The Effects of Opening and Closing Procedures on the NYSE and Nasdaq

Jeff Bacidore
New York Stock Exchange
11 Wall Street
New York, New York

and

Marc L. Lipson
Terry College of Business
University of Georgia
Athens, GA

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ABSTRACT

We study the effects of opening and closing procedures on the NYSE and Nasdaq by examining firms that moved from the Nasdaq to the NYSE and a sample of size-matched firms. We find that opening trades on the NYSE are about 20 percent less costly to execute than later comparable trades, while closing trades are slightly more costly. On the Nasdaq, both opening and closing trades are slightly more costly. The savings on the NYSE open are increasing with the size of firms. While the consolidation of orders at the NYSE opening auction appears to reduce costs, we also find that opening quotes are subject to temporary price pressures though transaction prices appear to be unaffected. At the close, NYSE trades obtain comparable executions and quotes do not appear to be distorted. However, closing trades appear to be affected by temporary liquidity pressures, particularly market-on-close orders. We find that price discovery overnight and through the first half hour of trading is comparable across both market systems. However, price discovery is more pronounced in the earlier part of the rest of the day on the NYSE. Also, opening quotes are delayed as NYSE specialists complete opening auctions, thus delaying price discovery during the first half hour of trading. Finally, we find that the official closing quote on the NYSE reflects more information than quotes prevailing at end of the day, the last third market quote, either of the last two transactions of the day, or the very last quote provided for a given stock.

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1. Introduction

The price uncertainty surrounding initial public offerings, the liquidity effects of institutional traders as they flock to buy firms on the day they are added to a major index, and the price impact of very small orders executed after regular trading hours, have drawn attention the impact of opening and closing mechanisms on price formation and price quality. Furthermore, these mechanisms differ between the Nasdaq multiple-dealer market and the New York Stock Exchange (NYSE) specialist market. We examine the effects of differing procedures on price discovery, price quality, and volatility using a sample of firms that moved from the Nasdaq to the NYSE and a larger sample of size-matched firms.

Trading commences on the NYSE with an auction. The specialist observes electronically submitted trading interests and interests represented on the floor of the exchange, and sets a single opening price that clears the market. Of course, the specialist may take part in this auction and may therefore influence the opening price. On the Nasdaq market, on the other hand, the various dealers who trade a security will post non-binding quotes before the market opens, at which time trading begins and is conducted as at any other time, with dealers executing the orders which they receive.[1] Thus, we have essentially two mechanisms for price discovery – the specialist-managed opening call auction where all orders are executed at a single price, and the

[1] Madhavan and Panchapagesan (1999) have shown that the specialist's chosen opening price is a more accurate estimate of later prices than the price that clears the electronic orders. On the other hand, Cao, Ghysels, and Hathaway (1999) have demonstrated that quotes posted during the pre-opening period on the Nasdaq influence the prices at which trading eventually begins.

multiple-dealer pre-opening where dealers can reveal information on their trading interest through non-binding quotes.

Closing procedures also differ across these markets. The NYSE specialist collects all the orders by traders who wish to execute at the closing trade price (market-on-close orders). The market essentially closes as it opens, with a single price auction - the closing price is set to clear market-on-close orders against any floor interest and the specialist's inventory. On the Nasdaq, there is no analogous mechanism, though dealers may take orders from their customers that specify execution at the closing price.

As with regular trading procedures, opening and closing procedures fulfill a dual role - they facilitate the incorporation of information into prices (price discovery) while allowing traders to establish desired positions (liquidity). The central argument in favor of using auctions is that a larger pool of trading interests is gathered together in the auction and this leads to better pricing (more information is available) and improved liquidity (more chances for liquidity motivated trading interests to cross).[2] On the other hand, temporary demand imbalances may be accentuated. This may cause unnecessary price movement and increased trading costs as traders/market makers take positions only after prices have been temporarily distorted.[3] Interestingly, despite the attention now focused on opening and closing procedures, there has been no systematic comparison of price discovery and liquidity across market systems at these times.

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[2] Admati and Pfleiderer (1988) provides a model of these effects. The suggest that these effects explain the "U" shaped pattern commonly observed in volatility throughout the day.

[3] A number of authors have focused on the effects of temporary liquidity demands on the day stocks are added or deleted from major stock indexes. Beneish and Whaley (1996) provide a recent examination of the effects associated with S & P additions and how these have changed in light of new rules.

We examine the impact of opening and closing procedures using a sample of firms that changes listings from Nasdaq to the NYSE as well as a sample of size-matched firms. The switching sample is particularly appropriate for contrasting the impact of exchange mechanisms since most of the underlying firm characteristics are held constant. However, this sample is relatively small and, without a detailed model of the choice of listing venue, there may be effects that we do not control for. For this reason we also include a large size-matched sample. The matched sample also allows cross-sectional analysis within market structures. Interestingly, almost all our results differ little across these samples.

To ensure that our changes are unrelated to changes brought about by new order handling rules phased in on the Nasdaq during 1996 and 1997 or the changes by both the NYSE and Nasdaq to a $1/16 tick size, we restrict our analysis to time periods after all these changes have been implemented.

We find that a larger fraction of volume at the beginning of trading is executed in the first transaction on the NYSE than in the first transaction on the Nasdaq. For example, for the firms that change listings, the opening trade accounts for about 30% of the first fifteen minutes of volume on the Nasdaq, and this rises to about 64% on the NYSE. Similarly, a large fraction of daily volume is executed in the last trade of the day, though the degree of the clustering is much smaller. These results are consistent with the clustering or trading volume at the opening and closing auctions of the NYSE. We also find a slight reduced level of trading volume in the late afternoon on the NYSE, excluding the last trade.

We examine adjacent trades to evaluate the impact of opening procedures on trading costs. We find that the effective spread is substantially lower on the NYSE for the first trade relative to the second. In fact, the cost of the first trade is about 75% to 80% of the next trade,

depending on the sample. On the Nasdaq first trades are actually slightly *more* expensive than second trades. It is possible that these trading costs reflect changes in quoted spreads rather than the effects of crossing orders. However, we find that the changes in trading costs are mirrored in the proportion of price improvement. Specifically, first trades are more likely to be price improved on the NYSE whereas that are less likely to be price improved on the Nasdaq. Looking at the last two adjacent trades, we find that the effective spread for last trades are statistically larger than the second-to-last trades on both exchanges. There is weak evidence, and only in the match sample, that the difference in costs are lower on the NYSE.[4]

We examined effective spreads for the cross-section of firms sizes and find that the savings for the opening auction are more pronounced for larger firms. Taken together, our results suggest there are substantial savings associated with opening auctions, particularly for large firms, while there seems to be little benefit for closing auctions.

The same clustering of volume at the opening and closing auctions that helps lower trading costs might, however, also lead to liquidity induced temporary price pressures. Specifically, the large volumes that trade at the open and closing auction may also lead to large imbalances that might strain the stabilizing capabilities of the specialist. This is particularly true since the NYSE accepts "market on close" orders, which are orders that receive the closing price.

We look for possible price pressures by examining the autocorrelation in returns around opening and closing prices. Negative correlations would indicate temporary price pressures in quotes. We find that opening quotes on the NYSE are distorted compared to the subsequent quote, while there is weak evidence that the Nasdaq opening quotes are more accurate than the subsequent quote. However, we find no significant effects for transaction prices. As for closing

[4] In this analysis we are comparing the difference between adjacent trades – effective spreads are substantially

prices, we find little evidence of distortions in closing quotes associated with the closing auctions, though we do find evidence that closing transactions on the NYSE are affected by temporary price pressures.[5] We also look at those days on which the specialist executed market-on-close orders. The distortion in closing transactions is more pronounced on those days. These results suggest that the clustering of trading during auctions can temporarily distort prices.

