Is Reversal of Large Stock-Price Declines Caused by Overreaction or Information Asymmetry: Evidence from Stock and Option Markets*

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Abstract

We reexamine the role of option markets in the reversal process of stock prices following stock price declines of 10 percent or more. We find that the positive rebounds for non-optionable firms are caused by an abnormal increase in bid-ask spread on and before the large price decline date. On the other hand, the bid-ask spreads for optionable firms decrease on and before the large price decline date. We also find an abnormal increase in open interest and volume in the option market on and before the large price decline date. Overall, our results suggest that the stock price reversal is not a result of overreaction, nor can it be simply explained by bid-ask bounce.

Is Reversal of Large Stock-Price Declines Caused by Overreaction or Information Asymmetry: Evidence over Stock and Option Markets

I. Introduction

Over the last two decades, the concept of market overreaction to negative news events has received considerable attention in the literature. DeBondt and Thaler (1985) define the overreaction hypothesis as the overreaction to unexpected and dramatic news events. Brown and Harlow (1988) find evidence on short-term corrections to negative events, which is consistent with the overreaction hypothesis. Atkins and Dyl (1990), and Bremer and Sweeney (1991) find that statistically significant reversals for stock prices following large price declines occurred during a single trading day. Bremer and Sweeney (1991) present evidence of the long recovery period of the stock price reversal. This slow recovery is inconsistent with market efficiency. However, Cox and Peterson (1994) report that the degree of reversals vanishes through time. They document that for National Market System (NMS) securities, much of the reversals are attributable to the bid-ask bounce. They find no evidence that stocks with greater initial declines have greater subsequent reversals, rejecting the overreaction hypothesis. Peterson (1995) examines the effect of organized options trading on stock price behavior immediately following large stock price declines. He finds that non-optionable firms tend to have reversals immediately following large price declines, while optionable firms do not.

An alternative explanation for the dynamics of stock prices around large price declines can be explained by the asset flow theory postulated by Caginalp and Balenovich (1999). They argue that the existence of two or more groups with widely differing assessments of value could result in overreaction. More recently, they argue "The overreaction happens because too many traders are caught short or underinvested, and there is a subsequent stampede to buy. This situation is analogous for the downward spike on Day 0" (Duran and Caginalp (2007), pp. 325).[1]

In this study, we reexamine the role of options market in the reversal process of stock prices following large one-day declines. The options market provides additional information to the underlying securities and also increases stock market liquidity by providing hedging alternatives. Hence, the options market plays an important role in the stock price reversal process and may reduce the potential for overreaction through the following two different mechanisms. On the one hand, if the informed traders prefer initiating trades in the options market around the large decline date then the adverse selection costs in the stock market would decrease reducing the potential for rebound after the event. Grossman (1988) suggests that the price of a traded option can convey more information than the replication portfolio can. Detemple and Selden (1991) show that in incomplete markets, the equilibrium stock price depends on the exercise price of the option available. More recently, Pan and Poteshman (2004) provide evidence that there is informed trading in the option markets and that the predictability from option signals for stocks increases with concentrations of informed traders and with greater leverage.

On the other hand, optionable stocks would be more liquid than non-optionable stocks in general. After controlling for other factors, Peterson (1995) shows that CARs are approximately 1.57 percent lower for firms with exchange-traded options than for firms without options. He argues that the enhanced liquidity of optioned stocks results in quickening the price-adjustment process.

By simultaneously examining stock and options markets, our study makes four important contributes to the literature. First, we provide evidence whether the differential price reversal process surrounding large price declines for optioned and non-optioned stocks has persisted over

[1] We thank the referee for pointing out this alternative explanation.

time. Second, we are able to provide direct evidence on the role of bid-ask spread in the price discovery process surrounding large price declines. Third, by directly examining the trading volume and open interest in the options market, we are able to examine whether there is a migration of the informed traders from the stock markets to options market. Finally, we provide evidence on the role played by option market makers through their hedging strategies.

We find that the cumulative abnormal returns (CARs) over the two days following the large price decline date for non-optionable NYSE/AMEX firms are 0.72 per cent, while those of optionable NYSE/AMEX firms are -0.24 per cent. Also, we observed the significant rebound of 0.78 per cent only for the non-optionable NASDAQ firms, while the two-day CARs of optionable NASDAQ stocks are 0.06 per cent. The significant asymmetric reactions to the large price declines between optionable and non-optionable firms are consistent with Peterson's finding, although we examine the different stock exchanges and sample periods.

Cox and Peterson's argument that the bid-ask bounce causes this abnormal rebound leads us to a testable hypothesis that the bid-ask spread should significantly decrease following the large price decline date. We find that the bid-ask spread of non-optionable NASDAQ firms increases even before the large price decline date and decreases back to normal range in the following days. For optionable NASDAQ firms, the bid-ask spread decreases before the large price decline date and continues to stay at the same level in the following week. We also find that about 65 per cent of the closing transactions of non-optionable NASDAQ firms are seller initiated. From these findings, we conclude that the abnormal bid-ask spread change combined with the high volume of seller initiated trades causes this rebound.

This differential bid-ask spread movement between optionable and non-optionable firms around the large price decline date is consistent with the existence of informed traders and their preference to trade in option markets over stock markets. Consistent with this argument, we also find that the open interest and volume increases abnormally around the large price decline date in option markets. At-the-money and in-the-money call option open interest and at-the-money and out-of-the-money put option open interest increased significantly even before the large price decline date. From these findings, we argue that this abnormal rebound phenomenon is evidence of the migration of the informed traders from the stock markets to the option markets.

Finally, we examine the effect of delta hedging to the reversal process. Assuming option market makers are more likely to delta hedge their position, they may function as indirect informed traders in the stock markets. We find a positive relation between the average option delta change and the stock return over the normal period, which is consistent with the hypothesis that option market makers usually are net option sellers. But this relation disappears right after the large price decline date, implying that option market makers become net call option purchasers, while they still are net put option sellers. The positive relation does not disappear right before the large price decline date, so we argue that informed traders do not trade in option markets aggressively enough to change the option market makers' net position. Option market makers do not act as indirect informed traders in the stock markets, although bid-ask spread analysis and open interest change analysis show the migration of informed traders from the stock markets to the option markets.

The remainder of the paper is organized as follows. We review the related literature in Section II. Section III describes the data and methodology. The empirical finding are presented and discussed in Section IV. Section V provides a brief conclusion.

II. Related Literature

2.1 Studies on the stock price reversal process

A number of authors have studied the reversal process following large one-day stock price declines. Bremer and Sweeney (1991) find the recovery period of the stock price reversal to be approximately two days. They argue that this is too long to be consistent with the notion that market prices fully and quickly reflect relevant information. Their sample consists of the Fortune 500 firms. They find that large negative daily rates of return tend to be followed by positive rebounds over the next two days. For a –10 per cent trigger, the average day 1 rebound is 1.77 per cent, and by day 2 the cumulative rebound is approximately 2.2 per cent. They offer illiquidity as one potential explanation for these abnormally large returns.

Cox and Peterson (1994) examine the role of the bid-ask bounce, market liquidity, and overreaction in explaining price reversals in the three-day period immediately following large one-day declines. They examine daily stock returns for all NYSE, AMEX, and NMS firms that are listed on CRSP from January 1963 through June 1991. They report significant positive average cumulative abnormal returns for days 1 through 3. However, the degree of reversals tends to decline through time; following October 1987 there are on average no reversals. These inter-temporal patterns are consistent with the hypothesis that increased market liquidity through time may reduce the degree of reversals.

For NMS firms, they examine the abnormal reversals based on closing transaction prices and the average of closing bid and ask quotations. They find that the significant positive average abnormal transaction returns on day 1 become essentially zero in the first sub-period (January 1983 – August 1987) and negatively significant in the second sub-period (November 1987 – June 1991) after the bid-ask bounce is removed. They suggest that the bid-ask bounce is an important component of NMS reversals. For days 1 through 3, they still find significant abnormal returns in the first sub-period after the bid-ask bounce is removed, but there is no average reversal in the second sub-period, which is consistent with those for NYSE and AMEX securities and with the hypothesis that greater liquidity through time reduces the degree of reversals. Further, they do not find evidence consistent with the overreaction hypothesis.

