Intraday Patterns in the S&P 500 Index Futures Market

Peter D. Ekman

INTRODUCTION

Intraday patterns occur in NYSE returns and volume data, but have not been shown previously to occur in S&P 500 Index futures data. The NYSE patterns include patterns in average returns, returns volatility, volume, and the autocorrelation of returns. For example, returns volatility is high near the open and the close, resulting in a U-shaped intraday pattern. In futures markets, intraday patterns occur in soybean contract volume and volatility and in foreign-exchange volatility.

Several theories relate some or all of these patterns to changes in information trading across the day [see, e.g., Admati and Pfleiderer (1988); Foster and Viswanathan (1988)]. These explanations of the observed patterns suggest that there are many information traders active near the open, and, perhaps, many liquidity traders active near the close. Other explanations should be considered. These include: (1) the patterns are sample specific, i.e., they only occur in the relatively short periods studied; (2) the patterns are caused by institutional factors, i.e., different patterns may occur in different markets; and (3) some of the patterns may be caused by the effects of nonsynchronous trading on intraday indices.

The purpose of this study is to determine whether intraday patterns occur in six years of S&P 500 Index futures data for returns, returns volatility, and variables related to volume and the autocorrelation of returns. Any patterns similar to previously observed patterns would be consistent with the information trading theories; whereas, dissimilar patterns might be more consistent with other explanations of intraday patterns. The long sample period and the use of a single asset rather than a constructed index should show whether previously observed patterns are sample specific or caused by the effects of nonsynchronous trading on intraday indices. The effects of institutional factors on any patterns are less clear. For example, patterns in NYSE volume or volatility might cause similar patterns in S&P futures volume or volatility through arbitrage between the two markets. But the pattern in NYSE returns might not cause a pattern in S&P futures returns through arbitrage, as the systematic intraday changes in NYSE returns are much too small to overcome the costs of arbitrage.

This study does not attempt to distinguish among information trading models, but may provide information that will lead to a more complete modeling of market mi-

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crostructure. The detailed descriptions of intraday volatility and other variables may also contribute to the continuing public discussion on stock index futures.

PREVIOUSLY OBSERVED PATTERNS

The U-shaped intraday pattern in stock returns and returns variance are first documented by Wood, McInish, and Ord(1985) (WMO) and Harris (1986). Average index returns are positive near the open and near the close. Harris, however, shows that returns are, on average, negative near the Monday open. Because of the large amount of data needed for intraday studies, the sample periods are relatively short. Harris examines data from December 1981 to January 1983. WMO examine data for 1982 and in the six months ending February 1972. McInish and Wood (1990) extend WMO's volatility results for the years 1980–1984.

Other researchers find similar patterns in different datasets. Jain and Joh (1988) show U-shaped intraday patterns in hourly returns and volatility over a longer period (1979–1983) for data on the actual S&P 500 index. They also show that hourly NYSE volume is highest near the open and declines until about 1 PM. The volume then rises until the close.

Volume and price change volatility are highly correlated in soybean futures[1] and both variables have U-shaped intraday patterns, according to Neal (1988). Jordan et al. (1988) show that the soybean futures transaction price change volatility and the number of recorded trades have similar U-shaped patterns. Harvey and Huang (1990) document intraday patterns in foreign-exchange futures volatility, and show that the patterns differ across weekdays.

The relation between patterns in volatility and information trading is examined by French and Roll (1986) in a study of the weekly pattern in stock volatility. They state that time-varying returns variance "represents an empirical puzzle whose solution may provide a deeper understanding of information processing in financial markets." Public information, private information trading, or mispricing may cause patterns in returns variance. The public information explanation is rejected because it does not explain the change in variance over exchange holidays. Mispricing, as measured by returns autocorrelation, can account for no more than 12% of the daily variance. Thus, information trading appears to be the major cause of the weekly pattern in returns variance.

Admati and Pfleiderer (1988) seek to explain the patterns observed by WMO, Harris, and others with a game-theoretic model with three types of traders. Informed traders have information on the price of the security one period before it is publicly released. These traders increase price volatility in the periods in which they trade, and decrease volatility in the following periods. Some liquidity traders must trade in specific periods, but others have discretion on when they will trade. In this model's equilibrium, informed traders and discretionary liquidity traders concentrate their trading in one period in the day. Volume and volatility are concentrated in this period.

Admati and Pfleiderer suggest that the observed U-shaped patterns may be affected by the overnight nontrading period, or by the once-a-day settlement system. Foster and Viswanathan (1988) use a similar game theoretic model to explain patterns in returns volatility across weekdays, as well as intraday patterns.

[1]Karpoff (1987) reviews the many studies, including a few transaction data studies, which also show this correlation.

Glosten and Milgrom (1985) model the effect of information trading on returns autocorrelation. If market makers are competitive and a bid–ask spread exists, transaction price changes will be negatively autocorrelated according to their model. The existence of information traders causes the autocorrelation coefficient to increase (toward zero). This model is limited in that all information is publicly released between trades, but the conclusion that information traders cause an increase in transaction returns autocorrelation allows a preliminary evaluation of the hypothesis that there is an intraday pattern in information trading.

McInish and Wood (1988) attempt to determine whether the autocorrelation of one-minute index returns is caused by the effects of nonsynchronous trading on intraday indices or by information arrival. They document a U-shaped intraday pattern in one-minute index returns autocorrelation. Autocorrelation is high near the open and close. Since these periods also have high returns variance, a proxy for information arrival, and high trading frequency, McInish and Wood conclude that a pattern in information arrival contributes to the pattern in autocorrelation.

Gosnell (1989) documents an intraday pattern in the percentage of transaction price reversals, a proxy for transaction returns autocorrelation, in NYSE stocks. The percentage of reversals is low near the open, but rapidly increases in the first hour of trading, and then is stable through the rest of the day. The difference in the intraday patterns in two similar variables, one-minute index returns autocorrelation and transaction price reversals, may be related to the different time intervals or to different averaging procedures, but is nonetheless surprising.

The extent of the autocorrelation induced by nonsynchronous trading in stock indices is suggested by the study of MacKinlay and Ramaswamy (1988). They study 15-minute returns series of S&P index futures and the actual S&P index. The futures series have a very small negative autocorrelation (-0.03 on average), whereas the index series have a large positive autocorrelation (0.20 on average).[2]

DATA AND METHODOLOGY

The data used in this study are the "time and sales" files for the S&P 500 index futures market for January 4, 1983 to November 30, 1988. These files, provided by the Chicago Mercantile Exchange (CME), consist of the price and time (recorded to the second) of every nonzero price change. Over 3 million prices are recorded for all S&P contracts, and over 80% of these are in the closest maturity contract.

