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Trading Halts and Market Activity: An Analysis of Volume at the Open and the Close

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ABSTRACT

This paper analyzes how the daily opening and closing of financial markets affect trading volume. We model the desire to trade at the beginning and end of the day as a function of overnight return volatility. NYSE data from 1933–88 indicate that closing volume is positively related to expected overnight volatility, while volume at the open is positively related to both expected and unexpected volatility from the previous night. We interpret the symmetric response of trading at the open and the close to expected volatility as being due to investor heterogeneities in the ability to bear risk when the market is closed. This desire of investors to trade prior to market closings indicates a cost of mandating marketwide circuit breakers.

A GENERAL RESULT FROM theoretical, experimental, and empirical science is that perturbations occur at structural boundaries. Financial markets are no exception to this regularity. As measured by a number of standards, such as trading volume, mean returns, and price volatility, financial markets are most active at the beginning and end of the trading session. Theory suggests that much of the trading activity at the open and the close is due to information. But can some of the surge in trading at the open and the close be attributed to the trading halt, per se, and be independent of any effect of contemporaneous information?

In light of recent policy actions, obtaining an understanding of the source of the above-average trading activity around daily market openings and closings has taken on substantial importance. A number of stock and futures exchanges have instituted mechanisms for marketwide trading halts, commonly known as circuit breakers, in periods of above-average price movements. For example, a 250-point decline in the Dow Jones Industrial Average halts trading on the New York Stock Exchange (NYSE) for an hour.[1]

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[1] McMillan (1990) and Miller (1990) elaborate on the many variations of circuit breakers.

The novelty of the recently imposed circuit breakers precludes a direct, systematic study of their effects.[2] Grossman (1990) points out, however, that securities markets experience a daily "circuit breaker" between the close of trading on one day and the opening of trading the following morning. Hence, the analysis of volume and price movements at the open and close can provide some understanding of the effect of trading halts. Amihud and Mendelson (1987, 1990) and Stoll and Whaley (1990a), for example, analyze trading halts by comparing the volatility of open-to-open and close-to-close returns, while Brock and Kleidon (1991) model factors leading to wider bid-ask spreads at the beginning and end of trading.

We extend the prior research by examining the behavior of stock market volume at the open and the close of the trading day. We find that much of the clustering of volume around the open and the close is due to the desire of investors to exchange the risk of holding positions overnight. We suggest that this evidence on the desire of investors to trade prior to *predictable* market closings is a factor to consider in mandating marketwide circuit breakers. To the extent that circuit breakers increase the uncertainty regarding the ability to exit the market, an environment with circuit breakers may be less stable than an environment without circuit breakers. Our results, therefore, contrast with Greenwald and Stein's (1991) inferences that circuit breakers have a calming influence on market participants.

The following section reviews the evidence on intraday patterns in a variety of financial markets and compares it with our own data from the NYSE for the 1933–1988 period. We then consider the explanations previously offered for such patterns and sketch our interpretation of the regularities. Section III develops the statistical model used to test our conjectures and reports the empirical findings on the sources of opening and closing trading activity. We also supplement our findings on the effect of trading halts with related evidence from alternative market settings. Section IV concludes with a summary and some policy implications.

I. Evidence of Intraday Patterns

A number of recent studies report intraday regularities in a variety of financial markets. U-shaped patterns in volume, mean returns, and price variability are documented for the NYSE,[3] the London Stock Exchange,[4] and a host of other markets.[5] Related research shows that bid-ask spreads and

[2] McMillan (1990), however, provides a detailed case study of the performance of circuit breakers during the October 1989 market break.

[3] See Foster and Viswanathan (1989), Harris (1986a), Jain and Joh (1988), Lockwood and Linn (1990), Terry (1986), and Wood, McInish, and Ord (1985).

[4] See King and Wadhwani (1990). These authors also report above-average volatility in London in the period surrounding the daily opening of the NYSE. Harvey and Huang (1991) find similar international cross effects in currency futures.

[5] The other markets include the Toronto Stock Exchange (McInish and Wood (1988)), index futures (Ekman (1992) and Park (1990)), soybean futures (Neal (1988)), treasury bond futures (Ma, Peterson, and Kao (1990)), and program trading (Furbush (1990)).

the probability of trades at the ask also vary predictably within the trading day.[6] By all standards, the action in financial markets in recent years occurs at the beginning and end of the trading session.

Our own research finds similar U-shaped intraday patterns on the NYSE for the past 50 years. Using the *Wall Street Journal* and *Barron's*, we collect data on hourly NYSE trading volume for the 1933–88 period.[7] From the same sources, we also obtain hourly data on the Dow Jones 30 Industrial Index (for 1933–40) and the Dow Jones 65 Composite Index (for 1941–88). Our use of the Dow Jones data stems, in part, from the absence of data on broader indexes in public sources on an hourly basis for the lengthy period that we study. More importantly, the Dow Jones stocks experience greater trading frequency and are, therefore, less affected by nonsynchronous trading than are stocks in broader indexes. Stoll and Whaley (1990b), for example, document that the 20-stock Major Market Index (made up mostly of Dow Jones stocks) is less subject to nonsynchronous trading than the S & P 500 Index.

Table I details the particular aspects of the data. Based on the temporal changes in the hours and days of operation on the NYSE, we divide the data into seven subperiods. The segregation into subperiods also allows analysis of the robustness of the results across periods of differing levels of volatility and volume. For example, the years from 1933 to 1940 are analyzed separately because of the abnormally high volatility in that period that has been noted by Officer (1971), Schwert (1989), and others.

