10}^{t=-1} V_{i,t}$  and  $\bar{V}_i = \frac{1}{30} \sum_{t=-30}^{t=-1} V_{i,t}$ . To test the significance of difference in trading volume between benchmark and pre-rumor periods, we perform standard t-test. \*\*\* indicates that the null hypothesis is rejected at the 1% level of significance. Those companies for which there was news of investigation of insider trading activities are in bold.

Acquired company	Benchmark	Pre-rumor	
	(–140 to –41)	(–10 to –1)	(–30 to –1)
ADT Ltd.	2.89	4.14	4.20
ALC Communications Corp.	2.99	3.15	3.90
Alexander & Alexander Services	1.97	3.24	2.35
Blockbuster Entertainment Corp.	6.69	6.20	6.47
<b>Boatmen's Bancshares</b>	<b>4.10</b>	<b>4.24</b>	<b>3.73</b>
Bruno's Inc.	4.45	4.08	3.92
Caremark International	3.54	5.22	4.45
Cheyenne Software	7.70	7.21	6.61
Cleanese Corp.	5.06	5.50	4.49
Continental Bank Corp.	4.53	5.38	4.71
<b>Diamond Shamrock</b>	<b>1.87</b>	<b>5.23</b>	<b>2.50</b>
Dreyfus Corp.	1.51	4.90	2.84
First Boston Inc.	5.13	7.26	6.78
First Chicago Corp.	5.57	6.40	6.00
Freeport-McMoRan Gold Co.	3.71	4.83	3.58
Global Natural Resources	1.37	2.50	1.66
<b>Grumman Corp.</b>	<b>1.91</b>	<b>4.50</b>	<b>2.84</b>
IVAX Corp.	6.25	7.53	7.40
<b>MCI Communications Corp.</b>	<b>6.03</b>	<b>7.15</b>	<b>6.03</b>
Medical Care America Inc.	5.10	5.86	5.61
MFS Communications	4.97	5.99	5.46
<b>Norton Co.</b>	<b>2.97</b>	<b>7.69</b>	<b>5.37</b>
NWA Inc.	5.64	8.90	8.41
Owens-Illinois Inc.	5.92	7.00	6.93
Paramount Communications Inc.	6.70	6.93	5.76
Payless Cashways Inc.	3.25	7.60	7.09
Pet Inc.	5.94	6.43	6.41
RJR Nabisco Inc.	7.26	7.64	6.88
Santa Fe Pacific Gold	4.15	6.04	4.63
Syntex Corp.	7.35	6.90	6.94
Telebit Corp.	4.40	7.29	6.70
Ventritex Inc.	4.87	5.18	4.86
Viacom International Inc.	6.95	8.02	6.61
Average	4.63	5.94	5.22
t-statistic		5.56***	3.08***
Number (%) of companies with an increase		29 (88%)	21 (64%)

acquisition. We find that for both event windows, (–30 to –1) and (–10 to –1), the level of open interest in the pre-rumor period is significantly higher than that of the benchmark period. As with the volume increases, increases in open interest are statistically significant at the 1% level. In 26 of 33 cases, the open interest during the pre-rumor period of –10 to –1 days is greater than the prevailing level in the benchmark period. As outlined in Section 3, the exact trading strategy cannot be disentangled. However, the significant increase in open interest does suggest that informed traders show a willingness to hold a position in the target company options prior to the rumor date and their strategies involve taking additional positions as opposed to liquidating established positions. Overall, our results suggest that there is information in the call option volume and open interest regarding pending events.

### *5.2. Analysis of put option contracts*

Since informed traders can establish bullish positions with puts as well as calls, we also analyze the volume and open interest behavior of put options. Table 5 indicates that similar to call options, there is a significant increase in the trading activity in put options prior to the rumor of an acquisition. The increase is significant at the 1% and 5% levels for the –10 to –1 and –30 to –1 pre-rumor periods, respectively. For the shorter period, 70% of the companies experience increased put volume trading. As with calls, our individual company analysis highlights that those companies under investigation generally did experience a sharp increase in trading activity.

The results in Table 6 for open interest are similar. In both the pre-rumor periods, the level of open interest in put contracts is significantly greater than that which existed in the benchmark period. 79% of the companies experience an increase in the number of contracts outstanding during the pre-rumor period of –10 to –1 days. The open interest results suggest that, like call options, informed traders appear to take additional positions rather than close established positions.

To explore whether informed traders generally utilize strategies involving call options or put options, we examine the changes in the relative trading level between put and call contracts. Specifically, we examine whether there is a change in the ratio of put to call volume and open interest during the event window. The results are reported in Table 7. In terms of volume, we document a significant decline in the put to call ratio prior to the rumor of a takeover. This is consistent with larger volume increases in calls relative to puts. However, we do not find a significant decline when the open interest ratio is used. Thus, our findings suggest that call volume increases more than put volume, but there is no significant change in the ratio of outstanding contracts.

### *5.3. Equity and options volume daily analysis*

Table 8 reports the day-wise abnormal equity and options volume results. The results provide some support for the hypothesis that the options markets may lead

Table 4

**Call options open interest**

This table reports the open interest in call options for the benchmark period and the pre-rumor period for each of the 33 sample firms and the average across these firms. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days –140 through –41. We define two pre-rumor periods: –10 to –1 and –30 to –1. We use a logarithmic transformation of the open interest. We define  $O_{i,t}$  to be  $\ln(1 + \text{Open interest in call options on company } i \text{ on day } t)$ . We

compute the benchmark open interest as  $\bar{O}_i = \frac{1}{100} \sum_{t=-140}^{t=-41} O_{i,t}$ . We compute the pre-rumor period open

interest as  $\bar{O}_i = \frac{1}{10} \sum_{t=-10}^{t=-1} O_{i,t}$  and  $\bar{O}_i = \frac{1}{30} \sum_{t=-30}^{t=-1} O_{i,t}$ . To test the significance of difference in open interest

between benchmark and pre-rumor periods, we perform standard t-test. \*\*\* indicates that the null hypothesis is rejected at the 1% level of significance. Those companies for which there was news of investigation of insider trading activities are in bold.