Given the improved liquidity and clustering or trades at the auctions on the NYSE, we examine whether these auctions alter the timing of price discovery. Specifically, if the auction periods attract substantial informed trading that would otherwise occurred in other parts of the day, then price discovery will be larger around the auctions. We use the weighted price contribution (WPC) in order to assess whether there are changes in the timing of price discovery. The WPC measures the proportion of total price changes that occurs during specific time intervals. This measure reflects permanent changes in prices rather than temporary changes.

The analysis of price discovery is complicated on the NYSE since the specialist must take the time to execute the opening auction before trading begins. Clearly, the more complicated openings (those with more information to be included and a larger trading interest) will take longer. If we look at price discovery per unit of time and assume that no discovery occurs before an NYSE stock is opened, then there is less price discovery at the open and more in the first half hour of the trading day. If we consider the overnight period and the first half hour together (over 99% of stocks are opened within a half hour on the NYSE), there is no difference across exchanges. Interestingly, we find that price discovery during the remained of the day is higher

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smaller on the NYSE than the Nasdaq for all the trades we examine.

[5] Of course, there are price pressures associated with the opening and closing periods generally, though not the prices that are associated with opening and closing *procedures*. For example, during the regular trading day on the NYSE, correlations in half-hour returns are often positive as a result of smoothing by the specialist, while the specialist is under less obligation to smooth prices across market closures.

on the NYSE in the earlier part of the day than on the Nasdaq. This effect also appears to be slightly more pronounced for smaller firms.

Finally, we use the WPC and the absolute closing period return to examine issues related to closing prices on the NYSE. There are a large number of potential closing price benchmarks and the choice of these can dramatically affect traders and the pricing of mutual funds.[6] At this point, there are no clear standards for closing prices supplied by data vendors. We examine the pricing information reflected in a number of alternative benchmarks.

We find evidence that the last official NYSE closing quote is substantially more informative than the quote prevailing at 4:00 and generally more informative than third market quotes after 4:00 or the last quote in a given security. We also find that closing quotes are more informative that closing transaction prices. These results suggest that closing quotes are the best closing benchmark unless there is evidence of market-on-close activity, in which case the closing transaction is the best reflection of the information on a security.

The remainder of the paper is organized as follows. Section 2 discusses some of the details of opening and closing procedures and the dissemination of closing prices and quotes. Section 3 discusses our samples. Section 4 presents our analysis of liquidity at the open and close, while section 5 presents our analysis of price discovery and our tests of closing price alternatives. Section 6 concludes.

2. Closing Procedures

Trading at the NYSE begins and ends with a call auction. Prior to the 9:30 opening of the NYSE exchange, orders routed to the specialist post via floor brokers or the NYSE's SuperDot electronic order routing system are aggregated by the using the NYSE Opening Automated

Report Service (OARS). OARS stores pre-opening orders and provides the specialist with information regarding the order imbalance at every possible price level. The specialist is given some flexibility with respect to setting opening prices (first trade and first quotes).[7] If the chosen price results in an imbalance, the specialist must fill the imbalance out the specialist's own inventory. By consolidating all the order flow prior to the official opening, the specialist may be better able to determine the market's assessment of value (see Madhavan and Panchapagesan (1999) for a more thorough discussion of the role of the specialist at the open).

The close of the NYSE is also done via a call auction. Traders are able to enter market-on-close (MOC) orders and limit-on-close orders (LOC) either electronically or via floor brokers which, by definition, allow the trader to execute at the closing price. Floor brokers and specialists may also participate in the close, possibly by supplying the additional liquidity needed to execute these MOC/LOC orders. At 4:00 P.M., the NYSE stops accepting orders. However, the specialists may still be managing orders entered just prior to the close (e.g., those entered at 3:59:59), including assessing which closing price best clears the market. As a result, the NYSE closing trade may come several seconds after the ringing of the closing bell.[8] Following the closing trade, specialist is required to post a closing quote. This quote, however, is essentially non-binding since no orders may be executed until the open of trading the next day, at which point this quote would be updated. Nevertheless, this quote must be set so that the final transaction executes at or inside the closing quote.

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[6] Mention the WSJ article here where they talk about bad prices.

[7] The specialist must obtain approval from floor officials if the price the specialist wishes to establish at the open is sufficiently far away from the previous day's close.

[8] In those cases where an MOC imbalance exists, the specialist executes the imbalance against the bid (for sell imbalances) or offer (for buy imbalances), reporting this as one print. The matched orders are then paired off and printed at the price of the previous print. See Hasbrouck, Sofianos, and Sosebee (1993) for details.

For both the open and the close, the specialist may attempt to attract orders to offset any imbalance. For example, prior to the open, the specialist interacts with the crowd, giving floor brokers information regarding the current state of the imbalance as a means to attract additional liquidity if necessary. Also, the specialist notifies off-floor participants of the possible range of opening prices if the opening price will be sufficiently far from the previous day's closing price. For example, for stocks between $10 and $100, if the opening price is more than 10% or $3 (whichever is lower) away from the previous day's closing price, an indication must be disseminated before the stock can be opened. If the imbalance is sufficiently large, the specialist may delay the opening in order to collect more orders.[9]

At the close, the specialist is free to accept MOC orders of any kind until 3:40 P.M.[10] Furthermore, traders may not cancel these orders after 3:40 P.M. If there is a large imbalance, the specialist may publish an imbalance announcement on the Tape any time between 3:00 P.M. and 3:40 P.M. at the specialist's discretion. However, at 3:40 P.M., the specialist is required to publish imbalances of 50,000 shares or more (or smaller imbalances with Floor Official approval). If there are no imbalances, investors are restricted from placing further MOC orders. However, if an imbalance is published, traders are able to submit MOC orders to offset this imbalance, but may not submit orders which increase it. For example, if there is a 50,000 share buy imbalance, traders are permitted to enter MOC and LOC sell orders only. Furthermore, if an MOC imbalance had been published at 3:40 P.M., the specialist is required to update this information again at 3:50 P.M., which may involve informing the market that an imbalance no

[9] While specialists are given some discretion as to when they open their stocks, the NYSE has specific guidelines for what exactly constitutes a "delayed opening" and provides specific instructions about how these should be handled. An official delayed opening would involve any stock that has not opened for trading by 10:00 A.M. (via an opening trade or a reasonable quotation) or for which a tape indication is given after the opening bell. (NYSE floor Official manual).

longer exists. If an imbalance is not offset by other MOC/LOC orders or the floor interest presented prior to 4:00 P.M., the specialist may be forced to offset an imbalance using her own capital and/or adjusting the price so that the imbalance executes against orders already in the limit order book. As soon after the closing bell as practicable, the specialist pairs off MOC buys and sells, and executes the imbalance against the bid (offer) if there is a sell (buy) imbalance. The paired off portion is then reported to the Tape at the same execution price, with the paired off print denoted as "stopped stock" (See Hasbrouck, Sofianos, and Sosebee (1993) for details).

Another important point is that, although these auctions are positioned at the open and close of trading on the NYSE, trading does take place prior to the NYSE open and after the close on alternative markets in the over-the-counter market (including Instinet) and on regional exchanges. While trading tends to be light on these venues relative to the trading that occurs, additional price discovery both before and after trading begins on the NYSE may occur.