Table II presents computations of the mean percentage volume of shares traded by hour.[8] Data are also presented on the average level of turnover in each subperiod. For each of the seven subperiods, volume exhibits a noticeable U-shape across the trading day. Regardless of the number of operating hours or the level of turnover, volume is high in the first hour, tapers through the fourth hour, and then rises through the final hour.

The intraday periods of heaviest trading volume also experience the greatest price changes. Table III presents the mean returns, in absolute value, by hour for each of the subperiods. Like volume, the absolute value of returns is relatively large at the beginning and end of the day.

The pervasiveness of the U-shaped pattern of volume and absolute returns over time rules out many proffered explanations for the intraday regularities. Edward Miller (1989), for example, posits that the intraday patterns are due to rules mandating that NYSE specialists maintain price continuity. However, in results available upon request, we find that the U-shaped pattern in

[6] See McInish and Wood (1992) and Porter (1989).

[7] Our study begins in 1933 because this is the first year in which hourly price index data is reported in the public data sources. Available data on NYSE volume indicate U-shaped patterns in trading as far back as 1909.

[8] The percentage volume in a given hour is roughly equivalent for each weekday for the entire sample period. Beginning in 1963, however, the *level* of trading volume in each hour is lower on Monday than on the other days of the week. These results are available upon request. Note that Saturday is excluded from the calculations in Tables II and III due to its shortened trading session.

Table I

Data Description

This table describes the hours and days of operation of the New York Stock Exchange during our period of analysis—1933–1988. The variation in operating times segregates the data into the seven listed subperiods. The volume and price data for these time periods were taken from the *Wall Street Journal* and *Barron's*.

Subperiod	Time Period	Days	Hours
1933–40	May 19, 1933–December 31, 1940	Monday–Saturday	10–3, M–F, 10–12, Sat
1941–52a	January 2, 1941–September 26, 1952	Monday–Saturday	10–3, M–F, 10–12, Sat
Note: In the Summer months of 1945–52, the NYSE closed on Saturday.			
1952b–63a	September 29, 1952–November 1, 1963	Monday–Friday	10–3:30, M–F
Note: The source material does not report a 3 P.M. price during the 1952b–63a period.			
1963b–68a	November 4, 1963–January 19, 1968	Monday–Friday	10–3:30, M–F
Note: The NYSE shortened hours in the following periods: Jan. 22–Mar. 1, 1968 (10 A.M.–2 P.M.); Jan. 2–July 3, 1969 (10 A.M.–2 P.M.); July 7–Sept. 26, 1969 (10 A.M.–2:30 P.M.); Sept. 29, 1969–May 1, 1970 (10 A.M.–3 P.M.). Due to the early closings, these time periods are excluded from the analysis.			
1970b–74a	May 4, 1970–September 30, 1974	Monday–Friday	10–3:30, M–F
1974b–85a	October 1, 1974–September 26, 1985	Monday–Friday	10–4, M–F
1985b–88	September 30, 1985–December 30, 1988	Monday–Friday	9:30–4, M–F

Table II

Intraday Patterns in Trading Volume, 1933–1988

Cell entries report mean values by hour of the day of the ratio of hourly volume to daily volume. Standard deviation is reported in parentheses. "Average daily turnover" is the mean of (shares traded/shares outstanding) × 100 for the given subperiod. Data are collected from the *Wall Street Journal* and *Barron's*. Note that Hour 6 is a half hour in the 1952b–63a, 1963b–68a, and 1970b–74a periods. Hour 1 is a half hour in the 1985b–88 period. Further details on the specific subperiods are presented in Table I.

Hour	1933–40 10 A.M.–3 P.M.	1941–52a 10 A.M.–3 P.M.	1952b–63a 10 A.M.–3:30 P.M.	1963b–68a 10 A.M.–3:30 P.M.	1970b–74a 10 A.M.–3:30 P.M.	1974b–85a 10 A.M.–4 P.M.	1985b–88 9:30 A.M.–4 P.M.
Hour 1	0.265	0.219	0.211	0.267	0.266	0.257	0.149
	(0.061)	(0.045)	(0.031)	(0.028)	(0.031)	(0.030)	(0.035)
Hour 2	0.194	0.200	0.189	0.185	0.196	0.180	0.188
	(0.051)	(0.038)	(0.023)	(0.020)	(0.023)	(0.019)	(0.031)
Hour 3	0.149	0.161	0.156	0.146	0.152	0.139	0.154
	(0.043)	(0.034)	(0.021)	(0.018)	(0.021)	(0.016)	(0.026)
Hour 4	0.131	0.136	0.122	0.118	0.115	0.111	0.122
	(0.042)	(0.030)	(0.020)	(0.022)	(0.019)	(0.016)	(0.022)
Hour 5	0.263	0.285	0.145	0.152	0.149	0.135	0.103
	(0.067)	(0.053)	(0.025)	(0.020)	(0.024)	(0.019)	(0.022)
Hour 6	—	—	0.176	0.136	0.122	0.178	0.117
			(0.030)	(0.020)	(0.019)	(0.027)	(0.021)
Hour 7	—	—	—	—	—	—	0.171
							(0.037)
Average daily	0.101	0.062	0.058	0.070	0.081	0.134	0.249
turnover	(0.080)	(0.031)	(0.018)	(0.019)	(0.022)	(0.057)	(0.066)
No. of days	1906	2934	2832	1273	1115	2780	824

Table III

Intraday Patterns in Price Changes, 1933–1988

Cell entries report mean values by hour of the day of the absolute value of $\mathrm{Ln}(P_t/P_{t-1}) \times 100$, where P_t is the value of the Dow Jones 65 Composite in Hour t. Standard deviation is reported in parentheses. Data are collected from the *Wall Street Journal* and *Barron's*. The source material does not report at 3 P.M. price during the 1952b–63a period, hence Hour 6 spans an hour and a half in that period. Note that Hour 6 is a half hour in the 1963b–68a and 1970b–74a periods. Hour 1 is a half hour in the 1985b–88 period. Further details on the specific subperiods are presented in Table I.

