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An Investigation of Transactions Data for NYSE Stocks

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ABSTRACT

Using transactions data, the behavior of returns and characteristics of trades at the micro level is examined. A minute-by-minute market return series is formed and tested for normality and autocorrelation. Evidence of differences in return distributions is found among overnight trades, trades during the first 30 minutes following the market opening, trades at the close, and trades during the remainder of the day. The latter distribution is found to be normal. Unusually high returns and standard deviations of returns are found at the beginning and the end of the trading day. When the beginning- and end-of-the-day effects are omitted, autocorrelation in the market return series is reduced substantially. A number of patterns in trading are reported.

THIS PAPER EMPIRICALLY INVESTIGATES the nature of the return-generating process and the characteristics of trade size, price changes, trading frequency, and trading interval at the level of individual trades for a large sample of NYSE stocks. Previous studies of market indices have used daily, weekly, or monthly time-aggregated returns [1, 2, 3, 4, 5, 6, 9]. An equally weighted index of common stocks listed on the NYSE is examined for two time periods—the six months from September 1971 to February 1972 and calendar year 1982. The index is comprised of 946 and 1,138 common stocks, respectively, during these periods. Minute-to-minute values of the index are calculated using transactions data, and for each period, a return series for a typical trading day is formed by averaging across days within minutes.

The remainder of this paper is divided into five parts. The next section describes the data. The results are presented in three sections. In the first, descriptive statistics for the market returns are provided and the behavior of the series over the average trading day is examined. The following two sections describe the trading statistics for the market characteristics mentioned above and an autocorrelation analysis. The final section provides a summary and conclusions.

I. Description of the Data

The data employed in the study, which was obtained from the Francis Emory Fitch Company, consist of prices, number of shares traded, and time for every

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trade on the NYSE for the six months from September 1971 through February 1972 and for the calendar year 1982. Prior to analysis, prices were adjusted for dividends and changes in capitalization.

The database contained errors, some of which were so subtle that they could not be detected with simple filters. For example, a price of \$40 might be followed by two prices of \$4 and then a fourth price of \$40. A number of procedures were used to correct these errors including comparison of the transactions data with data from the CRSP daily tape and from the Standard and Poor's *Daily Stock Price Record.* When the data could not be satisfactorily corrected, the firms were removed from the sample. In addition, firms that were not available on the COMPUSTAT tapes were deleted. Eleven firms with prices less than \$4 also dropped from the 1982 data because their price movements between the bid and ask resulted in extreme return patterns.

The method used to calculate individual stock returns and the market indices is similar to that used in constructing the NYSE index and a number of other indices. The return for any minute during which a security traded (minute t) was calculated as follows:

$$r_t = \ln[(p_t + d_t)/p_{t-1}]$$

where p_t is the price of the security during the trade minute, p_{t-1} is the price in the prior minute, and d_t is any dividend declared since the last trade. The return for any minute during which a security does not trade is zero. This method of calculating returns is based on the assumption that security returns are generated in transactions time.

The equally weighted market index is obtained by summing returns for each of the firms (946 for 1971–1972 and 1,138 for 1982) for each minute and dividing by 946 or 1,138, respectively. The 1971–1972 data contain returns for 126 trading days while the 1982 data contain returns for 252 trading days. A profile of the typical trading pattern during the day ("trading day" return series) is obtained by averaging across trading days within each trading minute. If the r_{jt} are independent (k_t, σ_j^2), or the $(r_{jt}, r_{j,t+s})$ are uncorrelated for $s \geq$ the number of minutes in a trading day, then it follows that a given minute in each of the two successive days generates independent observations. Since all stocks are subject to the same information, r_{jt} is distributed with mean k_t and variance σ_j^2, and summation across days is appropriate. Both the market return series and the trading day return series are examined below.

Because in the limit only one security trades at a given instant, the meaning of a market return for transactions data is ambiguous. Hence, two alternatives to the method of computing a market index just described were explored. In the first, based on the calendar time return-generating model, returns were divided evenly over the minutes between trades. In a second alternative, only those trades occurring near a particular minute were used to estimate the market return for that minute. Specifically, returns for all stocks trading at minute $t - 1$ and again at t could be used to estimate the market return for that one minute interval. Further, information could be gained from returns observed for the intervals $t - 2$ to t and $t - 1$ to $t + 1$. Expanding in this manner, a simultaneous equation system can be derived to estimate the minute-by-minute market return series.

About 10% of all trades occur with a one-minute interval, while 35% of trades occur within a four-minute interval. A first-order approximation to the inverse of the variance/covariance matrix of the one-to-four-minute interval simultaneous equation system was derived and used to estimate the market return series. These two alternative approaches induced substantial autocorrelation in the market return series. Therefore, the transactions time series was chosen for this study.

II. Behavior of Market Index During the Average Trading Day

A. Behavior of the Trading Day Return Series: Graphical Results

Recall that to form this series, the minute-by-minute market return series is averaged across days by trading minutes within the day. Figure 1 shows the trading day market returns, including the first return of the day (an overnight return) plotted against trading minutes. The pattern shows high initial returns (about 12×10^{-5} for the 1971–1972 data), followed by a drop to returns which span zero within the first hour. In the 1982 data, these high initial returns are dampened and less monotonic, but still clearly present. When overnight returns are excluded (not shown), high returns during the initial minutes of trading are present, but much less pronounced in both periods. Another interesting finding is the very high return recorded in the last trading minute. These high end-of-the-day returns are more pronounced for the 1982 data than for the 1971–1972 data.