One technical point that needs to be discussed is the identification of "closing quotes" on the NYSE. As of 4:00, the NYSE system accepts no more electronic orders and the specialist can only finish floor transactions currently under way. The clerk continues to execute orders that have arrived prior to 4:00 and updates quotes accordingly. The NYSE system automatically marks these as "closing quotes". Now, the specialist will close stocks they have that require the specialist to make judgements about closing prices. These quotes are then posted as "closing quotes". Finally, the NYSE has two systems that also look for stocks for which there has been no closing quote and reissues the last quote as a "closing quote". Of course, this may happen before the specialist is finished making closing quote decisions. The net result, is that there may be multiple closing quotes, though the last official "closing quote" will be either the specialist's

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[10] Prior to June 1998, the cut-off time was 3:50 P.M., except for option expiration dates when the cut-off was 3:40.

chosen quote or a default which reflects the last quote issued in a stock. For our purposes, therefore, the last "closing quote" will be designated as the "closing quote" in our analysis. Finally, it should be noted that quotes from other sources will also appear after 4:00. For the Nasdaq, these quotes are essentially non-binding since the Nasdaq system has been shut down. For the third market, these quotes may reflect the activities on the third market.

Nasdaq does not consolidate orders at the open or close, but individual market makers may offer to execute certain orders at a single open or closing price. In fact, the existence of multiple dealers could facilitate price discovery in that a given dealer facing a large imbalance may be able to unwind some of this position to other dealers, thereby sharing risk more effectively than the specialist who is effectively the "liquidity supplier of last resort." Furthermore, dealers may be able to communicate to others via their bids and offers and/or through the orders they route to other dealers. Even though the Nasdaq's regular market session does not begin until 9:30 A.M. dealers can communicate via non-firm quotes posted in during the pre-opening period (see Cao, Ghysels, and Hatheway (2000)). This pre-trade communication provides an alternative form of price discovery that may generate outcomes similar to that of a batched auction.

Now the many opening and closing procedures affect price discovery and liquidity is, in the end, an empirical question. The central purpose of this paper is to provide a systematic examination of these issues and take advantage of the differences across market structures to provide additional insight. We should not that the general results we document do not exclude the possibility that individual instances may be different. For example, we find that opening trades are generally less costly on the NYSE, but there may very well be circumstances where this is not the case. Clearly, more analysis of opening and closing procedures is warranted.

See NYSE Information Memo #98-02.

3. Sample

For the sample of firms that changed exchanges (the switch sample), we obtained from the Center for Research in Security Prices (CRSP) data set a list of all firms that changed listing from the Nasdaq to the NYSE during the 1997-1998 time period that satisfied the following restrictions. While on the Nasdaq the firms must have had the new order handling rules implemented prior to the beginning of our sample period – 100 days before the listing change. In addition, the firms must be trading in sixteenths for all of the sample period – the 100 days before the listing change through 100 days after the change. For each of these listing changes, we gather trade and quote data from the NYSE's Trade and Quote (TAQ) data set. We require that each firm have at least 10 days in the sample period with at least one valid quote. The switch sample contains 68 listing changes.

For the sample of firms matched on equity capitalization (the matched sample) we began with a list of all common stocks traded on the NYSE and Nasdaq as of 10/13/97 (the start of our sample period and chosen since all order-handling rules and exchange tick size changes will have been completed). We then matched, without replacement, NYSE firms to Nasdaq firms with market capitalization within 10%. From these we choose a stratified random sample of 400 pairs with 80 firms in each market capitalization quintile in the initial set of matched pairs.

A summary of sample characteristics is presented in Table 1. As usual, the number of trades and daily share volume are all substantially higher on the Nasdaq. This is because a single initiated transaction may lead to multiple reported trades as the shares are first transacted with one broker and then placed with another broker. Also typical of the differences across these two exchanges, the quoted and effective spreads are lower on the NYSE than on the Nasdaq. Interestingly, the averages for the switch sample and match sample are quite similar. For the

match sample, firms vary in size from about $700 million to 3 billion with shave volume following market capitalization: rising from about 28,000 shares a day to about 400,000 shares a day on the NYSE and from about 50,000 shares a day to about 1.1 million shares a day on the Nasdaq.

Table 2 presents our analysis of the clustering of trading volume at the open and close. We calculated the trading volume per time period as a faction of the trading volume reported on TAQ.[11] As expected, there is substantially clustering of volume on the NYSE opening auction. For example, the proportion of the volume in the first fifteen minutes that is executed in the first trade is about 26% for the Nasdaq match sample and rises to about 68% for the NYSE match sample. There is a much less pronounced effect at the closing auction, though the proportion executed in the last trade increases from about 54% to about 73% for the match sample. We also note that there is less trading activity near the end of the day on the NYSE, though it appears to be recaptured at the very end of the day.

4. Analysis of Liquidity

The clustering of trading activity at the opening and closing auctions on the NYSE raises an important question: to what extent does this clustering contribute to or strain available liquidity? On the one hand, additional trading volume clustered at a single point in time provides greater opportunities for trading interests to cross, thus improving liquidity and reducing trading costs. On the other hand, by forcing a large set of transactions to take place at a given instant in time, the effects of temporary liquidity imbalances might be accentuated. While it is possible that liquidity providers can offset the larger temporary imbalances at the auctions, there are two reasons this may not be the case. First, the results on price contribution suggest that a non-trivial

portion of the trading activity is from informed traders, so the larger positions are not simply liquidity shocks. The larger positions therefore impose larger costs on liquidity providers. Second, particularly at the close of trading, opportunities for liquidity providers to lay-off their positions may be more costly that during regular trading hours. For this reason, larger imbalances may lead to higher trading costs in the form of temporary price distortions.

This section explores the impact of opening and closing procedures on liquidity. The first set of tests compares the opening and closing prices to immediately adjacent prices. If, for example, the opening auction reduces trading costs by providing better opportunities to cross trades, then the cost of the first trade should be lower than the cost of the second (non-auction) trade. To ensure that these trades are taking place under comparable conditions, we only consider pairs of trades that are no more than 60 seconds apart. In addition, to increase the likelihood that the first trade is an outcome of the opening auction, we require that the first transaction occur before 9:45. Finally, to ensure that our measures are representative, we include a firm (or pair of firms) in our analysis only if there are at least 5 observations of adjacent trades on each market system.[12] Since these data restrictions reduce the size of our sample, particularly for the study of closing prices, we present the number of observations (switching firms or pairs of firms) used in our tests.

The second set of tests looks for possible price distortions by examining the autocorrelation of returns around the open and close. Once again, we note that our tests look at costs and distortions *on average*. It may be possible, for example, that there are occasions when trading costs are higher at the auction due to imbalances, even if the average cost is lower.

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[11] There is some after-hours executed volume that is not available on the TAQ data.

[12] Results are qualitatively similar if this last constraint is ignored, but the magnitude of the effects, particularly when expressed as a proportional change or difference, are larger.

Table 3 presents our analysis of trading costs using adjacent prices. The first part of the table examines opening trades. We begin by comparing the proportional effective spread for the first transaction where the effective spread is calculated as follows:

$$(P_i - (Bid_i + Ask_i)/2)/((Bid_i + Ask_i)/2)$$

where P_I is the execution price for trade i, Bid_t and Ask_t are the bid and ask quotes prevailing at time at the time trade i was executed.[13]

Consider the switch sample. As is typical, the Nasdaq effective spread exceeds the NYSE effective spread. Since a direct comparison of spreads is not important to our analysis, we do not present statistical test of that difference (they are always significant). The focus of our analysis is the relation between first and second trades. On the Nasdaq the first trade is actually more costly than the second trade. On the NYSE the first trade is less costly – the relative effective spread is 0.42% for the first transaction and 0.52 for the second.

