The Hidden Cost of Trading at the Close

DAVID CUSHING AND ANANTH MADHAVAN

DAVID CUSHING
is managing principal at Inference Group LLC, in Waltham, MA.

ANANTH MADHAVAN
is managing director, research at ITG Inc. in New York, NY.

Closing stock prices are widely used as benchmarks of value. Portfolio returns and mutual fund net asset values are computed using closing prices and some contracts and after-hours trading on various Alternative Trading Systems (ATS) and Electronic Communications Networks (ECNs) are based on closing prices.[1] For these reasons, many traders, especially institutions such as passive index funds, try to trade at or near the day's close. Increasingly large trading volumes at the end of the trading day have in turn complicated the task of price discovery and led to growing concern about the ability of markets to provide liquidity in this critical period. Indeed, herding by institutional traders can cause large price movements at the close, typically in the same direction as institutional demand. As such, these price movements represent a substantial transaction cost, even to those traders who trade at the closing price of the day.

A recent case involving Safeway stock offers an interesting, albeit unusual, example of these issues. On November 12, 1998, Safeway stock was to be added as of the close to the S&P 500, following an announcement made the previous week.[2] Consequently, many index funds wanted to add Safeway stock to their portfolios at the closing price on November 12. High demand resulted in a large order imbalance at the close and closing price was set at $55, up 11% from the previous trade. In subsequent overnight trading Safeway stock fell in price, closing at $51.1875 the following day. There was considerable criticism of large closing price movement by institutional traders who argued that they had overpaid for the stock. The Safeway case spurred "intensive debate over how the close, the most critical time of the day, should be handled." (Ip [1999]) Similarly chaotic closings for other S&P 500 additions and deletions including Amoco Corporation and America Online Inc. on December 31, 1998 also illustrate the difficulties in determining efficient closing prices and the importance of widely disseminating information on order imbalances.

Indeed, increasingly large order imbalances toward the end of the trading day have been the source of considerable concern. Specifically, exchanges have imposed various rules on the submission of market and limit-on-close orders to alleviate problems associated with day-end order imbalances.[3] Similarly, the Standard & Poor's Corporation announced on December 30, 1998 that it would delay announcement of additions and deletions from its stock indexes after the close of trading, noting that "We don't want our announcements to affect a stock's official closing price for the day."[4]

Although a considerable body of research has documented various anomalies in intraday returns, volumes, and volatility,[5] research on how closing prices are determined is relatively recent. Hillion and Suominen [1998] study the closing prices of the CAC 40 stocks of the

Paris Bourse and find evidence of reversals in the overnight period and also higher volatility and spreads at close. Thomas [1998] studies the effect of the implementation of a closing call auction on the CAC 40 stocks of the Paris Bourse. She finds that orders are larger and there are fewer cancellations at the close. Further, the negative correlation with intraday returns observed before the implementation of a closing call disappears after the change in closing procedures. Finally, the closing period exhibits more intensive trading and larger volumes following the rule change.

While these studies shed light on how closing prices are set, many questions remain unanswered. Specifically, we focus on three key questions. First, we want to examine the magnitude of returns at day-end. Anecdotal evidence suggests the closing period return accounts for a disproportionately large share of the daily return. Is this the case, and if so, is there any evidence that end of day returns reflect systematic factors common to a broad cross-section of stocks? Second, we are interested in the determinants of returns toward the close. Specifically, are day-end returns driven by order flow or are returns more sensitive to order flow at the close? The answer to this question would shed additional light on observed return anomalies and the possibility of market manipulation or gaming at the close. Third, from a policy perspective, new protocols have been implemented to disseminate order imbalance information at the close to reduce price volatility. But does the publication of order imbalances at the close successfully eliminate temporary price pressure, and if not, are there predictable price reversals the following day? This article examines these three sets of issues across the stocks of the Russell 1000 index using: 1) transaction-level data for the period July 1997 to June 1998, and 2) the complete record of all Market On Close (MOC) order imbalance indications issued by the New York Stock Exchange (NYSE).