The standard deviations of the returns calculated across days for each trading minute (Figure 3) follow a pattern similar to that of mean returns—high variation early in the trading day (standard deviations about 33×10^{-5} in both 1971–1972 and 1982) which drop to a more stable pattern in the first hour. Several unusually high variances also occur in the last trading hour. When overnight returns are excluded (not shown), the variances drop for the opening minutes (averaging 12×10^{-5} for 1971–1972), leaving a discernable, but greatly dampened, downward drift at the opening.

Examining Figure 1 in conjunction with Figure 2 indicates that both the mean market return and risk are higher during the first few minutes of trading. For 1971–1972, the ratio of market return to its standard deviation, the reward/risk ratio, shows a downward trend from just over 0.3 near the opening to zero within 60 minutes. The 1982 data also shows a downward trend in the opening hour. The market appears to pass through a seasoning process at each opening, reminiscent of the seasoning pattern observed in other studies.

B. Behavior of the Return Series: Statistical Results

Table I (Panels A and B) presents the first four moments for the return series spanning all days and the average trading day series along with minimum, maximum, and quartile return values. The results for columns 2 through 8 are for the same data presented in Figure 1. When the market index is considered for all minutes for 1971–1972 (Panel A, column 1), the returns range from 14.2917

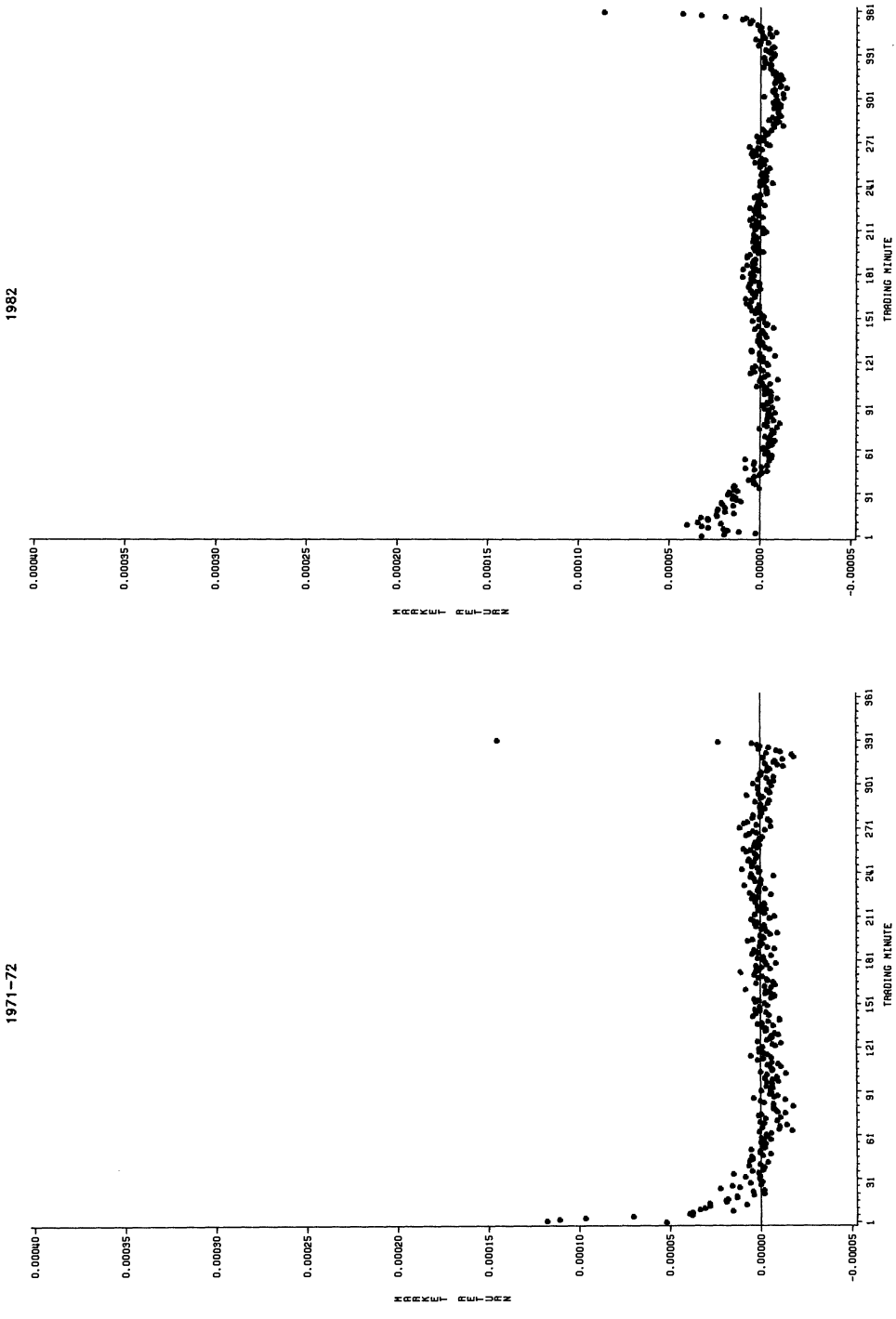

Figure 1. Means of Market Return Across Days (by minute, overnight returns included)

