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Trading strategies during circuit breakers and extreme market movements

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Abstract

We study the trading strategies of NYSE market participants through their choice of venue, order type and timing during the turbulent October 1997 period. During this period, we find the implicit costs of supplying liquidity through the electronic limit order book become so high as to induce market participants to withdraw depth from the book, opting instead for the flexibility and discretion of floor trading. In addition, we find that ahead of a market-wide closure, market participants display behavior consistent with the magnet effect, while during the market-wide closure they curtail activity. Our results have implications for the viability of ECNs and electronic limit order books during turbulent periods as well as regulation aimed at maintaining the orderly working of markets during crisis periods.

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1. Introduction

The equity trading landscape is made up of many different trading systems, each with its own unique set of advantages and disadvantages. On one end of the spectrum are electronic limit order books, which provide fast executions and yield low transaction costs. Prominent examples include the New York Stock Exchange's

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(NYSE) SuperDot system, Nasdaq's SuperMontage, Electronic Communication Networks (ECNs), alternative trading systems such as Posit or Primex, and international equity exchanges in Paris and Toronto. On the other end of the spectrum are more human interactive systems, such as the negotiated dealer system of Nasdaq, the floor of the NYSE and the upstairs market, that provide a rich environment on which to condition orders, thereby enabling a high level of trading discretion. These two types of systems, electronic and human based, co-exist in the US equity markets and in other markets around the world. Within this landscape, market participants are constantly making trading choices, weighing the costs and benefits of these competing systems. As part of an overall trading strategy, market participants choose the trading venue on which to trade, the type of order to send, and the timing of their actions. Depending on market conditions, traders might prefer one alternative to another. The ultimate choices of market participants have the ability to bring to light many of the economic tradeoffs they face when trading.

Our focus is the strategic trading decisions made by market participants and how these vary with market conditions. We compare the trading behavior of NYSE floor and SuperDot market participants over a relatively calm period and see how their behavior is altered during a particularly turbulent period in the market, namely the market break on October 27–28, 1997.¹ Specifically, we analyze three questions: (1) Whether the choice of trading platform changes depending on market conditions, i.e., do market participants prefer to trade through an electronic limit order book or on the exchange floor during periods of market turbulence, and does the decision depend on the characteristic of the stock traded? (2) Do market participants switch order type, and, if so, are market orders or limit orders preferred during periods of extreme market movements? (3) When do market participants begin to implement these changes?

Each of these questions remains open both theoretically and empirically. For example, with respect to the venue choice, there are two contrasting models. On one hand, [Glosten \(1994\)](#) develops a model where the electronic limit order book market dominates any competing exchange thereby becoming the inevitable focal point for liquidity. On the other hand, using the ideas that limit orders are limited in the variables on which they can condition and that market participants value trading flexibility, [Grossman \(1992\)](#) demonstrates that the added flexibility offered by the

¹On Monday, October 27, stock prices on the New York Stock Exchange (NYSE) declined precipitously, as shown in the Appendix. By 2:36 PM, the Dow Jones Industrial Average (DJIA) had lost 350 points from the previous day's close, causing the "circuit breaker" provision of NYSE Rule 80B to be triggered for the first time since the rule was adopted in late 1988, resulting in a half hour market-wide trading halt. Although trading resumed at 3:06 PM, by 3:36 PM, the DJIA fell another 200 points, once again triggering Rule 80B, thus shutting the market for the remainder of the day. This 554-point drop in the DJIA on October 27th marked the largest single-day point drop to that date. On the following day, Tuesday, October 28, 1997, the DJIA regained 337 points, the largest single-day point increase up to that time. In addition, trading volume on the NYSE soared to a record 1.2 billion shares, almost doubling its previous record of 684 million shares set on January 23, 1997. Moreover, each of the trading days between Thursday, October 23, 1997 and Thursday, October 30, 1997 rank in the top 10 busiest NYSE trading days up to that date. For an extensive description of the NYSE trading activity over this period see [Ross and Sofianos \(1998\)](#).

upstairs market over traditional limit orders may allow the upstairs market to continue functioning while the “downstairs” market may fail or shut down with very wide bid–ask spreads. Bessembinder and Venkataraman (2003) provide empirical evidence for the issues raised in Grossman (1992) using data from the Paris Bourse.² In addition, Lyons (2000) shows that in foreign exchange markets, the direct dealer market is chosen over the use of limit orders in the electronic broker market under extreme circumstances.

There are also a number of papers that investigate order placement strategies, in particular the trade-off between market and limit orders. For example, Demsetz (1968) and Cohen et al. (1978, 1981) argue that if the probability of execution is low enough, limit order traders will prefer to submit market orders and at times prefer not to trade at all. As a consequence, although limit orders typically provide stable bid–ask spreads, especially for active stocks, unusually large bid–ask spreads may “persist” in the event that limit order trading becomes too costly. Rock (1990) and Seppi (1997) model another cost of limit order trading, namely the adverse selection cost imposed by competing liquidity providers. Given the notion that standing limit orders are open options to trade, floor traders and specialists have the ability to pass through to the limit order book undesirable order flow. As the cost of this undesirable order flow rises, limit order traders may opt to provide less liquidity. On the other hand, Chakravarty and Holden (1995), Harris and Hasbrouck (1996) and Handa and Schwartz (1996) demonstrate the benefits, under normal market conditions, of placing limit orders at or inside the bid–ask spread thereby taking advantage of cost savings as well as a high probability of execution.

A number of papers related directly to the issue of timing have focused on the circuit breaker debate.³ Some, such as Kyle (1988), Greenwald and Stein (1988, 1991), Kodres and O'Brien (1994), and Brady (1998) argue that a temporary closure allows liquidity providers, particularly buyers, to ‘catch-up mentally’. These papers argue that market participants are likely to remain active during a market closure, repositioning their orders to account for the lower prices. Others, such as Coursey and Dyl (1990), Grossman (1990), Subrahmanyam (1994, 1995) and Ackert et al. (2001) suggest that a temporary market closure at best postpones market activity until trading can again generate information and, at worst, may have the perverse effect of increasing price volatility by triggering the ‘magnet effect’. These papers suggest that activity is likely to be accelerated ahead of the closure trigger and there is likely to be no activity during the closure.

Our results show that a substantial liquidity shift from the electronic system to the NYSE floor occurred not on the day of the market break (Monday, October 27th) but rather on the following day (Tuesday, October 28th), consistent with the suppositions of Cohen et al. (1978, 1981) and Grossman (1992). While these results

² Similarly, Venkataraman (2001) shows that trading costs are lower on the NYSE than on the electronic limit order book of the Paris Bourse, and also argues that the reason for this difference is the benefit of the flexibility of the floor brokers on the NYSE over the inflexibility of the limit orders on the Bourse.

³ For example, see Cochrane (1998) and Lucchetti and Ip (1998). See Harris (1998) for comprehensive overview of the circuit breaker debate.

are similar, they are more dramatic than those for single-stock trading halts found in [Bhattacharya and Spiegel \(1998\)](#) and [Corwin and Lipson \(2000\)](#). This displayed liquidity drain is characterized by significantly wider limit order book spreads as well as significantly diminished depth throughout the limit order book. However, unlike the results under normal conditions suggested by [Cohen et al. \(1981\)](#), [Chakravarty and Holden \(1995\)](#) and [Harris and Hasbrouck \(1996\)](#) suggesting that traders will submit limit orders that tighten limit order book spreads if they get too wide, limit order book spreads widened and remained wide all day Tuesday. Despite the significantly diminished liquidity provision by the limit order traders, quoted spreads remained relatively narrow with normal quoted depth, supporting the suggestions of [Grossman \(1992\)](#) that more brokered markets are more valued within complex information environments and may stay open even when limit order book markets fail. Since these changes occurred around the time of the execution of the first circuit breaker, the results suggest that the impetus for the switch from the electronic limit order book system to the exchange floor was the uncertainty associated with the possibility of not being able to trade rather than the sharp decline in prices.

Given these circumstances, traders revealed both the value of discretionary floor trading and the implicit cost in submitting an order electronically. On Tuesday, trading on the floor of the NYSE accounted for significantly more of the overall trading volume than that which arrived electronically via SuperDot, implying a significant shift in trading venue on the part of market participants in favor of discretion and flexibility during difficult market conditions as predicted by [Grossman \(1992\)](#). While we know from [Demsetz \(1968\)](#), [Cohen et al. \(1981\)](#), [Harris and Hasbrouck \(1996\)](#) and others that limit orders tighten the spread under normal conditions, it appears that the *reverse* result occurs during unusual times. Surprisingly, the migration of liquidity from the book to the floor was most keenly seen in the high trading volume stocks, especially those that are part of the Dow Jones Industrial Average (DJIA), that are normally most dependent on the limit order book for setting the spreads. While [Demsetz \(1968\)](#), [Cohen et al. \(1981\)](#) and [Bhattacharya and Spiegel \(1998\)](#) suggest that more active stocks will have tighter spreads, we find that high trading volume stocks showed much wider limit order book spreads than low trading volume stocks. By changing trading platforms in the high volume stocks, traders revealed that the relative costs of submitting a limit order changed more dramatically in high volume stocks than in low volume stocks, a result which has particular resonance for ECNs that tend to focus on higher volume stocks.

