Is there evidence of front-running before analyst recommendations? An analysis of the quoting behavior of Nasdaq market makers

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Abstract

This study investigates analysts' potential conflicts of interest due to the relationship between research and trading departments. We find evidence of information leakage and front-running before revisions in analyst recommendations for Nasdaq-listed stocks. Specifically, we examine the quoting behavior of the market maker who is affiliated with the same brokerage house as the recommending analyst ("recommending market maker"). In the hour and a half before upgrades, the proportion of time that the recommending market makers quote at the inside bid increases significantly, whereas their quoting behavior at the ask does not change. In the three hours before downgrades, the proportion of time that the recommending market makers quote at the inside ask increases significantly, whereas their quoting behavior at the bid does not change. This pattern in the quoting behavior of recommending market makers anticipates the direction of the pending recommendations and is highly significant, even after controlling for their own behavior in non-announcement periods and for the quoting behavior of other market makers.

1. Introduction

Many market participants have substantial conflicts of interest. Recent market events have generated renewed interest in whether these conflicts of interest create conditions that compromise market integrity. In this paper, we evaluate Nasdaq market makers' quoting behavior for evidence that this behavior is influenced by analysts' conflicts of interest due to their relationships with the trading departments of their firms. The underlying cause of the recommending analysts' conflicts of interest is that both the performance evaluation of research departments and the compensation of individual analysts are based on the value they add to the investment banking and trading departments of their firms. Following the meltdown of internet and technology stocks and the high profile corporate bankruptcies occurring since 2000, lawmakers, regulators, and investors have questioned the extent to which the biased incentives created by this compensation arrangement have led to behavior that is disadvantageous to other market participants.

To investigate this issue, we evaluate the quoting behavior of market makers before analysts announce revisions in their recommendations. More specifically, we compare the quoting behavior of the market maker affiliated with the analyst's brokerage firm ("recommending market maker") both to their own normal quoting behavior and to the quoting behavior of other market makers. Not only do we find strong evidence that recommending market makers systematically change their quoting behavior well before the public announcement, but we also find strong evidence that they change their quoting behavior earlier, and more dramatically, than other market makers. Further, the recommending market makers' change in quoting behavior anticipates the direction of the pending revisions. Overall, these findings are consistent with analysts leaking information to the recommending market makers, to investors affiliated with the analysts' brokerage firms, or to outside investors, and with the information recipient using the information to subsequently front-run. In the context of this study, we understand front-running to occur when a trader acts on non-public information to trade ahead of investors lacking that knowledge.[1]

[1] This definition is similar to one found in Craig and Kelly (2003).

Previous research has investigated analysts' conflicts of interest due to their relationships with the investment banking business of their brokerage firms. Researchers have found that analysts issue more optimistic earnings forecasts for their firms' investment banking clients than do non-affiliated analysts. The buy recommendations of affiliated analysts are less informative, while their sell recommendations are more informative compared to the respective recommendations of non-affiliated analysts [Dugar and Nathan (1995), Lin and McNichols (1998), and Michaely and Womack (1999)]. Hong and Kubik (2002) show that earnings forecast accuracy and optimism help analysts advance their careers by moving to firms with higher reputations. Further, accuracy is less important and optimism is more important when analysts cover initial public offerings (IPOs) underwritten by their own firms. Researchers have also examined the interactions between research and trading departments, and between investment banking and trading departments. For example, Irvine (2001) finds that the initiation of analyst coverage for a stock is followed by a 3.8% increase in his/her firm's share of total trading volume in that stock. Further, Aggarwal (2000), Ellis, Michaely, and O'Hara (2000), and Schultz and Zaman (1994) show that lead underwriters are the most active market makers in the post-IPO market.

The contribution of our paper is that it is the first study, to our knowledge, that addresses the important issue of whether analysts' conflicts of interest are associated with information leakage and front-running. Our specific findings are that for an hour and a half before upgrade announcements, the recommending market makers quote at the inside bid a greater proportion of time than they usually do, but they do not change the proportion of time that they quote at the inside ask. Conversely, for three hours before downgrade announcements, the recommending market makers quote at the inside ask a greater proportion of time than they usually do, but they do not change the proportion of time that they quote at the inside bid. This behavior is consistent with leakage of the upcoming revisions and with subsequent front-running, which is illegal and unfair to other market participants.

The paper is organized as follows. Section 2 develops the test hypothesis. Section 3 explains the sample construction and describes the data. Section 4 reports the empirical results and Section 5 concludes.

2. Hypothesis

As background for our hypothesis, it is helpful to review the potential recipients of leaked information, the analysts' motives for leaking information to them, and the behavior that will lead to anticipatory quote adjustment by the recommending market maker. Leakage to the recommending market maker, to the firm's trading department (inside investors), or to the firm's customers (outside investors) would potentially generate an early reaction by the recommending market maker.

Information leaked directly to a recommending market maker would allow the market maker to manage inventory in anticipation of post-recommendation order flow and price movement. To accomplish this inventory adjustment, the recommending market maker would change her quotes appropriately, thus reacting early.

Information might also be leaked to investors, either inside or outside the firm. If information is leaked to her firm's trading department, the firm's traders would profit from front-running. If it is leaked to an outside investor, the recommending market maker's firm is giving the outside investor an opportunity to profit from front-running. In return, the recommending market maker's firm hopes for future business from the outside investor (through investment banking or trading).

Information leaked to both inside and outside investors would lead to the early reaction by the recommending market maker if these investors place their front-running trades with the recommending market maker. These informed investors might choose to trade through the recommending market maker to conceal the information from the rest of the market. Outside investors also might choose to trade through the recommending market maker in order to give the analyst credit for their trading volume, thus encouraging the analyst to provide non-public information in the future.[2]

[2] For example, Solomon Smith Barney analyst Jack Grubman claimed that he had generated $300 million in trading commissions and $400 million in investment banking fees in 2000 for which he received tens of millions of dollars [Smith and Craig (2003)].

Regulators have investigated situations in which information was leaked to investors.[3] Investors can front-run either by placing market orders or by placing limit orders. Market orders do not directly affect the quotes posted by the recommending market maker, but the market maker tries to infer information from their incoming order flow, and would adjust her quotes in response to increased volume on one side of the spread. Limit orders could directly affect the quotes of the recommending market makers, since Nasdaq market makers are obliged to display customer limit orders.[4] Consequently, the quotes displayed by market makers can be either their own quotes or investor's limit orders.

All of the described forms of information leakage and front-running are illegal. Direct leakage to the recommending market maker and leakage to outside investors for the purpose of soliciting trading volume are in violation of Rule 2110-3 of the National Association of Securities Dealers (NASD).[5] Leakage to traders in the analyst's brokerage firm or to outside investors before a public announcement violate insider trading laws if the information recipients subsequently front-run.[6]

Although all these types of information leakage could cause an early reaction, the objective of this paper is not to determine which type of information leakage or front-running actually occurs, but rather to investigate the existence of an early reaction by the recommending market maker. More specifically, this paper investigates whether recommending market makers change their quoting behavior before the pending public announcements and whether this change occurs before other market makers change their quoting behavior. We test the following hypothesis:

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[3] For an example of a brokerage firm attempting to front-run a research report, see a report by Dow Jones Online News on investor suits and an SEC investigation about a research note provided by First Boston on June 27, 1997. For an example of information leakage to outside institutional investors, see Smith and Morse (2002).

[4] The Order Handling Rules (OHRs) introduced by the NASD in 1997 stipulate this. These rules were introduced in reaction to the seminal work in Christie and Schultz (1994) and Christie, Harris, and Schultz (1994) and subsequent class action lawsuits.

[5] This rule, approved by the Securities and Exchange Commission in August 1995, aims at prohibiting a member firm "from purposefully establishing, creating or changing the firm's inventory position" in a particular security "in anticipation of the issuance of a research report regarding such security by the member firm." In addition, a member firm cannot use this information to solicit order flow from its clients.

[6] Analysts may also leak information to their friends or relatives who in turn can make insider trading profits. This also would break the insider trading laws. However, trading may not go through the recommending market maker because the analyst would also want to hide the trading from his own firm. Taylor (1995) provides an example of this type of insider trading.

Hypothesis: If there exists information leakage and front-running before upgrade (downgrade) recommendations, recommending market makers will increase the time they quote at the inside bid (ask) before the public announcements and before other market makers change their quoting behavior. Recommending market makers will reduce or will not change the time they quote at the inside ask (bid).

In the case of a pending upgrade, if the information is leaked to the recommending market maker, she would like to build a long position before the announcement in anticipation of order flow and price movement related to the upgrade. By quoting aggressively at the inside bid, she attracts investors who want to sell stock to her. Alternatively, if the information is leaked to either inside or outside investors, these investors can place marketable limit orders to buy through the recommending market maker and their limit orders will be at the inside bid. If the change in the quoting behavior of the recommending market maker occurs not only before the public announcement, but also before any changes in the quoting behavior of other market makers, it would suggest that the change in quoting behavior cannot be explained by anticipation in the overall market but instead is unique to the recommending market maker.

