"The Information Content of Market-on-Close Imbalances, the Specialist and NYSE Equity Prices"

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Abstract

We examine the relationship between announcements of (a) market-on-close orders, (b) price dynamics and (c) specialist trading on the New York Stock Exchange. We find that the closing order imbalance affects prices even prior to the announcement of the imbalance. This is consistent with investors expressing their demands through both market-on-close orders and direct purchases—so that some of the price impact could occur before the specialist's announcement of the imbalance. However, to a degree the specialist himself is trading ahead of the announcement, which also helps explain why price movement occurs before dissemination of the imbalances. Consequently, the remaining traders (other than the specialist) are actually trading *against* the direction of their closing imbalances and the specialist is *not* helping to smooth investor demands. Because of the structure of the mechanism and the volatility of prices near the close (which is especially elevated at the deadline for market on close orders at 3:40 p.m.), this is an interesting context for studying how information gets reflected in price.

1. Introduction

It is usually difficult to study the price formation process because the nature of liquidity demands by investors and the structure of information facing investors often are not clearly defined. An interesting context for studying how information gets impounded in pricing and the price discovery process is the New York Stock Exchange's mechanism for handling information about liquidity demands at the daily close of the market through its treatment of "market on close" orders and the circumstances in which disclosure of order imbalances occurs. This is a setting with a clearly defined information structure, under which there were opportunities for the specialist to influence the disclosure of potentially relevant order imbalance information during the trading process. However, the nature of the specialist's informational advantage varies during the run-up to the close as well as systematically with market conditions and the specialist's actions.[1]

The determination of the closing price has been an area of longstanding interest in the financial markets. The valuation of many assets, such as mutual and hedge funds, as well as the associated valuation of market benchmarks, are typically based upon "closing" prices. Consequently, when these funds face predictable purchases or redemptions there is a strong desire to hedge the underlying valuation cost of such transactions with closing transactions. Similarly, leveraged mutual funds (and more recently leveraged ETFs) generate predictable rebalancing trades targeted to the closing price because their objective is to replicate a multiple of the return on the underlying target portfolio and

[1] Of course, the potential advantages of the specialist highlighted in this paper (and various advantages identified by other researchers, such as the study of the opening by Stoll and Whaley (1990)) are potentially offset by various legal obligations.

matching the return requires adjustment in the portfolio to match convexity.[2] Additional important features of the closing price are that it is based upon a widely anticipated scheduled market closure and that the closing price mechanism is structured to facilitate the aggregation of many orders.

Recent market activity illustrates that there can be disproportionate volatility near the close and that investors are willing to subject themselves to it to obtain the closing price for their executions. Indeed, research on the pricing of prepackaged baskets (Kavajecz and Keim (2005)) and the extensive literature on price effects associated with index additions and deletions, illustrate the willingness to pay to obtain the benchmark price. Recent market activity late in the trading day helps amplify the interest in the closing mechanism. Hong and Stein (1999) examine theoretically the implications of periodic closures and show that when there is more fundamental uncertainty, liquidity providers are especially reluctant to hold positions overnight—highlighting why when fundamental volatility is especially large, price volatility and trading activity will be especially concentrated near the close. Somewhat relatedly, Brock and Kleidon (1992) adapt a Merton continuous-time model to show that the optimal portfolio differs at the close of trading because the investor will be unable to update his portfolio for awhile after the periodic closure (except at high costs). Consequently, portfolio demands become more inelastic near the close—helping to explain attention to "market on close" executions. These rationales for executing at the closing price are especially important in volatile

[2] For example, if the product provides double the daily returns, then daily trades are required to match the corresponding exposure. In this case purchases are required after positive returns and sales are required after a negative return. Cheng and Madhavan [2009] examine in detail leveraged and inverse ETFs, including their impact on liquidity and market volatility and the associated market microstructure effects.

market conditions. In fact, these motivations for particular interest in closing executions suggested by Brock and Kleidon (1992) and Hong and Stein (1999) are motivated by portfolio theoretic objectives rather than agency considerations, such as the importance of the process for benchmarking funds and asset managers.

During the trading day investors place “market on close” orders for execution at the close of trading. At the heart of the “market on close” mechanism is that trading occurs in the underlying securities (both by the specialist and other investors) throughout the trading day, but that “market on close” orders are accepted only until 3:40 p.m. (and under some circumstances until 3:50 p.m. or 4:00 p.m.) with limited potential disclosure of trading imbalances. The specialist is not a passive participant in this process, but also can participate in the underlying trading. However, at certain stages in the process and under certain conditions the specialist possesses potentially valuable information through his knowledge or potential knowledge of the order imbalance. It is interesting to observe that empirically price volatility is especially high around 3:40 p.m. when the information in the market on close orders is being aggregated and disseminated.

Since market participants recognize the structure of the market, the information content of such imbalances can be assessed by how investors trade with the market specialist. This provides a natural way to use the mechanism to measure the effect of asymmetric information. Though less fundamental, we also are interested in how the specialist utilizes his informational advantage. Our empirical results highlight that the information content of the closing order imbalances is reflected in the marketplace, even prior to their

announcement by the specialist. This could potentially reflect both the specialist trading prior to the announcement of the imbalances as well as the marketplace aggregating imbalance orders that are transmitted by market participants. However, we do not take a stand on whether the specialist's trading behavior described in the paper, such as possible trading before announcement of pending imbalances, constitutes illegal trading. Rather we offer economic evidence that documents interesting statistical features of the trading data and spotlights the impact of the "market on close" trading mechanism and the consequences of the dissemination of "market on close" imbalances.[3] The evidence illustrates a mechanism by which the specialist can exercise discretion in his trading.

Of course, an important purpose of the overall mechanism and specifically, disclosure of order imbalances, is to facilitate the emergence of balancing orders on the other side of the market in order to potentially enhance the efficiency of the price discovery process. The exposure of these imbalances is somewhat like "sunshine" trading in that there is potential "advertising" as the mechanism may elicit orders on the *opposite* side of the market—though, as in sunshine trading, at the cost of various traders legitimately executing on the *same* side in advance of the orders being involuntarily deferred. This context points to a number of questions about the trading mechanism (for example, see, Stoll and Whaley [1990], Biais, Hillion and Spatt [1999] and Brock and Kleidon [1992]). For example, how should a trading platform design its mechanism? What is the role of dissemination of imbalances? Is it advantageous that this be in the hands of a single

[3] Somewhat analogously, the monopoly power in opening trading by the specialist that was documented in Stoll and Whaley [1990] was not the focus of regulatory enforcement actions.

trader? What's unique about the closing process for disclosure of imbalances and how should the timing and frequency of the disclosures be viewed?

The fine structure of the procedure is certainly relevant to these types of assessments. The trading process (both the extent of adverse selection and the specialist's attempt to utilize his information) is influenced when the specialist has information that is soon to be disclosed? In several ways the process suggests some natural experiments—one would be to examine what happens before and after the disclosure and another would be to suppose that the imbalance is slightly above or below the 50,000 share threshold for disclosure of imbalances. Of course, the latter isn't a complete natural experiment because the specialist's trades prior to the cutoff time potentially influence whether the threshold is attained and consequently the existence of potential payoffs at a later stage of the game.

In light of the structure of the on-close orders and their dissemination by the specialist there are implications for both the market's pricing of the security and the specialist's decisions. In particular, prior to the dissemination of imbalances at 3:40 p.m. and 3:50 p.m. the specialist has an informational advantage with respect to his knowledge of the upcoming dissemination. Indeed, our empirical results document that some of the information content in the dissemination of the market on close net order is reflected in the market price prior to the dissemination. However, traders also could legitimately hold back some of their information before the dissemination so as to not provide their full information to other bidders. This is analogous to an interesting result in Treasury auctions (e.g., Simon, [1994])—considerable aggregation of information occurs in the

trades shortly after the bidding deadline, even though the auction results will not be announced for a few hours as bidders were not trading aggressively in advance of the auction to limit the informativeness of their trades and not undercut themselves in the auction. Additionally, at least hypothetically the specialist can influence whether there is announcement of an order imbalance (and informational dissemination) to the extent that he can potentially influence whether the 50,000-share threshold is attained through his own trading and setting of the relevant price level.[4]

The empirical result that the closing order imbalance affects prices even prior to the announcement of the imbalance is consistent with a number of alternative interpretations and explanations. For example, it is. consistent with investors expressing their demands through both market-on-close orders and direct purchases—so that some of the price impact of the imbalance would occur before the specialist's announcement of that imbalance. This explanation for why pricing could lead the imbalances could arise even absent a specialist—then the trading imbalance would be released through an exchange official who was not permitted to trade, but the actions of the traders themselves (as described above) would allow information to be reflected in the pricing prior to the announcement. An alternative explanation is that the specialist utilizes his informational advantage in trading and therefore, pricing reflects the imbalances prior to their dissemination. These alternative explanations cannot be distinguished by looking only at pricing data, but our dataset includes the specialist trades. That data suggests that the specialist is trading in the direction of the imbalances prior to their dissemination.

[4] However, the market may be trading too fast for the specialist to be able to control whether the threshold is attained.

Consequently, the remaining investors must be trading in the opposite direction in the aggregate, which is inconsistent with those investors spreading orders between the actual contemporaneous market and market-on-close imbalances.

