

Intra-day Trading Volume Patterns Of Equity Markets: A Study Of US And European Stock Markets

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ABSTRACT

We investigate the pattern of intra-day volume of trading in five different equity markets: The New York Stock Exchange and NASDAQ in the US, and The London Stock Exchange, Deutsche Boerse, and Euronext Paris in Europe. For the European markets, we repeat our investigation for two separate study periods to check for the consistency of our results and also to account for important rule changes that took place in the middle of the year in those markets. For the US markets, the intra-day pattern of volume is a reverse J-shape, consistent with previous literature. On the other hand, for all the European markets, volume is quite low at the open and picks up towards the end of the trading day. The most striking case is the London Stock Exchange, where, at the beginning of the day, the volume is the lowest across all markets studied. Additionally, we find that the rule changes in the European markets pertaining to introduction of call auctions, and extension of trading hours met with mixed success.

Keywords: Trading Volume, Market Microstructure, Market Efficiency, Equity markets

1. INTRODUCTION

The ability of an equity market to attract a significant and consistent amount of trading is an important aspect of its quality, and will lead to more meaningful price discovery of stocks traded in that market. If the trading volume is not consistent or the traders shy away from the market during certain periods of the day, such as the opening of trading or during extended trading hours or call auctions, then the price discovery process of traded stocks is not efficient during those periods in that market. Such inefficiency is costly to the market in aggregate. It discourages trades, lowers portfolio performance for most traders and makes portfolio returns more uncertain for everybody.

In this study, we investigate intra-day volume trends both inter-temporally and across several stock markets, and pay particular attention to trading rule changes that occurred especially in the European markets during our study period. We investigate intra-day volume patterns in five different market centers. By investigating this issue across different market centers with different market structures, we are able to draw conclusions on whether or not there is any significant variation across different market structures on this issue.

If traders wait before entering the market or shy away from the market during certain intervals, then the prices discovered in the market will reflect the beliefs of only the subset of traders who do choose to trade. In other words, stock prices discovered in that market will be less accurate.

In this study, we attempt to capture the intra-day patterns of volume by dividing the trading day into half hour periods, such as 9:30 to 10:00, 10:00 to 10:30 etc. In a trading day that is six hours long we have twelve half hour periods. Half-hour intervals are commonly used both in the academic literature (e.g. Coughenour 2001) and in the popular media, such as the Wall Street Journal, to report intra-day statistics pertaining to equity trading. We do not include overnight periods in the intra-day study and concentrate only on the price changes during the official trading hours.

As noted, this study uses data from 5 different markets. The New York Stock Exchange and the Nasdaq Stock Market in the U. S., and Deutsche Boerse, Euronext Paris, and the London Stock Exchange in Europe. In each of these markets, we study the individual stocks that comprise a major index (Nasdaq 100 and S&P 100 in the US, FTSE 100 in England, CAC 40 in France and DAX 30 in Germany) during the calendar year 2000. The reason why we choose year 2000 is because during this year there were important trading rule changes in all the European markets that influenced how volume of trading was spread out during the day in that respective market. During our study period, both Deutsche Boerse and Euronext Paris extended their trading hours, London Stock Exchange introduced a closing call auction, and Deutsche Boerse increased the number of intra-day call auctions to two.

Furthermore, there is a wide spectrum of different market structures and opening procedures employed in these five markets. As a result, we are able to investigate whether or not patterns of volume differ across various market centers and market opening procedures.

The remainder of the paper is organized as follows. Section 2 provides a literature review. Section 3 reviews the opening procedures in the alternative market centers studied. Section 4 describes the data. Section 5 is a discussion of the methodology and empirical results. Section 6 concludes the study.

2. LITERATURE REVIEW

Market quality has been a subject of national debate since the 1970s. Even though market quality has been a focus of national debate due to the recent requirement by the Securities and Exchange Commission for stock markets to provide detailed disclosure of their execution quality, there is no single agreed upon metric to assess it. Academic literature on market quality is vast, with different researchers focusing on different aspects of market quality. These studies are either broad investigations that look at measures such as spread, depth, volume and liquidity for different market centers (e. g. Chordia, Roll and Subrahmanyam (2000) and Stoll (2000)). Or they are more specific studies that concentrate on how different market structures respond to important rule changes (e. g. Chakravarty, Wood and Harris (2002) investigate the impact of decimalization).

In a comprehensive study that investigates liquidity and trading activity in the NYSE over the period of 1988 to 1998, Chordia, Roll, and Subrahmanyam (2000) find a relative lack of change in absolute daily prices (0.56%) compared to average absolute change in daily liquidity variables (about 2%), average absolute change in daily depth variables (about 4-5%), and average absolute change in daily trading activity variables (15-20%). In this study, the authors use quoted and effective spreads and depth as the measures of daily liquidity and volume and number of daily transactions are used as the measures of trading activity.

An emerging sub-field of research in market quality is a transaction level analysis of the period surrounding the opening of trading after a period of non-trading (e. g. the overnight period or a trading halt). Typically these studies find that the opening of trading after a period of non-trading is a stressful period, and that informal or formal mechanisms are necessary to improve the efficiency of the opening. In a recent study, Cao, Ghysels and Hatheway (2000) document the price discovery that takes place in the Nasdaq market during the pre-opening period (8:00 am to 9:30 am). Biais, Hillion, Spatt (1999) provide an analysis of the Paris Bourse pre-opening period and show that there is price discovery during the pre-opening even in the absence of specialist intervention.

Madhavan and Panchapagesan (2000) examine the process of price discovery at the New York Stock Exchange single-price opening auction. The authors argue that the presence of designated dealers (i. e specialists) facilitates price discovery relative to a fully automated call auction market without intermediation.

Lee, Ready and Seguin (1994) investigate the pattern of volume and volatility following the NYSE trading halts and find that the implementation of trading halts increase, rather than decrease, both volume and volatility following the halt. Christie, Corwin and Harris (2002 JF), on the other hand, in a similar study find that the post trading halt period is associated with unusually high volatility and share volume in the Nasdaq market.

