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STOCK MARKET MICROSTRUCTURE AND RETURN VOLATILITY

Evidence from Italy

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This paper studies the impact of the stock market microstructure on return volatility and on the value discovery process in the Milan Stock Exchange. The primary trading mechanism employed by this exchange is a call market, which is usually preceded and followed by trading in a continuous market. We find that the opening transaction in the continuous market has the highest volatility, and that opening the market with the call transaction seems to produce relatively lower volatility. In the closing transaction, investors correct perceived errors or noise in the prices set at the call. The implications of the results for market design are examined.

1. Introduction

Many of the stock exchanges in continental Europe are distinguished by trading methods which differ significantly from those in London, the United States and Japan.[1] Some of these exchanges apply a 'call market', a public auction procedure,[2] where a designated auctioneer calls out the price of a stock and traders on the trading floor enter their buy and sell orders at that price. If there is excess demand at the call price, the auctioneer raises the price; if there is excess supply, he lowers the price. The process continues

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[1]For a comparison of trading methods around the world, see Whitcomb (1985).

[2]For theoretical analyses of the call market procedure, see Mendelson (1982, 1985, 1986).

until equilibrium is reached or until some predetermined price-change limit is hit. Stocks are called in a pre-specified order, and the execution of trades is sequential.

Many of the European exchanges have recently expanded the menu of available trading methods. For example, in Paris, the *Bourse* instituted continuous trading employing a Computer Assisted Trading System (CATS) based on an open limit order book. The Tel Aviv Stock Exchange started a trading procedure by which, after the open call transaction, bilateral continuous trading in some stocks takes place using a pit-like arrangement. Other European markets, in particular the *Borsa Valori di Milano*, are considering the incorporation of alternative trading mechanisms. Empirical evidence on the effects of trading mechanisms on the behavior of stock prices is of obvious importance for the evaluation of such alternatives. The objective of this paper is to study these effects using data from the Milan Stock Exchange.

The *Borsa Valori di Milano* has a particularly interesting setting for the evaluation of trading mechanisms, since it uses a trading system which incorporates *both* a call market and a continuous market. Normally, trading in major stocks starts with bilateral transactions in the continuous trading ring, then proceeds to the major transaction of the day in a call auction market, and again proceeds in the continuous trading ring until the close. Thus, the *Borsa* provides a unique opportunity to study the effects of trading under the two mechanisms on stock price behavior.

This paper compares the price behavior of heavily traded stocks on the Milan Stock Exchange under the two trading mechanisms. For a sample of 12 stocks, we examine and compare the stock return behavior (and, in particular, the return volatility) under both the call and the continuous trading regimes. This comparison applies to prices generated for the same stocks in the same market center over the same time period. Since the resulting prices are affected by the very same information, differences in price behavior reflect the differences in the trading method as well as the timing of transactions. Thus, our methodology enables us to evaluate the effect of the trading mechanism and the time at which it operates on stock return volatility.

In an earlier study, Amihud and Mendelson (1987) analyzed the price behavior of the 30 stocks which constituted the Dow Jones Industrial Index on the New York Stock Exchange (NYSE). At the opening transaction in these stocks, which we call the 'clearing transaction', buy and sell orders are aggregated and sorted by the specialist according to their limit prices.[3] Then, the orders are crossed at a price which equilibrates the market demand and supply, and all orders are executed at this single price. The call auction

[3]The NYSE specialist is assisted by a computer system called OARS.

transaction in the *Borsa* resembles the clearing transaction on the NYSE in one important aspect: for a given stock, all orders which qualify are executed at a single price. However, there are important differences between the two types of transactions: the transactions in Milan are bilateral and are not fully centralized, and traders continuously obtain information from the contracting process between the parties on the floor. They observe the excess demand at each called price, and the convergence process of prices to their equilibrium levels is open. In contrast, the clearing transaction on the NYSE has the flavor of a 'sealed bid' auction.[4] Another difference is that the auction in the *Borsa* is held sequentially for each stock, whereas the NYSE opening transactions in heavily traded stocks take place at almost the same time (when the exchange opens). Finally, the call auction in the *Borsa* is usually preceded by a period of bilateral continuous trading, whereas the opening clearing transaction in the NYSE is preceded by a long period of no trade.

Amihud and Mendelson (1987, 1989b) have observed unusual behavior of stock prices at the opening of the trading day, and in particular – higher return variances at the opening transaction.[5] As they point out, this might be due to two factors: (i) the trading mechanism used in the opening transaction, and (ii) the fact that the first transaction of the day follows a long period of no-trade. The latter factor implies that at the opening, traders have no recent price information to look at, and thus are uncertain regarding the equilibrium price, leading to greater price volatility at the opening. The call transaction in the *Borsa* is usually preceded by continuous transactions, but on some days and for some of the stocks it is the first transaction of the day. Thus, the data from the *Borsa* enables us to study the price behavior of the call transaction under two scenarios: when it follows other transactions during the trading day, and when it is the first transaction of the day.