Hour	1933–40 10 A.M.–3 P.M.	1941–52a 10 A.M.–3 P.M.	1952b–63a 10 A.M.–3:30 P.M.	1963b–68a 10 A.M.–3:30 P.M.	1970b–74a 10 A.M.–3:30 P.M.	1974b–85a 10 A.M.–4 P.M.	1985b–88 9:30 A.M.–4 P.M.
Hour 1	0.502	0.268	0.234	0.235	0.422	0.356	0.390
	(0.537)	(0.285)	(0.250)	(0.225)	(0.378)	(0.339)	(0.505)
Hour 2	0.305	0.163	0.134	0.118	0.202	0.183	0.263
	(0.355)	(0.187)	(0.144)	(0.118)	(0.201)	(0.159)	(0.317)
Hour 3	0.228	0.119	0.100	0.090	0.146	0.148	0.222
	(0.288)	(0.159)	(0.109)	(0.100)	(0.147)	(0.136)	(0.320)
Hour 4	0.238	0.111	0.095	0.077	0.139	0.149	0.189
	(0.328)	(0.145)	(0.113)	(0.098)	(0.160)	(0.144)	(0.233)
Hour 5	0.391	0.203	—	0.107	0.180	0.203	0.195
	(0.465)	(0.224)		(0.121)	(0.195)	(0.184)	(0.249)
Hour 6	—	—	0.199	0.102	0.130	0.245	0.223
			(0.235)	(0.128)	(0.129)	(0.232)	(0.276)
Hour 7	—	—	—	—	—	—	0.342
							(0.444)
No. of days	1906	2934	2832	1273	1115	2780	824

NYSE volume and returns holds in the mid-1930s, prior to the development of rules discussed by Wolfson and Russo (1970) that mandated the specialist's obligations to maintain continuity.

Anecdotal analysis often attributes the heavy activity at the end of the day to institutional investors. The argument is that the performance of institutional portfolios is assessed using close-to-close returns data and that the managers of the portfolios wish to match their actual trades as nearly as possible to the performance benchmark. The existence of the U-shape in volume throughout the past half-century, however, weakens this institutional argument. Indeed, Table IV indicates a downward trend since the 1960s in the percentage of volume at day end, in contrast to the rising fraction of block trading done by institutions. The evidence suggests that institutions are not the cause of the regularities in intraday trading volume.

II. Modelling the Intraday Patterns

A. Recent Models

Recent theoretical models suggest systematic reasons for the intraday regularities in financial markets. Admati and Pfleiderer (1988) propose that the intraday patterns are due to the interaction between informed and uninformed investors. The uninformed investors include nondiscretionary traders, who have no ability to time their trades, and discretionary traders, who have some ability to time their trades.

The uninformed investors face an adverse selection problem which those with timing ability combat by trading when volume is heavy. The clustering of the uninformed investors draws informed traders to the market, potentially resurrecting the adverse selection problem. Given their assumption of risk-neutral informed traders, however, Admati and Pfleiderer (1988) show that competition among informed investors leads to lower costs for the

Table IV

Block Trading and End-of-Day Abnormal Volume

This table compares block trading with abnormal end-of-the-day trading for selected years in the 1960–1988 time period. Block trading data are from the *NYSE Fact Book*. Last hour abnormal volume is computed as the difference between the mean percentage traded in the final hour and the null, where the null equals 1 divided by the number of trading hours in the day.

Year	Block Trading (% of NYSE Volume)	Last Hour Abnormal Volume (Actual—Expected)
1960	2.0%	9.7%
1970	15.4	2.9
1980	29.2	0.7
1988	54.5	1.4

uninformed, resulting in an equilibrium of concentrated trading. Admati and Pfleiderer's model is consistent with the empirical evidence on intraday trading volume as well as with the finding that prices are most variable when volume is heavy.

Although the Admati and Pfleiderer (1988) model is consistent with the presence of intraday regularities, the model does not address the precise timing of the patterns. The authors conjecture (p. 34) that the absence of 24-hour trading in a single market causes the orders of nondiscretionary traders to heighten at the opening and closing of trading. The accumulation of the nondiscretionary orders draws the discretionary uninformed and the informed traders. The result is a clustering of volume at the beginning and end of the trading day.

These conjectures are more explicitly developed by Brock and Kleidon (1991). They argue that much of the trading at the open and close stems from the inability to trade when the market is closed. Clearly, much of the volume at the open reflects trades that would have been made earlier had the market been open. The clustering of volume at the close is somewhat less intuitive. Brock and Kleidon (1991) consider the notion that the optimal portfolio when the market is open differs from that when the market is closed. Assuming some heterogeneity across investors regarding tastes or risk tolerances, the desire for portfolio alterations leads to increased volume prior to periodic market closures that is independent of any contemporaneous information effects. Symmetrically, the heterogeneous investors recontract at the open of the following day, resulting in volume that is unrelated to unanticipated overnight information.