Acquired company	Benchmark	Pre-rumor	
	(–140 to –41)	(–10 to –1)	(–30 to –1)
ADT Ltd.	7.86	8.41	8.14
ALC Communications Corp.	7.51	8.22	8.10
Alexander & Alexander Services	6.62	6.94	6.80
Blockbuster Entertainment Corp.	10.33	10.15	10.34
<b>Boatmen's Bancshares</b>	<b>8.35</b>	<b>8.32</b>	<b>8.29</b>
Bruno's Inc.	8.49	8.39	8.27
Caremark International	8.51	8.32	8.17
Cheyenne Software	10.38	9.53	9.92
Cleanese Corp.	7.85	7.65	7.31
Continental Bank Corp.	8.37	8.71	8.74
<b>Diamond Shamrock</b>	<b>6.62</b>	<b>7.33</b>	<b>6.50</b>
Dreyfus Corp.	6.32	6.79	6.20
First Boston Inc.	8.27	9.68	9.42
First Chicago Corp.	9.35	9.84	9.71
Freeport-McMoRan Gold Co.	8.04	8.23	8.10
Global Natural Resources	5.69	6.99	6.84
<b>Grumman Corp.</b>	<b>6.93</b>	<b>6.75</b>	<b>6.61</b>
IVAX Corp.	9.99	10.89	10.41
<b>MCI Communications Corp.</b>	<b>9.88</b>	<b>9.91</b>	<b>9.90</b>
Medical Care America Inc.	8.66	8.89	8.88
MFS Communications	8.93	9.29	9.40
<b>Norton Co.</b>	<b>7.42</b>	<b>8.75</b>	<b>7.85</b>
NWA Inc.	8.87	10.68	10.17
Owens-Illinois Inc.	9.13	9.93	9.86
Paramount Communications Inc.	9.45	9.47	9.46
Payless Cashways Inc.	7.12	9.87	9.45
Pet Inc.	9.35	10.23	10.23
RJR Nabisco Inc.	10.26	10.57	10.36
Santa Fe Pacific Gold	9.77	9.82	9.57
Syntex Corp.	10.90	11.22	11.09
Telebit Corp.	7.98	9.40	9.04
Ventritex Inc.	8.21	8.71	8.20
Viacom International Inc.	9.73	10.20	9.94
Average	8.52	9.03	8.83
t-statistic		4.22***	2.96***
Number (%) of companies with an increase		26 (79%)	23 (70%)

Table 5

**Put options trading volume**

This table reports the trading volume in put options for the benchmark period and the pre-rumor period for each of the 33 sample firms and the average across these firms. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days –140 through –41. We define two pre-rumor periods: –10 to –1 and –30 to –1. Due to the wide variation in the number of option contracts traded daily, we use a logarithmic transformation of the volume. We define  $V_{i,t}$  to be  $\ln(1 + \text{Number of put options on company } i \text{ traded on day } t)$ . We compute the benchmark volume as  $\bar{V}_i = \frac{1}{100} \sum_{t=-140}^{t=-41} V_{i,t}$ . We compute the pre-rumor period volume as  $\bar{V}_i = \frac{1}{10} \sum_{t=-10}^{t=-1} V_{i,t}$  and  $\bar{V}_i = \frac{1}{30} \sum_{t=-30}^{t=-1} V_{i,t}$ . To test the significance of difference in trading volume between benchmark and pre-rumor periods, we perform standard t-test. \*\*\* (\*\*) indicates that the null hypothesis is rejected at the 1% (5%) level of significance. Those companies for which there was news of investigation of insider trading activities are in bold.

Acquired company	Benchmark	Pre-rumor	
	(–140 to –41)	(–10 to –1)	(–30 to –1)
ADT Ltd.	1.08	1.61	1.66
ALC Communications Corp.	1.26	1.95	2.40
Alexander & Alexander Services	0.59	0.89	1.08
Blockbuster Entertainment Corp.	5.16	4.89	5.54
<b>Boatmen's Bancshares</b>	<b>1.87</b>	<b>2.64</b>	<b>1.66</b>
Bruno's Inc.	1.43	0.33	0.41
Caremark International	2.66	1.92	1.50
Cheyenne Software	5.84	4.88	4.70
Cleanese Corp.	4.30	3.30	3.33
Continental Bank Corp.	2.50	2.23	2.24
<b>Diamond Shamrock</b>	<b>0.40</b>	<b>2.95</b>	<b>1.39</b>
Dreyfus Corp.	0.91	1.56	1.01
First Boston Inc.	2.92	4.95	4.74
First Chicago Corp.	3.89	3.91	3.91
Freeport-McMoRan Gold Co.	2.18	1.03	1.65
Global Natural Resources	0.25	1.01	0.74
<b>Grumman Corp.</b>	<b>1.48</b>	<b>1.56</b>	<b>1.21</b>
IVAX Corp.	4.96	5.92	6.17
<b>MCI Communications Corp.</b>	<b>4.46</b>	<b>5.16</b>	<b>4.76</b>
Medical Care America Inc.	3.95	3.79	3.82
MFS Communications	2.92	4.39	4.52
<b>Norton Co.</b>	<b>0.83</b>	<b>4.90</b>	<b>3.08</b>
NWA Inc.	3.16	7.04	6.24
Owens-Illinois Inc.	2.87	4.33	4.38
Paramount Communications Inc.	4.17	3.89	3.48
Payless Cashways Inc.	1.07	5.11	4.51
Pet Inc.	3.62	5.22	4.98
RJR Nabisco Inc.	5.92	5.88	5.12
Santa Fe Pacific Gold	2.82	3.75	2.74
Syntex Corp.	6.49	7.00	6.49
Telebit Corp.	1.09	4.30	3.18
Ventritex Inc.	2.56	3.59	2.62
Viacom International Inc.	4.81	5.33	4.17
Average	2.86	3.67	3.32
t-statistic		3.26***	2.20**
Number (%) of companies with an increase		23 (70%)	20 (61%)



Table 6

**Put options open interest**

This table reports the open interest in put options for the benchmark period and the pre-rumor period for each of the 33 sample firms and the average across these firms. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days –140 through –41. We define two pre-rumor periods: –10 to –1 and –30 to –1. We use a logarithmic transformation of the open interest. We define  $O_{i,t}$  to be  $\ln(1 + \text{Open interest in put options on company } i \text{ on day } t)$ . We compute the benchmark open interest as  $\bar{O}_i = \frac{1}{100} \sum_{t=-140}^{t=-41} O_{i,t}$ . We compute the pre-rumor period open interest as  $\bar{O}_i = \frac{1}{10} \sum_{t=-10}^{t=-1} O_{i,t}$  and  $\bar{O}_i = \frac{1}{30} \sum_{t=-30}^{t=-1} O_{i,t}$ . To test the significance of difference in open interest between benchmark and pre-rumor periods, we perform standard t-test. \*\*\* indicates that the null hypothesis is rejected at the 1% level of significance. Those companies for which there was news of investigation of insider trading activities are in bold.