The results also showed that market participants were conscious of the timing of their actions. As the probability of a market-wide circuit breaker increased, market participants wanted to avoid being constrained not to trade, so they accelerated the timing of their trades consistent with the ‘magnet effect’ suggested by [Subrahmanyam \(1994\)](#). Specifically, market participants increased demand for sellside immediacy by submitting market sell orders in such a way that they became more numerous, more aggressive and on average larger while limit buy orders cancelled with greater intensity. In an analogous way, market participants demonstrated their preference for unconstrained trading: during the circuit breaker market participants generally used the opportunity to cancel limit orders rather than to place new ones.

The consequence was decreased depth on the limit order book—especially for limit order prices further from the quotes—from the time the circuit breaker was lifted until the end of trading.

Thus, this analysis is important for a number of reasons. First, the analysis reveals the forces that both promote and hinder the provision of liquidity via limit orders, a fundamental aspect for all liquidity provision mechanisms, especially electronic limit order book systems. Specifically, the ability to trade with *discretion* is highly valued during periods of extreme market movements. As a result, limit order trading at the margin becomes unprofitable, causing those who would be liquidity providers in more calm markets to switch to being liquidity demanders during more turbulent times. Second, ECNs and electronic limit order book systems are ubiquitous, and are often advertised as the future of security trading, as noted in [Schack \(2000\)](#) and [Kutler \(2001\)](#). Given this billing, it is important to understand how changes in the preferences of market participants will impact these systems during periods of market turbulence, particularly given the possibility of electronic market failure in [Cohen et al. \(1981\)](#), [Grossman \(1992\)](#), and [Subrahmanyam \(1994\)](#). Finally, the analysis has implications for the effectiveness of regulations set out to maintain the orderly working of markets during crisis periods. Our results reveal that the market wide halt appears to have accelerated trade ahead of the trigger and dampened all activity during the halt. Consequently, the actions of market participants indicate that the market-wide circuit breakers at best may have no effect and at worst could exacerbate the very problem they were meant to address.

The remainder of the paper is organized as follows. Section 2 describes the strategic tradeoffs facing market participants in the context of the venue, order type, and timing choices they make as well as some example trading strategies. Section 3 describes the data, time period investigated, and methodology used in constructing the estimates of the limit order books. Section 4 investigates the choice of trading venue and the types of orders submitted. Section 5 details the timing of market participant activity surrounding the market wide circuit breaker. Section 6 concludes.

2. Strategic tradeoffs

A trader's order submission strategy encompasses a variety of choices, including trading venue, order type, and the timing of their actions. Each of these three choices involves tradeoffs. While during relatively normal periods, market participants may avail themselves of all of these choices, there may be times when market participants have a specific preference for one type or another of the joint venue/order type/timing choice. The three choices we address are not only highly inter-related; they are also invariably connected to the decision to provide liquidity. We discuss each in turn.

2.1. Trading venue

At the NYSE, the electronic limit order book is linked to the floor-based trading platform through the specialist. In this case, there are two separate, yet co-existing,

trading platforms that trade the same stocks, at the same time, during the same market conditions. Market participants decide between these two platforms in how their trading interest is routed to, and handled in, the market. On the one hand, traders can send their orders to the market electronically through the NYSE SuperDot system.⁴ In this case, the electronic routing system itself acts as “agent” on behalf of the trader for the order. This method allows for fast, cost-effective trading, but provides limited conditioning of orders beyond size, direction (buy or sell), and price. On the other hand, traders can send their orders to the market via a broker who represents their interest within a larger trading crowd. In this case, the human broker acts as agent on behalf of the trader for the order. As Grossman (1992) argues, human interactive systems provide contingent/discretionary trading where the broker can condition on many current market factors such as the crowd size, direction of the market, size of the bid–ask spread, depth imbalance, or the movement of other stocks or futures contracts. Thus, these markets allow for more human discretion, but are often slower and more expensive in terms of direct brokerage costs.⁵ Thus, when deciding between trading venues, market participants weigh the speed and cost effectiveness of the electronic systems against the flexibility of the floor-based systems. When uncertainty about the state of the market is low, the cost effectiveness of the electronic system may be preferred; however, when there is great uncertainty about the state of the market, the need for discretionary trading may dominate.⁶

2.2. Order type

Market participants also weigh the costs and benefits of submitting a market order versus submitting a limit order. Market orders bear price risk in that they guarantee execution but transact at a price that is unknown *ex ante*. In contrast, non-marketable limit orders bear execution risk since they have a guaranteed price but

⁴SuperDot is an electronic routing system by which brokers can submit orders directly to the specialist post on the floor of the NYSE, where the order will either be placed on the limit order book or be represented to the trading crowd. See Hasbrouck et al. (1993) for more institutional details on the SuperDot system.

⁵These systems work in significantly different ways. The SuperDot system directly routes an order electronically to the specialist post for either entry onto the limit order book (in the case of a limit order) or representation to the floor (market order). As a result of this electronic transmission, the receipt of the order at the specialist post is almost instantaneous. However, an order sent to a floor broker first arrives at the trading booth of the floor broker, where a clerk notes its details. These trading booths are on the perimeter of the NYSE floor, and trading clerks are not allowed to cross onto the NYSE trading floor itself. During the time period of this study, to get the order to the floor broker, the clerk must either use a “runner” employed by the NYSE to walk the order to the broker, or the clerk must page the broker. To answer the page, the broker must either return to the booth or step out of a trading crowd to use telephones on the floor of the NYSE, get the order, and then return to the trading crowd. This process, while relatively fast, is still much slower than the electronic submission mechanism of SuperDot.

⁶Cohen et al. (1981) and Grossman (1992) note that it is even possible for traders to shun the electronic limit order books altogether in favor of discretionary market orders. In these cases, the savings in potential execution costs may far outweigh the limited additional brokerage costs incurred with human—as opposed to electronic—systems.

face the possibility that the order may go unexecuted. Furthermore, limit order traders decide on the aggressiveness of the order through their choice of a limit price. As noted in Harris and Hasbrouck (1996), limit prices close to (far from) the quoted prices have an increased (decreased) chance of being executed, yet the order recoups less (more) of a premium relative to a market order.

A useful way of summarizing the tradeoffs between market and limit orders is through the decision either to consume or supply liquidity. By demanding immediate execution, market orders can be thought of as demanding liquidity. In contrast, limit orders allow the execution of their order to be determined by another trader, thereby providing the market with a free option to trade, as noted in Rock (1990) and Harris and Panchapagesan (2002). In this way, limit order traders are supplying liquidity to the market. Limit order traders are faced with many risks when supplying liquidity: the risk that they trade with someone possessing superior information, the risk that a market maker passes on undesirable order flow, and the risk associated with price uncertainty. During periods when these risks are heightened, limit order traders may strategically choose to reduce liquidity, either by shifting depth away from the quotes or reducing the depth provided at a given price. In fact, it is possible that limit order traders may no longer be willing to supply *any* depth at certain prices, and may become liquidity *demanders* instead of liquidity *suppliers*, as in Cohen et al. (1981) and Harris and Hasbrouck (1996).

2.3. *Timing of actions*

A trader's decision concerning the timing of their actions often revolves around whether the set of feasible actions either becomes constrained or expanded at some point in the future. Under the basic notion that options/possibilities are valuable, then, if the set of feasible actions has a possibility of becoming constrained, traders may decide to act ahead of the change. Similarly, if the feasible set of actions has a possibility of expanding, traders may wait to take advantage of the alternative possibilities. This decision begins to play a central role during fast-moving markets where the current market environment is fleeting as well as surrounding a market-wide trading halt, as noted in Subrahmanyam (1994).

2.4. *Trading strategies*

A market participant's trading strategy combines all these individual decisions to achieve a particular objective. Given that these choices are not independent, that is, certain types of orders may only be used on certain systems, there are two basic strategies that are at the core of our analysis to follow: discretionary orders and marketable limit orders.