Stoll and Whaley (1990) investigate the relationship between volume and volatility, and find an inverse relationship between volume and daytime volatility, but a positive relationship between volume and overnight volatility.

Intra-day patterns in volume and volatility were first documented by Wood, McInish and Ord (1985), Jain and Joh (1988) and Harris (1986). Subsequently, this area has been investigated by other academic studies including Madhavan et al (1997) and Gerety and Mulheren (1994). Generally, these studies find a U-shape in volume and volatility across the markets studied. One of the more important differences between these studies and the current one is that, in these studies, patterns of stock indices are investigated as opposed to the patterns of individual stocks that are investigated in the current study. Furthermore, those studies used US data and we show in this paper that the intra-day volume patterns in the European markets are quite different compared to the US markets.

The intra-day pattern of the bid-ask spread has also been investigated in the academic literature. These studies show that there is some variation across different market structures in terms of the pattern of the spread. More specifically, even though Wood and McInish (1992) find that spreads in the NYSE have a U-shaped pattern during the day, other studies investigating the bid-ask spread in dealer markets do not find a similar shape. Chan, Christie and Schultz (1995) use a sample of Nasdaq stocks and find that spreads are relatively stable throughout the trading day but narrow significantly during the last hour of trading. Kleidon and Werner (1993), on the other hand, identify a pattern of declining intra-day spreads during the trading day in the London Stock Exchange. This finding is also consistent with the findings of the current study since large spreads are typically associated with a lack of trading volume.

Admati and Pfleiderer (1988) provide a theoretical explanation for the intra-day U-shaped patterns in volume and volatility in which concentrated-trading patterns arise endogenously as a result of the strategic behavior of liquidity traders and informed traders. In this model, information comes to the market randomly throughout the day, inducing the informed traders to act upon their information when they receive it. On the other hand, liquidity traders can time their trades and they choose to concentrate their trading at the open and at the close. The rationale for this behavior is their attempt to minimize the adverse selection costs they would incur when they trade against the informed traders by increasing their chances of trading with another liquidity trader through bunching together. As a result, due to the strategic behavior of traders, the trading is concentrated at the open and the close, creating the U-shaped patterns of volume and volatility.

There are several empirical studies that document the price discovery that takes place through trading. For example, Fleming and Remolina (1999) show, using US Treasury Market data, that prices adjust to new information arrival over a two stage prolonged period as opposed to an immediate adjustment. The authors show that in the first stage, prices adjust sharply to just released new information, showing trading is not essential for price discovery. However, high volume and volatility are observed over the prolonged second stage, indicating a residual disagreement about among traders. After this second stage volume and volatility returns to normal levels.

Finally, Chordia and Swaminathan (2000) show that the stocks with lower trading volume respond more slowly to new information in market returns compared to the stocks with higher trading volume, once again indicating the importance of trading to price discovery.

Several researchers argue that the trading costs should increase towards the end of the trading day, creating more volume and volatility near the closing of trading. Examples include Bessembinder (1994), and Brock and Kleidon (1992). These studies argue that traders (and market-makers) try to rebalance their portfolios at the end of the trading day to minimize the costs of carrying inventory overnight, causing the observed increases in volume and volatility. In other words, the pressure of the approaching market close creates an environment with higher volume and volatility.

Since European markets make extensive use of the call-auction trading mode in addition to the continuous trading, we are able to make inferences on the relative merits of call auctions in this study. During our study period, there has been important rule changes in the European markets regarding call auction trading as London Stock

Exchange introduced a closing call auction and Deutsche Boerse increased the number of intra-day call auctions to two. Schwartz (1993) defines a call market as a market where orders are batched for simultaneous execution at a single price when the market is “called”. This is in contrast to continuous trading where trading takes place “continuously” whenever a buy order meets a sell order during the trading hours.

3. OPENING PROCEDURES IN ALTERNATIVE MARKETS

Opening of trading following a period of non-trading such as the overnight or weekend market close is a particularly stressful period for market participants. It is during this time that all the information that accumulated during the non-trading period needs to be incorporated into stock prices. As a result, during the opening period there is greater uncertainty regarding the stock prices’ ability to reflect new information. Furthermore, the variation across market participants in regards to the interpretation of news (also known as heterogeneous expectations) could also add to the stress of this particular period.

Since the opening interval is an important period of price discovery, many equity markets employ special protocols to facilitate the start of trading. Domowitz and Madhavan discuss both the importance and the challenges of the opening procedures in an article in a book edited by Schwartz (2001). The authors write that “efficient price discovery is a crucial function for a securities market. Opening procedures play an especially important role in facilitating price discovery following the enforced trading halt induced by the overnight or weekend non-trading period. Indeed, many markets use special opening procedures designed to provide traders with information regarding market clearing prices with a view toward enhancing liquidity and reducing intra-day price volatility”.

Since this study investigates five different equity markets, we can indirectly assess whether or not there are any significant variations in trading volume during the opening across markets. All of the five markets we study are structured differently, and they employ unique protocols to open the market in the morning. This section provides an overview of the different opening procedures followed by the equity markets included in our study.

New York Stock Exchange has a formal opening procedure that may be characterized as an intermediated opening. For each stock on the NYSE, there is a designated specialist whose duty it is to set the opening price. As a matter of fact, the specialist has a broader obligation to maintain a fair, competitive, orderly and efficient market and to provide price continuity for the stocks that he or she is responsible for.

At 9:30, the specialists choose the prices at which the market will open. At this price, all the market on open orders and limit orders (with prices at or better than the opening price) trade. In addition to these obligations and setting the price of the stock, the specialist is also allowed to trade the stock proprietarily, and as a result enjoys, as a trader, the unique informational advantage that stems from being able to observe the order flow. At the open, the specialists, once they set the opening price, must absorb any excess demand or supply at the opening prices from their inventories.