Cox and Peterson (1994) also report the significantly negative average cumulative abnormal returns for days 4 through 20. They conclude that large one-day price declines are more a precursor of negative performance than of positive performance. Pritamani and Singal (2001) and Larson and Madura (2003) show that large price changes accompanied by a public announcement display price continuation. Their finding supports the notion that uninformed events are associated with overreaction, whereas informed events are associated with underreaction.

Peterson (1995) examines the effect of organized options trading on stock price behavior immediately following stock price declines of 10 per cent or more. He analyzed 203 pairs of NMS optionable and non-optionable firms from June 1985 through December 1992. After controlling for the bid-ask bounce, firm size, share price, return standard deviation, and beta, he finds that three-day cumulative abnormal returns for optionable firms are approximately 1.57 per cent less than those for non-optionable firms. He suggests that option trading enhances market efficiency and/or liquidity. He interprets the disappearance of the degree of reversals in Cox and Peterson's work (1994) as a result of the increasing number of listed options.

Caginalp and Balenovich (1999) argue that overreaction occurs because of the finiteness of assets rather than infinite supply of assets assumed by the advocates of Efficient Market Hypothesis (EMH). Caginalp, Porter, and Smith (2000) model the asset pricing behavior in the context of experimental markets. They assume that the investors follow a combination of two factors in setting asset prices—fundamental and the recent price trend (momentum). They document that the price behavior is affected by traders who trade based on the recent price movements than on the fundamentals. Akhigbe, Larson, and Madura (2002) do a focused study on the response of technology stocks to extreme price changes. They construct a controlled sample of non-technology stocks with a similar extreme price change on that event date. They conclude that market is over optimistic when it revalues technology stocks relative to non-technology stocks. Sturm (2003) also documents evidence in support of overreaction hypothesis. In particular, he documents that pre-event return and firm characteristics influence investor behavior and that in turn affects their response to negative price shocks. Madura and Richie (2004) extend the literature of study of overreaction to exchange-traded funds (ETFs). Using a sample of 1,989 extreme ETF price changes, they document substantial overreaction of ETFs during normal trading hours and after hours. They conclude that their evidence supports the notion that informed traders benefit at the expense of uniformed traders and systematically correct for their overreactions.

More recently, using a large data set consisting of closed-end funds, Duran and Caginalp (2005, 2007) analyze overreaction behavior. They use closed-end funds for their analysis as the Net Asset Value of the fund is determined on a regular basis. Unlike other studies that have focused on the long-term deviations, they focus on the changes in the discount or premium that occur on a short term basis. An examination of significant rise or fall price deviations and market prices reveal a diamond pattern. They provide evidence that any significant deviation between the market price return and fundamental value is followed by a reversal. More interestingly, they are able to document that during the pre-event days, there is a marked tendency to move in the opposite direction. Thus, we see that the literature focusing on overreaction has been significantly extended by Duran and Cagnialp among others in recent years.

2.2 Studies on the links between stock and option markets

Ever since Black (1975) suggested that informed traders might prefer option markets to stock markets because of the higher leverage, many researchers have studied the links between option and stock markets. Conrad (1989) shows that an introduction of individual options causes a permanent increase in price and decrease in volatility. From the fact that the price increase is positively related to opening day trading volume in options, she suggests that the dealers or other traders are building inventory for hedging purposes. Fedenia and Grammatikos (1992) show that the listing of options significantly affects the spread on the underlying stock. Kumar, Sarin, and Shastri (1998) find that option listings are associated with a decrease in the bid-ask spread and with an increase in depth, trading volume, transaction size, and trading frequency. They also find that option listings are associated with a decrease in the adverse selection component of the underlying stock's bid-ask spread.

Easley, O'Hara, and Srinivas (1998) show that stock prices lead option volumes, probably because of hedging-related trading in options and because some option volumes lead stock price changes. They suggest option markets as a place for information-based trading. Chan, Chung, and Fong (2002), however, suggest that informed investors initiate trades in the stock markets but not in the option markets by showing that stock net-trading volume has a strong predictive ability for stock and option quote revisions, while option net-trading volume has no incremental predictive ability. They suggest that although informed investors trade in the option markets, they do not trade aggressively, probably because of the low liquidity in the option markets. Chakravarty, Gulen, and Mayhew (2003) show that the level of contribution of the option markets to price discovery is related to market frictions – option markets tend to be more informative when option effective spreads are narrow and when stock spreads are wide. By examining a dataset of quarterly holdings of hedge fund advisor, Aragon and Martin (2007) find the predictive power of option holdings. After excluding zero delta strategies, stocks underlying holdings of calls and puts exhibit annualized risk-adjusted returns of 6.7% and −11.3%, respectively. This finding supports that option markets are still an important venue for informed traders.

Ni, Pearson, and Poteshman (2005) provide evidence that option trading changes the prices of underlying stock. By focusing on option expiry dates, they show that the closing prices of stocks with listed options cluster at option strike prices. They attribute this to rebalancing done by option market makers. Cao and Ou-Yang (2005) show that trades of the underlying stock depend on the open interest in options. They show that the open interest and trading volumes in options are higher around the dates of public announcements. Recently, Pearson, Poteshman, and White (2007) find a negative relationship between the gamma of the net option position of likely delta-hedgers and the absolute return of the underlying stock. These findings provide added evidence that option market activity has a pervasive impact on the price paths of underlying stocks.

III. Data and Methodology

i) Sample Selection

We examine daily stock returns following one-day price declines of 10 per cent or more. Daily returns for all NYSE, AMEX, and NASDAQ firms that are included on CRSP are analyzed. We also examine the features of the options underlying stocks included in our sample for the comprehensive studies of the effect of the option markets to the stock price reversals. Daily volume, open interest, bid-ask spread, and option delta for each option contract are obtained from OptionMetrics. Since the option data from OptionMetrics are available from January 1996, the sample period for our study is from January 1996 through December 2004.

To make the optionable and non-optionable sample firms as similar as possible, we impose the following selection criteria. Closing stock prices on the day before the large price decline date must be at least $15[2]. All stocks must trade on the large price decline date and the following three trading days. In order to estimate market model parameters, we set the pre-event benchmark period from 105 through six trading days prior to the large price decline date. We eliminated stocks traded less than 30 days over the benchmark period.

We rank all firms with daily price declines of at least 10 per cent that meet the above criteria alphabetically for each trading day.[3] The first firm with traded options and the first non-optionable firms are selected. Any dates that do not have at least one optionable and non-optionable firm are discarded. Only one observation in each group is allowed per day to maintain statistical independence. For NASDAQ firms, we examine both returns based on closing transactions and returns based on the closing average of bid and ask prices to remove the bid-ask bounce effect to the reversal process.

ii) Stock price reversals following the large price decline date

We compute abnormal returns from the market model approach using the equally-weighted CRSP index return as a market proxy and then we sum the two-day abnormal returns to form a cumulative abnormal return (CAR). As the previous studies suggest, we find that the reversal is complete for most stocks by the end of the next day to the large price decline date. We examine the effect of options trading on the stock price reversal process by cross-sectionally regressing the CARs against a dummy variable representing the presence or absence of exchange-traded options and control variables. The model is

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[2] We report the results with the cut off price of $15 to be consistent with Peterson (1995).

[3] This methodology is identical to the one used by Peterson (1995) among others.

$$CAR_i = \alpha_0 + \alpha_1 AR0_i + \alpha_2 OPTDUM_i + \alpha_3 PRICE_i + \alpha_4 AvgTurnover_i \qquad (1)$$

$$+ \alpha_5 SD_i + \alpha_6 Decimal_i + \alpha_7 AR0_i * OPTDUM_i + \varepsilon_i$$

where

$CAR_i =$ the cumulative abnormal return for firm i's common stock over two days following the large price decline date;

$AR0_i =$ the abnormal return for firm i's common stock on the large price decline date;

$OPTDUM_i =$ a dummy variable equal to one if there are exchange-traded options for firm i, and zero otherwise;

$PRICE_i =$ the closing stock price for firm i six trading days before the large price decline date;

$AvgTurnover_i =$ the average daily turnover, which is calculated by dividing the daily trading volume by the number of shares outstanding, of firm i's common stock over trading days 105 through 6 before the large price decline date;

$SD_i =$ the standard deviation of firm i's common stock over trading days 105 through 6 before the large price decline date;

$Decimal_i =$ the dummy variable equal to one for NYSE (NASDAQ) firms with large price decline date of no earlier than January 29, 2001 (April 9, 2001);

$AR0_i * OPTDUM_i =$ the interaction terms between the abnormal return for firm i's common stock on the large price decline date and the optionable firm dummy variable; and

$\varepsilon_i =$ a regression error term for firm i.