While an order submitted via SuperDot results in a faster transmission to the floor of the NYSE than using a floor broker, the choice of order type on SuperDot is relatively limited. Orders submitted via SuperDot are typically either simple market orders or simple limit orders. In contrast, there are a number of more sophisticated orders that can be employed if the order is submitted to the floor—such as “not

held” orders, or go-along orders—that can more fully condition on the state of the market. The ultimate of such orders, the discretionary order, allows the broker to use his/her discretion as to how and when the order should be executed. For these orders, the broker can condition on many factors, such as the size of the crowd, the direction of the market, the size of the bid–ask spread, the relative imbalance of the quoted depths, and the movement of other stocks or futures contracts. Another benefit of these discretionary orders is the ability to interact with orders submitted by other traders, including those sent electronically.⁷ Furthermore, while orders sent electronically through SuperDot are known to market participants on the floor, those held by floor brokers are not necessarily disclosed. As [Blume and Goldstein \(1997\)](#) note, there may be times when this discretion of whether or not to disclose or display trading interest may be valuable, particularly if the order is large relative to the normal trading size in that stock.

A marketable limit order is an electronic order that attempts to combine the benefits of various orders. Recall that a market order is not guaranteed execution at the prices posted at the time of order submission. It is possible that prices may move between the time the order is submitted and the time it is executed on the floor. This movement of prices may be significant, particularly during a period of fast moving prices, resulting in a guaranteed execution but at a price that is potentially unacceptable to the trader. For this reason, some traders may use the strategy of submitting marketable limit orders—limit orders whose price upon submission make them eligible for immediate execution based on the bid–ask spread at the time of arrival on the floor. If the prices do not move, the order will get executed at an acceptable price; if the prices do move adversely for the trader, the order will remain unexecuted on the limit order book. Such a strategy relies on the rapid transmission of the order and protects the trader from adverse movements, but at the cost of less opportunity for price improvement, as noted by [Angel \(1994\)](#) and [Peterson and Sirri \(2002\)](#).

Thus, depending on market conditions, one strategy might dominate others. Moreover, different strategies will be optimal for traders at different times, and may vary from stock to stock based on the size of the order and the trading volume of the stock. For example, in relatively normal times, the risk of market movements is small and the speed/brokerage cost differential may offset execution risk such that a strategy of using limit orders to capture the spread might be profitable with little risk, as suggested by [Demsetz \(1968\)](#), [Cohen et al. \(1981\)](#), or [Chakravarty and Holden \(1995\)](#). During turbulent markets, however, the heightened execution risks might more than offset any of the other perceived benefits making this a risky strategy indeed. Therefore, we would expect that during turbulent markets, traders are more likely to avoid limit order strategies and prefer those with market orders. In addition, the value of discretion should rise, thus more orders should be routed to the brokers on the floor. Of course, different stocks have different trading characteristics that

⁷ [Blume and Goldstein \(1997\)](#) provides a detailed example of how a broker with a “not held” order may interact with orders coming from the limit order book so as to maintain the last mover advantage described in [Rock \(1990\)](#).

might also affect the choice of strategy. Those stocks that during more calm periods have active limit order book competition are likely to be affected more significantly by the move to the floor than those who normally see little, if any, limit order book competition.

3. Data, methodology, and sample statistics

We use order data and quote data provided by the NYSE to explore these tradeoffs.⁸ The order data consists of order placement records as well as execution and cancellation records placed through the SuperDot system. The quote data is made up of prices and depths posted by NYSE specialists. The stock sample was generated from the 100 surviving common stocks of the Trades, Orders, Reports and Quotes (TORQ) database at the time the data was collected, November 1997.⁹ Table 1, panel A, provides some summary characteristics for the stocks in our sample. The market capitalization, trading volume and price variables were calculated as of year-end 1996. We divided our sample into three groups. Since the event we are examining is related to changes in the DJIA, we separated out the six DJIA stocks: ATT, Boeing, Exxon, General Electric, IBM, and Philip Morris. The remaining 94 stocks are divided evenly into high and low volume groups, based on each stock's volume in December 1996.

Given our interest in recovering market participants' preferences through changes in their actions, we choose a period that was sufficiently turbulent that their preferences will be revealed relatively unambiguously, and compare it with a more normal control period. We therefore define our turbulent period as the period surrounding the October 1997 market break of Friday, October 24, 1997 to Wednesday, October 29, 1997.¹⁰ We also construct two control periods prior to the event, although our choice of control periods was constrained in two ways. First, since the NYSE reduced its minimum tick size on June 24, 1997, periods before and shortly after the tick size change would be inappropriate for use as control periods due to the shift in liquidity provision described in Goldstein and Kavajecz (2000) and Jones and Lipson (2001). Second, periods close to the October market break are also inappropriate for use as control periods as they may potentially display some preliminary effects of the market break. To minimize these confounding effects in our control sample, we use July 18–23, 1997 as the first control period and September 12–17, 1997 as the second control period. Both control periods and the

⁸We thank the NYSE for providing the data for this study.

⁹The TORQ database is a stratified sample of 144 stocks and contains all trades that took place, all orders that were placed through one of the automated routing systems, a detailed report on the listing of counterparties, and the specialist's quotes. For more information about the TORQ database see Hasbrouck (1991).

¹⁰A synopsis and brief chronology of events on these days can be found in the Appendix.

Table 1

Sample summary statistics

Table 1 contains summary statistics on our data set. Means, medians, and standard deviations are presented for the entire sample of 100 stocks, as well as by trading volume category. DJIA represents stocks that were components of the Dow Jones Industrial Average on October 1997. High volume and Low volume represent high and low volume stocks based on December 1996 average monthly trading volume, respectively. Market capitalization is in millions of dollars as of 1996 year end. Trading volume is in thousands of shares per month. Price level is taken at 1996 year end. Quoted depth is the total of the bid and ask depth in shares. The limit order book spread and depth represent the difference between the best sell- and buy-side limit prices and the total depth at the best prices in shares, respectively. Liquidity characteristics are based on the July and September 1997 control periods.

Variable	Mean	Standard deviation	Median
<i>A. Stock characteristics</i>			
Market capitalization (\$ millions)			
DJIA	93,731	43,671	85,218
High volume	6,103	7,661	3,516
Low volume	551	616	351
Trading volume (shares/month)			
DJIA	58,169	21,843	63,507
High volume	10,727	12,353	5,949
Low volume	718	644	475
Price level (\$ per share)			
DJIA	101.88	34.80	102.69
High volume	35.25	20.49	31.75
Low volume	31.40	37.05	24.38
<i>B. Liquidity characteristics</i>			
Quoted spread (\$ per share)			
DJIA	0.10	0.06	0.06
High volume	0.12	0.07	0.13
Low volume	0.26	0.48	0.13
Limit order book spread (\$ per share)			
DJIA	0.08	0.08	0.06
High volume	0.17	0.37	0.06
Low volume	0.66	1.77	0.13
Quoted depth (shares)			
DJIA	29,418	35,994	18,550
High volume	11,544	14,735	6,900
Low volume	5,083	6,587	2,800
Limit order book depth (shares)			
DJIA	29,117	35,212	18,540
High volume	10,743	15,662	6,200
Low volume	5,468	6,941	3,045

market break period begin at 12:00 noon on Friday and end at the close the following Wednesday to reduce any day-of-the-week effects.¹¹

Data from each of the three periods are used to construct limit order book estimates using the technique described in Kavajecz (1999). The principle behind the limit order book estimation is that at any instant in time the limit order book should reflect those orders remaining after the orders placed prior to the time in question are netted with all prior execution and cancellation records. The first step involved in estimating the limit order book at a particular point in time is estimating the limit order book at the beginning of the period. We use data from March 1997 through November 1997 to search for all records that have order arrival dates prior to the period in question. We use the good-'til-cancelled limit orders to form an estimate of the initial limit order book (or "prebook") at the start of the period.

After the prebook is constructed, current records in the database are processed. To estimate the limit order book for a given date and time, all records with a date and time stamp prior to the chosen date and time are selected and separated into their respective categories: orders, executions and cancellations. New orders are added to the prebook and execution and cancellation records are matched to existing orders on the limit order book, where matched orders are eliminated. The remainder, the set of orders or residual orders that were not executed or cancelled, becomes our estimate of the limit order book for the chosen date and time.

This methodology allows us to create a sequence of "snapshots" of the limit order book by sequentially updating the limit order book estimates. Limit order books are estimated at 30-minute intervals on the half-hour; however, there are two exceptions to this rule. The first exception is the initial limit order book estimates of each day, which is calculated at the time of each stock's opening quote. The second exceptions are the estimates at 2:30, 3:00 and 3:30 PM on October 27, 1997 that are instead calculated at 2:36 PM (the initiation of the first circuit breaker), 3:06 PM (the end of the first circuit breaker) and 3:40 PM (just after the halting of the market for the day) to coincide with the market-wide trading halts. The result is a sequence of limit order books "snapshots" comprised of approximately 50 observations in each of the three periods for each of the 100 stocks in the sample. Unless otherwise noted, results are equally weighted averages across stocks within a given thirty minute time period.