Since the recommending market maker wants to hold a long position before the upgrade, she does not want to sell shares to investors. This implies that she will reduce the time she quotes at the inside ask. However, it is not clear that we can observe this. First, the recommending market maker might already rarely quote at the inside ask and thus a reduction would be not possible. Second, even if she moved her dealer quote away from the inside ask, customer limit orders could still be at the inside ask. This is especially true since upgrades are often preceded by increases in prices.[7] For downgrades, the behavior is analogous.

[7] A price run-up would pick off stale limit orders.

3. Data Description and Methodology

3.1. Sample Selection

We collect all analyst recommendations for Nasdaq-listed firms during the period from January 1, 1999 to July 31, 1999 from *Dow Jones Interactive* (DJI). DJI reports public announcements of analyst recommendations to both institutional and individual investors. For each announcement, we retrieve the company name, ticker, analysts' brokerage house affiliation, type of recommendation, and date and time (to the minute) of the first announcement on DJI. The number of analyst recommendations in this initial sample is 4,959.

To be included in the final sample, Center for Research in Security Prices (CRSP) data and Nastraq data must be available for the companies during the sample period. This yields 3,811 recommendations. Further, the brokerage house's previous recommendation must be available. For 3,280 analyst recommendations, we are able to match the brokerage house with the respective market maker ID used in the Nastraq database. The Nastraq database supplies intraday trade, inside quote, and dealer quote data. Appendix A describes the data filters that are used to ensure the integrity of the trade and quote data. The dealer quote files from the Nastraq database identify the market maker or electronic communication network (ECN) associated with each quote.[8]

Stocks are restricted to ordinary stocks of firms incorporated in the U.S., i.e., we exclude ADRs (American Depository Receipts), SBIs (Shares of Beneficial Interest), REITs (Real Estate Investment Trusts), and foreign companies. For each recommendation, the sample window (i.e., the event and control period described in detail in Section 3.2) is defined as the 26 trading days centered on the analyst recommendation. We exclude recommendations for which the stock price is less than $1 or the number of shares outstanding changes by more than 5% during the sample window. Recommendations for stocks that have non-ordinary dividends, i.e., exchanges and reorganizations, during the sample window are also excluded. The sample window for each recommendation must start after January 4, 1999, the starting date

[8] We use the expression market maker throughout the paper to refer to both Nasdaq market makers and electronic communication networks (ECNs).

of the Nastraq database. Further, to prevent any potential contamination, we exclude all revisions that occur within 15 trading days of another recommendation by the same analyst and for the same stock.

We define a brokerage house to be an active market maker in a stock if there is at least one valid quote observation from that brokerage house during the six trading days centered on the revision announcement. If the brokerage house is not an active market maker, the analyst recommendation is excluded because there are no quotes to analyze and because there are no potential conflicts of interest due to the relationship between research and trading departments. We only consider analyst recommendations that occur during regular trading hours, i.e., between 9:30 AM and 4 PM EST.

Our sample includes only recommendation revisions: that is, upgrades and downgrades. Initial coverage or reiterations of previous recommendations are excluded. This leaves us with 844 analyst recommendation revisions in our final sample, of which 411 are upgrades and 433 are downgrades.

The analyst recommendations are standardized by following the I/B/E/S (Institutional Broker Estimate System) conversion system whenever possible, and by augmenting the system manually when necessary. The conversion system has five categories: "strong buy", "buy", "hold", "sell", and "strong sell".[9] Panel A of Table 1 reports the distribution of recommendation revisions. Consistent with previous studies, sell recommendations ("sell" and "strong sell") are very rare. Changes of one category are more common than changes of two or more categories. For example, there are 140 downgrades from "strong buy" to "buy", and 205 downgrades from "buy" and "hold", but only 81 downgrades from "strong buy" to "hold".

Panel B of Table 1 summarizes the intraday distribution of recommendation revisions. It is apparent that for both upgrades and downgrades most observations occur in the morning hours. Since this would give the recommending market maker or informed investors little or no time to trade before the announcement, they might take positions in pre-opening trading, in after-hour trading on the previous day, or even on previous trading days. In this study, we are not able to analyze behavior beyond the

[9] This should not affect our results, since we classify all revisions into upgrades and downgrades and focus on these two sub-samples.

regular trading hours since the Nastraq database does not contain the necessary data. This concern is limited by the fact that informed traders will trade during regular trading hours on preceding days, if possible, to avoid the limited liquidity in off-hour trading.

3.2. Event vs. Non-Event Period

For each recommendation revision, the event half hour is the half-hour interval in which the recommendation was reported on DJI. Since a calendar trading day has 13 half-hour trading intervals during regular trading hours, we define a "day" as 13 half-hour trading intervals. For example, "day +1" denotes the 13 half-hour trading intervals immediately following the event half hour. These 13 half-hour trading intervals usually span two calendar trading days. The event period contains the event half hour, three days before, and three days after the recommendation revision. Thus, the event period is defined as the 79 half-hour intervals centered on the event half hour. The control period is defined as the 260 half-hour intervals surrounding the event period, i.e., ten days before and ten days after the event period. Thus, the sample window for each revision has 339 half-hour intervals centered on the event half hour.

3.3. Sample Firm Characteristics

Table 2 provides descriptive statistics for the companies in the sample of recommendation revisions. Within our sample, there is significant cross-sectional variation in firm characteristics. For example, market capitalization averages about $ 3.3 billion, with a median of about $ 442 million. Daily share volume averages about 974 thousand shares, with a median of about 281 thousand shares. The proportional inside half-spread has a mean of 0.6% and a median of 0.45%.[10] The last row in Table 2 reports descriptive statistics for each firm's number of active market makers. Most stocks in our sample attract a relatively large number of market makers. On average, there are about 27 market makers active and the median number of active market makers is 23. More than 75% of our sample has 16 or more active market makers.

[10] We compute time-weighted spread measures. The percentage half-spread is defined as (Ask-Bid) / (Ask+Bid).

3.4. Methodology

We focus on differences between the event period and the control period for our variables of interest. For each recommendation and for each of the 13 half-hour intervals of a calendar trading day, we compute the mean of any variable of interest over the 20 trading days of the control period, the *Control Mean*. Because there is potential intraday variation in market microstructure variables, we match each of the 79 event-period half-hour intervals with the *Control Mean* for the same time of day.[11] We then compute the difference between the event interval value of the variable of interest, *Event*, and the *Control Mean*. For example, the volume between 10:00 AM and 10:30 AM on a day during the event period is compared to the mean volume for all 20 half-hour intervals between 10:00 AM and 10:30AM in the control period. Differences are computed as raw deviations or as percentage deviations:

$$Raw\ Deviation = Event - Control\ Mean$$

$$Percentage\ Deviation = \frac{Event - Control\ \ Mean}{Control\ \ Mean} \cdot 100$$

Finally, the measures reported in the tables and figures are "event-period means", which are the cross-sectional means of the deviations in the variables of interest across our recommendation sample.

To assess statistical significance, we employ a Monte Carlo simulation similar to Lee, Mucklow, and Ready (1993). For each interval in the event period, the event-period mean is compared to an empirical distribution of the same variable, obtained by random sampling with replacement, from the control period. This procedure yields the significance level for the test against the null hypothesis that the event period observations represent random draws from the empirical distribution in the control period.

In the following paragraphs, we describe the procedure for the computation of event-period means and control-period empirical distributions. We illustrate the procedure with one variable in one event period: the proportion of time the recommending market maker quotes at the inside ask during the half-hour interval immediately preceding the announcement, i.e., interval –1. The proportion of time the

[11] For example, see Chan, Christie, and Schultz (1995) for intraday variation of inside and dealer spreads for a sample of Nasdaq-listed stocks.

recommending market maker quotes at inside ask is calculated as follows: if a market maker quotes an ask price equal to the inside ask for 24 minutes during interval -1, the proportion of time at the inside ask equals 80%. The procedure is identical for each of the remaining 78 half-hour intervals in the event period and for each of the other measures we consider in the analysis.

The procedure comprises two steps. First, we obtain the event-period mean. We compute the following raw deviation: recommending market maker's proportion of time at the inside ask minus control-period time-of-day-matched sample mean. We then compute the equally-weighted mean of these raw deviations across all recommendations, which yields the event-period mean for interval -1.

Second, we create the empirical distribution. For each recommendation included in the event-period mean for interval -1, we draw a random observation with replacement from the control period for the same recommendation, the same recommending market maker, and the same time of the day. For example, if a recommendation announcement occurs at 11:47 AM, interval -1 is the half hour between 11:00 AM and 11:30 AM and we randomly draw one of the half-hour intervals between 11:00 AM and 11:30 AM during the control period. Then, we compute the raw deviation of the proportion of time the recommending market maker quotes at the inside ask during that randomly selected half-hour interval from the control-period time-of-day-matched mean. This raw deviation is denoted as a "control observation." The equally-weighted mean of the control observations is computed across all recommendations, and is denoted as "random sample mean." This sampling procedure is repeated 1,000 times, generating 1,000 random sample means for each event-period mean and yielding the empirical distribution for the statistical tests.