If the overreaction hypothesis holds, α_1 will be negative, since the greater overreaction would lead to the greater correction. If option markets reduce the reversal process, α_2 will be negative. Peterson (1995) suggests that the stock price level may proxy for liquidity. If lower-price stocks reverse more than higher-price stocks, α_3 will be negative. We also include the average daily turnover variable to control the liquidity in the reversal process. If the reversal process is caused by the illiquidity, then α_4 will be significantly negative. If the reversal process is related to return volatility, which is captured by the standard deviation, then α_5 will be significantly positive. We include the decimalization dummy variable. All NYSE-listed stocks were switched to a decimal trading system on January 29, 2001, and all NASDAQ stocks followed suit on April 9, 2001. Quoted and effective bid-ask spreads declined substantially on each market with the conversion to decimalization (see, NASDAQ (2001) and Bessembinder (2003)). If bid-ask bounce is the main source of the abnormal return, then α_6 will be significantly negative because of the decreased spread. Finally, we include the interaction terms between the abnormal return on the large decline date and the optionability dummy variable. If the significant rebounds on the non-optionable firm are caused by the overreaction, then α_7 will be positive.

iii) The effect of the bid-ask bounce to the reversal process

Even if the bid-ask bounce is the main source for the reversal process, the bid-ask bounce alone cannot account for the significant influences of option trading documented in Peterson (1995). The abnormal positive returns are not likely to be detected when the bid-ask spreads stay within the normal range under the condition that the average bid-ask prices remain constant. We examine the bid-ask spreads for all NASDAQ firms in the sample to understand the investors' behavior. We calculate the average bid-ask spread for each stock in the sample over the benchmark period, trading days 105 through 6 before the large price decline date, to compute the excess spread of each closing bid-ask spread on day -5 through day 5, while day 0 is the large price decline date and day 5 (day -5) is the fifth trading day after (before) day 0.

Also, it is consistent with the overreaction hypothesis to expect that most of trades on the large price decline date will be seller-initiated. However, for optionable firms, under the hypothesis of increased information flow from option markets to stock markets, investors may be able to estimate the true value of the stock so they are not forced to sell the stock for lower prices than the true value of the stock. By examining whether the trades on the large price decline date are dominated by seller-initiated trades or not, we can understand the effect of option markets to the stock price overreaction and reversal behavior.

We classify trades with an approach similar to the one used by Lee and Ready (1989) and Keim (1989). Since we cannot differentiate the buyer-initiated trades from the seller-initiated trades with our data, we treat the trade with a transaction price higher than the average of bid and ask prices as the buyer-initiated trade and the trade with a transaction price lower than the average of bid and ask prices as the seller-initiated trade. Since only inter day transaction data are available, we exclude the trade with the price equal to the average of bid and ask prices in this study. On average, the closing transaction price is the average of bid and ask prices because the last trade of any day would be seller initiated as much as buyer initiated. Hence, the comparison t-test between the sample seller-initiated trade percentage and the hypothetical value, 50 per cent, provides a framework for examining the overreaction and reversal on and after the large price decline date.

iv) Bid-Ask Spread, Volume, and Open Interest in option markets

We also examine the bid-ask spread in the option markets. One has to be careful when comparing the bid-ask spread with the benchmark bid-ask spread in the context of option markets. The important difference between stocks and options is that, as time goes on, the time-to-expiration of option decreases, resulting in reduced option value and price. Since the bid-ask spread is positively correlated with security price, we cannot directly compare the bid-ask spread of options with the benchmark spread. Hence we compare the percentage bid-ask spread of options to the benchmark spreads. If the informed traders are likely to initiate trades in the option markets, we expect spreads to widen in the option markets (see Glosten and Milgrom (1985)).

We also examine the volume and open interest for the options on the underlying stocks in the sample. Although all the options are American options, options do not have to be closed before the expiration when the market price is greater than the payoff, so there is likely to be an increasing trend in the open interest. In order to account for this trend in the open interest, we compare daily open interest change to the average daily open interest change over the benchmark period, day -105 through day -6. We calculate daily open interest changes on the individual option contract basis and sum them across all trades in a given option series (i.e., given strike price, expiration date, and underlying stock) on a given day. If we find the abnormally increased open interest near the large price decline date, this could show the preference of informed traders.

Also, although informed traders may prefer option markets for several reasons, the illiquidity – relatively large bid-ask spread – hinders them from trading aggressively in the option markets. We classify options into three moneyness groups and three time-to-expiration groups. At-the-money (ATM) options are defined as having a strike price within 10 per cent of the underlying stock price on day -6. In-the-money (ITM) and out-of-the-money (OTM) options have strike prices greater or less than 10 per cent of the underlying stock price on day –6, where the payoff from the former is positive but the payoff from the latter is zero. On the other hand, short-term-to-expiration (STX) options are defined as having a time-to-expiration date of less than 30 calendar days and long-term-to-expiration (LTX) options are defined as having a time-to-expiration date of greater than 90 calendar days on each day. Otherwise, options are defined as mid-term-to-expiration (MTX) options on each day.

v) Delta hedging effect

Since option market makers are likely to delta hedge their net option positions (see Cox and Rubinstein (1985)), we are able to analyze the information flow from option markets to stock markets by examining the relation between option deltas and stock returns. If option market makers are net call option writers (purchasers), then they have to buy (sell) underlying stocks to make their net option position to be delta neutral. Therefore, if the option delta increased today, then they have to buy (sell) more underlying stocks tomorrow, which may result in the positive (negative) relation between today's net increase in option delta and the tomorrow's underlying stock return. It is likely that option market makers trade during the day to delta-hedge their position. Given the limitation of our data, which provide daily closing prices and features, we can only examine the inter-day relationship. If option market makers are net put option writers (purchasers), then they have to sell (buy) underlying stocks to make their net option position to be delta-neutral. Since the put option delta is negative, while the call option delta is positive, if the option delta increased today then net put option writers have to sell (buy) fewer underlying stocks tomorrow. As a result there exists a positive (negative) relation between today's net increase in put option delta and tomorrow's underlying stock return like call options.

We examine the effect of the changes in option delta on the stock price reversal process by cross-sectionally regressing daily holding period stock return on day t against the daily changes in option delta on day t-1 over the four different periods – (day -105, day -6), (day -5, day -1), (day 1, day 5), and (day 6, day 105). We calculate the daily option delta change on the individual option contract basis and average them in a given option series on a given day. The model is

$$ret_{ti} = \alpha_0 + \alpha_1 \Delta\delta_{t-1\,i} + \varepsilon_{ti} \qquad (2)$$

where

$ret_{t\,i}$ = the daily holding period return on stock *i* on day *t* in percentage;

$\Delta\delta_{t-1\,i}$ = the average daily option delta change in a given option series on day *t*-1; and

$\varepsilon_{t\,i}$ = a regression error term for firm *i* on day *t*.

If option market makers are net option writers (purchasers), then α_1 will be positive (negative). Since the aggregate position of the whole option contract series to the option market makers matters when they delta hedge on day *t*, we focus on the average daily option delta change in a given option series on a given day. For some illiquid options, the option price does not change when the underlying stock price changes. In order to examine the effect of liquidity in the option markets on the relation between the average daily option delta change and the daily stock return, we classified the options into three moneyness groups and three time-to-expiration groups, as defined in the previous section. We then run the regression analysis above for each sub-group. Also the magnitude of α_1 may tell us how much information the order flow from option market makers can translate from the option markets to the stock markets.

IV. Empirical Findings

The sample consists of 1,018 pairs of optionable and non-optionable NYSE/AMEX firms[4] and 1,443 pairs of optionable and non-optionable NASDAQ firms that experience stock

[4] On June 13th 1997, the stock price of Berkshire Hathaway Inc. dropped 18.74% from $47,500 per share. Although this case does not affect any features of the sample other than average stock price, we decided to

price declines of at least 10 per cent on the same day. We present the frequency of paired observations in Table 1. In Table 2, we compare the variables of interest in the study between optionable and non-optionable firms across different stock exchanges. Although the average size of optionable firms is much greater than that of the non-optionable firms, other liquidity proxies such as price, volatility, and turnover are similar in both groups. The average standard deviation of daily stock return of NYSE/AMEX (NASDAQ) optionable firms is 3.4 (4.9) per cent, where that of non-optionable firms is 3.6 (4.9) per cent.