Even though the specialist typically trades at the open either to offset a buy/sell order imbalance or as a proprietary trader, it has been shown that their relative trading volume in larger and more liquid stocks is significantly less than their trading volume in smaller and less liquid stocks. As a result, we expect that the specialist intervention will be less for our NYSE sample that consists of very large capitalization and highly liquid stocks. It is not clear, however, whether the benefits of the specialist intervention would have remained for a call auction that provides full transparency before the market open (such as the case with the opening protocol of Euronext Paris).

Compared to the NYSE that is a floor based auction market where there is only one specialist making the market per stock, the Nasdaq Stock Market consists of competing market makers and Electronic Communication Networks (ECNs) that enter the bid and the ask quotes. The highest bid and the lowest ask that are quoted are called the inside quotes, and trading takes place at these quotes. Contrary to the NYSE, Nasdaq does not have a formal opening procedure. Furthermore, Nasdaq does not have a trading floor.

In Nasdaq, market makers and ECNs start entering their bid and ask quotes to the system as early as 6:00 am. Until June 5, 2000, the quotes that were entered by the market makers before the 9:30 am market open were not binding but merely “indicative”. However, On June 5, 2000 a new “trade or move” rule was implemented. According to this rule, the market makers that enter a locking or crossing quotation between 9:20:00 am and 9:29:59 am are required to either trade at that price or to change their quotations to unlock/uncross the market within 30 seconds. Formal trading starts at 9:30 am on the Nasdaq market and all the quotes entered become firm quotes. In other words, starting at 9:30 am market makers have an obligation to buy and sell the minimum share size at the quoted prices.

A study by Cao, Ghysels and Hatheway (2000) shows that even though there is no formal opening procedure at the Nasdaq market, the market makers do engage in informal price discovery during the pre-opening period of 8:00 am to 9:30 am.

As a result, there is price discovery in the Nasdaq market before the market opens and the opening price reflects the cumulative information of all market makers that participated in the pre-opening. According to these authors, this outcome is mutually beneficial for all the market makers in Nasdaq. It is also important to note that, in addition to revealing information about the stock prices, the market makers also reveal their identity when they post their quotes in the pre-opening period. Since market opening is a repeated game, market makers who try to exploit their information at the expense of other market makers might find fewer counter-parties to trade within the future.

The European markets we investigate, the Deutsche Borse, Euronext Paris and London Stock Exchange, are all electronic order-driven markets, and in this respect they are relatively similar to the NYSE. However, none of them has a physical trading floor. Also, the London Stock Exchange comes from a dealer-market structure that used to resemble the Nasdaq Stock Market. All of these European markets open their trading in the morning with a call auction. After the opening auction in each market, trading starts in the form of continuous trading. At the Euronext Paris and Deutsche Bourse the opening call auction takes place at 9:00 am. On the other hand, the opening call auction takes place at 8:00 am on the London Stock Exchange. However, if we take into consideration the one-hour difference between England and the Continental Europe, then we see that the start of trading is synchronized for all three European markets studied.

One of the more important differences between Deutsche Borse and Euronext Paris with respect to their opening procedures is that Deutsche Borse has intermediated openings (with the help of a “kursmakler”), whereas the opening at the Euronext Paris is fully automated. Deutsche Borse has a specialist system that is similar to the specialist system of the NYSE. Again there is only one specialist in the Deutsche Borse, called “Kursmakler”, for each stock, and one kursmakler can make the market for multiple stocks. Furthermore, the kursmakler is also able to trade proprietarily for her account. At the opening call auction, it is the kursmakler who sets the opening price based on the order flow that came in during the non-trading period.

There are no specialists at Euronext Paris and as a result the opening price that is the outcome of the opening call auction depends solely on the orders that came in during the pre-opening period. The pre-opening period of the Euronext Paris is further characterized by a high degree of transparency, where the traders can observe the evolution of the limit order book. Furthermore, until it is very close to the opening, traders are able with relative ease to cancel the orders they placed. In contrast, the Deutsche Borse call auctions are characterized by a relative lack of transparency.

Biais, Hillion and Spatt (1999) investigate the price formation process during the pre-opening period at Paris Bourse. The authors show that the indicative opening price is very informative in reflecting the overnight information accumulation. Learning among traders that leads to price discovery does take place during the pre-opening period. However, the high level of transparency, coupled with the ease with which traders can cancel their orders before the opening auction might let them “game” the market by withholding their most informative orders until the market is very close to opening (this phenomenon is also known as “suckering”). Pagano and Schwartz (2002) show that price discovery at the Euronext Paris’ market opening (and close) was improved by the institution of a call auction to close the market in 1996.

London Stock Exchange made a number of enhancements to their opening call auction on May 30th 2000, simultaneously with introducing the closing call auction. These enhancements were the availability of market orders in addition to the limit orders, calculation and dissemination of an indicative auction price during the call period, random end to the auction call period, auction call period extensions under specific situations such as significant price moves, and alignment of the matching algorithm with the other European markets.

Similar to the Nasdaq market, the London Stock Exchange also has a competing dealer market structure in addition to the electronic SETS system. There is a further aspect that distinguishes London Stock Exchange from the other markets studied. Trading on the LSE is dominated by the institutional traders, in contrast to a more balanced combination of retail and institutional trading observed in the other markets. Clearly, this is an important factor that might impact the trading culture on the LSE not only during the trading hours but also during the period that covers the opening.

4. DATA

4.1 US Markets

Two domestic markets are studied: The New York Stock Exchange and the Nasdaq Stock Market. Intraday trades data for both markets were obtained from the TAQ (Trades and Quotes) database of the NYSE. The trade files include the time of each transaction (stamped to the nearest second), its price and size, the exchange on which the trade took place and various other specifications relating to the transaction.

The study period is the calendar year 2000. We include in our study the stocks that make up a major index for both market centers. For Nasdaq, we choose the stocks that were a part of the Nasdaq 100 index on December 31, 2000 and for NYSE, we choose the stocks that were a part of the S&P 100 index on December 31, 2000. Of course, the S&P 100 index contains a few Nasdaq stocks and we eliminate these stocks from our NYSE sample. Furthermore, we eliminate from both samples the stocks that were included into the indices mid-year. As a result, we end up with 72 stocks for our NYSE sample and 78 stocks for our Nasdaq sample.