Following Amihud and Mendelson (1987), we distinguish between the intrinsic value of a security and its observed price, with the differences being attributed to two market-microstructure factors: (i) a partial price-adjustment process, and (ii) trading noise [see Black (1986)]. The first factor pertains to the speed of adjustment of market prices to new information about the security, and the second to transitory price fluctuations generated by friction in the trading process. In this paper, we study the volatility of stock returns in three transactions: (i) the first transaction of the continuous market, (ii) the call market transaction, and (iii) the last transaction of the day, which takes place in the continuous market. We focus on differences in the volatility of the observed returns, which reflect the differential impact of the 'noise' under the alternative trading mechanisms. Volatility is clearly of

[4]However, the NYSE specialist can observe all the bids and offers in the system.

[5]Stoll and Whaley (1989) have studied the return volatility in the opening and closing of the trading day on a much larger sample of NYSE stocks, reaching qualitatively the same results.

interest to any risk-averse trader as well as to policy-makers. In addition, volatility induced by noise in the trading process makes it more difficult for investors to extract signals from stock prices, reducing their information content. Thus, comparing the return volatility generated by the three transactions studied enables us to compare the value discovery processes under different trading mechanisms.

In the next section, we describe the method of trading on the Milan Stock Exchange. We then present our empirical analysis in section 3, and offer our concluding remarks in section 4.

2. Institutional characteristics and the Italian market architecture

In this section we describe the main features of the Italian stock market. This research studies stocks listed in the main market (*Mercato ufficiale*) of the *Borsa Valori di Milano*. We describe the institutional characteristics of the market in section 2.1 and the trading mechanisms operating in it in section 2.2.

2.1. Institutional characteristics

The *Borsa Valori di Milano* is a non-profit institution, regulated and administered by public laws and agencies. There are 10 regional stock exchanges in Italy, but almost the whole transaction volume – about 94% in 1988 – is concentrated in the Milan Stock Exchange. Trading in the main market is restricted to issues that satisfy some listing requirements. By the end of 1988, there were 317 listed stocks in this market, representing the securities of 211 companies. The aggregate market capitalization reached \$135 billion, and the daily average trading volume was about \$125 million. Stocks which do not satisfy the listing requirements are traded in the much smaller regulated market (*Mercato Ristretto*) or the informal over-the-counter market (*Terzo Mercato*). Block trading in listed stocks takes place out of the market. In addition, banks usually bring to the market only the net amount of buy and sell orders submitted by their customers, while those orders which match they execute in-house.

Trading on the Milan exchange is conducted by official stockbrokers (*Agenti di Cambio*). They (or their attorneys) are the only intermediaries admitted to the trading floor and allowed to transact in listed issues. Stockbrokers act on behalf of their clients, and cannot trade for their own account. Public regulations prohibit stockbrokers from pursuing any commercial activity related to securities or financial markets.

2.2. Trading mechanisms

Stock transactions in the main market can take place under two different trading mechanisms: a call auction market and a continuous auction market. The latter is regularly observed for the most active stocks such as the ones in our sample. We are thus able to examine the price behavior of the same stocks traded on the same exchange over the same time period under the two different trading regimes.

2.2.1. The call market

Call transactions are conducted by stockbrokers in three special rings (called *corbeille del listino*). The call market produces the official daily prices for the listed stocks, called *prezzo di listino*. The listed issues are called during the trading session (usually from 10:00 a.m. to 1:45 p.m.) at the ring where they are assigned in a prespecified order (usually alphabetically) by an auctioneer, who is a public employee. The auctioneer opens the market by calling the stock's name and its starting price, which is the call price of the previous day. He manages the call trading session, adjusting the price continuously in response to observed imbalances between buy and sell orders shouted by the stockbrokers: raising the price if there is excess demand and lowering the price if there is excess supply. The activity of the auctioneer is strictly informational, i.e., he interacts with the floor brokers, asking whether there are orders at the price he is declaring. Inside the ring, the stockbrokers – while revealing their orders – seek trading partners on the other side of the market. Each trade is bilateral between the trading brokers. Thus, for example, a broker handling a large order may deal with many counterparties simultaneously, and if the price changes during the call auction process, he will have to recontract his previous tentative trades, seeking again other counterparties. These bilateral contracts become firm only at the end of the call auction for the stock, when there is no order imbalance at the called price.

When the price reaches the point where the quantity exchanged is maximized, the auctioneer and the representative of the Brokers' Council close the session for the stock and declare the day's call price which is the same for all trades consummated in the call market. It is important to note that these transactions do not have any bid–ask spread, since the buyer's price is equal to the seller's price. The parties to the transaction have to pay just a fixed commission to the stockbroker.