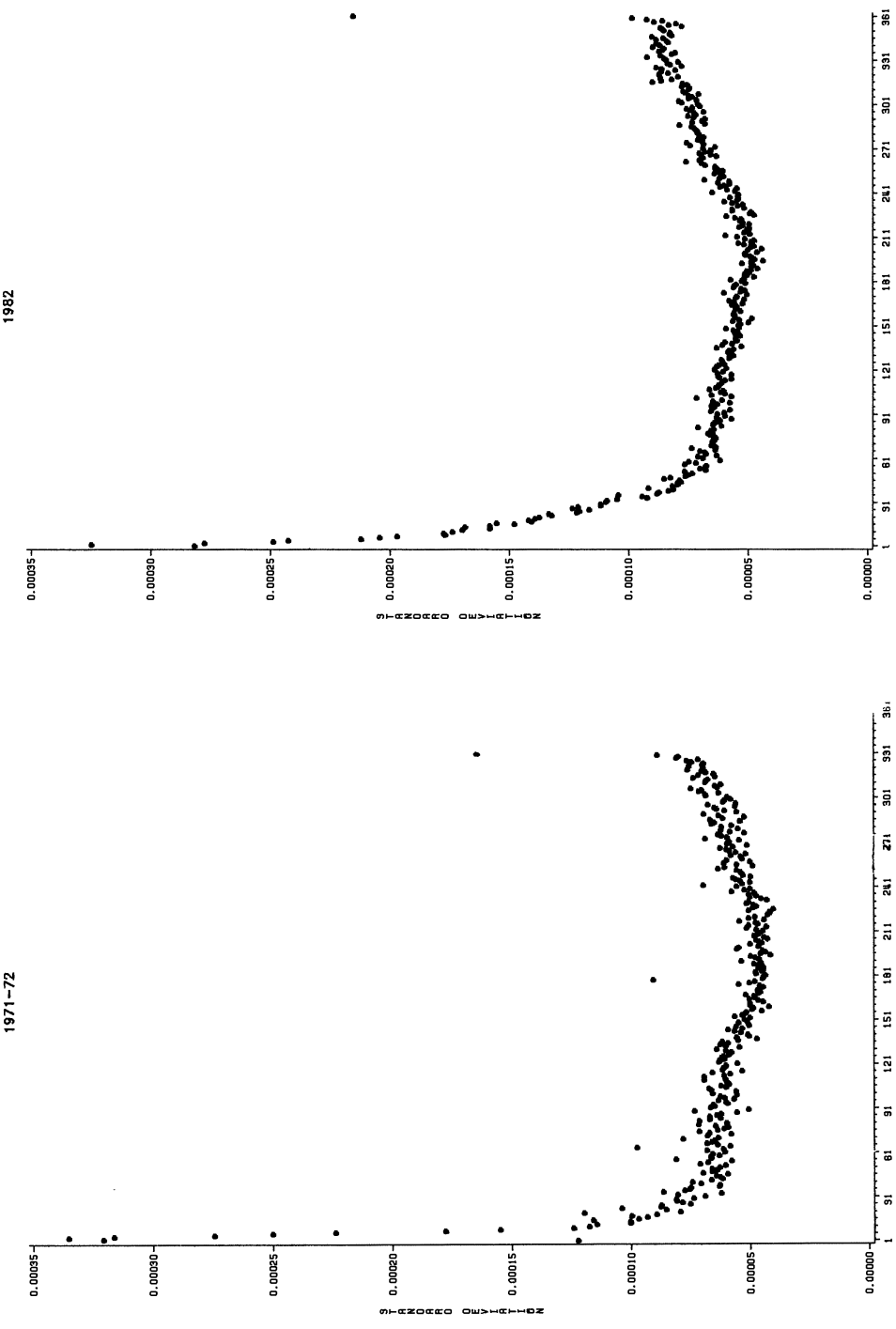

Figure 2. Standard Deviations of Market Return Across Days (by minute, overnight returns included)

Table I

Statistics for Minute-by-Minute Market Return Series Including and Excluding Overnight Returns

Panel A: Returns for Six Months (September 1971–February 1972)

	All Minutes		Averaged Across Sample Days Within Trading Minutes (Trading Day)					
	41,706 Minutes	41,580 Minutes	All 331 Minutes		First 30 Minutes		31–331	31–330
Statistic	Including Overnight Returns	Excluding Overnight Returns	Including Overnight Returns	Excluding Overnight Returns	Including Overnight Returns	Excluding Overnight Returns	Including Overnight Returns	Including Overnight Returns
Mean	0.0180	0.0058	0.0180	0.0058	0.2840	0.1240	−0.0085	−0.0104
Std. Dev.	0.7622	0.6565	0.1591	0.1084	0.3204	0.0978	0.1007	0.0514
Skewness	1.45*	0.42*	5.52*	7.98*	1.67*	0.34	10.20*	−0.18
Kurtosis	28.91*	7.81*	38.64*	104.76*	2.31*	0.71	147.93*	0.43
D-Statistic	0.88*	0.04*	0.27*	0.18*	0.79	0.96	0.19*	0.04
Quartiles								
Maximum	14.2917	10.6776	1.4523	1.4828	1.1787	0.3945	1.4523	0.1537
75%	0.3595	0.3630	0.0306	0.0338	0.3792	0.1909	0.0186	0.0222
50%	−0.0099	−0.0092	−0.0038	−0.0012	0.1872	0.1359	−0.0093	−0.0063
25%	−0.3752	−0.3807	−0.0467	−0.0453	0.0565	0.0524	−0.0501	−0.0485
Minimum	−13.4514	−11.9710	−0.1830	−0.1789	−0.0172	−0.0523	−0.1830	−0.1739