The Commodity Futures Trading Commission requires that every nonzero futures price change be accurately recorded within ten seconds. The lack of any obvious recording errors, such as those found by WMO and Harris in NYSE data, and the technical sophistication of the recording system,[3] suggest that these data are in many ways more accurate than NYSE transaction data. However, transactions that result in no price change are not recorded, and actual intraday CME volume data are not released to the public. Thus, the proxy used in this study for volume, the number of recorded transactions (TRADES), might possibly be biased, e.g., if there are intraday patterns in average trade size or in the number of trades resulting in no price change. Nevertheless, the number of recorded transactions is used as the basis for the CME's estimated volume figures, which are calculated and distributed as trading occurs.

[2]MacKinlay and Ramaswamy very carefully document the relation between intraday index returns and S&P Index futures returns but do not examine intraday patterns.

[3]The CME's *Market Reporter's Manual* describes this system in detail.

Trading halts are extremely rare in the S&P futures. Data from the 21 15-minute intervals, in which no trading occurred, are deleted from the sample. Two failures of the CME's computers account for the majority of these intervals. Data from September 27, 1985 are deleted because the NYSE was closed due to Hurricane Gloria and S&P futures trading was very light. Data from the October 1987 crash period (10/19–11/11) are deleted because trading hours were curtailed during this period.

Stoll and Whaley (1987) show that NYSE volume and NYSE volatility are high in the hour before the quarterly expiration of an S&P contract (2–3 PM Central time), the so-called "triple witching hour." The data from all expiration days are deleted for the sample used in this study. Results when expiration days are included are very similar to the results shown.

Data from only one contract maturity, the dominant contract, are examined for each day. The dominant contract can be defined by the area of the pit where most traders trade. On an announced day during the final month of each contract, the contract with about three months to expiration begins trading in the dominant contract area. On this date the number of trades in the second closest maturity contract jumps by about 60%; the number of trades in the delivery month contract falls by a similar amount.

For this study each day is divided into 15-minute intervals, which are numbered from 1–25, plus an overnight period. On September 30, 1985, trading hours were extended from 9:00 AM to 3:15 PM Central time to 8:30 AM to 3:15 PM. Data from the interval 11:00–11:30 are deleted from the extended hours for ease of comparison across years. Average values for two subsamples (1/4/83–9/26/85 and 9/30/85–11/30/88) are presented graphically without the 11:00–11:30 deletion. Statistical results from these subsamples are similar to the overall sample, and are available from the author.

The 3:15 PM futures close occurs 15 minutes after the NYSE close.[4] Information flow is likely to be different during this 15-minute period from the rest of the day. Occasionally, trades are recorded after the official closing time. Prices recorded in the first minute past the close are probably the result of slightly delayed reporting or an especially busy closing period that extends 15 or 30 seconds past the official close. These price changes are included in Interval 25. Very occasionally, prices are recorded after 3:16. These prices are deleted in the following tests, but tests which include these data have nearly identical results.

Returns are calculated for each 15-minute interval as the logarithm of the last price of the interval minus the logarithm of last price of the previous interval. The overnight and first interval returns are calculated using the first recorded price of the day. Only transaction prices are used in these calculations so the overnight return may differ from returns calculated using the opening price and the previous settlement price.

Since futures openings appear to be chaotic to some observers, an alternative measure of the overnight return is also examined. For the alternative measure, the overnight and the first interval returns are calculated using the first price following the second minute of trading.[5]

[4]When the expiration occurred on Friday afternoon, the expiring contract closed trading at 3 PM when the NYSE closed trading and the final settlement value for the index was calculated. Other contracts continued trading until 3:15 PM.

[5]Futures openings are indeed very busy. A transaction was recorded in the third minute of trading for all but three days. The first price of the fourth minute was used for these days.

The absolute value of the return, |RETURN|, is used to measure price volatility. As |RETURN| is used rather than variance, variance ratios, such as those used by French and Roll, are not calculated. However, Stuart and Ord (1987) show that the mean absolute deviation times a constant is an asymptotically unbiased estimator of the standard deviation. Thus, the ratio of the means of |RETURN| for different periods is approximately the square root of the variance ratio. If information arrives at a constant rate, the variance ratio should equal the ratio of the length of time in the periods compared; the ratio of the mean |RETURN|'s should equal the square root of the time ratio.

The autocorrelation of one-minute returns (AUTOCOR1) and the precentage of transaction price reversals (REVERSALS) are used as a proxies for the autocorrelation of transaction returns. A reversal is defined as a sign change in consecutive nonzero price changes. Working (1954) and Niederhoffer and Osborne (1966) used this variable in the first characterizations of "negative transaction returns autocorrelation." Its use is convenient in most microstructure research because of discreteness in price changes. It is especially convenient in futures market microstructure research because of the lack of recorded zero price changes.

AUTOCOR1 is the autocorrelation of the 15 one-minute returns in each period. This measure is roughly comparable to the autocorrelation of one-minute index returns used by McInish and Wood. Nevertheless, the use of AUTOCOR1 as a proxy for transaction returns autocorrelation may be limited due to the large number of trades per minute. This problem may be especially severe during the last three years of the sample.

The equality of means of a variable across intraday intervals (excluding the overnight interval) is tested for each weekday with F statistics (F interval), which are computed from dummy variable (ANOVA) regressions. The equality of means within an interval across all weekdays is tested similarly with the F statistic, F days. The F statistics F Mon and F Fri test the hypotheses that the Monday interval mean equals the other weekday interval means, and that the Friday interval mean equals the other weekday interval means. Dummy variables for years or months are included in the regressions where there are significant differences in the levels of the variables across years or months. Both yearly and monthly dummy variables are included for |RETURN|, TRADES, and REVERSALS.[6] Only yearly dummies are included for AUTOCOR1. None are included for returns.

The variance of all five variables differs across intraday intervals for each weekday and, to a much smaller extent, across weekdays within some intervals. The effect of heteroskedasticity on this type of regression is minor, and slightly biases the F tests against rejecting the hypothesis that the means are equal across periods [see, e.g., Neter, Wasserman, and Kutner (1985), pp. 623–634].

INTRADAY PATTERNS IN S&P 500 INDEX FUTURES

Patterns in Returns

The mean return for each 15-minute interval and the overnight interval are shown in Table I for each weekday. The pattern in S&P futures returns is roughly similar to the pattern shown by Harris in NYSE index returns. The average returns for the

[6]The results are very similar when only dummy variables for years are used.

