THE JOURNAL OF FINANCE • VOL. LV, NO. 4 • AUGUST 2000

Order Flow and Liquidity around NYSE Trading Halts

SHANE A. CORWIN and MARC L. LIPSON*

ABSTRACT

We study order flow and liquidity around NYSE trading halts. We find that market and limit order submissions and cancellations increase significantly during trading halts, that a large proportion of the limit order book at the reopen is composed of orders submitted during the halt, and that the market-clearing price at the reopen is a good predictor of future prices. Depth near the quotes is unusually low around trading halts, though specialists and/or floor traders appear to provide additional liquidity at these times. Finally, specialists appear to "spread the quote" prior to imbalance halts to convey information to market participants.

THE COSTS AND BENEFITS ASSOCIATED with New York Stock Exchange trading halts are the subject of continuous debate. The stated purpose of trading halts is to allow investors a chance to react to new information and to facilitate the orderly emergence of a new equilibrium price (see, e.g., NYSE (1999)). However, little is known about the extent or nature of investor reactions to trading halts. Furthermore, it is unclear whether these reactions support or confound attempts to reach a new equilibrium price. To address these issues, we use nonpublic NYSE data on all SuperDOT (electronic) orders to analyze the effects of trading halts on order flow, spreads, and the limit order book. We also examine the relationships between the limit order book and the reopening price and between liquidity and post-halt volatility.

Information on order flow is an important missing element in the ongoing debate about the usefulness of trading halts. One argument against trading halts is that they impede price formation because trading aggregates information that is distributed across market participants. However, submissions and cancellations of orders during a halt may provide an alternative source of information that, combined with published indications of possible reopening prices, may assist with price formation. An argument in favor of trading halts is that when traders are given an opportunity to cancel orders

* Corwin and Lipson are from the Terry College of Business at the University of Georgia. We thank Franklin Allen, Jeff Bacidore, Michael Goldstein, Jeff Harris, Ken Kavajecz, Jeff Netter, George Sofianos, Dan Weaver, and seminar participants at the Federal Reserve Bank of Atlanta, the University of Minnesota, Vanderbilt University, the University of Virginia, and the NYSE JB Seminar for helpful comments. We are also grateful to the New York Stock Exchange for providing data. The comments and opinions expressed in this paper are the authors' and do not necessarily reflect those of the directors, members, or officers of the New York Stock Exchange, Inc. The authors are responsible for any errors.

during extreme market changes, they may be more willing to supply liquidity during normal conditions. Our analysis allows us to examine whether traders take advantage of this opportunity to reposition their trading interest.

Whereas analysis of order flow provides insight into the actions of traders during halts, the net effect of this activity on liquidity is reflected in spreads and the limit order book. The limit order book competes with specialists and the trading floor for order flow and provides a pool of trading interest that can dampen temporary price fluctuations. Thus, changes in the limit order book may impact spreads and volatility. We characterize the limit order book and bid-ask spreads before, during, and after trading halts to provide new evidence about changes in liquidity around halts and the impact of the limit order book on volatility and price discovery around halts.[1]

We find that limit order submissions and cancellations are extremely high during halts and remain high for several hours after the halt. In addition, we find that there is a surge in market order submissions and cancellations during halts and just before order imbalance halts. Although the cancellation of orders might be expected as traders wait to see how market conditions unfold, the large increase in submissions suggests that they are also willing to reenter the market before trading resumes. Furthermore, changes in order flow prior to order imbalance halts are limited to the 30 minutes immediately preceding the halt. This result suggests that the change in market conditions is abrupt and there is little time for the NYSE specialist to draw liquidity to the market.

We find that limit order book depth near the quotes is unusually low before, during, and after trading halts. This reduction likely reflects investors' reduced willingness to supply liquidity at these times. The significant lack of depth just prior to a trading halt is also consistent with halts being called when there is valid concern about the quality of current prices. Notably, we find that a large proportion of the limit order book at the reopen is composed of orders that were placed during the trading halt. Combined with the increased submissions and cancellations observed during halts, this result suggests that traders use the halt as a chance to reposition their trading interest. As further evidence of this repositioning, we calculate the price that clears supply and demand in the limit order book just prior to the reopen. Our tests show that this market-clearing price is a good predictor of subsequent equilibrium prices.

In examining bid-ask spreads, we find that the quoted spread and several measures of limit order book spread are unusually high at the reopen. This increase generally dissipates within two minutes for order imbalance halts and within 30 minutes for news halts. Interestingly, we find evidence of a dramatic increase in quoted spreads prior to order imbalance halts. Mean quoted spreads increase from approximately \$0.23 to over \$1.80 in the 10 to 15 minutes prior to imbalance halts. This increase is consistent with the specialist

[1]This analysis focuses on the net effect of order flow on the limit order book during times of market stress. See Biais, Hillion, and Spatt (1995) for an analysis of the dynamic interactions between order flow and the limit order book during normal market conditions.

"spreading the quote" in response to a substantial order imbalance. By spreading the quote, the specialist conveys information about the imbalance to market participants and gives market orders a chance to be canceled. Consistent with the decrease in limit-book depth, we also find that the specialist's quoted depth is unusually low prior to and immediately after trading halts. However, the proportion of depth contributed by floor participants actually increases immediately after halts, suggesting that floor participants, including the specialist, step in to provide liquidity after trading halts.

Consistent with Lee, Ready, and Seguin (1994), we find that both volume and volatility increase significantly after NYSE trading halts. We also find weak evidence that this increased volatility is related to decreased depth in the limit order book. However, changes in liquidity appear to explain, at best, a small portion of the increased volatility observed after trading halts.

It should be emphasized that our results cannot resolve the question of whether trading halts and related actions like "spreading the quote" are desirable. The central problem is that we cannot know what would have occurred in the absence of a halt or what equilibrium trading patterns would be in a market where halts are not permitted. However, our results do provide a more complete understanding of trading activity during halts and the associated effects on liquidity, price discovery, and volatility.

The remainder of the paper is organized as follows. In Section I, we discuss the central arguments associated with trading halts and the related evidence. The trading halt sample is described in Section II. In Section III, we analyze order flow and the state of the limit order book around trading halts. In Section IV, we examine the role of the limit order book in determining posthalt prices. Section V presents our analysis of posthalt volatility, and Section VI concludes.

I. Trading Halts

There are two primary categories of security-specific trading halts on the NYSE: news halts and order imbalance halts.[2] News halts include both news pending and news dissemination halts and are initiated by exchange officials when an information release is expected to have a significant impact on prices.[3] Order imbalance halts are initiated by the exchange specialist when a large imbalance exists between buy and sell orders. During both types of halts, the specialist posts quote indications to signal the possible reopening price, and traders are permitted to submit or cancel orders. In

[2] Our analysis and discussion focus exclusively on individual-security halts. NYSE Rule 80B also allows for marketwide trading halts (or circuit breakers) in the event of extremely large market movements. These circuit breakers were initiated for the first and only time on October 27, 1997. Goldstein and Kavajecz (2000b) provide a detailed analysis of liquidity provision during this marketwide circuit breaker.

[3] News-related trading halts are also implemented on the Nasdaq stock market, though no mechanism exists on that exchange for order imbalance halts. See Christie et al. (2000) for a discussion and analysis of Nasdaq trading halts.

addition, whereas the specialist is expected to provide price discovery during the halt, the specialist's obligations to provide price continuity and price stabilization are suspended until trading resumes.[4] Trading is reopened with a call market similar to that used at the morning open.

Several papers delineate the benefits of trading halts. Greenwald and Stein (1988, 1991) argue that traders are reluctant to enter a market when they are unsure of the price at which their market orders will be executed. In their model, trading halts can facilitate price discovery by reducing this "transactional risk" and thereby encouraging traders to participate in the market. Kodres and O'Brien (1994) highlight an additional benefit of trading halts based on the fact that traders may not be able to instantaneously adjust their trading interests to new information (due to technological limitations or the costs of continuous monitoring). They show that Pareto-optimal risk sharing can be achieved through the use of price limits that prevent sudden, extreme movements in prices.

In contrast, a number of models suggest that trading halts may actually reduce the informativeness of prices. In these models, trading is necessary for information distributed across multiple participants to be reflected in prices (see, e.g., Brown and Jennings (1989) and Grundy and McNichols (1989)). Consistent with these models, Amihud and Mendelson (1987), Stoll and Whaley (1990), and Gerety and Mulherin (1994) find that market openings are associated with high levels of temporary volatility. In addition, Lee et al. (1994) find evidence of unusually high volatility after NYSE trading halts, and Christie, Corwin, and Harris (2000) document unusually high volatility after Nasdaq trading halts. Grossman (1990) expresses the more direct concern that a trading halt "merely prevents consenting adults from carrying out their desires on the floor of the stock exchange."

This paper contributes to the trading halt literature by providing some of the first empirical evidence related to the actions of investors *during* trading halts. In particular, we document that traders do, in fact, adjust their positions during trading halts. This activity is a necessary condition for a reduction in transactional risk. In addition, although overall liquidity is reduced during this period of market stress, we show that submissions and cancellations of orders during halts result in significant price discovery.

II. Data and Sample Characteristics

Using the NYSE's trading halt files, we identified 469 intraday trading halts called for NYSE-listed common stocks during 1995 and 1996. Because we wish to analyze trading activity and the state of liquidity before and after halts,

[4] The rules governing specialist trading activities generally prevent specialists from making trades that reinforce market movements (destabilizing trades). In addition, specialists are expected to maintain price continuity by limiting price changes larger than the minimum tick size. The combination of these two obligations essentially forces the specialist to buy as prices fall and sell as prices rise.

Table I

Summary Statistics for Trading Halts

The sample is taken from the set of all news and order imbalance halts called for NYSE-listed common stocks during 1995 and 1996. We exclude opening delays, halts prior to 10:00 a.m., halts that are not resolved prior to the close, halts for which we do not have complete data, and observations for which two or more halts are called on the same day for a particular stock. Price change is measured from the last trade price prior to the halt to the reopening trade price. Duration is defined as the number of minutes from the beginning of the halt to the reopening trade.