In Section 2 we describe the underlying trading mechanism and the structure of market and information in practice. We describe the data and various descriptive statistics in Section 3 and our main empirical results from the trading process in Section 4.

2. Description of the Trading Process

Our description of the marketplace is based upon the New York Stock Exchange trading floor during the first quarter of 2005, the period of our sample. The NYSE close utilized a call auction in which the specialist has some discretion in setting the crossing price. Our analysis highlights the consequences of the disclosure of imbalances associated with on-close orders. Traders could enter market-on-close orders (MOC) and limit-on-close orders (LOC) either electronically or through floor brokers throughout most of the day. These orders allowed traders to execute at the close and potentially influence the determination of the closing price. In addition, pending orders in the market could be executed at the close, including discretionary orders represented by floor brokers and the specialist (as a broker) along with the specialist's closing execution for his own book to supply additional liquidity to execute the on-close orders.

An important aspect of the trading process is the structure of disclosure of on-close orders and the interaction of these disclosures with contemporaneous trading prior to the close.

The specialist routinely accepted on-close orders (both market and limit) until 3:40 pm. These orders could not be cancelled or reduced after 3:40 pm.[5] If there were a large imbalance, the specialist had discretion to publish imbalance information between 3:00 p.m. and 3:40 p.m., but more generally was required to publish imbalances of at least 50,000 shares at 3:40 p.m. If no imbalance message is published (indicating that an imbalance is smaller than 50,000 shares), the transmission of additional on-close orders ends for that day. Of course, the "no imbalance" signal, i.e., the lack of an imbalance message, does not imply that there is a perfect match between buy and sell on-close orders, simply that the imbalance is relatively small. If instead, an imbalance is published around 3:40 p.m., traders are allowed to submit on-close orders regardless of size to potentially offset the imbalance until 3:50 p.m., but not to submit on-close orders that add to the published imbalance. In effect, if there is an excess of at least 50,000 shares of on-close buy (sell) orders at the indicated price, then only MOC and LOC sell (buy) orders can be accepted during the subsequent 10-minute interval. Consequently, the direction of the imbalance can be reversed when the specialist is required to publish another imbalance message at 3:50 p.m. (or the imbalance can be eliminated or the direction can persist). If there is an imbalance published at 3:50 p.m. (if there is a "no imbalance" message published at 3:50 p.m., the imbalance is within 50,000 shares), then offsetting orders (including floor interest) will again continue to be accepted. At 4:00 pm, the specialist stops accepting all orders and then closes the market.

[5] ETFs and other similar financial products are not subject to these restrictions as order entry and cancellation for these products are not subject to any timetable.

The imbalance is computed based on the last sale price at 3:40 p.m. for the first dissemination and based on the last sale price at 3:50 p.m. for the second dissemination. The overall imbalance calculations reflect all market-on-close orders and the marketable limit-on-close orders at a price better than the last sale price. It may take the specialist time to manage and assess the orders at the close, but this actually provides a potentially significant last-mover advantage.[6]

In fact, the analysis begs the question as to why investors transmit their order materially in advance of the deadline, especially to the degree that this were to provide an advantage to either the specialist or to other investors at the point of the dissemination of the imbalance.[7] Among the potential advantages accruing to actual use (but not specific order submission timing) of the market-on-close order are the opportunity to execute at the closing price auction (without the transactions cost "haircut" that would arise under some alternative trading mechanisms), the ability to receive the official closing price (important for indexers as well as certain hedging and arbitrage strategies and businesses whose valuations for flows occur at the close of daily trading) and the ability to place the order in a less hectic time period.

Following the closing trade, the specialist is required to post a closing quote. Although these closing quotes are non-binding, they must be at or outside of the closing trade price.

[6] When a MOC imbalance exists, the specialist executes the imbalance against the bid (for sell imbalances) or offer (for buy imbalances) and reports it as one print to the tape. Then, the matched MOC/LOC orders are paired off and the aggregate volume of matched orders is reported in another print to the tape (as stopped stock).

[7] A similar effect arises in Biais, Hillion and Spatt [1999], where investors provide orders in the pre-opening of a market substantially in advance of the nominal deadline.

There may be multiple closing quotes since closing quotes may be generated automatically by NYSE systems and then submitted again by the specialist.[8]

Summary of Closing Timeline

3:00 p.m. Voluntary publication of the imbalance permitted with Floor Official approval.
Unlimited entry of MOC/LOC orders.
Floor brokers representing MOC/LOC orders must communicate their irrevocable interest to the specialist by 3:40 p.m.

3:40 p.m. No more cancellations of MOC/LOC.
Mandatory publication of the imbalance, if 50,000 shares or more.
Voluntary publication of the imbalance permitted with a Floor Official's approval.
If an imbalance is published, entry of MOC/LOC on contra side is permitted.
Note that there is no limitation on the size of orders entered, so there could be a reversal in the imbalance at 3:50 p.m.

3:50 p.m. If the order imbalance is less than 50,000 shares, a "no imbalance" message is published unless approval is granted by a Floor Official to publish an imbalance message.
If the order imbalance is 50,000 shares or more, the size and direction of the imbalance will be published.
If an imbalance is published, entry of MOC/LOC on contra side is permitted.

4:00 p.m. Closing call auction

The imbalance of MOC/LOC orders is determined using the last sale price as the reference price. LOC orders with prices at the reference price are not included in the imbalance calculation.

3. Descriptive Statistics

Our data was provided by the New York Stock Exchange (NYSE). The data contains comprehensive information on orders, trades and closing imbalance indications on the NYSE for all NYSE-listed securities from January 1, 2005 to March 31, 2005. Specifically, the NYSE CAUD database provides detailed information on each transaction as well as the parties involved in the trades. The NYSE SOD database

[8] Bacidore and Lipson [2001] study uses the closing quotes with the latest time stamp as the official closing quotes.

provides us with detailed information on orders that are entered electronically on the NYSE (nearly all orders). These datasets allow us to focus upon the specialist's trades and construct the dynamic evolution of the specialist's order book (except for the initial level). The NYSE Alerts database provides us with detailed information on closing imbalance disseminations. Some basic descriptive statistics from the data are reported in Table 1.

We now present a variety of additional statistics to highlight the behavior of order imbalances and related trading behavior of the specialist. We employ a number of common filters to the data to remove spurious data. Specifically, we use the TAQ data, but remove quotes with bid or offer price equal to 0 or less, quotes with bid or offer size equal to 0 or less, and quotes with spread greater than $5 or 40% of the midpoint bid and offer price. We then examine the quoted inside depth and the quoted inside spread before and after a dissemination of a market on close (MOC) buy or sell imbalance. The overall depth is measured as the sum of the inside bid and offer sizes. The percent spread is measured as offer price minus bid price as a percentage of the midpoint of the bid and offer prices. All measures are weighted by time. Returns are measured using the midpoint of the bid and offer prices. An illustrative order book is provided in Figure 1.

Table 2, Panel A shows descriptive statistics for buy imbalances at 3:40 p.m. The average MOC buy imbalance is 148,984 shares. Interestingly, the bid and offer increase by about 3 cents after a buy imbalance dissemination. There is a positive return of about 2 basis points for the 10 minutes before the dissemination and a positive return of about 9

basis points for the 10 minutes after the dissemination. It is not surprising that prices increase after disclosure of excessive buying interest. The percent spread also increases by about 0.2 basis points. The overall depth increases by 7,500 shares. The small increases in spread and depth suggest that liquidity providers react to the news by providing more liquidity at a higher cost.

Table 2, Panel B shows descriptive statistics for sell imbalances at 3:40 p.m. The average MOC sell imbalance is 160,542 shares. The bid and offer decrease by about 2 cents after a sell imbalance dissemination. The return for the 10 minutes before the dissemination is not significant, but there is a negative return of about 7 basis points for the 10 minutes after the dissemination. It is not surprising that prices decrease after disclosure of excessive selling interest. The percent spread also increases by about 0.2 basis points. There is no significant change in depth. The small increase in spread suggests that liquidity providers react to the news by providing liquidity at a higher cost.

Table 2, Panel C shows descriptive statistics for buy imbalances at 3:40 p.m. and 3:50 p.m. There is a 46.9% drop in the size of the imbalance from 3:40 p.m. to 3:50 p.m. which suggests that the mechanisms for reducing MOC imbalances are moderately successful. The bid and offer increase by about 2 cents after the 3:50 p.m. buy imbalance dissemination. There is a positive return of about 9 basis points for the 10 minutes before the dissemination and a positive return of about 3 basis points for the 10 minutes after the dissemination. It is not surprising that prices increase after disclosure of excessive buying interest. The quoted spread and percent spread increase by about 0.2 cents and

0.8 basis points, respectively. The bid, offer and overall depth increase after the 3:50 p.m. imbalance dissemination. The small increases in spread and depth suggest that liquidity providers react to the news by providing more liquidity at a higher cost.