Our study yields several new results. First, we show that the last five minutes of the trading day explains a disproportionate fraction of the variation in daily returns. Interestingly, this effect is much stronger in portfolios than in individual stocks. Indeed, in portfolios, this fraction is almost 18% although the closing period constitutes only 1.3% of trade time. By contrast, in individual stocks, the corresponding fraction is only 4%. This finding is consistent with the hypothesis that institutional trading interest induces a common component to stock returns at the end of the day. Second, we examine the cause of the disproportionately large closing period returns. We use a model of the return-generating process and find that the closing period return behavior reflects two factors: 1) the percentage of large-block trades *decreases* at the end of the day, and prices are more sensitive to nonblock order flow than to block order flow, and 2) nonblock order flows have a greater price impact at the close relative to other times of the day.

Third, we analyze return patterns following order imbalance publications. We find positive (negative) overnight returns following publicized sell (buy) imbalances. This effect is especially strong on index expiration days where the imbalances arise primarily from liquidity trading. Interestingly, the same pattern of reversals is observed in next-day returns as well. This phenomenon does not reflect negative autocorrelation in order flow. Rather, our evidence suggests that prices overreact to order imbalances at the close. The return reversal the following day occurs because the opening price the next day is "sticky" in the sense that it is a weighted average of the previous day's close and the price implied by overnight flows. From a practical viewpoint, these results demonstrate that transitory order imbalances can bias closing prices. We discuss the implications of our results in terms of the effectiveness of imbalance publications, and explore alternatives to enhance price efficiency and lower volatility at the close. These include greater transparency, wider dissemination of order imbalances, and special protocols at the close such as a call auction in active stocks or on expiration days.

The article proceeds as follows: The second section describes our data sources and procedures. The third section provides evidence on the relative contribution of closing period returns to the daily return. The fourth section examines the determinants of closing returns across stocks focusing on the role of order flow. The fifth section discusses the properties of returns following publication of order imbalances, and the sixth section concludes by summarizing our results and their policy implications.

DATA SOURCES AND PROCEDURES

The primary source of our data is the NYSE's Trades and Quotes (TAQ) files for July 1997 to June 1998. The TAQ files record, on a stock-by-stock basis, transaction-level data on prices, quotes, and volumes, time-stamped to the second. Our sample universe is the Russell 1000. The Frank Russell Company equity indexes are popular benchmarks of US stock market performance. The Russell 1000 Index® consists of the top 1,000 U.S. stocks by market capitalization. The universe of stocks from which

Russell chooses index constituents includes domestic common stocks and REITs but excludes certain issue types such as royalty trusts and closed-end mutual funds. In order to restore its capitalization-based definition and replace stocks that drop out over time due to corporate actions and bankruptcies, the Russell 1000 is reconstituted annually at the end of June. This fact accounts for our choice of July 1 as the starting date of the data set. We restrict attention to common stocks that were continuously present in the Russell 1000 universe during the sample period and for which all study data were available.

Some of our analyses require information on the net order flow. We use the procedure suggested by Lee and Ready [1991] to classify trades as buyer- or seller-initiated. Specifically, we compare the trade price to the midpoint of the "prevailing" bid and ask quotes; we use a 15-second lag on quotes to correct for differences in the clock speed with which trades and quotes are reported. Trades whose prices are above (below) the midpoint are classified as "positive" ("negative") volume. Trades at the quote midpoint (e.g., upstairs crosses) generally cannot be classified in this manner, and are classified as "zero" volume trades. We define net order flow as positive share volume less negative share volume. We eliminated from the sample those stocks for which volume data was incomplete (e.g., because of difficulties in matching quotes and trades) and stocks that did not trade at least once per day, leaving us with a sample of 769 stocks.

Finally, from the NYSE we obtained information on whether there was a publicized market-on-close buy or sell imbalance for each stock for each of the 252 days in the sample period.[6] Imbalances were disseminated in an effort to reduce problems associated with market-on-close (MOC) orders.[7]

THE IMPORTANCE OF DAY-END RETURNS

We begin our analysis by asking whether returns toward the end of the day are "important" in the sense that they represent a large fraction of the day's return. We decompose the open-to-close period from 9:30 a.m. to 4:00 p.m. into 13 half-hour intervals or trading sessions. We then regress, for each of the 769 sample stocks,

$$\text{DailyRet} = \alpha + \beta \text{CloseRet} \tag{1}$$

where CloseRet is the return from 3:55 to 4:00 p.m. and DailyRet is the daily return.

