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Market Depth, Liquidity and the Effect of Dual Trading in Futures Markets

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ABSTRACT

This paper examines market depth and other characteristics of the liquidity of the S&P 500 index futures market and how they were affected by the CME's top-step rule. We find that the S&P 500 futures market is deep and that (unlike some previous studies) the rule did not have a significant impact on its liquidity. Specifically, the rule did not affect (1) the behavior of stock and futures prices surrounding large futures trades, (2) the extent to which the index futures are mispriced relative to their theoretical prices, and (3) the ability of dual trading brokers to provide liquidity during periods of high trading volume. Finally, unlike Fishman and Longstaff (1992), we find that there is no relationship between dual trading and the high-low price spread.

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I. Introduction

Regulatory concern about dual trading in the futures markets was spurred by the market crash of October, 1987 and the practice has long been controversial. Dual trading refers to the practice of brokers trading for their personal accounts in addition to trading for their customers in the same securities[1]. Proponents of dual trading point to the benefits of enhanced market liquidity through lower bid-ask spreads and lower transactions costs. Opponents emphasize the potential for a conflict of interest between dual trading brokers and their customers and thus lessening the integrity of the market[2]. Although the Chicago Mercantile Exchange banned dual trading in all active contracts effective May 20, 1991, as part of a market reform package, the exchange now faces growing resentment over the ban, with floor brokers and the locals on opposite sides of the debate[3]. This points to the importance of finding empirical evidence

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[1]This trading practice had been pervasive across securities markets until it was banned in the futures markets in 1991. See Grossman (1989) for a detailed description of the practice of dual trading in the securities markets in the U.S. and other countries.

[2]For example, suppose a broker receives a large buy order from his customer. If he expects the price to go up when the customer's order is executed, he may buy the security using his own account before he executes his customer's order. The broker profits from this illegal "front running" if the price goes up later as expected after his customer's order is executed. To minimize the trading abuse of brokers, the CFTC (Commodity Futures Trading Commission) has used "thirty minutes time bracketing" regulation for futures contracts which requires all brokers to report every thirty minutes all relevant transactions-related information.

[3] The floor brokers claim that, stripped of the opportunity to dual trade, they have lost an important source of income and that market liquidity has been weakened while locals contend that the ban puts them on a more equal footing with the brokers in bidding business from customers and that liquidity has remained intact. See Chicago Tribune, February 4, 1992 and

regarding the effect of dual trading on various market characteristics.

This paper investigates the liquidity of the S&P 500 index futures market and tests whether the liquidity is affected by the restriction on dual trading activity such as the CME's top-step rule[4] (made effective on June 21, 1987). In measuring liquidity, we examine various market characteristics such as market depth, trading volume and transactions, high-low price spreads and brokers' participation rate. In estimating market depth, we distinguish between any permanent price effects caused by informationally motivated large trades and temporary mispricings due to the impact of large trades on market makers' inventory carrying costs. To our knowledge, this paper represents the first study to examine market depth of the futures market and the effect of dual trading on market depth. As a by-product, we examine the impact of large futures trades on the spot market, which has been controversial.

The results show that the S&P 500 futures market is a liquid market and that it remains so even after the promulgation of the top-step rule. The rule caused some reduction in both the dual trading volume and the number of transactions by dual trading brokers. However, the behavior of stock and futures prices surrounding large futures trades show no significant impact from the rule. Similarly, while there is significant underpricing of the index futures, there is no additional mispricing due to the rule change. Our findings are inconsistent with some previous

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the Wall Street Journal, February 7, 1992 for articles concerning the controversy.

[4]According to the special executive report of the CME, the top-step rule (Rule 541) states: *A member, who has executed an S&P 500 futures contract order while on the top step of the S&P 500 futures pit, shall not thereafter on the same day trade S&P 500 futures contracts for his account.* As stated in the special report of the CME to the CFTC, the major reason for applying the top-step rule only to the S&P 500 futures was the growing public concern over the relation between the spot index and its futures prices. The relation had often been out of the line prior to June 1987 and the exchange had been pressed to restrict dual trading.

studies which find a negative relation between dual trading and either the bid-ask spread (e.g., Walsh and Dinehart (1991) and Smith and Whaley (1990)) or execution costs (Stanley (1981) and Grossman (1990b)). In particular, Smith and Whaley (1990b) find a 33% increase in the effective bid/ask spread after the implementation of the top-step rule[5]. We also find no significant relationship between price volatility and dual trading activity, contradicting the findings of Fishman and Longstaff (1992) that dual trading and price volatility are negatively related. In addition, dual trading brokers' participation rate is found to be positively correlated with periods of high volume. But, again, the top-step rule has no effect on the correlation of participation.

Section II reviews the literature on dual trading and discusses our hypotheses. Section III describes the data and the econometric methodology for the tests to be performed. Sections IV and V report the results on liquidity of the futures market and the effect of dual trading on the liquidity, respectively, and Section VI concludes.

II. Literature Review and Theoretical Background

Most previous studies of dual trading use the bid-ask spread as a measure of liquidity of the market. However, as pointed out by Grossman and Miller (1988), the bid-ask spread can be misleading unless buy and sell orders arrive simultaneously. They stress using the impact of large orders on prices as a measure of liquidity. More importantly, Ho and Macris (1985) suggest that "trading rules often result in a trade-off between a tighter market-spread and a more

[5] It is important to note that liquidity is not determined by the spread alone. In fact, as discussed in Ho and Macris (1985) and Vijh (1990), one should expect a trade-off between market depth and the spread.

liquid market." In other words, there is an inverse relationship between the effective spread and the market "depth". The intuition is as follows: suppose there is some trading rule that results in a tighter bid-ask spread. This will reduce revenues to market makers in the aggregate and cause some market makers to leave the market. Thus, market makers' inventory carrying capacity will be reduced and so the market's ability to absorb large orders will be impaired. With dual trading, this tendency might be exacerbated since some market makers will remain in the market but switch to brokering customer orders only. Vijh (1990) confirms this relationship empirically for Chicago Board of Option Exchange equity options. The argument suggests that it is important to consider the effects of any dual trading regulation on both the spread as well as the depth.

Grossman (1989) argues that dual trading leads to a reduction in direct brokerage costs and therefore to lower effective spreads. This is because trading skills are crucial for brokers in futures markets and the revenues from dual trading provide an additional source of compensation to brokers for such skills. Regarding market depth, Grossman (1989) contends that "dual trading creates a reserve group of potential brokers" who can switch to customer trades when the volume of business is high. This leads to an increase in the total number of market makers and brokers, in particular during periods of high customer volume, when they are needed most. Therefore, when dual trading is allowed, futures markets will have a greater capacity to absorb large orders due to economies of scale in brokerage services. We will refer to this as a "scale" or "inventory" effect.

In contrast, Roell (1991) and Sarkar (1991) both argue that, for informational reasons, dual trading may lead to a reduction of market depth (the "information" effect). The result stems from the observation that the size and the sequence of customer trades are sources of information to dual trading brokers. This allows the brokers to free-ride on the information of informed investors[6]. As a consequence, a larger proportion of the total order flow is likely to be information-based when dual trading is permitted. Market makers are aware of this and will execute large orders (if these are more likely to emanate from informed traders) at less favorable prices.

There are several empirical studies which test the relationship between dual trading activity and market liquidity by examining the bid-ask spread only. For example, Smith and Whaley (1990b) find a 33% increase on average in the effective bid/ask spread after the implementation of the top-step rule and attribute this to less competition among liquidity traders. However, the significant increase of the spread occurs mainly in distant futures contracts whose trading volumes are very low. Further, the S&P 500 price volatility (one of the factors used to estimate the bid-ask spread) was increasing even before the October 1987 market crash and may well have been the real culprit behind the increase in the spread.

A study by the Commodity Futures Trading Commission (1989) shows that dual trading brokers do not provide better execution costs (as measured by the average bid-ask spread over a five minute interval) to their customers relative to exclusive brokers. Walsh and Dinehart (1991) point out that the CFTC's estimate of the bid-ask spread uses the average absolute price changes which is one tick (a constant) for most of their observations, and thus the CFTC's

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[6]If some informed traders are more concerned about information leakage and less so about their brokers' trading skills, there will be an incentive for some brokers not to commit to dual trade. In fact, this is exactly what occurs in the futures markets.

measure of the bid-ask spread is faulty. Further, the CFTC's study combines different markets into a single regression analysis which forces the relationship between trading activity and the spread to be the same across all markets. Walsh and Dinehart control for several of these factors and find, using wheat, soybean and MMI futures markets for three weeks in the fourth quarter of 1988, that dual trading narrows the bid-ask spread and so enhances liquidity in some markets.

In a related research, Fishman and Longstaff (1992) argue that, since dual trades of brokers occur in the same direction as informed trades, dual trading reduces the variance of price changes as well as the high-low spreads. Using the Chicago Board of Trade soybean futures contracts for 469 trading days in 1983-84, they confirm that price volatility (as measured by the high-low spread) is negatively related to dual trading volume. Fishman and Longstaff also show that dual trading may lead to a lowering of transactions costs, at least for "uninformed" traders, if brokers pass on some of their dual trading profits in the form of lower commission fees. Finally, Stanley (1981) shows, through a simulation, that dual trading would lead to a decrease of brokerage fees and faster execution of customer orders.

In summary, previous studies have mainly focused upon a relationship between dual trading and some estimates of the bid-ask spread. They have mostly found that dual trading is associated with lower bid-ask spreads. One of our contributions in this paper lies in emphasizing market depth or the price impact of large trades and showing, at least for our sample, that a restriction in dual trading activities is not harmful to the maintenance of deep markets.

III. DATA AND METHODOLOGY

A. Data

Three sets of data are used in this study. First, we use the CME's Computerized Trade Reconstruction (CTR) data for two years, June 22, 1986 to June 21, 1988 with the inception of the Top- Step Rule falling in the middle of the sample period. This file contains, for each trade, the customer type, trade type, the number of contracts traded and prices but dated only by the half-hour. The customer type is classified as four indicators with respect to the floor brokers or floor traders according to Regulation 1.35 of the Commodity Exchange Act. CTI 1 refers to brokers trading for their own account; CTI 2 to brokers trading for their clearing members' house account; CTI 3 to trading for another member present on the exchange floor or an account controlled by such other members; and CTI 4 for trading for any other type of customers.

Second, we use the CME's time and sales data which contain the time and price of each S&P futures transaction. This data base includes only transactions with price changes as reported for futures contracts and the value of the spot index. Finally, to construct theoretical futures prices, we obtained the S&P 500 stock index quotes, dividend yields from the CRSP tapes and daily interest rate data for T-bills from the Data Resources Inc.

B. Methodology

First, we construct estimates of the price impact of large futures trades ("market depth") and second, we estimate the effect of the top-step rule on market depth. Our estimates of market depth are based upon the methodology used by Vijh (1990) for the CBOE equity options. The potential price impact of large trades can be either of a permanent or a temporary nature. If large futures trades are carried out because informed traders have superior information about future stock prices, then this should lead to a permanent change in both stock and futures prices surrounding large futures trades. On the other hand, if large futures trades cause additional inventory carrying costs for market makers, then this should cause a temporary deviation of the market futures price from its theoretical price. Also, since the magnitude of the deviation depends upon transactions costs (sum of commission costs in the stock and futures markets plus market impact costs of putting the trades initially), estimating the deviation would be an indirect way of measuring the effect on transactions costs.

To estimate market depth, we first identify "large" futures trades and the time brackets in which they occur. A large trade is defined in the following way. The average volume per transaction (ATV) is defined as the ratio of total volume to the total number of transactions for each time bracket[7]. For each of the two trade types (buys and sales), a large trade for that type is defined as a trade (ATV) one standard deviation greater than that trade type's daily mean for the entire two year sample period.