		Mean Values			
Sample	Number of Halts	Duration in Minutes	Reopening Volume	Price Change (%)	Absolute Price Change (%)
Full sample	295	81.41	66,294	0.47	3.93
Order imbalance halts	44	55.71	167,147	1.16	5.71
Positive price change	21	63.53	195,962	7.19	7.19
Zero price change	5	49.85	55,240	0.00	0.00
Negative price change	18	48.22	164,617	−5.57	5.57
News halts	251	85.92	48,614	0.35	3.62
Positive price change	90	89.93	61,704	5.54	5.54
Zero price change	52	83.03	21,654	0.00	0.00
Negative price change	109	83.98	50,668	−3.76	3.76

delayed openings are not considered. For similar reasons, we exclude halts called before 10:00 a.m. (44 halts) and cases where the same stock experienced more than one halt on the same day (14 halts). Finally, we exclude halts that were not resolved within one trading day (104 halts) and halts for which we have incomplete data (12 halts). This leaves a sample of 295 trading halts.

Data on each trading halt are obtained from the NYSE's trading halt files. These data include the time of the halt, the halt type, the last trade price prior to the halt, the reopening price, the reopening time, and the volume traded in the reopening transaction. In addition, we collect trade and quote data for each halt, in addition to NYSE System Order (SOD) data for the 21-day period from 10 days prior to the halt through 10 days after the halt. The trade and quote data come from the NYSE's Trade and Quote (TAQ) database. The SOD data include detailed information on all SuperDOT (electronic) orders. This information includes the order submission time, the number of shares submitted, whether the order is a buy or a sell, the order type (market or limit), order conditions (day order, good-till-canceled, etc.), and the limit price (if applicable). If any portion of the order is executed or canceled, the data also include the time of the execution or cancellation, the number of shares executed or canceled, and the execution price (if applicable).

Summary statistics for the trading halt sample are provided in Table I. Of the 295 halts in the sample, 44 are order imbalance halts and 251 are news halts. The mean value of trading halt duration is 81.4 minutes in the full

sample and is higher for news halts (85.9 minutes) than for order imbalance halts (55.7 minutes). The average absolute return during trading halts is 3.93 percent and is smaller for news halts (3.62 percent) than for order imbalance halts (5.71 percent). Twenty-one of the 44 order imbalance halts resulted in positive price changes, five led to no price change, and 18 led to negative price changes. Ninety of the 251 news halts led to positive price changes, while 52 led to no price change and 109 resulted in negative price changes. These values are generally consistent with those reported in Lee et al. (1994) for trading halts during 1988 and in Corwin (1999) for trading halts during 1992.

III. Order Flow and the Limit Order Book

In this section, we examine the behavior of investors around NYSE trading halts and the resulting effects on liquidity. We begin by analyzing submissions, executions, and cancellations of limit orders on days when halts occur. We then examine the effects of this activity on the condition of the limit order book, bid-ask spreads, and quoted depth before and after the halt.

A. Order Flow

Throughout the paper, we compare trading activity and market conditions on the halt day to the same characteristics on normal trading days. For all of the characteristics that we examine, we follow Lee et al. (1994) in calculating abnormal measures on the halt day relative to nonhalt days, stated as a percentage of the nonhalt day value. For example, for each time period we define abnormal order submissions on the halt day as:

$$100 * \left[\frac{\textit{Shares Submitted on the Halt Day} - \textit{Mean Shares Submitted on Nonhalt Days}}{\textit{Mean Shares Submitted on Nonhalt Days}} \right], \tag{1}$$

where we define nonhalt days as the 10 days prior to and the 10 days after the halt day; time periods on both halt and nonhalt days are defined based on the halt time and reopening time. Throughout the paper, we report tests based on the median abnormal statistic across all sample halts. Except where noted, results based on mean abnormal statistics are similar.

Submissions and cancellations of limit and market orders on the halt day are summarized in Table II. For each period, the table lists the median number of shares submitted, executed, or canceled and the median value of the abnormal statistic. The abnormal statistic can be interpreted as the percentage difference between the halt day and the average nonhalt day. For example, the value of −36.28 reported in the fourth column of Table II suggests that market order submissions during period −4 (defined below) are 36.3 percent lower on the halt day than on the average nonhalt day.

Table II

Total Submissions, Executions, and Cancellations around Trading Halts

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Submissions, executions, and cancellations are identified using NYSE System Order Data. The table lists the median number of shares submitted, executed, or canceled and the median value of abnormal submissions, executions, and cancellations. The abnormal submissions measure is defined as the shares submitted on the halt day minus the mean number of shares submitted on nonhalt days, stated as a percentage of the nonhalt day mean. Abnormal cancellations are defined similarly. Nonhalt days include the 10 days before and 10 days after the halt. For the abnormal measures, ***, **, and * indicate that the median is statistically significant at the 1, 5, and 10 percent levels, respectively, based on a signed-rank test. The halt period extends from the beginning of the halt to the reopening trade. Thirty-minute prehalt periods are measured backward from the beginning of the halt. Thirty-minute posthalt periods are measured forward from the reopening time.

		Market Order Submissions		Market Order Cancellations		Limit Order Submissions		Limit Order Cancellations	
Period	*N*	Halt Day Submissions	Abnormal Submissions (%)	Halt Day Cancellations	Abnormal Cancellations (%)	Halt Day Submissions	Abnormal Submissions (%)	Halt Day Cancellations	Abnormal Cancellations (%)
Panel A: News Halts									
−4	182	880	−36.28	0	**−100.00*****	6,500	−43.74	1,000	**−66.47****
−3	197	500	**−65.07*****	0	**−100.00*****	5,000	−33.43	812	**−65.34***
−2	214	500	−31.22	0	**−100.00*****	4,536	−39.19	1,000	**−73.95***
−1	251	884	−31.24	0	**−100.00*****	6,200	−26.65	2,000	−45.02
During halt	251	4,227	**56.82*****	500	**618.88*****	41,340	**150.45*****	38,900	**371.50*****
+1	222	6,585	**689.84*****	0	−100.00	37,858	**488.17*****	16,820	**471.23*****
+2	184	2,850	**167.37*****	0	**−100.00****	21,200	**195.17*****	6,648	**138.57*****
+3	160	1,706	**53.66*****	0	**−100.00*****	18,482	**129.04*****	5,030	**23.32*****
+4	119	1,630	**22.98*****	0	**−100.00*****	13,365	**81.50*****	4,200	**30.29*****
Panel B: Order Imbalance Halts									
−4	24	3,232	21.42	0	−100.00	8,199	−8.44	5,338	−38.87
−3	31	900	−30.00	0	**−100.00*****	11,975	−19.52	6,512	−19.18
−2	37	850	−42.15	0	**−100.00*****	11,314	6.48	1,600	−60.98
−1	44	13,009	**569.51*****	50	**189.86****	34,853	**326.66*****	13,300	**356.26*****
During halt	44	11,677	**319.71*****	9,705	**8,028.89*****	116,452	**1,183.85*****	78,240	**1,847.19*****
+1	40	18,956	**1,484.22*****	0	−100.00	54,156	**815.63*****	34,995	**1,298.63*****
+2	37	9,767	**204.51*****	0	−100.00	28,080	**231.53*****	12,350	**335.54*****
+3	36	6,675	**340.45*****	0	−100.00	25,831	**160.79*****	13,341	**234.22*****
+4	31	4,144	**87.90*****	0	−100.00	17,000	**126.98*****	7,900	**69.64*****

The halt period begins at the time the halt is called and includes all activity through the reopening trade. Thirty-minute prehalt periods are measured backward from the halt beginning time to the open, and 30-minute posthalt periods are measured forward from the reopening time to the close. We include results for the period from two hours prior to the halt to two hours after the halt. In addition, we report separate results for news halts (Panel A) and order imbalance halts (Panel B). Statistical tests are based on the signed-rank test.

Panel A of Table II lists results for the sample of news-related halts. In the four pre-halt periods (−4 through −1), measures of abnormal trading activity (i.e., submissions and cancellations) are generally negative. However, there is little evidence of statistically reliable differences.[5] These results suggest that there is little change in prehalt activity relative to nonhalt days. Beginning at the halt time, however, trading activity changes dramatically relative to nonhalt days. During the halt, submissions and cancellations are significantly higher than nonhalt day values for both market and limit orders. Most notably, limit order cancellations during the halt period are 371 percent higher than nonhalt day values, and market order cancellations are over 600 percent higher. In addition, market order submissions during the halt increase by 50 percent relative to nonhalt days, and limit order submissions more than double (an increase of 150 percent). Whereas market order cancellations are only evident during the halt, other categories of trading activity continue to be higher after the halt. During the first 30 minutes after the halt, market order submissions are nearly 700 percent higher than on nonhalt days, and both submissions and cancellations of limit orders are over five times nonhalt day levels. Although the abnormal statistics decrease in magnitude over time, market order submissions, limit order submissions, and limit order cancellations all remain unusually high for at least two hours after the halt.

Results for order imbalance halts are provided in Panel B of Table II. With the exception of market order cancellations, none of the abnormal measures is statistically different from zero in periods −4 through −2. Unlike news halts, however, order imbalance halts are associated with increased trading activity in the 30 minutes *prior* to the halt. Market order submissions increase by 569 percent relative to nonhalt days, and limit order submissions increase by over 300 percent. In addition, both market order cancellations and limit order cancellations are substantially higher than on nonhalt days. These results are consistent with the unusual trading conditions that would result in an order imbalance trading halt. Notably, these results suggest that market conditions change abruptly, providing little time for the specialist to draw liquidity to the market.

[5] The abnormal measure of cancellations is generally equal to −100 percent in the prehalt and posthalt periods. However, this results from zero cancellations on the halt day and a positive but small mean number of cancellations on nonhalt days. The economic importance of these numbers is therefore minimal.

During and after the halt, the results for order imbalance halts are similar to those for news halts but are much larger in magnitude. Market order submissions are 319 percent higher during the halt, over 1,400 percent higher during the first posthalt period, and remain significantly higher for up to two hours after the halt. In addition, market order cancellations during the halt are over 8,000 percent higher than nonhalt day values. Both limit order submissions and cancellations during the halt are over 1,100 percent higher than nonhalt day values. As is the case with news halts, limit order activity remains significantly higher than nonhalt day levels for at least two hours after the halt.

Together, the results in Table II suggest that investors use the temporary stoppage of trade to cancel old limit orders and reposition their trading interests both during and following the halt. The increased activity documented in Table II is also consistent with price discovery. However, we are unable to determine whether price discovery is improved or limited by the trading halt. Finally, the results suggest that the conditions that precipitate an imbalance halt develop quickly.

B. The Limit Order Book

The results in Section III.A point to a marked increase in order activity during trading halts and for several periods after trading halts. The increase in cancellations during the halt is particularly noticeable. In this section, we examine whether these changes in order activity have a significant impact on the state of the limit order book around the time of the halt.