Table I—*Continued*

Panel B: Returns for Calendar 1982

	All Minutes		Averaged Across Sample Days Within Trading Minutes (Trading Day)					
	90,972 Minutes	90,720 Minutes	All 361 Minutes		First 30 Minutes		31–361	31–356
Statistic	Including Overnight Returns	Excluding Overnight Returns	Including Overnight Returns	Excluding Overnight Returns	Including Overnight Returns	Excluding Overnight Returns	Including Overnight Returns	Including Overnight Returns
Mean	0.0229	0.0225	0.0229	0.0225	0.2136	0.2144	0.0056	−0.0110
Std. Dev.	0.8587	0.7639	0.2095	0.2095	0.0821	0.0801	0.2090	0.0520
Skewness	0.92*	0.89*	13.32*	13.39*	0.18	0.27	14.78*	0.19
Kurtosis	12.55*	10.88*	218.26*	219.67*	0.10	−0.54	245.84*	0.24
D-Statistic	0.08*	0.05*	0.28*	0.28*	0.99	0.95	0.32*	0.03
Quartiles								
Maximum	14.6901	14.6890	3.5237	3.5265	0.4013	0.4050	3.5237	0.1720
75%	0.4058	0.4124	0.0375	0.0370	0.2848	0.2753	0.0273	0.0264
50%	−0.0058	−0.0020	−0.0011	−0.0032	0.2045	0.2144	−0.0111	−0.0120
25%	−0.4105	−0.4076	−0.0427	−0.0450	0.1490	0.1377	−0.0469	−0.0471
Minimum	−8.7263	−14.3703	−0.1423	−0.1421	0.0251	0.0962	−0.1423	−0.1423

Notes: All returns are logarithms of price relatives multiplied by 10^4. Skewness and kurtosis values adjusted to average zero for a normal distribution. Normality is tested for skewness and kurtosis with a goodness-of-fit test [7, 8].

* Significantly different from zero at the 0.01 level.

to −13.4514 with a mean of 0.0180 and a standard deviation of 0.7622. As expected, averaging the returns across days reduces the range of returns (1.4523 to −0.1830), but yields the same mean return (0.0180). For the trading day return series, the standard deviations reflect the variability of the return by trading minute across the average trading day.

The 1971–1972 data show a substantial impact from overnight trades with more than two-thirds of the total return being earned overnight. The impact on higher moments is also large in this period, but the direction of change varies with the averaging procedures. In 1982, the overnight return has little effect on the first four moments.

The first thirty minutes of the average trading day (columns 3 and 4) is quite different from the remainder of the day. Mean returns are much higher for this period. The indicated lack of departure from normality, relative to columns 1 to 4, probably reflects the small number of degrees of freedom.

Columns 7 and 8 reflect the highly nonnormal behavior of end-of-the-day returns (last minute in 1971–1972 and last five minutes in 1982). When these returns are dropped (along with the first thirty minutes) from the average trading day series (column 8), almost all departures from normality vanish—e.g., kurtosis drops from 147.93 (column 7) to 0.43 in 1971–1972 and from 245.84 to 0.24 in 1982. (When the statistics for column 1 are calculated with the first thirty and last five minutes omitted for each day, skewness and kurtosis for 1971–1972 drop to 0.07 and 3.98, and for 1982 to 0.25 and 2.99, respectively.) The return distributions for the average trading day for both periods are quite similar when opening and closing minutes are omitted (column 8). In both, mean returns are slightly negative; all positive returns are earned in the first thirty minutes and at the close.

These results provide evidence that the return-generating process varies systematically across the trading day and overnight. It appears that the mixtures of distributions being observed when returns are aggregated for daily or longer periods result from components due to an overnight distribution, an opening distribution, an end-of-day distribution, and an intraday distribution, with only the latter being normally distributed.

III. Autocorrelation Results

A. Trading Day Return Series

Figure 3, Panel A, shows the autocorrelation function for the trading day return series over the entire trading day (including overnight returns, but excluding the last minute). The decay rate of the autocorrelation function, which declines from 0.810 for a one minute lag to 0.090 for a twenty-four minute lag, is much slower than the exponential decay which would be expected for a low-order autoregressive process. The decay rate for the 1982 data (Figure 3, Panel B) is lower than for the 1971–1972 period. These patterns indicate possible nonstationarity in the series, raising the issue (addressed below) of how the autocorrelation function varies over the trading day.