The *listino* has daily price limits ranging from 10% to 20% of the previous day's price. When a stock reaches its price limit, the auctioneer halts trading in the stock. It will then be called again at the end of the call-session of that ring. Subsequently, the stock price is allowed to fluctuate without limits, unless there is a particular reason to suspend the daily call (then, there will be no official call price). Interestingly, the trading procedure at the call market closely resembles the classical *tatonnement*, where parties contract and recontract at prices called out by an auctioneer until an equilibrium price, at which all transactions take place, is reached.

2.2.2. *The continuous market*

The continuous market, called *durante*, is conducted by stockbrokers in three other special rings (called *corbeille del durante*) during the daily trading session. The continuous session has no specific rules for opening or closing the market, nor are there any price limits. When there is a trading halt for a stock in the call market, it also cannot be traded in the continuous market.

Trades occur whenever stockbrokers cross their orders at the post, and prices in the continuous market can be observed before and after the stock has been traded in the call market, but not during the call. For active stocks, the typical trading session starts in the continuous market, then the stock is traded in the call market, and subsequently trading carries on in the continuous market. Floor traders see the *durante* prices on a board which is updated electronically.

3. The empirical study

In this section, we present our empirical study of the relation between return volatility and the trading mechanism. We examine the behavior of stock prices under the two trading mechanisms described above, the continuous trading regime – the *durante* – and the call auction transaction – the *listino*. Usually, trading in the *durante* takes place both before and after trading in the *listino*. That is, we ordinarily observe for each stock an opening transaction at the *durante*, then the major call transaction of the day in the *listino*, and subsequently – continuous transactions in the *durante*.

Examining the price behavior at the opening transaction of the day may confound the effect of the trading method applied at the opening transaction and the effect of the no-trade period which precedes it [see Amihud and Mendelson (1989b)]. Therefore, we examined for each day the price behavior of both the first and the last transaction executed in the *durante* ring. We are thus comparing here the behavior of stock prices in three cases: the first transaction of the *durante*, the *listino* transaction, and the last transaction of the day in the *durante*. We label these transactions, respectively, by *primo* (PR, first), *listino* (LI) and *ultimo* (UL, last).

3.1. *The data*

The data used in this study are drawn from the Milan Stock Exchange's database, constructed by the Department of Business Research of the University of Pavia, Italy.[6] For the period January 2, 1984 – April 30, 1987, we selected individual stocks that were continuously traded under both the *listino* and the *durante* for at least 150 days. This time period was chosen to avoid missing data in the stock return files and also to exclude the second half of 1987, which was tainted by the stock market 'crash'. These criteria resulted in a sample of 12 stocks (10 common and 2 preferred), that are among the most important Italian 'blue chips'. In the period examined, they accounted for more than 42% of the total trading volume in the call market of the Milan Stock Exchange.[7] Thus, our sample should not suffer from many of the non-trading problems that are usually present in thin markets.[8]

Our empirical comparison of price behavior under the two trading mechanisms uses two daily *durante* prices, $P_{PR,t}$ and $P_{UL,t}$, recorded at the beginning and at the end of the continuous trading session, and the daily call price, $P_{LI,t}$. All prices were adjusted for splits and dividends. Accordingly, we defined the returns in the continuous market by

$$R_{PR,t}=\log(P_{PR,t})-\log(P_{PR,t-1}) \quad \text{and}$$

$$R_{UL,t}=\log(P_{UL,t})-\log(P_{UL,t-1}).$$

Finally, the call market return on day t is given by

$$R_{LI,t}=\log(P_{LI,t})-\log(P_{LI,t-1}).$$

Each stock thus has, for each elapsed trading day, three returns which measure the (logarithmic) price changes between the transactions executed under the same trading method in two adjacent trading days.

Our methodology enables us to control for information effects while examining the effects of different trading mechanisms and different time of trading. Over the whole sample period (except for the first and the last days), these returns should equally reflect any new information about the value of the stock, and thus should have the same information-induced volatility. In addition, each return series reflects the effect of the trading method by which the transaction was executed. For example, suppose some new information

[6]The database contains daily prices of the individual stocks and market indexes suitable for academic research. It is updated annually with the cooperation of the EDP Centre (*CED Borsa*) and the Statistics Division of the Milan Stock Exchange. The *Banca Commerciale Italiana* has provided the market index (*Comit Globale*).

[7]Data on trading volume in the continuous market was not available.

[8]Market thinness in the Italian Stock Exchange has been recently examined by Murgia (1989).

arrives on day t before the opening of trading, which implies an increase of 1% in the stock price. Then, all three returns for day t will reflect the 1% appreciation, but they may still differ because of the differences in the types of transactions. If the new information arrives, say, just before the *ultimo* transaction, then the appreciation will be reflected in $R_{UL,t}$ and in $R_{PR,t+1}$ and $R_{LI,t+1}$, implying again that the 1% change will affect the volatilities of all three return series. If there were no differences in the effect of the trading methods or of the timing of transactions on the behavior of stock prices, all three return series for each stock would exhibit exactly the same volatility. As it turns out, differences in return volatilities do exist.