Acquired company	Benchmark	Pre-rumor	
	(–140 to –41)	(–10 to –1)	(–30 to –1)
ADT Ltd.	6.50	7.50	7.45
ALC Communications Corp.	6.28	7.38	6.97
Alexander & Alexander Services	4.52	5.73	5.49
Blockbuster Entertainment Corp.	10.11	9.89	9.93
<b>Boatmen's Bancshares</b>	<b>7.23</b>	<b>7.34</b>	<b>7.27</b>
Bruno's Inc.	6.77	6.30	6.19
Caremark International	8.47	8.31	8.45
Cheyenne Software	9.29	8.54	8.88
Cleanese Corp.	7.45	7.21	6.96
Continental Bank Corp.	7.38	7.42	7.43
<b>Diamond Shamrock</b>	<b>4.47</b>	<b>5.70</b>	<b>4.91</b>
Dreyfus Corp.	5.37	6.64	6.55
First Boston Inc.	6.78	7.73	7.52
First Chicago Corp.	7.65	7.96	7.90
Freeport-McMoRan Gold Co.	7.14	7.26	7.11
Global Natural Resources	4.78	5.64	5.51
<b>Grumman Corp.</b>	<b>6.84</b>	<b>6.01</b>	<b>5.86</b>
IVAX Corp.	9.11	10.03	9.86
<b>MCI Communications Corp.</b>	<b>9.02</b>	<b>9.34</b>	<b>9.42</b>
Medical Care America Inc.	7.85	8.19	7.85
MFS Communications	7.90	8.19	8.33
<b>Norton Co.</b>	<b>4.80</b>	<b>7.02</b>	<b>6.14</b>
NWA Inc.	7.04	8.96	8.47
Owens-Illinois Inc.	6.97	7.33	7.53
Paramount Communications Inc.	7.76	7.74	7.76
Payless Cashways Inc.	5.74	7.75	7.33
Pet Inc.	7.74	8.95	8.86
RJR Nabisco Inc.	9.02	9.09	8.80
Santa Fe Pacific Gold	9.25	9.28	9.13
Syntex Corp.	10.12	10.35	10.20
Telebit Corp.	5.38	6.88	6.55
Ventritex Inc.	7.08	7.25	6.91
Viacom International Inc.	7.98	8.88	8.74
Average	7.27	7.81	7.64
t-statistic		4.07***	3.42***
Number (%) of companies with an increase		26 (79%)	21 (64%)

Table 7

## Put to call options volume and open interest ratios

This table reports the ratio of trading volume (open interest) in put options to trading volume (open interest) in call options for the benchmark period and the pre-rumor period for each of the 33 sample firms and the average across these firms. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days -140 through -41. We define two pre-rumor periods: -10 to -1 and -30 to -1. We use logarithmic transformations of volume and open interest. For trading in put options, we first define  $V_{i,t}$  to be  $\ln(1 + \text{Number of put options on company } i \text{ traded on day } t)$ . We compute the benchmark volume as  $\bar{V}_i = \frac{1}{100} \sum_{t=-41}^{t=-1} V_{i,t}$ . We compute the pre-rumor period volume as  $\bar{V}_i = \frac{1}{10} \sum_{t=-10}^{t=-1} V_{i,t}$  and  $\bar{V}_i = \frac{1}{30} \sum_{t=-30}^{t=-1} V_{i,t}$ . We similarly compute the benchmark and pre-rumor period call options volume, put options open interest, and call options open interest. Then we compute the appropriate ratios. To test the significance of difference in ratio of put to call options volume (open interest) between benchmark and pre-rumor periods, we perform standard t-test. \*\* indicates that the null hypothesis is rejected at the 5% level of significance. Those companies for which there was news of investigation of insider trading activities are in bold.

Acquired company	Ratio based on volume			Ratio based on open interest		
	Benchmark (-140 to -41)	Pre-rumor (-10 to -1)	Pre-rumor (-30 to -1)	Benchmark (-140 to -41)	Pre-rumor (-10 to -1)	Pre-rumor (-30 to -1)
ADT Ltd.	0.25	0.16	0.25	0.26	0.43	0.51
AIC Communications Corp.	0.13	0.48	0.30	0.28	0.43	0.33
Alexander & Alexander Services	0.11	0.08	0.19	0.12	0.30	0.26
Blockbuster Entertainment Corp.	0.41	0.28	0.54	0.80	0.78	0.66
<b>Boatmen's Bancshares</b>	<b>0.23</b>	<b>0.38</b>	<b>0.32</b>	<b>0.33</b>	<b>0.38</b>	<b>0.36</b>
Bruno's Inc.	0.09	0.01	0.01	0.17	0.12	0.12
Caremark International	0.48	0.06	0.08	0.99	0.98	1.34
Cheyenne Software	0.18	0.11	0.23	0.33	0.37	0.35
Cleanse Corp.	0.50	0.09	0.25	0.71	0.63	0.69
Continental Bank Corp.	0.20	0.05	0.24	0.37	0.28	0.28
<b>Diamond Shamrock</b>	<b>0.12</b>	<b>0.08</b>	<b>0.09</b>	<b>0.13</b>	<b>0.17</b>	<b>0.19</b>
Dreyfus Corp.	1.10	0.22	0.09	0.82	0.63	1.10
First Boston Inc.	0.15	0.12	0.14	0.23	0.15	0.15
First Chicago Corp.	0.23	0.13	0.16	0.18	0.15	0.16
Freepoint-McMoRan Gold Co.	0.28	0.01	0.13	0.41	0.38	0.37
Global Natural Resources	0.10	0.19	0.16	0.47	0.26	0.26