4. Empirical Evidence

4.1. Inside Spreads and Volume

Figure 1 plots the percentage deviations of proportional inside spreads during the event period.[12] Solid data points indicate significance at 5% based on the Monte Carlo simulation procedure. The measure tested is the cross-sectional mean of the percentage deviations between event and control period, for upgrades and downgrades respectively, as described above. For brevity of exposition, we only report results for intervals –13 to +26 (day –1 to day +2), although the event period includes intervals –39 to +39 (day –3 to day +3). Statistical significance is mostly concentrated in the shortened window for which we report results. Spreads tend to be lower during the event period for both upgrades and downgrades. However, spreads are not significantly lower until an hour or a half hour before the analyst recommendation and stay significantly lower for more than two days.

Figure 2 plots the percentage changes in share volume. Volume is significantly higher during the entire event period and spikes surrounding the recommendation announcement. The increase in volume is more dramatic for downgrades, which is eight times normal volume during the event half-hour, interval 0, compared to about four times normal volume for upgrades. The increased volume might partially explain the decreased spreads documented in Figure 1.

4.2. Market Maker Quoting Behavior

For each recommendation revision, we examine the proportion of time at the inside quote for the recommending market makers, and the average proportion of time at the inside quote both for all non-recommending ("other") market makers and for the peer group of each recommending market maker. The proportions are calculated separately for bid and ask prices. We follow Huang (2002) in defining five peer groups: institutional brokers, wire houses, wholesalers, electronic communication networks (ECNs), and minors. Appendix B provides a list of the brokerage firms in each peer group. Each recommending

[12] All spread measures are based on half-spreads and are time-weighted. We often refer to half-spreads simply as spreads.

market maker is compared to the other market makers in its peer group. Due to the lack of peers for some of the recommendations, there are 393 upgrades and 403 downgrades in the peer market maker sample.

For an initial test, we analyze the proportion of time that market makers quote at the inside, adjusted for their own control period behavior. Figures 3 and 4 plot the results for upgrades and Figures 5 and 6 for downgrades. Each graph reports raw deviations from the control period mean for the recommending market makers, the other market makers, and the peer market makers. For the group of other (peer) market makers, we first compute the average raw deviation across all other (peer) market makers for a particular recommendation. We then compute the mean of the average raw deviations across the recommendations in our upgrade and downgrade samples, respectively.

For upgrades, our hypothesis predicts that the recommending market maker will not quote more aggressively at the ask side but will quote more aggressively at the bid side before the announcement, to build up a position in the stock in anticipation of the positive price reaction to an upgrade. Figure 3 shows that for upgrades, the recommending market maker's time at the inside ask decreases non-significantly before the announcement. Recall that even if a recommending market maker does move her own quotes away from the inside ask, she might be displaying customers' limit orders, which may obscure the recommending market maker's ask quotes. On day +1, she increases the time at the inside ask significantly in 5 out of 13 intervals. Thus, the evidence supports our hypothesis that the recommending market maker does not quote more aggressively at the ask before upgrades.

The other market makers increase the time they quote at the inside ask around the announcement, and this increase is strongly significant from interval -7 to more than 13 intervals after the announcement. However, the economic significance of this result is minor since the difference between the time at the inside ask during the event and the control period is about one percent. The results for the peer market makers have a similarly insignificant, and less pronounced pattern, than do the other market makers.

Figure 4 shows that the recommending market makers quote more aggressively on the bid side before upgrades. The increase in the proportion of time at the inside bid is significant for about an hour

and a half before the announcement and the increase, of up to 4.7%, is economically meaningful.[13] In contrast, the other market makers and the peer market makers actually decrease the proportion of time at the inside bid. Thus, these results, combined with the inside ask results, are consistent with the hypothesis that there is information leakage and front-running before analyst recommendation revisions.

For downgrades, our hypothesis predicts that before the announcement, the recommending market maker will quote more aggressively on the ask side, but not on the bid side. Figure 5 reports the results for the time at the inside ask. The reaction of recommending market makers to downgrades is even more dramatic than to upgrades. The proportion of time at the inside ask for recommending market makers increases significantly three hours before the announcement and the increase is as high as 4.9% in the half-hour interval before the announcement. The other market makers also experience a slight increase in the proportion of time at the inside ask, but the increase is neither economically meaningful, at around 0.7%, nor is it consistently significant. Similarly, the peer market makers do not exhibit a significant increase in time at the inside ask.

On the other hand, Figure 6 shows that recommending market makers do not quote more aggressively on the bid side before downgrades. There is no clear pattern apparent for recommending market makers and none of the changes in proportion of time at the inside bid are significant. For the other market makers, there is a slight increase for two or three half-hour intervals before the announcement and a significant increase after the announcement. As discussed before, this could be partially due to limit orders being picked off in a down market. The evidence for the peer market makers does not show any pattern or significance. Thus, the recommending market makers' aggressive bidding at the ask and normal bidding at the bid is consistent with the hypothesis that there is information leakage and front-running before analyst recommendation changes.

In summary, the evidence presented in Figures 3 through 6 is consistent with our hypothesis regarding anticipatory quoting behavior by recommending market makers before recommendation

[13] The change in quoting behavior may even occur on the previous trading day, since the frequency of recommendation changes is higher in the morning hours and the event period spans trading days.

revisions, and thus it is also consistent with information leakage and front-running. The evidence is statistically significant and economically meaningful, with an increase in the proportion of time at the inside quotes of more than 4%. The evidence is stronger for downgrades than for upgrades, which is consistent with the observation that downgrades usually induce stronger price reactions [Womack (1996)] and thus offer opportunity for greater profits from non-public information.

4.3. Comparison of Recommending and Non-Recommending Market Makers' Quoting Behavior

In the results reported above, each market maker's quoting behavior is adjusted only for her own behavior during the control period. To control for the quoting behavior of the other market makers and of the peer market makers, we subtract the other (peer) market makers' mean quoting-behavior change during the event period[14] from the recommending market maker's quoting behavior change during the event period. Figures 7 through 10 and Tables 4 and 5 report the mean of these differences in quoting behavior changes across all recommendations, with significance levels from our Monte Carlo simulations.

Table 3 shows that for upgrades, the recommending market maker is less often at the inside ask compared to both other and peer market makers before the announcement. The differences are not statistically significant. The recommending market maker is more aggressive on the ask side starting in interval +4 and extending for about one day, but again, most differences are not significant. As before, the evidence for the time at the inside ask is consistent with the hypothesis of information leakage and front-running. Figure 7 plots the results.

Table 3 also reports the results for the bid quotes. As predicted for upgrades, the recommending market maker is more aggressive on the bid side than the control groups before the announcement. The differences are strongly statistically significant starting in interval -3 and the differences are economically significant at around 5%. This supports our earlier findings and is consistent with the hypothesis of information leakage and front-running. Figure 8 gives a plot of the results.

[14] The change is measured by the raw deviation from the own control-period time-of-day-matched mean.

The results for downgrades are also consistent with information leakage and front-running. Table 4 shows that the differences in quoting behavior on the ask side between the recommending market maker and the two control groups are significant for about three hours before the announcement. The recommending market makers are more aggressive in their quoting behavior on the ask side and the differences are economically meaningful at between 3 and 5 percent. Figure 9 plots the results.

Table 4 also reports the results for bid quotes around downgrades. Before the recommendation announcement, the difference in quoting behavior between the recommending market makers and the control groups is not statistically significant. Figure 10 gives a plot of the results.

In summary, the evidence in this section further supports the hypothesis of information leakage and front-running. The quoting behavior of the recommending market maker changes significantly in the direction of recommendations well before the public announcements, even after controlling for her own behavior during the non-event period and for the quoting behavior change of other market makers.

4.4. Robustness Check

As a robustness check, we also perform a rank order test. Each market maker's rank is based on the proportion of time at the inside quote. We use the rank to compute a score for each market maker. Hong and Kubik (2002) use a similar rank score to rate the relative performance of analysts. The rank score is defined as

$$Score_{i,j,t} = 100 - \left[\frac{Rank_{i,j,t} - 1}{Number\ of\ Market\ Makers_{j,t}} \right] \times 100,$$

where $Rank_{i,j,t}$ is the rank of market maker *i*, for security *j*, during half-hour interval *t*, for the percentage of time a market maker quotes at the inside, and $Number\ of\ Market\ Makers_{j,t}$ is the number of market makers for security *j* during half-hour interval *t*. This score is computed for ask and bid quotes separately. If a market maker has a rank of one for a given half-hour interval, i.e., the market maker quotes more often at the inside than any other market maker, this market maker receives a score of

100. On the other hand, a market maker who is the least often at the inside receives a score of 0. This rank score compares one market maker's behavior to the behavior of all other market makers and thus controls for effects that impact all market makers.