Table 2, Panel D shows descriptive statistics for sell imbalances at 3:40 p.m. and 3:50 p.m. There is a 39.1% drop in the size of the imbalance from 3:40 p.m. to 3:50 p.m. which suggests that the mechanisms for reducing MOC imbalances are moderately successful. The bid and offer decrease by about 1.5 cents after the 3:50 p.m. buy imbalance dissemination. There is a negative return of about 5 basis points for the 10 minutes before the dissemination and a negative return of about 7 basis points for the 10 minutes after the dissemination. It is not surprising that prices decrease after disclosure of excessive selling interest. There is no change in spreads. The offer and overall depth increase after the 3:50 p.m. imbalance dissemination. The small increase in depth suggests that liquidity providers react to the news by providing more liquidity.

Tables 3 and 4 present average returns before and after imbalance disseminations. Buy (sell) imbalances result in positive (negative) returns. We use the terminology “buy-buy” (“sell-sell”) to denote buy (sell) imbalances at 3:40 p.m. and 3:50 p.m., “buy-none” (“sell-none”) to denote buy (sell) imbalances at 3:40 p.m. and a no imbalance dissemination at 3:50 p.m., “buy-sell” (“sell-buy”) to denote buy (sell) imbalances at 3:40 p.m. and a sell (buy) imbalance at 3:50 p.m. For the buy-buy (sell-sell) category, there is a cumulative return of about 16 (-19) basis points using quote midpoints. For the buy-none (sell-none) category, there is a cumulative return of about 7 (-11) basis points using

quote midpoints. For the buy-sell (sell-buy) category, there is a cumulative return of about 50 (-25) basis points during the first 10 minutes and -1 (20) basis points during the time from the last imbalance dissemination to close.

Tables 3 and 4 also show evidence that prices move in the direction of the imbalance prior to the imbalance dissemination. Returns are about 2 (-1) basis points prior to a 3:40 p.m. buy (sell) imbalance dissemination. To evaluate whether this increase is due to investor behavior or specialist pre-trading with the imbalance information, we examine specialist trading around imbalance disseminations.[9] Table 5 shows specialist aggregate purchases and sales before and after these imbalance disseminations. We find evidence that is consistent with specialist pre-positioning prior to imbalance disseminations.[10] During the five minutes prior to a 3:40 p.m. buy (sell) imbalance dissemination, the specialist is a net buyer (seller) of 2,642 (3,599) shares. In addition, the specialist participation rate is at its highest level during this time period which is suggestive of more aggressive specialist trading during this period.

For buy imbalances, there is some evidence that the specialist is a net seller with the largest net selling taking place at the closing auction. During the period from five minutes prior to the 3:40 p.m. imbalance dissemination to the close, the specialist sells 8,747 shares, on average, offsetting about 5.8% of the 3:40 p.m. order imbalance. For

[9] As noted in our introduction we do not attempt to evaluate whether or under what circumstances pre-positioning by the specialist in advance of the imbalance dissemination is permissible or legally barred.

[10] The evidence is also consistent with an alternative explanation. If investors notice that prices are moving against them, they may switch to orders that execute at the close rather than during the trading day. This would have the effect of reducing investor trading prior to imbalance disseminations and exacerbate the size of closing order imbalances.

sell imbalances, we find that the specialist only does significant net buying in the closing auction. During the period from five minutes prior to the 3:40 p.m. imbalance dissemination until just prior to the closing auction, the specialist sells 5,746 shares, on average, exacerbating the existing sell imbalance. However, in the closing auction, the specialist buys 9,699 shares, resulting in net buys from five minutes before the 3:40 p.m. imbalance dissemination through the closing auction of 3,953 shares and offsetting about 2.4% of the 3:40 p.m. order imbalance.

Table 6 shows the counterparties to the specialist's trades. During the period from about 3:35 p.m. to 3:50 p.m., the specialist trades more frequently with limit orders than market orders. However, as we move nearer to the close, the specialist trades more frequently with market orders than limit orders.

Table 7 shows the closing book at three points in the trading day: 3:40 p.m., 3:50 p.m., and at the close. The most striking finding is that market orders make up the vast majority of the executable on-close orders. For example, market on-close orders make up about 85.9% of the shares submitted for sell imbalances. Also, about 67.9% (59.5%) of the 3:40 p.m. buy (sell) imbalance gets resolved by the 3:50 p.m. dissemination. Assuming that the disseminated order imbalances are correct, non-system orders do not impact the 3:40 p.m. and 3:50 p.m. imbalances very much. However, at the closing auction, the non-system orders tend to offset a substantial portion of the remaining imbalance. For buy imbalances, non-system orders offset about 81.9% of the imbalance. For sell imbalances, non-system orders offset about 81.5% of the imbalance. The

remaining portion of the imbalance, 18.1% for buy imbalances and 18.5% for sell imbalances, is offset by the specialist. For the average buy (sell) imbalance, the specialist offsets 4,326 (9,699) shares at the close.

4. Empirical Results

4.1 Closing Imbalance Information Formation

While on-close orders can be submitted throughout the trading day until 3:40 p.m. each day, the specialist possesses an informational advantage on these orders because the imbalance is only revealed to the public after 3:40 p.m. and then only if the imbalance is at least 50,000 shares. While some investors may be able to mitigate this advantage by the ability to time their order submission near the 3:40 p.m. deadline, other investors may not have the ability to do so. Since many investors rely on brokers and other market intermediaries to submit their orders to the NYSE, the order submission times are largely at the discretion of the market intermediary.[11] In addition, market intermediaries typically set cut-offs for their customers to submit on-close orders that are much earlier than the 3:40 p.m. deadline, such as 3:38 p.m.[12] Since it is unclear how much information about the 3:40 p.m. closing imbalance is available to the specialist prior to 3:40 p.m. and since the information is not released until at least 3:40 p.m., we measure the dynamics of this informational advantage over the time leading up to 3:40 p.m.

[11] Similarly, in the pre-opening process in the Paris Bourse (see Biais, Hillion and Spatt [1999]) some of the virtual orders arrive substantially before the opening and indeed, about ten minutes prior to the opening the indicative price has information content about the opening price and fundamental value.
[12] The empirical submission times are consistent with this explanation.

We measure how the information content of these on-close orders builds prior to 3:40 p.m. applying a variation of a technique first used by Barclay and Warner (1993) to measure price discovery over time.[13] Specifically, we calculate the order imbalance for on-close orders at 10:00 a.m., 11:00 a.m., 12:00 p.m., 1:00 p.m., 2:00 p.m., 3:00 p.m., 3:30 p.m., 3:35 p.m., 3:38 p.m., and 3:39 p.m. and 3:40 p.m. for all 3,499 securities. We calculate each time period's contribution to imbalance discovery for each day, its weighted imbalance contribution (WIC), using the following equation:

$$WIC_t = \sum_{i=1}^{n} \frac{\left|imb_{s,i}\right|}{\sum_{i=1}^{n}\left|imb_{s,i}\right|} \times \frac{imb_{t,i}}{imb_{s,i}}$$

where $imb_{s,i}$ is the imbalance at 3:40 p.m. for stock i, $imb_{t,i}$ is the imbalance at an earlier time (say 3:00 p.m.) for stock i. Effectively, we measure the portion of the 3:40 p.m. imbalance that developed at an earlier time period and use the 3:40 p.m. imbalance as a weight across stocks. Then, we average the imbalance contribution across days for each time period to arrive at the WIC measure reported in the table.

Not surprisingly, we find that a substantial proportion of imbalance discovery occurs after 3:00 p.m. Table 8 and Figure 2 indicate that about 31% of the imbalance is discovered by 3:00 p.m. and 60% is discovered by 3:30 p.m. on an average day. Almost 88% of the imbalance information is revealed by 3:38 p.m. and nearly 98% of the imbalance is revealed by 3:39 p.m. Thus, it appears that the specialist has a few minutes

[13] Other academic papers that have used this measure include Cao, Ghysels, and Hatheway (2000), Huang (2002), and Barclay and Hendershott (2003).

prior to 3:40 p.m. when he is very well informed about on-close imbalance. The results are similar whether we include all stocks or only stocks with 3:40 p.m. imbalance disseminations.

4.2 Effect of Closing Imbalance Information on Price

There are potentially two ways in which prices can be influenced by closing imbalance information. Since only imbalances of at least 50,000 shares are required to be disseminated to the public, the first effect we study is whether the dissemination of order imbalances has a different impact on prices than order imbalances that are not disseminated. Table 9 indicates that there is significant movement of prices in the direction of the imbalance for both disseminated and non-disseminated order imbalances. Panel A shows that the magnitude of the price changes are about two to three times larger for disseminated imbalances than non-disseminated imbalances. However, this does not adjust for the disseminated imbalances being much larger than the non-disseminated imbalances and potential selection by the specialist about whether the closing imbalance is disseminated. We use a linear regression model to adjust for the size of the imbalance. Panel B shows that the non-disseminated imbalances actually have a larger per share association with price changes than disseminated imbalances. In the next section, we investigate potential causes for this price change (e.g., is the specialist using his information about these smaller imbalances to move prices?). Overall, it appears that closing imbalance information is getting impounded in stock prices regardless of whether the closing imbalance is disseminated or not.

The second effect we study is whether prices move in the direction of the closing order imbalance prior to the imbalance dissemination. This effect is consistent with the specialist using information about an impending large order imbalance to profitably trade or to "get out of the way" on one side of the market. Table 9, Panel A shows that there is a significant amount of price movement in the direction of the imbalance up to 10 minutes prior to the imbalance dissemination for both buy and sell imbalances. In contrast, the results are less significant for imbalances that are not disseminated as only 4 out of 8 time periods show significant movements. Panel B shows that larger imbalances lead to larger price moves in the direction of the imbalance prior to 3:40 p.m. The results are only significant for 2 out of 4 time periods for non-disseminated imbalances. These results are consistent with the specialist's informational advantage at that time.