Table I
MEAN RETURNS (TIMES 1000) IN S&P 500 INDEX FUTURES, BY 15-MINUTE INTERVALS AND WEEKDAYS

Interval	Mon.	Tues.	Wed.	Thurs.	Fri.	STD[a]	*F* Days	*F* Mon.	*F* Fri.
Overnight	−0.281	0.399	0.092	0.135	0.290	3.89	1.27	1.34	0.38
1	−0.270	0.213	0.226	0.270	0.309	2.12	3.59[b]	8.08[b]	0.22
2	0.023	−0.110	0.027	−0.014	0.051	1.95	0.31	0.00	0.02
3	−0.042	−0.016	0.102	−0.283	−0.246	1.87	2.22	0.86	5.00[c]
4	−0.050	−0.091	0.042	0.023	−0.037	1.52	0.38	0.53	0.38
5	−0.160	0.037	0.043	0.095	−0.172	1.58	1.80	2.44	2.68
6	0.096	0.041	0.055	−0.091	−0.014	1.47	0.69	0.11	0.31
7	0.020	−0.099	−0.019	−0.002	−0.076	1.52	0.32	0.10	0.20
8	−0.063	−0.041	0.180	−0.113	0.023	1.45	1.82	4.10[c]	1.69
9	−0.039	−0.117	−0.129	−0.030	0.091	1.44	1.06	0.58	3.35
10	0.096	0.219	−0.041	0.090	−0.036	1.37	1.85	1.46	0.00
11	−0.117	−0.009	0.066	0.092	−0.024	1.42	0.97	2.45	0.58
12	0.141	−0.017	0.080	0.167	0.149	1.36	0.90	0.29	0.37
13	0.169	−0.083	−0.194	−0.033	−0.014	1.47	2.35	8.96[b]	2.15
14	−0.086	−0.059	−0.059	−0.122	−0.007	1.56	0.21	0.04	0.16
15	0.014	0.014	0.063	0.034	−0.180	1.54	1.10	0.15	3.58
16	−0.045	−0.156	−0.187	0.059	−0.270	1.64	1.76	1.10	0.37
17	0.106	−0.194	0.071	−0.009	−0.018	1.74	1.32	0.06	0.37
18	0.047	0.125	0.016	−0.164	0.078	1.81	1.09	0.04	0.17
19	0.074	0.130	0.061	0.098	−0.122	2.15	0.59	0.01	1.04
20	0.326	0.080	−0.222	0.195	−0.022	2.09	2.93[c]	10.06[b]	1.33
21	−0.035	−0.185	0.027	0.043	0.092	2.17	0.72	0.12	0.13
22	0.448	0.304	0.053	−0.044	0.038	2.24	2.48[c]	4.58[c]	0.01
23	0.052	0.013	−0.077	−0.046	−0.318	2.46	0.97	0.40	1.38
24	0.036	−0.065	0.000	−0.193	−0.166	2.09	0.66	0.04	0.91
25	0.328	0.170	0.171	0.406	−0.065	1.66	3.31[c]	1.28	2.90
F interval	2.30[b]	1.72[c]	1.22	2.02[b]	1.53[c]				
Days	282	302	302	291	275				

The *F* statistics test whether the means are equal across weekdays (*F* days), whether the Monday mean is equal to the other weekday means (*F* Mon.), whether the Friday mean is equal to the other weekday means (*F* Fri.), and whether the means are equal across Intervals 1–25 (*F* interval). The *F* statistics are calculated from separate dummy variable regressions for each interval and each weekday.

[a]Standard deviation of returns (times 1000).

[b]Significant at the 0.01 level.

[c]Significant at the 0.05 level.

first and last intervals of the day are positive for each weekday, except for Interval 1 on Monday and Interval 25 on Friday. Each average overnight return is positive except for the weekend (Monday overnight) return. All these results, except the negative Friday Interval 25 return, are consistent with Harris's results for NYSE index returns.

For each weekday, except Wednesday, the interval means differ significantly at the 0.05 level, across the day. The Monday Interval 1 mean is significantly lower than the other weekday Interval 1 means. However, the weekend return is not significantly different from the other overnight returns. These results are unchanged when the alternative measure of overnight and Interval 1 returns are examined. The Interval 25 means differ significantly across weekdays, but neither the Monday or Friday Interval 25 means is significantly different from the other weekday means. Few other differences across weekdays are apparent.

Figure 1 plots the average cumulative returns across the day for both subsamples. Both plots are roughly similar to the pattern shown by Harris, but statistical results (not shown) are weaker for the subsamples, particularly for the second subsample.

The economic significance of these patterns is less clear than the statistical significance. For example, in the first subsample, a trader who buys one contract at the beginning of the closing interval and sells at the end of the opening interval for each of the ordinary weeknights, gains, on average, about 0.07%, roughly $50 per contract, before transaction costs. Reversing the strategy over the weekend would, on average, gain a similar amount. In the second subsample the gains from this strategy would be about 0.08% ($105) for ordinary weeknights, and about 0.05% ($65) over the weekend.

Transaction costs for off-floor traders should include a round-turn commission of about $25 per contract.[7] The bid–ask spread appears to be 1 tick (0.05 index points, or $25 per contract), since over 95% of all recorded transaction price changes are 0.05 or −0.05 points. Therefore, an off-floor trader would pay all or most of the gains from this strategy in transaction costs. A member of the CME would pay only about $2 per contract in clearing fees, and might be able to avoid paying the bid–ask spread. Thus, the patterns in returns may be economically significant to CME members. Nevertheless, the high standard deviation of the returns, shown in the STD column in Table I, suggests that a risk-averse trader would not use this strategy.

Patterns in Volatility

The intraday and overnight interval means of |RETURN| are shown in Table II for each weekday. The pattern is roughly U-shaped, but a decline in the means occurs in the last few intervals of the day, for each weekday except Friday. This pattern can be seen in Figure 2 for the two subsamples. Statistical results for both subsamples are very similar to the results for the overall sample. The means of |RETURN| differ significantly at the 0.01 level across Intervals 1–25 for each weekday.

Few significant differences occur across weekdays. The weekend mean is significantly larger than other weeknight means, as is expected due to the longer weekend time period. But the weekend mean is much lower than would be expected if variance is caused solely by public information which arrives at a constant rate, consistent with the results of French and Roll. The ratio of the mean weekend |RETURN| to the mean of the other weeknight |RETURN|'s is 1.27, even though the weekend period is almost four times as long. If information arrives at a constant rate over these periods the ratio should be 1.94, i.e., the square root of the ratio of the length of the time periods.