If returns across trading sessions contribute equal amounts to the whole day's return, the regression R-squared (a measure of goodness of fit) is approximately 1/78 (or 1.28%). However, if trading in the last five-minute period is unusually informative, the R-squared should be greater than 1.28%. Conversely, if the last five-minutes of trading are predominantly affected by liquidity trading, adding noise to the process, the R-squared will be below this figure.

The results of this exercise confirm our intuition about the closing period. Indeed, the regression R-square is 3.81% for all stocks, much higher than the naive benchmark (this is also statistically significant). Similarly, we find that the return in the last half-hour represents a disproportionately large fraction of the day's return in the most active stocks, but not in less active stocks.

Could institutional trading at the close explain the results above? In particular, suppose that institutional trading contained a common component that was especially present at the close. Then, since institutions are trading together—and are more likely to be doing so at the close than at other times, this common component would be manifested in a higher correlation among stock returns in the closing period. In other words, if we were to repeat the regression exercise above, grouping stocks into portfolios, we would expect an even more dramatic effect in the closing period.

Accordingly, to focus attention on factors common to all the sample stocks, we group stocks into portfolios by trading activity deciles. We then estimate regressions of a similar form to those reported above where returns are equally weighted for decile portfolios and for all stocks in the sample. Specifically, each regression is of the form:

$$\text{DailyPortRet} = \alpha + \beta \text{ClosePortRet} \tag{2}$$

Exhibit 1 summarizes the results for regressions of individual and portfolio daily returns on returns in the last five minutes of trading. The portfolio analogue of the individual regression model offers strikingly different results. Indeed, in all deciles, the adjusted R-squared is much higher in portfolios, as is evident in Exhibit 1, and overall it is 17.55%.

This shows that the abnormal returns in the last five minutes tend to be common across stocks, i.e., market-wide in nature. These systematic factors are not averaged out in the portfolio formation process unlike the idiosyncratic returns in the previous 25 minutes, consistent with

EXHIBIT 1

Percentage of Daily Returns Attributable to Last Five Minutes

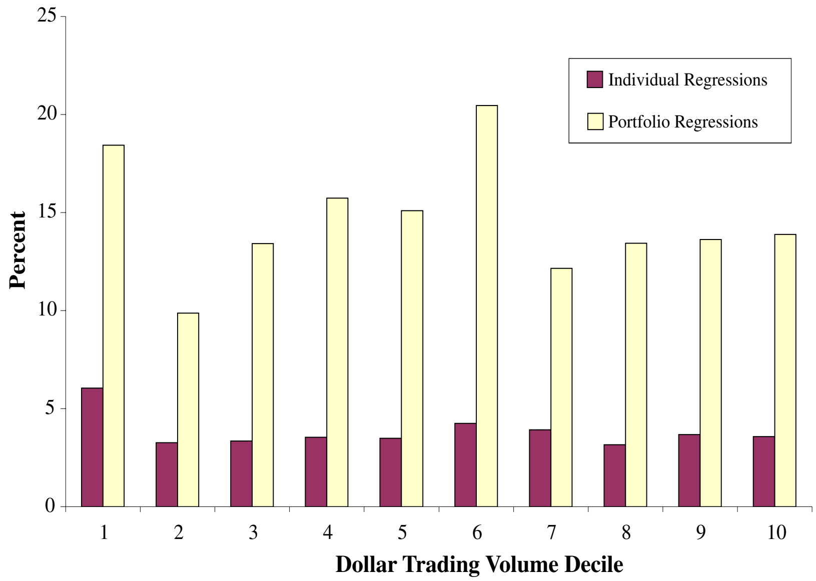
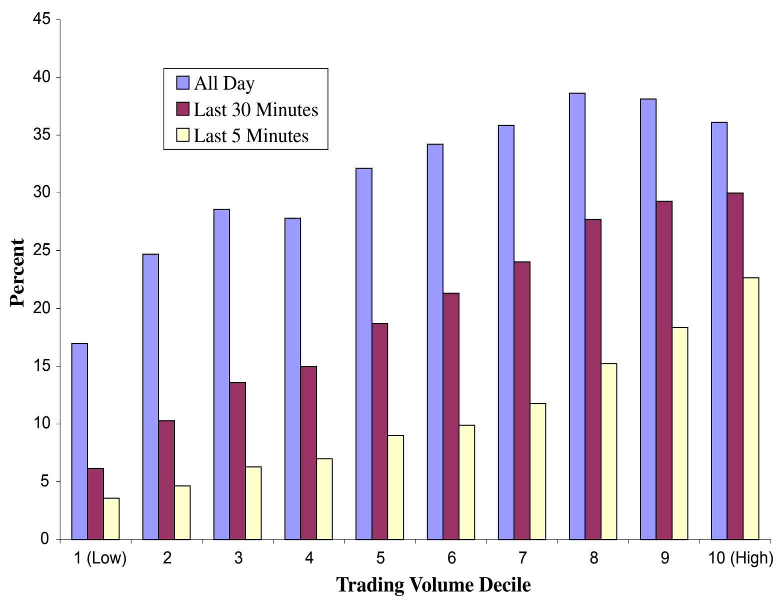