In our study, we distinguish between two types of days: 'PR-days', when the first *durante* transaction, the *primo*, is the first transaction of the day; and 'LI-days', when the *listino* is the first transaction of the day, followed by the *primo* transaction in the *durante*. Table 1 describes the stocks included in our study and the sample periods for each stock. The table shows the proportion of PR-days. On average, the *durante* transaction preceded the *listino* in 66% of the days, but the median is higher – 82%. The variability of these percentages is large, and for three stocks, the first transaction of the day in most days takes place in the *listino*. For all stocks in all days, the last transaction of the day was a *durante* transaction. The table also shows the trading volume for the *listino* transaction; volume data were unavailable for the *durante* transactions.

The last two columns of table 1 show the average volume of trading in the *listino* transaction on PR-days and on LI-days. It could be thought that if trading in the *listino* is preceded by trading in the *primo* transaction, the trading volume in the *listino* will be lower. But, on the other hand, the fact that the *primo* precedes the *listino* indicates that there was a relatively high demand to trade on that day, possibly due to the arrival of new information. Investors would then hasten to trade on the new information and their intensified activity would be reflected in higher volume. The data show that this was indeed the case: the average trading volume for all stocks was considerably higher on PR-days than on LI-days.

3.2. Results

We first examined the relative volatilities of the three return series R_{PR}, R_{LI} and R_{UL}. On average, the variance of R_{PR} was 10% greater than that of R_{LI} (for the same stock), and the variance of R_{UL} was 7% lower than that of R_{LI}. However, the comparison of the three return variances confounds the effect of the trading method with the order in which trading takes place. Since the first transaction of the day is expected to have greater volatility and the first transaction is sometimes the *primo* and sometimes the *listino*, we can hardly tell from this comparison the effect of the trading method per se

Table 1

Stocks, sample periods, trading volume and the timing of price formation in the call (LI) and in the first transaction of the continuous market (PR). On PR-days, the *primo* precedes the *listino*, and on LI-days, the *listino* comes first.

No.	Stock	Trading ring	Sample period	Trading days	Proportion *primo* before *listino*	Thousands of shares traded in the *listino* (daily average)		
						All days	PR-days	LI-days
1	Assicurazioni Generali	A	840102–870430	838	0.93	85.9	90.8	20.7
2	Ciga Hotels	C	841228–851219	249	0.79	128.9	143.4	75.3
3	Fiat Common	A	840102–870430	838	0.92	1,042.4	1,095.4	390.7
4	Fiat Preferred	A	840102–870430	838	0.84	737.9	806.7	372.8
5	Ifi Preferred	B	851129–870120	282	0.03	118.0	167.3	113.4
6	Montedison	A	840102–870430	838	0.67	2,317.4	3,578.6	1,229.8
7	Nuovo Banco Ambrosino	B	840824–850726	233	0.54	191.5	248.9	125.1
8	Olivetti	A	840102–840926	189	0.95	209.7	215.7	102.3
9	Pirelli Spa	B	850821–860610	200	0.22	468.5	669.8	410.9
10	Ras	A	851011–870430	387	0.85	85.8	94.8	32.1
11	Sai	A	850918–870430	404	0.88	109.0	115.6	60.6
12	Snia Bpd	B	850827 870107	340	0.28	442.5	586.2	385.2
			Sample median		0.82	200.6	232.3	119.3
			Sample average		0.66	494.8	651.1	276.5

on the return volatility. A comparison of return volatilities should control for the differences between PR-days, when trading opened with a *durante* transaction, and LI-days, when the first transaction was a *listino* transaction. We thus estimated for each stock the following time-series models:

$$DPRLI_t = c_0 + c_1 \cdot ORDER_t + c_2 \cdot NEWS_t + c_3 \cdot DVOL_t + c_4 \cdot DVOL_{t-1} + e_t \quad \text{and} \tag{1a}$$

$$DULLI_t = c_0 + c_1 \cdot ORDER_t + c_2 \cdot NEWS_t + c_3 \cdot DVOL_t + c_4 \cdot DVOL_{t-1} + e_t \tag{1b}$$

where the first dependent variable $DPRLI_t = R^2_{PR,t} - R^2_{LI,t}$ measures the difference in return volatility between the *primo* and the *listino*, and the second, $DULLI_t = R^2_{UL,t} - R^2_{LI,t}$, measures the difference in return volatility between the *ultimo* and the *listino*. The *listino* is chosen as the benchmark since it is the major transaction of the day.