The means in the periods surrounding the weekend, Monday's Interval 1 and Friday's Interval 25, are significantly larger than the means for the same intervals on

[7]See "Your Money Matters," *The Wall Street Journal,* October 13 1988, p. C1, for a list of discount futures brokerage commissions.

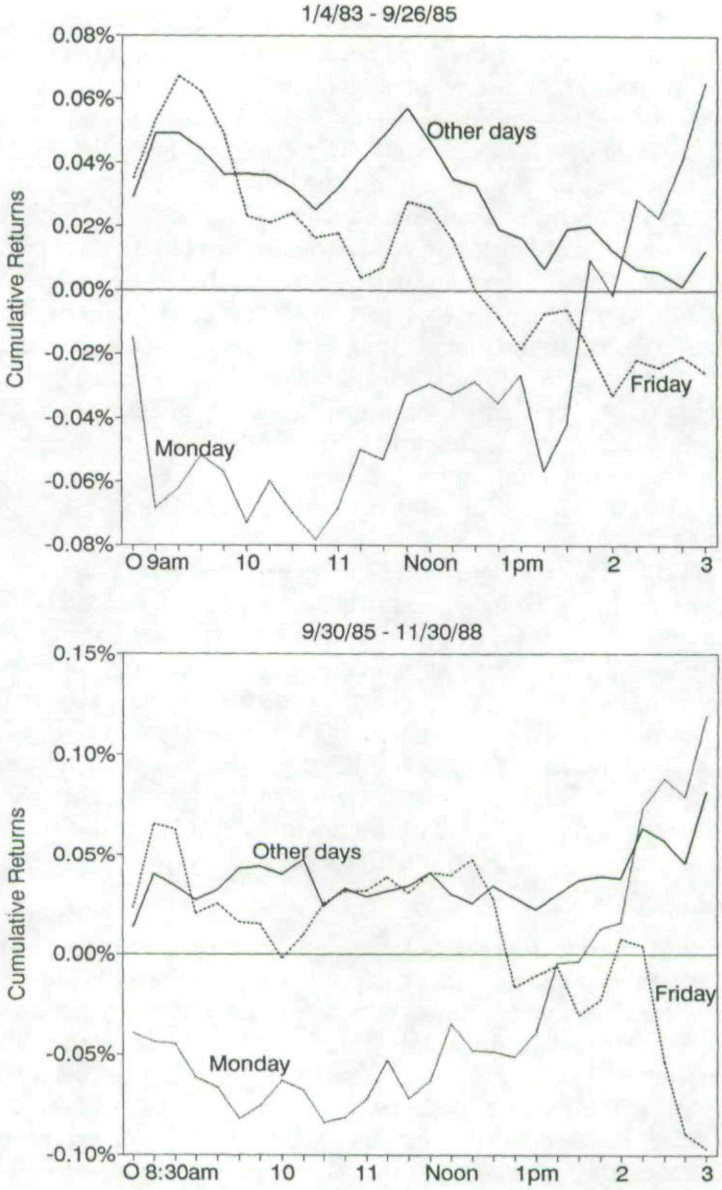

Figure 1

The mean cumulative returns in the S&P 500 Index futures market by 15-minute interval and for the overnight interval (Interval O).

other weekdays. Much of the difference in Monday's Interval 1 mean is apparently caused by the first two minutes of trading, because there is no significant difference across Interval 1 for the absolute value of the alternative measure of returns.

The nontrading period (overnight) means are relatively low compared to the trading period means, consistent with French and Roll's results. For example, the weekend is about 260 times as long as 15-minute interval, so the ratio of the weekend mean |RETURN| to an interval mean should be 16.16 if the rate of information arrival is constant. The ratio of the weekend mean to the lowest Monday interval

Table II

MEAN ABSOLUTE VALUE OF RETURNS (TIMES 1000) IN S&P 500 INDEX FUTURES, BY 15-MINUTE INTERVALS AND WEEKDAYS

Interval	Mon.	Tues.	Wed.	Thurs.	Fri.	STD[a]	*F* Days	*F* Mon.	*F* Fri.
Overnight	3.16	2.46	2.11	2.60	2.77	2.89	5.66[b]	20.77[b]	8.37[c]
1	1.79	1.60	1.46	1.50	1.61	1.41	2.76[c]	9.04[b]	2.02
2	1.50	1.42	1.35	1.33	1.34	1.36	0.83	1.86	0.00
3	1.35	1.16	1.26	1.32	1.34	1.36	1.05	0.71	0.65
4	1.05	1.19	1.21	1.14	1.09	1.02	1.23	3.30	2.05
5	1.12	1.17	1.10	1.09	1.10	1.11	0.30	0.13	0.00
6	0.96	1.06	1.01	1.08	1.13	1.03	1.20	0.32	2.24
7	1.01	0.98	1.04	1.20	1.12	1.08	1.86	0.12	0.74
8	0.98	0.99	1.10	1.09	1.05	1.01	0.90	2.07	0.33
9	1.03	1.05	1.13	1.09	0.95	0.98	1.32	1.52	4.73[c]
10	0.95	0.96	1.02	0.99	1.00	0.95	0.23	0.60	0.08
11	1.04	0.96	1.12	0.99	0.91	1.00	1.83	0.94	6.20[c]
12	1.00	0.96	1.03	1.04	0.93	0.94	0.76	0.12	1.74
13	1.02	1.14	1.17	1.10	0.95	0.99	2.59[c]	3.58	7.69[b]
14	1.06	1.03	1.18	1.20	1.06	1.10	1.47	1.40	1.94
15	1.15	1.13	1.20	1.19	1.10	1.02	0.47	0.29	1.42
16	1.25	1.22	1.17	1.13	1.24	1.12	0.72	0.96	0.66
17	1.16	1.38	1.31	1.28	1.23	1.19	1.38	1.97	0.81
18	1.28	1.36	1.33	1.40	1.36	1.22	0.33	0.23	0.04
19	1.44	1.40	1.47	1.45	1.39	1.61	0.15	0.03	0.48
20	1.49	1.45	1.51	1.50	1.54	1.46	0.11	0.02	0.03
21	1.55	1.59	1.80	1.73	1.37	1.45	3.99[b]	3.81	13.74[b]
22	1.58	1.62	1.84	1.64	1.47	1.54	2.34	4.31[c]	8.77[b]
23	1.74	1.61	1.76	1.74	1.49	1.80	1.16	0.02	3.24
24	1.33	1.53	1.39	1.37	1.35	1.55	0.08	0.20	0.06
25	1.19	1.21	1.16	1.29	1.41	1.12	2.50[c]	0.12	8.00[b]
F interval	12.90[b]	11.54[b]	12.85[b]	9.70[b]	6.32[b]				
Days	282	302	302	291	275				

The *F* statistics test whether the means are equal across weekdays (*F* days), whether the Monday mean is equal to the other weekday means (*F* Mon.), whether the Friday mean is equal to the other weekday means (*F* Fri.), and whether the means are equal across Intervals 1–25 (*F* interval). The *F* statistics are calculated from separate dummy variable regressions for each interval and each weekday, which include dummy variables for years and months.