B. An Extended Model

We follow the insights of Brock and Kleidon (1991) by attributing volume at the end of the day to trades between heterogeneous investors. As the source of end-of-the-day volume, we focus on the assumption that investors differ in their willingness and/or ability to hold positions overnight.[9] For example, some market participants might specialize in marketmaking or arbitrage functions for individual stocks during the day, but may not desire to retain their specialized holdings overnight. The marketmakers would exchange their specialized holdings at the end of the day for a more diversified market basket. Alternatively, variations in legal restrictions or capital constraints might induce investor heterogeneity in the ability to bear overnight risk. Those investors having relatively less ability to bear overnight

[9] Karpoff (1986) also provides a model where investor heterogeneities induce trading volume. While investor heterogeneities in Karpoff's model come from idiosyncratic life-cycle desires, we emphasize the ability to bear risk overnight. Additionally, while Karpoff provides a general reason for positive trading volume even in the absence of information events, our analysis specifically focuses on the impending close of trading as a source of volume at the end of the day.

risk will exchange their positions with investors having a greater ability for overnight risk bearing, creating above-average volume at the close.

Our discussion, therefore, assumes the presence of "day traders" that specialize in performing arbitrage functions during active trading but do not necessarily maintain their positions overnight. Observers of financial markets have long acknowledged the presence of day traders. Keynes (1936, p. 160), for example, notes that "when Wall Street is active, at least half of the purchases or sales of investments are entered upon with the intention on the part of the speculator to reverse them *the same day*." While Keynes drew negative implications from the existence of day traders, more recent microstructure analysis suggests that day traders aid in providing liquidity to the market. Bradfield (1979), for example, formally models NYSE specialists as day traders. Investors that trade via limit orders can also be included under the label of day traders, as most limit orders expire at the end of the trading day.[10] In futures markets, day traders are those who hold positions for more than a few minutes but for less than a day and are specifically characterized by their "unwillingness to assume the risk of adverse news that might occur overnight or on weekends" (Chance (1989), p. 259).

If investors are transferring the risk of holding a position while the market is closed, then volume at the end of the day should be directly related to the volatility expected to occur overnight. The greater is expected overnight volatility, the heavier is volume at the close. Correspondingly, if the investors that transfer overnight risk reacquire their positions at the next day's open, then the same factor affecting volume at one day's close should also affect volume at the next day's open. Hence, opening volume should be directly related to the expected volatility from the previous night.

This symmetric component of closing and opening volume distinguishes our description of intraday volume from the usual information stories in the trading volume literature. Both the Sequential Information Arrival Model of Copeland (1976) and the Mixture of Distributions Hypothesis discussed by Harris (1986b) and others predict a contemporaneous relation between trading volume and price volatility. We extend these theories by predicting a relation between closing volume and expected overnight volatility. More distinctly, we suggest that the same expected volatility that induced trading volume at the close will also be related to volume at the open due to recontracting between day traders and other investors. This relation between opening volume and the "old" information contained in expected overnight volatility would not be predicted by extant explanations of trading volume.

The theories of trading volume, however, suggest that overnight innovations in information will affect trading activity at the open. We proxy overnight information with unexpected overnight volatility. We expect a positive relation between opening volume and unexpected overnight volatility.

[10] We thank Bob Schwartz for pointing this out to us.

III. Empirical Analysis

A. Estimating Expected and Unexpected Volatility

To perform the empirical tests, we first compute estimates of expected and unexpected volatility. Our estimation procedure follows a method developed by Davidian and Carroll (1987) that has been used by Schwert (1989, 1990) and a number of other authors in financial applications.[11] This particular method accommodates the stylized facts on volatility including its persistence, its seasonal variation, and its relation with the level of the market.[12]

The technique involves iterating between the following set of equations:

$$\text{Return}_t = \sum_{i=1}^{n} \sum_{j=1}^{m} h_i d_j + \sum_{k=1}^{p} \alpha_k \text{Return}_{t-k} + \varepsilon_t \tag{1}$$

$$|\text{Resid}_t| = \sum_{i=1}^{n} \sum_{j=1}^{m} h_i d_j + \sum_{k=1}^{q} \beta_k |\text{Resid}_{t-k}| + \tau_t \tag{2}$$

where Return_t is the hourly return on the Dow Jones price index, h_i is a set of hour-of-the-day dummy variables, d_j is a set of day-of-the-week dummy variables, p and q are lag lengths chosen by the Schwarz criterion (see Schwarz (1978)), and Resid_t is the residual from equation (1).

The technique involves first estimating conditional expected returns in equation (1) using OLS. The day and hour dummies account for known regularities in returns. The inclusion of lagged returns allows for shifts in expected returns over time. The lag length p used for equation (1) in a particular time period is chosen using the Schwarz criterion.

The absolute value of the residuals from equation (1) becomes the dependent variable in equation (2). Day and hour dummies are again included to account for patterns in volatility. Lagged residuals are used to allow for persistence in volatility shocks. As in equation (1), the lag length q is chosen by the Schwarz criterion.