TAQ data is not error filtered. The following filters and corrections were used to remove errors: Any trade prices that were non-positive were eliminated. The data were adjusted for stock splits, and cash and stock dividends. The out of sequence trades and other erroneous data entries were eliminated. Also, the days where trading was stopped earlier than the usual close, were eliminated. Finally, the end of the trading day is defined as 4:05 pm rather than 4:00 pm due to possible delays in time stamping the trades and quotes around the close.

4.2 European Markets

The three foreign markets that are studied include the Euronext Paris (Paris Bourse), Deutsche Boerse and the London Stock Exchange. For each market we study the transaction records, during the year 2000, of stocks that make up a major index. We use the BDM database of the Paris Bourse for the transactions of the stocks that make up the CAC 40 index, and the Transaction Data Service database of the London Stock Exchange for the transactions of the stocks that make up the FTSE 100 index. The transactions database of the stocks that make up the DAX 30 index was obtained from the Deutsche Boerse.

Trading hours at the Paris Bourse at the beginning of 2000 were 9:00 am to 5:00 pm. The hours were extended on April 1st to 9:00 am to 5:30 pm. The market opens with a call auction within the first minutes after 9:00 am, and there is another call auction that takes place about 5 minutes after the close. We divide the study period into two intervals: the first interval is from January 1st to March 31st and the second period is from April 2nd to December 31st. The first interval corresponds to the shorter trading hours and the second interval corresponds to the longer trading hours.

Trading hours for Deutsche Boerse at the beginning of the year were 9:00 am to 5:30 pm, but they were extended to 9:00 am to 8:00 pm on June 2nd, 2000. Similar to the Paris Bourse, trading opens with an opening call

auction that takes place within the first few minutes after 9:00 am. There is an intraday call auction a few minutes after 1:00 pm. Also, again similar to the Paris Bourse, there is a call auction that takes place about 5-10 minutes after the close. Before the extension of trading hours, the closing call was around 5:40 pm. After the extended trading hours, this call is kept as the second intraday call auction and the closing call auction takes place few minutes after 8:00 pm. Again, we divide the study period into two intervals. The first interval is from January 1st to May 31st, corresponding to the shorter trading hours, and the second interval is from June 3rd to December 31st, corresponding to the longer trading hours.

Trading hours for the London Stock Exchange are 8:00 am to 4:30 pm. If the one-hour time difference between England and Continental Europe is taken into consideration, then the trading starts at the same time in all three markets. A closing call auction was introduced on May 30th 2000 to the London Stock Exchange. Starting with this date, trading has been ending with a call auction that takes place several minutes after 4:30 pm. We again divide the study period into two intervals. The first interval is from January 1st to May 29th, corresponding to the period without the closing call auction, and the second interval is from June 1st to December 31st, corresponding to the period with the closing call auction.

We include in our study all the stocks that were a part of the DAX 30 and CAC 40 indices as of December 31, 2000, and those for which we have uninterrupted data for the whole year. Our sample selection criteria for the London Stock Exchange stocks are slightly stricter than Deutsche Boerse and Euronox Paris. We treat each of the two periods separately and select the stocks that remained in the index throughout the corresponding study period. The reason is twofold: First, the composition of the FTSE 100 index goes through revisions more often than both the DAX 30 and the CAC40; and second, since there are more stocks in the FTSE 100 index than both DAX 30 or the CAC40, the elimination of several stocks will not diminish the number of stocks we study significantly.

Finally, in order not to have a liquidity bias, for all the markets we eliminated the stocks that traded (over the full span of trading days) in less than 90% of all half hour intervals. Additionally, six days that had a market-wide trading halt in Deutsche Boerse were eliminated. Finally, the data were filtered for any observations with missing volume information. As a result, this methodology gives us a sample of 28 stocks for the Deutsche Boerse, and 39 stocks for the Paris Bourse. In the London Stock Exchange, during the first study period we have 85 stocks and during the second study period we have 88 stocks.

5. EMPIRICAL METHODOLOGY AND RESULTS

Intra-day volume is calculated as the cumulative volume traded across all stocks per market per study period for each half hour interval. In other words, for each of the intra-day half hour periods, we add up all the volume executed for all the stocks in our sample for each market and study period. Since trading volume shows significant variation across different market centers, we present volume traded per half-hour period as a percentage of total volume traded per day. For example, 14 % during the first half hour period in the NYSE means on average 14% of the daily trading volume is executed during the first half hour in this market. In this way, we attempt to make the intra-day trading across markets and time periods comparable. Furthermore, by presenting the intra-day volume as a percentage of daily volume, we avoid the bias that would have been created by double counting in the Nasdaq market. The findings are reported in Figures 1 through 8. In these figures, the horizontal axis denotes the intra-day half hour periods throughout the trading day. The vertical axis denotes the cumulative intra-day volume for each of the half hour intervals as a percentage of daily trading volume executed during that half-hour interval.

As mentioned before, we capture the intra-day patterns of volume of trading by dividing the trading day into several half-hour periods. For example, in a market with a trading day that is six and a half hours long (eg. New York Stock Exchange and Nasdaq) we have thirteen half-hour periods: such as 9:30 to 10:00, 10:00 to 10:30 ... 3:30 to 4:00. We choose half-hour periods since they are commonly used both in the academic literature (e.g. Coughenour 2001) and in the popular media, such as the Wall Street Journal, to report intra-day statistics pertaining to equity trading. Furthermore, we only investigate the intra-day patterns in the largest and most liquid stocks in each of the five markets we studied (NYSE, Nasdaq, LSE, Deutsche Boerse, and Euronext Paris) to avoid any biases that may have been introduced due to a lack of liquidity that is typical of smaller capitalization stocks.

Our findings show a U-shaped intra-day pattern for trading volume in the US markets. However, we fail to find a similar U-shaped pattern for intra-day volume in the European markets. In the European markets, heavier trading occurs towards the end of the trading day. We believe, this issue is related to the time difference between USA and Europe, and that trading in Europe picks up when the trading in the US exchanges start due to information that flows from the US market into the European market.