We compare the difference in rank score of each market maker during the event period intervals to the mean rank score of that market maker during the corresponding half-hour intervals in the control period. Figures 11 and 12 plot the cross-sectional means of the raw deviations in rank scores for upgrades and downgrades, respectively. The results are consistent with our previous findings. Figure 11 shows that for upgrades the rank score of the recommending market maker does not change significantly for the ask quotes, but increases significantly for the bid quotes. The rank score increases are significant for three hours before the announcement, and they are considerably larger in magnitude for an hour and a half before the announcement. The increased rank score implies that the recommending market maker quotes more aggressively on the bid side in anticipation of the announcement. For downgrades, Figure 12 shows that the rank score for the recommending market maker does not significantly change for the bid quotes, but increases significantly for the ask quotes. The increase in rank score is highly significant for two hours before the announcement. Thus, recommending market makers are more aggressive on the ask side before downgrades. To summarize, the rank score analysis confirms our earlier results and provides strong evidence of information leakage and front-running before recommendation revisions.

5. Conclusions

This study investigates the question of whether there might be information leakage, and front-running, before analyst recommendation revisions. To this end, we investigate the quoting behavior of market makers who are affiliated with the same brokerage firms as the recommending analysts. We find strong empirical evidence consistent with the proposition that recommending market makers' quotes reflect prior knowledge of the analysts' pending announcements by the recommending market makers, by proprietary traders, or by outside investors. We find that for an hour and a half before upgrades, the proportion of time recommending market makers quote at the inside bid increases significantly, but their

quoting behavior on the ask side does not change. For three hours before downgrades, the proportion of time recommending market makers quote at the inside ask increases significantly, but their quoting behavior on the bid side does not change. The early reaction of the recommending market makers is highly significant after controlling for their own behavior during the non-event period and for the change in quoting behavior of other market makers. Thus, the evidence suggests that the recommending market makers react well before the public announcements and before other market makers. In conclusion, this paper provides evidence that analyst recommendation revisions are associated with information leakage and front-running. These actions are proscribed by regulation and degrade market integrity.

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Appendix A. Data Filters

We apply the following filters to the intraday Nastraq data. Observations violating these filters are classified as invalid. Invalid observations are not deleted, but subsequent analysis of intraday trade and quote data take the classification into account.

Dealer Quote Data Filters

- The market maker must be open to trade the stock.
- Ask quotes must be greater than bid quotes, which in turn must be greater than zero.
- Both bid and ask depths must be greater than zero.
- The time stamp must be before 4PM EST.
- We retrieve the last quote for each market maker before 9:30AM EST and all subsequent quotes.
- For each stock and day, we compute the minimum ask quote and the maximum bid quote. We require that dealer bid quotes are not less than 65% of the minimum daily ask quote, and that dealer ask quotes are not greater than 135% of the maximum daily bid quote.

Inside Quote Data Filters

- If there is an opening inside quote for a stock, we require the time stamp to be after the opening. If there is no opening inside quote, we keep the last quote before 9:30AM EST and all subsequent quotes.
- The time stamp must be before 4PM EST.
- Ask quotes must be greater than bid quotes, which in turn must be greater than zero.
- We require that bid and ask quotes are within 7.5 standard daily deviations from their respective daily means.

Trade Data Filters

- The time stamp must be within regular trading hours: 9:30AM to 4PM EST.
- We restrict trades to regular trades.

- Both the trade price and the trade size must be greater than zero.
- Trade prices must be within 7.5 standard daily deviations from the daily mean.

Appendix B. ECNs and Market Makers

We follow Huang (2002) in classifying market participants in the Nasdaq market into four major groups: institutional brokers, wire houses, wholesalers, ECNs. All remaining market participants not classified are labeled "Minors."

ID	Name
Institutional brokers	
BEST	Bear Stearns
BTAB	BT Alex. Brown
DBKS	Deutsche Bank Securities
DLJP	Donaldson, Lufkin & Jenrette
FBCO	Credit Suisse First Boston
GSCO	Goldman Sachs
HMQT	Hambrecht & Quist
JPMS	J. P. Morgan Securities
LEHM	Lehman Brothers
MONT	Banc of America Securities
MSCO	Morgan Stanley
RSSF	Robertson Stephens
WARR	UBS Warburg
Wire houses	
DEAN	Dean Witter Reynolds
MLCO	Merrill Lynch, Pierce, Fenner & Smith
PRUS	Prudential Securities
PWJC	Painewebber
SBSH	Salomon Smith Barney
Wholesalers	
FLTT	Fleet Trading
HRZG	Herzog, Heine, Geduld
MASH	Mayer & Schweitzer
NAWE	Nash Weiss
NITE	Knight/Trimark Securities
SHWD	Sherwood Securities
SLKC	Spear Leeds & Kellogg Capital
TSCO	Troster Singer
USCT	US Clearing Corporation
Electronic communication networks	
ARCA	Archipelago
ATTN	Attain
BRUT	Brass Utility
BTRD	B-Trade Services
INCA	Instinet
ISLD	Island
MKXT	Marketxt
NTRD	Pim Global Equities
REDI	REDI
STRK	Strike Technologies
TNTO	Terra Nova Trading

Table 1. Distribution of Analyst Recommendations

Panel A. Transition Matrix of Analyst Recommendations

From Recommendation of:	To Recommendation of:					
	Strong Buy	**Buy**	**Hold**	**Sell**	**Strong Sell**	**Total**
Strong Buy		140	81	0	0	221
Buy	196		205	1	0	402
Hold	37	172		5	1	215
Sell	0	2	1		0	3
Strong Sell	0	0	3	0		3
Total	233	314	290	6	1	844

Panel B. Intraday Distribution of Analyst Recommendation Revisions

Time Interval		Number of Upgrades	Number of Downgrades	Number of Recommendations
From	**To**			
09:30	10:00	90	76	166
10:00	10:30	57	80	137
10:30	11:00	43	52	95
11:00	11:30	53	49	102
11:30	12:00	28	37	65
12:00	12:30	19	21	40
12:30	13:00	16	19	35
13:00	13:30	27	22	49
13:30	14:00	13	16	29
14:00	14:30	17	22	39
14:30	15:00	18	12	30
15:00	15:30	9	15	24
15:30	16:00	21	12	33
Total		411	433	844

Table 2. Descriptive Statistics of Firms in Analyst Recommendation Revision Sample

There are 844 recommendation revisions in the sample. The event period is defined as the 79 half-hour intervals centered on the recommendation revision, i.e., three days before and three days after the announcement half-hour interval. The control period is defined as the 260 half-hour intervals surrounding the event period, i.e., the ten days before and ten days after the event period. Market capitalization is computed as the mean daily market capitalization during the control period using CRSP data. Price per share is the mean daily CRSP closing price during the control period. Daily share volume, daily dollar volume, and daily turnover are the daily means during the control period. Volumes are computed using Nastraq transaction data. Turnover is defined as the share volume on a given day divided by the number of shares outstanding as given by CRSP on that day. Volatility is the standard deviation of daily returns during the control period, daily returns are collected from CRSP. Proportional spread is the time-weighted mean inside half-spread during the control period. Number of market makers is defined as the number of market makers that are active in a stock for a specific recommendation, a market maker is active is there is at least one valid quote observation during the event period.

			Quartile		
Variable	**Mean**	**Standard Deviation**	**25%**	**50% (Median)**	**75%**
Market Capitalization *(in $ million)*	3,296	20,426	172	442	1,155
Price Per Share *(in $)*	25.47	24.88	9.92	17.99	31.78
Daily Share Volume *(in thousand shares traded)*	974	2,424	92	281	756
Daily Dollar Volume *(in $ thousand)*	46,138	167,716	1,077	5,140	17,440
Daily Turnover *(in %)*	1.41	1.28	0.55	1.04	1.86
Volatility *(in %)*	4.45	1.91	3.12	4.05	5.37
Proportional Spread *(in %)*	0.60	0.51	0.27	0.45	0.75
Number of Market Makers	26.85	14.76	16	23	35

Table 3. Upgrades - Differences in Percentage of Time at Inside Quotes Between Recommending Market Maker and Control Groups: Raw Deviations From Control Period

We compute the deviation in percentage of time at inside quotes during the event period from the control period for all market makers. We then calculate the difference in the quoting behavior changes between recommending market makers and the mean of all other market makers and peer market makers, respectively. The other market maker sample contains 411 upgrades and 433 downgrades. Due to the lack of peers, there are 393 observations for upgrades and 403 observations for downgrades in the peer market maker sample. The reported means are across all recommendations and p-values are obtained from Monte Carlo simulations. Boldface indicates significance at 5%.