The specialist's informational advantage about the closing order imbalance is largely dissipated at the 3:40 p.m. dissemination. Therefore, his informational advantage is highest just prior to 3:40 p.m. and any trading to take advantage of this information will drive prices in the direction of the imbalance. On the other hand, the specialist is able to maintain his informational advantage for stocks with no imbalance dissemination beyond 3:40 p.m. So, the specialist faces no pressure to react to these imbalances prior to 3:40 p.m. In addition, if the specialist was always able to predict at an earlier time, say 3:38 p.m., whether an imbalance will get disseminated or not, then it is optimal for the specialist to wait until his information set for on-close orders is complete at 3:40 p.m. before making any trades to exploit this information. However, if the specialist cannot fully predict the 3:40 p.m. imbalance earlier, then it may be optimal for him to trade prior

to 3:40 p.m. for some imbalances that never get disseminated. These results illustrate how information about the order imbalances gets impounded in prices, even prior to public disclosure of these imbalances.

4.3 Specialist Trading

In this section, we examine whether the specialist's trading behavior differs on days with large on-close imbalances compared to days with small on-close imbalances. We analyze both large on-close imbalances (50,000 shares or more) as well as medium-sized on-close imbalances (25,000 to 49,999 shares). We find that the specialist trading behavior changes significantly on days with large or medium-sized on-close imbalances.

Table 10, Panel A (E) shows the specialist's gross trading activity on large (medium) on-close imbalance days compared to other days. We find that the specialist's gross trading activity is significantly higher on large (medium) on-close imbalance days than on other days. This suggests that liquidity provision is more important on large (medium) on-close imbalance days or that there is more information available then.

Table 10, Panel B (F) shows the specialist's net trading activity on large (medium) on-close buy imbalance days compared to other days. We find that the specialist tends to be a net buyer on buy imbalance days, except in the closing auction where the specialist is a net seller, reflecting his market power in the closing auction (Stoll and Whaley [1990] have an analogous analysis for the opening). This suggests that the specialist is trading prior to the close to accumulate shares that he can use to accommodate the excess buying

demand in the closing auction and potentially trading before the closing demand for shares to purchase is fully reflected in the closing price.

Table 10, Panel C (G) shows the specialist's net trading activity on large (medium) on-close sell imbalance days compared to other days. We find that the specialist tends to be a net seller on sell imbalance days, except in the closing auction where the specialist is a net buyer. Again, this suggests that the specialist is pre-positioning his inventory to meet the excess selling in the closing auction and potentially trading before the closing demand for shares to sell is fully reflected in the closing price.

Table 10, Panel D shows the specialist's participation rate on large on-close imbalance days compared to other days. If the specialist's gross trading activity increases in proportion to any increase in overall trading activity, then we should see no change in the specialist participation rate. We find that the specialist is much more active, as measured by the specialist participation rate, on imbalance days during the periods from 3:35 p.m. to 3:40 p.m., during the period from 3:58 p.m. to 4:00 p.m., and during the closing auction. For medium-sized on-close imbalances in Panel H, the specialist is significantly more active from 3:35 p.m. through 4:00 p.m. and during the closing auction. These results are consistent with the specialist trading based on his informational advantage.

4.4 Specialist Inventory and Profits

We calculate the inventory positions of specialists and their profitability during the January to March 2005 time period. We assume that the specialist inventory is zero at the beginning of the period. We find that across 3,245 securities with at least one specialist trade, the average specialist trading profit per stock was $ 64,347. This includes average realized gains of $ 51,360 and average unrealized gains of $ 12,987 from an average absolute value of inventory at the end of March 2005 of 108,790 shares. The average realized gains amount to $ 212,176 per stock on an annualized basis. These results are consistent with the specialist being compensated, on average, for his provision of liquidity.

We are also interested in the distribution of specialist profits and inventory across securities. The specialist saw positive trading profits in about 69% of securities (2,249 out of 3,245 securities). The median specialist inventory was -500 shares at the end of March 2005 and the median specialist trading profit was $ 6,881. The median realized gain was $ 6,919. Thus, the specialist generates their entire profit for the median stock from realized trading gains rather than from inventory gains. These results are not surprising since the adverse selection costs for holding inventory in less active stocks are higher than more active stocks. Thus, it is more likely for specialist to be nearly flat for the median stock than the average stock.

Table 11 shows the mean and median specialist total profits and trading profit by time period. For imbalances of at least 50,000 shares, we find that the specialist generates more than $ 3,000 in total profits, on average, and over $ 400 in average trading profits

during the period from 3:30 p.m. to 3:50 p.m. However, the results suggest that the specialist acts on his informational advantage much earlier than we anticipated, before 3:39 p.m. For imbalances between 25,000 and 50,000 shares, we find that the specialist generates more than $ 500 in total profits, on average, but incurs an average of about $ 30 in trading losses during the period from 3:30 p.m. to 3:50 p.m. The lack of dissemination of these imbalances appears to work to the disadvantage of the specialist since he's the liquidity provider of last resort. For imbalances of less than 25,000, we find that the specialist generates more than $ 60 in total profits, on average, and about $ 10 in average trading profits during the period from 3:30 p.m. to 3:50 p.m. Thus, the univariate results suggest that larger imbalances lead to higher average profits.

We compare specialist profitability on days with imbalances of 50,000 shares or more to days with imbalances of less than 50,000 shares for each stock using a paired t-test. There is no significant difference in specialist profitability during any of the periods tested.

We measure the relationship between the size of the imbalance and specialist profitability before and after imbalance dissemination. Panel A of Table 12 shows the relationship between specialist total profits and the 3:40 p.m. imbalance using a fixed effects model. For imbalances of at least 50,000 shares, we find that the relationship between specialist total profits and the size of the imbalance is mixed depending on the time period. From 3:38 p.m. to 3:50 p.m., the regression coefficient is negative suggesting that larger imbalances lead to smaller specialist total profits. This result is consistent with the

specialist's obligation to be a liquidity provider of last resort leading to a reduction in specialist profits. The model suggests that an imbalance of 100,000 shares will lead to specialist total profits of about $ 146 from 3:39 p.m. to 3:40 p.m. and additional profits of about $ 2,161 from 3:40 p.m. to 3:50 p.m.

For imbalances between 25,000 and 50,000 shares, we find a negative relationship between specialist trading profits and the size of imbalance. This result is also consistent with the specialist's obligation to be a liquidity provider of last resort leading to a reduction in specialist profits. The model suggests that an imbalance of 49,000 shares will lead to specialist total profits of about $ 217 from 3:39 p.m. to 3:40 p.m. and additional profits of about $ 319 from 3:40 p.m. to 3:50 p.m.

For imbalances of less than 25,000 shares, we find a positive relationship between specialist total profits and the size of the imbalance. This is consistent with the explanation that small imbalances entail little risk for the specialist but generate positive profits for the specialist. The model suggests that an imbalance of 24,000 shares will lead to specialist total profits of about $ 693 from 3:40 p.m. to 3:50 p.m.

Panel B of Table 12 shows the relationship between specialist trading profits and the 3:40 p.m. imbalance using a fixed effects model. For imbalances of at least 50,000 shares, we find that the relationship between specialist trading profits and the size of the imbalance is generally positive. That is, the larger the imbalance, the more private information he can use to trade profitably prior to the dissemination. However, the results are only

significant for the five and ten minute periods surrounding 3:40 p.m. This suggests that the specialist acts on his informational advantage much earlier than we anticipated. The model suggests that an imbalance of 200,000 shares will lead to specialist trading profits of about $ 378 from 3:30 p.m. to 3:40 p.m. and additional profits of about $ 202 from 3:40 p.m. to 3:50 p.m.

For imbalances between 25,000 and 50,000 shares, we find a negative relationship between specialist trading profits and the size of imbalance. This result is also consistent with the specialist's obligation to be a liquidity provider of last resort leading to a reduction in specialist profits. The lack of dissemination of these imbalances appears to work to the disadvantage of the specialist since he's the liquidity provider of last resort. The model suggests that an imbalance of 49,000 shares will lead to specialist trading profits of about $ 13 from 3:30 p.m. to 3:40 p.m. and trading losses of about $ 82 from 3:40 p.m. to 3:50 p.m.

For imbalances of less than 25,000 shares, we find a no relationship between specialist trading profits and the size of the imbalance during the time periods from 3:30 p.m. to 3:50 p.m.