Panel A: September 1971 Through February 1972

AUTOCORRELATIONS

LAG	CORRELATION	-5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	1.00000	|********************|
1	0.80969	. |***************** |
2	0.68015	. |*************** |
3	0.57252	. |************ |
4	0.46331	. |********* |
5	0.38926	. |******** |
6	0.34782	. |******* |
7	0.29966	. |****** |
8	0.27168	. |***** |
9	0.24772	. |***** |
10	0.23362	. |***** |
11	0.21034	. |****. |
12	0.21442	. |****. |
13	0.20351	. |****. |
14	0.18669	. |****. |
15	0.15135	. |*** . |
16	0.12940	. |*** . |
17	0.11419	. |** . |
18	0.10898	. |** . |
19	0.09361	. |** . |
20	0.11987	. |** . |
21	0.11953	. |** . |
22	0.11101	. |** . |
23	0.10631	. |** . |
24	0.09011	. |** . |

Panel B: Calendar 1982

AUTOCORRELATIONS

LAG	CORRELATION	-4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	1.00000	|********************|
1	0.75827	. |**************** |
2	0.67771	. |*************** |
3	0.63752	. |************** |
4	0.59013	. |************* |
5	0.57001	. |************* |
6	0.54898	. |************ |
7	0.54195	. |************ |
8	0.50280	. |*********** |
9	0.45740	. |********* |
10	0.44696	. |********* |
11	0.41839	. |******** |
12	0.41164	. |******** |
13	0.38977	. |******** |
14	0.34811	. |******* |
15	0.34716	. |******* |
16	0.33355	. |******* |
17	0.30428	. |****** |
18	0.30675	. |******. |
19	0.30335	. |******. |
20	0.26320	. |***** . |
21	0.25033	. |***** . |
22	0.24829	. |***** . |
23	0.22050	. |**** . |
24	0.18114	. |**** . |

'.' MARKS TWO STANDARD ERRORS

Figure 3. Autocorrelation Function for Average Trading Day Market Return Series (overnight returns included)

When the autocorrelation function for the average trading day market return series for the first thirty minutes of trading during the 1971–1972 period is examined (not shown), the first twelve autocorrelation coefficients conform to a first-order autoregressive process. But, the lags of twelve and beyond show slightly negative values (albeit on very small sample sizes) suggestive of some degree of nonstationarity even within the first thirty trading minutes. No other intervals of thirty minutes or more, including the last 300 trading minutes, exhibit significant autocorrelation. No significant autocorrelation was found for any subinterval in 1982.

For both the 1971–1972 and 1982 data, the autocorrelation function for the trading day market return series which excludes overnight returns indicates no significant autocorrelation for the entire trading day, nor for any subinterval examined. While the method used to form this series would induce some autocorrelation, this proved to be negligible. Thus, autocorrelation for the series including overnight returns results from a combination of infrequent trading and intraday/overnight return distribution differences.

B. Market Return Series: Results by Day

For lags of one to twenty minutes, autocorrelation coefficients are calculated for the market index for each of the days in the sample. These correlations are calculated for all minutes, for the first thirty minutes, and for the trading day excluding the first thirty minutes. Averages of these daily correlation coefficients are presented in Table II, Panel A.

For each cell in Panel A (Table II), Panel B shows the percentage of days for which the t-statistics for the correlation coefficients are significant at the 5% confidence level are shown. When autocorrelation is measured over all minutes, a majority of days have significant t-statistics for one- to nine-minute lags for the 1971–1972 period and for one to fifteen minutes for the 1982 period. Few significant t-statistics are found beyond the one-minute lag for the first thirty minutes; this may reflect the small number of degrees of freedom. A lower percentage of days have significant t-statistics at the 5% level for lags of up to twenty minutes when the first thirty minutes are excluded. This pattern provides further evidence that autocorrelation is induced by infrequent trading and large overnight trades.

Comparable results were examined for a return series obtained from the most frequently traded quintile of stocks in both periods. For 1971–1972 autocorrelation virtually disappeared for the last 300 trading minutes, (correlation coefficient = 0.025 for one-minute lag) while for 1982 the size of the correlation coefficients dropped (one minute lag = 0.192; ten-minute lag = 0.170). The percentage of significant correlation coefficients also dropped in 1982 (one-minute lag, 67.9%; ten-minute lag, 59.1%).

For 1982, autocorrelation coefficients are calculated before and after August 13, which marked a turning point from a mild bear market to a strong bull market. The coefficients are larger during the bull market (one minute; bull = 0.515, bear = 0.368; ten minutes: bull = 0.367, bear = 0.248); 70% of the ten-minute lags were significant during the bear market after the first thirty trading minutes, while 87% were significant during the bull market. To further investigate this relationship, the absolute value of the t-statistics for one-, five-, and ten-minute lags (calculated for the return series which excludes overnight returns in order to avoid autocorrelation induced by large overnight trades and infrequent trading) are regressed, in turn, on the absolute value of the preceding overnight return and the number of shares traded during the day. (Number of shares proved to be a better predictor than number of trades.) In 1971–1972, the absolute value of the overnight return is highly significant, but number of shares traded is not significant. Both variables are highly significant for 1982 (with the number of shares traded having greater significance); the coefficients of determination range from 0.16 to 0.46. Thus, the extent of autocorrelation in the market is correlated with the amount of information present.