Average daily abnormal returns from the market model approach using the equally-weighted CRSP index return[5] as a market proxy and t-values are presented in Table 3. For NASDAQ firms, abnormal returns are calculated based on both transaction closing prices and average of closing bid and ask quotations. Non-optionable NYSE/AMEX (NASDAQ) firms have positive and statistically significant CARs of 0.72 (7.8) per cent with t-stat (2.30) ((3.04)) over the two days following the large price decline date. However, CARs for optionable NYSE/AMEX (NASDAQ) firms are negative 0.24 (positive 0.06) per cent and are not statistically different from zero. When we use the average of closing bid and ask quotations we do not find any rebound after the large price decline date. These results are consistent with Peterson's (1995), although we use different sample period and sample firms from different stock exchanges.

We present regression results from the estimation of equation (1) in Table 4[6]. Panel A (B) presents the results for NYSE/AMEX (NASDAQ) firms. In Panel A and Panel B, AR0 is

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drop this case from our sample so that our sample can represent the comparable range of optionable and non-optionable stock prices.

[5] We also examine the abnormal returns with the value-weighted CRSP index return and find the similar results reported in Table 2. Therefore we report only the result with the equally weighted index henceforth.

[6] We report the regression results with the dependent variable of CARs to be consistent with previous studies such as Bremer and Sweeney (1991), Cox and Peterson (1994), Peterson (1995), and Sturm (2003). Since the reversal is complete for most stocks by the end of the next day to the large price decline date, we

significantly positive. This is inconsistent with the overreaction hypothesis, which assumes the greater overreaction would lead to the greater correction[7]. The option dummy variable is significantly negative in both panels, suggesting that option trading affects the stock price reversal process by providing efficiency and/or liquidity to the stock markets. However, the interaction term between the abnormal return on the large decline date and the optionable firm dummy variable is not significant in both panels. This strengthens the suggestion that the rebounds are not caused by the overreactions. These findings are consistent with those of Cox and Peterson (1994) and Peterson (1995).

However, the stock price, the volatility, and the turnover affect the reversal process differently across stock exchanges. The coefficient of stock price for NYSE/AMEX (NASDAQ) firms is positive (negative) but the magnitudes are very small for both. This is different from Peterson (1995) who reports a significant negative coefficient for stock price with the sample of NASDAQ firms. Although the average turnover variable is statistically significant for NASDAQ firms, that of NYSE/AMEX firms is not different from zero. The coefficient of standard deviation is only significant negative for NYSE/AMEX firms. From these findings, we posit that the liquidity (or the bid-ask spread) itself in general does not affect the stock price reversal process. The decimalization dummy variable is negative but not significant for both panels. This supports that liquidity plays in the stock price reversal process very little. We present results showing that the abnormal bid-ask spread movement around the large price decline date causes the stock price rebound.

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also run the regression analysis with the dependent variable of the abnormal return on day 1. The unreported table shows the qualitatively same result with this alternative dependent variable.

[7] Duran and Caginalp (2007) find the magnitude of reversal increases as the degree of shock increases. Since they define the shock as the price deviation from the net asset value of the closed-end funds and we examine the large price decline of the ordinary stocks, these results may not be in conflict with each other.

So far we have seen that the abnormal rebound still exists immediately following large stock price declines. Table 3 shows that the rebound disappears when the averages of closing bid and ask quotations are employed. This implies that the bid-ask bounce does substantially account for the reversal process. We present the bid-ask spread movements of NASDAQ firms around the large price decline date in Figure 1. We find that the bid-ask spread of non-optionable firms decreases significantly on day 1 from day 0, while the spread of optionable firms shows no change. We interpret this finding as being consistent with the argument that the market makers in the stock markets try to reduce the adverse selection by increasing the bid-ask spread of non-optionable firms (see Glosten and Milgrom (1985)). We use the average spread over day -105 through -6 as our benchmark spread level. We also find that the bid-ask spreads for non-optionable firms already increased above the benchmark spread level, even before the large price decline date, and after the large price decline date the bid-ask spreads revert to normal range.[8] On the other hand, the bid-ask spreads for optionable firms already decreased below the benchmark spread level before the large price decline date and continue to stay at the same level in the week following.

We also present the percentage of seller-initiated trades on and after the large price decline date in Figure 2 and Table 5. For non-optionable firms, 64.7 (35.3) per cent of closing transactions are seller (buyer) initiated[9] while 50 (50) per cent of closing transactions of optionable firms are seller (buyer) initiated. The argument that the bid-ask bounce accounts for the reversal process could be supported by this abnormal increase in the seller-initiated trades for non-optionable firms. However, without the bid-ask spread change presented in Figure 1, the

[8] We repeated the analysis using three different benchmark periods (-155 through -6, -55 through -6, and -25 through -6). Qualitatively our results were similar.

[9] Unreported t-test shows that the buy/sell ratio for the non-optionable firms is significantly different from 50% at the 1% level.

abnormal return caused by the seller-initiated trades cannot be greater than the normal bid-ask spread itself. From these two findings, we suggest that in addition to the bid-ask bounce, the bid-ask spread change around the large price decline date is the major contributor to the reversal process.

The differential bid-ask spread movements for non-optionable and optionable firms presented in Figure 1 could be due to the preference of informed traders. If the informed traders prefer to trade in option markets rather than stock markets then we should observe an abnormal increase in bid-ask spread in the option markets before the large decline date as we observe in the stock markets for the non-optionable firms. Figure 3 shows that the percentage spread increases for both call options and put options relative to their benchmark spreads[10] before the large decline date. This finding is consistent with the argument that the informed traders initiate trading even before the large price decline date in the option markets. As the number of informed traders increases in the option markets, option market makers increase the bid-ask spread even before the large price decline date. We also present the aggregate open interest and the trading volume around the large price decline date in Figures 4 and 5, respectively. As we hypothesized, the open interest and trading volume are significantly greater around the large decline date than during the benchmark period. Also, the open interest seems to increase significantly more on day 0 than on any other days, but Figure 4 shows the increasing trend in the open interest at the same time.

In order to detrend open interest, we compare the daily open interest changes and present the results in Table 6 and Table 7. We compare daily open interest change to the average daily

[10] We used the 100 days benchmark period over day -105 through -6 for Figures 3 through 5. We repeated the analysis using three different benchmark periods (-155 through -6, -55 through -6, and -25 through -6). Our results were qualitatively similar.

open interest change over the benchmark period, day -105 through day -6[11]. Positive (negative) numbers indicate that the open interest increases more (less) than the benchmark average on a given day. Negative numbers do not necessarily mean that the option contracts were closed on a given day. We present the aggregate results for all options across all exchanges in our sample in Table 6 and Table 7. In Table 6, we document a significant increase in open interest in ATM and ITM call options as well as in OTM put options. Despite the expensive trading costs for OTM options, OTM put option open interest increases significantly between day -3 and day -1. Although our data provides only an aggregate number of open interest contracts, we assume that these abnormal increases in put option open interest are long positions. These findings are consistent with the argument that informed traders initiate trades in the option markets even before the large price decline date, resulting in increased option spread and decreased stock spread. In Table 7, STX and MTX option open interest increases abnormally before the large price decline date, but LTX option open interest does not seem to increase. This is consistent with the hypothesis that the informed traders take trading costs into consideration.

Finally, we present the results from the regression model (2) in Table 8. In both Period I (-105,-6) and Period IV (6,105), the coefficient of average daily option delta change is positive and statistically significant. This implies that option market makers are net option writers of both call and put options over the normal period. In Period III, immediately following the large price decline date, the average daily option delta changes have limited explanatory power[12]. This implies that option market makers become net call option purchasers, while they still remain in the net put option short position because of the significantly decreased underlying stock prices. This is also consistent with the abnormally increased open interest on day 0.

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[11] We repeated the analysis using three different benchmark periods (-155 through -6, -55 through -6, and -25 through -6). Qualitatively our results were similar.

[12] The result does not depend on the inclusion of daily option delta change on day 0. The average daily option delta changes lose their explanatory power again over the period of days 2 through 5.

Although we see an abnormal increase in open interest in some classes of options even before the large price decline date, the coefficient of daily option delta change is still significantly positive in Period II (-5,-1), right before the large price decline date. From this we conclude that the abnormal increase in open interest in some option classes is not sufficiently large enough to change the option market makers' net position of call options. As a result, the stock market maker may not be able to detect any information from the order flow from the option market maker before the large price decline date. The option market maker does not work as an indirect informed trader in the stock market before the large price decline date. This is consistent with the reduced bid-ask spreads for optionable stocks in the stock market before the event date.