If large futures trades are motivated by superior information about the underlying stocks, then stock prices surrounding the large futures trade should be permanently affected. Denote the half-hour time bracket in which the j-th large futures trade occurs as the j-th interval. Let S_{oj} be the spot price (midpoint of the last quote) of the S&P 500 stock index just before the beginning of the j-th interval. Then r_t, the average spot price relative to S_{oj}, is:

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[7]The reason we construct a measure of average volume instead of just working with the raw volume variable is that, since trades are only dated by the half-hour, when more than one trade occurs within a half-hour bracket these cannot be time-ordered. In contrast, there is just one value of ATV per half-hour bracket.

$$r_t = \Sigma_{j=1}^{n}(S_{tj}/nS_{oj}) \quad (1)$$

where n is the number of large futures trades and S_{tj} is the stock price t minutes from the beginning of the j-th interval. For each t, r_t should be equal to 1 (ignoring a small return for a few minutes) if large futures trades were not information-based. r_t should increase (decrease) with t if traders have information that the spot index will increase (decrease)[8].

r_t is calculated for values of t ranging from 15 minutes before to 15 minutes after the beginning of the j-th interval. For example, suppose only two large trades occur in the sample (n=2), one in the 10-10.30 AM bracket and the other in the 3-3.30 PM bracket. If we set t=-15 minutes, then r_{-15} is calculated by first taking the ratios of the spot prices at 9.45 AM and 2.45 PM to the spot prices just before 10 AM and 3 PM, respectively, and then averaging the two ratios. r_t is calculated for time periods before the j-th interval in this way to reflect the possibility that the market may learn about a large trade before it actually occurs.

If a large futures trade is information based, it may also have a permanent effect on the surrounding futures prices. This effect is estimated by the statistic f_t which measures the average futures price relative to F_{oj}, the market futures price just before the j-th interval. f_t is defined in identical fashion to r_t, with the futures prices replacing the spot prices.

A large futures trade may also cause a temporary divergence between the market futures price and its theoretical price if it increases market makers' inventory carrying costs. To estimate

[8]A potential problem with this test is that we do not know exactly when the j-th trade occurs within the half-hour bracket. This is because of the way the CTR data is constructed. If it occurs towards the end of the j-th interval, then S_{oj} will be a stale price. So we repeat the test, but calculate the average spot price relative to S_{cj}, the spot index price just after the j-th interval. The second reference point S_{cj} is meant to capture the information effect of large trades occurring towards the end of the j-th interval.

this "inventory" effect for a futures contract expiring at time T, define the "mispricing" variable x_{tjT} as follows[9]:

$$x_{tjT} = [F_{tjT} - S_{tj}e^{(r-d)(T-t)}]/S_{0j} \tag{2}$$

where F_{tjT} is the market price of the futures contract t minutes from the beginning of the j-th interval, S_{tj} is the index value, and r and d represent the risk-free rate and the dividend rate, respectively. We choose stock index quotes 30 minutes apart (the limits chosen to coincide with those of the half-hour brackets in the CTR data) so that the mispricing variable is defined for half-hour intervals. Averaging over all large trades:

$$m_{tT} = \Sigma_{j=1}^{n}(x_{tjT}/n) \tag{3}$$

where n is the number of large futures trades.

After measuring the liquidity of the S&P 500 futures market, we test whether the top-step rule has a significant impact on the liquidity. Following Fishman and Longstaff (1992), dual trading volume is identified with member trading volume (customer type indicators or CTI codes 1,2 and 3) and nondual trading volume with public trading volume (CTI code 4)[10]. The average per transaction dual trading volume (ADTV) is proxied by the ratio of member volume to the number of member transactions for each time bracket. The average non-dual trading volume (ANTV) is similarly defined. Then, for each of the four trade types (dual buys and sales; nondual buys and sales), a large trade for that type is defined as a trade (ADTV or ANTV) one

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[9]In our tests, we only consider nearby contracts, which have the highest trading volumes.

[10]We have repeated our tests with a narrower definition of dual trades by using trades identified under CTI code 1 only - as in the CFTC (1989) study. This does not change any of our results materially. The results will be available upon request from the authors.

standard deviation greater than that trade type's daily mean for the entire two year sample period. The sample period is divided into three sub-periods - period 1 for the pre-rule-change regime (6/22/86-6/21/87), period 2 for the post-change but pre-crash situation (6/22/87-10/18/87) and period 3 for the post-crash interval (10/19/87-6/21/88). To test the significance of changes in market depth, if any, among the three sample periods, we run the dummy regressions for both r_t and m_{tT}. For example, for m_{tT}, we estimate the following equation:

$$m_{tT} = \alpha_o + \alpha_1 D_{t1} + \alpha_2 D_{t2} + \epsilon_t \qquad (4)$$

where $D_{t1} = 1$ for sample two (post rule change and pre-crash) and zero otherwise and $D_{t2} = 1$ for sample three (post-crash) and 0 otherwise. Under the null hypothesis, α_1 and α_2 are zero. If α_1 is significantly less (greater) than zero, then depth is higher (lower) in the dual trading regime.

In addition to testing the price impact of large futures trades, we also estimate their effect on price volatility. Using the high-low spread as a measure of price volatility, we perform two tests: first, we count the number of occurrences for which the j-th interval's high-low spread is increased or decreased relative to the previous day's median spread. This allows us to examine whether high volume days are generally associated with increased price volatility. Second, we compute the statistic p_t, defined as:

$$p_t = \Sigma_{j=1}^{n}(P_{tj} - \bar{p})/S_{0j} \qquad (5)$$

where P_{tj} is the high-low spread t half-hour intervals (i.e. 30t minutes) from the j-th interval and

$\bar{p}$ is the average high-low spread computed over the previous 8 days[11]. The difference between these two variables is normalized by S_{0j}, the spot price just before the beginning of the j-th interval, and then averaged across all large trades. If the volatility is unaffected by large trades, then $p_t=0$ for each t.

Although trading volume and volatility may be positively correlated in general, Fishman and Longstaff (1992) claim that dual (nondual) trading volume and volatility are negatively (positively) correlated. To check this claim, the above two tests are repeated for both dual and nondual large trades and for each of the three sample periods[12].

Finally, we test Grossman's (1989) conjecture that dual trading creates a reserve pool of brokers who can switch to servicing customers in high volume periods. Define the broker participation rate for the i-th time bracket, BPR_i, as:

$$BPR_i = \frac{\text{number of member transactions in the i-th interval}}{\text{total number of member and non member transactions}}.$$

We interpret this ratio as a proxy for the number of active dual trading brokers in the relevant time bracket. If dual trading has no effect on brokers' participation rate, then BPR_i should be constant over time for each i. Otherwise, the ratio should be positively correlated with the relative dual trading volume (i.e. the ratio of dual trading volume to total volume in the i-th interval).

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[11]8 days is used to account for the bunching of large trades over consecutive days (see section V.B for a more detailed discussion of this bunching phenomena). Since the number of such consecutive large volume days never exceeds 9, we expect this average to be representative of a typical day.

[12]One advantage of equation (5) is that it can take account of possible bunching effects of large futures trades as shown in section V.D.

IV. Liquidity of the S&P 500 Futures Market.

Table 1 reports the effects of large futures trades on the surrounding spot prices, based on the assumption that the large trades occur towards the beginning of the half-hour brackets[13]. The surrounding spot prices appear to be unaffected, with r_t being very close to one for all values of t for both buyer and seller initiated trades. This indicates that, within a 30 minute span around the occurrence of the large futures trades, the underlying spot prices remain virtually unchanged on average. Further, r_t does not increase or decrease with t, indicating that the large futures trades are not motivated by superior information. This is not surprising, since the underlying asset is not an individual stock but the S&P 500 index and thus, to obtain profitable trading opportunities, investors would need to have privileged access to market-related information. These results are consistent with the effect of large options trades on surrounding stock prices, as reported in Vijh (1990)[14].

Table 2 shows that, for large futures trades, the market price is consistently below its true theoretical price. The reason may be that it is easier (because of short-selling restrictions in the spot market) to sell futures and hold a long position in the S&P 500 index, rather than buy futures and go short in the index. Thus, whenever futures are over-priced, arbitragers can correct this but the reverse is not equally feasible[15].

Consistent with previous studies, Table 3 shows that volume and volatility are, in

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[13]The qualitative results do not change if the tests are repeated with the large futures trades assumed to occur towards the end of the half-hour brackets.

[14]We have also tested, but not reported, the effect of large futures trades on the surrounding futures prices. The results are similar to those reported in the paper regarding the spot prices. They will be available upon request from the authors.

[15]We are indebted to Jay Ritter for suggesting this explanation.

general, positively correlated - large futures trades cause an increase in the high-low spread relative to its average over the previous eight days. If the large trade occurs in the j-th interval, then the spread starts to increase from at least interval j-2 (one hour before), peaks in interval j-1 (half-hour before) and then returns to its average level by interval j+2 (one hour after). At the five percent level, the increase is significant in interval j-2 for large sales and in interval j-1 for both large purchases and sales.

Summarizing, our results show that the S&P 500 index futures market has great depth in its capacity to absorb large trades without a significant price impact and without causing a serious misalignment in futures prices from their true underlying values. Large futures trades do, however, cause higher price volatility as measured by the high-low spread.

V. The Effect of Dual Trading on Liquidity In The S&P 500 Futures Market.

A. Transactions, Trading Volumes and Broker Participation Rates.

Tables 4-6 contain some summary statistics on the mean dual trading and nondual trading volume (DTV and NTV), number of transactions (DTT and NTT) and the average volume per transaction (ADT and ANT) for each half-hour time bracket and each time period. Both the number of transactions and the trading volume for all three periods are high around opening time, decrease until noon and rise again until the market closes, so that the familiar U-shaped pattern emerges. This is consistent with previous studies (eg. Admati and Pfleiderer (1988), Wood, McInish and Ord (1985) and Park (1992)). Note also that the average volume per transaction is U-shaped as well, which implies that relative to the number of transactions, the dollar volume is more concentrated around the opening and closing times. Figures 1-6 illustrate.

The letters on the horizontal axis refer to the time brackets following the conventions of the CTR data. For example, a is the 8-8.30 AM bracket, b is the 8.30-9 AM bracket and so on.

Table 7 shows how the sample means of these variables differ across the three regimes. The rule change reduces the sample mean of DTV by about 6.61%, which is significant at the five percent level[16]. This number is somewhat consistent with the estimate in the CFTC (1989) study of a reduction in DTV by 7.4%-12% if dual trading were completely eliminated (which is not the case here)[17]. The time bracket most affected by the rule change is the 3-3.30 PM interval where DTV drops by 11.78%. The crash reduces DTV by a further 40.95%. On the other hand, NTV is hardly affected by the rule change (0.8% reduction) whereas the crash causes a drop of 35.58%. The reduction in the sample mean of DTT due to the rule change and the crash are 7.77% (significant at the 2.5% level) and 32.2%, respectively. The corresponding numbers for NTT are 3.15% and 42.56%. Again, the 3-3.30 PM time interval suffers the most with a DTT reduction of about 11.94%.

Given that the rule change reduces total dual trading volume and transactions proportionately, it follows that the average per transaction dual trading volume ADT is relatively unchanged over the first two periods (a change of +0.87%). In fact, it is of roughly the same order as the change in ANT (+0.54%). The effect of the crash is more interesting. Whereas

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[16]To test whether the changes in the mean among different sample periods are statistically significant, the daily averages were regressed on two dummies to isolate the effects of the rule change and the crash. Table 8 provides the regression results. The coefficient of the crash dummy is highly significant for all the variables whereas the coefficient of the rule change dummy is never significant for any of the non-dual trading variables. The rule change dummy coefficient is significant for DTT and marginally significant for DTV.

[17]This shows that our definition of dual trading, though somewhat rough compared to that of the CFTC, still provides a reasonable basis for our study.

ADT is reduced by 6.03%, ANT actually increases by 20.32%. The reason is that total public volume is decreased but the shrinkage in the number of public trading transactions is far larger.

Dual trading may enhance market depth by increasing broker participation in high volume periods. With this in mind, we calculate for each half-hour interval i the Pearson and Spearman rank correlation coefficients between the broker participation rate BPR_i and the ratio of dual trading volume to total trading volume. The correlation coefficients should be positive by hypothesis. The results reported in Table 9 show that the coefficients are positive and highly significant for each time bracket, ranging from 0.71 to 0.86 in the pre-rule change period, from 0.67 to 0.94 in the post-change pre-crash period and from 0.76 to 0.94 in the post-crash period. The stability of the correlations over the three sample periods suggests that the reduction in dual trading activity is not sufficient to diminish the provision of liquidity services to brokerage customers.