		Differences in Percentage of Time at Inside Ask				**Differences in Percentage of Time at Inside Bid**			
	Half-Hour	**Other Market Makers**		**Peer Market Makers**		**Other Market Makers**		**Peer Market Makers**	
Day	**Interval**	**Mean (%)**	**p-value**	**Mean (%)**	**p-value**	**Mean (%)**	**p-value**	**Mean (%)**	**p-value**
	-13	-0.65	0.560	-0.04	1.000	-2.15	0.072	**-2.55**	0.036
	-12	0.17	0.780	0.69	0.466	-1.15	0.334	-1.82	0.136
	-11	-0.18	0.864	0.05	0.946	-0.89	0.482	-0.60	0.676
	-10	-0.09	0.920	0.12	0.902	0.00	1.000	0.62	0.596
	- 9	-1.92	0.046	-1.64	0.100	-0.34	0.840	0.81	0.538
	- 8	-1.85	0.058	-1.25	0.234	0.41	0.716	1.13	0.354
-1	- 7	-0.74	0.502	-0.55	0.614	0.20	0.900	0.89	0.502
	- 6	-1.69	0.088	-1.51	0.136	0.21	0.864	0.95	0.420
	- 5	-1.39	0.172	-0.99	0.360	0.61	0.596	1.41	0.262
	- 4	**-1.98**	0.050	-1.55	0.154	1.77	0.132	**2.71**	0.036
	- 3	-1.45	0.122	-0.43	0.720	**3.22**	0.004	**4.81**	0.000
	- 2	-1.38	0.176	-0.80	0.440	**4.30**	0.000	**5.28**	0.000
	- 1	-1.82	0.078	-1.03	0.348	**4.74**	0.000	**5.37**	0.000
Event	0	-0.97	0.326	-0.90	0.400	**4.19**	0.002	**4.62**	0.000
	1	-1.13	0.248	-1.15	0.294	**3.18**	0.008	**3.59**	0.006
	2	-1.44	0.162	-0.88	0.428	**4.06**	0.000	**4.70**	0.000
	3	-1.15	0.254	-0.89	0.382	**3.88**	0.002	**4.98**	0.000
	4	1.10	0.284	1.90	0.092	**3.99**	0.000	**5.33**	0.000
	5	-0.28	0.764	0.27	0.792	**3.57**	0.000	**4.42**	0.000
	6	0.05	0.924	0.47	0.634	**3.54**	0.000	**3.58**	0.004
+1	7	0.53	0.644	1.02	0.350	1.97	0.096	1.74	0.166
	8	1.23	0.254	**2.52**	0.026	**2.51**	0.040	**2.52**	0.040
	9	**2.72**	0.010	**3.50**	0.002	**4.22**	0.000	**4.96**	0.000
	10	1.66	0.098	**2.28**	0.028	**2.79**	0.024	**3.65**	0.004
	11	1.53	0.122	**2.49**	0.010	**3.13**	0.014	**3.89**	0.000
	12	1.12	0.232	**2.15**	0.050	**3.50**	0.004	**4.19**	0.000
	13	0.32	0.796	1.18	0.312	1.99	0.116	**2.83**	0.030
	14	-0.22	0.794	0.41	0.684	1.49	0.206	1.81	0.148
	15	-0.44	0.634	-0.14	0.908	2.11	0.074	2.29	0.056
	16	0.75	0.434	1.61	0.152	1.72	0.124	1.94	0.120
	17	-0.13	0.906	1.08	0.342	2.02	0.094	1.94	0.116
	18	1.12	0.248	**2.81**	0.004	0.41	0.720	0.43	0.730
	19	0.50	0.576	1.60	0.116	1.63	0.178	1.88	0.138
+2	20	0.05	0.888	0.88	0.394	2.11	0.086	2.57	0.034
	21	1.23	0.226	1.68	0.132	1.13	0.326	2.26	0.082
	22	0.29	0.760	1.25	0.224	1.68	0.190	2.04	0.108
	23	-0.39	0.644	0.57	0.598	**2.27**	0.046	2.19	0.084
	24	0.06	0.954	1.17	0.266	1.56	0.202	1.09	0.368
	25	0.68	0.496	1.90	0.068	0.31	0.772	0.81	0.530
	26	-0.02	0.998	0.97	0.338	1.84	0.124	**2.47**	0.046

Table 4. Downgrades - Differences in Percentage of Time at Inside Quotes Between Recommending Market Maker and Control Groups: Raw Deviations From Control Period

We compute the deviation in percentage of time at inside quotes during the event period from the control period for all market makers. We then calculate the difference in the quoting behavior changes between recommending market makers and the mean of all other market makers and peer market makers, respectively. The other market maker sample contains 411 upgrades and 433 downgrades. Due to the lack of peers, there are 393 observations for upgrades and 403 observations for downgrades in the peer market maker sample. The reported means are across all recommendations and p-values are obtained from Monte Carlo simulations. Boldface indicates significance at 5%.

		Differences in Percentage of Time at Inside Ask				**Differences in Percentage of Time at Inside Bid**			
	Half-Hour	**Other Market Makers**		**Peer Market Makers**		**Other Market Makers**		**Peer Market Makers**	
Day	**Interval**	**Mean (%)**	**p-value**	**Mean (%)**	**p-value**	**Mean (%)**	**p-value**	**Mean (%)**	**p-value**
	-13	**2.30**	0.024	2.16	0.052	0.62	0.568	0.42	0.700
	-12	1.24	0.250	1.51	0.198	-0.64	0.554	-1.59	0.210
	-11	0.57	0.594	0.88	0.454	-0.60	0.572	-1.28	0.330
	-10	1.60	0.136	1.57	0.188	0.35	0.742	-0.33	0.772
	- 9	0.44	0.696	0.13	0.866	-0.51	0.656	-0.57	0.636
	- 8	-0.41	0.666	0.59	0.576	-1.31	0.236	-1.93	0.140
-1	- 7	0.80	0.454	1.70	0.174	0.42	0.666	-0.78	0.542
	- 6	**3.01**	0.004	**3.23**	0.010	0.08	0.958	0.10	0.956
	- 5	**3.10**	0.000	**3.08**	0.002	0.95	0.380	1.93	0.140
	- 4	**3.07**	0.000	**2.60**	0.032	0.72	0.516	2.39	0.066
	- 3	**2.70**	0.016	2.25	0.056	-1.20	0.288	0.14	0.880
	- 2	**3.36**	0.004	**3.72**	0.002	-0.78	0.490	0.09	0.924
	- 1	**4.53**	0.000	**4.90**	0.000	-1.11	0.346	0.26	0.828
Event	0	**4.02**	0.002	**5.37**	0.000	**-2.49**	0.024	0.11	0.980
	1	**2.96**	0.008	**4.25**	0.000	**-2.01**	0.048	-0.57	0.642
	2	**2.39**	0.016	**3.69**	0.000	-1.32	0.216	-0.41	0.702
	3	**2.72**	0.006	**2.75**	0.018	-0.76	0.554	0.34	0.784
	4	**3.35**	0.004	**3.41**	0.000	-0.81	0.500	-0.20	0.844
	5	**2.62**	0.022	2.35	0.060	**-2.37**	0.026	-2.17	0.072
	6	2.04	0.076	0.98	0.408	-1.78	0.096	-1.29	0.316
+1	7	**4.01**	0.000	2.22	0.062	-2.15	0.052	-1.65	0.190
	8	**3.29**	0.006	2.64	0.040	**-3.11**	0.008	-1.98	0.088
	9	**3.04**	0.008	1.97	0.124	-1.87	0.088	-0.01	0.992
	10	1.78	0.104	1.92	0.106	**-2.63**	0.010	-1.15	0.286
	11	**2.70**	0.014	**3.44**	0.002	**-3.12**	0.008	-1.05	0.426
	12	1.33	0.228	**2.54**	0.036	-1.45	0.190	-0.43	0.768
	13	1.63	0.128	1.74	0.140	-0.97	0.370	0.75	0.566
	14	0.87	0.430	1.16	0.358	-1.34	0.246	0.41	0.736
	15	1.10	0.312	1.80	0.150	-1.84	0.076	-0.04	0.966
	16	0.82	0.372	0.75	0.464	-0.21	0.878	1.48	0.228
	17	1.16	0.276	**2.40**	0.050	-1.34	0.232	-0.10	0.994
	18	0.63	0.578	1.50	0.196	**-2.20**	0.044	-1.58	0.210
	19	-0.52	0.636	-0.50	0.718	-1.73	0.154	-1.02	0.444
+2	20	-1.18	0.276	-1.02	0.354	-1.81	0.144	-1.50	0.254
	21	-0.36	0.764	0.12	0.872	-1.08	0.328	-1.73	0.170
	22	-0.70	0.536	0.10	0.898	-0.47	0.656	-0.95	0.418
	23	0.34	0.698	1.20	0.332	-1.07	0.332	-1.25	0.356
	24	0.66	0.552	1.09	0.328	-0.15	0.958	0.59	0.618
	25	0.96	0.382	0.31	0.792	-0.92	0.342	0.68	0.638
	26	-0.18	0.922	-1.58	0.204	-0.12	0.904	1.57	0.178