Panel B of Table 1 provides some summary statistics on the average quoted spread and depths as well as the average limit order book spread and depth for our sample during the control period. The liquidity measures are calculated during the control periods to provide a benchmark for evaluation of the results to come. Note that during the control period both the quoted and the limit order book spread (depth) were smallest (largest) for the DJIA stocks, then for the high volume group, and finally for the low volume group. In particular, during the control period the mean

¹¹ To verify that market-wide factors do not lead to similar effects on the trading behavior of all firms (beyond that of the market movements under question) and thereby violate independence assumptions, we applied each of the tests using one of the control periods as the "event" and the other control period as the "control" to check whether rejections of the null are infrequent. The results overwhelmingly failed to reject the null.

quoted spread was \$0.10, \$0.12 and \$0.26 for the DJIA, high volume and low volume stocks respectively. Together, the spread and depth measures indicated that during normal periods the DJIA stocks were the most liquid, followed by the high volume stocks, and that the low volume stocks are the least liquid.

4. The joint decision of venue and order type

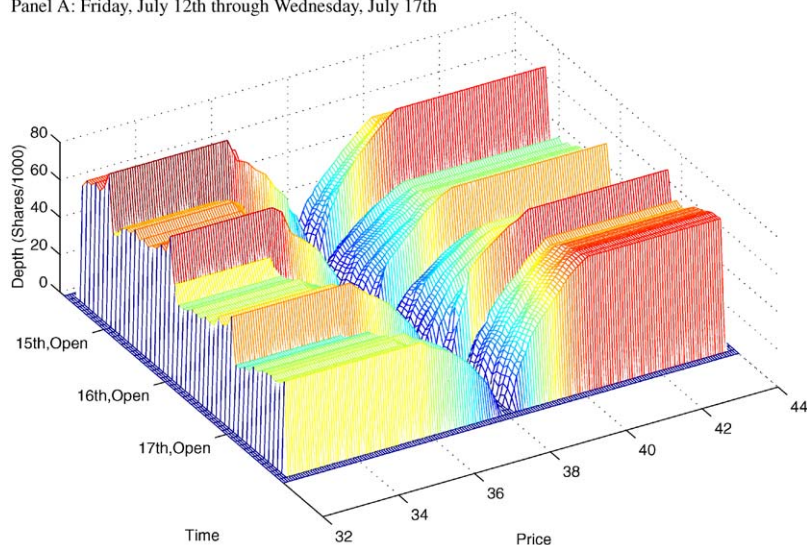
Our analysis of a trader's joint decision of venue and order type investigates the relative contributions to liquidity provision by limit order traders as well as the level of activity taking place on the exchange floor. We analyze whether the choice of trading platform changes depending on market conditions. In particular, we look to answer the first question posed in the introduction, namely, do market participants prefer the electronic limit order book during relatively calm periods and the floor during periods of market turbulence?

To answer this question, we begin by investigating limit order book liquidity provision to establish whether market participants did, in fact, reduce their participation in the limit order book. We do so by analyzing the limit order book spread, i.e., the spread between the best buy-side and sell-side limit order prices, and the cumulative depth, i.e., the sum of all shares available at a particular price or better on the limit order book, at successively distant prices.¹² Chart 1 displays 3-dimensional images of the time series of half-hour cumulative limit order book depth observations for all stocks in our sample. The data were calculated by averaging the cumulative depths across the sample stocks in increments of sixteenths as far away as two dollars from the best buy-side and sell-side limit prices. These averages are then placed at the appropriate dollar distance from the average best buy-side and sell-side limit prices. Therefore, the right (left) side of each panel indicates the average cumulative depth of sell (buy) limit orders. The average limit order book spread is the range of prices over which the cumulative depth is zero, which creates the floor of the valley in the center. The rising cliffs on each side represent the cumulative depth on the buy-side (sell-side) as limit prices fall (rise). Consequently, each panel displays the time series of average demand (buy-side) and supply (sell-side) schedules for all of the stocks in our sample.

Panel A of Chart 1 displays the limit order book over the control period July 12–17, 1997, while Panel B displays the limit order book over the market break period October 24–29, 1997. Panel A consistently shows large cumulative depth and small limit order book spreads, indicating strong liquidity provision by market participants via the limit order book over the control period. In stark contrast is

¹² More specifically, cumulative depth on the buy side is measured from the highest limit order on the buy (bid) side of the limit order book, while cumulative depth on the sell side is measured from the lowest sell limit order price on the sell (ask) side of the limit order book. This definition is different than if measured from the midpoint of the bid–ask spread, as in [Corwin and Lipson \(2000\)](#), or from the quoted bid and quoted ask respectively, as in [Goldstein and Kavajecz \(2000\)](#). The more conservative method used in this paper biases the results away from finding changes in cumulative depth, since unlike the other methods, it does not include the size of the limit order spread in its calculations.

Panel A: Friday, July 12th through Wednesday, July 17th



Panel B: Friday, October 24th through Wednesday, October 29th

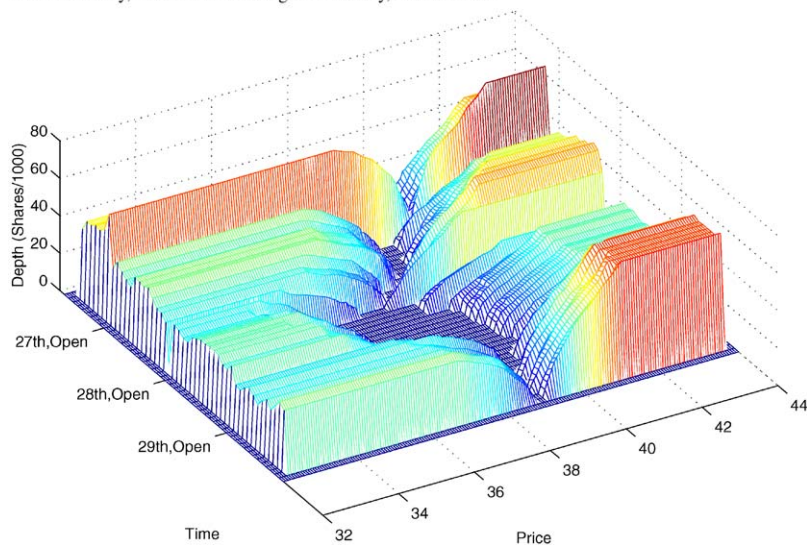


Chart 1. Aggregate cumulative limit order book depth. The chart depicts the average cumulative limit order book depth for the 100 stocks in our sample each half-hour over the period Friday, July 12, 1997 at noon through the close Wednesday, July 17, 1997 (Panel 1) and Friday, October 24, 1997 at noon through the close Wednesday, October 29, 1997 (Panel 2). Limit order books (LOB) were estimated using the technique described in Kavajecz (1999). The prices of the buy (sell) orders in each stock's thirty-minute snapshot are adjusted so that the spacing between the buy (sell) orders is maintained and the best buy (sell) orders are positioned at the average midpoint price for all of the stocks plus (minus) one half the average limit order book spread. The chart shows equally weighted averages of these adjusted snapshots for each time interval. The valley in the center represents the average limit order book spread.

Panel B, which provides the analogous view of average cumulative depth over the October market break. Note that in Panel B the limit order book spreads over the three days vary dramatically, unlike the control period. The average limit order book spreads on Monday, Tuesday and Wednesday were \$0.75, \$2.90, and \$0.57 respectively. Interestingly, with few exceptions, the values on Monday are not significantly different from the limit order book spreads of the control sample, while the values for Tuesday, the day *after* the market drop, are significantly different from the control sample at the 5% level throughout the entire day.¹³

Thus, despite the steadily declining market throughout Monday, the level of cumulative depth remains statistically in a normal range until the end of the initial trading halt. Cumulative depths during the last half-hour of trading on Monday and throughout Tuesday were statistically lower than the control sample for limit prices an eighth or more away from the best buy-side price and a quarter or more away from the best sell-side price, indicating a decreased willingness on the part of market participants to display liquidity away from the most aggressive prices after the first circuit breaker was executed. Surprisingly, the depths at the best buy-side and sell-side limit prices are in general not statistically different from the depths in the control sample, even though 17 limit order books estimates were empty on the buy-side at some point on Monday or Tuesday, while there were only four cases during the control periods.^{14,15}

The contrast between Panels A and B is striking and consistent with the predictions of [Cohen et al. \(1981\)](#). As of late Monday afternoon, there was a dramatic decrease in market participants' willingness to provide liquidity through the electronic limit order book. The absence of a statistical difference in both Monday's limit order book spread and cumulative depth series versus the control sample suggests that, in general, limit order traders continued to use the electronic limit order book even through the steep decline in the market until the market-wide trading halt was initiated. However, by failing to replace day limit orders that expired on Monday, market participants chose not to provide liquidity via the electronic limit order book the following day.¹⁶

¹³ Throughout the paper, to consider a result significant at the 5% level, we require that the p -values for both parametric and nonparametric tests be less than 5%. In particular, we require that t -tests for both equal and unequal variances have p -values less than 0.05 and that the Wilcoxon 2-sample test and the Kruskal–Wallis test had p -values of less than 0.05. Only in the case that all four tests had p -values less than 0.05 do we consider the results significant at the 5% level.