(continued)

Table 7 (continued)

## Put to call options volume and open interest ratios

Acquired company	Ratio based on volume		Ratio based on open interest	
	Benchmark (-140 to -41)	Pre-runor (-10 to -1)	Benchmark (-140 to -41)	Pre-runor (-10 to -1)
		(-30 to -1)		(-30 to -1)
<b>Grumman Corp.</b>	<b>0.84</b>	<b>0.08</b>	<b>0.94</b>	<b>0.45</b>
IVAX Corp.	0.38	0.20	0.42	0.42
<b>MCI Communications Corp.</b>	<b>0.32</b>	<b>0.14</b>	<b>0.46</b>	<b>0.57</b>
Medical Care America Inc.	0.60	0.35	0.45	0.48
MFS Communications	0.24	0.25	0.35	0.34
<b>Norton Co.</b>	<b>0.37</b>	<b>0.09</b>	<b>0.18</b>	<b>0.15</b>
NWA Inc.	0.15	0.16	0.16	0.18
Owens-Illinois Inc.	0.07	0.06	0.10	0.07
Paramount Communications Inc.	0.12	0.05	0.19	0.18
Payless Cashways Inc.	0.08	0.13	0.25	0.12
Pet Inc.	0.12	0.32	0.20	0.28
RJR Nabisco Inc.	0.38	0.20	0.29	0.23
Santa Fe Pacific Gold	0.46	0.17	0.58	0.58
Syntex Corp.	0.51	1.20	0.46	0.41
Teletbit Corp.	0.09	0.07	0.08	0.08
Ventritex Inc.	0.17	0.32	0.32	0.24
Viacom International Inc.	0.18	0.06	0.22	0.27
Average	0.29	0.19	0.37	0.35
t-statistic		-2.03**		-1.10
# (%) of companies with a decrease		24 (73%)		21 (64%)
		20 (61%)		19 (58%)

the equity markets. Trading in both markets appears to increase significantly prior to the rumor, consistent with informed trading in both markets. For call options, abnormal trading volume is statistically significant as early as 8 days before the rumor. For put options, the statistical significance is reduced but an abnormal increase in trading is suggested 3 days before the rumor. Volume in the stock market shows an abnormal increase only on the day prior to the rumor of a takeover.

The pattern is perhaps clearer in Figure 1, which plots the ratio of the daily volume during the days prior to the rumor of a takeover to the average benchmark period volume. Call volume appears to show the largest runup and clearly precedes the runup in stock volume. The ratio for stock volume is fairly close to one for all days prior to the rumor of a takeover except for day  $-4$ . In contrast, the ratio for call volume is considerably above one on most days and the ratio for put volume is also above one on several days. Put volume appears to lead stock volume; however, the equity volume ratio surpasses the put volume ratio in day  $-1$ .

Overall, these results are consistent with other studies that argue that the options markets lead the stock markets in price discovery. In addition, this approach verifies the robustness of our earlier results. Using an event study approach that has been used in the literature for stock volume, we continue to find evidence of informed trading in the options market prior to the rumor date.

#### *5.4. Analysis based on moneyness and maturity of option contracts*

The literature generally suggests that informed trading in option contracts should be concentrated in those call contracts that are closest to maturity and are deep out-of-the-money, since these represent the highest leverage positions and the lowest time premiums. To test this hypothesis, we split our sample into two groups. The first group consists of those call options with a maturity of less than 60 days and a stock to exercise price ratio of less than one. We include all options not meeting these criteria in the second group. All grouping is done on a daily basis. The results of this analysis are presented in Table 9. In Panel A of Table 9, we present the results for call options volume and open interest. As expected, the volume of contracts traded for the first group (i.e., out-of-the-money short-term options) shows a significant increase during the event window. We also find a significant increase in open interest for the first group. The second group exhibits a small statistically insignificant increase in open interest.

Interestingly, the volume of trading activity in the second group also increases prior to the rumor date. As documented in several papers, including Schwert (1996), there is typically a stock price runup prior to the acquisition. Though the CBOE is prompt in introducing new option contracts when there is a price runup in the underlying security, these actions can potentially come with some delay. Therefore, informed traders may trade on available options contracts that have become in-the-money due to the price runup. It is also possible that informed traders were uncertain about the terms of the merger. Thus, it may not be surprising that we find similar

Table 8

**Day-wise abnormal option and stock volumes**

This table reports the day-wise abnormal option and stock trading volumes for the pre-rumor period defined as –30 to –1 and for the event day 0. Days –140 through –41 constitute the benchmark period. The analysis is performed using log transformed variables. Thus, for the call option trading volume event studies, we use  $V_{i,t}$ , defined as  $\ln(1 + \text{Number of call options on company } i \text{ traded on day } t)$ . We use similar log transformed variables for put volume and stock volume. Day-of-the-week dummy variables are employed in the stock volume event study. For details of the methodology, please see Sanders and Zdanowicz (1992).