Deutsche Boerse data allow us to isolate the volume traded during the opening and intra-day call auctions as well as the closing call auctions. The call auctions in the Deutsche Boerse are the most successful, in terms of volume traded, across the call auctions in all three European markets. For both of the study periods there is heavy trading at the intra-day call auctions.

On June 2nd, 2000, trading hours at the Deutsche Boerse were extended from 9:00-5:30 to 9:00-8:00. However, the findings show that the extended hours were not very successful as the trading activity from 5:30 to 8:00 is much lower compared to the rest of the day. Furthermore, average volume traded per stock on a trading day remains almost the same across both periods. As a result, the effect of extending the trading hours has been spreading the volume over a longer trading day. These findings suggest that there is a memory carry-over. Namely, that 5:30 remains the effective close even after the trading hours were extended.

Similar to Deutsche Boerse, the trading hours on the Euronext Paris have been extended by half an hour by changing the close from 5:00 pm to 5:30 pm on April 1st, 2000. Contrary to Deutsche Boerse, this extension appears to have been successful as the trading volume is the highest during the period 5:00 to 5:30 pm.

Finally, one striking finding regarding the domestic markets is the similarity in the intra-day pattern of volume in Nasdaq and the NYSE. Both markets show that volume is U-shaped with a bigger spike at the open in both markets. One difference between the two markets is that volume is marginally lower at Nasdaq compared to the NYSE both at the opening and the closing half-hour. We should caution that we are not referring to the “level” of volume in this study, simply to its pattern over the trading day.

The relationship between volume and volatility is an interesting empirical question. We expect that if a certain part of the day is characterized by higher volatility (and inefficient price discovery) then investors might be more wary of trading during that part of the day. In this case, we would expect to see a lower trading volume during higher volatility periods. Also, it might be the lack of volume that creates the excessive volatility. In a market without liquidity, the impact of individual trades would be greater in moving the prices in comparison to a market with more participants. On the other hand, if it is volume (or trading activity) that creates the volatility, then we should observe higher volatility during the periods that have higher relative volume.

In addition to the old Wall Street adage “It takes volume to move the prices,” there are several academic studies that show that there is a positive relationship between volume and volatility. On the other hand, there are also several academic studies that suggest that high volatility is followed by low volume or that volatility discourages trades from the market. These studies were reviewed in section two, literature review.

Even though the focus of the current study is not the relationship between volume and volatility, our findings are note-worthy in the sense that the European market results do not confirm to other studies that find that there is typically a U-shaped pattern to both intra-day volume and volatility. A study of volatility patterns in the five markets included in the current study can be found at Ozenbas (2006).

For instance, Ozenbas (2006) shows that opening half-hour volatility in the London Stock Exchange is extremely accentuated, it is more than 3 times the average mid-day volatility. On the other hand, volume in the morning period in this market is the lowest among the five markets studied. Only about 2% of daily volume is executed in the first half hour at the LSE compared to 14% for Nasdaq and NYSE, 5% for Deutsche Boerse and 7% for Euronext Paris. This is an unexpected result in the light of several academic studies that find a positive link between volume and volatility. The finding suggests reluctance on the part of LSE traders to trade during the highly volatile morning hours.

6. DISCUSSION AND FUTURE RESEARCH

In this paper, we investigate the pattern of intra-day volume of trading in five different equity markets: The New York Stock Exchange and NASDAQ in the US, and The London Stock Exchange, Deutsche Boerse, and Euronext Paris in Europe. For the European markets, we repeat our investigation for two separate study periods to check for the consistency of our results and also to account for important rule changes that took place in the middle of the year. Also, in all the markets in this study, we choose the most liquid stocks during each study period in order to avoid any bias that may stem from a lack of liquidity that is typical of smaller capitalization stocks. Clearly, extending our research into lower capitalization stocks is an important venue that might merit future research.

The five markets we choose represent a wide array in terms of the structures of these markets. The New York Stock Exchange is an order-driven market with a trading floor. The Nasdaq Stock Market is a dealer market, however with a growing order-driven electronic trading component (the Electronic Communication Networks). The European markets are all electronic trading platforms, however with distinctive characteristics in each. The London Stock Exchange, for instance, has evolved from a dealer-market structure and is still influenced by this culture. Deutsche Boerse is the only market in this study that employs intra-day call auctions, and Euronext Paris is a market with a relatively high level of transparency.

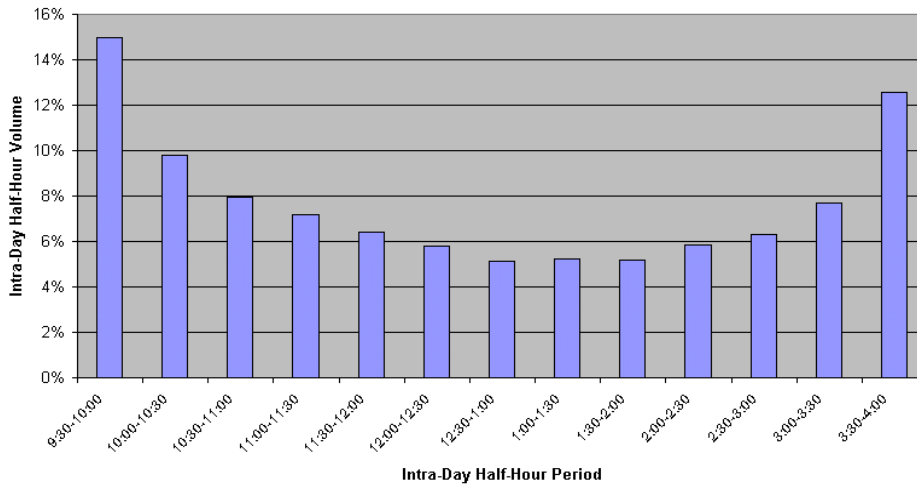
Our results show that the pattern of trading volume varies substantially across different markets. For the US markets, the intra-day pattern of volume is a reverse J-shape, very similar to the intra-day pattern of volatility.