Given the large difference in effective spreads across the market systems, the most relevant comparison across the systems is not the difference in effective spreads, but the proportional increase from first to second trades. Table 3 presents the average proportional difference in trading costs for each exchange.[14] For the switch sample the first transaction on the Nasdaq is about 2% more expensive. However, on the NYSE, the first transaction is about 28% cheaper. These differences are statistically significant. For the match sample, the results are

[13] In some cases the prevailing quote for the first transaction will be the opening quote. It is possible that the opening quote may not be representative of regular quoting behavior since it may be influenced by the choice of opening transaction on the NYSE or a result of the pre-open quoting period on the Nasdaq. However, our results are similar if we use the quote prevailing at the second transaction, the quote at 9:45 or the opening quote for *both* transactions as the benchmark.

[14] Note that we present the average percentage change from the first to second transaction across all firms, not the percentage change in the average across all firms.

qualitatively identical, though the savings on the NYSE are not quit as great as for the switch sample – the first transaction is about 18% cheaper than the second.

To provide some additional assurance that these trading cost differences are a reflection of the auction process on the NYSE and not a function of changes in quoted spreads, Table 3 also presents the proportion of executions that receive price improvement (the proportion of executions within the quoted spread). If a larger fraction of trades obtain price improvement on the first trade, this would suggest that auction provides an opportunity for trading interests to "cross", with natural buyers and sellers meeting at a single price. The qualitative changes are consistent with the changes in trading costs – the NYSE auction provides more frequent price improvement for the first trade than what is obtained by the second trade. The differences are significant in both samples. Interestingly, on the Nasdaq the first trade is actually price improved less frequently than the second trade, on average.

The next part of Table 3 examines closing trades. In contrast to the opening auction, the trading costs for the closing auction on the NYSE are generally higher than for the second to last trade. However, the results are statistically significant only in match sample for the NYSE. Trading costs for the Nasdaq are significantly higher for the last trade than the trade just prior to it.[15]

We also calculated the gains for the first trade across the five size quintiles. The results are in Table 3B. This table presents the proportional difference between the cost of the first trade and the second trade. For example, in the smallest quintile on the NYSE, the effective spread on the first trade is about 15% lower than the effective spread on the second trade. This increases to

[15] In these tests we looked at all last trades within the last fifteen minutes of the day in order to provide a clear comparison to the Nasdaq. Since only an NYSE trade that executes at or after 4:00 is the outcome of a closing auction, we could restrict our sample to only those trades. Results are essentially identical.

about 26% for the largest quintile. The differences between first and fifth quintiles are statistically significant based on a t-test. The first trade is seen to be slightly more expensive on the Nasdaq. When comparing the two exchanges, the smallest firms save about 22% by using the opening auction and the savings increase to about 36% for the largest firms.

These results suggest that opening auctions are particularly beneficial at the start of trading, and not at the close. This may be due to the fact that at the close of trading there may be fewer participants willing to provide liquidity since it will be more difficult to unwind any positions once regular trading hours are over. This would explain why trading costs are lowest for the larger firms – there are more possible opportunities to cross trades at the open and the greater liquidity of the larger firms makes it less costly for liquidity providers to enter the auction.

Table 4 presents our analysis of the autocorrelation in returns around the opening and closing periods. The first part of that table looks at all opening and closing periods, while the second part looks at closing periods on the NYSE when there are trades that are marked on the TAQ data in a manner that is consistent with execution as a market-on-close execution (the trade is executed after 4:00 and is marked as "stopped stock"). While all firms are used in tests for the on all periods, a number of firms have no orders of the specified type (for example, a number of firms have no market-on-close executions), so we report the number of firms (or matched pairs) used in our tests.

Table 4 presents the average (across firms) of individual firm correlations. The correlations are calculated between the return from 3:30 mid-quote to the given price, and the return from the given price and the mid-quote prevailing at 10:00 the next day. If there are temporary price pressures, we would expect to see negative correlation in returns. On the other

hand, it price changes are smoothed (specialists on the NYSE are required to provide price continuity) then there will be positive correlation. If there are no imperfections, we would expect correlations to be close to zero.

We begin by examining opening quotes and, as with the adjacent price analysis for execution costs, comparing these with the adjacent (subsequent) quote. Table 4 first presents the correlation for the opening quote. For the match sample we see that on both exchanges correlations are significantly negative, indicating some temporary price changes. More important for us is the comparison between first and second prices, which is shown next. Note that we present the correlation for the first trade again because we limit our analysis to only days when there is a second quote shortly after the first. In this analysis we see some indication of price pressures on the NYSE – the correlation for the second quote on the match sample is an insignificant –0.002, while for the first quote it is –0.105. For the match sample, the Nasdaq opening quote actually appears to be less influenced by temporary pressures.

In addition to quotes, we examine execution prices. Given bid-ask bounce, we certainly expect the correlations to be negative (particularly on Nasdaq since spreads are larger). However, we can examine whether there is a difference across first and second trades. In these tests we find no significant differences.

Next on Table 4 is the analysis of closing prices. Once again, we require closing quotes to be printed after 3:45 and for the adjacent quotes to be within 60 seconds of each other. In this analysis results are mixed. For the switch sample there are no statistically significant differences between adjacent trades except that closing quotes are slightly more negative on the Nasdaq. For the match sample, the closing quote on the NYSE is significantly closer to zero than the prior

quote. If we look at transactions, we find that the correlation for the last trade is more negative, suggesting price pressures.

We conclude Table 4 with an analysis of correlations for trades that are the result of market-on-close orders. These trades are ones for which the potential problems of clustered trading would be most pronounced. In the switch sample, there are no significant results. For match sample, however, we observe a more negative correlation for the market on close orders.

These results provide some evidence of price distortions, particularly for trades at the close. Taken together, the results in this section suggest that there are substantial benefits to participating in opening auctions, though little gain at the close. The gains are most pronounced for larger firms. The clustering of trading activity does seem to distort prices slightly.

5. Price Discovery and Alternative Closing Prices

We follow Barclay and Warner (1993), Cao, Ghysels, Hatheway (1999), and Barclay and Henderschot (2000) and use the weighted price contribution (WPC) as a measure of the information flow associated with various time periods. In effect, the weighted price contribution measures the proportion of eventual price changes that occur during a given time period. The WPC is defined as follows:

$$WPC_i = \sum_{t=1}^{100} \left(\frac{|\Delta P_t|}{\sum_{t=1}^{100} |\Delta P_t|} \right) \times \left(\frac{\Delta P_{i,t}}{\Delta P_t} \right)$$

where ΔP_t is the noon-to-noon price change ending on day *t*, and $\Delta P_{i,t}$ is the price change during period *i* of day *t* for changes after the open or the change during period *i* of day *t – 1* for changes that occur before the open. Time periods are fifteen-minute intervals starting at 9:30AM (open) until 4:00 (close) plus the interval from the close until the open and are numbered from 1

to 27 where period 27 is the overnight period. The above formula is for the 100 day sample period for the switch sample. For the match sample, the sums are over the 460 days analysis period. Since there will be no quote at exactly 9:30 on the NYSE, we take the first quote in the first five minutes. In addition, if a quote is not available in the first fifteen minute period, we use the closing quote from the prior day.

The results for the WPC in the switch sample are shown in figure 1 for the switch sample and figure 2 for the match sample. The first part of each figure shows the WPC for each of the time periods for both the NYSE and Nasdaq. The second part of each figure shows the difference in the WPC across exchanges. Changes that are significant at the 5% level are shown in bold. The "U" shaped price contributions are consistent with prior studies of volatility throughout the day, suggesting that more information is generated or incorporated into prices at the start of trading and at the end of the day.

The most notable result in both figures is the much smaller overnight price discovery on the NYSE and the much larger price discovery in he first few periods on the NYSE. One possibility is that the opening quote is less informative on the NYSE. However, a confounding effect is that the specialist must take the time to open a stock. No all stocks are opened in the first five minutes and these will show no price discovery over that time. In our samples, the specialist will have opened 99% of stocks within the first half hour. In the next analysis we will consider the price discovery in total overnight and including the first half hour as stocks are opened.