EXHIBIT 2

Percentage of Volume in Blocks by Time of Day



the concentration of institutional trading at the close. It is worth noting that this result is unlikely to be driven solely by nonsynchronous trading since the stocks in the sample trade frequently. This is especially so for the stocks in the active deciles that trade very frequently, often several times in a minute.

ORDER FLOW AND RETURNS AT THE CLOSE

The Composition of Trading Volume

The previous section demonstrates that the closing period return is important in a real sense, especially when measured in portfolios, but does not explain *why* this is the case. We turn now to an analysis of the determinants of this return. Our theoretical hypotheses suggest that the observed return behavior may reflect the effects of larger order flows at the close, perhaps arising from institutional trading. Since institutions are more likely to place large-block trades than retail traders, it makes sense to begin by studying the composition of trading volume.

Exhibit 2 plots the average daily block-trading volume as a percentage of total trading volume (where a block is defined as 10,000 or more shares), the average daily block-trading volume 30 minutes before closing as a percentage of total trading volume 30 minutes before closing, and the average daily trading volume five minutes before closing as a percentage of total trading volume five minutes before closing. Overall, the volume of trading done in blocks was 31.3% of total trading.

Two findings are apparent from the figure. First, more active stocks tend to have a larger fraction of volume in large-block trades in all time periods. Second, and contrary to popular belief, the frequency of block trading actually diminishes toward the close. For all stocks, the percentage of block volume in the last half hour is 19.6% and just 10.8% in the last five minutes of trading. Many large-block trades originate in the so-called "upstairs" market where block brokers facilitate large trades by locating counterparties. This process takes time and traders seeking immediacy may not wish to run the risk of failing to execute because the difficulty in locating counterparties is toward the end of the day. The result is also consistent with a high demand for immediacy at day-end that may reflect the actions of institutional traders seeking to trade at or near the closing price. But can these results help explain why closing period returns account for such a significant fraction of the day's returns in portfolios? To answer this question, we need to model the return-generating process.

A Model of the Return-Generating Process

In the classical model of an efficient security market, prices move in response to new public information that causes traders to simultaneously revise their beliefs. The process of trading itself may generate price movements because of frictions such as inventory control by market makers or because order flow is motivated by private information. Madhavan, Richardson, and Roomans [1997] show that price movements reflect both public information and trading volume.