On the other hand, for all the European markets, volume picks up towards the end of the trading day. The most striking case is the London Stock Exchange, where, at the beginning of the day, the volume is the lowest and the volatility accentuation is the highest, across all markets studied.

The pattern of volume in the European markets suggests that the opening of trading in the US markets (and the consequent transfer of information) is important in the price formation process for European stocks. Clearly, one more area that is a natural extension of this study is to find whether there are any variations in the volume patterns of cross-listed stocks. Conversely, one would expect the American Depository Receipts to have a unique volatility/volume pattern, as opposed to the domestic stocks, due to the price discovery that carries over from their home market to the US market.

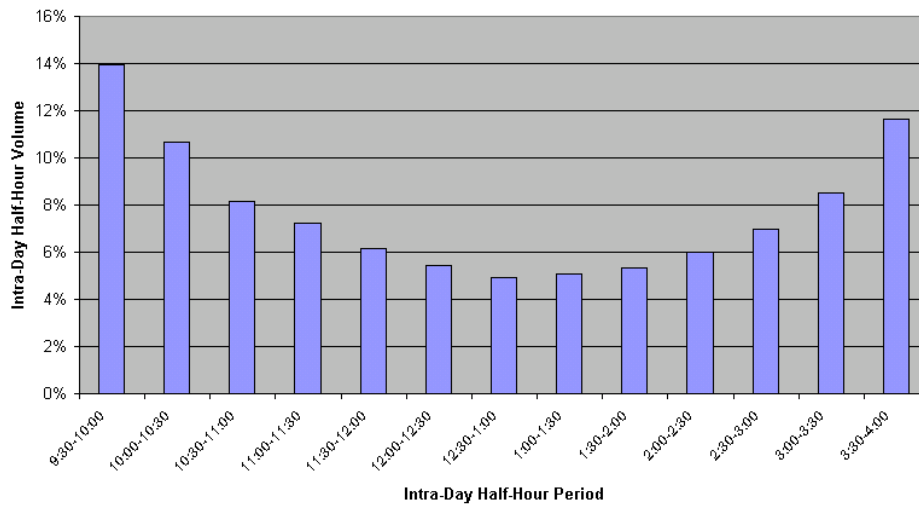
The intra-day pattern of stock trading volume indicates a very intricate process of price discovery in equity markets. We are able to make statements about the quality and efficiency of markets through investigating these patterns. All told, an intra-day analysis of trading volume raises many exciting questions that should lead the way to new and fruitful research.

Figure 1. Intra-Day Volume, New York Stock Exchange



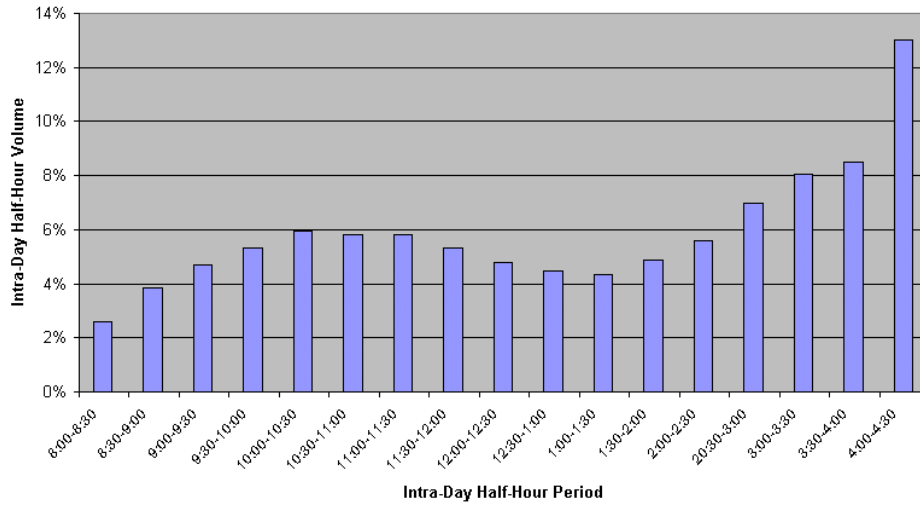
Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The study period is January-February 2000.

Figure 2. Intra-Day Volume, Nasdaq Stock Market



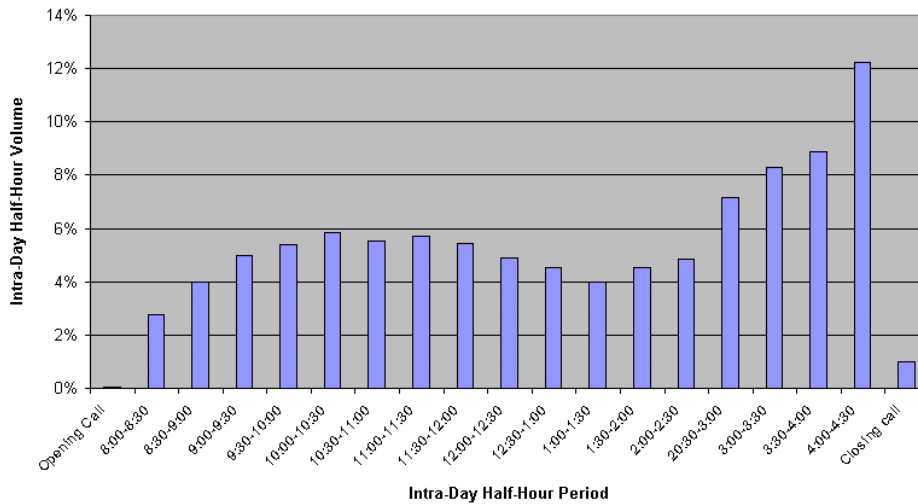
Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The study period is January-February 2000.