The predicted values of $|\text{Resid}_t|$ from equation (2) are then used to reestimate equation (1) using weighted least squares. After the second pass on equation (1), the absolute value of the residual from this regression is normalized by $(\pi/2)^{1/2}$, forming the estimate of the standard deviation of returns in a given hour (or overnight).[13] To derive the expected and unexpected components of the standard deviation of returns, the normalized residuals from equation (1) are then used in the following equation:

$$\text{NResid}_t = \sum_{i=1}^{n} \sum_{j=1}^{m} h_i d_j + \sum_{k=1}^{s} \tau_k \text{NResid}_{t-k} + \delta_t \tag{3}$$

where NResid_t is the estimate of the standard deviation in time t, h_i and d_j are hour and day dummies, and s is a lag length chosen via the Schwarz

[11] See also Bessembinder and Seguin (1990), Ferson and Harvey (1991), Hsieh and Miller (1990), and Schwert and Seguin (1990). For a general review of methods to estimate volatility, see Pagan and Schwert (1990).

[12] Papers describing the established properties of volatility include Christie (1982), French, Schwert, and Stambaugh (1987), Harris (1986a), and Officer (1971).

[13] This normalization is used because the expected value of $|\text{Resid}_t|$ in equation (2) is less than the standard deviation of a normal distribution (see Schwert (1989, p. 1118, footnote 5)).

criterion. The predicted values from this regression are the expected standard deviation, σ_{exp}, and the residuals are the unexpected standard deviation, σ_{unexp}.

B. The Empirical Tests

These values of σ_{exp} and σ_{unexp} are then used to estimate the following equations:[14]

$$\text{Volume}_{c,t} = \alpha_0 + \alpha_1\sigma_{exp,t} + \alpha_2\sigma_{unexp,t} + \alpha_3\text{Return}_t + \alpha_4|\text{Return}_t| + \varepsilon_t \quad (4)$$

$$\text{Volume}_{o,t+1} = \beta_0 + \beta_1\sigma_{exp,t} + \beta_2\sigma_{unexp,t} + \beta_3\text{Return}_{t+1} + \beta_4|\text{Return}_{t+1}| + \tau_{t+1} \quad (5)$$

where $\text{Volume}_{c,t}$ is the share turnover[15] in the hour prior to the close on day t; $\text{Volume}_{o,t+1}$ is the share turnover in the opening hour of trading on day $t+1$; $\sigma_{exp,t}$ is the expected overnight volatility between day t and day $t+1$; and $\sigma_{unexp,t}$ is the unexpected overnight volatility between day t and day $t+1$. ε_t and τ_{t+1} are assumed to be normally distributed with zero covariance. The coefficients α_1, β_1 and β_2 are expected to be significantly greater than zero while α_2 is expected not to differ from zero.

In addition to the main variables of interest, the regression equation is augmented with Return_t, the market return in hour t, and $|\text{Return}_t|$, the absolute value of the market return in hour t. According to prior theoretical and empirical research, both of the supplemental variables are expected to be positively associated with trading volume, thereby implying that α_3, α_4, β_3, and β_4 will all be significantly greater than zero.[16]

The results of the regressions are presented in Table V (closing hour volume) and Table VI (opening hour volume). In Table V, the coefficient for expected volatility, α_1, is positive in all seven subperiods and more than two standard deviations above zero in five subperiods. Hence, trading volume in the closing hour is directly related to the price variability expected to occur overnight. The results hold for a number of institutional settings and for varied trading hours. The results are also robust to varying levels of trading

[14] Before estimating the regressions, we test for the stationarity of our variables. Using tests suggested by Dickey, Bell, and Miller (1986), we find no systematic evidence of non-stationarity. All estimated regressions are checked for heteroscedasticity. Where heteroscedasticity is detected, the standard errors of the coefficients are corrected using the White (1980) adjustment to the variance-covariance matrix. All coefficient estimates are corrected for autocorrelation with an AR process chosen by the Schwarz criterion.

[15] Use of share turnover, defined as shares traded divided by shares outstanding, accounts for the increase in the stock listings and the shares outstanding on the NYSE over time. Data on NYSE shares outstanding come from the *Survey of Current Business*.

[16] Karpoff (1987) provides a comprehensive survey of the theoretical and empirical relation between volume and Return_t and $|\text{Return}_t|$. In related regressions that excluded Return_t and $|\text{Return}_t|$, the results were the same as those reported in the text. Similarly, in a specification that used opening hour and closing hour volatility rather than Return_t and $|\text{Return}_t|$, the results were identical.

volume, lessening the likelihood of spurious regression problems such as nonsynchronous trading.[17] These robust results support our interpretation that the trading activity at the end of the day is related to the desire by some investors to shed their exposure to overnight risk.

In contrast to the results for expected volatility, unexpected overnight volatility has a minimal, if any, effect on closing volume. While the coefficient of unexpected volatility, α_2, is more than two standard deviations above zero in three of seven subperiods, the coefficient is less than one-tenth of the size of the coefficient on expected overnight volatility. The small magnitude of the coefficient on unexpected volatility is reassuring since, by construction, unexpected overnight volatility should not be anticipated by investors and should not affect trading decisions at the end of the day. The presence of a statistically significant coefficient in three of the subperiods most likely stems from the fact that we cannot model all of the information used by investors to make their forecasts of overnight volatility. Consistent with prior research, the coefficients of Return_t and $|\text{Return}_t|$ are generally positive and significant.