We reconstruct the limit order book at 30-minute intervals around the trading halt using NYSE System Order Data and the methodology of Kavajecz (1999). The basic methodology involves three steps: First, we use execution and cancellation records to identify the set of limit orders outstanding at the beginning of the sample period (day −10). This set of orders, referred to as the prebook, includes all limit orders that were canceled or executed during our sample period and for which the submission date is prior to day −10. Second, we update the prebook with all submissions prior to the date and time of interest. Finally, we remove any orders that were executed or canceled prior to the date and time of interest. The remaining orders provide an approximation of the limit order book at a particular point in time.

At each 30-minute interval, we compute four measures of share depth in the limit order book: the cumulative depth within \$0.25 of the quote midpoint, the cumulative depth within \$0.50 of the quote midpoint, the cumulative depth within \$1.00 of the quote midpoint, and the total depth in the limit order book. Together, these measures provide a detailed characterization of the limit order book.[6] Results are provided for combined bid-side and ask-side depth (Table III) and separately for bid-side and ask-side depth

[6] Goldstein and Kavajecz (2000a, 2000b) use similar measures to study market depth around the change in tick size on the NYSE and the marketwide circuit breaker on the NYSE, respectively.

Table III

Limit Order Book Depth around Trading Halts

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Limit order book depth is estimated using NYSE System Order Data and the methodology of Kavajecz (1999). Statistics are generated for share depth within $0.25 of the specialist's quote midpoint, share depth within $0.50 of the midpoint, share depth within $1.00 of the midpoint, and total share depth. For each depth category, the table lists the median depth and the median value of abnormal depth. The abnormal depth measure is defined as the depth on the halt day minus the mean depth on nonhalt days, stated as a percentage of the nonhalt day mean. Nonhalt days include the 10 days before and 10 days after the halt. For the abnormal measures, ***, **, and * indicate that the median is statistically significant at the 1, 5, and 10 percent levels, respectively, based on a signed-rank test. Thirty-minute prehalt periods are measured backward from the beginning of the halt. Thirty-minute posthalt periods are measured forward from the reopening time.

		Depth within $0.25		Depth within $0.50		Depth within $1.00		Total Depth	
Period	*N*	Halt Day Depth	Abnormal Depth (%)	Halt Day Depth	Abnormal Depth (%)	Halt Day Depth	Abnormal Depth (%)	Halt Day Depth	Abnormal Depth (%)
				Panel A: News Halts					
−4	182	11,571	**−21.36****	18,370	−12.06	29,775	−11.21	54,249	**−8.40****
−3	196	9,442	**−28.07*****	17,023	**−22.31*****	28,900	**−17.56*****	51,887	**−8.00****
−2	214	11,350	**−27.19*****	20,300	**−21.09*****	27,194	**−15.77*****	49,400	**−8.07*****
−1	250	10,822	**−28.08*****	20,000	**−18.90*****	29,400	**−13.85*****	49,736	**−9.70*****
Halt	251	10,950	**−30.42*****	20,858	**−18.76*****	32,360	**−12.53*****	55,545	**−10.66****
Reopen	251	9,206	**−42.95*****	29,950	**−24.64*****	32,225	**−15.20***	62,414	−3.31
+1	222	11,348	**−35.17*****	23,035	**−21.40*****	35,185	**−14.03****	64,229	**3.75***
+2	184	13,395	**−25.60****	28,667	−12.95	43,150	−0.53	73,157	**11.30*****
+3	160	15,012	**−14.98***	29,291	−2.01	42,543	**9.93***	73,849	**13.46*****
+4	119	16,743	−8.05	31,934	−0.02	47,183	3.82	83,212	**13.14*****
				Panel B: Order Imbalance Halts					
−4	25	7,450	−16.27	10,400	−21.48	13,700	−20.37	38,307	−19.97
−3	31	2,500	**−60.19*****	10,650	**−28.87****	12,593	**−30.11****	28,274	**−13.72****
−2	37	5,200	**−52.73***	8,300	**−48.19***	13,500	−26.75	29,400	−18.67
−1	44	2,500	**−56.05****	5,700	−41.34	10,790	−35.54	29,581	−18.49
Halt	44	3,700	**−55.93***	6,162	**−59.31***	11,000	−40.33	30,117	6.42
Reopen	44	5,650	**−73.29****	13,507	−43.47	20,849	−7.10	81,560	**67.85*****
+1	40	4,900	−22.71	16,222	−20.55	23,000	**27.08****	63,740	**78.97*****
+2	37	6,500	−47.09	13,925	10.88	25,475	**40.04****	89,683	**72.76*****
+3	36	6,800	−15.93	11,900	14.56	27,798	**44.25*****	84,727	**62.50*****
+4	31	5,808	−22.64	14,672	−0.06	23,183	**46.53*****	85,561	**92.44*****

(Table IV). For the separate analyses of bid and ask-side depth, the sample is categorized according to the price change during the halt. As in Table II, we calculate abnormal statistics for each time period by comparing the halt day value with the average value across nonhalt days. For each period, the table lists the median share depth across all halts and the median value of the abnormal depth statistic. Statistical tests are again based on a signed-rank test.

Panel A of Table III presents the results for the subsample of news halts. Examining the periods prior to the halt, we see that limit order book depth is substantially lower on the halt day than on nonhalt days. This reduction in depth is most evident near the quotes. At the time of the halt, for example, depth within \$0.25 of the midpoint is 30 percent lower on the halt day than on nonhalt days, whereas total depth is only 11 percent lower.

At the reopen of trading, depth within \$0.25 of the midpoint remains significantly lower than on nonhalt days. This reduction persists for approximately one hour after the halt. As we move away from the quotes, however, we see a different picture. Share depth within \$0.50 of the midpoint and within \$1.00 of the midpoint is significantly lower than on nonhalt days in period +1 but does not differ from nonhalt days thereafter. For total depth, we observe abnormally low depth prior to the halt but abnormally *high* depth after the halt. One possible explanation for this difference could be increased activity by limit order traders who face substantial uncertainty about the new price. Another possible explanation is that this increased depth results from stale limit orders that do not reflect new information. We address these possibilities below.

Panel B of Table III presents results for order imbalance halts. The results are similar to those reported for news halts with the following exceptions. First, depth prior to the halt is only marginally lower than on nonhalt days, with the most significant difference evident 90 minutes prior to the halt. Second, only depth within \$0.25 of the midpoint is significantly lower at the reopen. This lack of significance may be the result of the small number of order imbalance halts in the sample. Despite the sample size, however, total depth is significantly higher at the reopen,and both total depth and depth within \$1.00 of the midpoint are significantly higher than on nonhalt days in periods +1 through +4.

Separate results for bid-side and ask-side depth are provided in Table IV. Results for positive, negative and zero price change halts are listed in Panels A, B, and C, respectively.[7] Results for depth near the quotes are similar for all price change categories and are consistent with the results from Table III. Both bid-side and ask-side depth near the quotes is significantly lower on the halt day than on nonhalt days, especially in the periods immediately before and immediately after the halt. Interestingly, even for zero

[7] In Table IV, the samples of order imbalance and news halts are combined due to the small number of order imbalance halts in each price change category.

Table IV

Limit Order Book Depth around Trading Halts (by price change category)

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Limit order book depth is estimated using NYSE System Order Data and the methodology of Kavajecz (1999). Statistics are generated for share depth within $0.25 of the specialist's quote midpoint and share depth within $1.00 of the midpoint. For each depth category, the table lists the median depth and the median value of abnormal depth and the median value of abnormal depth/volume. The abnormal depth measure is defined as the depth on the halt day minus the mean depth on nonhalt days, stated as a percentage of the nonhalt day mean. Nonhalt days include the 10 days before and 10 days after the halt. For the abnormal measures, ***, **, and * indicate that the median is statistically significant at the 1, 5, and 10 percent levels, respectively, based on a signed-rank test. Thirty-minute prehalt periods are measured backward from the beginning of the halt. Thirty-minute posthalt periods are measured forward from the reopening time.

		Bid-Side Depth				Ask-Side Depth			
Period	*N*	Halt Day Depth within $0.25	Abnormal Depth within $0.25 (%)	Halt Day Total Depth	Abnormal Total Depth (%)	Halt Day Depth within $0.25	Abnormal Depth within $0.25 (%)	Halt Day Total Depth	Abnormal Total Depth (%)
Panel A: Positive Price Change Halts									
−4	80	5,550	−31.71	19,550	**−25.87*****	4,750	**−43.17*****	27,969	**−16.92****
−3	87	5,060	−40.26	18,400	**−27.00****	4,700	**−48.94*****	28,551	**−18.55*****
−2	97	5,700	−35.35	18,200	**−24.70****	4,650	**−40.26*****	28,553	**−12.32****
−1	111	4,562	**−46.16****	18,200	**−24.94*****	5,750	**−44.76*****	29,448	**−11.69***
Halt	111	4,800	**−42.84***	18,150	−17.33	4,213	**−47.39*****	29,051	**−19.29****
Reopen	111	3,475	**−54.75*****	41,325	**33.19*****	1,850	**−85.09*****	24,150	**−36.86*****
+1	98	5,974	**−47.16*****	37,887	**32.35*****	4,800	**−47.52***	32,129	−15.57
+2	82	7,042	−34.97	45,275	**39.25*****	7,340	−18.51	38,197	1.41
+3	74	6,050	−32.24	42,725	**36.25*****	10,350	−3.33	39,275	4.59
+4	48	5,700	−24.39	42,800	**29.78*****	14,000	14.41	47,814	**8.11***