Figure 3. Intra-Day Volume, London Stock Exchange, First Study Period



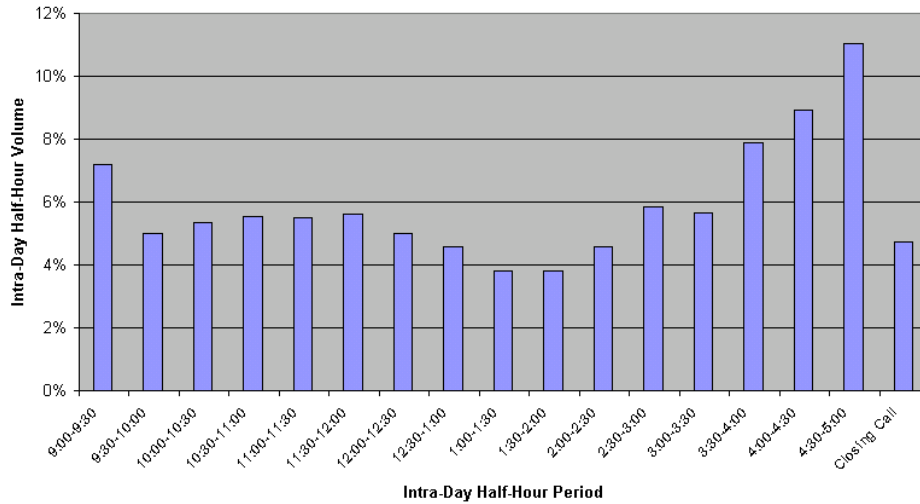
Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The first study period is January-May 2000 and the second study period is June-December 2000.

Figure 4. Intra-Day Volume, London Stock Exchange, Second Study Period



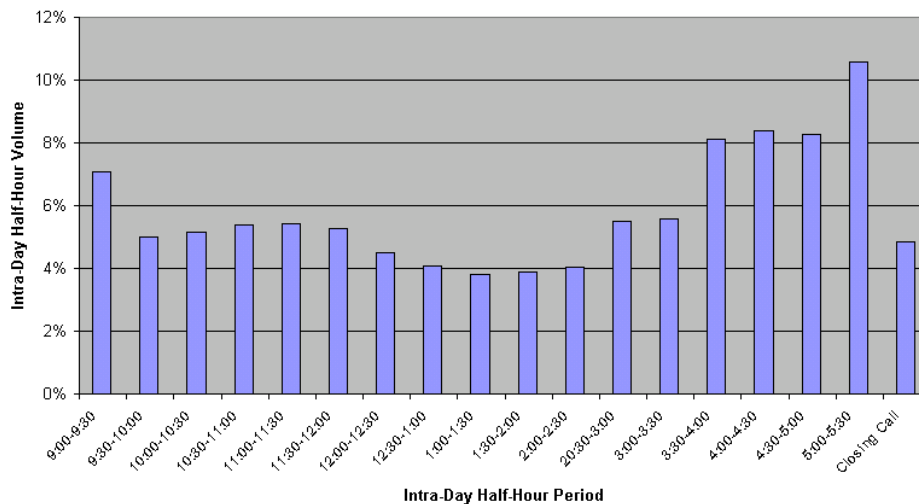
Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The first study period is January-May 2000 and the second study period is June-December 2000.

Figure 5. Intra-Day Volume, Euronext Paris, First Study Period



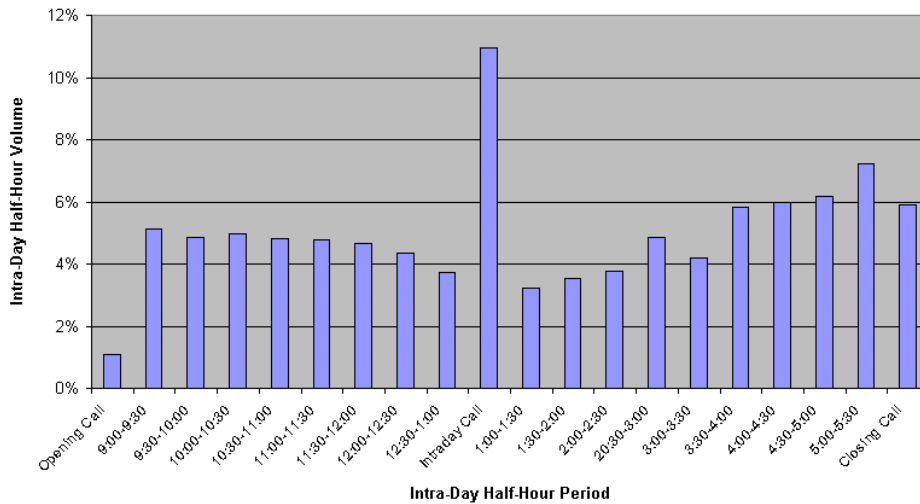
Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The first study period is January-March 2000 and the second study period is April-December 2000.

Figure 6. Intra-Day Volume, Euronext Paris, Second Study Period



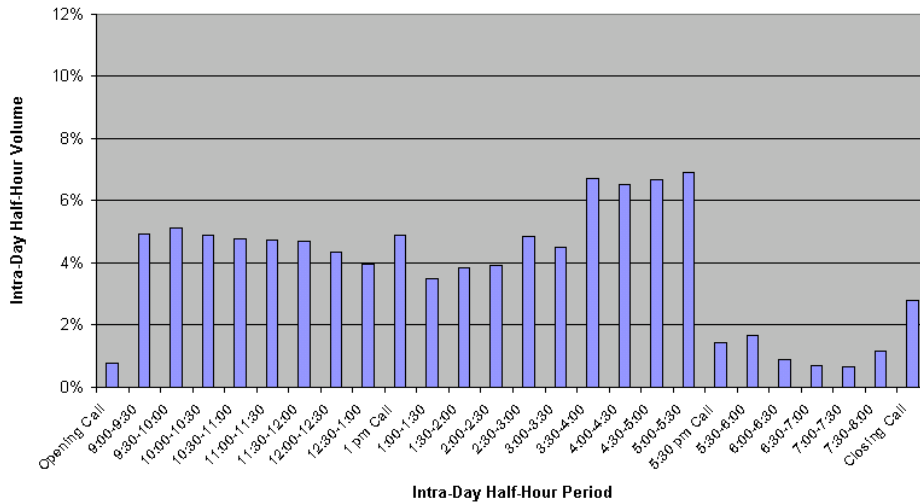
Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The first study period is January-March 2000 and the second study period is April-December 2000.