In Table VI, the coefficient of expected volatility, β_1, is positive in all subperiods and statistically significant in six subperiods. Trading in the opening hour is influenced by the previous night's expected overnight volatility. Indeed, the same factor that induced trading at the end of the previous day also affects trading at the open of the following day. This supports our notion that some investors are day traders who transfer the risk of holding positions when the market is closed and reacquire positions when a continuous market becomes available.

Unanticipated overnight information also affects opening volume. Unlike closing volume, opening hour volume is positively and significantly related to unexpected overnight volatility in all subperiods. This supports the intuition that some of the trading at the open is due to new information that accrues overnight. The coefficients of Return_{t+1} and $|\text{Return}_{t+1}|$ are also generally positive and significant.

As an alternative method of structuring our tests, we analyze the relation between overnight volatility and a dependent variable that is the difference between the opening volume on one day and the closing volume from the previous day.[18] We predict that expected volatility would have no relation with the dependent variable—in essence, the differencing of opening and closing volume would net out the trading that is done in response to expected overnight risk. By contrast, we predict that unexpected volatility would be positively related to the differenced volume. As shown in Table VII, we find support for our predictions. The coefficient on expected volatility is less than

[17] The well-known phenomenon of nonsynchronous trading, discussed in Fisher (1966), induces serial correlation in price indexes and can produce spurious regression results. Nonsynchronous trading is more of a problem in an environment of light trading volume. Since our results are robust across subperiods having substantial variations in the level of trading volume, nonsynchronous trading does not appear to be inducing any noticeable biases.

[18] We thank Lisa Meulbroek for suggesting this alternative method of analysis.

Table V
Closing Hour Trading Volume, 1933–1988

This table reports results from the regression:

$$\text{Volume}_{c,t} = \alpha_0 + \alpha_1 \sigma_{exp,t} + \alpha_2 \sigma_{unexp,t} + \alpha_3 \text{Return}_t + \alpha_4 |\text{Return}_t| + \varepsilon_t$$

where $\text{Volume}_{c,t}$ is the share turnover in the hour prior to the close on day t; $\sigma_{exp,t}$ is the expected overnight volatility between day t and day $t+1$; $\sigma_{unexp,t}$ is the unexpected overnight volatility between day t and day $t+1$; Return_t is the percentage change in the Dow Jones 65 Composite Index in the closing hour on day t; $|\text{Return}_t|$ is the absolute value of Return_t. t-Statistics are reported in parentheses.

The χ^2-statistic reports the White (1980) test for heteroscedasticity. An asterisk beside the χ^2-statistic indicates significance at the five percent level and indicates that the regression t-statistics are corrected by using the White (1980) adjustment to the variance-covariance matrix. All estimates are corrected for the time series properties of the residuals using an AR process chosen by the Schwarz criterion.

Data are collected from the *Wall Street Journal* and *Barron's*. Note that the closing hour is a half hour in the 1952b–63a, 1963b–68a, and 1970b–74a periods. Further details on the specific subperiods are presented in Table I.

Coefficient	1933–40 10 A.M.–3 P.M.	1941–52a 10 A.M.–3 P.M.	1952b–63a 10 A.M.–3:30 P.M.	1963b–68a 10 A.M.–3:30 P.M.	1970b–74a 10 A.M.–3:30 P.M.	1974b–85a 10 A.M.–4 P.M.	1985b–88 9:30 A.M.–4 P.M.
α_0	0.12	0.13	0.07	0.09	0.09	0.17	0.19
	(4.96)	(14.61)	(12.76)	(15.44)	(19.66)	(2.73)	(21.59)
α_1	20.06	13.37	12.66	1.25	1.39	13.83	4.37
	(4.08)	(6.16)	(5.52)	(0.33)	(1.34)	(5.26)	(2.26)
α_2	0.98	0.10	0.76	−0.46	−0.003	1.76	0.94
	(2.04)	(0.17)	(2.47)	(−0.94)	(−0.014)	(4.17)	(0.88)
α_3	0.61	−0.78	0.65	2.09	1.13	2.73	3.76
	(1.13)	(−1.33)	(1.31)	(3.04)	(3.35)	(7.59)	(2.96)
α_4	9.20	6.56	3.83	2.30	5.00	10.50	10.84
	(9.94)	(5.17)	(5.21)	(1.43)	(9.33)	(14.63)	(5.93)
R^2	0.74	0.68	0.69	0.50	0.45	0.75	0.26
F-statistic	200.3	267.6	520.3	168.9	243.3	284.6	733.9
χ^2-statistic	43.7*	51.7*	9.21	3.14	0.85	16.4*	44.3*
d.f.	2213	3398	2753	1028	1079	2698	796

Table VI
Opening Hour Trading Volume, 1933–1988

This table reports results from the regression:

$$\text{Volume}_{o,t+1} = \beta_0 + \beta_1 \sigma_{exp,t} + \beta_2 \sigma_{unexp,t} + \beta_3 \text{Return}_{t+1} + \beta_4 |\text{Return}_{t+1}| + \tau_{t+1}$$

where $\text{Volume}_{o,t+1}$ is the share turnover in the opening hour on day $t + 1$; $\sigma_{exp,t}$ is the expected overnight volatility between day t and day $t + 1$; $\sigma_{unexp,t}$ is the unexpected overnight volatility between day t and day $t + 1$; Return_{t+1} is the percentage change in the Dow Jones 65 Composite Index in the opening hour on day $t + 1$; $|\text{Return}_{t+1}|$ is the absolute value of Return_{t+1}. t-Statistics are reported in parentheses.