Another interesting pattern in the two figures is that price discovery seems to be, in general, a bit higher in the earlier part of the day for the NYSE than for the Nasdaq. In fact, for the matched sample, there appears to be a pronounce decline in the amount of price discovery

just before the close. We cannot, of course, determine whether this represents a delay in trading or the result of earlier trading. In other words, we cannot tell if price discovery is faster or slower on the NYSE, we can only note that a smaller proportion of daily discovery occurs just before the close.

To provide a more careful study of the pattern of price discovery over time and in total overnight (including the time it takes to open stocks), we conduct our analysis for four separate time periods – close until 10:00, 10:00 until noon, noon until 2:00 and 2:00 until the close. In effect, we have divided the day into three equal parts (morning, midday, and afternoon) after allowing an overnight period that is large enough to have stocks virtually all opened.

The analysis of these time periods is presented in Table 5. In addition, we have partitioned the sample into days where the price change (noon-to-noon) was greater than $1.00 and less than (or equal to) $1.00. This division provides some information on the ability of the market to generate price discovery when there are significant information flows. First, we note that there is no difference in the overnight periods across the market systems for either sample. Thus, on average, the same amount of price discovery occurs. However, for the remaining three time periods we observe that price discovery in the morning is generally higher on the NYSE than on the Nasdaq and lower on the NYSE than on the Nasdaq in the afternoon.

For the two partitioned samples, we observe that there is less price discovery overnight for the NYSE when there are large price moves in the day. This may be a result of the obligation of the specialist to provide price continuity, or it may be that traders are more willing to be patient when trading on the NYSE. These results suggest opportunities for further research. For the purposes of this study, it does not appear to be the case that the auction on the NYSE facilitates the revelation of information by attracting trading interests to that single point in time.

Finally, to evaluate cross-sectional characteristics, figure 3 presents the results for each of four time periods in table 5 for each of the size quintiles in the matched sample. We present only the differences between the NYSE and the Nasdaq. Dark bars are significant at 5%. Once again, the pattern of diminishing price contribution across the day is apparent. However, we see that this effect is more pronounced for the larger firms. In fact, while there are no differences in price discovery across exchanges overnight (on average), for the second smallest quintile there is more price discovery while for the largest quintile there is less.

We examine one other issue, which is of particular interest only for prices on the NYSE. At the close of trading, the specialist will set an official closing quote and this will be indicated when the quote is published. Sometimes it might take the specialist a little time to "close" a stock, especially if there are a large number of market-on-close orders. Also, the specialist will take orders right up to the close of the market. Thus, the official closing price is set sometime after 4:00.

Now, between 4:00 and the official close, and even after the official close, other quotes may be broadly disseminated. These may originate with the NYSE or, more likely, on the third market. Also, the closing quote will be influenced by liquidity demanded from market-on-close orders. Finally, the specialist has a great degree of flexibility in setting closing quotes since the specialist is not obligated to transact at those quotes.

We examine the price contribution of each of these quotes to see (1) the closing quote may not be informative due to specialist discretion or liquidity pressures at the close, and (2) whether the prices emanating from other exchanges are more or less informative than the NYSE official close.

Our results are shown in table 6. This table shows the WPC calculated from 3:45 to the given quote. The table shows the mean WPC across the samples. To ensure that our results are not driven by a selection bias (not all the alternative quotes exist every day), we contrast WPC of the alternatives with the WPC of the NYSE's official closing quote only when both quotes exist.

What we find is that the NYSE official closing quote is generally more informative than all the other benchmark prices we consider. For example, the official closing quote is more informative than the 4:00 prevailing quote, the quote prior to the closing quote, quotes from the third market (diseminationed after 4:00) and the last quote. The improvement over the last quote is particularly interesting because the last quote occurs after the official closing quote about two thirds of the time.

The one unusual result is that the transaction price where then are market on close orders appears to be slightly more informative that the closing quote. The difference is small and only significant for the match sample, but it does suggest that even when there are large trading interests at the end of the trading day, the specialist sets a closing price that is informative.

6. Conclusion

We examine opening and closing prices across the NYSE and Nasdaq to ascertain whether the differences in their opening and closing procedures influence price discovery and liquidity. We find evidence that suggests the opening auctions on the NYSE reduce trading costs, though prices are slightly distorted. We find little evidence that auctions at the close are beneficial. We also find that price discovery tends to occur more in the morning on the NYSE than on the Nasdaq.

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Table 1
Sample Summary Statistics

Summary statistics for exchange switch sample and stratified random sample of matched pairs of NYSE and Nasdaq firms. Firms were matched by market capitalization as of 10/13/97 (firm's were matched without replacement and the difference in market capitalization could not exceed 10% of the average market capitalization of the pair). The study period begins on 10/13/97 (after all Nasdaq firms have adopted recent order handling rules and after both exchanges have switched $1/16 tick sizes). Firm characteristics are given as of the close of trading the day before the listing change for the switch sample and the close of trading on 10/13/97 for the match sample. The trading activity figures are the daily averages for 100 days before (Nasdaq) or after (NYSE) the listing change for the switch sample, and for the 460 day study period for the matched sample. The quoted spread is the time-weighted difference between the ask and bid divided by the midpoint of the ask and bid. The effective spread is twice the dollar-weighted difference between a transaction price and the midpoint of the prevailing quote at the time of the transaction.

		Price	Equity Value ($1,000)	Daily Share Volume	Daily Number of Trades	Relative Quoted Spread (%)	Relative Effective Spread (%)
Switch (68 exchange switches – 100 trading days)							
Total Sample	*NYSE*	$27.34	1,112,239	157,298	84	0.83	0.64
	Nasdaq	$27.34	1,112,239	305,813	185	1.32	0.93
Match Sample (400 pairs of firms – 460 trading days)							
Total Sample	*NYSE*	23.06	763,794	124,296	74	0.98	0.76
	Nasdaq	26.17	703,220	324,527	234	1.93	1.44
Quintile 1	*NYSE*	14.82	82,686	28,182	19	1.44	1.08
	Nasdaq	16.72	82,690	49,563	31	3.14	2.30
Quintile 2	*NYSE*	19.45	173,502	43,497	31	0.99	0.76
	Nasdaq	22.06	173,759	84,359	53	2.20	1.58
Quintile 3	*NYSE*	23.30	286,448	72,352	46	1.04	0.82
	Nasdaq	24.41	291,524	136,980	84	1.82	1.36
Quintile 4	*NYSE*	25.15	461,886	104,131	68	0.84	0.64
	Nasdaq	28.19	494,190	220,112	141	1.68	1.28
Quintile 5	*NYSE*	32.55	2,814,450	373,318	208	0.61	0.50
	Nasdaq	39.68	2,496,351	1,141,838	868	0.79	0.68

Table 2
Proportion of Daytime Volume

Proportion of daytime volume for select transactions and time periods. The proportion of daytime volume is the proportion of daytime trading volume (in percent) in the given period, where trading volume is the volume from the opening trade through the last trade reported on the Trade and Quote (TAQ) data set. Each time period given below extends from the earlier time up to, but not including, the later time. The first trade proportion is the size of the first trade relative to volume in the first fifteen minutes of trading. The last trade proportion is the size of the last trade relative to the volume from 3:45 until closing.