[a]Standard deviation of the absolute value of returns (times 1000).

[b]Significant at the 0.01 level.

[c]Significant at the 0.05 level.

mean is only 3.33. Similar ratios for the other weekdays average 2.58, though a ratio of 4.15 is expected if the rate of information arrival is constant.

The intraday pattern in S&P futures volatility is similar to the U-shaped patterns in volatility that are documented in stock market data, except for the decline in volatility in the last half hour of trading. The decline in volatility near the close is puzzling, but might be caused partially by a change in information arrival due to the close of the NYSE 15 minutes before the close of S&P futures trading.

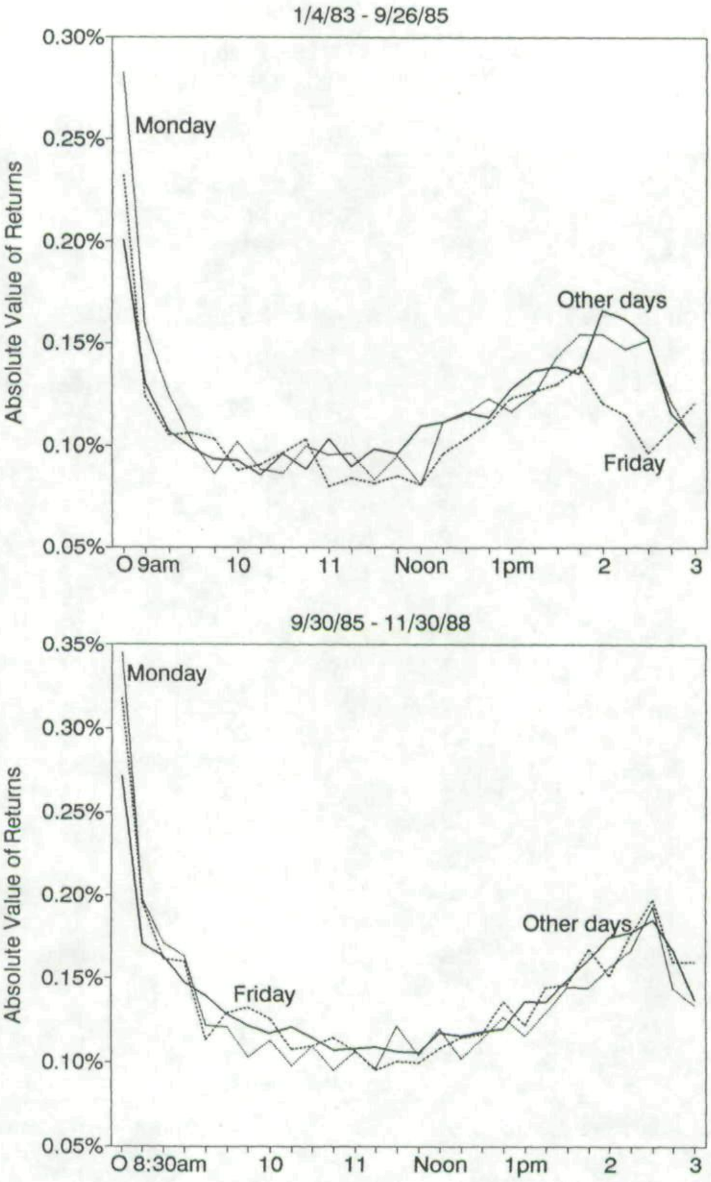

Figure 2

The mean absolute value of returns (|RETURN|) in the S&P 500 Index futures market by 15-minute interval and for the overnight interval (Interval O).

Patterns in the Number of Recorded Transactions

The interval means of TRADES are shown for each weekday in Table III, and for the two subsamples in Figure 3. A U-shaped intraday pattern occurs, with a slight downturn near the close of trading. Similar U-shaped patterns occur for each weekday and the interval means differ significantly across the day for each weekday at the 0.01 level. The U-shaped pattern occurs for both subsamples, even though there are large differences in the level of TRADES across subsamples. Statistical results in both subsamples are very similar to the results for the overall sample.