To investigate the effects of order flow on closing returns, we propose a trading model where prices respond to public information flows and to trading volumes. Specifically, we model the open-to-close return DailyRet as:

$$\text{DailyRet} = \alpha + \beta_1 \text{NonBlkDay} + \beta_2 \text{BlkDay} + \gamma_1 \text{NonBlkCls} + \gamma_2 \text{BlkCls} \quad (3)$$

where NonBlkDay is the signed nonblock order flow from the opening to 3:30 p.m. (expressed as a percentage of average daily volume in stock *i*), BlkDay is the corresponding signed block volume in the period prior to 3:30 p.m., NonBlkCls is the signed nonblock order flow (as a percentage of average daily volume in stock *i*) from 3:30 p.m. to the close, and BlkCls is the signed block volume in the period from 3:30 p.m. to the close. The coefficients (β and γ) are *order flow sensitivities* that capture the price impacts of nonblock and block volume in the period prior to and during the last half hour of trading, and α captures the mean revision in share prices associated with public information flows unrelated to trading volumes.

There are two major hypotheses of interest. First, we want to know if the reaction of prices to block and nonblock volumes is similar. Since block traders can always break up their trades into smaller packages for anonymous execution through automated systems such as SuperDOT on the NYSE or Small Order Execution System (SOES) on Nasdaq, we might expect that the price impact of a trade should be the same irrespective of whether it was executed as a block or as a smaller trade. Alternatively, if block order flow arises primarily from institutional traders, we expect that the responsiveness of prices to block and nonblock flows should be different because institutional traders may differ from the general public in terms of the perception for informed trading. Further, block trades may also be placed through the upstairs market (see, e.g., Keim and Madhavan [1998]) with possibly different price consequences.

The second question of interest is whether there are differences in the responsiveness of stock prices to order flow (both block and nonblock) at different times of the day. Again, our motivation is to detect whether order flow and its composition can explain our results concerning the returns toward day-end.

We estimated the regression model with order flow variables for individual regressions for all 769 stocks in the sample. The model performs very well; the coefficient estimates on volume are of the predicted positive sign and significance levels are generally high. The results are summarized in Exhibit 3.

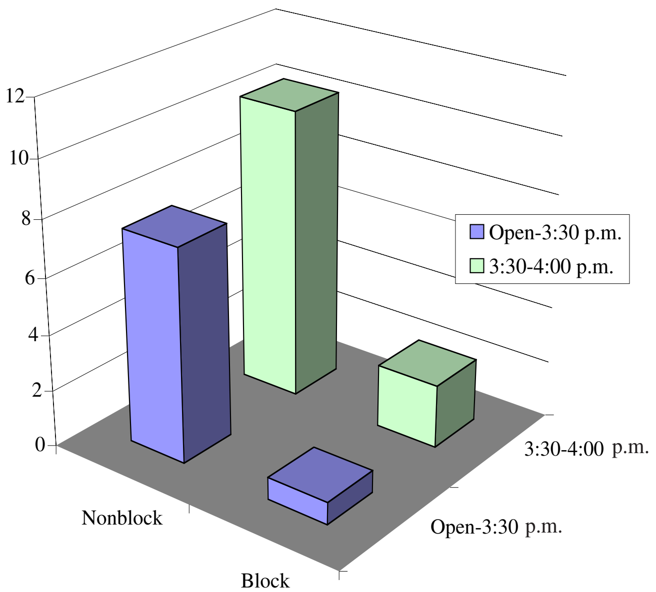
Two interesting points are worth noting: First, observe that the coefficients on nonblock volume are much larger in magnitude than the corresponding coefficients on block volume. For the average stock, the coefficient on nonblock volume is 7.57 in the time before the last half-hour but the corresponding coefficient on block volume is only 0.78. This is consistent with the hypotheses advanced in previous work that large-block trades have lower price impacts because they originate in the upstairs markets. This finding might explain part of the heightened sensitivity of closing period returns.

Second, the average sensitivities to block and nonblock order flow are *higher* in the closing period than in the rest of the day. The coefficients on nonblock and block volumes at the close are 10.29 and 2.24, respectively, as opposed to 7.57 and 0.78 in the period prior to 3:30 p.m. Third, there is a general tendency for the order flow sensitivities to increase with trading activity deciles, as does the adjusted R-square.