	Switch Sample			Match Sample		
	Nasdaq	**NYSE**	**Change**	**Nasdaq**	**NYSE**	**Difference**
Start of Trading						
First (Opening) Trade	2.66	5.79	+3.12***	2.61	6.52	+3.91***
9:30-to-9:45 (including first trade)	7.25	8.53	+1.30[a]	7.68	9.05	+1.37***
9:45-to-10:00	4.11	4.06	-0.05	4.10	4.03	-0.07
First Trade Proportion	29.60	63.96	+34.36***	25.62	67.85	+42.23***
End of Trading						
3:00 to 3:15	4.19	3.77	-0.41***	4.06	3.96	-0.10***
3:15 to 3:30	4.65	4.24	-0.40**	4.56	4.40	-0.16***
3:30 to 3:45	5.23	4.76	-0.47***	5.05	4.70	-0.35***
3:45 to4:00 (excluding last trade)	6.87	5.94	-0.93***	6.86	5.69	-1.17***
3:45 to close	8.19	9.60	+1.41***	9.30	10.65	+1.34***
Last Trade	4.16	6.28	+1.67***	4.17	7.55	+3.37***
Last Trade Proportion	58.70	65.48	+5.80[a]	53.61	73.14	+19.53***

*** Indicates significance at the 1% level
** Indicates significance at the 5% level
* Indicates significant at the 10% level.
[a] Median difference was significantly positive at the 1% level.

Table 3
Analysis of Trading Costs – Adjacent Price Analysis

Analysis of executions of adjacent trades. For opening trades (first and second transactions within 30 seconds of each other where the second transaction occurs before 9:45) the prevailing quotes is the quote at the time of the second trade. For closing trades (last and second-to-last trades within 30 seconds of each other where the second-to-last trade is before 3:45) the prevailing quote is the quote at the time of the second-to-last trade. For an exchange switching firm or matched-pair to be included, there must be at least one valid NYSE and Nasdaq observation. The number of firms is given for each analysis. This table presents the mean values and tests of significance are based on the distribution of changes (switch sample) or differences (match sample) across the NYSE or Nasdaq.

	Switch Sample		**Match Sample**	
	Nasdaq	**NYSE**	**Nasdaq**	**NYSE**
Opening Trades				
Effective Spread (%)				
First Transaction	1.47	0.42	1.88	0.58
Second	1.38	0.52	1.75	0.67
Difference Between Trades	+0.08***	-0.11***	+0.13***	-0.09***
Proportional Difference Between Trades	+2.31***	-27.62***	+7.33***	-18.04***
NYSE vs Nasdaq Proportion Difference	-33.93***		-25.37***	
Proportion of Trades within the Spread (%)				
First Transaction	6.90	77.03	6.05	64.48
Second	15.72	66.56	15.55	61.18
Difference Between Trades	-8.82***	+10.47**	-9.50***	+7.30***
Number of Observations	56		399	
Closing Trades				
Effective Spread (%)				
Last Transaction	0.72	0.55	1.15	0.63
Second-to-Last	0.68	0.54	1.10	0.60
Difference Between Trades	+0.04**	+0.01	+0.05***	+0.03*
Proportional Difference	+6.30**	+4.22	+7.63***	+4.78***
NYSE vs Nasdaq Proportion Difference	-2.06		-2.85*	
Number of Observations	50		375	

*** Indicates significance at the 1% level
** Indicates significance at the 5% level
* Indicates significant at the 10% level.

Table 3B
Analysis of Trading Costs – By Quintile

Analysis of cost of first trades relative to second trades, by quintile. First and second transactions must be within 30 seconds of each other and the second transaction must occur before 9:45. This table presents the proportional difference between the effective spread on the first transaction and the effective spread on the second transaction. Effective spreads are calculated relative to the prevailing quote (for the first trade on the NYSE, the prevailing quote is the opening quote). This table presents the mean values and tests of significance are based on the distribution of changes (switch sample) or differences (match sample) across the NYSE or Nasdaq.

	Proportion Difference		**Difference**
	NYSE	Nasdaq	
Quintile 1 (smallest)	-14.77***	+7.00***	-21.7***
Quintile 2	-12.45***	+6.33***	-18.70***
Quintile 3	-15.97***	+6.29***	-22.26***
Quintile 4	-21.03***	+7.20***	-28.23***
Quintile 5 (largest)	-25.94***	+9.79***	-35.74***

Table 4
Analysis of Possible Price Distortions – Autocorrelation Analysis

Autocorrelation of the indicated returns around opening and closing quotes. Tests of the significance of the autocorrelation are based on a *t*-test across firms for the difference in autocorrelation on each exchange. We include an analysis only on those days when Market on Close orders are executed. Not all firms have these orders, so the number of observations is given in this analysis. Tests of significance for changes in autocorrelation use a *t*-test on the distribution of pair-wise differences between means for NYSE listing and Nasdaq listing periods.

	Switch Sample		**Match Sample**	
	Nasdaq	**NYSE**	**Nasdaq**	**NYSE**
Opening Periods				
Opening Quote	+0.005	+0.008	-0.031***	-0.068***
Observations	68	68	400	400
Opening Quote with Adjacent Quote	-0.076	+0.008	-0.003	-0.105***
Adjacent Quote	-0.148*	+0.077	-0.028	-0.002
Difference	+0.073	-0.069***	+0.031**	-0.108***
Observations	50	68	372	400
Opening Trade	-0.340***	+0.052*	-0.336***	-0.026***
Observations	68	68	########	########
Opening Trade with Adjacent Trade	-0.286***	-0.235***	-0.267***	-0.083**
Adjacent Trade	-0.289***	-0.232***	-0.265***	-0.082***
Difference	+0.003	-0.003	+0.002	-0.001
Observations	49	66	399	399
Closing Periods				
Closing Quote	-0.051**	-0.049**	-0.103***	-0.061***
Observations	68	68	400	400
Closing Quote with Adjacent Quote	-0.046	-0.057**	-0.109***	-0.066***
Adjacent Quote	-0.007	-0.058**	-0.108***	-0.076***
Difference	-0.038*	-0.001	-0.001	+0.010***
Observations	67	68	400	400
Last Trade	-0.183***	-0.079***	-0.279***	-0.109***
Observations	65	66	396	399
Last Trade with Adjacent Trade	-0.236***	-0.116**	-0.278***	-0.129***
Adjacent Trade	-0.229***	-0.065	-0.258***	-0.098***
Difference	-0.007	-0.051	+0.020**	-0.031***
Observations	51	63	384	395
Last MOC trade with Adjacent Trade		-0.062		-0.131
Adjacent Trade		-0.216**		-0.070
Difference		+0.154		-0.061***
Observations		40		321

*** Indicates significance at the 1% level
** Indicates significance at the 5% level
* Indicates significant at the 10% level.

Table 5
Weighted Price Contribution

Comparisons across exchanges of the Weighted Price Contribution (WPC) and proportion of daily volume for specified time periods. The weighted price contribution is equal to

$$WPC_i = \sum_{t=1}^{T}\left(\left|\Delta P_t\right| \Big/ \sum_{t=1}^{T}\left|\Delta P_t\right|\right) \times \left(\Delta P_{i,t} / \Delta P_t\right)$$

where ΔP_t is the total price change from noon on day $t-1$ to noon on day t, $\Delta P_{i,t}$ is the price change during period i of day t, and T is the number of days in the analysis. Period i varies and is identified in the table below. This table also presents the WPC for days with at least a one dollar noon-to-noon price change (large change) and the rest of the sample (small change). The number of firms that have at least one observation is less than the full sample for days with large changes. For this reason, the number valid pairs is given for each test.