The regression results based on the time-to-expiration groups (not reported) show a similar pattern. The regression results based on the moneyness groups (not reported) similar pattern except for period III for at-the-money options. For this regression coefficient is significantly negative. This might be caused by the fact that the call options are more actively traded than put options in this subgroup. However, the coefficient is significantly positive for all the moneyness subgroups in Period II, rejecting the hypothesis that the option market maker would act as an indirect informed trader in the stock market before the large price decline date.

Although the coefficient of the average daily option delta change is significantly positive except for Period III, the magnitude of the coefficient is about 2.4 (2.1) for options on NYSE/AMEX Call (Put) options in Period I. Even if the option delta increased 0.1 per cent (the mean average daily delta change in Period I) on day t-1, the underlying stock return would increase only 0.24 (0.21) basis points for NYSE/AMEX firms on day t. From this fact, we suggest that the delta-hedging effect may be limited to transfer the information from the option markets to the stock markets unless there are huge open interest changes as we have seen on the large price decline date. In the results, the bid-ask spreads for optionable firms in the stock markets decrease before the large price decline date, while the option spreads increase.

V. Conclusion

We reexamine the role of option markets in the reversal process of stock prices following large one-day price declines. We find a significantly positive rebound only for non-optionable firms over two-days following the large price decline date regardless of the exchange on which the stock is listed. Furthermore, we find that that the bid-ask spread of non-optionable NASDAQ firms increases even before the large price decline date and then decreases back to normal range in the following days. The bid-ask spread of optionable NASDAQ firms decreases even before the large price decline date and stays at the same level over the following week. On the other hand, the percentage spread increases for both call and put options relative to their benchmark spread before the large price decline date. This opposite movement of the bid-ask spread in the stock markets and the option markets is consistent with the existence of informed traders and their preference to trade in option markets. We also find that about 65 per cent of the closing transactions of non-optionable NASDAQ firms are seller initiated on the large price decline date. The disappearance of price rebound after removing the bid-ask bounce suggests that without the bid-ask spread change, the abnormal return caused by the seller-initiated trades alone must be small. From these findings, we conclude that this abnormal rebound phenomenon is consistent with the migration of informed traders from the stock markets to the option markets.

Consistent with informed traders' preference for trading in option markets, we find that the open interest and volume increase around the large price decline date. When we exclude the trend in the open interest by using the daily open interest change, we find that the open interest has begun to increase abnormally before the large price decline date. Despite the higher trading costs for out-of-the-money (OTM) options, OTM put option open interest increases significantly between day -3 and day -1. This further provides strong evidence of the presence of informed traders in the option markets. However, the evidence that the abnormal increase of open interest occurs mostly in the at-the-money options and mid-term-to-expiration options shows that the informed traders are concerned with liquidity.

Finally, we explain the role of the option market makers as indirect informed traders in the stock market in the reversal process. We find that there is a positive relation between the average daily option delta change on day t-1 and the daily stock return on day t. This implies that the option market makers are net option writers in general. Because of the large increase in open interest on the large price decline date, this positive relation disappears right after the event date. However, the positive relation still exists until the event date. This shows that only call option market makers change their net position after the event and that the informed traders do not trade in option markets aggressively enough to change the option market makers' net position before the large price decline date. As a result, the option market makers do not act as indirect informed traders in the stock market in the reversal process.

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Table 1. Frequency of Pairs of Optionable and Non-Optionable Firms per Quarter

The optionable and non-optionable firms that experienced one-day price declines of 10 per cent or more are selected from the CRSP daily return tape over the sample period of January 1996 through December 2004. Closing stock prices on the day before the large price decline date must be at least $15. All stocks must trade on the large price decline date and the following three trading days. We eliminated stocks traded less than 30 days over the benchmark period, day -105 through day -6. We rank all firms that meet the above criteria alphabetically for each trading day and the first firm with traded options and the first non-optionable firms are selected. Any dates that do not have at least one optionable and non-optionable firm are discarded.

Year	Quarter	Frequency		Year	Quarter	Frequency	
		NYSE/AMEX	NASDAQ			NYSE/AMEX	NASDAQ
1996	1	16	39	2001	1	40	54
	2	25	40		2	31	54
	3	27	48		3	38	53
	4	26	40		4	26	43
1997	1	38	45	2002	1	21	45
	2	28	45		2	29	32
	3	29	50		3	30	43
	4	32	48		4	20	28
1998	1	19	47	2003	1	14	22
	2	28	47		2	10	23
	3	50	49		3	9	25
	4	36	47		4	18	23
1999	1	39	50	2004	1	16	31
	2	31	34		2	15	32
	3	39	30		3	20	33
	4	32	37		4	10	20
2000	1	51	48				
	2	41	52	Total		1,018	1,443
	3	41	45				
	4	43	41				

Table 2. Summary Statistics

This table summarizes the characteristics for a sample of 1,018 pairs of NYSE/AMEX firms and 1,443 pairs of NASDAQ firms over the period January 1996 to December 2004. Mean (median) values for each variable is reported. *AR0* denotes the abnormal return on day 0, the large stock price decline date. *PRICE* denotes the closing stock price for firm *i* six trading days before the large price decline date. *SIZE* denotes the market value for firm *i* six trading days before the large price decline date. *Turnover* denotes the average daily turnover of firm i's common stock over trading days 105 through 6 before the large price decline date. *SD* denotes the standard deviation of firm i's common stock return over trading days 105 through 6 before the large price decline date. *p*-values from the paired t-test (sign M-test) are reported in the last column.

Panel A. NYSE/AMEX

	Optionable Firm	Non-Optionable Firm	*p*-value
AR0	-14.4%	-14.2%	41.4%
	(-12.6%)	(-12.4%)	(47.10%)
Price	34.49	30.26	1.31%
	(27.92)	(23.50)	(0.00%)
Size	6,427.69	472.63	0.00%
	(1,734.11)	(264.30)	(0.00%)
SD	0.034	0.036	0.25%
	(0.031)	(0.031)	(87.52%)
Turnover	1.02%	0.82%	25.17%
	(0.67%)	(0.36%)	(0.00%)
N	1,018	1,018	1,018

Panel B. NASDAQ

	Optionable Firm	Non-Optionable Firm	*p*-value
AR0	-15.2%	-14.3%	0.10%
	(-12.8%)	(-12.7%)	(20.64%)
Price	30.85	25.47	0.00
	(25.00)	(21.31)	(0.00%)
Size	1,740.19	262.23	0.00
	(711.36)	(185.62)	(0.00%)
SD	0.049	0.049	0.712
	(0.046)	(0.044)	(1.53%)
Turnover	1.99%	1.28%	0.00%
	(1.60%)	(0.65%)	(0.00%)
N	1,443	1,443	1,443

Table 3. Abnormal Returns of NYSE/AMEX and NASDAQ Firms Following One-Day Price Declines of at Least 10 per cent

Daily security abnormal returns are calculated from the market model approach using the equally-weighted CRSP index return as a market proxy. Cumulative abnormal returns are formed by summing daily abnormal returns. Mean abnormal returns are presented with cross-sectional t-values in parentheses. Day 0 is the large price decline date.

	Option Firms			Non-Option Firms		
	NYSE/AMEX	NASDAQ	NASDAQ (Bid-Ask Avg.)	NYSE/AMEX	NASDAQ	NASDAQ (Bid-Ask Avg.)
Day0	-0.1445	-0.1518	-0.1513	-0.1422	-0.1432	-0.1310
	(-75.48)***	(-72.25)***	(-59.46)***	(-66.66)***	(-83.87)***	(-47.98)***
Day1	-0.0009	0.0001	-0.0001	0.0054	0.0081	-0.0036
	(-0.45)	(0.04)	(-0.05)	(2.01)**	(3.82)***	(-1.56)
Day2	-0.0015	0.0004	0.0000	0.0017	-0.0003	-0.0011
	(-1.06)	(0.23)	(0.01)	(0.96)	(-0.17)	(-0.55)
Days 1-2	-0.0024	0.0006	-0.0001	0.0072	0.0078	-0.0047
	(-1.04)	(0.21)	(-0.06)	(2.30)**	(3.04)***	(-1.17)

The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively, using a 2-tail test.