Panel B: Negative Price Change Halts									
−4	92	3,200	**−37.57*****	18,250	**−19.48****	4,634	**−37.18***	28,800	−9.69
−3	101	3,875	**−41.03*****	16,890	**−21.80*****	2,500	**−45.09*****	27,295	−7.08
−2	112	3,100	**−46.61*****	17,740	**−17.63****	3,000	**−42.62****	26,981	−11.75
−1	126	3,600	**−46.89*****	21,512	**−18.43*****	3,000	**−43.59*****	27,000	−13.35
Halt	127	3,750	**−41.21*****	21,700	−16.84	2,450	**−58.26*****	28,168	−6.29
Reopen	127	2,309	**−71.21*****	19,002	−23.30	1,900	**−82.82*****	44,991	**15.35*****
+1	111	3,198	**−47.11*****	24,512	−26.54	4,200	**−51.18*****	39,450	**21.39*****
+2	93	3,500	**−51.53*****	28,452	−15.44	5,000	**−41.10*****	47,146	**18.60*****
+3	80	3,800	**−49.67****	30,300	−10.37	5,800	−29.85	50,025	**20.56*****
+4	67	4,922	−34.93	33,599	−9.30	5,800	−41.01	54,400	**29.77*****
Panel C: Zero Price Change Halts									
−4	34	3,100	−29.33	18,600	−3.39	9,100	**53.80****	24,525	8.00
−3	39	4,320	−39.13	17,550	−3.12	3,800	−2.61	24,512	5.72
−2	42	5,000	−33.03	20,003	−3.40	5,100	−9.50	23,490	−0.42
−1	57	4,600	**−52.14****	17,549	−3.78	3,700	−19.32	21,350	−2.07
Halt	57	3,285	**−45.76****	18,600	−6.27	4,000	−20.32	21,190	−2.16
Reopen	57	3,000	**−61.88*****	25,900	0.34	2,500	**−27.92****	25,500	−9.45
+1	53	5,000	**−36.17****	25,800	−5.49	3,165	−50.44	28,690	−5.44
+2	46	5,150	**−31.86****	26,750	1.04	3,450	**−64.14****	29,110	−7.11
+3	42	3,500	**−39.40***	27,170	3.10	5,250	−30.95	34,376	−4.30
+4	35	5,900	−31.77	25,100	−3.89	6,525	−44.53	38,352	−7.34

price change halts, bid-side depth near the quotes appears to be unusually low around trading halts. For positive and negative price change halts, there is also evidence that total depth is low in the prehalt periods relative to nonhalt days.

The results for total depth in the posthalt periods provide some insight into the source of increased depth away from the quotes. For positive price change halts, total depth on the bid side is significantly higher than on nonhalt days, whereas total depth on the ask side does not differ from nonhalt day values. Just the opposite pattern is evident for negative price change halts. These results suggest that at least some of the increase in total depth in the posthalt periods may be due to stale limit orders that do not reflect new information. As the price moves away from these orders, depth away from the quotes increases but only on one side of the market. The results for zero price change halts are consistent with this explanation, because there is no evidence of an increase in total depth on either the bid or ask side for these halts.

The results in Table IV suggest that a significant number of stale limit orders may remain on the book after the halt. However, the results in Table II provide evidence of substantial submission and cancellation activity before, during, and after halts. To determine what portion of the limit order book represents new relative to stale orders, we break down the total limit-book depth at the reopening time into orders submitted prior to the halt (*Old*) and orders submitted during the halt (*New*). The breakdown is presented in Figure 1. Panels A, B, and C provide results for zero price change halts, positive price change halts, and negative price change halts, respectively.

For positive and negative price change halts, the vast majority of limit-book depth is associated with new orders. In addition, the increased bid depth for positive price change halts and increased ask depth for negative price change halts appears to result primarily from new orders submitted during the halt rather than from old orders that do not reflect new information. For positive and negative price change halts, there also appears to be a significant amount of "new" depth on both sides of the book. These results suggest that, during the halt, the limit order book fills in around a new consensus price.[8] The results for zero price change halts provide an interesting contrast. For these halts, total depth is higher throughout the limit order book, and the majority of limit-book depth comes from orders submitted prior to the halt. These results suggest that information effects, rather than the halt itself, cause traders to cancel old orders and reposition their trading interests.

In summary, the results in Tables III and IV suggest that limit order book depth is low prior to trading halts, especially near the quotes. After the halt, depth near the quotes is marginally lower than on nonhalt days, whereas depth away from the quotes is actually higher than on nonhalt days. Although

[8] The relation between the limit order book and reopening price is analyzed in Section IV.

a portion of this increased depth appears to be the result of stale limit orders, the results in Figure 1 suggest that the majority of the reopening limit order book is made up of new orders.

C. Bid-Ask Spreads and Quoted Depth

As an alternative description of liquidity around trading halts, we analyze four measures of the bid-ask spread: the specialist's quoted bid-ask spread, the limit order spread, the 5,000-share spread, and the 10,000-share spread. The first measure is the difference between the specialist's posted ask and bid quotes. The second measure is the difference between the best ask price and the best bid price in the limit order book. These measures represent the cost of transacting small orders. The final two measures are meant to proxy for the transactions costs associated with large trades. The 5,000-share spread is the difference between the 5,000-share ask and the 5,000-share bid, where the 5,000-share ask (bid) is the price one would have to go up to (down to) to reach 5,000 shares of cumulative depth in the limit order book. The 10,000-share spread is defined similarly for 10,000 shares of cumulative depth.[9] Using all four measures allows us to examine transaction costs affecting a variety of traders. All spreads are stated as a percentage of the bid-ask midpoint.

The results of the bid-ask spread analysis are provided in Table V. The table lists both the median percentage spread on the halt day and the median abnormal spread measure calculated relative to nonhalt days. For news halts (Panel A), the limit order spread in all prehalt periods is significantly lower than on nonhalt days. In addition, both the limit order spread and the specialist's quoted spread are unusually low at the time of the halt, though the magnitude of the difference is small for the quoted spread. There is little evidence of a systematic pattern in either the 5,000-share or 10,000-share spread prior to the halt. At the reopen, all four spread measures are significantly higher than on nonhalt days. The specialist's quoted spread is 31 percent higher than the nonhalt day value, whereas the differences in limit-order spreads range from 21 percent higher for the best limit order spread to eight percent higher for the 10,000-share spread. In the posthalt periods, there is some evidence that spreads are lower than on nonhalt days,

[9] In many cases, the total depth on either the bid or ask side of the limit order book is less than 5,000 (or 10,000) shares. To handle these situations, we define the minimum 5,000-share bid (maximum 5,000-share ask) as the quoted bid price minus \$2.00 (quoted ask price plus \$2.00). This results in a maximum 5,000-share spread equal to the quoted spread plus \$4.00. Similarly, we define the minimum 10,000-share bid (maximum 10,000-share ask) as the quoted bid price minus \$3.00 (quoted ask price plus \$3.00). The conclusions are unchanged if minimum bids and maximum asks are defined based on the minimum bid and maximum ask in the limit order book, respectively. We also reach similar conclusions if the 5,000-share and 10,000-share spread are defined as missing when the total depth on either side of the book is less than 5,000 or 10,000 shares, respectively.

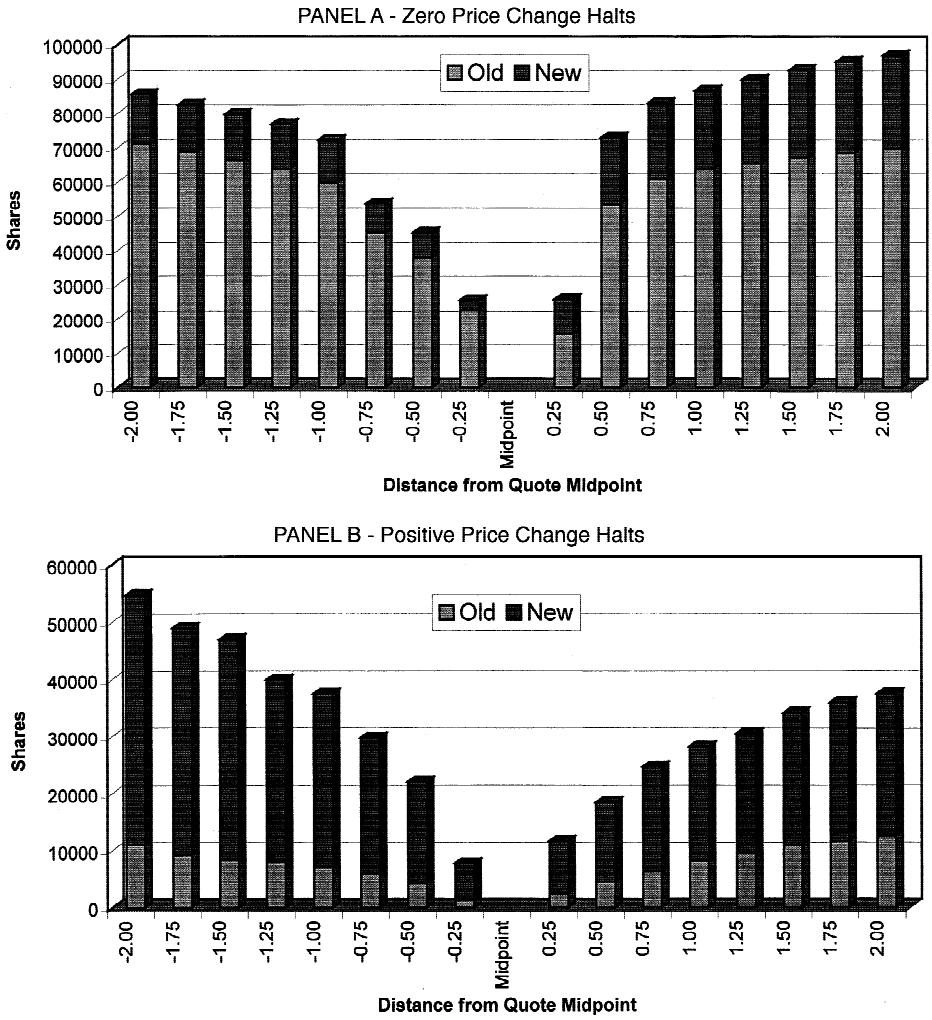

Figure 1. Limit order book depth at the reopen. The figures show cumulative limit order book depth at various distances away from the bid-ask midpoint. Limit order book depth is estimated using NYSE System Order Data and the methodology of Kavajecz (1999). *Old* represents orders submitted prior to the halt time. *New* represents orders submitted during the halt. Panel A provides results for halts that result in no price change. Results for positive price change halts and negative price change halts are provided in Panels B and C, respectively. (*Figure continues on facing page.*)

especially for the 5,000-share and 10,000-share spread measures. This result is consistent with the increase in posthalt depth away from the quotes, as discussed in Section III.B.[10]

[10] The distribution of abnormal spreads is skewed. Based on mean abnormal statistics, all spread measures are significantly higher at the halt time, reopen time, and period +1, whereas there is little evidence that spreads differ relative to nonhalt days for other prehalt and posthalt periods.