IV. Trading Statistics

Table III shows trading statistics summarized by various transaction/firm attributes for all the trades for six months in 1971–1972 and for a sample of one-

Table II

Average of Autocorrelation Coefficients Estimated for Each Trading Day

Panel A: Mean Lag Correlation Coefficients

	September 1971–February 1972			Calendar 1982		
Min. Lag	All Minutes	First 30 Min.	Last 300 Min.	All Minutes	First 30 Min.	Last 300 Min.
1	0.281	0.263	0.145	0.425	0.273	0.314
2	0.253	0.192	0.142	0.405	0.212	0.308
3	0.231	0.132	0.139	0.395	0.179	0.310
4	0.208	0.080	0.142	0.376	0.140	0.300
5	0.195	0.043	0.142	0.366	0.107	0.300
6	0.188	0.015	0.141	0.350	0.087	0.285
7	0.185	0.010	0.145	0.334	0.043	0.277
8	0.173	−0.003	0.138	0.320	0.028	0.265
9	0.169	−0.016	0.138	0.308	0.017	0.256
10	0.166	−0.019	0.135	0.294	−0.013	0.247
11	0.159	−0.033	0.133	0.280	−0.027	0.235
12	0.154	−0.041	0.132	0.269	−0.038	0.227
13	0.147	−0.049	0.123	0.259	−0.040	0.219
14	0.148	−0.059	0.128	0.244	−0.066	0.207
15	0.139	−0.062	0.120	0.229	−0.086	0.197
16	0.142	−0.064	0.121	0.216	−0.090	0.183
17	0.127	−0.071	0.104	0.201	−0.091	0.171
18	0.124	−0.075	0.102	0.196	−0.105	0.169
19	0.130	−0.082	0.114	0.183	−0.109	0.157
20	0.125	−0.083	0.103	0.169	−0.121	0.147

Panel B: Percentage of Days With Significant *t*-Statistics, By Lag, 5% Confidence Level

1	73.8	44.4	50.0	95.6	40.5	88.9
2	73.0	15.9	47.6	95.2	21.8	84.9
3	69.8	2.4	46.0	95.6	5.6	89.7
4	65.9	0.8	51.6	93.3	0.8	88.5
5	60.3	0.0	48.4	92.9	0.8	85.3
6	61.9	0.0	46.0	93.7	0.0	84.9
7	59.5	0.0	44.4	91.7	0.0	81.3
8	59.5	0.0	49.2	88.1	0.0	77.4
9	51.6	0.0	43.7	88.5	0.0	79.0
10	51.6	0.0	40.5	84.5	0.0	76.6
11	52.4	0.0	40.5	81.7	0.0	72.2
12	44.4	0.0	40.5	74.6	0.0	67.1
13	39.7	0.0	36.5	71.0	0.0	62.3
14	37.3	0.0	38.9	64.3	0.0	57.9
15	33.3	0.0	33.3	57.5	0.0	49.2
16	32.5	0.0	30.2	49.6	0.0	45.2
17	26.2	0.0	23.0	40.1	0.0	35.7
18	23.0	0.0	19.0	33.7	0.0	32.5
19	27.8	0.0	23.0	22.2	0.0	31.3
20	23.8	0.0	19.0	19.4	0.0	21.4

Table III

Summary of Trading Statistics

Panel A: September 1971–February 1972

RNKPRICE	RNKEQT	PCHANGE	DAYMRK	RNKFREQ	No. of Trades	Size	Price	Interval	Absolute Price Change
•	•	•	•	•	3,233,706	446.4	36.22	12.2	0.69
•	•	•	•	1	1,733,634	439.3	38.35	4.5	0.58
•	•	•	•	2	682,794	481.7	35.12	11.6	0.74
•	•	•	•	3	420,081	451.0	32.29	18.9	0.82
•	•	•	•	4	262,112	439.7	34.00	30.1	0.93
•	•	•	•	5	135,085	357.3	30.96	58.1	1.02
•	•	•	0	•	3,116,184	422.7	36.32	10.7	0.66
•	•	•	1	•	117,522	1,074.7	33.39	51.5	1.56
•	•	•	0	1	1,709,928	409.2	38.38	4.5	0.57
•	•	•	0	2	659,089	458.9	35.12	11.3	0.71
•	•	•	0	3	396,269	434.1	32.33	18.0	0.78
•	•	•	0	4	238,485	429.9	34.02	26.9	0.87
•	•	•	0	5	112,413	359.6	31.08	41.8	0.94
•	•	•	1	1	23,706	2,608.8	35.96	9.2	1.71
•	•	•	1	2	23,705	1,116.8	35.10	18.2	1.64
•	•	•	1	3	23,812	732.0	31.62	33.2	1.49
•	•	•	1	4	23,627	538.1	33.79	62.0	1.55
•	•	•	1	5	22,672	345.9	30.37	138.7	1.42
•	•	−5/8	•	•	955	6,774.8	60.05	22.8	5.00
•	•	−4/8	•	•	10,605	1,957.7	131.58	19.6	4.00
•	•	−3/8	•	•	20,671	1,083.1	71.99	23.1	3.00
•	•	−2/8	•	•	233,565	524.9	46.39	20.9	2.00
•	•	−1/8	•	•	510,951	450.7	30.50	12.5	1.00
•	•	0/8	•	•	1,656,313	392.0	34.07	9.7	0.00
•	•	1/8	•	•	525,135	427.2	31.81	11.3	1.00
•	•	2/8	•	•	234,067	446.3	46.67	19.0	2.00