The dummy variable $ORDER$ controls for the order of trading at the opening of the day. $ORDER_t$ takes on the value 1 in LI-days, when the first transaction of day t or day $t-1$ was in the *listino*, and is zero otherwise. The reason for this assignment of values to $ORDER_t$ is that the return is given by the price difference between days t and $t-1$. Thus, if the fact that the *listino* is first adds noise to the price on day t, then it should affect both the return on day t, $\log(P_t) - \log(P_{t-1})$, and the return on day $(t+1)$, $\log(P_{t+1}) - \log(P_t)$.

As we pointed out, the earlier opening of trading on PR-days could signify the arrival of new information on those days, which may affect the return volatility in some unusual way. In these days, traders hasten to trade in the *durante* rather than wait for the *listino*. We therefore added a set of variables which control for the arrival of company-specific information and for unusual trading activity. For the arrival of information, we searched *Il Sole 24 ORE*, the major Italian financial newspaper, for news and articles pertaining to the companies in our sample. The dummy variable $NEWS_t$ equals 1 if any article about the company was published in *Il Sole 24 ORE* on day t or on day $t-1$, and is zero otherwise. Next, we added the variable $DVOL_t$ which is the 'abnormal' daily trading volume in the *listino* transaction relative to the mean. Specifically, $DVOL_t = (VOL_t - AVOL)/AVOL$, where VOL_t is the trading volume in the *listino* on day t and $AVOL$ is the average daily *listino* volume for the stock. Thus, positive values of $DVOL_t$ indicate above-average trading activity, whereas $DVOL_t < 0$ implies below-average volume.

In both models, c_0 represents the difference between the variance of the PR [in (1a)] or UL [in (1b)] returns and that of the LI return in PR-days (i.e., when the order of transactions is PR, LI, UL), whereas the coefficient c_1 reflects the *additional* effect of opening the trading in the *listino* transaction on the variance differential. Thus, the sum of the coefficients $c_0 + c_1$ is the variance differential between the PR or UL returns and the LI return on LI-days. These estimates pertain to 'normal' days of no news arrival and of average trading volume in the *listino*. The coefficients c_2, c_3 and c_4 control for possible differences in return variances on days of special events and abnormal trading activity. The estimation of models (1a) and (1b) uses the generalized least squares (GLS) method, to account for autocorrelation in the residuals e_t, by applying the Cochrane–Orcutt iterative estimation of the autocorrelation coefficient.

Table 2 presents the results of the variance-differential coefficients estimated from models (1a) and (1b), controlling for the effects of news and

Table 2

Results of models (1a) and (1b). The estimated coefficients were multiplied by 1,000.

Stock	DPRLI [eq. (1a)]			DULLI [eq. (1.2)]		
	c_0	c_1	c_0+c_1	c_0	c_1	c_0+c_1
1	0.0614	−0.0438	0.0176	−0.0471	0.0119	−0.0352
2	0.1130	−0.0866	0.0264	0.0498	−0.1170	−0.0672
3	0.0494	−0.0969	−0.0475	−0.0057	0.0332	0.0275
4	0.0786	−0.0909	−0.0123	0.0003	−0.0050	−0.0047
5	0.4300	−0.4700	−0.0400	−0.4670	0.1820	−0.2850
6	0.0064	−0.1440	−0.1376	0.1400	−0.2950	−0.1550
7	0.0635	0.1300	0.1935	−0.0494	0.0391	−0.0103
8	0.0482	−0.1310	−0.0828	−0.0074	−0.0479	−0.0553
9	0.2070	−0.2020	0.0050	−0.1730	0.1590	−0.0140
10	0.3460	−0.2650	0.0810	−0.0239	−0.0098	−0.0337
11	0.2640	−0.3460	−0.0820	−0.0142	0.0694	0.0552
12	0.0855	−0.1250	−0.0395	−0.0617	0.0079	−0.0538
Median	0.0821	−0.1280	−0.0259	−0.0191	0.0099	−0.0344
Mean	0.1461	−0.1559	−0.0098	−0.0549	0.0023	−0.0526
Std. dev.	0.1348	0.1530	0.0863	0.1487	0.1240	0.0899
Number of positive	12	1	5	3	7	2

abnormal trading activity. Consider first model (1a). In PR-days, the variance of R_{PR} is greater than that of R_{LI}, as evidenced by the uniformly positive c_0. On LI-days, the variance of R_{LI} becomes relatively higher, as indicated by the nearly-uniform negative sign of c_1. Still, in LI-days there is no consistent difference between the variances of R_{PR} and R_{LI}, as indicated by the fact that the sum c_0+c_1 is about equally likely to be positive or negative.

These results are obtained after controlling for the effects of information arrival and of abnormal trading activity in the *listino* transaction. The most pronounced effect of these controls is that of $DVOL_t$: The coefficient c_3 is usually negative, implying that an unusual trading activity in the *listino* is associated with greater return volatility in this transaction relative to the return volatility in the other two transactions, PR and UL. This indicates that the *listino* transaction absorbs much of the shock in unusual trading days.