¹⁴ For conservatism, we assign non-two-sided limit order books a limit order book spread of *zero*, the smallest possible limit order book spread. In this way, we bias against finding large changes in the limit order book spreads during times of empty limit order books, such as on Tuesday.

¹⁵ Interestingly, the possibility of empty limit order books was predicted by [Cohen et al. \(1981\)](#), who noted that once spreads get wide enough, it is possible, although “atypical”, that “the limit order book would be empty on one or both sides”.

¹⁶ Wednesday shows some signs of recovery as the limit order book spread returns to normal levels; however, the lower cumulative depth persists. Although not shown, cumulative depths on Wednesday afternoon are statistically smaller than the control sample for limit prices an eighth away from the best buy-side price and within an eighth of the best sell-side price. In this way, these results are consistent with [Cohen et al. \(1978\)](#), which suggests that while traders' dynamic choices of market versus limit orders tend to provide stable spreads, disequilibrium or unusually large spreads “can persist over many transactions.”

It is possible, however, that not all stocks experienced similar liquidity drains, since investors may often choose different trading strategies for different stocks depending on the stocks' trading characteristics. To investigate this possibility, Table 2 examines quote and limit order book behavior for our three sub-groups: the six DJIA stocks, and the high trading volume stocks and low trading volume stocks. (Chart 2 provides a visual representation of the spread data.)

As Table 2 and Chart 2 indicate, on Monday both the quoted and limit order book spreads remained in a normal range and maintained their normal relation among the three groups, namely that the DJIA stocks had the smallest spread, followed by the high volume stocks, while the low volume stocks had the largest spread. While on Tuesday the quoted spreads remained in a normal range and maintained their relative ordering, this was not true for the limit order book spreads. The dramatic increase in limit order book spreads on Tuesday shown in Chart 1 occurred for DJIA, high volume, and low volume stocks alike. The average limit order book spread for the DJIA stocks, which was only six cents when the market shut on Monday, increased 5250% to \$3.21 at Tuesday's open. By Tuesday's close, the average limit order book spread for the DJIA stocks had increased to \$4.09, a 6717% increase over the previous day's close. Even more notable, however, is that on Tuesday market participants' behavior *reversed* the normal ordering among the average limit order book spread for the DJIA stocks, the high volume group, and the low volume group. Even though the average limit order book spread for both the high and low volume groups was economically and statistically significantly higher than the control periods, they were still *smaller* than the average limit order book spread for the DJIA stocks by 25 to 50 cents.¹⁷ These results on quoted and limit order book spreads after a market-wide event differ from the theoretical predictions of Demsetz (1968) and Cohen et al. (1981) and the empirical single stock trading halt results in Bhattacharya and Spiegel (1998), which found that the largest stocks are more liquid than smaller firms based on percentage quoted bid–ask spread measures.

Thus, unlike Monday, where market participants maintained the normal liquidity ordering among the three groups, Tuesday displayed a marked aversion to providing liquidity via the limit order book, particularly for the DJIA stocks.¹⁸ The results on the quoted spread, however, stand in direct contrast to the limit order book spread results. Not only was the normal relation among the quoted spread and depth of the three groups maintained, but unlike the limit order book spread, the quoted spread increased only slightly and remained relatively constant on Tuesday. These results suggest that despite abandoning the electronic limit order book, at least some market participants were willing to supply liquidity via the floor on Tuesday.

Additional evidence of a change in trading strategies over this period, particularly the order type used, can be uncovered through a closer comparison of quoted and

¹⁷ As mentioned previously, non-two-sided limit order books were conservatively assigned a limit order book spread of zero in Table 2. We re-ran the limit order book spread statistics in Table 2, removing all non-two-sided limit order books. All of the results remained similar or increased in significance.

¹⁸ Although similar in nature, these market-wide results are deeper and longer-lasting than those in Corwin and Lipson (2001) for individual stocks.

Table 2

Quoted and limit order book spread depth by volume group

This table presents data on the limit order book spread as well as the cumulative depth on the buy-side and sell-side of the limit order books of the 100 stocks in our sample for October 27 and 28, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1999). Results are from equally weighted averages across stocks of snapshots of the limit order books at each point in time. The LOB spread is the spread between the best buy-side and sell-side limit order prices. Cumulative depth is the sum of all shares available at a particular price or better on the limit order book. Cumulative depth is measured from the best limit order price on the limit order book on that side of the market. Values in **bold (bold italics)** are significantly larger (smaller) than the control periods July 18–23, 1997 and September 12–17, 1997 at the 5% level for both parametric and non-parametric tests.

Time	DJIA stocks					High volume stocks					Low Volume Stocks				
	Quoted		LOB			Quoted		LOB			Quoted		LOB		
	Spread	Depth	Spread	Depth at best	Depth $\frac{1}{4}$ away	Spread	Depth	Spread	Depth at best	Depth $\frac{1}{4}$ away	Spread	Depth	Spread	Depth at best	Depth $\frac{1}{4}$ away
<i>A. Monday, October 27, 1997</i>															
Open	0.17	9,483	0.28	6,772	38,203	0.22	3,239	0.52	3,567	8,066	0.37	1,719	2.01	2,160	5,641
10:30	0.10	8,650	0.04	5,602	53,404	0.15	3,532	0.15	2,945	11,048	0.27	1,888	1.53	2,042	5,636
11:30	0.13	26,325	0.08	13,111	57,158	0.19	3,957	0.34	3,667	13,037	0.30	1,988	1.89	3,248	6,537
12:30	0.10	9,650	0.07	7,310	42,046	0.15	4,596	0.18	4,525	16,453	0.28	2,776	1.02	3,212	6,886
1:30	0.21	5,933	0.03	4,267	38,180	0.16	5,089	0.22	4,369	15,460	0.29	3,564	0.81	3,200	7,189
2:36	0.16	10,892	0.03	18,499	61,184	0.17	5,477	0.40	4,820	13,721	0.26	2,534	0.97	2,135	6,641
3:06	0.17	9,550	0.04	21,784	64,323	0.12	5,636	0.42	4,442	10,510	0.26	2,629	1.10	1,989	5,880
3:36	0.22	7,742	0.06	13,451	31,910	0.17	4,082	0.57	3,642	8,804	0.30	1,572	1.20	2,072	5,402
<i>B. Tuesday, October 28, 1997</i>															
Open	0.17	8,175	3.21	9,854	23,820	0.24	3,485	1.81	3,768	6,946	0.52	1,512	2.25	1,862	5,160
10:30	0.19	17,110	3.26	9,153	10,771	0.20	3,240	2.80	3,573	6,336	0.29	2,074	2.97	3,994	6,605
11:30	0.28	6,858	3.43	8,482	11,275	0.15	4,192	2.81	4,600	9,887	0.29	1,692	2.94	4,133	6,861
12:30	0.13	15,200	3.43	8,580	13,078	0.15	5,416	2.89	3,230	12,002	0.27	2,603	2.91	4,672	8,166
1:30	0.14	3,917	3.57	10,249	13,989	0.14	5,488	2.91	4,572	11,756	0.35	1,973	2.93	4,323	7,978
2:30	0.10	2,408	3.55	9,040	24,759	0.19	2,990	2.91	2,726	10,422	0.35	2,193	3.02	4,467	7,403
3:30	0.27	10,700	3.97	8,138	28,805	0.17	3,364	2.91	2,968	8,574	0.28	1,400	3.25	4,157	7,071
Close	0.14	13,258	4.09	8,688	31,641	0.14	7,160	2.89	4,265	15,047	0.29	2,343	3.16	4,435	7,609