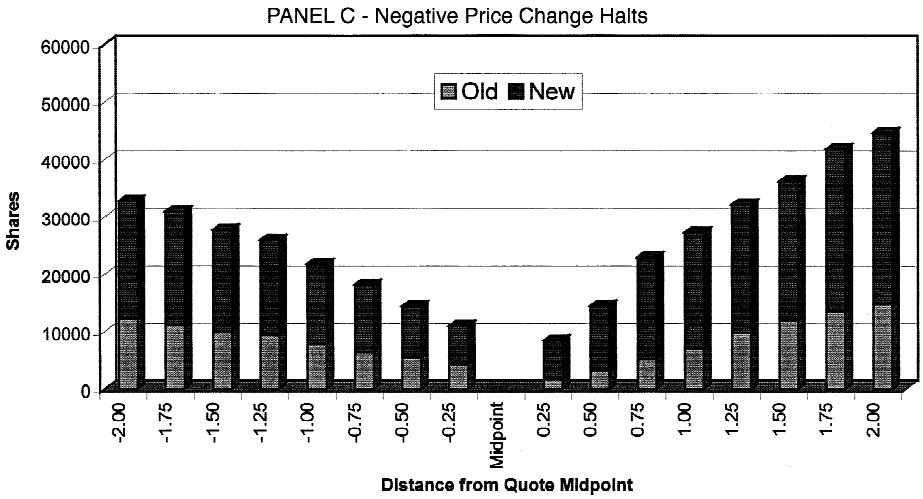

Figure 1. Continued

For imbalance halts (Panel B), the results are even more dramatic. Consistent with the results for news halts, both the 5,000- and 10,000-share spreads are significantly lower than nonhalt day values in the posthalt periods. Although there is little evidence of abnormal spreads in periods −4 through −1, the quoted spread, the 5,000-share spread and the 10,000-share spread at the halt time are all significantly wider than on nonhalt days. Most notably, the quoted spread at the time of the halt is 361 percent above nonhalt levels. In addition, the median quoted spread is 2.33 percent, whereas the median limit order book spread is only 0.38 percent. These striking results for imbalance halts are consistent with specialists "spreading the quote" to signal the price level necessary to resolve the imbalance. Specifically, if the specialist expects that a substantial price move would be necessary to execute electronic market orders, the specialist may move one side of the quote to indicate the likely execution price. Traders then have the opportunity to cancel their market orders in light of this new information.[11]

To more closely examine the time-series behavior of spreads around trading halts, we calculate average dollar spreads at 15-second intervals prior to and after the halt. Cross-sectional means are calculated separately for news and for order imbalance halts.[12] These average spreads are plotted in Figure 2. For both halt types, dollar spreads average approximately 20 to 25 cents during nontrading periods. For news halts, quoted spreads increase

[11] During this brief period, the specialist may post quotes that bypass existing limit orders. This is evident in Panel B of Table V, where the quoted spread at the halt time exceeds the best limit order spread. Of course, the limit orders would be appropriately filled if an execution were to occur.

[12] Where necessary, intervals from the day prior to the halt and the day after the halt are included to ensure that all halts have the same number of prehalt and posthalt observations.

Table V

Bid-Ask Spreads around Trading Halts

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Quoted bid and ask prices are identified using the TAQ database. The limit order book is reconstructed using NYSE System Order Data and the methodology of Kavajecz (1999). Quoted spread is the specialist's quoted bid-ask spread. Limit order spread is the spread between the best bid and best ask prices in the limit order book. The 5,000-share spread is the difference between the 5,000-share ask and the 5,000-share bid, where the 5,000-share ask (bid) is the price associated with 5,000 shares of cumulative depth on the ask (bid) side of the limit order book. The 10,000-share spread is defined similarly. All spread variables are measured as a percentage of the bid-ask midpoint. For each spread measure, the table lists the median spread and the median value of the abnormal spread. The abnormal spread measure is defined as the spread on the halt day minus the mean spread on nonhalt days, stated as a percentage of the nonhalt day mean. Nonhalt days include the 10 days before and 10 days after the halt. For the abnormal measures, ***, **, and * indicate that the median is statistically significant at the 1, 5, and 10 percent levels, respectively, based on a signed-rank test. Thirty-minute prehalt periods are measured backward from the beginning of the halt. Thirty-minute posthalt periods are measured forward from the reopening time.

	Quoted Spread		Limit Order Spread		5,000-Share Spread		10,000-Share Spread	
Period	Halt Day Spread (%)	Abnormal Spread (%)	Halt Day Spread (%)	Abnormal Spread (%)	Halt Day Spread (%)	Abnormal Spread (%)	Halt Day Spread (%)	Abnormal Spread (%)
				Panel A: News Halts				
−4	0.90	−5.23	1.00	**−27.84*****	4.54	−6.05	9.77	**−5.42***
−3	0.90	−8.47	1.00	**−28.22*****	4.44	−11.82	10.00	0.05
−2	0.90	−7.07	1.13	**−16.75****	4.55	**−11.30****	10.07	−2.53
−1	0.88	−5.65	1.00	**−16.30****	4.85	−4.78	9.93	−3.80
Halt	0.97	**−1.02****	1.05	**−21.10*****	5.26	0.44	9.73	1.01
Reopen	1.03	**31.48*****	1.41	**21.32*****	5.63	**18.55*****	9.35	**8.02*****
+1	0.93	**−3.33*****	1.15	−11.51	4.96	−1.10	8.39	−3.38
+2	0.86	−9.36	0.91	**−16.54****	3.01	**−11.68***	6.54	**−9.77****
+3	0.76	**−13.58***	0.88	**−17.73*****	3.11	**−8.99***	5.53	**−20.69*****
+4	0.70	−9.42	0.84	**−18.16***	2.87	**−14.25***	6.46	**−14.60****
				Panel B: Order Imbalance Halts				
−4	0.62	2.24	0.53	**−24.48***	4.39	4.11	9.27	4.75
−3	0.63	−5.02	0.91	3.03	4.86	**8.72***	8.77	5.21
−2	0.61	−3.23	0.65	−20.82	4.97	1.51	9.48	3.53
−1	0.52	**9.58***	0.81	−14.73	5.27	3.64	9.85	3.91
Halt	2.33	**361.86*****	0.38	−60.33	9.01	**33.33*****	12.61	**35.13*****
Reopen	0.76	**42.92*****	1.94	**54.25*****	4.00	−3.39	7.11	−5.25
+1	0.56	−1.57	0.70	−25.75	4.03	−18.67	6.28	**−22.59****
+2	0.54	−0.14	0.81	−8.19	3.16	−11.48	5.84	**−19.94****
+3	0.50	−7.93	0.72	−24.43	3.19	**−37.98****	4.92	**−26.67*****
+4	0.60	9.09	0.61	−23.26	3.31	**−25.95*****	5.88	**−31.24*****

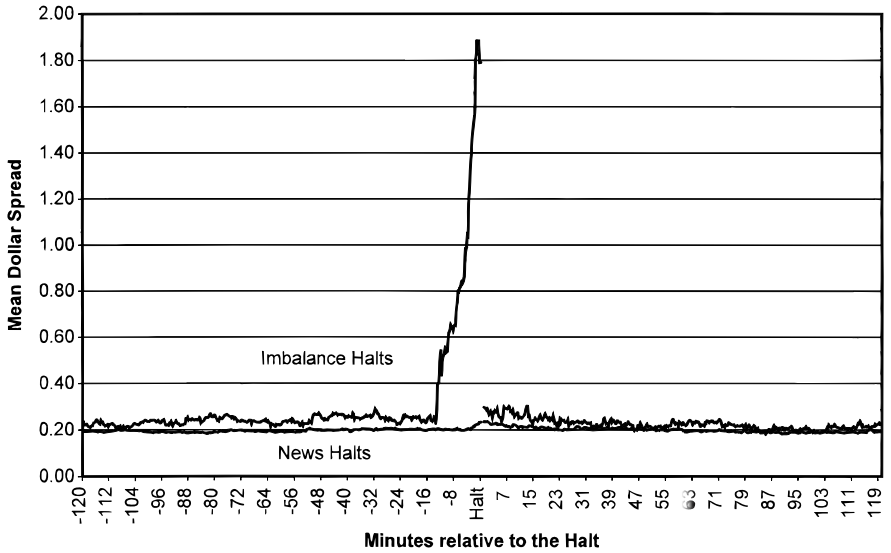

Figure 2. Mean dollar spreads around trading halts. The figure plots the mean dollar spread by halt category at 15-second intervals prior to and after the halt. The halt sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m.

slightly prior to the halt, remain higher at the reopen, and quickly return to prehalt levels. However, the most significant results are apparent for order imbalance halts. Average dollar spreads begin to widen in the minutes prior to imbalance halts, increasing to as much as $1.80. As we discussed above, this result is consistent with specialists "spreading the quote" prior to order imbalance halts. Interestingly, reopening spreads for order imbalance halts appear to be very close to normal prehalt levels. For news halts, tests of means and medians suggest that spreads begin to increase approximately 15 to 90 seconds prior to the halt and return to prehalt levels (defined as one hour prior to the halt) within 21 minutes. For order imbalance halts, similar tests suggest that spreads begin to increase 12 to 13 minutes prior to the halt and are back to normal within two minutes of the reopen.

The results in the previous two sections provide evidence that limit order book depth is unusually low and bid-ask spreads are unusually high immediately after trading halts. Given this decrease in liquidity, it is interesting to determine whether the specialist and floor participants step in to provide additional liquidity around trading halts. To address this question, we examine the quoted depth (at the best bid or offer) and the floor contribution to depth. The floor contribution is calculated by subtracting from the quoted depth the total depth available from the limit order book at prices at or better than the posted quote. The floor contribution to depth is presented both in terms of shares contributed and proportion of quoted depth contributed. The results for news and imbalance halts are presented in Panels A and B of Table VI, respectively.

Table VI

Quoted Depth and Floor Contribution to Depth around Trading Halts

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Quoted depth is the sum of the bid and ask depths quoted by the specialist. The depth contributed by floor participants is defined as the difference between the quoted depth and the total depth on the limit order book at or inside the quotes. Limit order book depth is estimated using NYSE System Order Data and the methodology of Kavajecz (1999). The percentage of depth contributed by floor participants is defined as depth contributed by the floor divided by total quoted depth. The abnormal depth measure is defined as the depth on the halt day minus the mean depth on nonhalt days, stated as a percentage of the nonhalt day mean. Abnormal measures of floor contribution are defined similarly. Nonhalt days include the 10 days before and 10 days after the halt. For the abnormal measures, ***, **, and * indicate that the median is statistically significant at the 1, 5, and 10 percent levels, respectively, based on a signed-rank test. Thirty-minute prehalt periods are measured backward from the beginning of the halt. Thirty-minute posthalt periods are measured forward from the reopening time.