•	•	3/8	•	•	21,831	725.0	69.08	23.2	3.00
•	•	4/8	•	•	11,447	887.1	128.15	19.2	4.00
•	•	5/8	•	•	1,140	2,468.1	57.02	20.5	5.00
•	1	•	•	•	148,565	310.3	13.35	26.3	0.62
•	2	•	•	•	155,912	332.0	18.10	25.4	0.70
•	3	•	•	•	202,084	335.1	20.26	19.6	0.68
•	4	•	•	•	250,902	361.0	23.34	15.6	0.65
•	5	•	•	•	293,726	399.7	23.50	13.5	0.65
•	6	•	•	•	329,415	425.0	31.23	12.0	0.68
•	7	•	•	•	305,713	478.2	41.33	12.8	0.77
•	8	•	•	•	408,913	492.4	32.99	9.7	0.65
•	9	•	•	•	472,269	497.8	36.63	8.4	0.71
•	10	•	•	•	666,207	521.3	62.66	5.9	0.73
1	•	•	•	•	292,358	358.7	10.13	13.4	0.46
2	•	•	•	•	415,486	381.4	15.08	9.5	0.49
3	•	•	•	•	304,256	408.8	18.86	13.0	0.57
4	•	•	•	•	326,591	417.3	22.15	12.0	0.61
5	•	•	•	•	294,269	441.9	26.28	13.4	0.64
6	•	•	•	•	351,617	460.2	30.24	11.3	0.65
7	•	•	•	•	275,405	495.3	35.44	14.2	0.74
8	•	•	•	•	276,043	542.3	41.97	14.3	0.77
9	•	•	•	•	281,460	558.1	50.38	14.1	0.87
10	•	•	•	•	416,221	443.1	98.55	9.4	1.09
Panel B: Calendar 1982									
•	•	•	•	•	3,383,611	1,315.5	30.01	10.1	0.81
•	•	•	•	1	1,901,294	1,477.5	33.85	3.6	0.76
•	•	•	•	2	709,294	1,314.1	26.47	9.7	0.83
•	•	•	•	3	407,154	1,008.6	24.06	16.9	0.87
•	•	•	•	4	243,434	875.9	24.43	28.3	1.01
•	•	•	•	5	122,435	703.6	21.92	55.9	1.01
•	•	•	0	•	3,288,899	1,251.2	30.17	9.0	0.79
•	•	•	1	•	94,712	3,549.2	24.55	50.6	1.53
•	•	•	0	1	1,882,353	1,386.0	33.88	3.5	0.75

Table III—*Continued*

Panel B: Calendar 1982

RNKPRICE	RNKEQT	PCHANGE	DAYMRK	RNKFREQ	No. of Trades	Size	Price	Interval	Absolute Price Change
•	•	•	0	2	690,099	1,254.8	26.49	9.5	0.81
•	•	•	0	3	387,694	971.4	24.11	16.3	0.84
•	•	•	0	4	224,405	848.0	24.55	25.7	0.97
•	•	•	0	5	104,348	703.1	22.16	40.7	0.95
•	•	•	1	1	18,941	10,570.5	30.18	9.3	1.81
•	•	•	1	2	19,195	3,447.1	25.79	16.5	1.55
•	•	•	1	3	19,460	1,749.8	23.00	29.5	1.48
•	•	•	1	4	19,029	1,205.7	23.07	59.8	1.48
•	•	•	1	5	18,087	706.6	20.55	143.2	1.32
•	•	−5/8	•	•	780	22,283.0	34.75	29.0	5.00
•	•	−4/8	•	•	3,150	13,832.9	46.07	27.6	4.00
•		−3/8	•	•	5,819	10,834.1	39.92	24.4	3.00
•	•	−2/8	•	•	163,098	1,750.9	35.82	19.1	2.00
•	•	−1/8	•	•	565,951	1,297.7	28.61	11.1	1.00
•	•	0/8	•	•	1,878,693	1,142.5	29.53	8.2	0.00
•	•	1/8	•	•	573,904	1,309.6	29.26	9.9	1.00
•	•	2/8	•	•	164,154	1,420.0	35.28	18.1	2.00
•	•	3/8	•	•	5,960	6,528.8	41.24	23.9	3.00
•	•	4/8	•	•	3,172	8,068.8	49.60	25.1	4.00
•	•	5/8	•	•	728	15,970.4	37.66	25.4	5.00
•	1	•	•	•	85,921	648.7	11.62	39.6	0.69
•	2	•	•	•	117,693	672.4	14.13	29.6	0.72
•	3	•	•	•	151,391	695.2	18.96	22.6	0.89
•	4	•	•	•	180,400	878.6	20.97	18.9	0.86
•	5	•	•	•	234,633	969.7	19.96	14.7	0.79
•	6	•	•	•	287,858	1,163.9	23.32	12.0	0.94
•	7	•	•	•	327,635	1,226.4	24.60	10.4	0.80
•	8	•	•	•	434,888	1,401.5	27.34	7.9	0.76
•	9	•	•	•	568,368	1,494.9	30.92	6.0	0.82