Figure 1. Proportional Inside Spreads

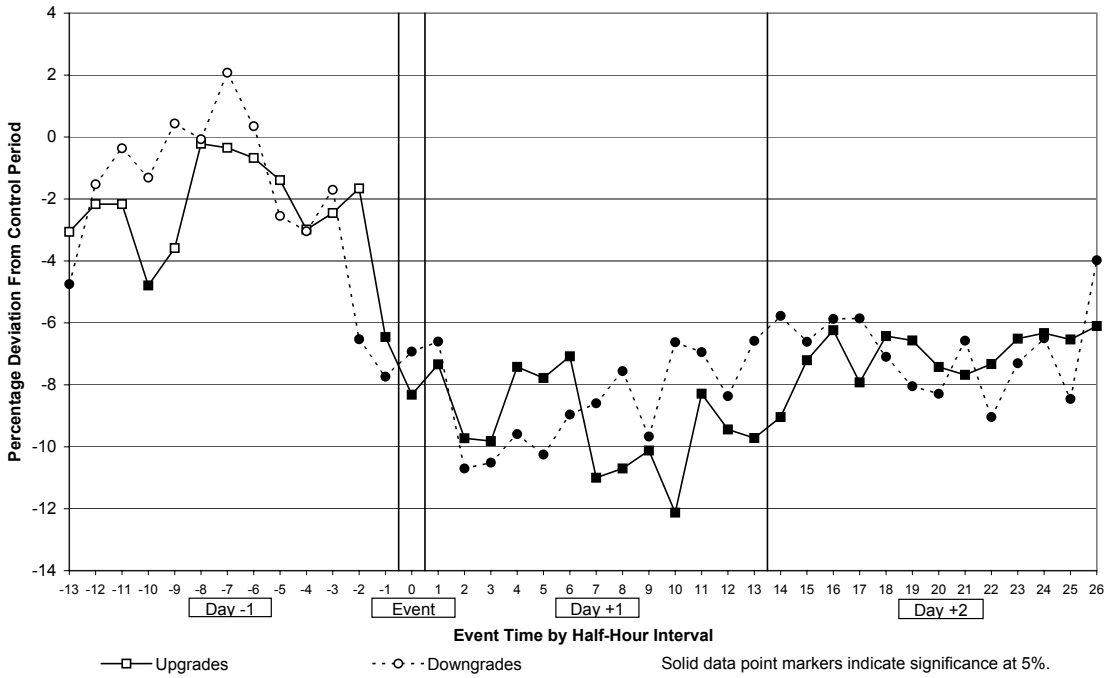

Figure 2. Share Volume

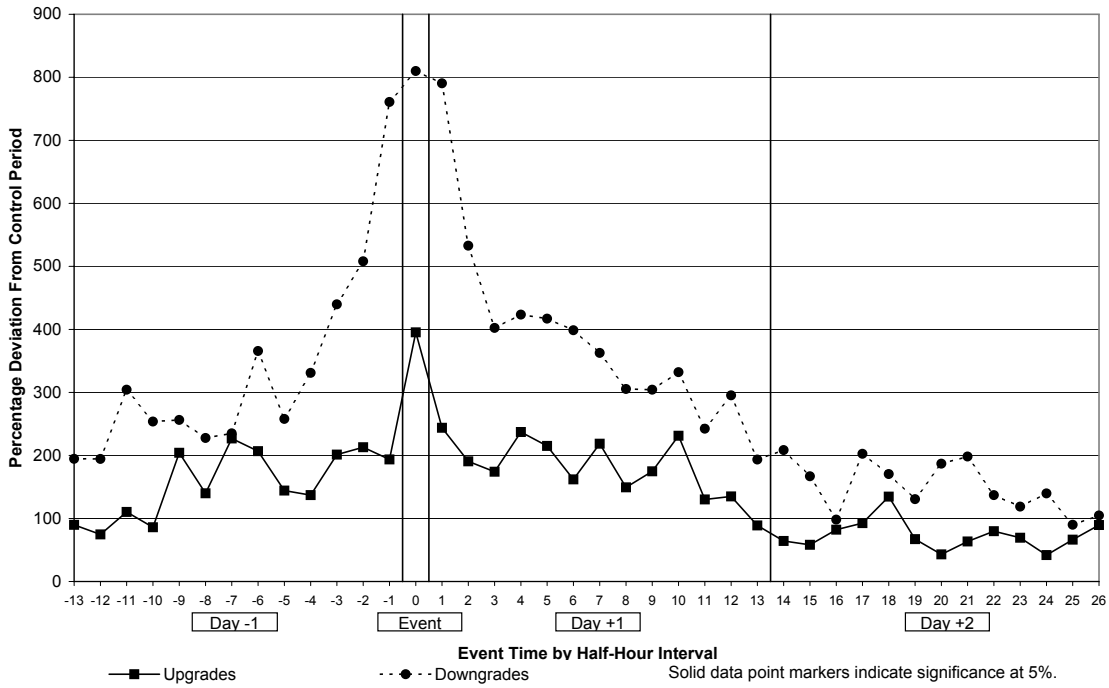

Figure 3. Upgrades - Percentage of Time at Inside Ask

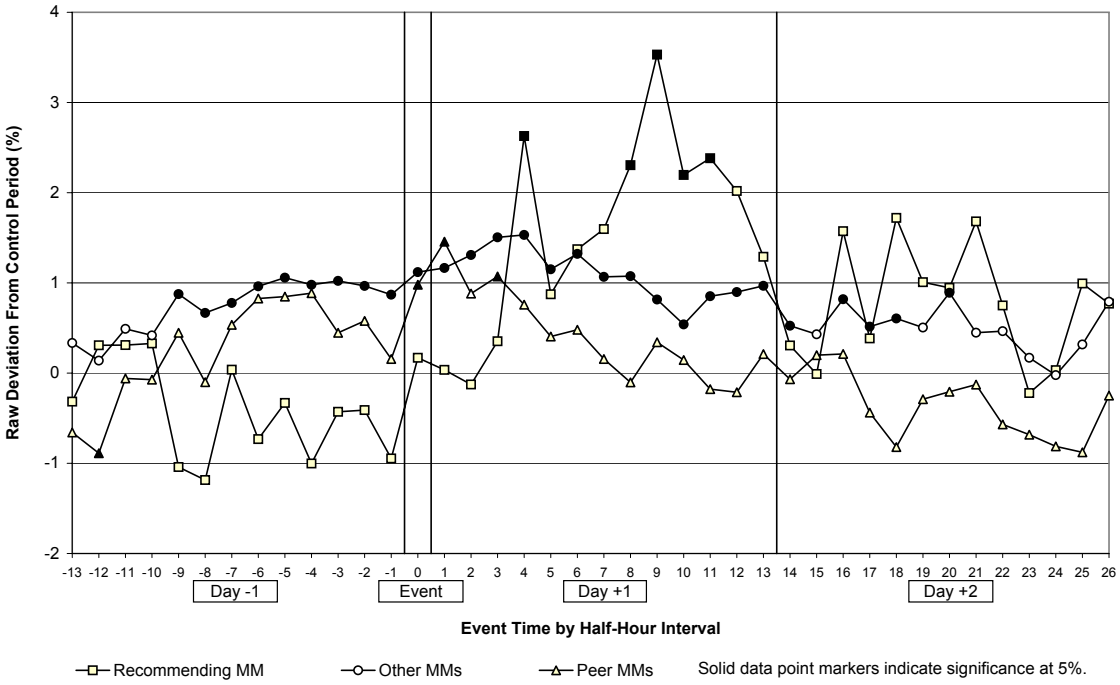

Figure 4. Upgrades - Percentage of Time at Inside Bid

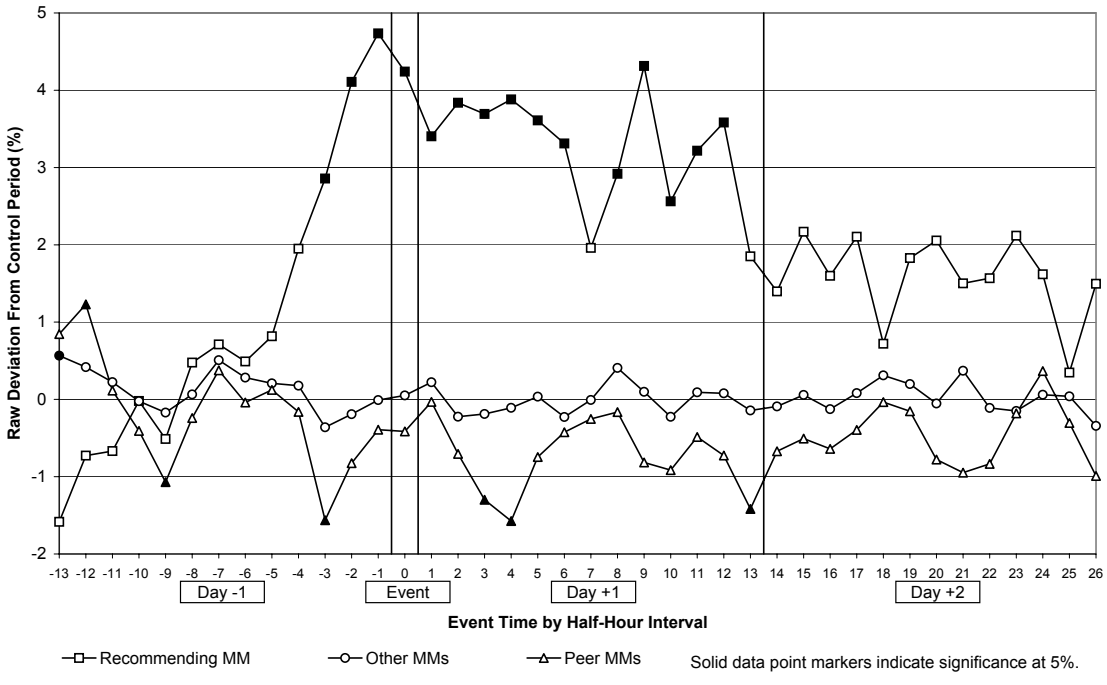

Figure 5. Downgrades - Percentage of Time at Inside Ask

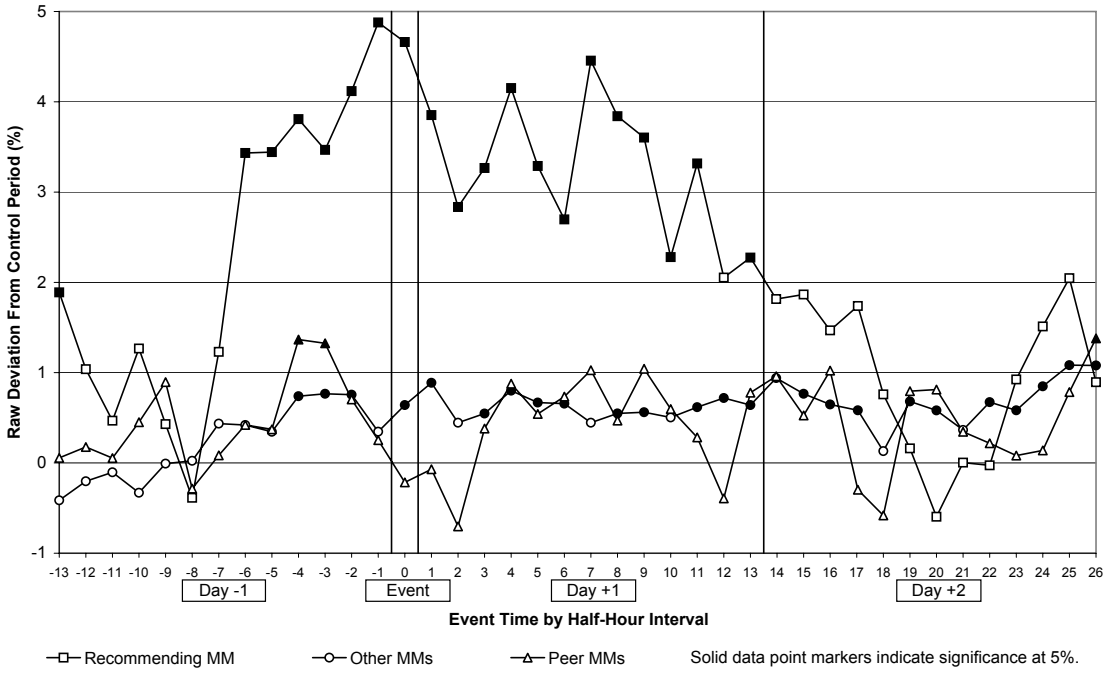