Returning to our key results reflected by the coefficients of c_0 and c_0+c_1, we found that while opening with a *durante* transaction creates a consistently higher volatility of the opening transaction, opening with a *listino* does not cause the first transaction volatility to be higher than the volatility of the following transaction (which takes place in the *durante*). This supports the notion of opening the market by applying the call market method rather than by a continuous market transaction.[9]

[9]See Amihud and Mendelson (1988).

Next, consider model (1b) which compares the *ultimo* to the *listino*. Nine out of the $12c_0$ coefficients are negative, and 10 out of the $12(c_0+c_1)$ are negative, indicating that the variance of R_{LI} is usually higher than the variance of R_{UL} on both PR-days and LI-days.

We further estimated the effect of the type of the opening transaction on the return volatility as follows. We calculated for each stock the return series,

$$R_{2t}=\begin{cases} R_{LI,t} & \text{for PR-days,} \\ R_{PR,t} & \text{for LI-days.} \end{cases}$$

That is, $\{R_{2t}\}$ is the sequence of returns between the second-recorded prices of each day in our database.[10] regardless of whether they were created in the *listino* or in a *durante* market. We then estimated model (1.2) with R_{2t} replacing $R_{LI,t}$. We obtained again that on PR-days (when $R_{2t}=R_{LI,t}$), $R_{UL,t}$ had a lower volatility as c_0 was usually negative; but when the *listino* came first and thus $R_{2t}=R_{PR,t}$, the lower volatility advantage of R_{UL} compared to R_2 was reduced – the coefficient of the variable *ORDER* was mostly positive. Put differently, the variance differential between R_2 and R_{UL} was smaller when trading opened with a call transaction. This suggests that the call provides better value discovery at the opening of trading than does the continuous method.

The volatility of returns under each trading method and for each point in time can be either due to the common market volatility, or due to stock-specific noise. We therefore reestimated the volatility of returns in the three transactions – PR, LI and UL – controlling for the common market factor. The straightforward way to control for the market volatility is by estimating the volatility of the residuals from the market model regression

$$R_{ijt}=\alpha_{ij}+\beta_{ij}\cdot R_{mjt}+e_{ijt}, \tag{2}$$

where i denotes the stock, $j=PR$, LI or UL denotes the type of transaction, R_{mjt} is the market index for transaction-type j, α_{ij} and β_{ij} are coefficients and e_{ijt} are the residuals, all pertaining to daily data with time denoted by t. While estimation by this model is usually straightforward, in our case, there are a number of econometric problems which have to be resolved:

(i) The market index is not available for each of the trading mechanisms. We thus constructed an index which constitutes of the average of the returns on the sampled stocks for the respective transaction-type.
(ii) Traders in each transaction cannot observe the market index used in the estimation model (2). In the *listino*, trading is sequential for stocks in the

[10]This is, of course, to be distinguished from the second transaction of the day.

Table 3

Results of models (1a) and (1b) for the residual returns from the market model (2), using the Scholes–Williams method. The estimated coefficients were multiplied by 1,000.

Stock	DPRLI c_0	c_1	c_0+c_1	DULLI c_0	c_1	c_0+c_1
1	0.0514	0.0329	0.0843	−0.0774	0.0443	−0.0331
3	0.1320	−0.5870	−0.4550	0.0019	−0.0234	−0.0215
4	0.1230	0.0684	0.1914	−0.0497	−0.0378	−0.0875
5	0.3800	−0.3870	−0.0070	−0.4710	0.2990	−0.1720
6	−0.1160	−0.0912	−0.2072	−0.1450	−0.1690	−0.0314
10	0.1170	0.0418	0.1588	−0.1290	0.0509	−0.0781
11	0.0206	0.0252	0.0458	−0.1460	0.1090	−0.0370
12	0.2520	−0.1860	0.0660	−0.0904	0.0511	−0.0393
Median	0.1200	−0.0330	0.0559	−0.1097	0.0476	−0.0587
Mean	0.1200	−0.1354	−0.0154	−0.1383	0.0405	−0.0978
Std. dev.	0.1490	0.2387	0.2150	0.1436	0.1341	0.0999
Number of positive	7	4	5	1	5	0

same ring. Thus, when transacting the stocks which trade first in the *listino*, traders do not known the *listino* R_m, which also includes the returns on stocks which would trade later. The other two indices suffer from a similar problem of nonsynchronous trading, which usually leads to biased coefficient estimates. However, consistent estimation can be obtained by the Scholes–Williams (1977) method, which employs the sequence of returns $R_{m,t-1}, R_{mt}$ and $R_{m,t+1}$. We applied the Scholes–Williams method using the following sequence of indices: $R_{m,PR,t}$, $R_{m,LI,t}$, $R_{m,UL,t}$, $R_{m,PR,t+1}$, $R_{m,LI,t+1}$, $R_{m,UL,t+1}, \ldots$. The estimation of the market model for LI on day t employed the indices $R_{m,PR,t}$, $R_{m,LI,t}$ and $R_{m,UL,t}$. The estimation for UL on day t employed the indices $R_{m,LI,t}$, $R_{m,UL,t}$ and $R_{m,PR,t+1}$. Similarly, the estimation of the market model for PR on day t employed $R_{m,UL,t-1}$, $R_{m,PR,t}$ and $R_{m,LI,t}$.