Table 4. Cross-sectional Regression Estimates for the Relation between Post-Drop Cumulative Abnormal Returns, Listed Options, and Control Variables

The dependent variable in the cross-sectional regression model is the abnormal return on day 1. AR0 denotes the abnormal return on day 0, the large stock price decline date. The OPTDUM dummy variable takes the value of unity if the stock i is optionable and zero otherwise. PRICE denotes the closing stock price for firm *i* six trading days before the large price decline date. AvgTurnover denotes the average daily turnover of firm i's common stock over trading days 105 through 6 before the large price decline date. SD denotes the standard deviation of firm i's common stock over trading days 105 through 6 before the large price decline date. The decimal dummy variable takes the value of unity if the large price decline date is no earlier than 1/2/2001 (4/9/2001) for NYSE/AMEX (NASDAQ) firms.

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)
			Panel A. NYSE/AMEX				
Intercept	0.0153	0.0072	-0.0002	0.0025	0.0113	0.0269	0.0278
	(3.22)***	(2.64)***	(-0.08)	(1.26)	(2.31)**	(3.97)***	(3.58)***
AR0	0.0899					0.0895	0.0958
	(2.97)***					(2.96)***	(2.34)**
OPTDUM		-0.0097			-0.0105	-0.0103	-0.0123
		(-2.48)**			(-2.69)***	(-2.64)***	(-1.29)
PRICE			0.0001		0.0001	0.0001	0.0001
			(1.62)		(1.87)*	(1.84)*	(1.85)*
AvgTurnover				-0.0113	0.0006	0.0014	0.0011
				(-0.22)	(0.01)	(0.03)	(0.02)
SD					-0.1900	-0.2100	-0.2094
					(-1.78)*	(-1.96)*	(-1.95)*
Decimal						-0.0067	-0.0067
						(-1.60)	(-1.60)
AR0*OPTDUM							-0.0139
							(-0.23)
Adj. R^2	0.0038	0.0025	0.0008	-0.0005	0.0042	0.0086	0.0081
N	2,026	2,026	2,026	2,026	2,026	2,026	2,026
			Panel B. NASDAQ				
Intercept	0.0179	0.0078	0.0075	0.0076	0.0090	0.0261	0.0309
	(4.34)***	(3.04)***	(2.68)***	(3.59)***	(1.74)*	(3.86)***	(3.87)***
AR0	0.0926					0.0923	0.1273
	(3.70)***					(3.69)***	(3.21)***
OPTDUM		-0.0073			-0.0053	-0.0045	-0.0131
		(-2.00)**			(-1.43)	(-1.23)	(-1.56)
PRICE			-0.0001		-0.00010	-0.00010	-0.00010
			(-1.55)		(-1.22)	(-1.45)	(-1.43)
AvgTurnover				-0.2067	-0.2133	-0.19290	-0.19140
				(-3.16)***	(-3.01)***	(-2.69)***	(-2.67)***
SD					0.08050	0.0490	0.0525
					(0.92)	(0.55)	(0.59)
Decimal						-0.0064	-0.0064
						(-1.62)	(-1.62)
AR0*OPTDUM							-0.0580
							(-1.13)
Adj. R^2	0.0044	0.0010	0.0005	0.0031	0.0038	0.0085	0.0086
N	2,886	2,886	2,886	2,886	2,886	2,886	2,886

The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively, using a 2-tail test.

Table 5. The Percentage of Seller Initiated Trades of NASDAQ Firms over Day 0 through Day 3

The trades are classified using an approach similar to that used by Lee and Ready (1989). Since we cannot differentiate the buyer-initiated trades from the seller-initiated trades with currently given data, we treat the trade with transaction price higher than the average of bid and ask prices as the buyer-initiated trade and the trade with transaction price lower than the average of bid and ask prices as the seller-initiated trade. Since only inter-day transaction data are available, we exclude the trade with the price equal to the average of bid and ask prices in this study. The t-statistics from the comparison t-test between the sample seller-initiated trade percentage and the hypothetical value, 50 per cent, are present in the parentheses.

	day0	day1	day2	day3
Optionable Firms	50.0%	47.1%**	47.7%*	50.3%
	(0.00)	(-2.12)	(-1.69)	(0.22)
Non-Optionable Firms	64.66%***	50.2%	50.0%	48.6%
	(11.43)	(0.14)	(0.00)	(-1.00)

The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively, using a 2-tail test.

Table 6. Abnormal Daily Open Interest Change - Moneyness

At-the-money (ATM) options are defined as having a strike price within 10 per cent of the underlying stock price on day -6. In-the-money (ITM) and out-of-the-money (OTM) options have strike prices greater or less than 10 per cent of the underlying stock price on day -6 where the payoff from the former is positive but the payoff from the latter is zero. We compare daily open interest change to the average daily open interest change over the benchmark period, day -105 through day -6. We calculate daily open interest changes on the individual option contract basis and sum them across all trades in a given option series (i.e., given strike price, expiration date, and underlying stock) on a given day. We present abnormal daily open interest change for options underlying NYSE, AMEX, and NASDAQ stocks.

	Day -5	Day -4	Day -3	Day -2	Day -1	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
Panel A. Call Option											
ATM	99.74 ***	40.35*	53.23***	50.49***	81.82***	278.72***	141.59***	15.09	-47.91	-54.03	10.10
	(4.49)	(1.74)	(2.7)	(2.85)	(4.06)	(6.4)	(2.71)	(0.64)	(-1.55)	(-1.24)	(0.45)
ITM	-16.70	-31.42**	-4.72	5.71	54.27**	391.13***	370.79***	122.11***	107.44***	122.22***	95.34***
	(-0.96)	(-2.23)	(-0.33)	(0.4)	(2.54)	(8.89)	(8.42)	(3.92)	(4.41)	(5.63)	(3.69)
OTM	30.15	-2.34	-71.25	-74.21	48.74	-18.08	-1.94	-126.41***	-113.31***	-133.40**	-69.15***
	(1.18)	(-0.11)	(-0.74)	(-1.26)	(0.97)	(-0.57)	(-0.08)	(-4.44)	(-4.94)	(-2.07)	(-2.98)
Panel B. Put Option											
ATM	66.70***	22.62	35.65*	30.09*	37.18***	36.40	-92.94***	-98.82***	-82.17***	-80.91***	-36.32***
	(4.59)	(1.22)	(1.7)	(1.9)	(2.57)	(1.18)	(-4.72)	(-7.44)	(-4.21)	(-3.54)	(-2.41)
ITM	-21.29	-56.45***	-39.41	-57.33**	-9.99	-49.49***	-62.61***	-81.76***	-54.74***	-44.53***	-48.81***
	(-1.06)	(-2.82)	(-1.52)	(-2.48)	(-0.47)	(-3.99)	(-7.2)	(-6.73)	(-5.1)	(-3.59)	(-4.09)
OTM	23.76	18.14	45.50***	35.98**	55.68**	397.76***	290.04***	63.65**	58.18**	33.62*	35.39**
	(1.01)	(0.81)	(3.61)	(2.2)	(2.53)	(7.94)	(6.4)	(2.18)	(2.36)	(1.84)	(2.06)

The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively, using a 2-tail test.

Table 7. Abnormal Daily Open Interest Change – Time to Expiration

Short-term-to-expiration (STX) options are defined as having time-to-expiration days of less than 30 calendar days and long-term-to-expiration (LTX) options are defined as having time-to-expiration days of greater than 90 calendar days on a given day. Otherwise, options are defined as mid-term-to-expiration (MTX) options on a given day. We compare daily open interest change to the average daily open interest change over the benchmark period, day -105 through day -6. We calculate daily open interest changes on the individual option contract basis and sum them across all trades in a given option series (i.e., given strike price, expiration date, and underlying stock) on a given day. We present abnormal daily open interest change for options underlying NYSE, AMEX, and NASDAQ stocks.