Day	Calls		Puts		Stocks	
	Volume	Test Stat.	Volume	Test Stat.	Volume	Test Stat.
–30	–0.230	–0.90	0.238	0.90	0.13	1.10
–29	–0.004	–0.02	–0.177	–0.67	–0.05	–0.39
–28	–0.285	–1.11	0.065	0.24	0.04	0.33
–27	–0.311	–1.21	0.132	0.50	–0.09	–0.70
–26	0.341	1.33	0.104	0.39	–0.05	–0.38
–25	0.101	0.39	–0.118	–0.45	0.12	0.99
–24	–0.251	–0.98	0.063	0.24	–0.03	–0.26
–23	0.163	0.63	0.074	0.28	0.11	0.87
–22	0.109	0.43	–0.176	–0.66	0.04	0.30
–21	0.004	0.01	0.444	1.68*	–0.07	–0.55
–20	–0.376	–1.47	–0.446	–1.68*	–0.11	–0.90
–19	0.335	1.31	0.100	0.38	–0.02	–0.20
–18	0.325	1.27	–0.212	–0.80	–0.03	–0.24
–17	0.141	0.55	0.435	1.64	0.04	0.30
–16	–0.322	–1.26	0.265	1.00	0.17	1.36
–15	–0.177	–0.69	–0.023	–0.09	0.08	0.67
–14	0.279	1.09	–0.687	–2.59**	0.05	0.43
–13	–0.171	–0.67	–0.031	–0.12	–0.17	–1.42
–12	0.316	1.23	0.392	1.48	0.00	0.00
–11	0.373	1.45	0.086	0.32	–0.02	–0.15
–10	0.082	0.32	–0.076	–0.29	0.02	0.12
–9	–0.273	–1.06	0.039	0.15	0.12	0.99
–8	0.548	2.14**	0.261	0.98	0.11	0.87
–7	0.455	1.77*	0.203	0.77	0.11	0.91
–6	0.085	0.33	–0.281	–1.06	0.02	0.20
–5	–0.031	–0.12	0.041	0.15	–0.07	–0.56
–4	–0.124	–0.48	0.113	0.43	–0.20	–1.66*
–3	0.123	0.48	0.512	1.93*	0.09	0.71
–2	0.318	1.24	0.086	0.32	0.17	1.42
–1	1.352	5.27***	1.412	5.33***	0.44	3.60***
0	0.743	2.90***	1.399	5.28***	1.63	13.31***

\*\*\* Indicates statistical significance at the 0.01 level.

\*\* Indicates statistical significance at the 0.05 level.

\* Indicates statistical significance at the 0.10 level.

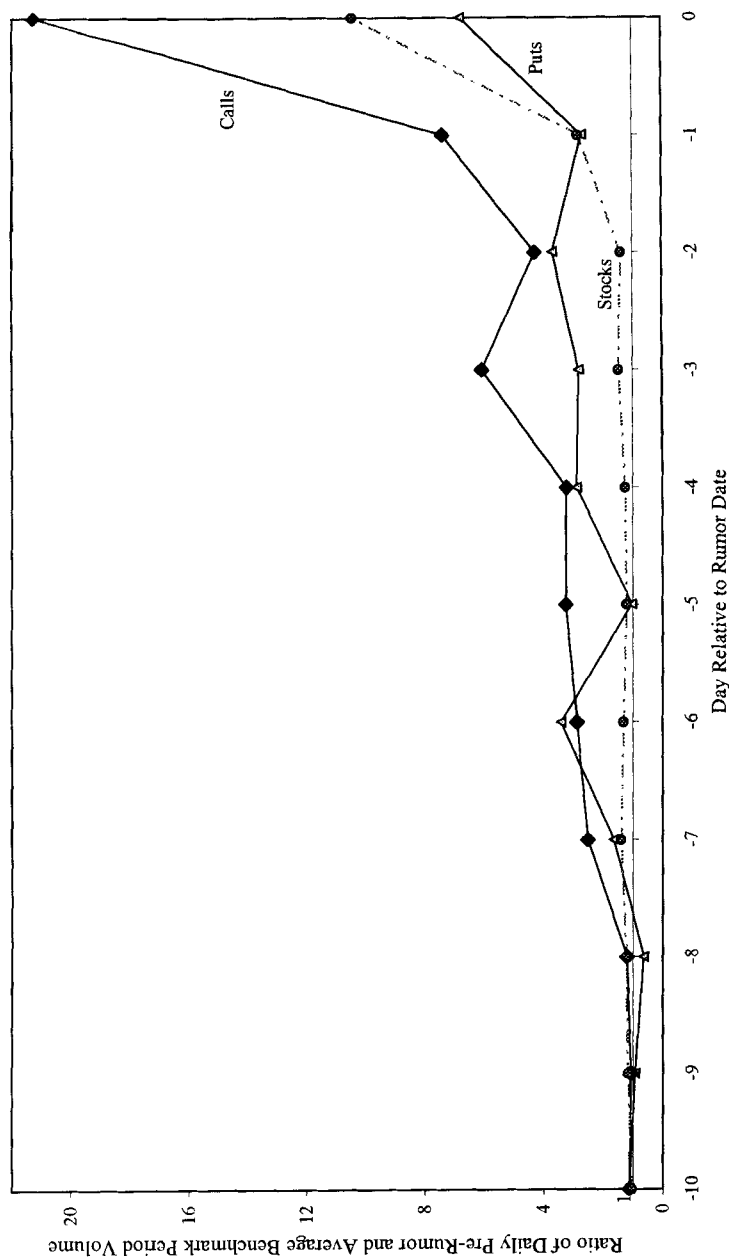


Figure 1

**Ratio of daily pre-rumor volume and average benchmark period volume**

This figure plots the ratio of the daily volume during the days prior to the rumor of a takeover to the average benchmark period volume. The day of the first rumor regarding an acquisition is defined as day 0, and the benchmark period is defined as days -140 through -41. Volume is the number of call options, put options, or shares traded in a firm. For each day during the pre-rumor period, -10 to -1, the ratio is computed for each sample firm and then averaged across the 33 sample firms.

Table 9

**Group-wise options trading volume and open interest**

This table reports the results of the analysis done to examine if informed trading is concentrated in those options that are closest to maturity and are deep out-of-the-money. We split our sample in two groups. The first group consists of those options that have a maturity of less than 60 days and are out-of-the-money (i.e., stock price/exercise price < 1 for calls and > 1 for puts). We include options not meeting these criteria in the second group. For both the groups, we look at trading volume as well as open interest for the benchmark and pre-rumor periods. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days –140 through –41. We define two pre-rumor periods: –10 to –1 and –30 to –1. We use logarithmic transformation of volume and open interest. For trading volume in call options in group 1, we first define  $V_{i,t}$  to be  $\ln(1 + \text{Number of group 1 call options on company } i \text{ traded on day } t)$ . We then compute the benchmark volume for group 1 call options as  $\bar{V} = \frac{1}{33} \sum_{i=1}^{33} \frac{1}{100} \sum_{t=-140}^{t=-41} V_{i,t}$ . We compute the pre-rumor period volume as  $\bar{V} = \frac{1}{33} \sum_{i=1}^{33} \frac{1}{10} \sum_{t=-1}^{t=-10} V_{i,t}$  and  $\bar{V} = \frac{1}{33} \sum_{i=1}^{33} \frac{1}{30} \sum_{t=-30}^{t=-1} V_{i,t}$ . We similarly compute the benchmark and pre-rumor period volume for call options in group 2, open interest for calls in group 1 and group 2, and volume and open interest for puts in group 1 and group 2. Note that the grouping is done on a daily basis. To test the significance of difference between benchmark and pre-rumor periods, we perform standard t-test. \*\*\*, \*\*, and \* indicate that the null hypothesis is rejected at the 1%, 5%, and 10% level of significance, respectively.