Having obtained the residuals from model (2) and applying (i) and (ii) above, we calculated $DPRLI_t$ and $DULLI_t$ as before, with the residual returns from model (2) replacing the respective returns in (1a)–(1b). In this analysis, we had only eight stocks which were continuously traded over the same time period (to enable us to construct a market index for each of the three transaction-types). We estimated again models (1a) and (1b) by the GLS method, to account for the autocorrelation in the residuals. The results are presented in table 3.

The pattern of the results in table 3 is similar in many respects to that in table 2. Consider first the results for *DPRLI*. The coefficient c_0 is mostly positive, implying that in PR-days (when PR is the first transaction of the day), the return volatility in the PR transaction is greater than that in the LI transaction. The results further show that when LI is the first transaction of the day, its return volatility is not significantly greater than that of the PR transaction, which then comes second. The sum c_0+c_1 is on average practically zero, indicating that the volatility of R_{LI} is not greater than that of R_{PR} when trading opens with the LI transaction. This again supports the policy choice of opening the trading day with a call market procedure. The results for *DULLI* show that the return volatility of the UL transaction is practically always lower than that of the LI transaction. All these results control for the market-wide effects as well as for the effects of news and abnormal trading activity.

Our results show that the volatility of the returns from LI to LI is usually higher than the volatility of the return from UL to UL transactions, which follow the LI transactions, particularly in days of unusual trading activity. It thus stands to reason that in the UL transaction, traders 'correct' the noise or any unusual price deviations discovered in the LI transaction. In addition, as pointed out above, the LI transactions are carried out sequentially, stock by stock, and in different rings, and traders in a particular stock do not have full information about the *listino* return on all the stocks in the market. As as result, the prices set at the LI transaction are based on incomplete information about the market and are subject to erfrors. At the UL transaction, however, traders can observe all the preceding LI prices and, processing more information, they can better assess the 'true' underlying asset price (which depends on the return on the market as a whole). This would reduce the noise in UL prices, i.e., the UL prices would be less volatile.

The resulting hypothesis is that information available to traders at the end of the trading day enables them to correct price errors which have been made at the earlier LI transaction. This hypothesis was tested as follows. We first estimated the market model for the *listino*,

$$R_{i,LI,t}=\alpha_i+\beta_i\cdot R_{m,LI,t}+e_{i,LI,t}, \tag{3}$$

where $R_{m,LI,t}$ is the market index of the LI prices, provided by *Comit Globale*. This index reflects the call prices of *all* stocks, not only those in our sample, and as such provides the most comprehensive information about market prices in the *listino*. Model (3) was estimated using the Scholes–Williams (1977) method. The residuals $e_{i,LI,t}$ represent the abnormal returns on stock i in the LI transaction. This abnormal return can reflect company-specific information which will have a permanent effect on the stock price, or it can reflect errors (or 'noise'). In the latter case, the errors can be corrected subsequent to the *listino* by market traders, after they have more complete information on market prices. Thus, the change in price between the LI and the UL transactions on day t,

Table 4

Correlation coefficients between the residual, $e_{i,LI,t}$, and the price difference from LI to UL, $R_{i,ULLI,t}$.

Stock	Correlation
1	−0.286
2	0.137
3	−0.221
4	−0.226
5	−0.453
6	−0.162
7	−0.003
8	−0.068
9	−0.162
10	−0.183
11	−0.001
12	−0.227
Mean	−0.155
Standard error	0.044

$$R_{i,ULLI,t} = \log(P_{i,UL,t}) - \log(P_{i,LI,t})$$

can be related to $e_{i,LI,t}$ as follows: If the abnormal return $e_{i,LI,t}$ reflects information, it should be unrelated to $R_{i,ULLI,t}$. But if it is due to noise which is subsequently corrected in the last transaction of the day, there should be a negative correlation between $e_{i,LI,t}$ and $R_{i,ULLI,t}$. In fact, even if $e_{i,LI,t}$ reflects some new information, it should still be positively correlated with $R_{i,ULLI,t}$, because of the usual lagged adjustment of prices to new information.[11]

The results on the correlation between $e_{i,LI,t}$ and $R_{i,ULLI,t}$ are presented in table 4. All the correlations but one are negative, and their mean is negative and significant. This strongly supports the hypothesis that at the UL transaction, traders correct what they perceive to be errors or noise in the *listino* price. This is indeed reflected by the lower volatility of the UL prices.