Statistical results confirm the intuition from the figure. In particular, in 93.37% of stocks, we can reject (at the 1% significance level) the null hypothesis that the composition of order flow does not matter. This is not surprising given the differences between block trades in upstairs and downstairs markets. More interesting are the results of the tests on whether the order flow sensitivities for the separate volume components are constant across periods. In the most active decile, the percentage of stocks for which we can formally reject the hypothesis of equal

EXHIBIT 3

Estimated Coefficients of Order Flow Model for All Stocks



sensitivities across periods (i.e., $\beta = \gamma$) is 35.07%. It is worth noting that these results are not driven by correlation in order flow, which although positive, is weak for both the block and nonblock components.

In summary, our results suggest that the closing return phenomena described in the previous section can be explained in terms of order flow: 1) the percentage of large-block trades decrease*s* at the end of the day, and prices are more sensitive to nonblock order flow than to block order flow, and 2) nonblock order flows have a higher price impact at the close relative to other times of the day.

EVIDENCE ON MOC IMBALANCES

To assess the relative importance of imbalance indications, we computed the size of disclosed imbalances relative to average daily volume in the stock over the entire sample of imbalances. For buy imbalances the mean ratio of the imbalance to average daily volume is 13.29% (the median is 4.30%) while for sell imbalances the corresponding ratio is 10.59% (median of 5.49%). Thus, the publicized size of imbalances is relatively large compared to average daily volume and the distribution is strongly right-skewed indicative of some extreme observations.

To understand the effectiveness of imbalance publications, we investigated the pattern of returns and volume following MOC imbalances focusing on the pre-June 24 period. We computed two returns following market-on-close (MOC) imbalance indications: 1) close to next-day open returns, and 2) next-day open to close returns, all in percent. We break this down separately for MOC buy and sell imbalance indications and for index expiration and nonexpiration related imbalances.

Exhibits 4 and 5 summarize our results for buy and sell imbalances, respectively, breaking this down by index expiration days and nonexpiration days. There is clear evidence that closing prices reflect temporary price pressure that is reversed in subsequent trading. For example, for buy imbalances, next day overnight and daily returns significantly are negative. On days following sell imbalances, returns both overnight and in the next day are positive and significantly different from zero. These patterns hold for both overnight and next day returns, and are especially strong on index expiration days. Since expiration related imbalances are unlikely to reflect fundamental information (Sofianos [1994]), the conclusion that emerges is that temporary liquidity effects bias closing prices.

Our finding that next day open-to-close returns are positive (negative) following sell (buy) imbalances merits further comment. One explanation for the documented return behavior on the next day after the imbalance is that it simply reflects negative autocorrelation in order flow. However, our evidence suggests otherwise. Rather, we believe that this pattern can be explained by the fact that closing prices overreact to order imbalances and that the opening price the next day is biased toward the previous day's close, as shown by Madhavan and Panchapagesan [2000].

CONCLUSIONS

Institutional traders place enormous importance on closing stock prices as benchmarks of value. Closing prices are used to calculate portfolio returns, tally the net asset values of mutual funds, and as a basis for certain types of contracts and after-hours trading. This article analyzes empirically the behavior of stock returns at the close across the stocks of the Russell 1000.

We demonstrate that the closing period accounts for a disproportionate fraction of a stock's daily return. This is due to two factors: First, the sensitivity of returns to order flow is greater in the closing period, implying higher market impact costs. Second, the ratio of volume