		Switch Sample			Match Sample		
Comparisons		All	Large Change	Small Change	All	Large Change	Small Change
Close-to-10:00	*Nasdaq*	24.9	32.7	22.1	26.4	34.9	22.6
(Overnight)	*NYSE*	23.2	22.5	23.7	26.3	32.5	23.9
	Mean Change	-1.7	-10.2**	+1.6	-0.1	-2.4**	+1.3***
10:00-to-12:00	*Nasdaq*	29.1	27.6	27.8	28.1	25.8	29.3
(Morning)	*NYSE*	32.6	35.8	31.8	30.5	29.6	30.8
	Mean Change	+3.5**	8.2**	+4.0**	+2.4***	+3.8***	+1.5***
12:00-to-2:00	*Nasdaq*	20.9	15.6	24.9	20.2	15.8	22.4
(Midday)	*NYSE*	20.0	17.0	20.3	19.5	16.6	20.7
	Mean Change	-0.9	+1.4	-4.6***	-0.7***	+0.8	-1.7***
2:00-to-close	*Nasdaq*	25.1	23.9	25.1	25.3	23.5	25.7
(Afternoon)	*NYSE*	24.2	24.6	24.1	23.8	21.2	24.6
	Mean Change	-0.9	+0.7	-1.0	-1.5***	-2.3***	-1.1***
Number of Pairs		68	63	68	400	384	400

*** Indicates significance at the 1% level
** Indicates significance at the 5% level
* Indicates significant at the 10% level.

Table 6
Analysis of Alternative Closing Benchmarks

Comparisons across alternative closing benchmarks of the weighted price contribution from the 3:45 prevailing quote alternative measures of the closing quote. The weighted price contribution is equal to

$$WPC_i = \sum_{t=1}^{T}\left(|\Delta P_t| \Big/ \sum_{t=1}^{100} |\Delta P_t| \right) \times \left(\Delta P_{i,t} / \Delta P_t \right)$$

where ΔP_t is the total price change from noon on day $t-1$ to noon on day t, $\Delta P_{i,t}$ is the price change from the 3:45 prevailing mid-quote to the alternative closing mid-quotes, and T is the number of days in the sample (100 for the switching sample and 460 for the matched sample). The NYSE closing quote is the last official NYSE closing quote to originate from the NYSE. The third market quote is the last quote *after* 4:00 that originates on the third market. The quote prior to the closing quote is the NYSE originating quote immediately prior to the NYSE indicated quote while the 4:00 prevailing quote is the NYSE originating quote immediately prior to 4:00 PM. We conduct our analysis only on those days where the alternative quote is available. For this reason, we present the NYSE closing quote WPC for each analysis. This table presents the median WPC and the median change (switch sample) or difference (match sample) across pairs of firms in each sample. Tests of significance are based on the Wilcoxon signed rank test.

	Switch Sample				Match Sample			
	Alternate	**Closing**	**Change**	**Number**	**Alternate**	**Closing**	**Difference**	**Number**
Weighted Price Control (%)								
Quotes								
4:00 Prevailing Quote	4.27	4.93	+0.38***	68	3.04	3.98	+0.80***	400
Quote prior to Closing Quote	5.14	5.33	+0.23***	68	3.96	4.42	+0.41***	400
Third Market Quote	4.78	5.14	+0.41***	67	3.78	4.25	+0.29***	390
Last Quote	4.43	4.97	+0.27***	68	3.85	4.03	+0.34***	400
Transactions								
Last Transaction	4.97	4.94	+0.38**	68	3.91	4.04	+0.07*	400
Second-to-Last Transaction	4.27	5.69	+1.01***	68	3.22	4.75	+1.39***	400
Third Market Transaction	6.14	6.69	0.0	64	4.67	5.73	+1.06***	387
Market on Close	5.83	3.75	0.0	48	4.45	4.02	-0.15*	344

*** Indicates significance at the 1% level, ** Indicates significance at the 5% level, * Indicates significant at the 10% level.

Table 7
Noisiness of Alternative Quotes

The average absolute value of the return from 3:45 PM to the given trade price or quote mid-point. The NYSE indicated closing quote is the last official NYSE closing quote to originate from the NYSE. The Nasdaq quote is the last quote *after* 4:00 that originates from the Nasdaq. The third market quote is the last quote *after* 4:00 that originates on the third market. The quote prior to the closing quote is the NYSE originating quote immediately prior to the NYSE indicated quote while the 4:00 prevailing quote is the NYSE originating quote immediately prior to 4:00 PM. We conduct our analysis only on those days where the alternative quote is available. For this reason, we present the NYSE indicated quote WPC for each analysis. Test of significance are based on the distribution of firm level differences between the WPC for each benchmark and the NYSE indicated quote. Standard t-tests are used for means and Wilcoxon signed-rank tests for medians. We present the percentage of non-zero changes that are positive along with an indicator of the significance of the Wilcoxon test.

	Switch Sample				Match Sample			
	Alternate	**Closing**	**Change**	**Number**	**Alternate**	**Closing**	**Difference**	**Number**
Absolute Return (%)								
Quotes								
4:00 Prevailing Quote	0.34	0.38	+0.04***	68	0.26	0.30	+0.04***	400
Quote prior to Closing Quote	0.41	0.43	+0.02***	68	0.35	0.35	+0.00	400
Third Market Quote	0.43	0.40	-0.03***	67	0.38	0.32	-0.06***	390
Last Quote	0.41	0.39	-0.02***	68	0.34	0.31	-0.04***	400
Transactions								
Last Transaction	0.48	0.39	-0.09***	68	0.45	0.30	-0.15***	400
Second-to-Last Transaction	0.44	0.47	+0.03	68	0.42	0.38	-0.04***	400
Third Market Transaction	0.60	0.50	-0.09**	64	0.55	0.37	-0.18***	387
Market on Close	0.66	0.58	-0.08***	48	0.77	0.44	-0.34*	344

*** Indicates significance at the 1% level
** Indicates significance at the 5% level
* Indicates significant at the 10% level.