4. Concluding remarks

In this paper we analyzed the effects of the stock market microstructure on the value discovery process and on return volatility in the Milan Stock Exchange. Normally, trading in this market opens for each stock with a transaction in a bilateral continuous trading market – *durante*, then there is a call transaction – *listino*, and subsequently trading proceeds in the *durante* ring until the closing. Thus, the Milan Stock Exchange affords us the opportunity to study the effect of the two trading methods – the continuous

[11] See Amihud and Mendelson (1980, 1982, 1987).

and the call – on stock price behaviour. In this market, there are also cases where the sequence of trading is changed, and the opening transaction is executed in the *listino* rather than by the *durante* method. This enables us to study both the effect of the trading mechanism and the effect of the timing of transactions on the behavior of stock prices.

The methodology we applied follows the one developed in Amihud and Mendelson (1987), which compares the return volatilities for a stock over the same period but under different trading mechanisms and at different times of the trading day. Thus, information which affects the stock value should be equally reflected in the returns under all trading mechanisms; if there are differences in the behavior of returns – in particular, in volatility – they can be attributed to the effects of the trading mechanism, to the timing of the transaction, or to both. We controlled for the effects of firm-specific news and unusual trading activity which could also affect the estimated differences in return volatilities.

Our results show that the return volatility at the opening *durante* transaction is higher than that of the following *listino* transaction, as one would expect. When the *listino* transaction is first, its return volatility is relatively higher than when it follows the *durante* opening. However, our evidence suggests that the call transaction provides a more effective value discovery mechanism at the opening of the trading day. When the *listino* is the first transaction of the day, its return volatility is not consistently higher than that of the subsequent *durante* transaction, whereas when the *durante* transaction is first, its return volatility is higher than that of the subsequent *listino* transaction for all stocks but one. Finally, we find that the price volatility of the last transaction of the day, which is carried out in the *durante* method, is usually lower than that of the *listino* transaction.

We show that continuous trading by the end of the trading day serves to correct errors or noise in the prices set earlier in the call transaction. As more stocks are traded in the *listino*, investors accumulate information about the market return. Then, observing previously-set prices which deviate from the general market trend, investors tend to correct such deviations by setting prices which better conform with the unfolding price trend. This result is quite unique in showing the dependence of stock prices on the information contained in the prices of *other* stocks, which is unraveled through trading. Our findings also suggest that the closing price in the Milan Stock Exchange provides better information than the call price, which is currently used as the official market price of the day.

To illustrate the application of our findings to market design, consider the recent changes in the trading procedures on the Tel Aviv Stock Exchange (TASE). Trading in this market applied the sequential call procedure similar to that in Milan. The TASE considered the introduction of continuous bilateral trading in some stocks. The question was whether to establish the continuous market at the opening of the trading day before the call, or after the call. The TASE decided to open the market with a continuous bilateral trading process. However, investors tended to shun the continuous trading at the opening and trading there was extremely thin. The TASE responded by changing its trading procedures and setting the continuous trading process following the call. Now, about half of the daily trading takes place in the post-call continuous market. Investors' preferences, as revealed in the case of the TASE, are consistent with our finding that the call market mechanism provides a more efficient value discovery process for opening the trading day, and that the continuous trading process which follows the sequential call has an important rôle in correcting errors in the prices set in the call transaction.

As securities markets around the world are considering changes in their trading mechanisms, it is important that they select trading methods which provide high levels of liquidity and efficient price discovery. High liquidity reduces the required return by investors and thus reduces the cost of capital to the issuers of securities.[12] Efficient price discovery processes, associated with lower volatility (noise), make market prices more informative and enhance the role of the market in aggregating and conveying information through price signals.

As a way to achieve these objectives, Amihud and Mendelson (1985, 1988, 1990) have proposed an integrated computerized trading system which will include two trading mechanisms operating side-by-side: The clearing transaction, where orders are accumulated, matched and executed at a single price (for each stock), with the ability to make an order for one stock contingent on the clearing prices of other stocks; and an ordinary continuous market.

While the Milan Stock Exchange has a system with a call in the middle of the trading day, our findings show that the price volatility in the call is higher than at the closing continuous transaction. This could reflect the differences between the 'call' and our 'clearing' transaction, suggesting that the call method applied in Milan could be improved. At the same time, given the advantages of the call transaction as evidenced by the large trading volume it attracts, it may be unwise for some markets to do away with it when changing the system to one of continuous trading.[13] Rather, the trading system should perhaps integrate a batched clearing process together with continuous trading.

[12] Amihud and Mendelson (1986, 1989a) found that stocks with lower liquidity, measured by the bid–ask spread, have higher returns, after adjusting for risk.

[13] See an analysis of investors' surplus and related advantages of the clearing transaction in Mendelson (1982, 1985, 1986, 1987) and in Amihud and Mendelson (1985, 1988).

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