Table 1: Number of NYSE Imbalance Events

January 1 to March 31, 2005

Description	**Number**
Trading days	61
Delayed Opening	203
- Price indications related to a delayed opening	270
- No resume during day	5
- Resume during day	198
- Average resume time from 9:30:00 am	20:10
- Minimum resume time from 9:30:00 am	6:37
- Maximum resume time from 9:30:00 am	2:49:04
- Average first indicated spread ($)	2.39
- Average first indicated spread (%)	6.65
3:40 pm At Close Order Imbalance Dissemination	3,909
- Buy imbalance	2,194
- Sell imbalance	1,715
- No imbalance (imbalances that first appear at 3:50 pm)	16
- Latest time of dissemination	3:49:56 pm
3:50 pm At Close Order Imbalance Dissemination	3,925
- Buy imbalance	672
- Sell imbalance	568
- No imbalance	2,685
- Latest time of dissemination	3:56:29 pm
- Buy to sell imbalance	17
- Sell to buy imbalance	28

Table 2, Panel A
Average Market Quality and Price Change Before and After Imbalance Dissemination
3:40 p.m. Buy Imbalance

This table shows average market quality characteristic and the average difference for the 10 minutes before and 10 minutes after buy imbalance dissemination. The security must have a buy imbalance at 3:40 p.m. to be included. There were 2,127 events with valid data. A paired t-test is used to test the significance of the difference between the two time periods. A t-test is used to test the significance of the average return. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Variable	Ten Minutes Before	Ten Minutes After	Difference
Imbalance	0	148,984	+148,984**
Bid Price	35.0268	35.0581	+0.0313**
Offer Price	35.0433	35.0749	+0.0316**
Bid and Offer Midpoint	35.0351	35.0665	+0.0314**
Return (%)	0.0196**	0.0875**	
Quoted Spread (¢)	1.6546	1.6836	+0.0290
Percent Spread (%)	0.0692	0.0715	+0.0023**
Bid Depth	59,629	62,253	+2,624
Offer Depth	84,721	89,597	+4,876
Bid + Offer Depth	144,350	151,850	+7,500*

Table 2, Panel B
Average Market Quality and Price Change Before and After Imbalance Dissemination
3:40 p.m. Sell Imbalance

This table shows average market quality characteristic and the average difference for the 10 minutes before and 10 minutes after sell imbalance dissemination. The security must have a sell imbalance at 3:40 p.m. to be included. There were 1,676 events with valid data. A paired t-test is used to test the significance of the difference between the two time periods. A t-test is used to test the significance of the average return. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Variable	Ten Minutes Before	Ten Minutes After	Difference
Imbalance	0	160,542	+160,542**
Bid Price	36.6659	36.6454	-0.0205**
Offer Price	36.6816	36.6614	-0.0202**
Bid and Offer Midpoint	36.6738	36.6534	-0.0204**
Return (%)	-0.0075	-0.0690**	
Quoted Spread (¢)	1.5744	1.6018	+0.0274
Percent Spread (%)	0.0666	0.0683	+0.0017**
Bid Depth	90,948	96,808	+5,859
Offer Depth	96,965	104,445	+7,480
Bid + Offer Depth	187,914	201,253	+13,340

Table 2, Panel C
Average Market Quality and Price Change Before and After Imbalance Dissemination
3:50 p.m. Buy Imbalance

This table shows average market quality characteristic and the average difference for the 10 minutes before and 10 minutes after buy imbalance dissemination. The security must have a buy imbalance at 3:40 p.m. and 3:50 p.m. to be included. There were 632 events with valid data. A paired t-test is used to test the significance of the difference between the two time periods. A t-test is used to test the significance of the average return. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Variable	Ten Minutes Before	Ten Minutes After	Difference
Imbalance	293,700	155,843	-137,858**
Bid Price	35.3753	35.3913	+0.0160**
Offer Price	35.3939	35.4122	+0.0183**
Bid and Offer Midpoint	35.3846	35.4017	+0.0171**
Return (%)	0.0919**	0.0281*	
Quoted Spread (¢)	1.8608	2.0914	+0.2306**
Percent Spread (%)	0.0832	0.0909	+0.0077**
Bid Depth	10,127	12,778	+2,651**
Offer Depth	14,335	16,542	+2,207*
Bid + Offer Depth	24,462	29,320	+4,858**

Table 2, Panel D
Average Market Quality and Price Change Before and After Imbalance Dissemination
3:50 p.m. Sell Imbalance

This table shows average market quality characteristic and the average difference for the 10 minutes before and 10 minutes after sell imbalance dissemination. The security must have a sell imbalance at 3:40 p.m. and 3:50 p.m. to be included. There were 534 events with valid data. A paired t-test is used to test the significance of the difference between the two time periods. A t-test is used to test the significance of the average return. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Variable	Ten Minutes Before	Ten Minutes After	Difference
Imbalance	331,951	202,268	-129,683**
Bid Price	34.1535	34.1387	-0.0148**
Offer Price	34.1704	34.1555	-0.0149**
Bid and Offer Midpoint	34.1619	34.1471	-0.0148**
Return (%)	-0.0477**	-0.0678**	
Quoted Spread (¢)	1.6908	1.6880	-0.0028
Percent Spread (%)	0.0904	0.0896	-0.0008
Bid Depth	19,062	21,268	+2,205
Offer Depth	18,704	23,300	+4,596**
Bid + Offer Depth	37,766	44,568	+6,801*

Table 3
Average Returns Before and After Imbalance Dissemination
3:40 p.m. Buy Imbalance

This table shows the average returns (in percent) for different categories of 3:40 p.m. buy imbalance disseminations. For example, the Buy-None category denotes a buy imbalance at 3:40 p.m. followed by a "no imbalance" dissemination at 3:50 p.m. Note that a "no imbalance" dissemination implies an imbalance of less than 50,000 shares but does not necessarily imply an imbalance of 0. Panel A shows the trade price returns and panel B shows the quote midpoint returns. A t-test is used to test the significance of the average returns. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Panel A: Trade Price Returns

Variable	Buy - Buy	Buy - None	Buy - Sell	Buy - Any
Number	642	1,523	17	2,185
3:40 Imbalance	293,687**	87,125**	369,724**	149,990**
5 Minute Return Before	0.0270**	0.0209**	0.0522	0.0232**
2 Minute Return After	0.0837**	0.0660**	0.3913*	0.0737**
5 Minute Return After	0.1218**	0.0789**	0.5141*	0.0948**
10 Minute Return After	0.0949**	0.0743**	0.4785*	0.0834**
3:50 Imbalance	159,292**	0	169,571**	48,123**
5 Minute Return Before	-0.0256**	-0.0024	-0.0351	-0.0095*
2 Minute Return After	0.0321**	-0.0035	-0.3036*	0.0046
5 Minute Return After	0.0393**	-0.0177**	-0.2352*	-0.0026
10 Minute Return After	0.1072**	0.0256**	-0.0117	0.0493**

Panel B: Quote Midpoint Returns

Variable	Buy - Buy	Buy - None	Buy - Sell	Buy – Any
Number	642	1,523	17	2,185
3:40 Imbalance	293,687**	87,125**	369,724**	149,990**
5 Minute Return Before	0.0276**	0.0215**	0.0509	0.0238**
2 Minute Return After	0.0781**	0.0637**	0.4413*	0.0708**
5 Minute Return After	0.1228**	0.0769**	0.5040*	0.0938**
10 Minute Return After	0.1073**	0.0729**	0.5027*	0.0863**
3:50 Imbalance	159,292**	0	169,571**	48,123**
5 Minute Return Before	-0.0157	-0.0011	-0.0224	-0.0056
2 Minute Return After	0.0194**	-0.0076**	-0.3645*	-0.0025
5 Minute Return After	0.0277**	-0.0191**	-0.2466*	-0.0071
10 Minute Return After	0.0546**	-0.0036	-0.0144	0.0134*

Table 4
Average Returns Before and After Imbalance Dissemination
3:40 p.m. Sell Imbalance

This table shows the average returns (in percent) for different categories of 3:40 p.m. sell imbalance disseminations. For example, the Sell-None category denotes a sell imbalance at 3:40 p.m. followed by a "no imbalance" dissemination at 3:50 p.m. Note that a "no imbalance" dissemination implies an imbalance of less than 50,000 shares but does not necessarily imply an imbalance of 0. Panel A shows the trade price returns and panel B shows the quote midpoint returns. A t-test is used to test the significance of the average returns. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Panel A: Trade Price Returns

Variable	**Sell - Sell**	**Sell – None**	**Sell - Buy**	**Sell – Any**
Number	545	1,139	28	1,717
3:40 Imbalance	321,080**	81,110**	401,104*	162,489**
5 Minute Return Before	-0.0204	-0.0159**	0.0658	-0.0158**
2 Minute Return After	-0.0563**	-0.0439**	-0.1371**	-0.0492**
5 Minute Return After	-0.0559**	-0.0470**	-0.1723*	-0.0514**
10 Minute Return After	-0.0424*	-0.0694**	-0.2629**	-0.0633**
3:50 Imbalance	199,676**	0	153,839**	65,889**
5 Minute Return Before	0.0050	-0.0188**	-0.0830*	-0.0121**
2 Minute Return After	-0.0316**	0.0021	0.1058*	-0.0071*
5 Minute Return After	-0.0818**	-0.0112*	0.1586**	-0.0310**
10 Minute Return After	-0.1734**	-0.0581**	0.2362**	-0.0898**

Panel B: Quote Midpoint Returns

Variable	**Sell - Sell**	**Sell – None**	**Sell - Buy**	**Sell - Any**
Number	545	1,139	28	1,717
3:40 Imbalance	321,080**	81,110**	401,104*	162,489**
5 Minute Return Before	-0.0158	-0.0141**	0.0534	-0.0134**
2 Minute Return After	-0.0614**	-0.0463**	-0.1483**	-0.0526**
5 Minute Return After	-0.0652**	-0.0510**	-0.1697*	-0.0570**
10 Minute Return After	-0.0488**	-0.0716**	-0.2471**	-0.0667**
3:50 Imbalance	199,676**	0	153,839**	65,889**
5 Minute Return Before	0.0106	-0.0182**	-0.0612	-0.0096*
2 Minute Return After	-0.0289**	0.0049	0.0897*	-0.0047
5 Minute Return After	-0.0758**	-0.0110*	0.1445**	-0.0292**
10 Minute Return After	-0.1400**	-0.0392**	0.1950**	-0.0673**

Table 5
Specialist Purchases and Sales Around Imbalance Dissemination

This table shows the average specialist purchases and sales around imbalance disseminations. Panel A shows buy imbalances and panel B shows sell imbalances. The 5-10 minute period after includes trading until the next dissemination or prior to the close. The participation rate is calculated as the 100 times the sum of specialist purchases and sales divided by reported share volume. A paired t-test is used to test whether there is difference in specialist purchases and sales during each time period. * denotes significance at the 95% level. ** denotes significance at the 99% level.