B. Information Effect of Dual Trading on Market Depth.

Figures 7-12 plot the frequency distribution of large dual and nondual trades over different time brackets for each day and over different trading periods. Large dual trades appear to have a pronounced U-shaped pattern. Large nondual trades exhibit a wave pattern with trading concentrated around the opening and early afternoon times, but tapering off towards the end. More importantly, large trades of both types are bunched together *over successive days*, interspersed with relatively quiet days in-between[18]. This result is consistent with the prediction of Admati and Pfleiderer (1988) that informed traders bunch with noise traders in order to hide

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[18]See section V.D below as to why this is important for our tests.

their information. Although Admati and Pfleiderer are, in their paper, primarily concerned with intra-day trade variation, their argument applies equally well to the inter-day variation in trades as well[19].

The spot prices during a 30 minute interval around the occurrence of large dual and non-dual futures trades do not appear to be affected (see Tables 10 and 11)[20]. For example, for the first sample period, r_t is 0.99988 for buyer-initiated and 1.00014 for seller-initiated dual trading at t=-5, i.e. 5 minutes before the beginning of the time bracket in which the large dual trade occurs. Further, within each sample period, r_t does not increase or decrease with t. Comparing between samples one and two, the rule change does not appear to have affected the behavior of the surrounding stock prices[21]. Nor do there appear to be any distinction between large dual and nondual trades in this respect.

In Tables 12-13, we report the effect of large futures trades on the surrounding futures prices. The results are very similar to the ones reported above for the spot prices. The surrounding futures prices are largely unaffected by large dual and nondual trades. A comparison of the mispricing variable across the three regimes show very little variation, with the t-statistics

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[19] It also appears that before the crash, large dual trades were more frequent than large nondual trades. After the crash, on the other hand, large nondual trades became twice as frequent as large dual trades. We can provide no explanation for this pattern. Certainly, it deserves further study.

[20] Although these calculations are based on the assumption that the j-th large futures trade occurs towards the beginning of the j-th interval, the qualitative results do not change if they occur towards the end of the interval. These latter results are not reported but are available upon request from the authors.

[21] Regressing r_t on two time dummies show that for r_{+5}, r_{+10} and r_{+15}, the crash coefficients are significant for both large dual purchases and sales. For purchases, the corresponding t-values are -2.671, -2.712 and -2.627, respectively, whereas for sales they are all greater than 4 in absolute value. None of the coefficients of the dual trading dummies are statistically significant.

on the time dummies being uniformly insignificant[22].

C. Inventory Effect of Dual Trading on Market Depth.

Consistent with our previous findings, large dual and nondual trades are priced systematically below their theoretical prices (see Tables 14 and 15). The magnitude of mispricing is significant in most cases except seller initiated dual trades for the first and second periods and buyer initiated non-dual trades in the second period. However, the regression results (not reported here to conserve space) show that, for both large dual buys and sales, the amount of mispricing is not affected by the top-step rule but is increased significantly by the crash. Therefore, it does not appear that the rule change imposed any further inventory carrying costs on market makers.

D. Effect of Dual Trading on Price Volatility.

Tables 16-17 show how the high-low spread changes relative to the previous day's median when a large futures trade occurs. According to Fishman and Longstaff (1992), spreads associated with large dual trades (both buys and sales) should increase after the inception of the top-step rule. The results are mixed, however. For large dual purchases, the rule change actually <u>reduces</u> by about 10% the number of trades for which the spread is increased and increases by about 7% the number for which the spread is decreased from the previous day's median. For large dual and nondual sales, exactly the opposite result is obtained.

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[22] The only exception is that, for large dual sales, the crash increases s_{-15} which has a positive dummy coefficient with a t value of +2.055.

The crash has very little effect on the high-low spread of large buys (dual and nondual). Surprisingly, the crash reduces the percentage of large sales (dual and nondual) for which the spread is increased. If the high-low spread is a measure of price volatility, this result flies against conventional wisdom. One explanation relies on our earlier observation that the bunching of large volume days increased after the crash (see Figures 8-9 and 11-12). The previous day's median spread, therefore, is likely to be larger on average after the crash. Of course, a typical large trade is also associated with a larger absolute value of the spread after the crash (see Tables 16-17). It appears, though, that the bunching effect dominates.

Since the results may be affected by the bunching of large volume trades (which is also evident before the crash), we perform the test specified in equation (5). Tables 18-19 report the results. The changes in the high-low spreads are significantly positive for large dual trades but not for large nondual trades with few exceptions. More importantly, the effect of the rule change is not significant. These results are not consistent with the predictions of Fishman and Longstaff (1992). The crash causes the spread to increase significantly for large dual buys and sells[23]. It is interesting, however, to note that large nondual trades are, in general, unaffected by the crash.

VI. Conclusion.

This paper investigates the liquidity of the S&P 500 index futures market and tests whether the liquidity is affected by the restriction on dual trading activity due to the CME's top-

[23]The results of dummy regressions for testing the differences among three different time regimes are available from the authors upon request. Also, when we repeated the tests using the average spread for the previous day only (instead of the previous 8 days), we found that even the effect of the crash is insignificant. This lends indirect support to the manner in which we have defined our statistic.

step rule. In measuring liquidity, we examine various market characteristics such as depth, trading volume and transactions, high-low spreads of prices and brokers' participation rate. In estimating depth, we distinguish between any permanent price effects caused by informationally motivated large trades and temporary mispricings due to the impact of large trades on market makers' inventory carrying costs.

Our results show that the S&P 500 index futures market is an extremely liquid market. It has great depth in its capacity to absorb large trades without a significant price impact. Large futures trades do, however, cause higher price volatility as measured by the high-low spread.

The restriction on dual trading (through the CME's top-step rule) caused some reduction in both the dual trading volume and the number of transactions while leaving the average order size per transaction unchanged. However, this reduction in dual trading activity does not appear to have significantly affected the liquidity of the S&P 500 index futures market. The behavior of stock and futures prices surrounding large futures trades show no significant impact from the top-step rule. Similarly, while there exists significant underpricing of the index futures, we can find no additional mispricing due to the rule change. Our results on the liquidity effects of dual trading are not consistent with some previous studies (in particular, Smith and Whaley (1990b)) which did find an adverse impact on the bid-ask spread due to the restriction on dual trading. Our results also contradict the findings of Fishman and Longstaff (1992) that dual trading and price volatility are negatively related. When we compare the high-low spread associated with a large trade with the previous day's median spread, the hypothesized relation holds for large dual sales but not for purchases. When compared to the average spread, however, no significant relationship is found between volatility and dual trading activity.

We do find that the participation of dual trading brokers is positively correlated with high volume trading intervals. However, the advent of the top-step rule again in no way diminishes the role of dual trading brokers in providing customers with liquidity services.

Not surprisingly, the market crash has significant effects on all characteristics of the market examined in this paper. Since the focus of the paper is on dual trading, we do not provide a detailed examination of market characteristics around the crash. However, the issue certainly deserves further study in the future.

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TABLE 1
Stock Prices Surrounding Large Futures Trades

The change in stock prices for the 30 minute window surrounding large futures trades (defined as the sample mean of ATV plus one standard deviation). The stock price reaction is measured by $r_t = \Sigma_j S_{tj}/nS_{0j}$, where S_{tj} is the stock price t minutes from the beginning of the time bracket when the j-th large trade occurs and n is the number of large trades. Buy and Sell indicate large purchases and sales. Standard errors are reported in parenthesis.

	r_{-15}	r_{-10}	r_{-5}	r_{+5}	r_{+10}	r_{+15}
Buy	1.00025 (.00055) N=279	0.99991 (.00048) N=279	0.99955 (.00043) N=279	0.99762 (.00067) N=274	0.99753 (.0007) N=274	0.99762 (.00081) N=274
Sell	0.99986 (.00038) N=457	0.99975 (.00034) N=457	0.99959 (.0003) N=457	0.99869 (.00049) N=448	0.99863 (.00051) N=448	0.99876 (.00038) N=448

TABLE 2
Mispricing In Futures Prices Surrounding Large Futures Trades

The mispricing variable for the j-th large trade is measured by $x_{tjT} = [F_{tjT} - S_{tj}e^{(r-d)(T-t)}]/S_{0j}$, where F_{tjT} is the market futures price of an index expiring at time T and S_{tj} is the index value. The averaging mispricing is given by $m_{tT} = \Sigma_{j=1}^{n} x_{tT}/n$, where n is the number of large trades. t takes on values within the 30 minute window surrounding large trades (defined as the sample mean of ATV plus one standard deviation). Buy and Sell indicate large purchases and sales. Standard errors are reported in parenthesis. N indicates the number of observations.

	r_{-15}	r_{-10}	r_{-5}	r_0	r_{+5}	r_{+10}	r_{+15}
Buy	-.0099 (.002) N=279	-.0097 (.002) N=279	-.0099 (.002) N=279	-.01 (.002) N=279	-.0086 (.002) N=274	-.0097 (.002) N=274	-.0091 (.002) N=274
Sell	-.006 (.001) N=425	-.0063 (.001) N=425	-.0062 (.001) N=425	-.0062 (.001) N=425	-.0056 (.001) N=416	-.0061 (.001) N=416	-.0057 (.001) N=416

TABLE 3

High-low Spread Relative To Average For Large Futures Trades

The high-low price spread P_j for the j-th large trade is compared to its average over the previous 8 days. The reported statistic is $p_t=\Sigma_{j=1}^{n}[P_{tj} - \bar{P}]/S_{0j}$, where P_{tj} is the high-low price spread t intervals from the interval in which j-th large futures trade occurred and S_{0j} is the index value at t=0. n is the number of large trades. t takes on values from -2 to +2, i.e. two half-hour time intervals before and after the j-th interval. Buy and Sell indicate large purchases and sales. Standard errors are reported in parenthesis. N indicates the number of observations.

	p_{-2}	p_{-1}	p_0	p_{+1}	p_{+2}
Buy	0.00229 (.0012) N=210	0.00249 (.001) N=257	0.0012 (.00092) N=257	0.0 (.0009) N=250	0.00061 (.0009) N=253
Sell	0.00175 (.00079) N=338	0.00196 (.00064) N=422	0.00062 (.00059) N=422	0.0 (.00059) N=409	0.00048 (.0006) N=413

TABLE 4
DUAL TRADING AND NON-DUAL TRADING TRANSACTIONS

The daily mean of the number of dual trading (DTT) and non-dual trading (NTT) transactions for each half-hour time interval for each of three sample periods. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. N gives the total number of observations for each sample period. The 12-12.30PM interval is omitted as it contains minimal trading activity.

	DTT1 (N=248)	DTT2 (N=83)	DTT3 (N=172)	NTT1 (N=248)	NTT2 (N=83)	NTT3 (N=172)
9-9.30AM	3588.63	3473.75	2272.89	1771.82	1783.23	912.87
9.30-10AM	2857.65	2589.65	1684.83	1337.94	1162.14	640.79
10-10.30AM	2152.65	2089.07	1297.16	991.27	964.37	511.29
10.30-11AM	1848.38	1718.05	1081.95	895.99	858.42	482.90
11-11.30AM	1717.04	1562.51	985.34	829.78	795.46	445.06
11.30-12PM	1471.22	1351.25	841.16	725.70	709.04	391.27
12.30-1PM	1445.05	1322.96	880.81	703.67	664.41	398.19
1-1.30PM	1610.88	1475.51	986.00	761.37	712.58	430.28
1.30-2PM	1764.05	1644.53	1137.33	817.20	780.58	467.33
2-2.30PM	1846.57	1710.81	1272.33	852.25	822.10	538.81
2.30-3PM	1974.99	1738.10	1314.77	964.08	916.74	571.09
3-3.30PM	2034.63	1791.66	1383.43	1052.56	1025.02	655.36
3.30-4PM	1884.67	1713.87	1282.36	1012.11	1062.23	633.40
4-4.30PM	1005.93	909.46	591.32	807.10	840.53	443.56

TABLE 5
DUAL TRADING AND NON-DUAL TRADING VOLUMES

The daily mean of the number of dual trading (DTV) and non-dual trading (NTV) volumes for each half-hour time interval for each of three sample periods. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. N gives the total number of observations for each sample period. The 12-12.30PM interval is omitted as it contains minimal trading activity.