	Day -5	Day -4	Day -3	Day -2	Day -1	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
Panel A. Call Option											
STX	66.08**	40.26	-30.18	28.38	136.67***	260.49***	166.43***	9.02	-42.10	-33.36	43.01
	(2.09)	(1.14)	(-0.35)	(0.66)	(4.37)	(5.25)	(4.98)	(0.2)	(-0.84)	(-0.37)	(1.24)
MTX	33.77**	16.49	53.65***	41.20**	26.41	292.42***	223.57***	64.25***	59.98***	40.22	65.75***
	(2.24)	(1.15)	(2.8)	(2.42)	(1.14)	(7.99)	(6.09)	(2.99)	(2.66)	(1.57)	(2.68)
LTX	40.79	-10.55	11.64	-20.20	77.16*	239.01***	260.17***	92.02***	65.58***	76.12**	51.89***
	(1.53)	(-1.04)	(1.03)	(-0.49)	(1.76)	(7.76)	(4.71)	(3.85)	(3.82)	(2.35)	(3.37)
Panel B. Put Option											
STX	62.67**	0.96	34.57	21.57	60.33	129.05***	-32.68	-87.01***	-20.31	-43.18	-21.70
	(2.14)	(0.03)	(1.04)	(0.82)	(1.82)	(2.87)	(-0.89)	(-2.88)	(-0.5)	(-1.16)	(-0.97)
MTX	9.17	4.74	26.14**	31.97**	22.42*	188.19***	144.67***	42.30*	21.98	15.35	2.17
	(1.01)	(0.41)	(2.4)	(2.56)	(1.93)	(7.09)	(5.4)	(1.75)	(1.47)	(1.2)	(0.18)
LTX	7.00	0.19	4.24	-11.00	42.32*	133.41***	127.69***	61.70***	31.35***	25.77***	37.53***
	(0.33)	(0.02)	(0.61)	(-0.5)	(1.85)	(7.62)	(6.17)	(3.78)	(3.99)	(2.35)	(2.5)

The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively, using a 2-tail test.

Table 8. Regression Estimation for the Relation between Daily Stock Returns and Average Daily Option Delta Change

The dependent variable in the cross-sectional regression model is the daily holding period return on stock *i* on day *t* in percentage. The explanatory variable, $\Delta\delta_{t-1\,i}$, is the average daily option delta change in a given option series on day *t*-1. Period I is from day -105 through day -6. Period II is from day -5 through day -1. Period III is from day 1 through day 5. Period IV is from day 6 through day 105. Day 0 is the large price decline date.

	NYSE/AMEX Call Option		NYSE/AMEX Put Option		NASDAQ Call Option		NASDAQ Put Option	
	Intercept	$\Delta\delta_{t-1\,i}$	Intercept	$\Delta\delta_{t-1\,i}$	Intercept	$\Delta\delta_{t-1\,i}$	Intercept	$\Delta\delta_{t-1\,i}$
Period I	0.0769	2.4378	0.0791	2.0713	0.1621	6.1563	0.1625	5.2733
	(6.26)***	(8.12)***	(6.39)***	(6.79)***	(11.01)***	(18.25)***	(11.04)***	(16.14)***
Period II	-0.2096	7.8423	-0.2284	8.6074	0.1214	19.5446	0.1163	15.9555
	(-3.05)***	(5.26)***	(-3.24)***	(5.52)***	(1.25)	(9.13)***	(1.19)	(7.86)***
Period III	-0.0573	-0.0652	-0.0787	-0.4303	0.1125	1.2654	0.0986	0.8608
	(-0.74)	(-0.08)	(-1.00)	(-0.56)	(1.38)	(1.26)	(1.22)	(0.95)
Period IV	0.0593	2.7147	0.0491	2.4380	0.0509	7.0017	0.0479	4.9151
	(4.49)***	(8.10)***	(3.68)***	(7.13)***	(3.45)***	(18.89)***	(3.24)***	(14.57)***

The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively, using a 2-tail test.

Figure 1. The Bid-Ask Spread Movement of NASDAQ Firms around the Large price decline date

We calculate the average bid-ask spread for each stock in the sample over the benchmark period, trading days 105 through 6 before the large price decline date to compute the excess spread of each closing bid-ask spread on day -5 through day 5, while day 0 is the large price decline date and day 5 (day -5) is the fifth trading day after (before) day 0.

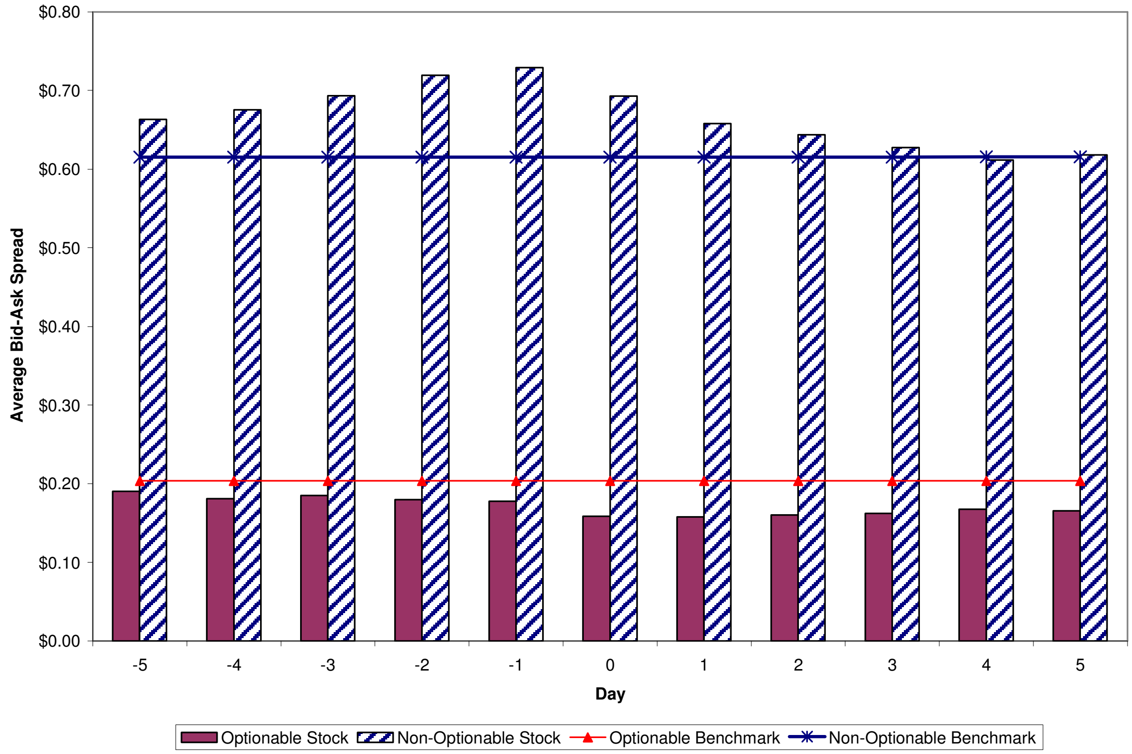

Figure 2. The Percentage of Seller Initiated Trades of NASDAQ Firms

We classify trades using an approach similar to that used by Lee and Ready (1989). Since we cannot differentiate the buyer-initiated trades from the seller-initiated trades with currently given data, we treat the trade with a transaction price higher than the average of bid and ask prices as the buyer-initiated trade and the trade with a transaction price lower than the average of bid and ask prices as the seller-initiated trade. Since only inter-day transaction data are available, we exclude the trade with the price equal to the average of bid and ask prices in this study.