Panel A: Buy Imbalances (3:40 p.m.)

Variable	Purchases	Sales	Difference	Participation Rate
Number	2,185			
3:40 Imbalance	149,990			
0-5 Minutes Before	8,795	6,153	2,642**	19.4
0-2 Minutes After	3,310	3,236	74	15.2
2-5 Minutes After	4,329	4,731	-402	16.1
5-10 Minutes After	7,259	8,192	-933*	16.1
3:50 Imbalance	48,123			
0-5 Minutes Before	7,335	8,264	-930*	15.9
0-2 Minutes After	3,227	3,613	-386	14.6
2-5 Minutes After	5,015	6,093	-1,078**	15.7
5-10 Minutes After	13,956	17,344	-3,388**	13.6
Closing Auction	964	5,310	-4,346**	2.5

Panel B: Sell Imbalances (3:40 p.m.)

Variable	Purchases	Sales	Difference	Participation Rate
Number	1,717			
3:40 Imbalance	162,489			
0-5 Minutes Before	7,116	10,715	-3,599**	19.7
0-2 Minutes After	3,272	3,278	-6	14.1
2-5 Minutes After	4,943	5,683	-741*	15.5
5-10 Minutes After	9,398	10,226	-827	17.5
3:50 Imbalance	65,889			
0-5 Minutes Before	9,536	10,473	-938	17.5
0-2 Minutes After	4,415	4,195	220	15.8
2-5 Minutes After	6,435	6,617	-181	15.7
5-10 Minutes After	19,599	19,273	326	13.8
Closing Auction	10,607	908	9,699**	3.7

Table 6
Counterparties to Specialist Trades Around Imbalance Dissemination

This table shows the percentage of specialist purchases and sales by counterparty around imbalance disseminations. Panel A shows results for specialist buys and Panel B shows results for specialist sells. The 5-10 minute period after includes trading until the next dissemination or prior to the close.

Panel A: Specialist Buys

Variable	SuperDOT Market Order	SuperDOT Limit Order	Other
3:40 Imbalance			
0-5 Minutes Before	44.83	49.26	5.90
0-2 Minutes After	43.00	51.14	5.87
2-5 Minutes After	44.60	50.91	4.50
5-10 Minutes After	44.74	47.29	7.97
3:50 Imbalance			
0-5 Minutes Before	44.47	47.67	7.86
0-2 Minutes After	44.19	47.37	8.44
2-5 Minutes After	47.85	44.97	7.19
5-10 Minutes After	51.00	35.00	14.00
Closing Auction	21.62	3.17	71.21

Panel B: Specialist Sells

Variable	SuperDOT Market Order	SuperDOT Limit Order	Other
3:40 Imbalance			
0-5 Minutes Before	47.45	46.20	6.35
0-2 Minutes After	45.40	50.78	3.82
2-5 Minutes After	44.68	49.66	5.67
5-10 Minutes After	47.87	46.06	6.07
3:50 Imbalance			
0-5 Minutes Before	47.92	46.20	5.88
0-2 Minutes After	50.61	44.66	4.73
2-5 Minutes After	52.08	43.37	4.55
5-10 Minutes After	53.06	34.73	12.21
Closing Auction	29.29	4.79	65.92

Table 7
Closing Book Around Imbalance Dissemination

This table shows the closing book at 3:40 p.m., 3:50 p.m., and the market close. The sum of the MOC buys and marketable LOC buys is represented by the buys row. The sum of the MOC sells and marketable LOC sells is represented by the sells row. The difference in the buys and sells denotes the closing order imbalance for system orders. The disseminated imbalance row denotes the imbalance reported by the specialist. The difference between the imbalance disseminated and the imbalance of system orders is the net non-system orders row. Panel A shows results for buy imbalances and Panel B shows results for sell imbalances.

Panel A: Buy Imbalance

Variable	**3:40 p.m.**	**3:50 p.m.**	**Close**
Buys	286,151	285,287	286,435
Sells	144,199	231,011	262,588
Difference	141,953	54,276	23,847
Disseminated Imbalance	149,990	48,123	
Net non-system orders	8,037 (Buy)	-6,153 (Sell)	-19,521 (Sell)
Market orders	408,931	482,460	485,857
Marketable limit orders	35,426	47,900	63,167

Panel B: Sell Imbalance

Variable	**3:40 p.m.**	**3:50 p.m.**	**Close**
Buys	194,407	267,302	303,774
Sells	357,952	354,588	356,244
Difference	-163,546	-87,286	-52,470
Disseminated Imbalance	-162,489	-65,889	
Net non-system orders	1,057 (Buy)	21,397 (Buy)	42,771 (Buy)
Market orders	509,220	572,801	561,929
Marketable limit orders	71,835	78,069	98,090

Table 8: Weighted Imbalance Contribution

This table summarizes the information discovery of the 3:40 p.m. on-close imbalance during the trading day. We measure how the information content of these on-close orders builds prior to 3:40 p.m. using a variation of a technique first used by Barclay and Warner (1993) to measure price discovery over time. We calculate each time period's contribution to imbalance discovery for each day, its weighted imbalance contribution (WIC), using the following equation where $imb_{s,i}$ is the imbalance at 3:40 p.m. for stock i and $imb_{t,i}$ is the imbalance at an earlier time (say 3:00 p.m.) for stock i:

$$WIC_t = \sum_{i=1}^{n} \frac{\left|imb_{s,i}\right|}{\sum_{i=1}^{n}\left|imb_{s,i}\right|} \times \frac{imb_{t,i}}{imb_{s,i}}$$

Then, we average the imbalance contribution across days for each time period to arrive at the WIC measure reported in the table. We calculate this measure separately for all securities and for only securities with a disseminated imbalance at 3:40 p.m. The analysis includes three months of data from January to March 2005. We calculate the on-close imbalance at a given point in time using NYSE SOD data. We identify the securities with a disseminated imbalance at 3:40 p.m. using NYSE Alerts data. The **, * indicates statistical significance at the 1 and 5% level in a two-tailed t test.

Weighted Imbalance Contribution

Time	All Stocks	Stocks with imbalance disseminations
10:00 AM	0.0136*	0.0065
11:00 AM	0.0447**	0.0339*
12:00 PM	0.0366**	0.0554**
1:00 PM	0.1088**	0.1235**
2:00 PM	0.1799**	0.1952**
3:00 PM	0.3103**	0.3175**
3:30 PM	0.5977**	0.6037**
3:35 PM	0.7325**	0.7431**
3:38 PM	0.8763**	0.8913**
3:39 PM	0.9755**	0.9844**
3:40 PM	1.0000**	1.0000**

Table 9: Price Changes and 3:40 p.m. On-close Imbalance

This table summarizes the relationship between price changes and the 3:40 p.m. on-close imbalance. The analysis includes three months of data from January to March 2005. Panel A shows the average percent change in price for stocks with disseminated imbalances (imbalances greater than or equal to 50,000 shares) and stocks with non-disseminated imbalances between 25,000 and 50,000 shares. A negative imbalance denotes a sell imbalance while a positive imbalance denotes a buy imbalance. Panel B shows the ordinary least squares regression coefficients for stocks with disseminated imbalances (imbalances greater than or equal to 50,000 shares) and stocks with non-disseminated imbalances between 25,000 and 50,000 shares. We calculate the non-disseminated imbalance using NYSE SOD data and obtain the disseminated imbalance from NYSE Alerts data. Regression coefficients are multiplied by 10,000. The **, * indicates statistical significance at the 1 and 5% level in a two-tailed test.