	DTV1 (N=248)	DTV2 (N=83)	DTV3 (N=172)	NTV1 (N=248)	NTV2 (N=83)	NTV3 (N=172)
9-9.30AM	13171.54	13036.89	7436.24	6948.48	7532.17	4485.69
9.30-10AM	9775.86	8746.53	4987.23	5099.42	4600.90	2877.74
10-10.30AM	7054.74	7012.78	3788.24	3636.64	3611.13	2200.24
10.30-11AM	6070.87	5746.00	3172.05	3242.55	3622.43	2083.05
11-11.30AM	5663.22	5122.07	2816.64	3003.08	2895.66	1952.15
11.30-12PM	4749.28	4528.92	2361.97	2640.94	2586.80	1550.92
12.30-1PM	4731.30	4262.66	2540.77	2516.40	2282.46	1623.87
1-1.30PM	5216.75	4772.45	2747.92	2718.84	2500.16	1754.18
1.30-2PM	5707.04	5460.07	3279.83	2852.29	2824.72	1912.97
2-2.30PM	5943.49	5677.04	3676.92	2985.79	2895.35	2162.40
2.30-3PM	6562.96	5937.81	3851.55	3344.67	3286.63	2148.89
3-3.30PM	7023.44	6196.37	4182.82	3735.00	3658.95	2469.08
3.30-4PM	6854.40	6323.89	4126.56	3826.66	4103.17	2599.41
4-4.30PM	4089.98	3668.08	2107.78	3034.67	3183.51	1870.25

TABLE 6
AVERAGE DUAL TRADING AND NON-DUAL TRADING VOLUMES

The daily mean of the (per transaction) average dual trading (ADT) and non-dual trading (ANT) volumes (defined as DTV/DTT and NTV/NTT, respectively) for each half-hour time interval for each of three sample periods. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. N gives the total number of observations for each sample period. The 12-12.30PM interval is omitted as it contains minimal trading activity.

	ADT1 (N=248)	ADT2 (N=83)	ADT3 (N=172)	ANT1 (N=248)	ANT2 (N=83)	ANT3 (N=172)
9-9.30AM	3.69	3.26	3.42	3.90	4.25	4.95
9.30-10AM	3.47	3.38	3.26	3.85	3.39	4.79
10-10.30AM	3.24	3.26	3.39	3.61	3.71	4.33
10.30-11AM	3.27	3.19	2.99	3.57	3.86	4.34
11-11.30AM	3.23	3.41	2.99	3.77	3.98	4.53
11.30-12PM	3.19	3.41	2.99	3.55	3.59	4.20
12.30-1PM	3.24	3.20	3.14	3.56	3.34	4.28
1-1.30PM	3.16	3.16	2.90	3.50	3.52	4.31
1.30-2PM	3.16	3.90	2.99	3.52	3.43	4.10
2-2.30PM	3.24	3.14	3.22	3.54	3.69	4.35
2.30-3PM	3.37	3.37	3.93	3.49	3.46	4.10
3-3.30PM	3.16	3.26	3.33	3.54	3.39	3.90
3.30-4PM	3.57	3.46	3.17	3.74	3.65	3.98
4-4.30PM	4.01	3.94	3.53	3.69	3.75	4.20

TABLE 7
SAMPLE MEANS FOR TRANSACTIONS AND TRADING VOLUMES

The sample means for trading volume (DTV and NTV), number of transactions (DTT and NTT), and average volume per transaction (ADT and ANT) for each of three sample periods. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. N gives the total number of observations for each sample period.

	Period1 (N=248)	Period2 (N=83)	Period3 (N=172)
DTV	92614.92	86491.57	51076.52
NTV	49585.36	49188.06	31690.84
DTT	27202.35	25091.17	17011.68
NTT	13522.85	13096.86	7522.20
ADT	3.4478	3.4791	3.2668
ANT	3.7188	3.7436	4.5014

TABLE 8
ESTIMATES FOR DUMMY VARIABLE COEFFICIENTS

The coefficient estimates for the regression $X_{it}=a_i+b_iD_{1t}+c_iD_{2t}$, for i=1 through 6. X_1=DTV, X_2=NTV, X_3=DTT, X_4=NTT, X_5=ADT and X_6=NDT. D_{1t}=1 in period 2 and 0 otherwise, D_{2t}=1 in period 3 and 0 otherwise. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. N gives the total number of observations for each sample period. T values are in parenthesis.

	b_i (N=502)	c_i (N=502)	a_i (N=502)
DTV	-6123.35 (-1.669)	-41538.40 (-14.466)	92614.92 (50.403)
NTV	397.30 (-0.163)	-17894.52 (-9.373)	49585.36 (40.585)
DTT	-2111.18 (-2.094)	-10190.67 (-12.916)	27202.35 (53.877)
NTT	-425.995 (-0.817)	-6000.65 (-14.699)	13522.85 (51.764)
ADT	-0.034 (-0.62)	-0.122 (-2.851)	2.276 (83.273)
ANT	0.095 (1.017)	0.252 (3.453)	1.263 (27.095)

TABLE 9
BROKER PARTICIPATION RATE

The Pearson (P_i) and the Spearman (S_i) rank correlation coeffcients for sample period i between the relative number of dual trading transactions BPR and the relative dual trading volume RDT for each time interval. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. BPR is defined as DTT/(DTT+NTT) and RDT is defined as DTV/(DTV+NTV). N gives the total number of observations for each sample period. The 12-12.30PM interval is omitted as it contains minimal trading activity.

	S1 (N=248)	S2 (N=83)	S3 (N=172)	P1 (N=248)	P2 (N=83)	P3 (N=172)
9-9.30AM	0.8504	0.8734	0.8634	0.8371	0.8429	0.8551
9.30-10AM	0.7744	0.9215	0.8431	0.7760	0.8694	0.7580
10-10.30AM	0.7106	0.9229	0.8633	0.7356	0.8762	0.7195
10.30-11AM	0.7261	0.7525	0.8165	0.7797	0.8354	0.7861
11-11.30AM	0.8176	0.9453	0.8507	0.7669	0.8389	0.7857
11.30-12PM	0.7914	0.8148	0.7703	0.7781	0.8069	0.7678
12.30-1PM	0.8234	0.8967	0.8167	0.8253	0.8377	0.7998
1-1.30PM	0.7839	0.8534	0.8832	0.7406	0.8319	0.7425
1.30-2PM	0.8534	0.7790	0.8729	0.8253	0.7571	0.8228
2-2.30PM	0.7994	0.7681	0.8613	0.7594	0.7760	0.8143
2.30-3PM	0.8611	0.8992	0.8545	0.8139	0.8730	0.7547
3-3.30PM	0.8027	0.8202	0.9178	0.8100	0.7921	0.8078
3.30-4PM	0.8294	0.9198	0.9461	0.7933	0.8819	0.7541
4-4.30PM	0.7454	0.6666	0.8487	0.7458	0.7078	0.7422

TABLE 10
Stock Prices Surrounding Large Dual Trades

The change in stock prices for the 30 minute window surrounding large dual trades (defined as the sample mean of ADTV plus one standard deviation) for each sample period. The stock price reaction is measured by $r_t = \Sigma_j S_{tj}/nS_{0j}$, where S_{tj} is the stock price t minutes from the beginning of the time bracket when the j-th large dual trade occurs and n is the number of large dual trades. Buy'i' and Sell'i' indicate large dual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
r_{-15}	1.00041 (.00033) N=155	0.99953 (.00060) N=52	1.00033 (.00104) N=131	1.00020 (.00020) N=303	0.99973 (.00037) N=103	1.00005 (.00076) N=192
r_{-10}	1.00003 (.00029) N=155	0.99930 (.00054) N=52	1.00001 (.00092) N=131	1.00015 (.00018) N=303	0.99974 (.00033) N=103	0.99993 (.00067) N=192
r_{-5}	0.99988 (.00022) N=155	0.99932 (.00048) N=52	0.99946 (.00084) N=131	1.00014 (.00015) N=303	0.99984 (.00028) N=103	0.99949 (.0006) N=192
r_0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
r_{+5}	0.99922 (.00039) N=150	0.99828 (.00077) N=49	0.99603 (.00130) N=126	1.00020 (.00024) N=295	0.99970 (.00043) N=101	0.99707 (.00095) N=189
r_{+10}	0.99920 (.00043) N=150	0.99809 (.00082) N=49	0.99582 (.00135) N=126	1.00020 (.00025) N=295	0.99960 (.00045) N=101	0.99689 (.00098) N=189
r_{+15}	0.99918 (.00047) N=150	0.99800 (.00089) N=49	0.99573 (.00141) N=126	1.00024 (.00027) N=295	0.99968 (.00047) N=101	0.99670 (.00103) N=189

TABLE 11
Stock Prices Surrounding Large Non-dual Trades

The change in stock prices for the 30 minute window surrounding large non-dual trades (defined as the sample mean of ANTV plus one standard deviation) for each sample period. The stock price reaction is measured by $r_t = \Sigma_j S_{tj}/nS_{0j}$, where S_{tj} is the stock price t minutes from the beginning of the time bracket when the j-th large non-dual trade occurs and n is the number of large non-dual trades. Buy'i' and Sell'i' indicate large nondual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
r_{-15}	1.00050 (.00045) N=80	1.00115 (.00050) N=26	0.99981 (.00061) N=270	0.99975 (.00032) N=157	1.00003 (.00038) N=67	0.99991 (.00053) N=308
r_{-10}	1.00035 (.00045) N=80	1.00087 (.00049) N=26	0.99964 (.00054) N=270	0.99968 (.00028) N=157	0.99996 (.00029) N=67	0.99984 (.00047) N=308
r_{-5}	1.00018 (.00041) N=80	1.00038 (.00037) N=26	0.99929 (.00049) N=270	0.99964 (.00024) N=157	0.99996 (.00029) N=67	0.99958 (.00043) N=308
r_0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
r_{+5}	1.00047 (.00045) N=80	0.99973 (.00085) N=26	0.99831 (.00079) N=269	0.99961 (.00036) N=154	0.99924 (.00054) N=67	0.99877 (.00073) N=306
r_{+10}	1.00027 (.00049) N=80	0.99959 (.00101) N=26	0.99829 (.00082) N=269	0.99946 (.00039) N=154	0.99907 (.00059) N=67	0.99868 (.00075) N=306
r_{+15}	0.99987 (.00061) N=80	0.99931 (.00115) N=26	0.99864 (.00092) N=269	0.99947 (.00042) N=154	0.99890 (.00061) N=67	0.99904 (.00084) N=306

TABLE 12
Futures Prices Surrounding Large Dual Trades

The change in futures prices for the 30 minute window surrounding large dual trades (defined as the sample mean of ADTV plus one standard deviation) for each sample period. The futures price reaction is measured by $f_t = \Sigma_j F_{tj}/nF_{0j}$, where F_{tj} is the futures price t minutes from the beginning of the time bracket when the j-th large dual trade occurs and n is the number of large dual trades. Buy'i' and Sell'i' indicate large dual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
f_{-15}	1.00045 (.00035) N=155	0.99988 (.00052) N=52	1.00219 (.00142) N=131	1.00015 (.00020) N=303	0.99988 (.00032) N=103	1.00172 (.00099) N=192
f_{-15}	1.00050 (.00023) N=155	0.99971 (.00046) N=52	1.00162 (.00129) N=131	1.00019 (.00013) N=303	0.99988 (.00025) N=103	1.00137 (.00091) N=192
f_{-5}	1.00016 (.00018) N=155	1.00021 (.00027) N=52	1.00094 (.00081) N=131	1.00001 (.00010) N=303	1.00020 (.00016) N=103	1.00068 (.00061) N=192
f_0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
f_{+5}	0.99978 (.00040) N=150	0.99891 (.0007) N=49	1.00071 (.00352) N=126	1.00011 (.00023) N=295	0.99987 (.00039) N=101	1.00033 (.00240) N=189
f_{+10}	0.99946 (.00043) N=150	0.99850 (.00115) N=49	0.99905 (.00377) N=126	1.00011 (.00023) N=295	0.99983 (.00046) N=101	0.99898 (.00255) N=189
f_{+15}	0.99974 (.00056) N=150	0.99850 (.00027) N=49	1.00166 (.00482) N=126	1.00015 (.00031) N=295	1.00022 (.00054) N=101	1.00084 (.00324) N=189