EXHIBIT 4
Returns Following MOC Sell Imbalance Publications

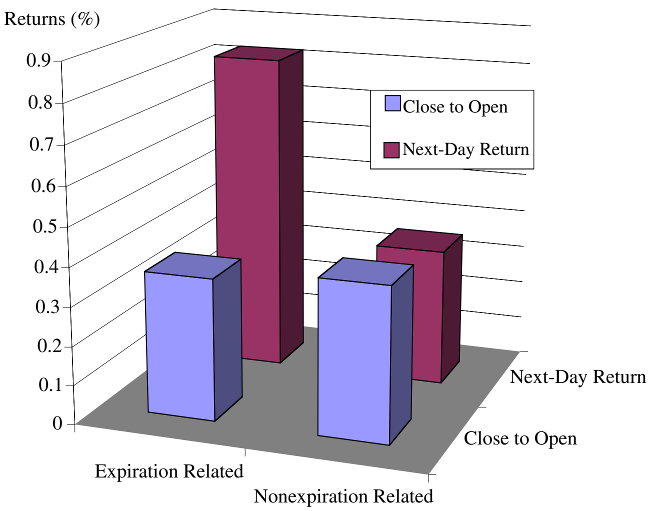
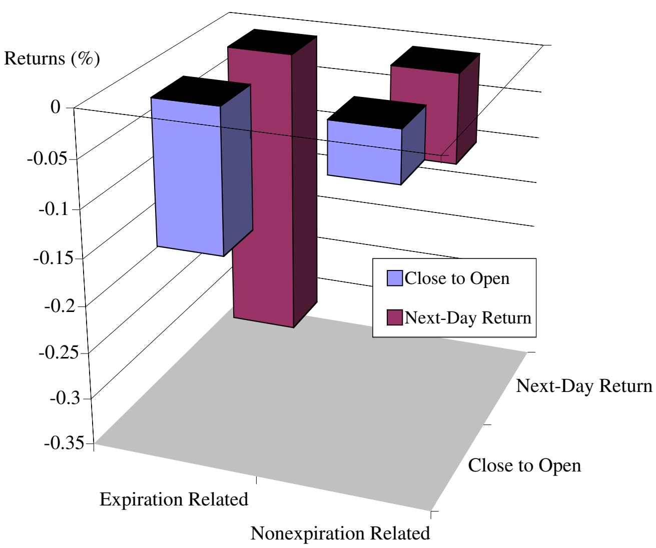


EXHIBIT 5
Returns Following MOC Buy Imbalance Publications



in large-block trades to total volume falls sharply in the last five minutes of the day, and nonblock trades have a greater price impact than large-block trades. The effect is significantly stronger in portfolios where almost 18% of the variation in daily returns is explained by the return in the last five minutes of trading, despite the fact that this period only accounts for 1.3% of the trading day. This result is consistent with the hypothesis that institutional trading interest induces a common component to stock returns at day-end. Finally, using new data on market-on-close order imbalance publications, we find systematic return reversals, especially on days related to index expirations. This is consistent with our hypothesis that liquidity trading at the close on these days creates transitory price movements that represent a substantial hidden cost to institutions.

Our analysis has several implications for investors, portfolio managers, regulators, and exchange officials. First, the results support the view that end-of-day return anomalies may be explained in terms of concentrated trading at the close. This implies that phenomena such as the end-of-day return anomaly (Harris [1989]) may not be arbitrage opportunities but rather a reflection of order flows. Second, the evidence presented suggests that institutional trading is correlated across stocks toward the day's end. This correlation could be the result of herding, but it does imply higher trading costs for portfolio managers. This occurs because, as noted above, the sensitivity of price to order flow is greater at the close. Note that even a manager that trades at the closing price (typically sending their orders to a broker for MOC execution) still faces these hidden costs if their order flows are correlated with other institutions, as is likely for index and value-oriented funds. One way for portfolio managers to improve their performance would be to reduce trading costs by placing orders earlier in the day. For an index fund, this strategy would increase the tracking error but has the advantage of lower costs. Third, closing prices are affected by transitory order imbalances associated with index expirations. Again, institutional investors pay a large premium to trade on such days if they are on the same side as the imbalance. Conversely, the return reversals documented here suggest profitable opportunities to investors who can act as liquidity providers at such times.

Given these results, it is natural to ask how we can reduce the volatility induced by transitory order flows and improve price efficiency at the close. One possibility is to disseminate information on order flows at the close in a more timely manner, in greater detail, and to a wider audience. Greater transparency might attract counterparties to take the opposite side of order imbalances, while simultaneously serving to alert potential traders that their orders may be executed at substantial premiums over previous trades. A more radical approach is to adopt special trading protocols at the close, for example, by replacing the current continuous trading with a formal closing call auction. Indeed, many other exchanges (e.g., the Paris Bourse) have implemented special closing procedures for exactly this reason. However, the evidence on the efficacy of such mechanisms is still in doubt. For example, there are extremely anomalous price movements in the closing prices of stocks in London following the institution of a closing call. Given the growing concern over price volatility at the close, a more detailed investigation of these and other options will undoubtedly prove to be valuable.