	Quoted Depth		Floor Contribution to Depth		% of Depth Contributed by the Floor	
Period	Halt Day Depth	Abnormal Depth (%)	Halt Day Depth	Abnormal Depth (%)	Halt Day Depth	Abnormal Depth (%)
			Panel A: News Halts			
−4	7,550	**−26.14****	1,422	**−56.78*****	33.02	−15.35
−3	7,400	**−39.10*****	1,256	**−61.46*****	31.43	−17.92
−2	8,000	**−30.74*****	1,250	**−52.85*****	33.33	−11.04
−1	8,000	**−28.06*****	1,200	**−52.40*****	32.33	−9.66
Halt	6,900	**−28.68*****	1,000	**−55.75*****	28.57	−23.81
Reopen	9,000	**−25.45*****	3,000	−33.07	50.82	**36.12*****
+1	9,000	**−35.13*****	2,000	−36.13	48.68	**21.38*****
+2	11,500	−15.33	2,915	−27.17	40.01	**14.37***
+3	11,000	−0.98	2,100	−35.90	34.64	3.02
+4	10,000	−12.21	2,000	−47.72	28.57	−20.32
			Panel B: Order Imbalance Halts			
−4	4,000	**−43.83*****	1,750	**−61.83*****	36.55	−19.06
−3	6,000	**−43.12****	2,000	**−34.39****	50.00	14.19
−2	5,500	**−23.08****	1,500	**−62.72***	41.53	−6.40
−1	4,800	**−37.68***	1,500	**−56.99***	61.82	8.26
Halt	10,100	−4.61	2,350	−51.50	72.35	26.15
Reopen	6,500	−24.31	3,350	−14.04	70.38	**21.61****
+1	6,000	−16.07	2,228	−27.64	50.00	−6.78
+2	9,700	−13.87	4,000	−9.25	56.43	30.50
+3	7,000	−24.17	2,250	−7.79	50.00	0.09
+4	8,750	−0.21	3,200	−24.28	50.00	4.80

For news halts, quoted depth is substantially lower before and for one-half hour after the trading halt. The quoted depth is 26 percent less than on nonhalt days in period −4, 28 percent less than on nonhalt days at the halt

time, and 25 percent less than on nonhalt days at the reopen. A similar pattern is observed for the floor contribution to depth, except at the reopen and just after the halt, where the floor contribution to depth does not differ significantly from nonhalt day values. These results are generally consistent with the decreased limit order book depth near the quote documented in Section III.B. However, results based on the proportion of depth contributed by the floor lead to a substantially different conclusion. At the reopen and for the next hour, the proportion of depth provided by the floor actually increases. For example, the proportion of depth contributed by floor participants is 36 percent higher than nonhalt day values at the reopen and remains 21 percent higher than normal after 30 minutes. The results for order imbalance halts (Panel B) are generally similar, though the significant increase in proportion of depth contributed is evident only at the reopen. Together, the results in Table VI suggest that floor participants, including the specialist, step in to provide liquidity following trading halts.

IV. The Limit Order Book and Reopening Prices

The results in Section III suggest that at least some traders reposition their trading interest around a new consensus price. As an additional test, we examine the informativeness of prices in the limit order book. Specifically, we follow Madhavan and Panchapagesan (2000) in calculating the prices that most closely equate supply and demand across all limit orders (the limit-book clearing price) and all market and limit orders (the system-clearing price). We then evaluate the informativeness of these prices by measuring the extent to which these prices can predict subsequent prices.[13]

This analysis is useful for a number of reasons. First, system-clearing and limit-book clearing prices may not exist if there is a substantial order imbalance. Thus, the existence of market-clearing prices provides one indication that a consensus price has been reached. Second, if the specialist has been successful at attracting depth around a new price, then the prices that clear supply and demand should be close to the new security value. On the other hand, if there is a wide gap between supply and demand, clearing prices will not be good estimates of future prices.

We measure the informativeness of market-clearing prices by testing the proportion of the total price change that is explained by the clearing price. In other words, a good price should explain a large proportion of the price change resulting from the halt. In addition, we follow Madhavan and Panchapagesan (2000) in testing whether the specialist's reopening price provides information beyond that contained in the clearing prices. This analysis

[13] This analysis focuses on price discovery during unscheduled market closures (trading halts). Several recent papers examine price discovery during scheduled market closures. These include Madhavan and Panchapagesan (2000) for the morning open on the NYSE, Biais, Hillion, and Spatt (1999) for the morning open on the Paris Bourse, and Cao, Ghysels, and Hatheway (2000) for the morning open on Nasdaq.

provides information about whether the specialist reacts to liquidity in the limit order book or uses additional information beyond the limit order book when setting the reopening price. We employ a two-stage regression approach, specified as follows:

$$\text{Stage 1:} \quad \ln(P_{i,post}/P_{i,pre}) = \alpha + \beta \ln(P_{i,1}/P_{i,pre}) + e_i, \tag{2}$$

$$\text{Stage 2:} \quad \hat{e}_i = \gamma + \delta \ln(P_{i,2}/P_{i,pre}) + u_i. \tag{3}$$

We define $P_{i,pre}$ as the price one hour before halt i and $P_{i,post}$ as the price one hour after halt i. These prices proxy for the initial equilibrium price and the new equilibrium price, respectively. Prices $P_{i,1}$ and $P_{i,2}$ are equal to the system-clearing price, the limit-book clearing price, or the specialist's reopening price for halt i, where the limit-book (system) clearing price is the price that most closely equates supply and demand across all limit orders (market and limit orders) just prior to the reopen. Thus, in the first-stage regression we evaluate the quality of a given price ($P_{i,1}$) and in the second stage we see what incremental value is contained in an alternative price ($P_{i,2}$). If $P_{i,1}$ is an unbiased predictor of the new equilibrium price and $P_{i,2}$ provides no additional information, then β will equal one and δ will equal zero. If, on the other hand, $P_{i,2}$ reflects some information not captured in $P_{i,1}$, then δ will be statistically different from zero.

The regression results are provided in Table VII. We find that a limit-book clearing price exists for every halt and a system-clearing price exists for all but two halts. Thus, extreme imbalances appear to have been all but eliminated. Most important, the clearing prices are good estimates of the subsequent equilibrium price. On average, the system-clearing price reflects 81 percent of the total price change, and the limit-book clearing price reflects 82 percent of the total price change. As in Madhavan and Panchapagesan (2000), the specialist's reopening price adds incremental explanatory power. For example, the specialist's reopening price has explanatory power for the residuals based on the system-clearing price, but the system-clearing price provides no additional information beyond that contained in the specialist's reopening price.

Together, the results in Table VII suggest that significant imbalances are eliminated prior to the reopening trade and that the clearing price is a good predictor of the future price. In addition, the specialist appears to use both clearing prices and supplemental information, such as interest from the trading floor, when setting the reopening price.

V. The Limit Order Book and Volatility

A. Abnormal Volatility

Lee et al. (1994) find that several measures of volatility are unusually high after NYSE trading halts. The temporary decrease in posthalt liquidity documented in Section III provides a possible explanation for this increase

Table VII

Informativeness of Opening Prices

The table lists results from the following two-stage regression analysis:

$$\text{Stage 1:} \quad \ln(P_{i,post}/P_{i,pre}) = \alpha + \beta \ln(P_{i,1}/P_{i,pre}) + e_i,$$

$$\text{Stage 2:} \quad \hat{e}_i = \gamma + \delta \ln(P_{i,2}/P_{i,pre}) + u_i,$$

where $P_{i,post}$ is the price one hour after halt i, $P_{i,pre}$ is the price one hour before halt i, $P_{i,1}$ and $P_{i,2}$ are equal to the system-clearing price, the limit-book clearing price, or the specialist's reopening price, and $\hat{e}_i$ are the residuals from the first regression. The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. The limit order book is reconstructed using NYSE System Order Data and the methodology of Kavajecz (1999). The limit-book (system) clearing price is defined as the price that most closely equates supply and demand across all limit orders (market and limit orders). The numbers listed in parentheses below the parameter estimates are *p*-values. Limit-book clearing prices exist for all of the sample halts, and system-clearing prices exist for 293 of the sample halts.

First-Stage Regression			Second-Stage Regression		
$\hat{\alpha}$	$\hat{\beta}$	Adj. R^2 (%)	$\hat{\gamma}$	$\hat{\delta}$	Adj. R^2 (%)
$P_{i,1}$ = system-clearing price, $P_{i,2}$ = opening price					
−0.002	0.81	57.2	0.001	0.35	22.5
(0.55)	(0.00)		(0.82)	(0.00)	
$P_{i,1}$ = opening price, $P_{i,2}$ = system-clearing price					
−0.002	1.06	86.3	−0.001	−0.001	0.3
(0.21)	(0.00)		(0.99)	(0.95)	
$P_{i,1}$ = limit-book clearing price, $P_{i,2}$ = opening price					
−0.002	0.82	57.6	0.006	0.35	21.9
(0.56)	(0.00)		(0.82)	(0.00)	
$P_{i,1}$ = opening price, $P_{i,2}$ = limit-book clearing price					
−0.002	1.06	86.3	−0.001	−0.003	−0.3
(0.21)	(0.00)		(0.99)	(0.90)	

in volatility. To formally address this possibility, we calculate abnormal measures of volatility similar to those analyzed in Lee et al. (1994). We then test whether these measures are related to the changes in liquidity documented in Section III.

For each time period, we calculate abnormal statistics for three measures of volatility: the number of quote revisions, the absolute value of the transaction price return, and the high–low transaction price range. For completeness, we also calculate the abnormal trading volume. Pre- and posthalt periods are defined as in the previous section.

Summary statistics for the abnormal volume and volatility measures are described in Table VIII. For each time period, the table lists the median value of the variable and the median value of the abnormal statistic across all halts in the sample. The results are consistent with the increase in vol-

Table VIII

Abnormal Volume and Volatility Measures

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Volume and volatility measures are estimated using trade and quote data from the TAQ database. *Volume* is the total share volume during the period. *Absolute Return* is the absolute value of the return from the last transaction price of the previous period to the last transaction price of the current period. *Price Range* is the difference between the highest and lowest transaction prices during the period. *Quote Revisions* is defined as the number of quote changes during the period for which either the bid or ask prices changed. For each variable, the table lists the median value of the variable and the median value of the abnormal measure. The abnormal volume measure is defined as the volume on the halt day minus the mean volume on nonhalt days, stated as a percentage of the nonhalt day mean. Abnormal return, range, and quote revisions are defined similarly. Nonhalt days include the 10 days before and 10 days after the halt. For the abnormal measures, ***, **, and * indicate that the median is statistically significant at the 1, 5, and 10 percent levels, respectively, based on a signed-rank test. Thirty-minute prehalt periods are measured backward from the halt time to the opening time. Thirty-minute posthalt periods are defined forward from the reopen time to the close of trading.