Panel A: Univariate Results

Price Change Period	Imb ≥ 50K	Imb ≤ -50K	50K > Imb ≥ 25K	-50K < Imb ≤ -25K
3:30 to 3:40 p.m.	0.0209**	-0.0085	0.0140**	-0.0021
3:35 to 3:40 p.m.	0.0185**	-0.0094*	0.0140**	0.0013
3:38 to 3:40 p.m.	0.0079**	-0.0088**	0.0059**	-0.0012
3:39 to 3:40 p.m.	0.0046**	-0.0065**	0.0018	-0.0038*
3:40 to 3:42 p.m.	0.0620**	-0.0424**	0.0178**	-0.0141**
3:40 to 3:45 p.m.	0.0925**	-0.0568**	0.0282**	-0.0247**
3:40 to 3:50 p.m.	0.0889**	-0.0661**	0.0395**	-0.0422**

Panel B: Regression Coefficients

$$\text{Price Change} = \alpha + \beta \, \text{Imbalance}$$

Price Change Period	Imb ≥ 50K	R-squared	50K > Imb ≥ 25K	R-squared
3:30 to 3:40 p.m.	0.00031**	0.004	0.00057	0.001
3:35 to 3:40 p.m.	0.00015**	0.002	0.00059*	0.001
3:38 to 3:40 p.m.	0.00008*	0.002	0.00003	0.001
3:39 to 3:40 p.m.	0.00003	0.001	0.00003*	0.001
3:40 to 3:42 p.m.	0.00045**	0.002	0.00077**	0.003
3:40 to 3:45 p.m.	0.00079**	0.026	0.00116**	0.004
3:40 to 3:50 p.m.	0.00065**	0.011	0.00178**	0.004

Table 10: Specialist Trading

This table summarizes descriptive statistics for specialist trading. Specialist gross volume is measured as the sum of shares bought and sold by the specialist. Specialist net volume is measured as shares bought by the specialist minus shares sold by the specialist. Specialist participation rate is measured as specialist gross volume divided by total trading volume. We use NYSE CAUD data to calculate the specialist's trading activity and total trading volume. We use NYSE Alerts data to identify securities with a disseminated imbalance at 3:40 p.m. and the reported size of the imbalance. For securities with no disseminated imbalance at 3:40 p.m. we use NYSE SOD data to calculate the on-close imbalance at 3:40 p.m. The analysis includes three months of data from January to March 2005. The 3:58 p.m. to 4:00 p.m. period excludes the closing auction. We compare the average value on trading days with 3:40 p.m. on-close imbalance of 50,000 shares or more to the average value on trading days with 3:40 p.m. on-close imbalance less than 50,000 shares for each stock in Panels A to D. We compare the average value on trading days with 3:40 p.m. on-close imbalance of 25,000 to 49,999 shares to the average value on trading days with 3:40 p.m. on-close imbalance less than 25,000 shares for each stock in Panels E to H. The **, * indicates statistical significance at the 1 and 5% level using a paired t-test.

Panel A: Specialist Gross Volume

Price Change Period	| Imb | ≥ 50K	| Imb | ≤ 50K	Difference
9:30 to 3:35 p.m.	360,971.75	307,557.89	53,413.86**
3:35 to 3:40 p.m.	7,217.89	5,315.05	1,902.80**
3:38 to 3:40 p.m.	3,068.21	2,206.39	861.82**
3:40 to 3:42 p.m.	2,850.50	2,023.08	827.41**
3:40 to 3:45 p.m.	7,599.15	5,452.87	2,146.28**
3:40 to 3:50 p.m.	15,995.64	11,665.89	4,329.75**
3:58 to 4:00 p.m.	15,463.65	5,357.49	10,106.16**
Closing Auction	12,486.71	5,499.86	6,986.85**

Panel B: Specialist Net Trading – Buy Imbalances (n=528)

Price Change Period	Imb ≥ 50K	| Imb | ≤ 50K	Difference
9:30 to 3:35 p.m.	2,309.23	-1,420.44	3,729.67**
3:35 to 3:40 p.m.	1,850.45	-287.85	2,138.30**
3:38 to 3:40 p.m.	712.65	-120.85	833.50**
3:40 to 3:42 p.m.	221.12	-81.81	302.93
3:40 to 3:45 p.m.	523.36	-220.20	743.56*
3:40 to 3:50 p.m.	-8.15	-689.56	681.41
3:58 to 4:00 p.m.	-5,063.64	-227.37	-4,836.27
Closing Auction	-4,510.49	270.92	-4,781.41**

Panel C: Specialist Net Trading – Sell Imbalances (n=404)

Price Change Period	Imb ≤ -50K	| Imb | ≤ 50K	Difference
9:30 to 3:35 p.m.	-10,327.50	-1,777.67	-8,549.83**
3:35 to 3:40 p.m.	-1,954.66	-361.50	-1,593.16**
3:38 to 3:40 p.m.	-1,349.73	-162.61	-1,187.12**
3:40 to 3:42 p.m.	-1,041.83	-132.74	-909.09**
3:40 to 3:45 p.m.	-1,936.01	-333.77	-1,602.24**
3:40 to 3:50 p.m.	-3,281.48	-988.47	-2,293.01**
3:58 to 4:00 p.m.	1,400.75	-282.71	1683.46
Closing Auction	12,355.80	628.38	11,727.42**

Panel D: Specialist Participation Rate

Price Change Period	| Imb | ≥ 50K	| Imb | ≤ 50K	Difference
9:30 to 3:35 p.m.	0.1832	0.1983	-0.015**
3:35 to 3:40 p.m.	0.1730	0.1509	0.0221**
3:38 to 3:40 p.m.	0.1637	0.1367	0.0269**
3:40 to 3:42 p.m.	0.1242	0.1234	0.0009
3:40 to 3:45 p.m.	0.1506	0.1477	0.0029
3:40 to 3:50 p.m.	0.1549	0.1588	-0.0040
3:58 to 4:00 p.m.	0.4383	0.1688	0.2695**
Closing Auction	0.3190	0.1676	0.1514**

Panel E: Specialist Gross Volume

Price Change Period	50K > | Imb | ≥ 25K	| Imb | ≤ 25K	Difference
9:30 to 3:35 p.m.	279,335.63	240,210.99	39,124.64**
3:35 to 3:40 p.m.	4,953.40	4,109.10	844.30**
3:38 to 3:40 p.m.	2,181.17	1,649.35	531.82**
3:40 to 3:42 p.m.	1,776.38	1,597.34	179.03*
3:40 to 3:45 p.m.	5,001.70	4,254.49	747.31**
3:40 to 3:50 p.m.	10,691.64	9,166.77	1,524.87**
3:58 to 4:00 p.m.	5,358.67	4,196.52	1,162.15**
Closing Auction	12,049.57	3,639.23	8,410.34**

Panel F: Specialist Net Trading – Buy Imbalances (n=745)

Price Change Period	50K > Imb ≥ 25K	| Imb | ≤ 25K	Difference
9:30 to 3:35 p.m.	-1,318.35	-472.66	-845.71
3:35 to 3:40 p.m.	578.78	-196.93	775.71**
3:38 to 3:40 p.m.	458.08	-92.61	550.69**
3:40 to 3:42 p.m.	293.89	-55.51	349.38**
3:40 to 3:45 p.m.	867.43	-175.55	1,042.98**
3:40 to 3:50 p.m.	1,385.69	-430.31	1,816.00**
3:58 to 4:00 p.m.	1,007.79	-396.10	1,403.89**
Closing Auction	-10,229.02	-77.98	-10,151.00**

Panel G: Specialist Net Trading – Sell Imbalances (n=641)

Price Change Period	-50K< Imb ≤ -25K	| Imb | ≤ 25K	Difference
9:30 to 3:35 p.m.	-4,777.35	-799.42	-3,977.93**
3:35 to 3:40 p.m.	-1,133.80	-237.31	-896.49**
3:38 to 3:40 p.m.	-632.70	-102.04	-530.66**
3:40 to 3:42 p.m.	-492.85	-89.13	-403.72**
3:40 to 3:45 p.m.	-1,098.48	-234.99	-863.49**
3:40 to 3:50 p.m.	-2,591.40	-611.49	-1,979.91**
3:58 to 4:00 p.m.	-1,249.79	-447.48	-802.31*
Closing Auction	11,946.11	29.93	11,916.18**

Panel H: Specialist Participation Rate

Price Change Period	50K > | Imb | ≥ 25K	| Imb | ≤ 25K	Difference
9:30 to 3:35 p.m.	0.1835	0.1919	-0.0084**
3:35 to 3:40 p.m.	0.1669	0.1465	0.0204*
3:38 to 3:40 p.m.	0.1602	0.1317	0.0285**
3:40 to 3:42 p.m.	0.1232	0.1175	0.0057
3:40 to 3:45 p.m.	0.1658	0.1405	0.0252**
3:40 to 3:50 p.m.	0.1765	0.1518	0.0247**
3:58 to 4:00 p.m.	0.2768	0.1637	0.1131**
Closing Auction	0.6923	0.1481	0.5443**

Table 11: Specialist Profitability

This table summarizes descriptive statistics for specialist profits. Total profit is measured as the gross trading profits plus unrealized profit or loss from an inventory position over a given period. We use NYSE CAUD data to calculate the specialist's inventory position and trading profits. We use NYSE Alerts data to identify securities with a disseminated imbalance at 3:40 p.m. and the reported size of the imbalance. For securities with no disseminated imbalance at 3:40 p.m., we use NYSE SOD data to calculate the on-close imbalance at 3:40 p.m. The analysis includes three months of data from January to March 2005. The **, * indicates statistical significance at the 1 and 5% level in a two-tailed test. [a, b] indicates statistical significance at the 1 and 5% level in a paired t-test with a scaled 10 a.m. to 3:30 p.m. period.