TABLE 13
Futures Prices Surrounding Large Non-dual Trades

The change in futures prices for the 30 minute window surrounding large non-dual trades (defined as the sample mean of ANTV plus one standard deviation) for each sample period. The stock price reaction is measured by $f_t = \Sigma_j F_{tj}/nF_{0j}$, where F_{tj} is the futures price t minutes from the beginning of the time bracket when the j-th large non-dual trade occurs and n is the number of large non-dual trades. Buy'i' and Sell'i' indicate large nondual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
f_{-15}	1.00016 (.00030) N=78	1.00157 (.00061) N=25	1.00110 (.00074) N=261	1.00008 (.00027) N=146	1.00013 (.00038) N=65	1.00086 (.00067) N=290
f_{-10}	1.00000 (.00025) N=78	1.00095 (.00040) N=25	1.00085 (.00069) N=261	1.00011 (.00021) N=146	1.00000 (.00028) N=65	1.00095 (.00062) N=290
f_{-5}	1.00000 (.00012) N=78	1.00027 (.00029) N=25	1.00038 (.00046) N=261	1.00010 (.00012) N=146	1.00013 (.00019) N=65	1.00042 (.00041) N=290
f_0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
f_{+5}	1.00009 (.00039) N=80	0.99946 (.00111) N=26	0.99978 (.00019) N=269	0.99984 (.00033) N=154	0.99941 (.00058) N=67	0.99952 (.00164) N=306
f_{+10}	0.99994 (.00046) N=80	0.99897 (.00143) N=26	0.99905 (.00195) N=269	0.99975 (.00034) N=154	0.99912 (.00069) N=67	0.99908 (.00174) N=306
f_{+15}	0.99962 (.00086) N=80	0.99873 (.00176) N=26	1.00067 (.00240) N=269	0.99976 (.00043) N=154	0.99912 (.00079) N=67	1.00058 (.00213) N=306

TABLE 14
Mispricing In Futures Prices Surrounding Large Dual Trades

The mispricing variable for the j-th large trade is measured as $x_{tjT} = [F_{tjT} - S_{tj}e^{(r-d)(T-t)}]/S_{0t}$, where F_{tjT} is the market futures price of an index expiring at time T and S_{tj} is the index value. The averaging mispricing is given by $m_{tT} = \Sigma_{j=1}^{n} x_{tjT}/n$, where n is the number of large trades. t takes on values within the 30 minute window surrounding large dual trades (defined as the sample mean of ADTV plus one standard deviation). Buy'i' and Sell'i' indicate large dual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis.N indicates the number of observations.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
m_{-15}	-.00189 (.00043) N=154	-.002 (.00066) N=52	-.01384 (.00337) N=131	-.00035 (.00033) N=288	-.00065 (.0005) N=95	-.01180 (.00256) N=173
m_{-10}	-.00146 (.00038) N=154	-.00193 (.00064) N=52	-.01407 (.00340) N=131	-.00036 (.00032) N=288	-.00069 (.00052) N=95	-.01236 (.00258) N=173
m_{-5}	-.00166 (.00036) N=154	-.00146 (.00053) N=52	-.01406 (.00355) N=131	-.00046 (.00031) N=288	-.00046 (.00047) N=95	-.01223 (.00268) N=173
m_{0}	-.00162 (.00049) N=154	-.00183 (.00062) N=52	-.01472 (.00341) N=131	-.00039 (.00031) N=288	-.00070 (.0005) N=95	-.01206 (.00255) N=173
m_{+5}	-.00138 (.00038) N=149	-.00168 (.00058) N=49	-.01200 (.00352) N=126	-.00036 (.00032) N=280	-.00048 (.0005) N=95	-.01020 (.00256) N=170
m_{+10}	-.00168 (.00037) N=149	-.00191 (.00065) N=49	-.01363 (.00336) N=126	-.00034 (.00033) N=280	-.00037 (.00052) N=95	-.01161 (.00242) N=170
m_{+15}	-.00135 (.00049) N=149	-.00172 (.00084) N=49	-.01320 (.00325) N=126	-.00032 (.00038) N=280	-.00005 (.00054) N=95	-.01128 (.00232) N=170

TABLE 15
Mispricing In Futures Prices Surrounding Large Nondual Trades

The mispricing variable for the j-th large futures trade is measured as $x_{tjT} = [F_{tjT} - S_{tj}e^{(r-d)(T-t)}]/S_{0j}$, where F_{tjT} is the market futures price of an index expiring at time T and S_{tj} is the index value. The average mispricing over all large trades is given by $m_{tT} = \Sigma_{j=1}^{n} x_{tjT}/n$, where n is the number of large trades. t takes on values within the 30 minute window surrounding large nondual trades (defined as the sample mean of ANTV plus one standard deviation). Buy'i' and Sell'i' indicate large nondual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis. N indicates the number of observations.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
m_{-15}	-.00154 (.00071) N=75	-.00012 (.00153) N=24	-.00818 (.00189) N=249	-.00278 (.00036) N=150	-.00159 (.00063) N=64	-.00639 (.00175) N=282
m_{-10}	-.00158 (.00069) N=75	-.00072 (.00160) N=24	-.00863 (.00190) N=249	-.00271 (.00035) N=150	-.00171 (.00064) N=64	-.00670 (.00176) N=282
m_{-5}	-.00135 (.0007) N=75	-.00007 (.00139) N=24	-.00851 (.0020) N=249	-.00266 (.00034) N=150	-.00121 (.00057) N=64	-.00658 (.00182) N=282
m_0	-.00128 (.0007) N=75	-.00025 (.00146) N=24	-.00852 (.00188) N=249	-.00273 (.00034) N=150	-.00145 (.00058) N=64	-.00656 (.00174) N=282
m_{+5}	-.00158 (.00071) N=75	.00020 (.00136) N=24	-.00788 (.00190) N=249	-.00292 (.00035) N=147	-.00106 (.00057) N=64	-.00637 (.00178) N=280
m_{+10}	-.00154 (.00071) N=75	-.00007 (.00144) N=24	-.00867 (.00186) N=249	-.00287 (.00035) N=147	-.00117 (.00059) N=64	-.00684 (.00171) N=280
m_{+15}	-.00136 (.00087) N=75	-.00019 (.00157) N=24	-.00837 (.00172) N=249	-.00283 (.00038) N=147	-.0009 (.00062) N=64	-.00658 (.00161) N=280

TABLE 16
CHANGE IN HIGH-LOW SPREAD FOR PURCHASES

The high-low spread for the j-th large buy P_j is compared to the median of the previous day's high-low spreads. PGDB(PLDB) gives the percentage of times that P_j exceeds(is below) the previous days' median for large dual buys. PEDB gives the percentage times the spread does not change. PGNDB, PENDB and PLNDB refer to nondual buys. 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are in parenthesis. N gives the total number of observations for each sample period.

	Period1	Period2	Period3
PGDB	64.09 (0.04) N=142	54.55 (0.076) N=44	53.91 (0.047) N=115
PLDB	3.52 (0.016) N=142	0.00 (0.0) N=44	3.48 (0.017) N=115
PLDB	32.39 (0.039) N=142	45.46 (0.076) N=44	42.61 (0.046) N=115
PGNDB	44.87 (0.057) N=78	48.00 (0.102) N=25	47.89 (0.031) N=261
PENDB	4.95 (0.022) N=78	0.00 (0.00) N=25	5.75 (0.014) N=261
PLNDB	51.28 (0.057) N=78	52.00 (0.102) N=25	46.36 (0.031) N=261

TABLE 17
CHANGE IN HIGH-LOW SPREAD FOR SALES

The high-low spread for the j-th large sale P_j is compared to the median of the previous day's high-low spreads. PGDS(PLDS) gives the percentage of times that P_j exceeds(is below) the previous days' median for dual sales. PEDS gives the percentage times the spread does not change. NDS refer to nondual sales. 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are in parenthesis. N gives the total number of observations for each sample period.

	Period1	Period2	Period3
PGDS	54.78 (0.03) N=272	63.83 (0.05) N=94	48.57 (0.038) N=175
PEDS	4.04 (0.012) N=272	2.13 (0.015) N=94	4.57 (0.016) N=175
PLDS	41.18 (0.03) N=272	34.04 (0.049) N=94	46.86 (0.038) N=175
PGNDS	45.21 (0.041) N=146	53.85 (0.062) N=94	45.86 (0.029) N=175
PENDS	4.80 (0.018) N=146	1.54 (0.015) N=94	4.48 (0.012) N=175
PLNDS	50.00 (0.042) N=146	44.62 (0.062) N=94	49.66 (0.029) N=175

TABLE 18
High-low Spread Relative To Average For Large Dual Trades

The high-low price spread P_j for the j-th large trade is compared to its average over the previous 8 days. The reported statistic is $p_t=\Sigma_{j=1}^{n}[P_{tj} - \bar{P}]/S_{0j}$, where P_{tj} is the high-low price spread t intervals from the interval in which j-th large futures trade occurred and S_{0j} is the index value at t=0. n is the number of large trades. t takes on values from -2 to +2, i.e. two half-hour time intervals before and after the j-th interval. Buy'i' and Sell'i' indicate large dual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis. N indicates the number of observations.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
p_{-2}	0.00289 (.00055) N=111	0.00215 (.00069) N=35	0.01029 (.0027) N=100	0.00209 (.00034) N=206	0.00157 (.00036) N=71	0.00656 (.00192) N=150
p_{-1}	0.00326 (.00046) N=142	0.00233 (.00056) N=44	0.01083 (.00234) N=115	0.00208 (.00027) N=269	0.00189 (.00031) N=94	0.00617 (.00168) N=175
p_0	0.00179 (.00041) N=142	0.0014 (.00046) N=44	0.00902 (.00215) N=115	0.00073 (.00023) N=269	0.00122 (.00038) N=94	0.00424 (.00155) N=175
p_{+1}	0.00125 (.00038) N=141	0.00264 (.00082) N=41	0.00904 (.00223) N=112	0.00039 (.00023) N=263	0.00113 (.00049) N=91	0.00425 (.0016) N=172
p_{+2}	0.00087 (.00027) N=137	0.00242 (.00111) N=40	0.00889 (.00211) N=109	0.00013 (.00017) N=261	0.00129 (.00062) N=88	0.00346 (.00151) N=170

TABLE 19
High-low Spread Relative To Average For Large Nondual Trades

The high-low price spread P_j for the j-th large trade is compared to its average over the previous 8 days. The reported statistic is $p_t = \Sigma_{j=1}^{n}[P_{tj} - \bar{P}]/S_{0j}$, where P_{tj} is the high-low price spread t intervals from the interval in which j-th large futures trade occurred and S_{0j} is the index value at t=0. n is the number of large trades. t takes on values from -2 to +2, i.e. two half-hour time intervals before and after the j-th interval. Buy'i' and Sell'i' indicate large nondual purchases and sales for sample period i. Sample period 1 is the pre-rule change period, 2 is the post-change but pre-crash period and 3 is the post-change post-crash period. Standard errors are reported in parenthesis. N indicates the number of observations.