The χ^2-statistic reports the White (1980) test for heteroscedasticity. An asterisk beside the χ^2-statistic indicates significance at the five percent level and indicates that the regression t-statistics are corrected by using the White (1980) adjustment to the variance-covariance matrix. All estimates are corrected for the time series properties of the residuals using an AR process chosen by the Schwarz criterion.

Data are collected from the *Wall Street Journal* and *Barron's*. Note that the opening hour is a half hour in the 1985b–88 period. Further details on the specific subperiods are presented in Table I.

Coefficient	1933–40 10 A.M.–3 P.M.	1941–52a 10 A.M.–3 P.M.	1952b–63a 10 A.M.–3:30 P.M.	1963b–68a 10 A.M.–3:30 P.M.	1970b–74a 10 A.M.–3:30 P.M.	1974b–85a 10 A.M.–4 P.M.	1985b–88 9:30 A.M.–4 P.M.
β_0	0.13	0.09	0.10	0.18	0.18	0.22	0.33
	(5.75)	(14.06)	(18.18)	(15.05)	(21.74)	(7.18)	(27.73)
β_1	21.30	13.54	7.89	6.40	8.31	38.25	1.52
	(6.64)	(6.06)	(13.29)	(4.11)	(3.77)	(8.49)	(0.77)
β_2	6.69	4.65	3.57	5.11	5.35	13.04	5.46
	(7.79)	(6.78)	(22.93)	(13.05)	(9.79)	(11.70)	(5.42)
β_3	−0.12	0.92	0.56	2.75	2.17	3.58	−3.05
	(−0.19)	(1.38)	(2.16)	(5.42)	(4.06)	(4.36)	(−2.30)
β_4	6.16	5.37	2.52	1.70	3.57	5.29	4.21
	(6.17)	(5.51)	(6.36)	(2.34)	(3.84)	(3.83)	(1.96)
R^2	0.72	0.62	0.66	0.73	0.52	0.76	0.24
F-statistic	143.8	318.0	256.9	117.3	280.5	245.8	290.4
χ^2-statistic	38.0*	50.6*	0.13	0.02	11.0*	21.5*	6.62*
d.f.	2217	3398	2752	1024	1079	2702	790

Table VII

The Difference of Opening and Closing Hour Trading Volume, 1933–1988

This table reports results from the regression:

$$d\text{Volume}_{t+1} = \beta_0 + \beta_1\sigma_{exp,t} + \beta_2\sigma_{unexp,t} + \beta_3\text{Return}_t + \beta_4|\text{Return}_t| + \beta_5\text{Return}_{t+1} + \beta_6|\text{Return}_{t+1}| + \tau_{t+1}$$

where $d\text{Volume}_{t+1}$ is the difference of share turnover in the opening hour on day $t+1$ and share turnover in the closing hour on day t; $\sigma_{exp,t}$ is the expected overnight volatility between day t and day $t+1$; $\sigma_{unexp,t}$ is the unexpected overnight volatility between day t and day $t+1$; Return_t is the percentage change in the Dow Jones 65 Composite Index in the closing hour on day t; $|\text{Return}_t|$ is the absolute value of Return_t; Return_{t+1} is the percentage change in the Dow Jones 65 Composite Index in the opening hour on day $t+1$; $|\text{Return}_{t+1}|$ is the absolute value of Return_{t+1}. t-Statistics are reported in parentheses.

The χ^2-statistic reports the White (1980) test for heteroscedasticity. An asterisk beside the χ^2-statistic indicates significance at the five percent level and indicates that the regression t-statistics are corrected by using the White (1980) adjustment to the variance-covariance matrix. All estimates are corrected for the time series properties of the residuals using an AR process chosen by the Schwarz criterion.

Data are collected from the *Wall Street Journal* and *Barron's*. Note that the opening hour is a half hour in the 1985b–88 period. Further details on the specific subperiods are presented in Table I.

Coefficient	1933–40 10 A.M.–3 P.M.	1941–52a 10 A.M.–3 P.M.	1952b–63a 10 A.M.–3:30 P.M.	1963b–68a 10 A.M.–3:30 P.M.	1970b–74a 10 A.M.–3:30 P.M.	1974b–85a 10 A.M.–4 P.M.	1985b–88 9:30 A.M.–4 P.M.
β_0	0.02	−0.04	0.04	0.09	0.10	0.12	0.17
	(2.01)	(8.90)	(7.89)	(9.94)	(14.37)	(10.32)	(14.47)
β_1	−4.21	2.04	−4.34	2.82	2.76	−4.82	−3.64
	(−1.67)	(0.94)	(−2.29)	(1.00)	(1.51)	(−1.50)	(−1.49)
β_2	6.30	4.90	2.80	5.44	5.04	10.31	4.32
	(9.21)	(8.22)	(5.87)	(13.94)	(8.17)	(11.81)	(3.29)
β_3	0.95	1.67	0.19	0.19	2.06	3.35	−2.28
	(1.73)	(4.33)	(0.25)	(0.37)	(3.10)	(6.90)	(−1.19)
β_4	−5.72	−7.99	−4.81	−0.98	0.69	−0.37	−1.82
	(−6.17)	(−8.41)	(−4.07)	(−0.81)	(0.66)	(−0.40)	(−3.47)
β_5	1.31	1.17	1.38	2.03	1.92	4.31	−2.28
	(2.18)	(1.77)	(1.98)	(4.03)	(3.39)	(6.66)	(−1.19)
β_6	7.22	4.19	0.90	2.64	3.17	4.78	1.77
	(8.06)	(4.32)	(1.30)	(3.65)	(3.29)	(4.53)	(0.57)
R^2	0.24	0.41	0.47	0.57	0.38	0.51	0.12
F-statistic	115.7	145.9	155.4	70.2	145.3	168.8	32.4
χ^2-statistic	90.7*	45.5*	34.8*	5.7	12.0*	29.1*	45.3*
d.f.	2217	3398	2752	1024	1079	2702	790

two standard deviations above zero in six of seven subperiods and is actually negative in the period in which it is statistically significant. By contrast, the coefficient on unexpected volatility maintains its positive, significant sign in all seven subperiods.