Panel A: Total Profit

Price Change Period	Imb ≥ 50K		50K > Imb ≥ 25K		25K > Imb	
	Mean	Median	Mean	Median	Mean	Median
9:30 a.m. to 3:30 p.m.	1,585.61	3,619.50	5.97	2,070.00	779.90**	103.00
10 a.m. to 3:30 p.m.	6,587.90	3,030.50	-247.48	1,427.00	946.73**	206.00
3:30 to 3:40 p.m.	1,551.24	0	123.92	0	31.61	0
3:35 to 3:40 p.m.	506.30	0	-126.25	0	40.64	0
3:38 to 3:40 p.m.	755.98	0	144.52	0	27.29	0
3:39 to 3:40 p.m.	-10.77	0	244.65	0	25.08*	0
3:40 to 3:50 p.m.	1,490.04	0	409.63	0	33.04	0

Panel B: Trading Profit

Price Change Period	Imb ≥ 50K		50K > Imb ≥ 25K		25K > Imb	
	Mean	Median	Mean	Median	Mean	Median
9:30 a.m. to 3:30 p.m.	4,449.39	3,325.13	5,465.01**	1,704.70	661.14**	53.00
10 a.m. to 3:30 p.m.	3,333.82	2,441.39	3,538,40*	1,068.28	421.92**	61.77
3:30 to 3:40 p.m.	138.66	0	29.06	0	7.80*	0
3:35 to 3:40 p.m.	82.00	0	-1.31	0	0.55	0
3:38 to 3:40 p.m.	-3.07	0	-28.99	0	0.32	0
3:39 to 3:40 p.m.	-11.86	0	-7.92	0	0.31	0
3:40 to 3:50 p.m.	272.56*	2.83	-62.54[a]	0	1.80[b]	0

Table 12: Specialist Profitability

This table summarizes the relationship between specialist profits and the 3:40 p.m. imbalance. Total profit is measured as the gross trading profits plus unrealized profit or loss from an inventory position over a given period. We use NYSE CAUD data to calculate the specialist's inventory position and trading profits. We use NYSE Alerts data to identify securities with a disseminated imbalance at 3:40 p.m. and the reported size of the imbalance. For securities with no disseminated imbalance at 3:40 p.m., we use NYSE SOD data to calculate the on-close imbalance at 3:40 p.m. The analysis includes three months of data from January to March 2005. We use a fixed effects regression to control for stock specific effects. Regression coefficients (β) are reported below (multiplied by 1,000). The **, * indicates statistical significance at the 1 and 5% level in a two-tailed test.

Panel A: Total Profit Regression Coefficients

$$\text{Total Profit}_{i,j} = \alpha + \beta \left| \text{Imbalance}_{i,j} \right| + \theta_i$$

Price Change Period	|Imb| ≥ 50K		50K > |Imb| ≥ 25K		25K > |Imb|	
	α	β	α	β	α	β
9:30 a.m. to 3:30 p.m.	-4,111.55	36.60*	4,706.85	-54.25	505.94	114.30
10 a.m. to 3:30 p.m.	3,319.19	21.02	3,638.21	-13.90	867.61**	4.15
3:30 to 3:40 p.m.	-255.94	11.62**	843.47	-16.45*	-2.11	17.24*
3:35 to 3:40 p.m.	247.29	1.67	458.94	-13.38**	39.28	0.69
3:38 to 3:40 p.m.	1,210.32	-2.92*	451.18	-7.01*	13.25	7.18
3:39 to 3:40 p.m.	426.76	-2.81**	480.19**	-5.38**	22.28	1.43
3:40 to 3:50 p.m.	3,369.65**	-12.09**	1,167.36*	-17.32**	-23.44	28.88**

Panel B: Trading Profit Regression Coefficients

$$\text{Trading Profit}_{i,j} = \alpha + \beta \left| \text{Imbalance}_{i,j} \right| + \theta_i$$

Price Change Period	|Imb| ≥ 50K		50K > |Imb| ≥ 25K		25K > |Imb|	
	α	β	α	β	α	β
9:30 a.m. to 3:30 p.m.	5,945.88	-9.61	8,708.00**	-67.35**	326.20**	137.70**
10 a.m. to 3:30 p.m.	4,121.47	-5.06	6,221.00**	-55.55**	191.26*	76.59**
3:30 to 3:40 p.m.	-695.72**	5.37**	159.91*	-2.99**	7.87	-0.04
3:35 to 3:40 p.m.	-473.54**	3.57**	94.32*	-2.19**	1.78	-0.62
3:38 to 3:40 p.m.	-8.45	0.04	33.95	-1.44**	1.06	-0.38
3:39 to 3:40 p.m.	-13.04	0.01	26.60	-0.79**	0.26	0.02
3:40 to 3:50 p.m.	115.03	1.01**	96.54	-3.64**	3.83	-1.03

The Slope of the On-Close Order Book

The slope of the closing book tends to be small, giving the specialist considerable discretion in setting a closing price. For in the illustrative example below from our sample, dropping the price by ten cents only results in an additional 17,000 shares to purchase and removes 47,200 shares to sell. Increasing the price by ten cents only results in an additional 5,400 sell shares and removes 400 buy shares. These numbers are small compared to the 590,800 shares in the closing trade. The specialist ended up executing the closing trade for $47.50, up $0.10 from the 3:50 p.m. price. The next morning, the opening trade was at $47.49 so the $47.50 closing price was relatively favorable in this case.

FIGURE 1

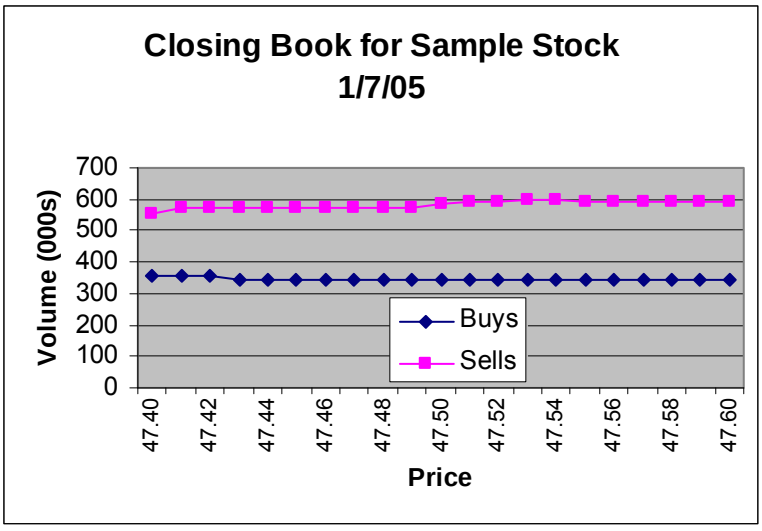
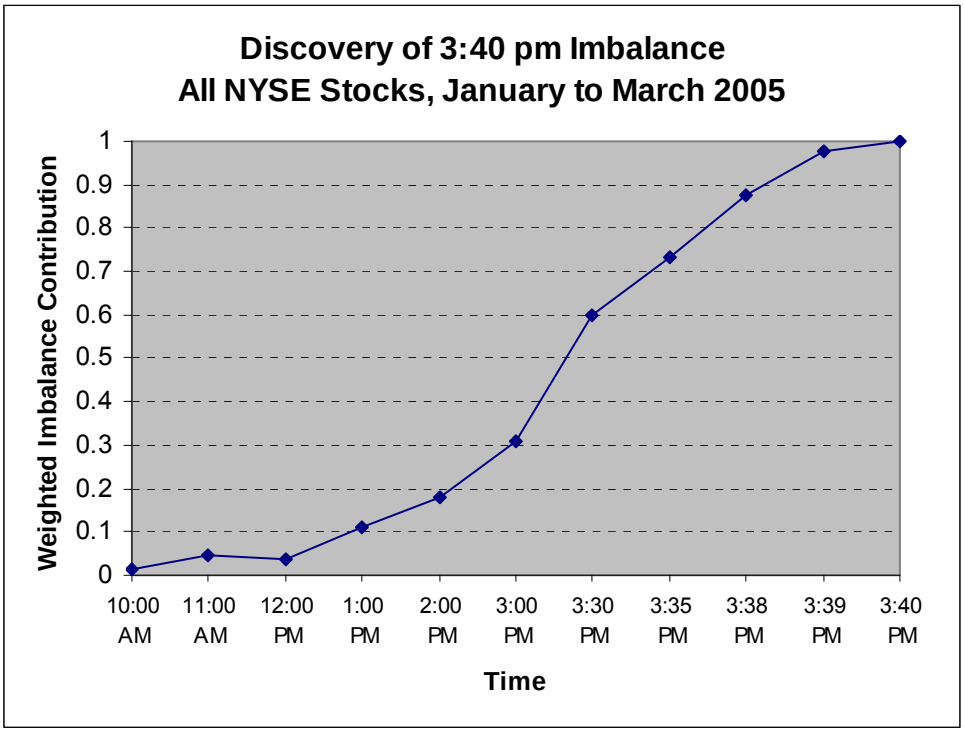


FIGURE 2


Discovery of 3:40 pm Imbalance
All NYSE Stocks, January to March 2005
Weighted Imbalance Contribution
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
3:30 PM
3:35 PM
3:38 PM
3:39 PM
3:40 PM
Time

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