ENDNOTES

The authors thank Art Asriev, Todd Keathley, Aristos Koyanis, and Sharon Sun for expert research assistance; and Jeff Bacidore, Simon Gervais, George Sofianos, and seminar participants at the 1999 Nasdaq/Notre Dame University Conference on Market Microstructure, National Bureau of Economic Research, and Renaissance Technologies Corporation for many useful suggestions. The comments and opinions contained in this article are those of the authors alone and do not necessarily reflect those of ITG Inc. (For further details see "Stock Returns and Institutional Trading at the Close," by David Cushing and Ananth Madhavan, *Journal of Financial Markets*, 3, pp. 45-67, 2000.)

[1]Examples include Instinet's and the NYSE's after-hours (Session I) crossing systems.

[2]See Ip [1998]. Safeway replaced Chrysler Corporation, which was dropped from the S&P 500 index because of its merger with Daimler-Benz, A.G., a foreign firm.

[3]Meier [1998] surveys 49 leading stock markets including the NYSE, Nasdaq, London Stock Exchange, Paris Bourse, and Frankfurt Stock Exchange. He finds that at year-end 1997, 35 (71%) exchanges used special procedures to open while 12 (25%) use special closing procedures.

[4]The change was prompted by large movements in shares of America Online Inc. following the announcement on December 22, 1998 that the stock would be added to the S&P 500 index. See "S&P is Changing an Index Procedure," *The New York Times*, December 31, 1998, p. C6.

[5]See, e.g., Jain and Joh [1988] and Harris [1988, 1989].

[6]We thank Jeff Bacidore and George Sofianos for their help in providing us with these data.

[7]As of June 24, 1998, all market-on-close orders had to be entered by 3:40 p.m., except to offset a published imbalance.

REFERENCES

Harris, L. "A Transaction Data Study of Weekly and Intradaily Patterns in Stock Returns." *Journal of Financial Economics*, 16 (1986), pp. 99-117.

——. "A Day-End Transaction Price Anomaly." *Journal of Financial and Quantitative Analysis,* 24 (1989), pp. 29-45.

Hillion, P., and M. Suominen. "Deadline Effect of an Order Driven Market: An Analysis of the Last Trading Minute on The Paris Bourse." Working paper, INSEAD, 1998.

Ip, G. "Unusual Trading in Safeway Stock Stirs Market." *The Wall Street Journal*, November 19, 1998, pp. C1, C19.

——. "Big Board Sets Pact in Rift With Specialist." *The Wall Street Journal*, June 25, 1999, pp. C1, C20.

Jain, P., and G. Joh. "The Dependence Between Hourly Prices and Trading Volume." *Journal of Financial and Quantitative Analysis*, 23 (1988), pp. 269-283.

Keim, D., and A. Madhavan. "The Costs of Institutional Equity Trades: An Overview." *Financial Analysts Journal*, Vol. 54, No. 4, (1998), pp. 50-69.

Lee, C., and M. Ready. "Inferring Trade Direction From Intradaily Data." *Journal of Finance*, 46 (1991), pp. 733-746.

Madhavan, A., and V. Panchapagesan. "Price Discovery in Auction Markets: A Look Inside the Black Box." *Review of Financial Studies*, 13 (2000), pp. 627-658

Madhavan, A., M. Richardson, and M. Roomans. "Why Do Security Prices Fluctuate? A Transaction-Level Analysis of NYSE Stocks." *Review of Financial Studies*, 10 (1997), pp. 1035-1064.

McInish, T., and R. Wood. "An Analysis of Intraday Patterns in Bid/Ask Spreads for NYSE Stocks." *Journal of Finance*, 47 (1992), pp. 753-764.

Meier, R. "Benchmarking Analysis of Stock Exchange Trading." Monograph, International Federation of Stock Exchanges (FIBV). SBF-Bourse de Paris, 1998.

Sofianos, G. "Expirations and Stock Price Volatility." *Review of Futures Markets*, 13 (1994), pp. 39-73.

Thomas, S. "End of Day Patterns After Implementation of A Call Auction on the Paris Bourse." Unpublished manuscript, SBF-Bourse de Paris, 1998.