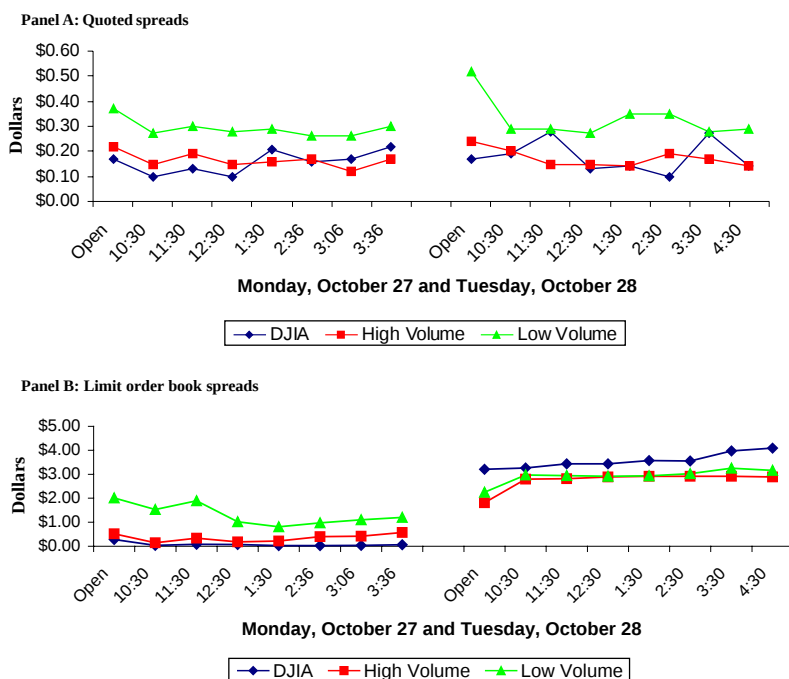


Chart 2. Quoted and limit order book spread by trading volume groups. This chart presents data on the limit order book spread and total cumulative depth of the limit order books of the 100 stocks in our sample for October 27 and 28, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1999). Results are from equally weighted averages of snapshots of the limit order books every thirty-minute. The LOB spread is the spread between the best buy-side and sell-side limit order prices. Cumulative depth is the sum of all shares available at a particular price or better on the limit order book. Cumulative depth is measured from the best limit order price on the limit order book on that side of the market.

limit order book spreads. Consider for example that on a normal day, some traders will decide on a trading strategy that employs marketable limit orders or limit orders that improve the quote on one side. While the submission of a quote-improving order will reduce the limit order bid–ask spread, it will not necessarily change the quoted spread as NYSE rules allow the specialist up to 30 seconds before the quotes must be changed to reflect a new limit order. Since the limit order book spreads in the DJIA stocks were less than the quoted spreads on Monday, the data in Table 2 indicates that at least some market participants were submitting quote-improving limit orders in every period where that was possible. In fact, since marketable limit orders will reduce the limit order book spread to zero immediately prior to their execution, we can infer that some of the orders submitted on Monday were marketable limit orders that were not immediately executed, as the limit order book spreads on Monday on DJIA stocks were less than the minimum tick size of \$0.0625. However, this is decidedly not the case on Tuesday. On Tuesday, the quoted spreads

were much smaller than the limit order book spreads. Thus, market participants displayed an increased willingness to submit quote-improving limit orders on Monday than on Tuesday in DJIA stocks.

While the results thus far have clearly demonstrated the avoidance of the electronic limit order book platform, they have only provided cursory evidence of a migration of trading activity to the exchange floor. Thus, while the exodus from the limit order book is apparent, the ultimate destination of that displaced liquidity is still unclear. It could be that liquidity suppliers transferred their liquidity provision to the floor. Alternatively, they could have been transformed from liquidity suppliers to liquidity demanders or may have simply left the market altogether.

In order to provide some direct evidence of the migration of activity to the exchange floor, we wish to compare the volume executed on the exchange floor to the volume executed via the SuperDot system. Unfortunately, we do not have direct measures of trading volume executed on the exchange floor itself. However, we do have information about volume executed on the SuperDot system and the total volume traded on the NYSE. Given that executions must either occur on the SuperDot system or on the exchange floor, a marked decline in the ratio of electronic (SuperDot) executions to total executions must necessarily imply a migration of executions and activity to the exchange floor.

We therefore sum the shares recorded as executed for all orders (market and limit, buy and sell) within the NYSE order data for each stock and each time period. We also sum the trading volume that is recorded in the TAQ database for each stock and each time period. Since our order data records shares for *both sides* of the transactions (buyer and seller), while the trading volume measures from TAQ record only the number of shares that change ownership, we construct our ratio by dividing the SuperDot executions by *double* the corresponding TAQ trading volume for that stock at that time.

Table 3 provides the results for each of our three trading volume groups. In general, Monday's percentages for all groups during the market break are not significantly different from the control period, except for the period just prior to the market wide trading halt where the percentage of total executions occurring on SuperDot is significantly *higher* than the control period. In contrast, periods after the market wide circuit breaker (the last half-hour of trading on Monday and all day Tuesday) have percentages that are dramatically lower, especially for the DJIA stocks. In particular, the mean daily percentages on Tuesday were 6.5, 21.5, and 17.7 for the DJIA, high volume and low volume groups respectively, while for comparison, the mean daily percentages across all volume groups for Tuesday's control periods ranged from 47.3 to 52.5. With rare exception, the percentages after the market wide circuit breaker are statistically significantly smaller than the control percentages for all three volume groups. Thus, consistent with Grossman (1992) the dramatically lower fraction of SuperDot executions on Tuesday provides strong direct evidence that market participants altered their venue and order type choices such that they migrated from the electronic limit order book to the exchange floor.

All told the results imply a direct change in trading strategies by market participants, particularly in very high volume stocks. As the most liquid stocks saw

Table 3
Percentage of total executions occurring on SuperDot and total trading volume by group

This table presents data on the percentage of total executions that occurred on SuperDot as well as the total trading volume for the 100 stocks in our sample for October 27 and 28, 1997. Total trading volume is calculated from the TAQ database and is defined as the sum of all shares traded for each group expressed in thousands of shares. The percentage of total executions occurring on SuperDot is calculated as all shares on SuperDot execution records (market, limit, buy and sell) divided by *double* the corresponding total trading volume for that period and that group. Total trading volume is doubled in the ratio to account for the order data having records for both sides of a transaction. Values in **bold (bold italics)** are significantly smaller (larger) than the control periods July 18–23, 1997 and September 12–17, 1997 at the 5% level for both parametric and non-parametric tests.

Time	DJIA Stocks			High volume stocks			Low volume stocks		
	Percentage of total executions occurring on SuperDot			Percentage of total executions occurring on SuperDot			Percentage of total executions occurring on SuperDot		
	Total trading volume	Market break	Control periods	Total trading volume	Market break	Control periods	Total trading volume	Market break	Control periods
<i>A. Monday, October 27, 1997</i>									
10:30	8460	45.9	36.8	6297	61.8	54.2	598	66.0	88.0
11:30	7506	57.3	51.5	5066	54.2	53.1	347	56.4	53.3
12:30	6126	48.1	38.4	5252	53.6	54.2	383	62.0	43.6
1:30	5656	57.4	53.6	5012	61.4	48.9	457	63.4	59.7
2:36	9899	57.3	36.5	6514	60.4	37.0	801	64.7	36.1
3:06	N.A.	N.A.	47.9	N.A.	N.A.	57.7	N.A.	N.A.	91.8
3:36	10187	42.8	53.0	7112	30.5	59.3	583	42.5	61.6
<i>B. Tuesday, October 28, 1997</i>									
10:30	20087	5.6	41.1	10080	24.3	52.3	715	24.9	78.4
11:30	15661	9.2	52.0	11589	26.8	50.7	1084	18.6	58.2
12:30	9897	6.6	54.0	7646	22.6	58.7	631	27.0	55.3
1:30	9463	7.1	62.1	6663	26.1	54.7	703	16.9	59.4
2:30	7093	7.9	59.3	6011	26.1	55.8	557	16.2	57.9
3:30	7797	8.5	59.8	7908	22.0	58.3	962	16.4	55.7
Close	51752	0.8	3.0	37929	2.3	2.1	3578	3.8	2.9

the more dramatic reaction, it is instructive to consider possible explanations for the disparate effect across groups. One possibility that explains both the reversed relation and the different results is that while all limit order traders would like to move from providing liquidity on the limit order book to providing liquidity on the floor, the only stocks for which that alternative is feasible are the frequently traded stocks. We draw upon two facts to support this explanation. First, [Table 1](#) indicates that under normal circumstances, the limit order book tends to determine the quoted spread for high volume stocks such as the DJIA stocks, while the floor tends to determine the quoted spread for low volume stocks. Second, in general only the frequently traded stocks have an active trading crowd on the floor of the exchange.¹⁹ Even though all liquidity providers prefer to move to the exchange floor during this period, only those traders that have a substantial probability of finding a counterparty on the floor will choose to migrate. Therefore, liquidity migration will be relegated to those stocks for which there is an active trading crowd. Consistent with this explanation, a movement of liquidity providers from the limit order book to the floor produces a dramatic deterioration in displayed liquidity on the limit order book for frequently traded stocks (DJIA stocks) but a much more muted deterioration for less actively traded stocks. Moreover, the results show that during periods of market turbulence, the floor determines the quotes not only for the infrequently traded stocks—as it usually does—but also for the frequently traded stocks, for which the limit order book usually sets the quotes.