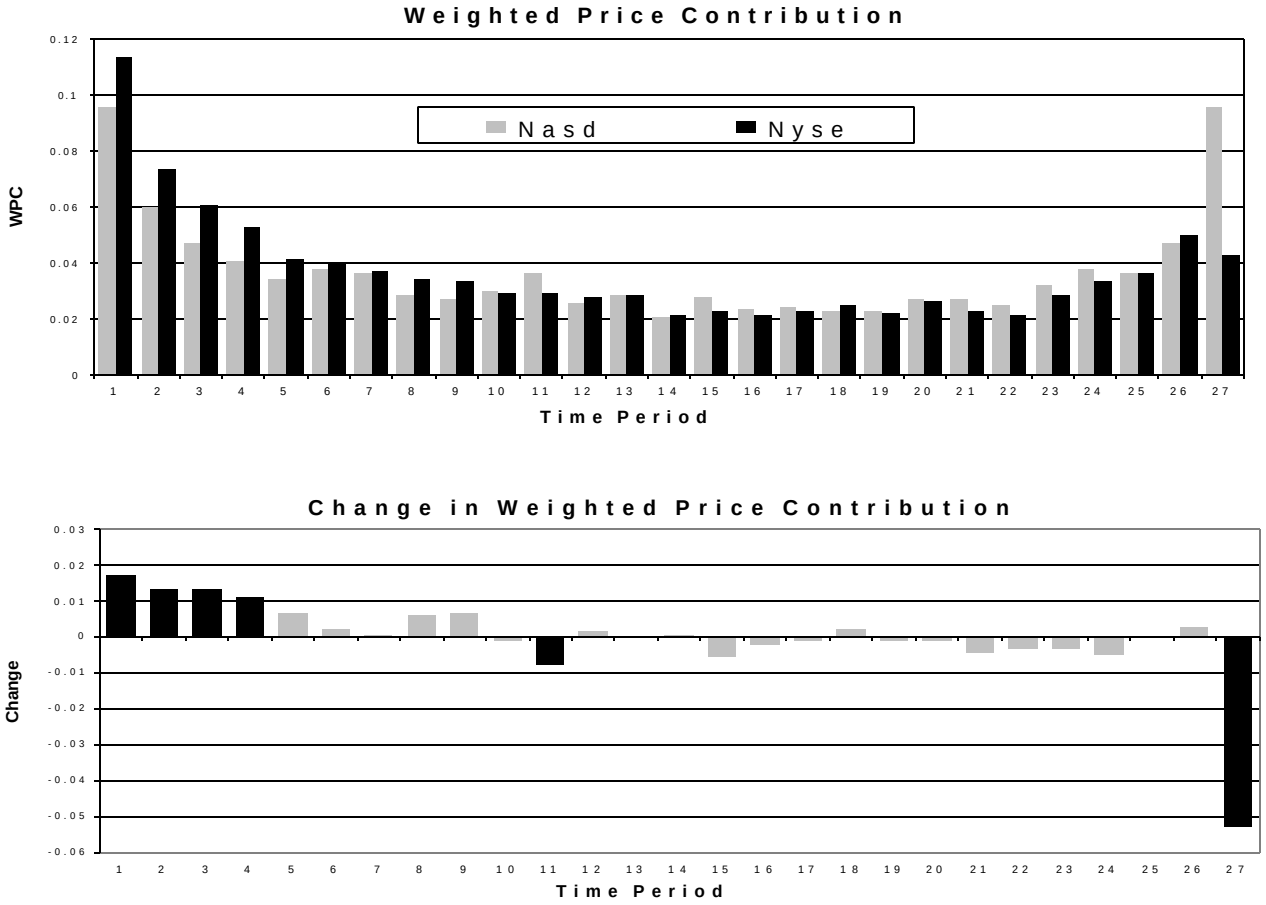

Figure 1
Analysis of Weighted Price Contributions – Switch Sample

Comparisons across exchanges of the information contribution of various trading periods using the weighted price contribution (WPC). The weighted price contribution is equal to

$$WPC_i = \sum_{t=1}^{T}\left(\left|\Delta P_t\right| \Big/ \sum_{t=1}^{T}\left|\Delta P_t\right|\right) \times \left(\Delta P_{i,t} / \Delta P_t\right)$$

where ΔP_t is the total price change from noon on day $t-1$ to noon on day t, $\Delta P_{i,t}$ is the price change during period i of day t, and T is the number of days in the analysis. Time periods are fifteen-minute intervals starting at 9:30AM (open) until 4:00 (close) plus the interval from the close until the open. Dark bars on the change in WPC graph indicate significance at the 10% level based on the distribution of the changes across firms in the WPC from before (Nasdaq) to after (NYSE) a listing change.

Figure 2
Analysis of Weighted Price Contributions – Matched-Pair Sample

Comparisons across exchanges of the information contribution of various trading periods using the weighted price contribution (WPC). The sample is 400 pairs of firms matched on market capitalization. The weighted price contribution is equal to

$$WPC_i = \sum_{t=1}^{T}\left(\left|\Delta P_t\right| \Big/ \sum_{t=1}^{T}\left|\Delta P_t\right|\right) \times \left(\Delta P_{i,t} / \Delta P_t\right)$$

where ΔP_t is the total price change from noon on day $t-1$ to noon on day t, $\Delta P_{i,t}$ is the price change during period i of day t, and T is the number of days in the analysis. Time periods are fifteen-minute intervals starting at 9:30AM (open) until 4:00 (close) plus the interval from the close until the open. Dark bars on the change in WPC graph indicate significance at the 10% level based on the distribution of the difference across matched pairs. Results are the average WPC across firms on each exchange.

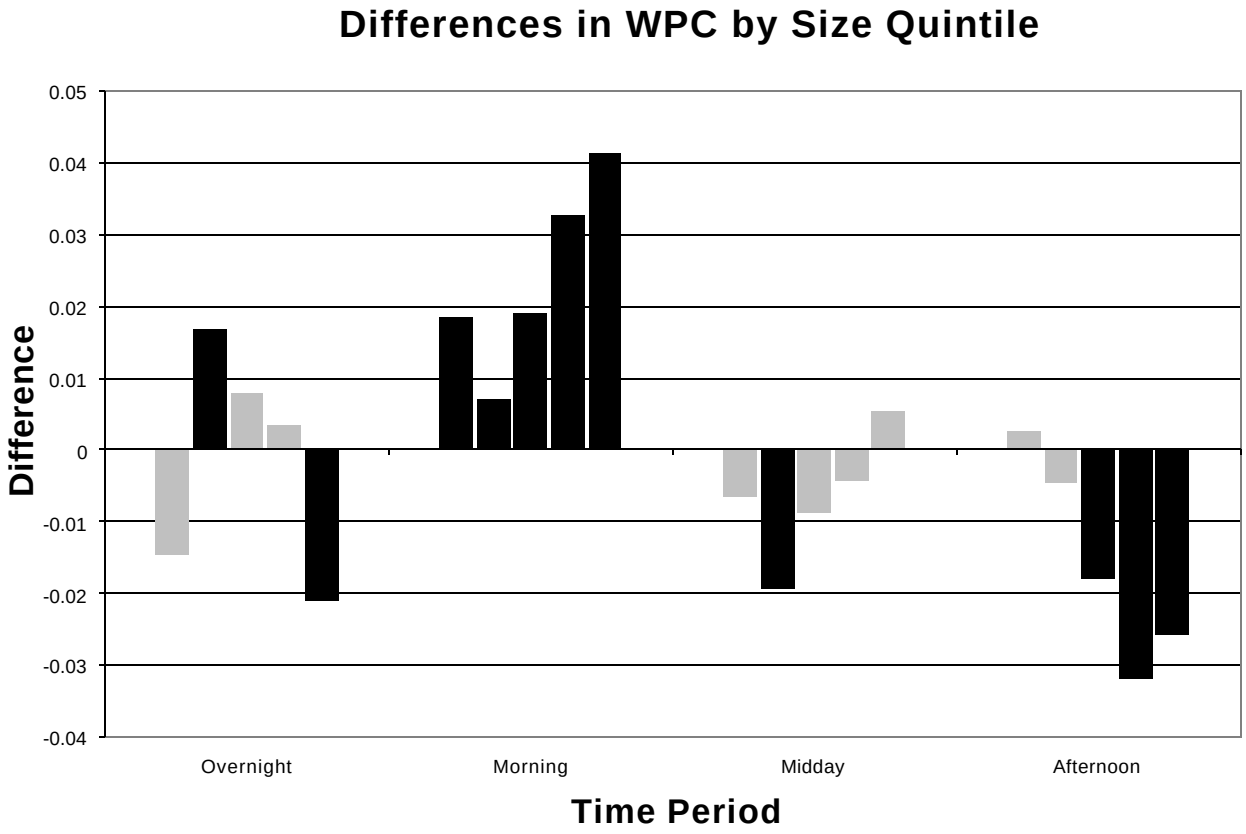

Figure 3
Differences in Weighted Price Contributions – Matched-Pair Quintiles

Comparisons across exchanges of the information contribution of various trading periods using the weighted price contribution (WPC). The sample is 400 pairs of firms matched on market capitalization. The weighted price contribution is equal to

$$WPC_i = \sum_{t=1}^{T}\left(\left|\Delta P_t\right| \Big/ \sum_{t=1}^{T}\left|\Delta P_t\right|\right) \times \left(\Delta P_{i,t} / \Delta P_t\right)$$

where ΔP_t is the total price change from noon on day $t-1$ to noon on day t, $\Delta P_{i,t}$ is the price change during period i of day t, and T is the number of days in the analysis. Time periods are fifteen-minute intervals starting at 9:30AM (open) until 4:00 (close) plus the interval from the close until the open. Dark bars on the change in WPC graph indicate significance at the 10% level based on the distribution of the difference across exchange pairs. Results are the average WPC across firms on each exchange.