Figure 7. Intra-Day Volume, Deutsche Boerse, First Study Period



Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The first study period is January-May 2000 and the second study period is June-December 2000.

Figure 8. Intra-Day Volume, Deutsche Boerse, Second Study Period



Intra-day half hour volume is presented as the cumulative volume traded during that half-hour period as a percentage of total daily volume traded. Volume is calculated as the cumulative volume across all the stocks in the sample for each of the half hour periods during the trading day. The first study period is January-May 2000 and the second study period is June-December 2000.

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Deniz Ozenbas is an Associate Professor of Finance at Montclair State University School of Business. Her research is mainly in the field of market microstructure and market efficiency. Her work has been published in journals that include *International Finance and Economics Letters*, and was presented at domestic and international conferences. She has been awarded the Nasdaq Dissertation Fellowship by the Nasdaq Stock Market in 2002, and received the Oscar Lasdon Award for best dissertation in the area of Finance from Baruch College, City University of New York in 2003. Her joint work with Robert A Schwartz and Robert A. Wood has received the Award for Excellence / Outstanding Paper award at the Global Conference on Business and Economics annual meeting in London, England. Dr. Ozenbas holds a PhD in Finance from Baruch College, City University of New York, and a BA from Bogazici University, Turkey.

REFERENCES

1. Admati, R. Anat, and Paul Pfleiderer, 1988, A theory of intraday patterns: Volume and price variability, *The Review of Financial Studies* 1, 3-40.
2. Bessembinder, Hendrik and Subhrendu Rath, 2002, Trading Costs and Return Volatility: Evidence from Exchange Listings, Working Paper.
3. Biais, Bruno, Pierre Hillion, Chester Spatt, 1999, Price discovery and learning during the pre-opening in the Paris Bourse, *Journal of Political Economy* 107, 1218-1248.
4. Brock, W and A Kleidon, 1992, Periodic Market Closure and Trading Volume: A Model of Intraday Bids and Asks, *Journal of Economic Dynamics and Control* 16, 451-489.
5. Cao, Charles, Eric Ghysels, and Frank Hatheway, 2000, Price Discovery without Trading: Evidence from the Nasdaq Preopening, *Journal of Finance* 56, 1339-1365.
6. Chakravarty, Sugato, Robert A. Wood, and Stephen Harris, 2002, Decimal Trading and Market Impact, Working Paper.
7. Chan, K, W Christie and P Schultz, 1995, Market Structure and the Intraday Pattern of Bid-Ask Spreads for NASDAQ Securities, *Journal of Business* 68, 35-60.
8. Chordia Tarun, Richard Roll and Avanidhar Subrahmanyam, 2001, Market liquidity and trading activity, *Journal of Finance* 56, 501-530.
9. Chordia T and B Swaminathan, 2000, Trading Volume and Cross-Autocorrelations in Stock Returns, *Journal of Finance* 55, 913-936.
10. Christie, W, S Corwin and J Harris, 2002, Nasdaq Trading Halts: The Impact of Market Mechanisms on Prices, Trading Activity, and Execution Costs," *Journal of Finance* 57, 1443-1478.
11. Coughenour, Jay, 2001, Price Movement and the Relative Flow of Different size Orders, Working Paper.
12. Domowitz, I and A Madhavan, 2001, Open Sesame: Alternative Opening Algorithms in Security Markets, *The Electronic Call auction: Market Mechanism and Trading* (ed. R A Schwartz), Kluwer Academic Publishers.
13. Fleming, Michael J, and Eli M Remolina, 1999, Price Formation and Liquidity in the US Treasury Market: The Response to Public Information, *Journal of Finance* 54, 1901-1915.
14. Gerety, M and JH Mulheren, 1994, Price formation on stock exchanges: the evolution of trading within the day, *Review of Financial Studies* 7, 609-629.
15. Harris, Lawrence, 1986, A transaction data study of weekly and intradaily patterns in stock returns, *Journal of Financial Economics* 16, 99-118.
16. Jain, Prem, and Gun-Ho Joh, 1988, The Dependence Between Hourly Prices and Trading Volume, *Journal of Financial and Quantitative Analysis* 23, 269-285.
17. Kleidon W and I Werner, 1993, Round the Clock Trading: Evidence from UK Cross-Listed Securities, Working Paper.
18. Lee, Charles M C, Mark J Ready, Paul J Seguin, 1994, Volume, volatility, and New York Stock Exchange trading halts, *Journal of Finance* 49, 183-215.
19. Madhavan, A and V Panchapagesan, 2000, Price discovery in auction markets: A look inside the black box, *Review of Financial Studies* 13, 627-658.

20. Madhavan, A, M Richardson and M Roomans, 1997, Why do security prices change? A transaction-level analysis of NYSE stocks, *Review of Financial Studies* 10, 1035-1064.
21. Ozenbas, Deniz, 2006, Pattern of Short-Term Volatility Accentuation Within the Trading Day: An Investigation of the US and European Equity Markets, *International Business and Economics Research Journal*.
22. Pagano, Michael S. and Robert A. Schwartz, 2002, A closing call's impact on market quality at the Paris Bourse, *Journal of Financial Economics*, forthcoming.
23. Schwartz, R A, 1993, Reshaping the Equity Markets, Irwin.
24. Stoll Hans R., and Robert E. Whaley, 1990, Stock Market Structure and Volatility, *Review of Financial Studies* 3, 37-71.
25. Stoll, Hans, 2000, Friction, *Journal of Finance* 55, 1479-1515.
26. Wood, Robert A. and Thomas H. McInish, 1992, An analysis of intraday patterns in bid/ask spreads for NYSE stocks, *Journal of Finance* 47, 753-764.
27. Wood, Robert A., Thomas H. McInish, and Keith Ord, 1985, An investigation of transactions data for NYSE stocks, *Journal of Finance* 40, 723-741.

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