In summary, the limit order book spread and depth measures over the course of Monday and Tuesday suggest that liquidity providers exited the electronic limit order book after the market wide closure late Monday afternoon. The reduction of liquidity provision by limit order traders during times of excessive price uncertainty and adverse selection risk is consistent with the theoretical predictions of [Rock \(1990\)](#), [Grossman \(1992\)](#) and [Seppi \(1997\)](#), as well as the empirical findings of [Lee et al. \(1993\)](#), [Bremer et al. \(1997\)](#), [Chung et al. \(1999\)](#) and [Kavajecz \(1999\)](#). In particular, our market-wide results show a longer and more pronounced reduction in liquidity similar in nature to those in [Corwin and Lipson \(2001\)](#) for uncertainty related to only individual stocks. While consistent with the existing literature, the contribution of our results is that the costs associated with supplying liquidity via a limit order book appear to be larger surrounding market *closures* than they are during *sharp price declines*, and that these effects varied across stocks. In addition, the lack of change in the quoted spread and depth measures and the reduced fraction

¹⁹ In addition, the number of floor brokers on the NYSE floor is fixed. Thus, during fast moving markets, brokers are likely to concentrate on the high volume stocks for two reasons. First, brokers are more likely to find a counterparty in the large crowds by active stocks. Since brokers are paid to use discretion and provide intelligent intermediation, they can do the best job for their clients when there are other brokers in the crowd. As a result, this network effect will cause brokers to tend to congregate with other brokers. Second, as brokers are paid on commission, they will receive the highest payoff on large volume trades that they can complete quickly. These will also be in the high volume stocks. As a result, brokers will be unlikely to “work” an order in a low volume stock in either good or bad markets: in good markets, there is little action and it is not worth it for the client; in fast moving markets, while it may be worth it for the client to pay more for a floor broker, it is not worth the broker’s time.

of SuperDot executions coupled with the differential impact across volume groups—frequently traded stocks experienced a more dramatic liquidity drain—suggests that liquidity providers redirected their trading interest to the floor for those stocks that naturally have an active floor crowd.

5. Timing decisions of market participants

We turn our attention to the preferences of market participants with respect to the timing of their trading activities. Our interest is in analyzing whether market participants gravitate toward periods where there is an expanded set of possible actions yet avoid periods where actions may be constrained. Our focal point is the trading activity surrounding the first-ever implementation of the market wide trading halt. The market wide trading restriction NYSE Rule 80B (otherwise known as the circuit breaker rule) requires that there be a period in which *trading* is halted whenever the DJIA declines by a predetermined amount within a single trading day. At the time of the 1997 market break, the regulation stated that a 350 (500) point drop in the DJIA would trigger a market-wide trading halt of 30 (60) minutes.²⁰ Given that the circuit breaker constrains market participants from trading, our hypothesis is that market participants will concentrate their activities (order placement, cancellations and trades) ahead of the approaching circuit breaker trigger level and avoid activity (order placement and cancellation) during the circuit breaker. Specifically, we analyze the flow of orders as the market approached the trigger level to understand whether market participants moved quickly to exit the market ahead of the circuit breaker trigger. Next, we investigate what new activities, if any, liquidity providers engaged in during and after the market wide trading halt. Together, these analyses address the third question we posed, i.e., when do market participants begin to implement the changes documented in the earlier two sections?

While our question concerning the timing of market participant actions is a general one, our specific choice of events (circuit breakers) provides us with some important theoretical background. Subrahmanyam (1994) analyzes market participant behavior ahead of an approaching market wide circuit breaker and hypothesizes that their actions are likely to create a ‘magnet effect’. Specifically, the magnet hypothesis suggests that market participants, fearing the inability to trade when the market is halted, will alter their trading strategies in order to exit their long positions before the market halts. The rush of market participants closing their positions quickly would then exacerbate the problem by pressing the price closer to the circuit breaker trigger level. Thus, under the magnet effect hypothesis, market participants should have an increasing demand for liquidity on the buy side of the market as prices approach the halt trigger level.

²⁰Subsequently, Rule 80B has been redefined to require a 10% (20%) drop in the DJIA based on the previous quarter’s average of closing prices. A 30% drop will now close the market for the remainder of the day.

While the magnet effect is a theoretical construct, actions by market participants could reveal the existence of the magnet effect in a number of ways. First, market participants should submit market sell orders at an increasing rate and in increasing sizes as the trigger approaches. Second, limit order traders wishing to sell should decide to cancel their limit sell orders and replace them with market sell orders, choosing to exchange trading profits for immediacy. Third, limit order traders wishing to buy shares should decide to cancel or reposition their limit orders in anticipation of the approaching market wide halt.

To examine whether market participants' behavior was consistent with the magnet effect, we take advantage of a "natural experiment": during the price drop on Monday, the DJIA approached the initial trigger level on two separate occasions, but only triggered it once. At approximately 1:59 PM the DJIA came within 6 index points of the 7366 trigger level that was eventually breached at 2:36 PM.²¹ In order to investigate whether traders accelerated their activities approaching the circuit breaker trigger level, we analyze three half-hour periods, one that was not close to the circuit breaker trigger (12:59–1:29 PM), one that came close to the circuit breaker trigger but did not trigger a halt (1:29–1:59 PM), and one that actually triggered the initial circuit breaker (2:06–2:36 PM). We analyze these three half-hour periods to control for the possibility that any effects we find are simply artifacts of a rapidly declining market and not due to the change in market participants' actions due to the circuit breaker. Thus, the first period, which was not close to the circuit breaker trigger, is used to control for the fact that Monday was a high volume day with a large decline in prices. The second period, which came very close to the trigger level, but did *not* breach it, is used to control for the market being near the trigger level while the third period is used to examine the actual triggering of the circuit breaker. Therefore, if the magnet hypothesis holds, we would expect to find changes in market participant behavior consistent with the magnet effect in the two periods that came close to triggering the market wide halt but not in the first period far from the trigger level.

Table 4 measures aspects of market participant buyside and sellside activity over 10 three-minute intervals for each of the three periods. In particular, we measure the number and average size of market sell orders submitted over the relevant interval as well as the average size of sell limit order submissions and the average size of buy limit order cancellations. The results of Table 4 show that market participants submitted relatively more market sell orders in the nine minutes immediately prior to the DJIA approaching the Rule 80B trigger point, both the first time when the market approached but did not trigger the rule (Panel B) and when it eventually did trigger the rule (Panel C), than during an earlier time period on Monday when the market was relatively far from the trigger point (Panel A). Four of the largest six counts of the number of orders occurred in the last nine minutes of those respective panels. However, a similar sized count occurred in the first period (1:20–1:23), and

²¹ We do not analyze the second trading halt, occurring at 3:36 PM, which was different from the initial halt for two reasons. First, it is conditional on the first halt being triggered and second, it had different consequences, namely, halting trade for the remainder of the day rather than for just 30 minutes.

the counts from 2:18 to 2:30, just six minutes before the first circuit breaker was executed, were relatively small for the day. Although the size of these market sell orders is often statistically larger than the size of market sell orders within the control period, the size does not monotonically increase as the end of the period approaches as would be predicted by the magnet effect. In fact, panel A displays a similar nine-minute interval with statistically increased market sell volume over a time period (1:08–1:17) that is not at all close to the trigger point of the circuit breaker. Furthermore, the average size of market sell orders during this period in Panel A is larger than the end of the other two periods near the circuit breaker.

In addition, the results on the submission of sell limit orders are not statistically different from the control sample as the market approaches the trigger value, nor are the three time periods noticeably different from each other. While we do not see statistically smaller average sell limit orders, the dispersion characteristics provide evidence that these limit orders are being placed at more aggressive prices, effectively creating a marketable limit order, although again we see these results as well during the first time period in Panel A.²² Thus, despite the fact that sell limit orders do not diminish in their average size, market participants chose their limit order prices in such a way that their placement effectively converts them from limit orders to market orders. However, consistent with the magnet effect, there is a concentration of significantly larger buyside cancellations in panels B and C in the last nine minutes of each respective period with no corresponding effect in panel A. The pattern of buyside cancellations reveals that to some extent, buy limit order traders are either exiting the market, or at a minimum, repositioning their orders, to account for some perceived oncoming downward pressure.

While the effects are at least partially driven by increased activity, Panels B and C of Table 4 do present evidence of market participants altering their timing behavior, in a manner consistent with a magnet effect toward an oncoming DJIA trigger level. Thus, we find evidence that both liquidity demanders and liquidity providers altered (accelerated) the timing of their actions as the circuit breaker trigger approached.