*Panel A: Call Options*

	Volume			Open interest		
	Benchmark	Pre-rumor		Benchmark	Pre-rumor	
	(–140 to –41)	(–10 to –1)	(–30 to –1)	(–140 to –41)	(–10 to –1)	(–30 to –1)
Group 1: Average	5.05	6.39***	5.62**	8.83	9.37***	9.09*
t-statistic		(4.76)	(2.61)		(3.67)	(1.71)
Group 2: Average	3.48	4.21***	3.78*	7.40	7.58	7.43
t-statistic		(3.70)	(1.84)		(0.93)	(0.17)

*Panel B: Put Options*

	Volume			Open interest		
	Benchmark	Pre-rumor		Benchmark	Pre-rumor	
	(–140 to –41)	(–10 to –1)	(–30 to –1)	(–140 to –41)	(–10 to –1)	(–30 to –1)
Group 1: Average	2.99	3.77***	3.42**	7.55	8.16***	7.93***
t-statistic		(3.17)	(2.05)		(4.39)	(3.04)
Group 2: Average	1.40	1.66	1.52	5.23	5.31	5.23
t-statistic		(1.32)	(0.83)		(0.23)	(–0.01)

results for both the groups. However, some caution should be used with the second group volume results since the statistical significance is marginal for the longer pre-rumor period.

In Panel B of Table 9, we present the results for put contracts. For short-term out-of-the-money options, both volume and open interest are significantly higher in the pre-rumor period as compared to the benchmark period. Other options do not show any significant change in the trading activity between the benchmark and

pre-rumor period. The results for put options support the hypothesis that informed traders prefer higher leveraged, shorter-term options.

### 5.5. Cross-sectional regressions

As discussed earlier, we identify five companies for which there was news of investigation of insider trading. These five target companies include Boatmen's Bancshares, Diamond Shamrock, Grumman Corporation, MCI Communications, and Norton. While our focus is not on insider trading, these five cases provide some anecdotal evidence of one source of informed trading. Utilizing insider trading investigation is similar in spirit to Meulbroek (1992), who examines unreported insider trades in the equity market prior to a takeover that were subsequently prosecuted by the SEC.<sup>10</sup>

To examine whether these companies showed a significant increase in trading activity relative to the rest of the sample, we perform cross-sectional regressions. Specifically, we use the change in trading volume and open interest of calls and puts as the dependent variable. *Investigation* is a dummy variable that takes a value of one for the five companies for which there was news of investigation of insider trading and zero otherwise. *Tender Offer* is a dummy variable that takes a value of one for companies for which there was a tender offer and zero otherwise. If cash tender offers have a higher degree of certainty regarding the transaction date and price, then insiders may have a significant informational advantage over other informed traders. Thus, if abnormal trading is attributable to insiders, then there may be a positive relationship between *Tender Offer* and volume and open interest. We control for premium paid for the acquisition, which is measured relative to the price prevailing at the end of the benchmark period (i.e., day -41). Table 10 shows the results.<sup>11</sup>

Using the increase in trading volume of calls as the dependent variable, the coefficient of the dummy variable *Investigation* is statistically significant at the 10% level. However, when we use the trading volume in puts as the dependent variable, the coefficient of *Investigation* is not significant. Consistent with our earlier finding based on put to call ratio that informed traders seem to prefer calls over puts, these results seem to suggest that the insider trading activity is probably more prevalent in call contracts than in put contracts. Our results may also simply suggest that the SEC monitors call options closer than put options. However, our results should be interpreted with caution, as our sample size is small. In both of the volume regressions, the coefficient of the *Premium* variable and the *Tender Offer* variable are not statistically significant. Using the increase in open interest as the dependent variable, none of our independent variables are statistically significant.

<sup>10</sup> Also, such an approach does not require assumptions about the information insiders had prior to the rumor date.

<sup>11</sup> The standard errors of the estimates are adjusted for heteroskedasticity (White, 1980).



Table 10

**Regression results**

This table reports the results of regressions to examine the cross sectional variation in the increase in trading volume and open interest of call and put options prior to the first rumor of acquisition. The trading volume and open interest increases are measured as the difference between the pre-rumor (–10 to –1) and benchmark (–41 to –140) trading volumes and open interests, respectively. *Investigation* is a dummy variable that takes a value of 1 for companies for which there was news of investigation of insider trading activities, and 0 otherwise. *Tender Offer* is a dummy variable that takes a value of 1 for companies for which there was a tender offer, and 0 otherwise. *Premium* is the difference between log of price paid for acquisition and log of price at the end of benchmark period on day –41. Adjusted t-statistics based on the heteroskedasticity-consistent covariance matrix as per White (1980) are in parentheses below the coefficients.

	Dependent Variable			
	Increase in trading vol. of calls	Increase in trading vol. of puts	Increase in open interest of calls	Increase in open interest of puts
Intercept	0.84* (1.66)	–0.13 (–0.30)	0.24 (1.01)	0.46 (1.56)
Investigation	1.24* (1.65)	0.90 (1.28)	–0.19 (–0.66)	0.07 (1.15)
Tender Offer	0.22 (0.44)	0.51 (1.31)	0.17 (0.84)	–0.01 (–0.03)
Premium	0.37 (0.41)	1.27 (1.12)	0.53 (0.93)	0.24 (0.40)
F-value	1.4	1.4	0.5	0.1
Adjusted R <sup>2</sup> (%)	3.3	3.9	0.0	0.0

\* Indicates statistical significance at the 0.10 level.