•	10	•	•	•	994,824	1,637.6	43.55	3.4	0.81
1	•	•	•	•	178,670	933.4	8.64	19.1	0.54
2	•	•	•	•	289,220	1,013.1	13.01	11.9	0.62
3	•	•	•	•	249,931	1,258.0	15.71	13.8	0.63
4	•	•	•	•	295,490	1,206.7	18.80	11.6	0.67
5	•	•	•	•	378,622	1,447.1	21.09	9.0	0.80
6	•	•	•	•	296,323	1,289.3	23.86	11.7	0.74
7	•	•	•	•	269,021	1,291.3	27.23	12.8	0.81
8	•	•	•	•	411,816	1,423.4	31.08	8.3	0.83
9	•	•	•	•	413,793	1,465.6	38.02	8.3	0.93
10	•	•	•	•	600,725	1,415.9	59.68	5.6	1.08

Notes: RNKPRICE, rank order by average price over sample period; RNKEQT, rank order by market value of equity; PCHANGE, price change in one-eights of $1; DAYMARK, 0 for intraday trades and 1 for overnight trades; RNKFREQ, rank order by trading frequency; Size, average number of shares per trade; Interval, average time between trades in minutes; Absolute Price Change, measured in $0.125. The results reported in Panel B represent a sample of one-third of the 1982 trades.

third of the trades for calendar 1982. The statistics summarized are number of trades, size of trades (number of shares), price, interval between trades in minutes, and absolute value of price change. These data are summarized as follows: deciles of stocks categorized by average price over the sample period (RNKPRICE); deciles of firms ranked by market equity (RNKEQT, calculated at year-end from the COMPUSTAT tape); quintiles of stocks categorized by trading frequency (RNKFREQ); price change in eights of $1 (PCHANGE); and intraday versus overnight trades (DAYMRK).

Several interesting patterns appear. The size of each trade in 1982 is 195% higher than in 1971–1972, while the number of trades per stock is 30% greater. The average price per share is 17% lower, which reflects a substantial reduction in the number of high priced stocks over the decade. After adjusting for inflation, the dollar value of the average trade was about the same in both periods. The size of overnight trades is more than 150% greater than intraday trades in both periods.

Trades are concentrated in the zero-price change category. Further, zero-return incidence is negatively correlated with RNKFREQ, suggesting that trading for liquidity rather than equilibrium adjustment increases for the more frequently traded stocks. Other factors, such as the breaking up of block trades, might contribute to this pattern.

The smallest trading size occurs with no price change (PCHANGE) and trading size is directly related to the absolute value of PCHANGE. The PCHANGE/SIZE relationship is skewed with the downsticks having greater number of shares per trade than comparable upsticks. Thus, the amount of information appears to affect both PCHANGE and SIZE, with a more pronounced effect on SIZE for downsticks. The direct relationship between trading interval and absolute value of the price change suggests that the information content of a trade tends to be greater as the time between trades increases.

Examining SIZE and RNKFREQ shows no pattern in 1971–1972 for intraday trades (DAYMRK = 0), while a negative correlation exists for overnight trades. The negative correlation is apparent for both intraday and overnight trades in 1982. For both periods, the absolute value of the price change is positively correlated with RNKFREQ for intraday trades, but negatively correlated for overnight trades.

V. Summary and Conclusions

Using transactions data for six months in 1971–1972 and calendar 1982, this paper examines the behavior of returns and various trading characteristics. A minute-by-minute market return series is tested for normality and autocorrelation. Evidence of differences in return distributions are found among trades occurring overnight, during the first thirty minutes of the trading day, at the market close, and during the remainder of the day. In the sample periods, all positive returns were earned during the first thirty minutes of trading and at the market close. When the first thirty minutes and closing minutes are excluded, market returns are found to be normally distributed, and autocorrelation is found to be substantially reduced. The overnight return combined with infrequent

trading is found to induce autocorrelation, particularly in 1971–1972. A number of patterns are found in trading frequency, number of shares per trade, size of price changes, length of time between trades, and the absolute value of price change.

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DISCUSSION

GEORGE TAUCHEN*: This is a very good paper. Professors Wood, Ord, and McInish have expended a great deal of effort to collect, edit, and analyze two very large data sets, and they are to be commended for undertaking such a task. Their work uncovers a number of interesting empirical regularities about short-term movements in stock prices that I believe will stimulate interesting follow-up work by financial market theorists.

The results of the analysis of the minute-by-minute market returns index can be summarized in three stylized facts. First, the process generating average market returns differs significantly over the trading day. Average returns tend to be high in the earliest part of the day, in particular in the first thirty minutes of trading, and then jump sharply upwards again at the very end of the trading day. The high early-day average returns are less apparent in 1982 data than in the 1971–1972 data, and they are less pronounced when overnight returns are excluded. Nevertheless, the evidence still points towards a concentration of high returns in the early part of the day and then again at the end of the day.

Second, the variability of returns also differs significantly over the day, and in a manner comparable with the interday differences in average returns. The standard deviation of returns when plotted against trading minute has a U-shape which is not quite symmetric, being thicker on the left side than on the right. Thus, the market becomes very active right at and just after the opening of

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