Table III
MEAN NUMBER OF RECORDED TRANSACTIONS (TRADES) IN S&P 500 INDEX FUTURES, BY 15-MINUTE INTERVALS AND WEEKDAYS

Interval	Mon.	Tues.	Wed.	Thurs.	Fri.	STD[a]	*F* Days	*F* Mon.	*F* Fri.
1	111.9	108.3	107.9	111.6	109.1	35.2	1.92	5.27[b]	1.26
2	90.0	89.9	88.2	92.4	87.5	32.9	1.83	1.15	0.00
3	80.8	83.7	84.6	84.6	81.8	32.9	1.59	4.89[b]	1.69
4	74.3	76.7	77.1	77.2	74.2	29.3	1.31	2.59	2.26
5	69.9	72.5	74.8	73.5	69.2	30.0	3.14[b]	7.70[c]	8.82[c]
6	66.3	68.3	67.5	70.1	64.3	28.5	2.43[b]	0.41	2.77
7	62.4	66.8	68.4	68.9	64.5	27.8	4.21[c]	11.23[c]	4.06[b]
8	62.3	65.9	68.0	68.4	61.0	26.3	6.48[c]	10.38[c]	14.56[c]
9	61.0	64.8	67.9	67.7	60.8	27.4	6.44[c]	14.18[c]	13.94[c]
10	60.7	65.3	67.9	65.4	59.1	28.1	7.16[c]	14.66[c]	21.34[c]
11	58.6	61.5	62.5	60.3	54.1	25.5	6.36[c]	4.41[b]	21.15[c]
12	57.3	61.5	62.2	61.6	53.0	25.7	9.12[c]	7.60[c]	25.62[c]
13	60.4	66.2	66.7	66.0	56.5	27.3	10.70[c]	10.59[c]	28.03[c]
14	61.8	68.9	68.0	68.0	59.5	28.3	8.84[c]	9.81[c]	17.75[c]
15	66.5	71.5	72.7	70.3	61.3	28.4	10.64[c]	9.65[c]	33.27[c]
16	68.5	73.3	73.0	72.0	65.0	27.9	6.81[c]	5.48[b]	17.76[c]
17	74.1	80.3	79.3	77.5	68.9	29.5	10.35[c]	6.72[c]	26.67[c]
18	74.2	81.5	81.0	79.6	72.0	29.3	8.76[c]	11.20[c]	19.58[c]
19	76.7	83.8	84.3	84.2	74.4	29.5	9.92[c]	12.93[c]	22.54[c]
20	80.9	84.9	87.2	84.5	75.8	29.9	9.10[c]	9.37[c]	30.85[c]
21	83.4	86.1	88.9	90.6	77.8	30.4	11.11[c]	6.80[c]	28.58[c]
22	82.2	85.1	89.1	89.4	76.6	30.9	11.79[c]	10.12[c]	33.90[c]
23	83.1	85.9	88.7	88.2	75.6	31.2	12.15[c]	6.98[c]	38.04[c]
24	77.6	80.2	84.1	82.3	74.5	29.6	7.14[c]	11.46[c]	23.28[c]
25	77.9	80.2	81.5	83.6	82.4	27.4	3.08[b]	4.31[b]	0.51
F interval	95.5[c]	74.7[c]	70.2[c]	72.2[c]	73.0[c]				
Days	282	302	302	291	275				

The *F* statistics test whether the means are equal across weekdays (*F* days), whether the Monday mean is equal to the other weekday means (*F* Mon.), whether the Friday mean is equal to the other weekday means (*F* Fri.), and whether the means are equal across Intervals 1–25 (*F* interval). The *F* statistics are calculated from separate dummy variable regressions for each interval and each weekday, which include dummy variables for years and months.

[a]Standard deviation of TRADES.

[b]Significant at the 0.05 level.

[c]Significant at the 0.01 level.

The interval means of TRADES differ significantly across weekdays through the late morning and afternoon. The Friday means are lower than other weekday means through most of the day, and the difference widens through the day. However, in Interval 25, near the close of trading for the week, the Friday interval mean is higher than the overall interval mean. This "crossover" pattern on Friday may be related to the long weekend nontrading period.

The intraday patterns in |RETURNS| and TRADES are similar to previously observed patterns, and are consistent with information trading explanations for the

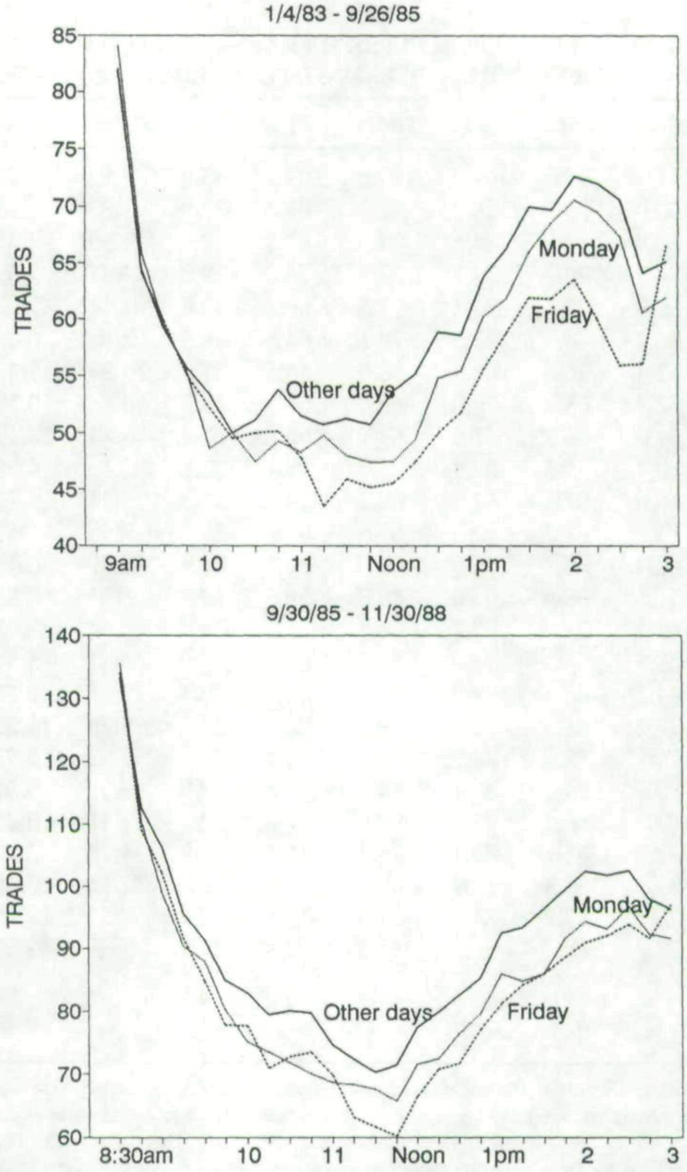

Figure 3
The mean number of recorded transactions (TRADES) in the S&P 500 Index futures market by 15-minute interval.

intraday patterns in NYSE data. But these patterns in the futures market might also be interpreted as simply showing that there is an intraday pattern in public information arrival, i.e., more information may be released publicly at different periods during the day and week. Therefore, in the next section, an examination is conducted on proxies for the autocorrelation of transaction returns, a variable that is more closely related in theory to information trading.