### 5.6. Post-rumor trading analysis

In this section, we report the results of additional analyses done to explore whether the level of trading activity in the options market continues to stay at the increased level or falls to the benchmark level. Studies of informed trading in the equities market have examined trading activities after the rumor date. For example, Schwert (1996) and Jarrell and Poulsen (1989) both examine pre-bid runups and post-bid markups. However, we know very little about trading in the options market after the rumor of a takeover.

It is likely that the volume of options contracts will continue to be at a higher level due to increased investor attention on these stocks. Additionally, risk arbitrageurs are likely to take positions in these contracts, based on their evaluation of the rumor and assessment of the probability of an actual takeover bid and the likelihood of its success. As Brooker (1998) points out, the risk arbitrageurs have become quite prominent during the 1990's and they tend to move in quickly and purchase substantial portions of target company's stock. For these reasons, we expect the level of the trading activity to continue to be higher relative to the benchmark period.

We explore this hypothesis and report the results in Table 11. We define two alternative post-rumor periods: +1 to +10 days and +1 to +30 days. Regardless of the post-rumor period used, the volume of call options continues to stay at the higher level. The results are similar for the put contracts. Additionally, the open interest in call and put contracts in the post-rumor period continues to be high relative to the benchmark period.

## 6. Conclusions

This paper provides empirical evidence on the level of trading activity in the stock options market prior to the rumor of a merger or an acquisition. Our findings are consistent with the hypothesis that there is information embedded in the options market regarding future events. We document a significant increase in trading activity in call and put options for companies with a pending takeover prior to the rumor of such an acquisition. Specifically, we find statistically significant increases in trading volume and open interest prior to the rumor of a takeover.

We also show that the options market appears to lead the equity market. Specifically, we use an event study approach and show that abnormal volume increases occur in calls and puts prior to abnormal volume runups in the stock market. This finding supports the growing body of literature suggesting that the options markets play an important role in price discovery. We also provide results consistent with the hypothesis that informed traders prefer options with high leverage and low option premiums. In addition, we document that the level of trading activity continues to remain at a higher level even after the rumor date. This shows increased investor attention on these stocks.

Further analysis utilizing transaction data to differentiate between informed and insider trading is a useful avenue for future research. We provide anecdotal evidence that the abnormal option volume increases are positively related to illegal insider activity. We explore cross-sectional differences in abnormal volume for five companies for which there was news of investigation of insider trading violations; however, a more complete analysis will provide interesting insights into whether volume runups are attributable to insiders. It will be interesting to study the different trading strategies risk arbitrageurs engage in and their implications for trading activity in the options market. In addition, there is a need for additional research on informed trading in related markets where securities such as junk bonds and convertible securities trade.

Table 11

Post-rumor options trading volume and open interest

This table reports the overall average across the 33 sample firms of trading volume and open interest in call and put options for the benchmark period and the post-rumor period. The day of the first rumor regarding an acquisition is defined as day 0. The benchmark period is defined as days -140 through -41. We define two post-rumor periods: +1 to +10 and +1 to +30. We use logarithmic transformation of volume and open interest. For trading volume in call options, we first define  $V_{i,t}$  to be  $\ln(1 + \text{Number of group } i \text{ call options on company } i \text{ traded on day } t)$ . We then compute the benchmark volume for call options as  $\bar{V} = \frac{1}{33} \sum_{i=1}^{33} \frac{1}{100} \sum_{t=-140}^{-41} V_{i,t}$ . We compute the post-rumor period volume as  $\bar{V} = \frac{1}{33} \sum_{i=1}^{33} \frac{1}{10} \sum_{t=1}^{10} V_{i,t}$  and  $\bar{V} = \frac{1}{33} \sum_{i=1}^{33} \frac{1}{30} \sum_{t=1}^{30} V_{i,t}$ . We similarly compute the benchmark and post-rumor period open interest for call options, and volume and open interest for put options. To test the significance of difference between benchmark and post-rumor periods, we perform standard t-test. \*\*\* indicate that the null hypothesis is rejected at the 1% level of significance.

		Volume			Open interest		
		Benchmark (-140 to -41)	Post-rumor (+1 to +10)	Post-rumor (+1 to +30)	Benchmark (-140 to -41)	Post-rumor (+1 to +10)	Post-rumor (+1 to +30)
Call Options:	Average	4.63	6.51*** (5.51)	5.98*** (3.81)	8.52	9.48*** (5.76)	9.47*** (4.96)
	t-statistic						
Put Options:	Average	2.86	4.64*** (4.87)	4.29*** (3.75)	7.27	8.25*** (5.15)	8.36*** (4.92)
	t-statistic						

## **Appendix 1. Details of companies possibly investigated for insider trading**

### **Boatmen's Bancshares**

There was an unusual surge in Boatmen's Bancshares stock prices and volume prior to its acquisition. Before the surge, two directors of Boatmen's Bancshares had made unusually large purchases of Boatmen's stock, and the value of their holdings increased substantially due to the surge. Missouri state security regulators indicated that they were looking into the trading in Boatmen's Bancshares stock. The SEC declined to confirm its investigation of the trading. The Wall Street Journal pointed out that the daily volume of options contracts on Boatmen's Bancshares stock also increased prior to its acquisition.

### **Diamond Shamrock**

The acquisition of Diamond Shamrock by Ultramar Corp. was announced on September 23, 1996. There was an unusual increase in trading of some of its call options prior to the announcement. Trading in certain calls increased from zero early in September to as many as 999 on September 13. The Chicago Board of Options Exchange said that it was looking into the surge in trading of Diamond Shamrock's call options.

### **Grumman Corp.**

The SEC, the NYSE and the CBOE launched investigations into unusually high share and options trading that preceded a tender offer for Grumman Corp. by Martin Marietta Corp. on March 7, 1994. The regulators were concerned that an 8.5% increase in Grumman's share prices and a substantial increase in options volume at the CBOE may reflect the possible use of insider information. Later in 1995, the SEC filed a complaint against two former Grumman's employees and five more people who were not Grumman employees that they illegally traded on insider information. The seven people agreed to pay nearly \$300,000 to settle the complaint.

### **MCI Communications**

The New York Times reported on November 5, 1996 that there was an unusual increase in trading of call options on MCI shares prior to the announcement earlier that month by MCI that it was considering a buyout offer from British Telecom. The CBOE said that it was conducting a routine investigation. The SEC did not confirm whether there was an investigation.