Figure 6. Downgrades - Percentage of Time at Inside Bid

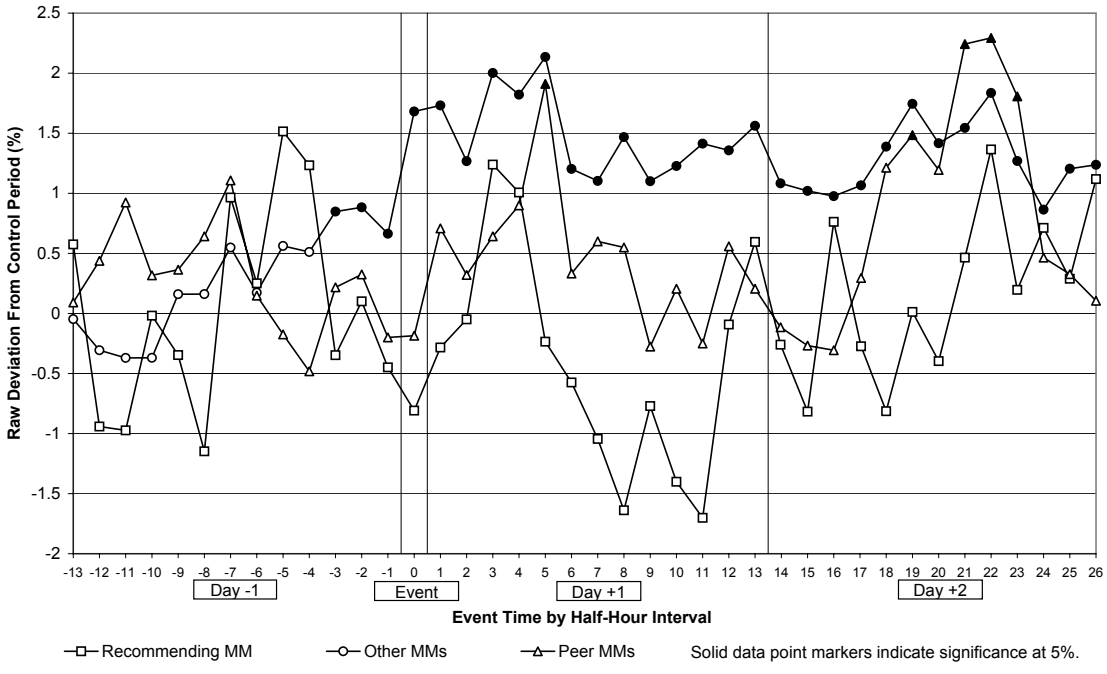

Figure 7. Upgrades - Differences in Percentage of Time at Inside Ask Between Recommending MM and Control Groups of Market Makers

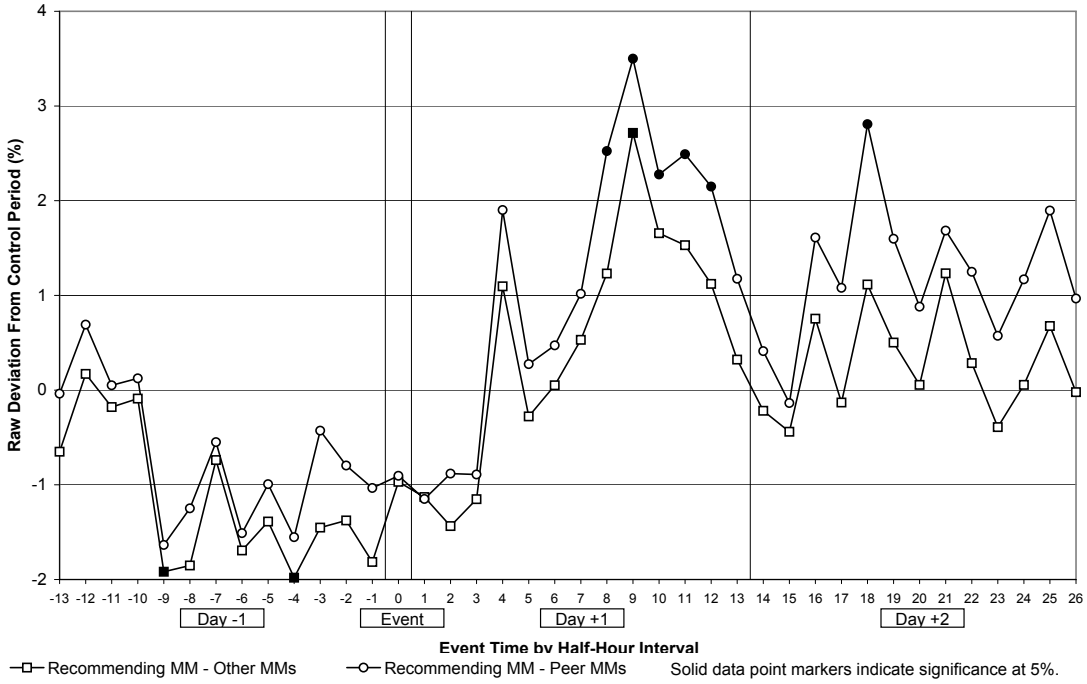

Figure 8. Upgrades - Differences in Percentage of Time at Inside Bid Between Recommending MM and Control Groups of Market Makers