Patterns in REVERSALS and AUTOCOR1

The interval means of REVERSALS are shown in Table IV for each weekday and in Figure 4 for the two subsamples. An S-shaped intraday pattern is apparent for each

Table IV
MEAN PERCENTAGE OF REVERSALS IN
S&P 500 INDEX FUTURES, BY 15-MINUTE INTERVALS AND WEEKDAYS

Interval	Mon.	Tues.	Wed.	Thurs.	Fri.	STD[a]	*F* Days	*F* Mon.	*F* Fri.
1	51.3	52.0	51.9	52.0	51.9	12.7	0.51	0.86	0.24
2	57.5	57.6	56.8	56.7	57.6	13.7	0.57	0.98	0.66
3	59.0	59.0	58.5	57.4	59.4	13.8	1.73	0.62	0.82
4	60.5	59.4	58.9	59.3	59.6	13.4	1.16	4.30[b]	0.31
5	60.9	60.2	59.7	60.5	60.9	13.4	0.83	2.08	1.82
6	61.8	61.0	61.4	60.7	61.3	13.5	0.46	0.16	0.23
7	61.7	61.0	60.7	60.2	61.3	13.1	0.69	1.14	0.18
8	60.6	60.7	60.0	59.4	61.1	12.7	0.87	0.40	1.16
9	61.3	60.8	60.2	59.2	62.6	12.9	3.94[c]	1.49	7.48[b]
10	61.4	60.1	59.5	60.1	61.6	13.2	2.14	4.93[b]	5.92[b]
11	61.0	60.0	59.1	60.7	61.3	13.3	2.42[b]	5.67[b]	6.70[b]
12	60.7	59.2	59.2	59.5	61.5	12.7	3.29[b]	3.26	8.46[c]
13	60.7	58.2	58.6	58.5	61.3	12.8	6.06[c]	6.79[c]	10.54[c]
14	59.3	57.9	58.0	58.6	61.1	12.6	4.71[c]	2.13	13.33[c]
15	58.0	57.7	57.2	57.7	59.3	12.3	1.51	0.92	5.72[b]
16	57.3	55.9	55.9	56.1	58.2	12.3	2.85[b]	2.89	7.26[b]
17	55.9	53.9	55.5	55.6	57.7	12.6	5.58[c]	0.14	6.35[b]
18	56.3	54.1	54.1	54.0	55.9	12.7	3.38[c]	7.02[b]	3.84
19	55.2	53.1	53.2	53.0	55.9	12.9	5.43[c]	6.42[b]	10.59[c]
20	53.7	52.3	52.4	52.5	55.9	13.5	6.19[c]	2.24	16.47[c]
21	52.6	51.0	52.2	51.1	54.0	13.3	4.10[c]	0.23	4.36[b]
22	51.7	50.8	50.5	50.8	53.7	13.3	4.97[c]	2.24	15.83[c]
23	51.4	50.9	51.1	50.5	55.1	13.7	10.11[c]	0.06	23.17[c]
24	54.6	54.0	53.3	53.3	56.9	14.2	5.95[c]	2.64	18.72[c]
25	60.4	59.4	60.1	59.2	59.4	13.9	0.91	0.06	1.68
F interval	43.9[c]	48.7[c]	43.6[c]	41.4[c]	24.7[c]				
Days	282	302	302	291	275				

The *F* statistics test whether the means are equal across weekdays (*F* days), whether the Monday mean is equal to the other weekday means (*F* Mon.), whether the Friday mean is equal to the other weekday means (*F* Fri.), and whether the means are equal across Intervals 1–25 (*F* interval). The *F* statistics are calculated from separate dummy variable regressions for each interval and each weekday, which include dummy variables for years and months.

[a]Standard deviation of the percentage of reversals.

[b]Significant at the 0.05 level.

[c]Significant at the 0.01 level.

weekday, and the means differ significantly across the day at the 0.01 level for each weekday. The differences in the interval means are large, e.g., the average difference between the Interval 8 mean and the Interval 1 mean is 9%, roughly a 0.18 difference in autocorrelation.[8] The statistical results for both subsamples are very similar to the results for the overall sample. The distinctive S-shaped pattern shown in

[8]Since almost all the recorded price changes are either 0.05 or −0.05, the autocorrelation coefficient for these data can be approximated as −2 (REVERSALS) + 1.

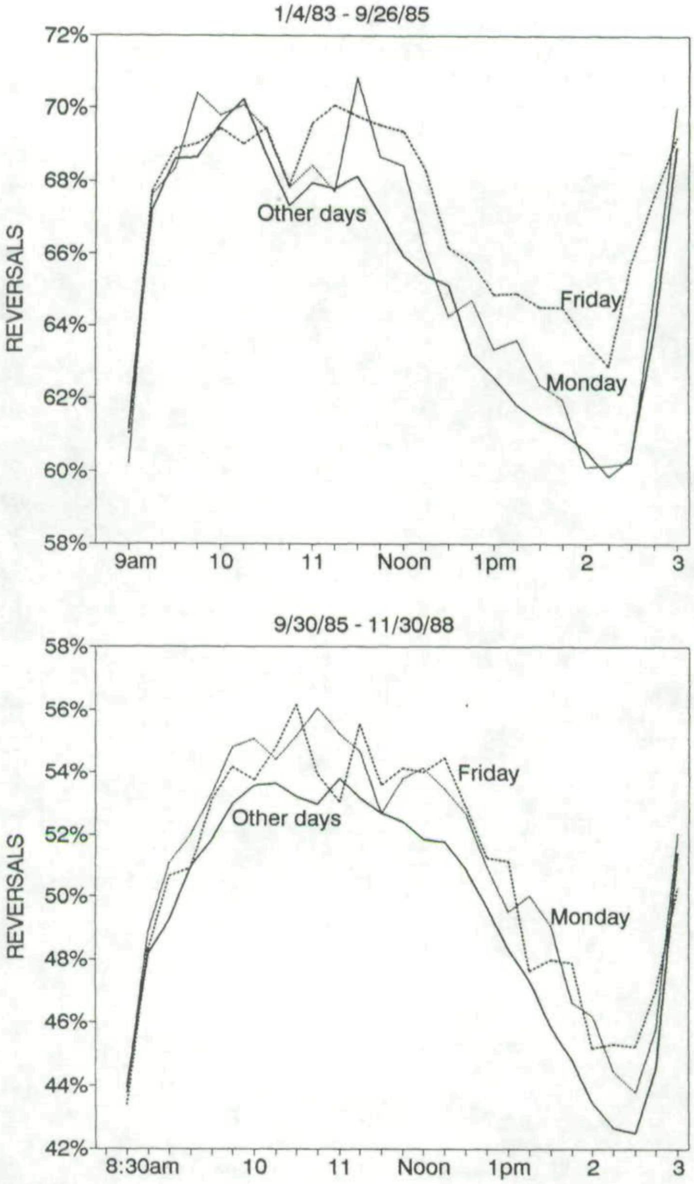

Figure 4

The mean percentage of transaction price reversals (REVERSALS) in the S&P 500 Index futures market by 15-minute interval.

Figure 4 is only similar to the pattern in NYSE stocks' REVERSALS shown by Gosnell in the first two hours of the day.

The interval means of REVERSALS differ significantly across weekdays through most of the afternoon. Interval means for Friday afternoon are significantly higher than the overall interval means except for the last interval of the day, when the Friday mean is insignificantly lower than the overall interval mean. This pattern in REVERSALS in the last 15-minute trading period of the week, Friday's Interval 25, is roughly similar to the "crossover" pattern in TRADES.