### **Norton Co.**

It was reported in 1992 that the SEC was investigating insider trading in shares of Norton Co. prior to its acquisition in 1990. The SEC later filed civil insider trading charges in 1996.

## References

- Ajinkya, B. B. and P. C. Jain, 1989, "The behavior of daily stock market trading volume," *Journal of Accounting and Economics* 11, 331-359.
- Amin, K. and C. Lee, 1997, "Option trading, price discovery, and earnings news dissemination," *Contemporary Accounting Research* 14, 153-192.
- Anthony, J., 1988, "The interrelation of stock and option market trading-volume data," *Journal of Finance* 43, 949-961.
- Arnold, T., G. Erwin, L. Nail, and T. Bos, 2000, "Speculation or insider trading: Informed trading in options markets preceding tender offer announcements," Working paper, University of Alabama at Birmingham.
- Arshadi, N., 1998, "Insider trading liability and enforcement strategy," *Financial Management* 27 (2), Summer, 70-84.
- Arshadi, N. and T. H. Eysell, 1993, "Insiders, outsiders, or trend chasers? An investigation of pre-takeover transactions in the shares of target firms," *Journal of Financial Research* 16, 49-59.
- Bessembinder, H., K. Chan, and P. J. Seguin, 1996, "An empirical examination of information, differences of opinion, and trading activity," *Journal of Financial Economics* 40, 105-134.
- Bessembinder, H., and P. J. Seguin, 1993, "Price volatility, trading volume, and market depth: Evidence from futures markets," *Journal of Financial and Quantitative Analysis* 28, 21-39.
- Black, F., 1975, "Fact and fantasy in use of options," *Financial Analysts Journal* 31, 36-41 and 61-72.
- Brooker, K., 1998, "Why companies hate risk arbitrageurs," *Fortune* 138, 270-271.
- Brown, S. and J. Warner, 1985, "Using daily stock returns: The case of event studies," *Journal of Financial Economics* 14, 3-31.
- Cao, C., Z. Chen, and J. M. Griffin, 1999, "Informed trading in the options market," Working paper, Pennsylvania State University.
- Cao, H. H., 1999, "The effect of derivative assets on information acquisition and price behavior in a rational expectations equilibrium," *Review of Financial Studies* 12, 131-163.
- Chakravarty, S. and J. J. McConnell, 1999, "Does insider trading really move stock prices?" *Journal of Financial and Quantitative Analysis* 34, 191-209.
- Chen, N., C. J. Cuny, and R. A. Haugen, 1995, "Stock volatility and the levels of the basis of open interest in futures contracts," *Journal of Finance* 50, 281-300.
- Cox, J. and M. Rubinstein, *Options Markets*, Englewood Cliffs, NJ: Prentice-Hall, 1985.
- Dennis, D. and J. J. McConnell, 1986, "Corporate mergers and security returns," *Journal of Financial Economics* 16, 143-187.
- Diamond, D. W. and R. E. Verrecchia, 1987, "Constraints on short-selling and asset price adjustment to private information," *Journal of Financial Economics* 18, 277-311.
- Easley, D., M. O'Hara, and P. S. Srinivas, 1998, "Option volume and stock prices: Evidence on where informed traders trade," *Journal of Finance* 53, 431-465.
- Friedman, A., 1998, "The striking price: Short cuts," *Barron's* 78.
- Jarrell, G. and A. Poulsen, 1989, "Stock trading before the announcement of tender offers: Insider trading or market anticipation," *Journal of Law, Economics, and Organization* 5, 225-248.
- Jayaraman, N., G. Mandelker, and K. Shastri, 1991, "Market anticipation of merger activities: An empirical test," *Managerial and Decision Economics* 12, 439-448.
- Jayaraman, N. and K. Shastri, 1993, "The effects of the announcements of dividend increases on stock return volatility: The evidence from the options market," *Journal of Business Finance and Accounting* 20, 673-685.
- Keown, A. J. and J. M. Pinkerton, 1981, "Merger announcements and insider trading activity: An empirical investigation," *Journal of Finance* 36, 855-869.
- Kumar, R., A. Sarin and K. Shastri, 1998, "The impact of options trading on the market quality of the underlying security: An empirical analysis," *Journal of Finance* 53, 717-732.
- Leisen, D. P. J. and K. L. Judd, 2000, "Explaining transaction volume and open interest in options in a symmetric information equilibrium between buyer and seller," Working paper, Stanford University.
- Levy, H. and J. A. Yoder, 1993, "The behavior of option implied standard deviations around merger and acquisition announcements," *The Financial Review* 28, 261-272.
- Longstaff, F. A., 1995, "Option pricing and the martingale restriction," *Review of Financial Studies* 8, 1091-1124.

- Manaster, S. and R. J. Rendleman, 1982, "Option prices as predictors of equilibrium stock prices," *Journal of Finance* 37, 1043-1057.
- Meulbroeck, L., 1992, "An empirical analysis of illegal insider trading," *Journal of Finance* 47, 1661-1699.
- Pound, J. and R. Zeckhauser, 1990, "Clearly heard on the street: The effect of takeover rumors on stock prices," *Journal of Business* 63, 291-308.
- Sanders, R. and J. Zdanowicz, 1992, "Target firm abnormal returns and trading volume around the initiation of change in control transactions," *Journal of Financial and Quantitative Analysis* 27, 109-129.
- Schachter, B., 1988, "Open interest in stock options around quarterly earnings announcements," *Journal of Accounting Research* 26, 353-372.
- Schwert, G. W., 1996, "Markup pricing in mergers and acquisitions," *Journal of Financial Economics* 41, 153-192.
- Sheikh, A. and E. Ronn, 1994, "A characterization of the daily and intraday behavior of returns on options," *Journal of Finance* 49, 557-580.
- Stephan, J. and R. Whaley, 1990, "Intraday price change and trading volume relations in the stock and stock option markets," *Journal of Finance* 45, 191-220.
- White, H., 1980, "A hetroskedasticity-consistent covariance matrix estimator and a direct test for hetroskedasticity," *Econometrica* 48, 817-838.
- Wilson, A. J., 1996, "Option trading around ex-dividend dates," *Journal of Derivatives* 3, 49-64.