	Volume		Quote Revisions		Absolute Return		Transaction Price Range	
Period	Median	Abnormal (%)	Median	Abnormal (%)	Median	Abnormal (%)	Median	Abnormal (%)
Full periods								
Pre-halt	39,700	−12.94	15	**10.26*****	1.19	**42.86*****	0.375	**22.33*****
Post-halt	140,150	**279.10*****	25	**272.09*****	1.44	**114.99*****	0.625	**167.42*****
30-minute post-halt periods								
+1	49,800	**618.82*****	12	**535.79*****	1.09	**285.38*****	0.375	**500.00*****
+2	26,150	**213.26*****	6	**192.68*****	0.56	**96.78*****	0.125	**150.00*****
+3	18,500	**121.65*****	5	**124.01*****	0.39	**38.27*****	0.125	**86.15*****
+4	14,500	**77.24*****	4	**61.29*****	0.26	**–5.55***	0.125	**33.33*****

ume and volatility documented by Lee et al. (1994). We find that trading volume in the prehalt period is comparable to that on nonhalt days. However, volume is nearly three times greater than nonhalt levels in the posthalt period. In fact, during the 30 minutes after the halt, volume is over 600 percent higher than on nonhalt days. In general, most of the volume increase occurs in the first 90 minutes after the halt, but trading volume remains abnormally high for at least two hours after the halt.

The results in Table VIII also confirm that volatility after trading halts is substantially higher than during comparable periods on nonhalt days. During the first 30 minutes after the halt, volatility ranges from three to six times that on nonhalt days. Consistent with the results of Lee et al. (1994), abnormal volatility is most significant immediately after the halt and diminishes over the next two hours. We also find that volatility is higher in the prehalt period, though the magnitude of the difference between halt and nonhalt days is not as great as for the posthalt period.

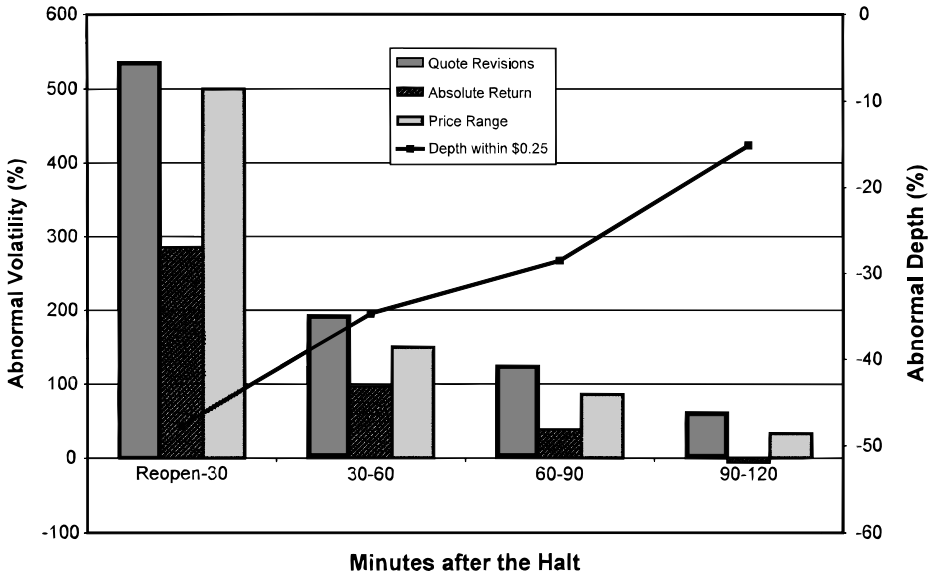

Figure 3. Abnormal volatility and limit order book depth. The figure plots median values of abnormal depth and abnormal volatility for 30-minute periods after trading halts. Abnormal volatility (the bars) corresponds to the left-hand *Y*-axis. Abnormal depth (the line) corresponds to the right-hand *Y*-axis. The halt sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Absolute return is the absolute value of the return from the last transaction price of the previous period to the last transaction price of the current period. High–low price range is the range between the highest and lowest transaction prices during the period. Number of quote revisions is defined as the number of quote changes during the period for which either the bid or ask price changed. Limit order book depth is estimated using NYSE System Order Data and the methodology of Kavajecz (1999). Depth is measured within $0.25 of the specialist's quote midpoint. Abnormal depth is defined as the percentage differences between the halt day value and the nonhalt day mean. Abnormal volatility measures are defined similarly.

B. Volatility and Liquidity

As a first look at the relation between volatility and liquidity following halts, we provide a graph of abnormal volatility and abnormal limit-book depth, where depth is measured at the beginning of each period. For each posthalt period, Figure 3 shows three measures of abnormal volatility (the bars) and the abnormal depth within $0.25 of the quote midpoint (the line). To limit scale differences, the abnormal volatility measures correspond to the left-hand *Y*-axis and the abnormal depth measure corresponds to the right-hand *Y*-axis. From Figure 3, it appears that there is a negative relation between abnormal volatility and abnormal depth.

To test the relation between abnormal volatility and abnormal depth, we first compare median abnormal volatility across groups ranked by abnormal depth. For each posthalt period, we divide the sample into two equal groups: those with abnormal depth above the median and those with abnormal depth

below the median. We then test whether median abnormal volatility differs across depth categories. Rankings are based on two alternative measures of abnormal depth, and tests are performed for all three measures of abnormal volatility. Statistical differences are based on the Wilcoxon rank-sum test.

The results of this analysis are provided in Table IX. The first result that is evident from the table is that the ranking produces a wide variation in abnormal depth. In all posthalt periods, abnormal depth differs significantly between the low-depth and high-depth groups at the one percent level. For period +1, there also appears to be a significant relation between abnormal depth and abnormal volatility. All measures of abnormal volatility during this period are higher in the low-depth group than in the high-depth group, and the difference is significant at the five percent level in all but one case. For periods +2 through +4, however, we find little evidence of a significant relation between abnormal volatility and abnormal depth.

The results in Table IX suggest that the high levels of volatility observed immediately after trading halts may result, at least partially, from changes in liquidity around the halt. However, these tests do not control for information effects and the unusually high volume on trading-halt days. To control for these effects, we estimate ordinary least squares (OLS) regressions of abnormal volatility on abnormal depth and several control variables. Based on the results in Table IX, we estimate regressions for period +1 only. The regressions take the following general form:

$$\begin{aligned} \textit{Abnormal Volatility}_i = {} & \alpha_0 + \alpha_1 * \textit{AbnDepth}_i + \alpha_2 * \textit{HaltRet}_i \\ & + \alpha_3 * \textit{AbnVolume}_i + \epsilon_i. \end{aligned} \tag{4}$$

The dependent variables are the abnormal measures of quote revisions, absolute transaction price return, and transaction price range defined above. The explanatory variables include the absolute return during the halt (*HaltRet*), the abnormal volume during period +1 (*AbnVolume*), and two alternative measures of abnormal depth: depth within \$0.25 of the quote midpoint and depth within \$0.50 of the midpoint. If the increase in abnormal volatility is related to the decrease in liquidity, we would expect the coefficient on abnormal depth to be negative. If large price changes result in increased price uncertainty, we would expect *HaltRet* to be positively associated with abnormal volatility. Finally, to the extent that abnormal volume reflects differences of opinion among investors, we expect abnormal volume to be positively associated with abnormal volatility. The intercept from the regression can be interpreted as the average level of abnormal volatility that cannot be explained by the control variables.

The regression results are provided in Table X. The adjusted R^2 is reported next to each equation, and p-values are reported in parentheses under each coefficient. In addition, the mean value of each abnormal volatility

Table IX

Abnormal Volatility Measures by Depth Category

The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. In addition, the tests include one observation for each 30-minute posthalt period up to two hours after the halt. Volatility measures are estimated using trade and quote data from the TAQ database. *Absolute Return* is the absolute value of the return from the last transaction price of the previous period to the last transaction price of the current period. *Price Range* is the difference between the highest and lowest transaction prices during the period. *Quote Revisions* is defined as the number of quote changes during the period for which either the bid or ask prices changed. Limit order book depth is estimated using NYSE System Order Data and the methodology of Kavajecz (1999). Depth is measured within \$0.25 of the specialist's quote midpoint and within \$0.50 of the quote midpoint. Abnormal depth is defined as the depth on the halt day minus the mean depth on nonhalt days, stated as a percentage of the nonhalt day mean. Abnormal measures of volatility are defined similarly. To perform the tests, observations are ranked according to the depth measure and grouped into two categories based on this ranking. Medians for the high and low depth categories are then compared using a Wilcoxon Rank Sum test. ***, **, and * indicate that medians are statistically different at the 1, 5, and 10 percent levels, respectively.