	Buy1	Buy2	Buy3	Sell1	Sell2	Sell3
p_{-2}	0.00091 (.00045) N=71	0.0006 (.00063) N=23	0.00237 (.0014) N=222	0.0016 (.00049) N=125	0.00166 (.00052) N=50	0.00204 (.00126) N=248
p_{-1}	0.00057 (.00045) N=77	0.00099 (.0007) N=25	0.00234 (.0012) N=261	0.0015 (.00036) N=146	0.00113 (.00039) N=65	0.00227 (.00109) N=290
p_0	0.00009 (.00032) N=77	0.00161 (.00131) N=25	0.00126 (.00112) N=261	0.00069 (.0003) N=146	0.00133 (.00057) N=65	0.00106 (.001) N=290
p_{+1}	0.00054 (.00055) N=76	0.00218 (.00166) N=25	0.00074 (.00114) N=259	0.00065 (.00042) N=146	0.00169 (.00073) N=64	0.0008 (.00104) N=285
p_{+2}	0.00005 (.00032) N=73	-.00039 (.00029) N=24	0.00033 (.0011) N=255	0.00052 (.00026) N=145	0.00182 (.02905) N=64	0.0005 (.001) N=279

Figure 1

Total Dual Trading Volume
for Different Time Brackets

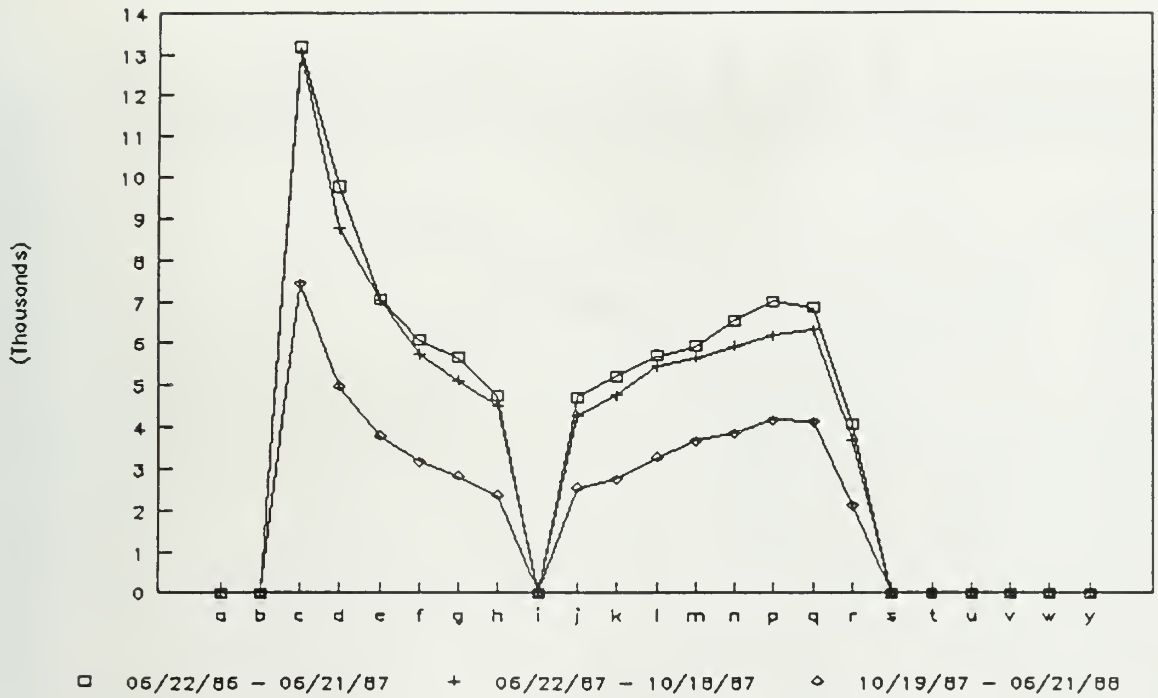

Figure 2

Total Non-Dual Trading Volume
for Different Time Brackets

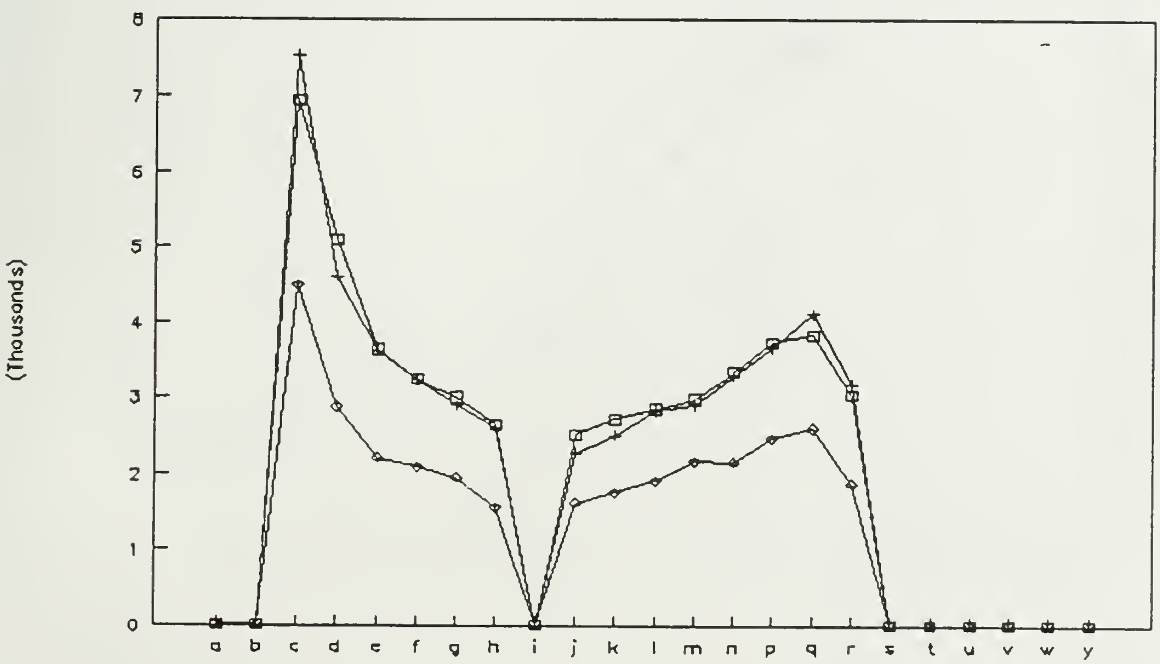

Figure 3

Average Per-transaction Dual Trading Volume

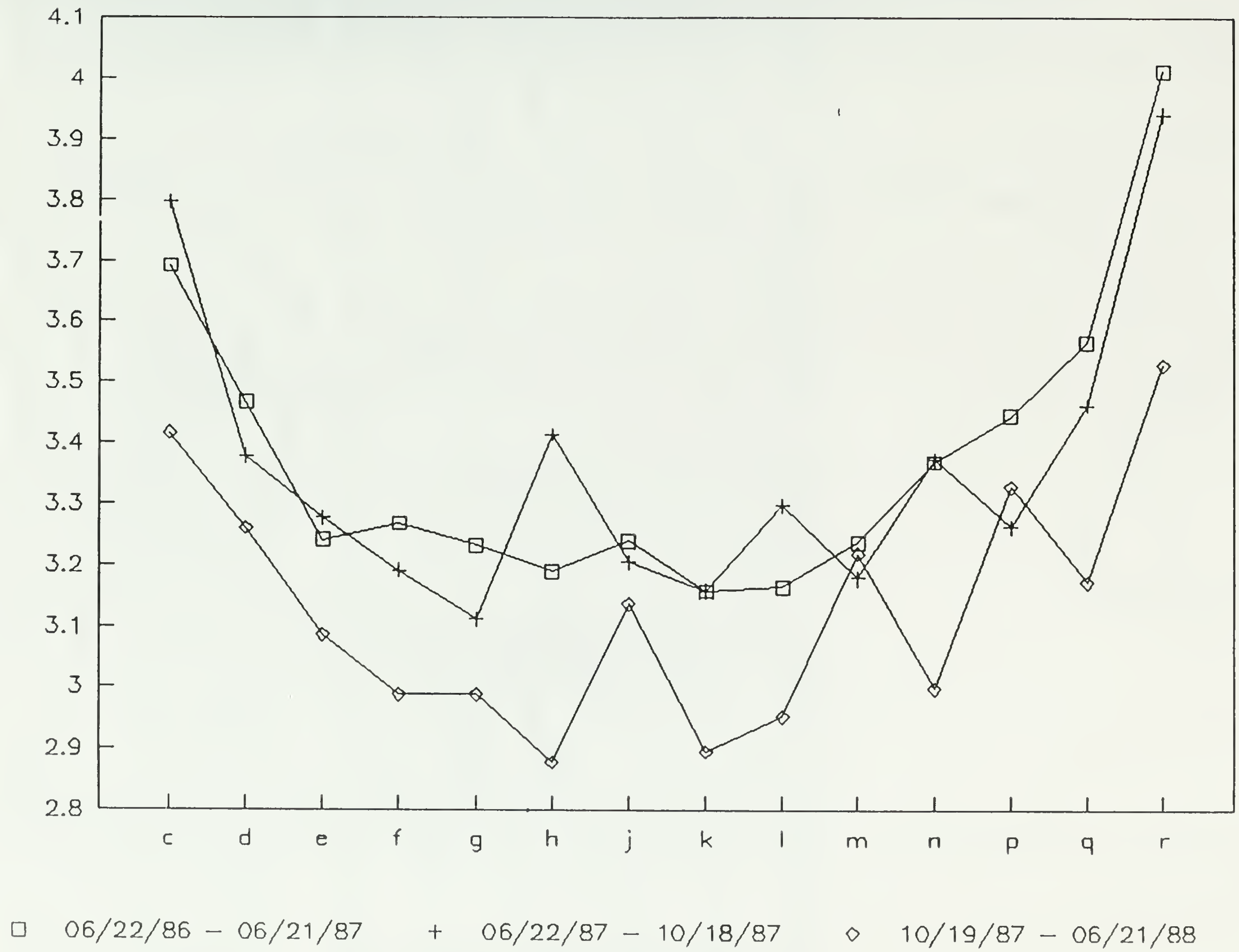

Figure 4

Average Per-transaction Non-Dual Trading Volmue

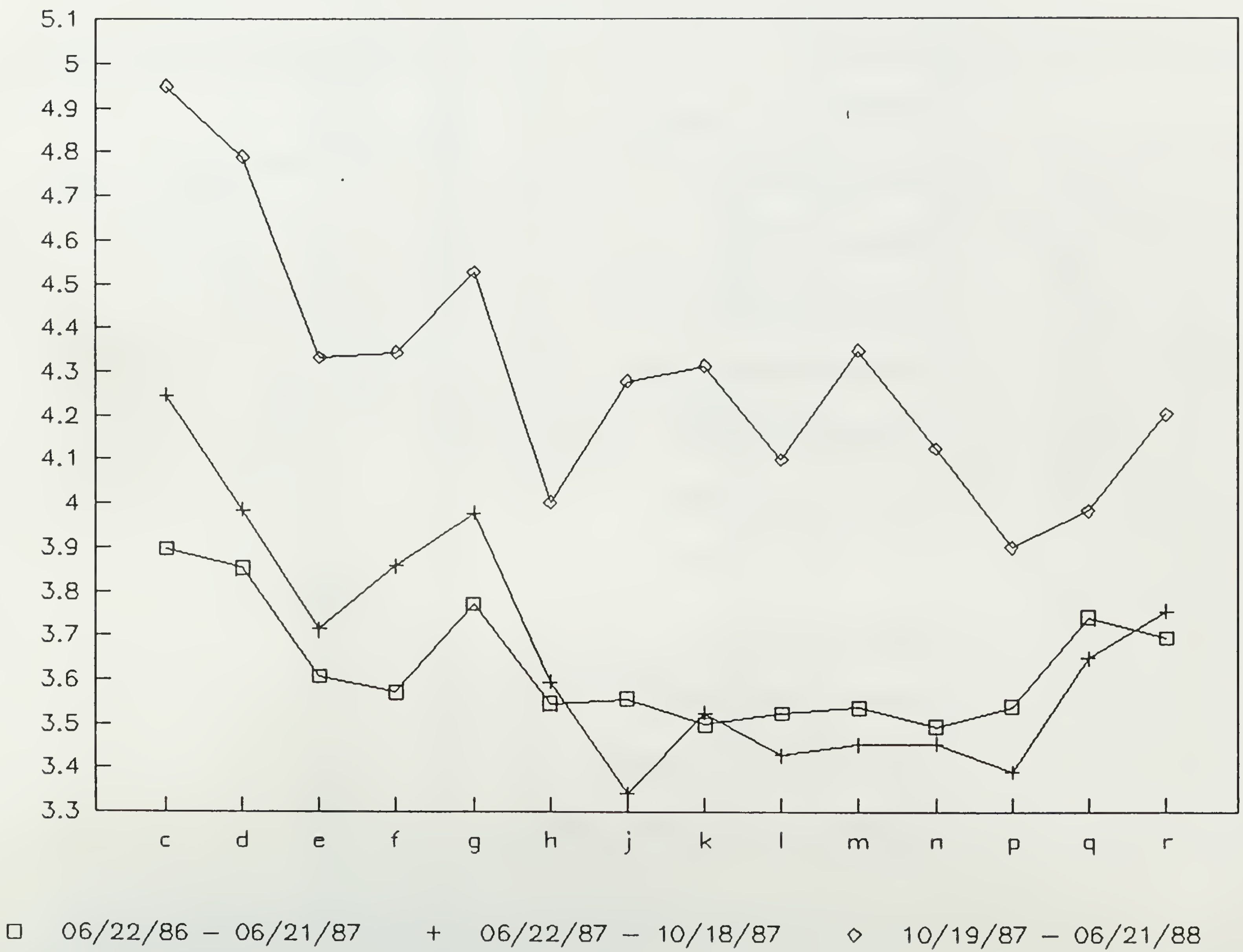

Figure 5

Total Number of Dual Trading Transactions
for Different Time Brackets

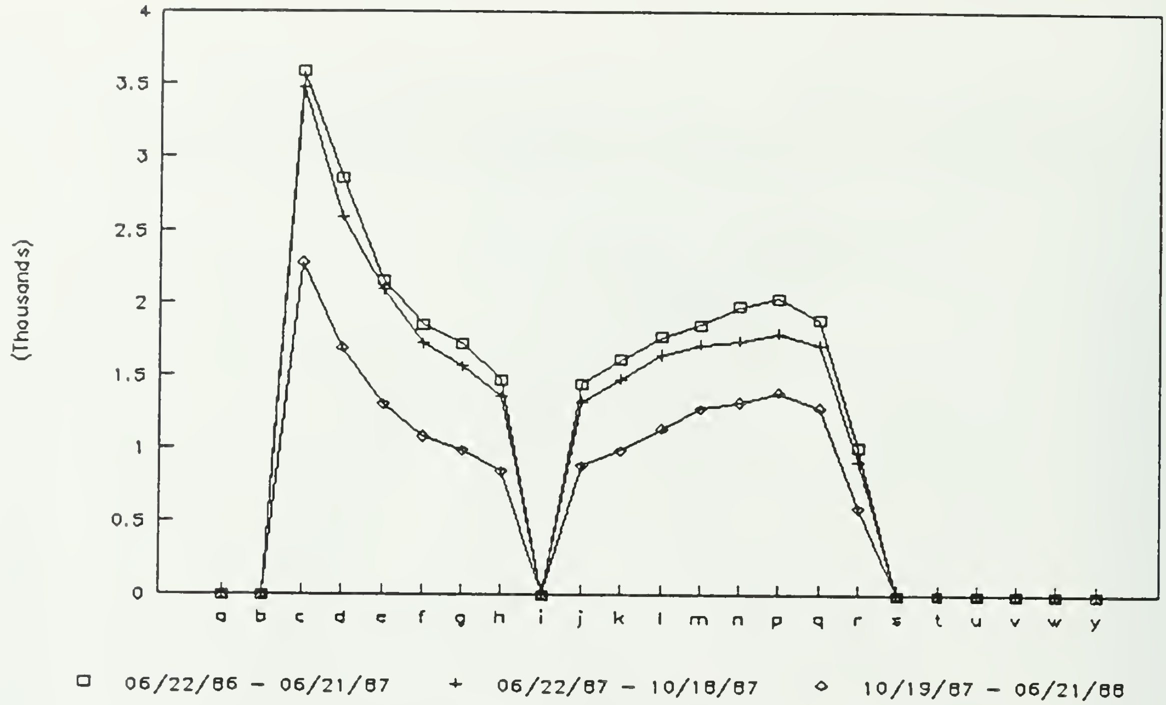