The S-shaped patterns in the interval means of AUTOCOR1 are shown in Table V for each weekday. This pattern is essentially the mirror image of the S-shaped pattern in REVERSALS. The interval means differ significantly across the day for each weekday. Few significant differences are apparent across weekdays. However, an examination of the patterns for the subsamples reveals that they are less obviously S-shaped in the second subsample, as the number of trades per minute becomes very large. Thus, the S-shaped pattern appears to be related to the

Table V
MEAN AUTOCORRELATION OF ONE-MINUTE RETURNS IN S&P 500 INDEX FUTURES, BY 15-MINUTE INTERVALS AND WEEKDAYS

Interval	Mon.	Tues.	Wed.	Thurs.	Fri.	STD[a]	*F* Days	*F* Mon.	*F* Fri.
1	−0.022	−0.046	−0.020	−0.068	−0.060	0.266	1.96	0.00	3.00
2	−0.071	−0.059	−0.068	−0.041	−0.077	0.251	0.82	0.02	0.11
3	−0.068	−0.102	−0.079	−0.092	−0.126	0.258	2.11	0.26	4.81[b]
4	−0.084	−0.087	−0.106	−0.106	−0.114	0.262	0.70	1.06	0.07
5	−0.089	−0.085	−0.103	−0.099	−0.098	0.262	0.27	0.45	0.09
6	−0.092	−0.106	−0.137	−0.111	−0.102	0.261	1.37	4.69[b]	3.06
7	−0.110	−0.097	−0.117	−0.091	−0.117	0.259	0.61	0.10	0.00
8	−0.092	−0.101	−0.081	−0.124	−0.130	0.257	1.93	0.25	5.10[b]
9	−0.107	−0.104	−0.097	−0.095	−0.130	0.252	0.80	0.20	2.31
10	−0.081	−0.095	−0.110	−0.108	−0.123	0.263	1.08	1.94	0.29
11	−0.122	−0.096	−0.095	−0.114	−0.127	0.269	0.86	1.50	1.98
12	−0.098	−0.088	−0.131	−0.095	−0.114	0.254	1.43	2.59	0.69
13	−0.103	−0.092	−0.056	−0.062	−0.115	0.255	2.88[b]	5.14[b]	7.58[c]
14	−0.089	−0.071	−0.075	−0.080	−0.107	0.267	0.79	0.40	2.05
15	−0.057	−0.048	−0.048	−0.061	−0.105	0.248	2.63[b]	0.20	7.78[c]
16	−0.098	−0.060	−0.079	−0.072	−0.085	0.249	0.94	0.80	0.09
17	−0.059	−0.018	−0.066	−0.046	−0.080	0.247	2.75[b]	0.15	0.42
18	−0.070	−0.067	−0.049	−0.047	−0.060	0.252	0.49	1.06	0.26
19	−0.061	−0.062	−0.017	−0.055	−0.075	0.254	2.17	4.40[b]	7.30[c]
20	−0.046	−0.036	−0.059	−0.058	−0.061	0.245	0.55	0.40	0.01
21	−0.029	−0.049	−0.032	−0.017	−0.035	0.253	0.62	0.02	0.01
22	−0.017	−0.043	−0.055	−0.060	−0.057	0.250	1.45	3.49	0.00
23	−0.026	−0.056	−0.046	−0.048	−0.062	0.254	0.79	0.96	0.46
24	−0.094	−0.079	−0.108	−0.085	−0.088	0.259	0.55	0.41	0.99
25	−0.135	−0.113	−0.123	−0.143	−0.123	0.261	0.69	0.35	0.01
F interval	4.45[c]	3.11[c]	5.48[c]	4.09[c]	3.34[c]				
Days	282	302	302	291	275				

The *F* statistics test whether the means are equal across weekdays (*F* days), whether the Monday mean is equal to the other weekday means (*F* Mon.), whether the Friday mean is equal to the other weekday means (*F* Fri.), and whether the means are equal across Intervals 1–25 (*F* interval). The *F* statistics are calculated from separate dummy variable regressions for each interval and each weekday, which include dummy variables for years.

[a]Standard deviation of the autocorrelation of one-minute returns.

[b]Significant at the 0.05 level.

[c]Significant at the 0.01 level.

autocorrelation of transaction returns rather than the autocorrelation of fixed-interval returns.

The difference between the patterns in one-minute autocorrelations from the NYSE and the S&P futures markets suggest that McInish and Wood's (1988) results may be strongly affected by nonsynchronous trading. The differences between the patterns in REVERSALS in the NYSE stocks and in the S&P futures is less easily explained.

CONCLUSIONS

Intraday patterns in the S&P 500 Index futures market occur in overnight and 15-minute returns, returns volatility (|RETURN|), the number of recorded transactions (TRADES), the percentage of transaction price reversals (REVERSALS), and the autocorrelation of one-minute returns (AUTOCOR1). The intraday patterns in returns are similar to the intraday patterns in NYSE index returns observed by Harris. The intraday patterns in |RETURN| and in TRADES are roughly U-shaped, consistent with previously observed patterns, but the means of these variables decline in the last half-hour of trading. Trading periods have very high volatility compared to nontrading periods. The intraday patterns in REVERSALS and AUTOCOR1 have distinctive S-shapes.

The intraday patterns in six years of S&P futures data are inconsistent with explanations that the NYSE patterns may be spurious due to short sample periods or the effects of nonsynchronous trading on intraday returns indices. Few results suggest that the patterns differ much across markets, or that the institutional features of one marketplace cause the patterns. For example, the end-of-the-day average price rise in S&P futures occurs in the 15-minute interval which follows the NYSE close, so that this pattern is not merely a reflection of the pattern in the underlying stocks.

The decline in the means of |RETURN| and TRADES in the half-hour before the close is puzzling, but may be related to the close of the NYSE 15 minutes before the S&P futures close. The study of this 15-minute period and its effect on both markets is an interesting topic for further research.

The S-shaped intraday patterns in REVERSALS and AUTOCOR1 are consistent with an intraday pattern in information trading since the autocorrelation of transaction returns is related to the amount of information trading in the model of Glosten and Milgrom. Further research may show why intraday patterns in autocorrelation-related variables differ across studies and across markets.

The consistent minor variations in the patterns across weekdays, especially the similar "crossover" patterns in TRADES and REVERSALS on Friday afternoons, show subtle complexities in intraday patterns not previously observed.

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