	Categorized by Depth within \$0.25 of the Midpoint				Categorized by Depth within \$0.50 of the Midpoint			
Period	Abnormal Depth (%)	Abnormal Quote Revisions (%)	Abnormal Return (%)	Abnormal Price Range (%)	Abnormal Depth (%)	Abnormal Quote Revisions (%)	Abnormal Return (%)	Abnormal Price Range (%)
Period +1								
Low depth	−85.82	652.69	304.08	620.00	−68.75	666.37	322.38	589.66
High depth	21.42***	459.83**	229.30	370.59**	20.45***	455.56***	203.80**	370.59**
Period +2								
Low depth	−71.17	224.56	114.04	150.00	−50.27	185.71	90.52	150.00
High depth	24.54***	182.86*	83.92	116.67	32.28***	201.08	107.91	150.00
Period +3								
Low depth	−67.39	102.19	48.27	100.00	−59.01	119.18	55.29	100.00
High depth	38.74***	148.08	17.45	81.82	36.52***	138.10	−6.04	58.00
Period +4								
Low depth	−59.06	57.57	3.79	41.60	−41.42	53.85	−0.35	27.66
High depth	29.88***	93.55	−3.06	27.02	37.50***	98.35	0.56	42.86

Table X

Abnormal Volatility Regressions for Period +1

The table lists coefficients from a regression of period +1 abnormal volatility on several explanatory variables. The sample includes 295 order imbalance and news halts of NYSE-listed common stocks that were called after 10:00 a.m. Period +1 extends from the reopen until 30 minutes after the reopen. The regression takes the following general form:

$$Abnormal\ Volatility_i = \alpha_0 + \alpha_1 * AbnDepth_i + \alpha_2 * HaltRet_i + \alpha_3 * AbnVolume_i + \epsilon_i$$

The dependent variables are abnormal measures of quote revisions, absolute transaction price return, and transaction price range. The number of quote revisions is defined as the number of quote changes during the period for which either the bid or ask price changed. Absolute return is the absolute value of the return from the last transaction price of the previous period to the last transaction price of the current period. High–low price range is the range between the highest and lowest transaction prices during the period. The explanatory variables are abnormal depth, absolute halt return, and abnormal volume. Limit order book depth is estimated using the methodology of Kavajecz (1999). The absolute return during the halt is defined as the absolute percentage return from the last price prior to the halt to the reopening price. Volume is the total share volume during the period. All abnormal measures are defined as the percentage difference between the halt day value and the nonhalt day mean, where nonhalt days include the 10 days before and 10 days after the halt. Panel A lists results based on depth within \$0.25 of the quote midpoint. Panel B lists results based on depth within \$0.50 of the quote midpoint. The numbers listed in parentheses below the coefficients are *p*-values. The mean value of each abnormal volatility measure is provided for comparison. Statistical tests are based on White's corrected χ^2-test if homoskedasticity is rejected at the 5 percent level.

Abnormal Volatility Measure	Mean Abnormal Volatility	Intercept (α_0)	Abnormal Depth (α_1)	Absolute Halt Return (α_2)	Abnormal Volume (α_3)	Adj. R^2
Panel A: Depth within \$0.25 of the quote midpoint						
Abnormal quote revisions	732.263	699.076	−0.591	—	—	0.0016
		(0.000)	(0.235)			
		443.157	−0.623	36.940	0.089	0.3538
		(0.000)	(0.122)	(0.000)	(0.000)	
Abnormal absolute return	468.946	468.481	0.156	—	—	−0.0034
		(0.000)	(0.701)			
		432.816	0.198	9.676	0.002	−0.0053
		(0.000)	(0.628)	(0.241)	(0.810)	
Abnormal price range	867.732	831.356	−1.608	—	—	0.0086
		(0.000)	(0.082)			
		653.859	−1.369	46.099	0.014	0.0362
		(0.000)	(0.135)	(0.006)	(0.440)	
Panel B: Depth within \$0.50 of the quote midpoint						
Abnormal quote revisions	732.263	704.536	−0.875	—	—	0.0069
		(0.000)	(0.098)			
		445.257	−0.982	38.026	0.088	0.3613
		(0.000)	(0.027)	(0.004)	(0.000)	
Abnormal absolute return	468.946	467.248	0.280	—	—	−0.0023
		(0.000)	(0.517)			
		432.017	0.282	9.322	0.002	−0.0046
		(0.000)	(0.515)	(0.256)	(0.801)	
Abnormal price range	867.732	853.976	−1.619	—	—	0.0093
		(0.000)	(0.073)			
		664.559	−1.607	48.231	0.013	0.0404
		(0.000)	(0.071)	(0.004)	(0.437)	

measure is provided for comparison. Panel A lists results based on depth within \$0.25 of the quote midpoint, and Panel B lists results based on depth within \$0.50 of the midpoint.

The results provide weak evidence of a relationship between abnormal depth and abnormal volatility. However, the control variables explain only a small portion of the observed abnormal volatility after halts. As expected, the coefficients on absolute halt return and abnormal volume are generally positive, though neither variable is significant in the absolute-return regression and only the halt return is significant in the price-range regression.

Examining depth within \$0.25 of the quote midpoint (Panel A), we find that abnormal depth is negatively related to abnormal quote revisions and abnormal price range. However, the coefficient on abnormal depth is significant at the five percent level in only one of the six specifications. The results based on depth within \$0.50 of the midpoint (Panel B) are somewhat stronger. The coefficient on abnormal depth within \$0.50 is negative and marginally significant in four of the six specifications. Most important, after controlling for the halt return, abnormal volume, and abnormal depth, the intercept remains significant in every specification. In addition, the magnitude of the intercept is similar to the magnitude of the mean abnormal volatility, suggesting that the model explains, at best, a small portion of the observed abnormal volatility.[14]

Taken together, the results in this section provide little support for the hypothesis that abnormal posthalt volatility is explained by decreased liquidity after the halt. It appears that other factors, such as unmeasured information effects or the closure of trading, explain the majority of the observed posthalt volatility.

VI. Conclusion

On the NYSE, trading halts can be called for individual securities when significant news is expected to impact prices or when large imbalances exist between buy and sell orders. These halts allow investors to react to new information and allow the specialist to determine the new equilibrium price in the absence of trading. However, some argue that trading halts inhibit the normal price discovery process and may result in less efficient prices. We address these issues by providing a detailed analysis of order flow and liquidity around NYSE trading halts. Our results provide important information related to the reactions of traders to halts and the resulting effects on liquidity, prices, and transaction costs.

[14] Conclusions regarding the explanatory power of abnormal depth are similar if either abnormal volume or the halt return is dropped from the regression. In addition, we reestimated the regressions including the duration of the halt as an additional explanatory variable. The length of the halt does not appear to affect abnormal volatility after the halt.

We find that submissions and cancellations are extremely high during and immediately after trading halts. We also find that the limit order book at the reopen consists primarily of orders submitted during the halt as opposed to stale orders. Consistent with the NYSE's objectives, these results suggest that investors use the halt as a chance to cancel old orders and reposition their trading interests around the new price. However, we also find evidence that traders are reluctant to provide liquidity during these unusual market conditions; limit order book depth near the quotes is unusually low before, during, and immediately after trading halts. During these periods, the specialist and/or floor traders appear to provide additional liquidity to the market.

For news halts, spreads are unusually wide at the reopen and return to normal levels within 20 to 30 minutes of the halt. These results are consistent with specialists setting wide quotes during unusual market conditions. In contrast, bid-ask spreads tend to increase dramatically in the 15 minutes prior to order imbalance halts, returning to normal levels almost immediately after the halt. These results are consistent with specialists "spreading the quote" prior to order imbalance halts in order to convey information about the imbalance to market participants.

Consistent with Lee et al. (1994), we find significant increases in volatility subsequent to trading halts. We find some evidence that this increased volatility is related to decreased liquidity around the trading halt. However, decreased limit order book depth appears to explain, at best, a small portion of the increased volatility. The remaining volatility may be the result of unmeasured information effects or the market closure itself.

In contrast to the limit order activity we observe for individual-security halts, Goldstein and Kavajecz (2000b) find that limit order traders either remained inactive or withdrew liquidity during the marketwide circuit breaker on October 27, 1997. In addition, they find that liquidity was substantially reduced on the day following the circuit breaker, whereas we find that liquidity returns to normal rather quickly after individual-security halts. These differences may be related to the degree of price uncertainty associated with these events or to institutional features that differ in the two situations. Clearly, additional study comparing these types of events is needed.

REFERENCES

Amihud, Yakov, and Haim Mendelson, 1987, Trading mechanisms and stock returns: An empirical investigation, *Journal of Finance* 42, 533–553.

Biais, Bruno, Pierre Hillion, and Chester Spatt, 1995, An empirical analysis of the limit order book and the order flow in the Paris Bourse, *Journal of Finance* 50, 1655–1689.

Biais, Bruno, Pierre Hillion, and Chester Spatt, 1999, Price discovery and learning during the preopening period in the Paris Bourse, *Journal of Political Economy* 107, 1218–1248.

Brown, David P., and Robert H. Jennings, 1989, On technical analysis, *Review of Financial Studies* 2, 527–552.

Cao, Charles, Eric Ghysels, and Frank Hatheway, 2000, Price discovery without trading: Evidence from the Nasdaq pre-opening, *Journal of Finance*, forthcoming.

Christie, William G., Shane A. Corwin, and Jeffrey H. Harris, 2000, Et tu, Brute? The role and impact of trading halts in the Nasdaq stock market, Working paper, Vanderbilt University.

Corwin, Shane A., 1999, Differences in trading behavior across NYSE specialist firms, *Journal of Finance* 54, 721–745.

Gerety, Mason S., and J. Harold Mulherin, 1994, Price formation on stock exchanges: The evolution of trading within the day, *Review of Financial Studies* 7, 609–629.

Goldstein, Michael A., and Kenneth A. Kavajecz, 2000a, Eighths, sixteenths and market depth: Changes in tick size and liquidity provision on the NYSE, *Journal of Financial Economics*, forthcoming.

Goldstein, Michael A., and Kenneth A. Kavajecz, 2000b, Liquidity provision during circuit breakers and extreme market movements, Working paper, NYSE.

Greenwald, Bruce C., and Jeremy C. Stein, 1988, The task force report: The reasoning behind the recommendations, *Journal of Economic Perspectives* 2, 3–23.

Greenwald, Bruce C., and Jeremy C. Stein, 1991, Transactional risk, market crashes, and the role of circuit breakers, *Journal of Business* 64, 443–462.

Grossman, Sanford J., 1990. Introduction to NBER symposium on the October 1987 crash, *Review of Financial Studies* 3, 1–3.

Grundy, Bruce D., and Maureen McNichols, 1989, Trade and revelation of information through prices and direct disclosure, *Review of Financial Studies* 2, 485–526.

Kavajecz, Kenneth A., 1999, The specialist's quoted depth and the limit order book, *Journal of Finance* 54, 747–771.

Kodres, Laura E., and Daniel P. O'Brien, 1994, The existence of Pareto superior price limits, *American Economic Review* 84, 919–932.

Lee, Charles M. C., Mark J. Ready, and Paul J. Seguin, 1994, Volume, volatility, and New York Stock Exchange trading halts, *Journal of Finance* 49, 183–214.

Madhavan, Ananth, and Venkatesh Panchapagesan, 2000, Price discovery in auction markets: A look inside the black box, *Review of Financial Studies*, forthcoming.

New York Stock Exchange, Inc., 1999, Maintaining a fair and orderly market: The critical role of trading halts and delays, *Exchange*, July, 1–3.

Stoll, Hans R., and Robert E. Whaley, 1990, Stock market structure and volatility, *Review of Financial Studies* 3, 37–71.