Figure 6

Total Number of Non-Dual Trading Transactions
for Different Time Brackets

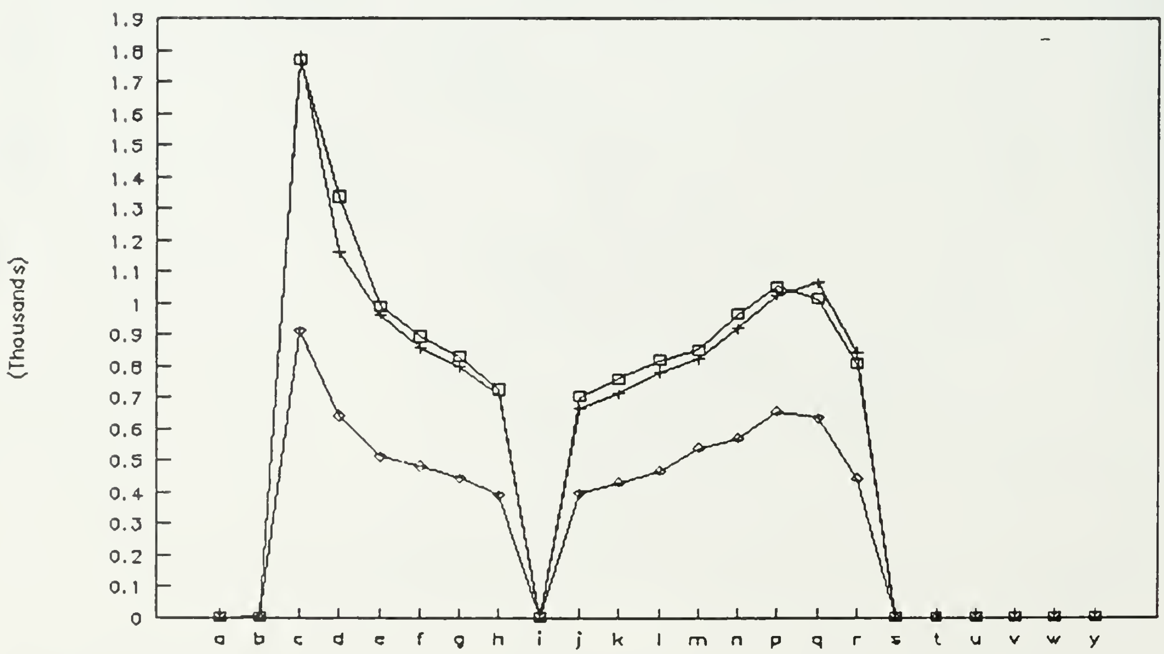

Figure 7
Intraday Variation of Large Purchases

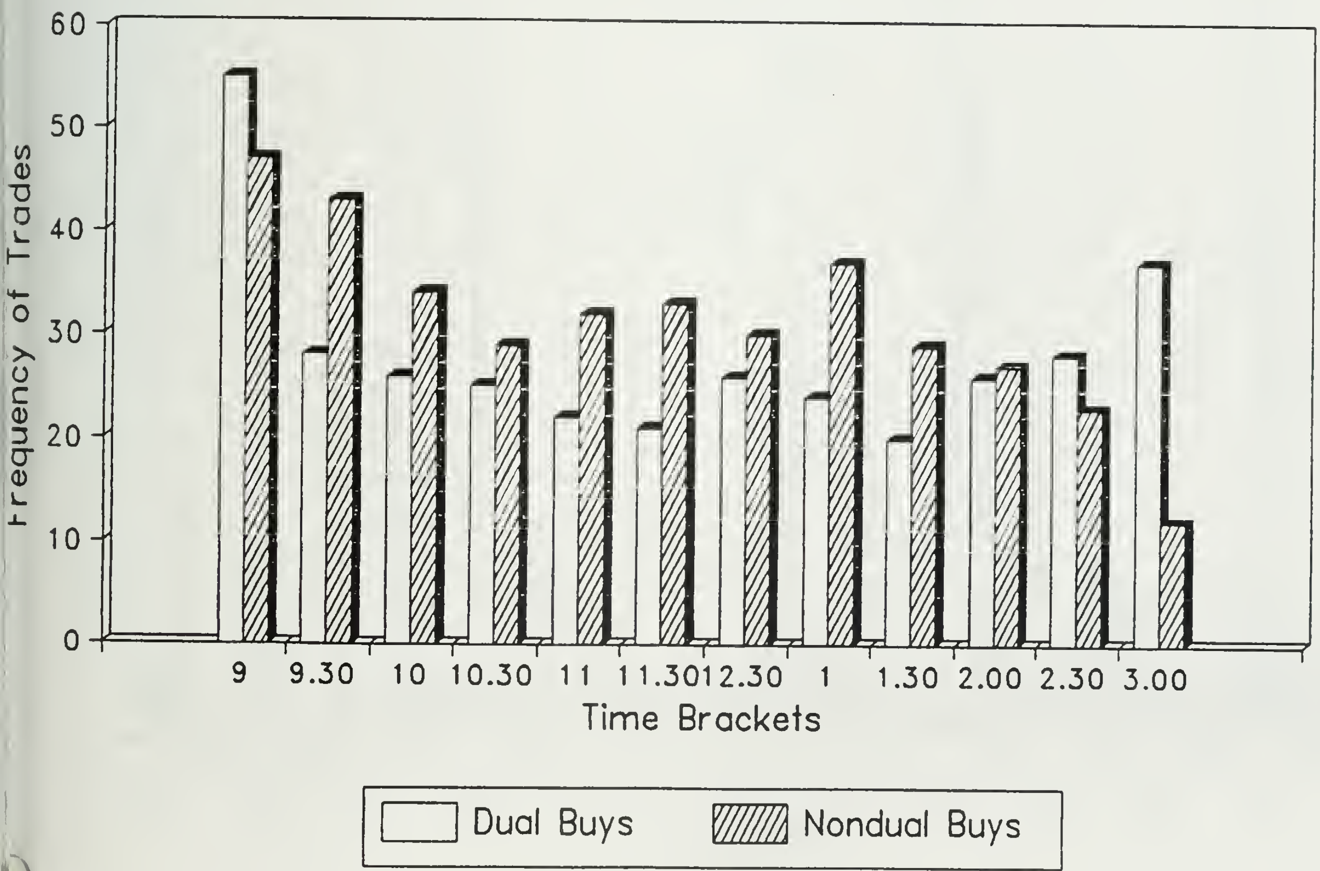

Figure 8

Daily Variation In Large Dual Buys

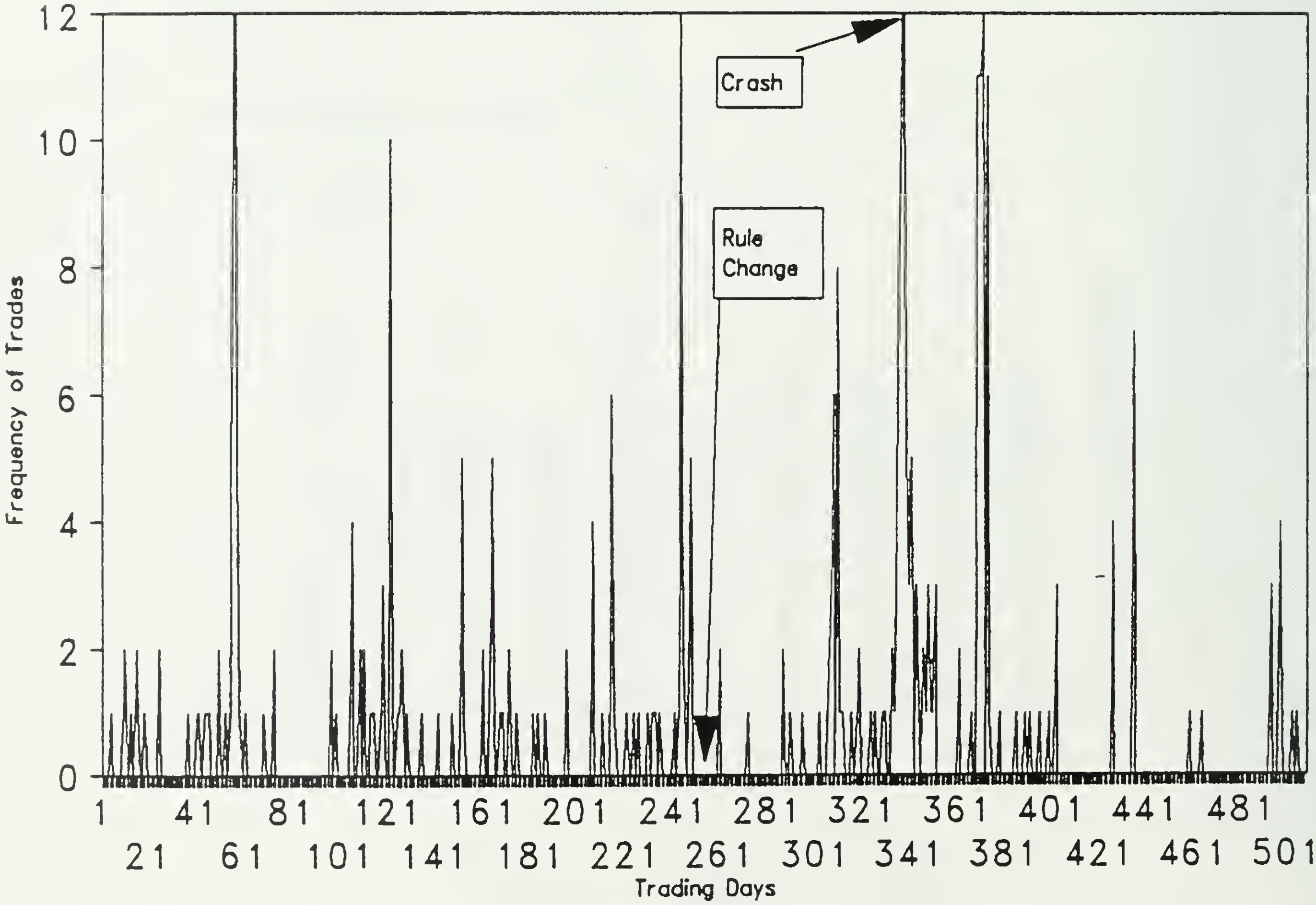

Figure 9
Daily Variation In Large Nondual Buys

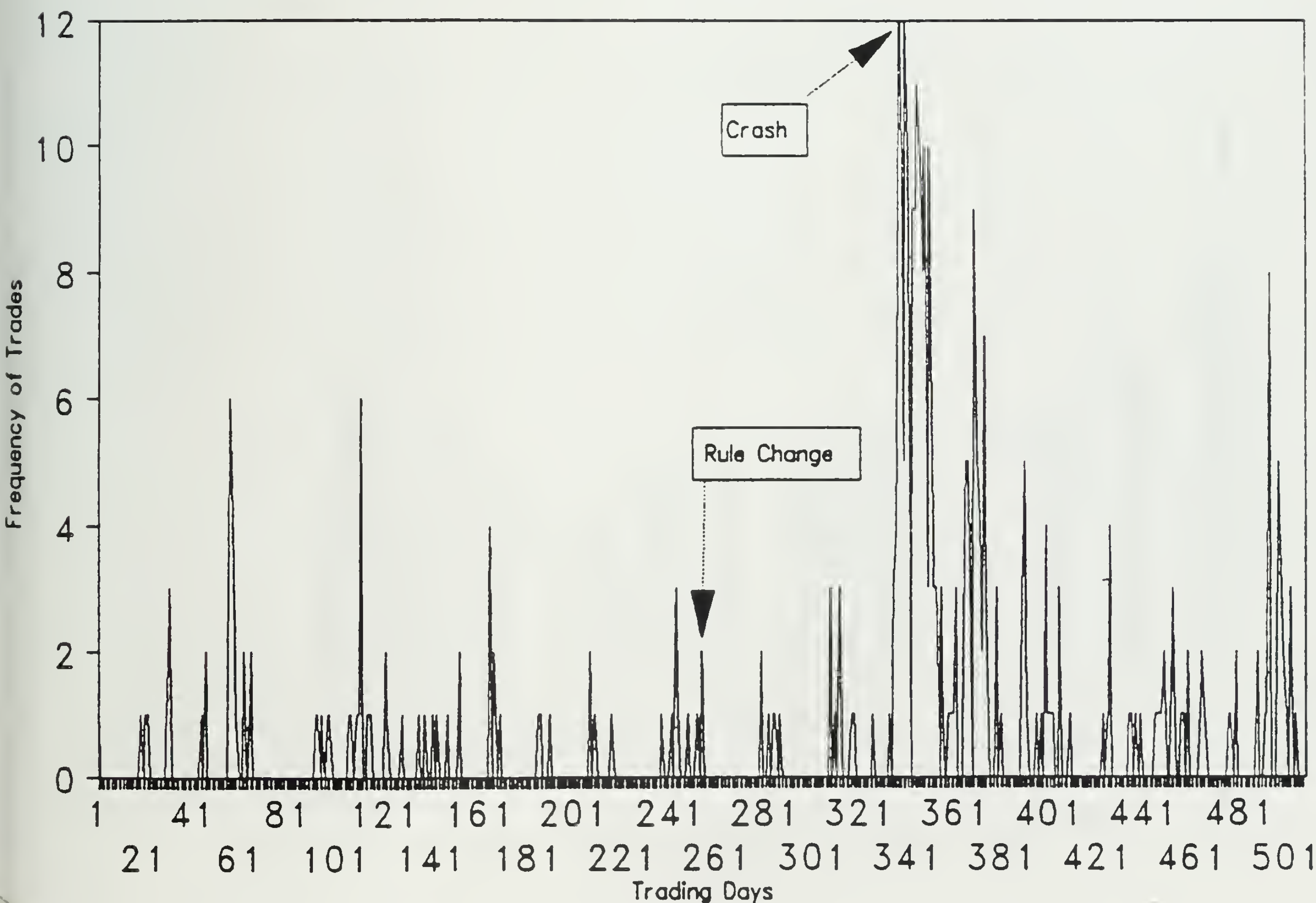

Figure 10
Intraday Variation of Large Sales

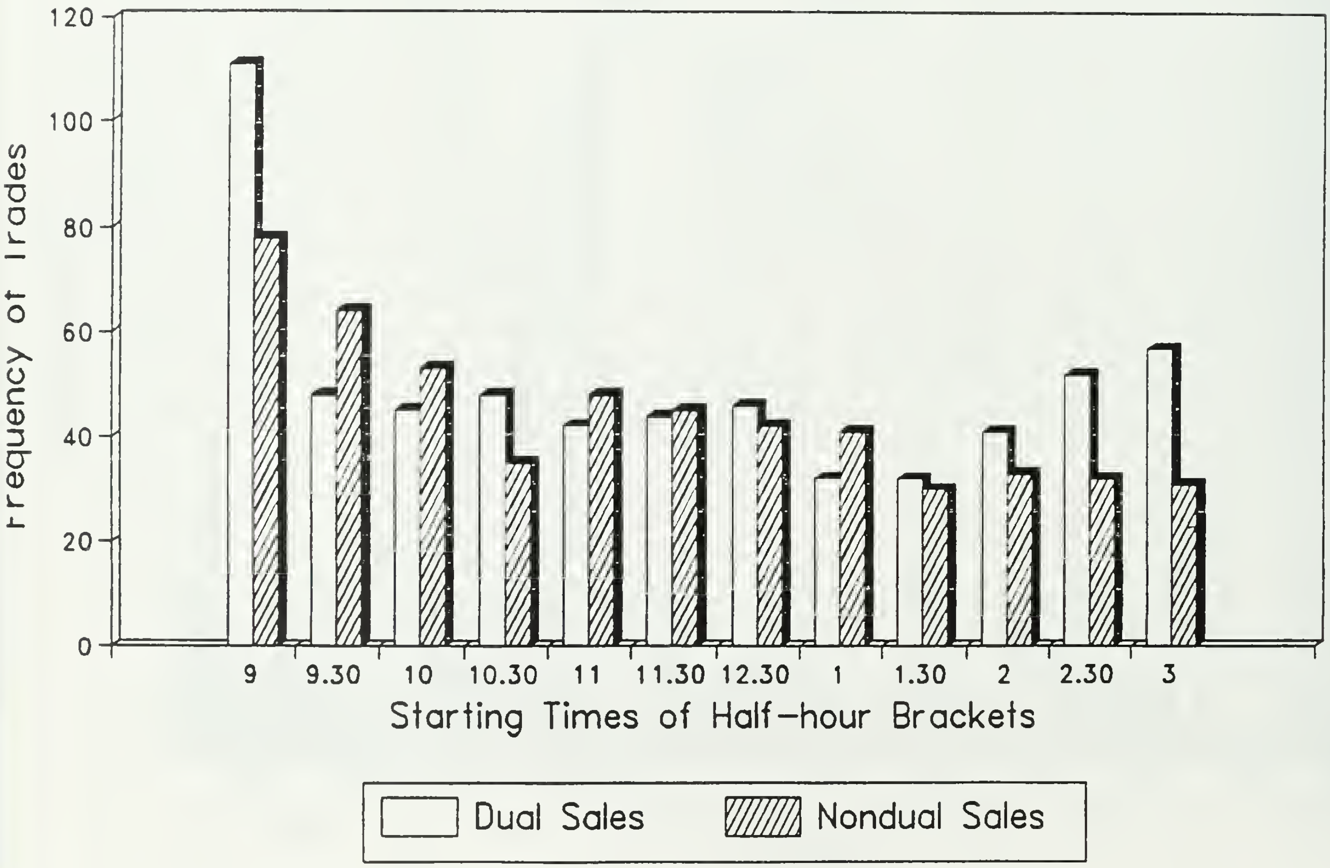

Figure 11
Daily Variation In Large Dual Sales

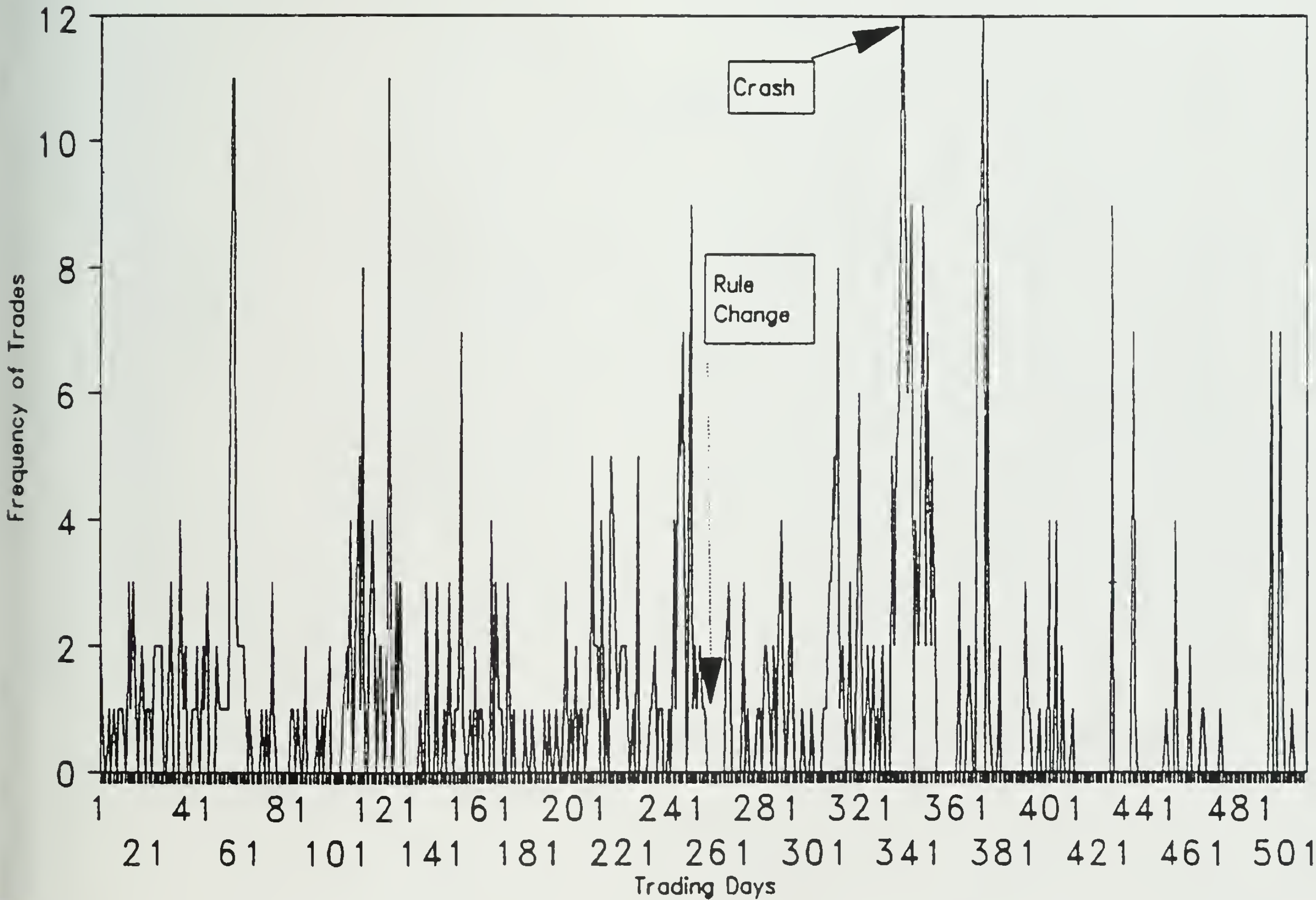

Figure 12
Daily Variation In Large Nondual Sales