C. Related Evidence from Alternative Market Settings

Our analysis has used a long time series of NYSE data to support the prediction that the heterogeneous ability to bear overnight risk, together with the absence of 24-hour markets, induces above-average volume at the end of the trading session on the NYSE. One would expect similar patterns in cross section. For example, Stoll and Whaley (1990a, p. 58) note that low-volume stocks have a relatively greater ratio of overnight to daytime volatility than do actively traded stocks. Given these facts on volatility, one would expect that the low-volume stocks would have greater relative volume at the beginning and end of the day. Recent empirical evidence confirms this expectation; Foster and Viswanathan (1989, p. 6) report that less active firms show a more pronounced U-shaped pattern in volume within the day.

Our analysis also addresses the effect that additional trading hours, evening trading sessions, and international cross listing would have on volume at the end of the regular trading session. According to our analysis, one would expect that added trading hours from, say, an evening trading session would dampen volume at the close of the regular session. For example, one would expect that the implementation of Globex, the proposed after-hours futures trading network, would lessen the upturn in volume at the end of the regular futures trading session. Indeed, in discussing the potential users of Globex, Hansell (1989, p. 187) states that some short-term traders may use "Globex's capability for defensive reasons—to get out of something at night if the market is moving." The implication is that the after-hours market allows day traders to hold greater positions without sacrificing immediacy, implying less relative volume at the close.

Such an effect of after-hours trading is illustrated in recent analysis of the evening trading session of the CBOT's Treasury bond futures contract. Ma, Peterson, and Kao (1990) analyze the effect of the addition in April 1987 of an evening session on the trading patterns in the regular daily session. Among other things, the results indicate that "the last daytime hour shows a marked decline in volume relative to volume in the rest of the day after evening trading commenced" (Ma, Peterson, and Kao (1990), p. 12). These findings are consistent with our results on the source of trading volume at the end of the day.

Another market structure for future research is the Tokyo Stock Exchange which closes for lunch and thereby has both morning and afternoon openings and closings. Amihud and Mendelson (1990) find that the morning opening is a period of relatively high volatility, but that the afternoon opening is no more volatile than the morning or afternoon closing. Given these results, we would expect to find a lesser incidence of trades that transferred "closed-market" risk between the morning close and afternoon open vis-à-vis the number of such trades between the afternoon close and the morning open.

IV. Summary and Policy Implications

A number of researchers have noted that trading activity in financial markets is heaviest at the beginning and end of the trading session. We find similar intraday patterns on the NYSE over the 1933–88 period. The pervasiveness of such results rules out anecdotal explanations based on particular factors such as exchange rules on specialists or the percentage trading done by institutional investors.

Empirically extending the insights of Brock and Kleidon (1991), we find that trading volume at one day's closing hour and the following day's opening hour are both related to expected overnight volatility. This is consistent with the argument that much of the clustering of trading around the open and the close is due to the desire of investors to exchange the exposure to price changes when the market is closed. Trading volume at the open is also related to unexpected volatility from the previous overnight period, confirming the intuition that the overnight accrual of information leads to trading activity at the open.

Our findings regarding the effect of daily trading halts on the desire to trade are relevant to recent proposals for marketwide trading halts. Existing exchange rules and proposed Congressional legislation impose mandatory halts, or circuit breakers, in periods of large price swings. The impetus for many of the proposals is the view of the Brady Commission (see Greenwald and Stein (1988, 1991)) that circuit breakers have a calming effect by allowing market participants to catch up on information flow in periods of high volatility. Goldman and Sosin (1979, p. 55), also suggest that, given sufficient uncertainty, policies such as trading halts can improve market efficiency.

Proponents of circuit breakers admit that the illiquidity caused by closing markets potentially could exacerbate credit problems by preventing investors from acquiring funds to meet margin calls. Our results point to a more fundamental cost of closing markets. The evidence indicates that some investors wish to shed the risk of holding positions when the market is closed. Mandatory trading halts prevent such a transfer, implying a loss of gains from trade. As noted by Alchian and Allen (1969, p. 602), "... stopping trading during those times [of high volatility] locks existing owners into continuing ownership even though they would prefer to shed the uncertainty by selling to those who are more willing to bear it."

Indeed, the possibility of a trading halt after a price change of a given percent would make investors generally skittish after price changes of some fraction of the trigger amount. Rather than calming markets, the presence of a circuit breaker can cause investors to overreact and leave the market more quickly than if a circuit breaker did not exist. As in the model of McMillan (1990), a circuit breaker could create a gravitational effect in which prices become more likely to move toward the trigger the closer prices are to the trigger. Hence, an environment with circuit breakers may have negative welfare implications vis-à-vis an environment without circuit breakers.

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