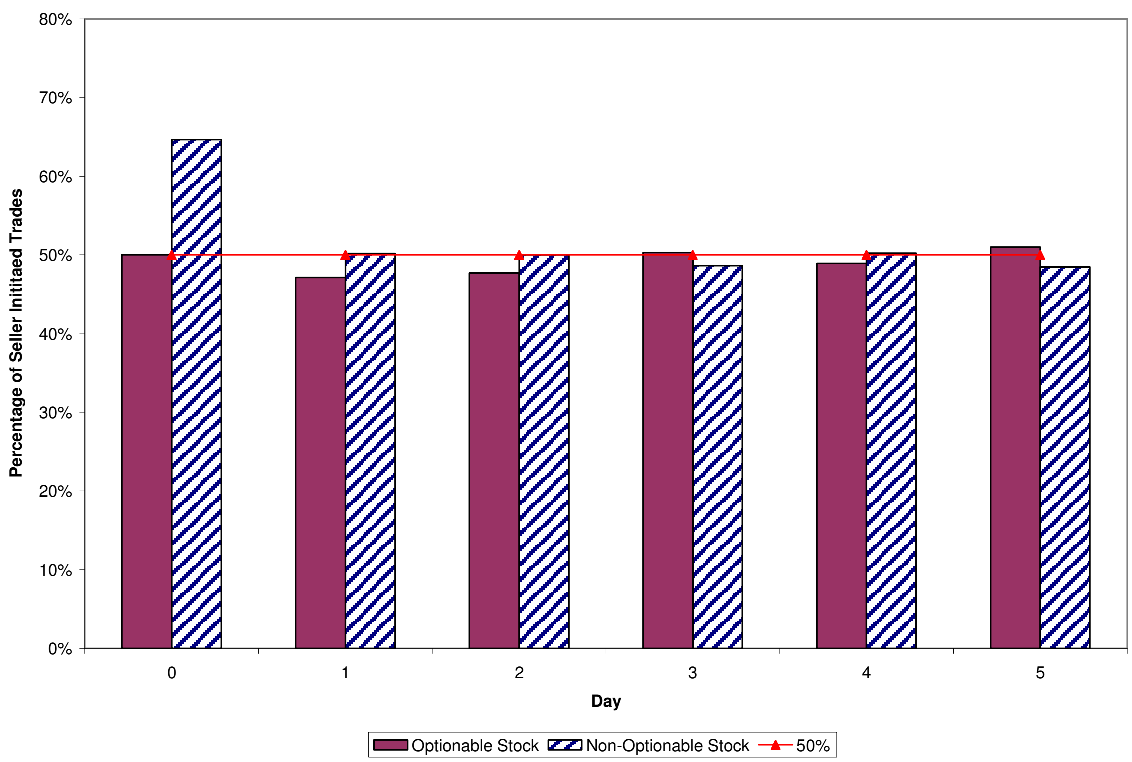

Figure 3. The Percentage Spread of Options underlying NASDAQ Firms

We calculate the average percentage bid-ask spread for each option contract underlying the NASDAQ firms in the sample over the benchmark period, trading days 105 through 6 before the large price decline date to compute the excess percentage spread of options on day -5 through day 5, while day 0 is the large price decline date and day 5 (day -5) is the fifth trading day after (before) day 0.

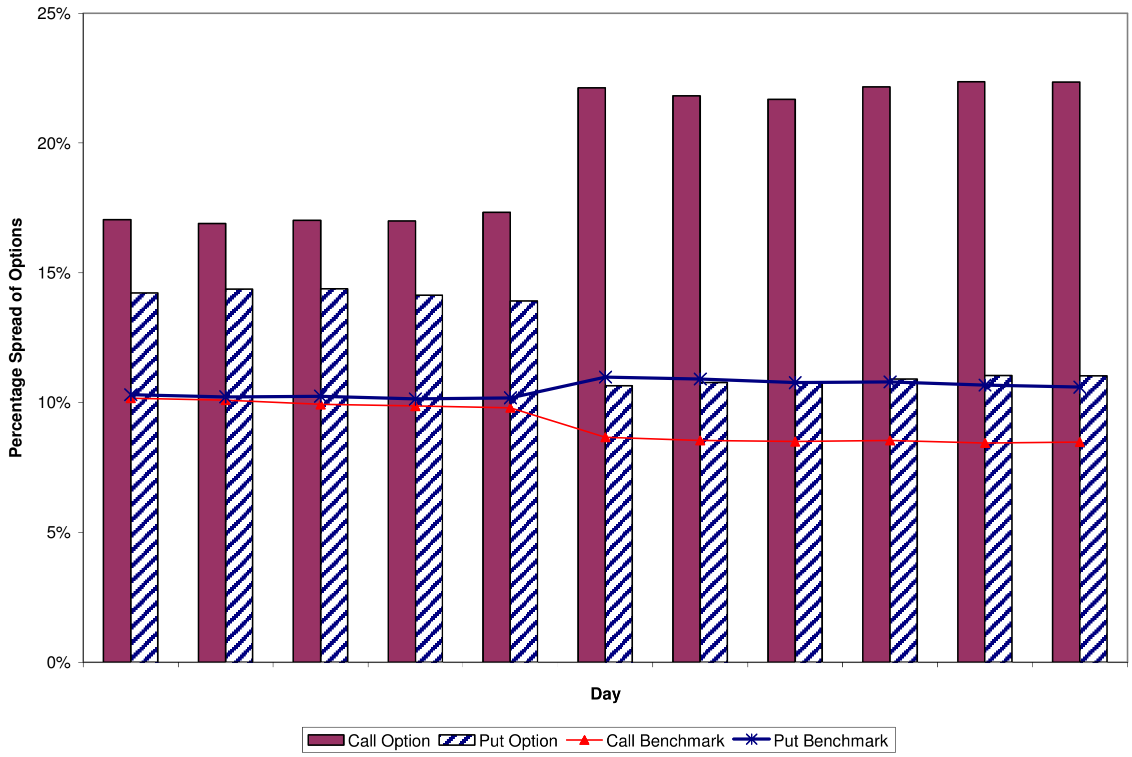

Figure 4. The Aggregate Open Interest of Options underlying NASDAQ Firms

We sum all the open interest across all the option series given NASDAQ stocks on a given day. We calculate the average daily open interest for each option series underlying the NASDAQ firms in the sample over the benchmark period, trading days 105 through 6 before the large price decline date to compute the excess open interest of options on day -5 through day 5, while day 0 is the large price decline date and day 5 (day -5) is the fifth trading day after (before) day 0.

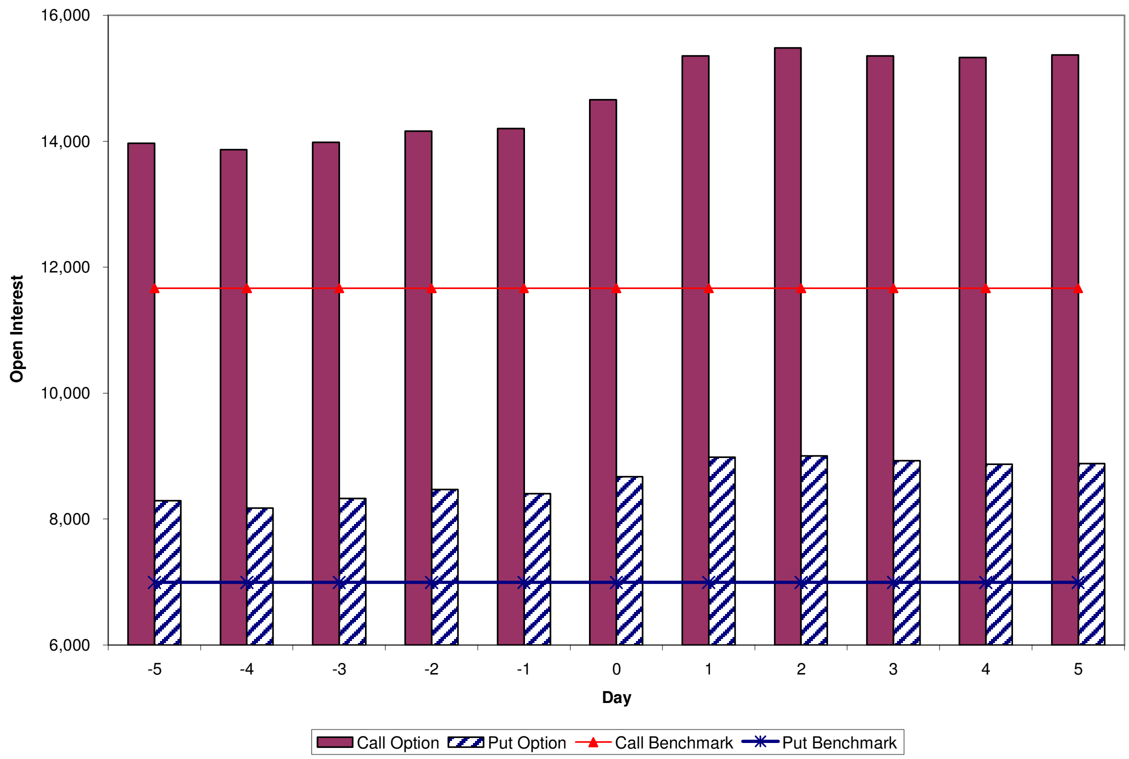

Figure 5. The Aggregate Volume of Options underlying NASDAQ Firms

We sum all the daily trading volume across all the option series given NASDAQ stocks. We calculate the average daily open interest for each option series underlying the NASDAQ firms in the sample over the benchmark period, trading days 105 through 6 before the large price decline date to compute the excess open interest of options on day -5 through day 5, while day 0 is the large price decline date and day 5 (day -5) is the fifth trading day after (before) day 0.