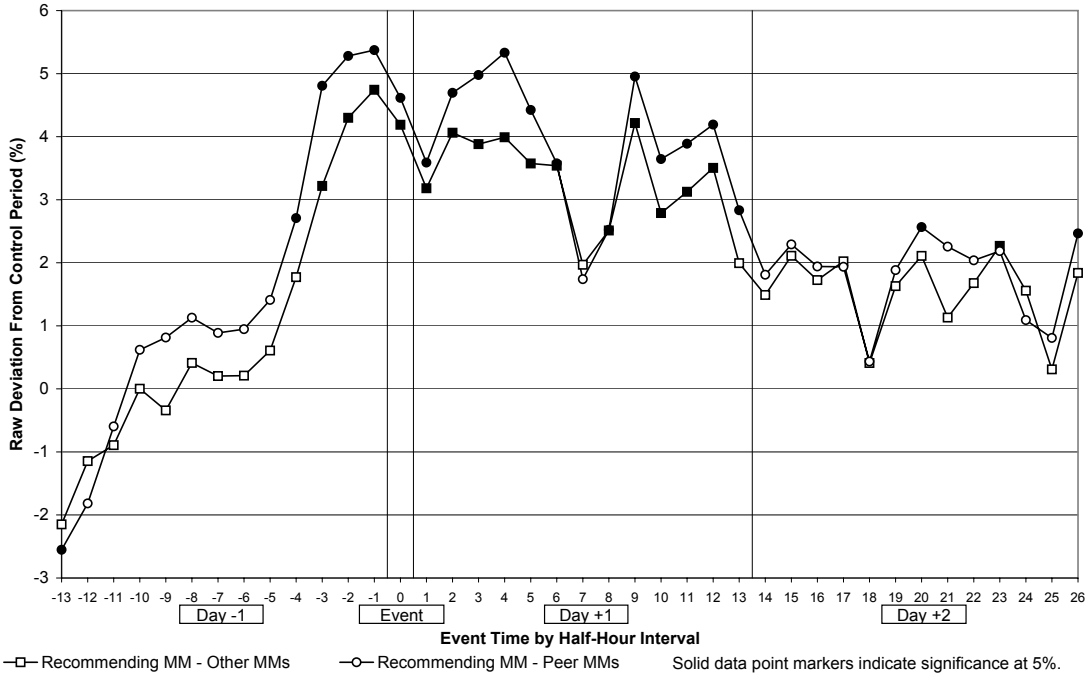

Figure 9. Downgrades - Differences in Percentage of Time at Inside Ask Between Recommending MM and Control Groups of Market Makers

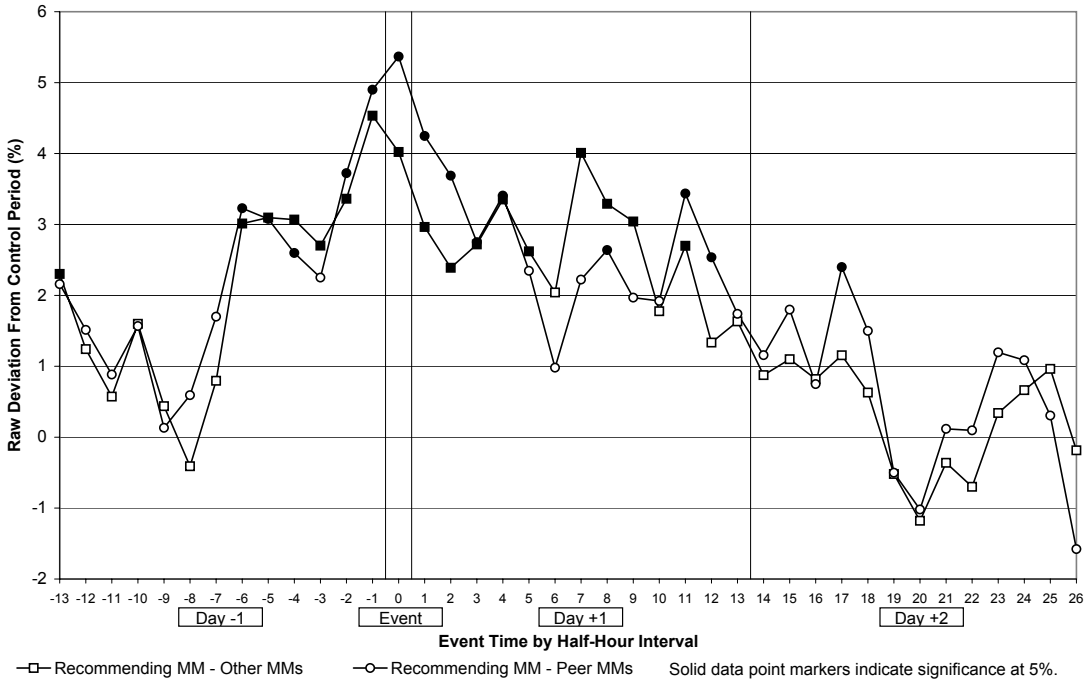

Figure 10. Downgrades - Differences in Percentage of Time at Inside Bid Between Recommending MM and Control Groups of Market Makers

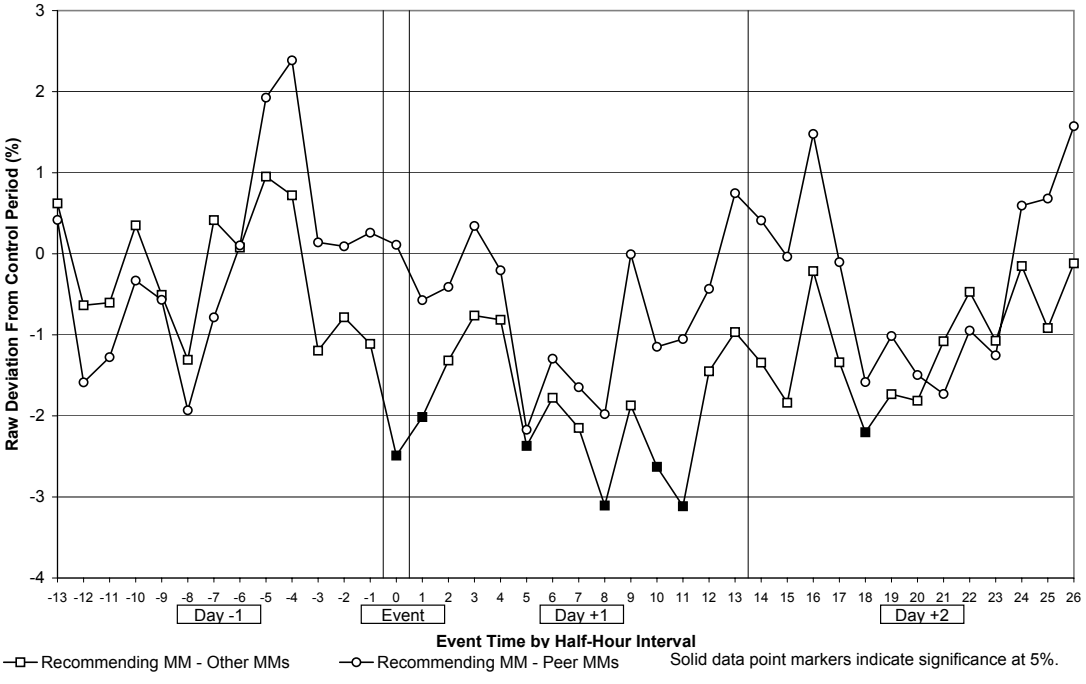

Figure 11. Upgrades - Rank Scores of Time at Inside Ask/Bid

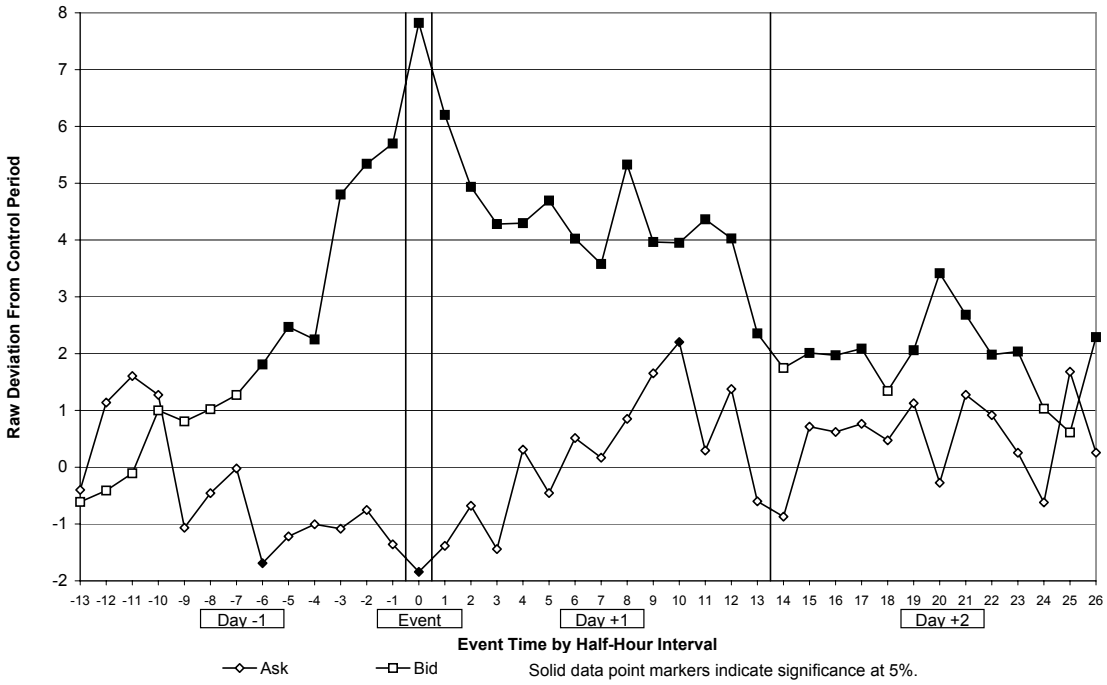

Figure 12. Downgrades - Rank Scores of Time at Inside Ask/Bid