Next, we analyze how market participants reacted during and after the market wide trading halt had been triggered. Again, our hypothesis is that in an effort to avoid periods with constrained action sets, market participants will refrain from any activity (order placements or cancellations) during the circuit breaker. Table 5 provides information on the change in the quoted spread and depth as well as the limit order book spread, depth and composition at 2:36, 3:06 and 3:36 PM. At the initiation of the first circuit breaker, none of the results in Table 5 were significantly different from the control group. During the circuit breaker, the quoted spread dropped from \$0.21 to \$0.19 while the limit order book spread increased from \$0.65 to \$0.71. The composition for both sides of the limit order book was relatively unchanged, although characterized by slightly fewer, but more dispersed, shares. There were important differences across the two sides of the market however. Specifically, while only four of the 100 stocks had no buy limit orders on them at the beginning of the circuit breaker, 15 stocks had no buy limit orders at the end of the

²² Note that in Section 4, we also found evidence of marketable limit orders on Monday.

Table 4

Order flow characteristics approaching the market-wide circuit breaker

This table presents data on the 100 stocks in our sample for three half-hour periods on Monday, October 27, 1997. The three periods displayed are the two consecutive half hour periods 12:59–1:29 PM and 1:29–1:59 PM as well as the period 2:06–2:36 PM. The periods are chosen to coincide with the DJIA approaching the circuit breaker trigger level of 7366. The DJIA came within 6 index points at 1:59 PM and actually breached the trigger level at 2:36 PM. Each of the three periods is segmented into 10 three-minute intervals. Sell placed and buy cancels represents the average order size for placed sell limit orders and cancelled buy limit orders, respectively. Sell dispersion is defined as the average dollar difference between the limit order price of the placed sell order and the current posted ask price. Values in **bold** are significantly different from the control period at the 5% level for both parametric and non-parametric tests.

	Monday, October 27, 1997						Control periods				
	Change in DJIA	Market sell orders		Limit orders			Market sell orders		Limit orders		
		Number	Volume	Sell placed	Sell disp.	Buy cancels	Number	Volume	Sell placed	Sell disp.	Buy cancels
<i>A. 12:59–1:29 PM (DJIA starts at 7530 and ends at 7458; loss of 72)</i>											
12:59–1:02	13	83	18601	1768	0.12	1348	61	1168	1486	0.13	3148
1:02–1:05	–11	101	1283	1937	0.16	2158	47	1089	2505	0.08	1914
1:05–1:08	–12	107	521	1652	0.01	2543	54	658	2035	0.12	2340
1:08–1:11	–27	174	2112	2432	–0.03	3731	53	662	1590	0.05	2440
1:11–1:14	–15	135	1072	2140	–0.01	2245	64	691	1667	0.04	2247
1:14–1:17	–18	178	1855	2048	–0.04	3121	55	813	1935	–0.02	2906
1:17–1:20	–10	189	2000	2456	0.07	2101	53	912	2337	0.19	1678
1:20–1:23	–2	225	2613	2239	–0.01	2994	44	521	2928	0.13	2355
1:23–1:26	–6	149	966	3517	0.04	2472	44	3606	2102	0.08	3553
1:26–1:29	15	126	1130	2380	0.08	2448	51	686	2133	0.10	2145
<i>B. 1:29–1:59 PM (DJIA starts at 7458 and ends at 7372; loss of 86)</i>											
1:29–1:32	6	135	2638	2407	–0.01	1928	45	1080	1893	0.02	2826
1:32–1:35	8	124	881	2571	0.07	3023	46	690	2446	–0.20	2654

1:35–1:38	9	94	561	1657	0.04	2773	45	441	1827	0.40	2340
1:38–1:41	–2	103	923	2609	0.01	2696	46	632	1788	–0.01	3413
1:41–1:44	–7	154	3784	2231	0.00	3909	43	706	1505	0.06	2737
1:44–1:47	–3	93	6046	2527	–0.06	2004	77	2375	1553	0.13	2396
1:47–1:50	–7	95	605	2000	0.00	2693	44	601	2561	0.05	2116
1:50–1:53	–35	328	1064	2122	–0.05	4486	47	737	2454	0.09	1790
1:53–1:56	–25	227	961	2256	0.03	3749	73	1100	1886	0.03	3098
1:56–1:59	–30	399	1679	2270	–0.03	4509	53	587	2166	0.11	2822

C. 2:06–2:36 PM (DJIA starts at 7419 and ends at 7361; loss of 58)

2:06–2:09	15	91	1115	2479	0.01	2038	53	558	1747	0.10	1742
2:09–2:12	4	140	780	2424	0.04	2738	66	676	1863	0.03	2190
2:12–2:15	–18	137	956	3132	–0.01	4155	60	617	1708	0.07	4028
2:15–2:18	–24	209	903	2171	–0.02	3684	87	757	1890	0.06	1781
2:18–2:21	–8	123	979	2405	0.04	2844	55	569	1329	0.20	1755
2:21–2:24	15	108	1109	3514	0.00	2257	44	753	1661	0.10	1861
2:24–2:27	3	98	758	2601	0.31	3039	82	497	1880	–0.02	2679
2:27–2:30	–12	111	1532	2327	0.11	3723	50	617	1966	0.08	1536
2:30–2:33	–27	276	1610	2346	–0.04	4697	72	956	1830	0.21	2290
2:33–2:36	–8	216	1079	1939	0.00	3215	56	656	1792	0.03	1640

Table 5

Limit order books during the market-wide circuit breaker

This table presents data on the 100 stocks in our sample for three points in time surrounding the implementation of the circuit breakers on Monday, October 27, 1997. Limit order books (LOB) were estimated using the technique described in Kavajecz (1999). The LOB spread is the spread between the best buy-side and sell-side limit order prices. Cumulative depth is the sum of all shares available at a particular price or better on the limit order book. Cumulative depth is measured from the best limit order price on the limit order book on that side of the market. Dispersion is defined as the average dollar difference between the limit order price of the placed or cancelled order and the current posted bid or ask price. Empty books are limit order books in which there were no recorded orders on that side of the book. The table provides average statistics on the state of the posted quotes as well as the state of the limit order book. Values in **bold (bold italics)** are significantly larger (smaller) at the 5% level for both parametric and non-parametric tests.

	2:36 PM	3:06 PM	3:36 PM
<i>A. Quoted price schedule</i>			
Spread	0.2144	0.1900	0.2350
Ask depth	5299	5076	3478
Bid depth	3608	3711	2766
<i>B. Limit order book</i>			
LOB spread	0.6458	0.7145	0.8345
Ask depth	3501	3511	2564
Sell cum. depth $\frac{1}{8}$ away	10417	8644	5486
Sell cum. depth $\frac{1}{2}$ away	21745	17714	14588
Bid depth	5257	5148	4422
Buy cum. depth $\frac{1}{8}$ away	7652	7992	6490
Buy cum. depth $\frac{1}{2}$ away	16249	14911	11375
Buyside			
Number of orders	144	144	126
Total shares	109138	107163	96269
Dispersion	-4.4219	-4.5141	-4.0467
Empty books	4	15	5
Sellside			
Number of orders	118	118	122
Total shares	164098	163515	175318
Dispersion	3.2143	3.3059	3.5243
Empty books	0	0	0

circuit breaker. Unlike the buyside, no limit order books were empty on the sellside either at the beginning or at the end of the period. The results for the half-hour of the circuit breaker are in contrast to the next half-hour, during which orders were actively placed and executed as the market plunged.

Overall, during the half-hour that the circuit breaker stopped trading, market participants reduced their order placement and order cancellation significantly as compared with comparable periods. Placement and cancellation activity dropped off

precipitously in the absence of trade. The circuit breaker, rather than allow traders time to place buy limit orders and increase liquidity, caused market participants to pause and wait until trading resumed to conduct business. In this way, our results are similar to the results in Lee et al. (1994), Bhattacharya and Spiegel (1998), Corwin and Lipson (2000) and Christie et al. (2002), which show for individual trading halts that market participants are reluctant to supply liquidity during unusual trading periods, resulting in wide bid–ask spreads.

6. Conclusion

We investigate the preferences of market participants revealed through their choice of venue, order type and timing to highlight the tradeoffs market participants face in formulating their trading strategies with respect to whether, where, and when to supply liquidity. Our focus on the NYSE during the October 1997 market break allows for a direct comparison of alternative competing venues—the electronic limit order book and the floor.

The results demonstrate that market participants preferred using the human-based trading mechanism of the floor and avoided the electronic limit order book not on the day of the market break (Monday, October 27, 1997) but rather on the following day (Tuesday, October 28, 1997). On Tuesday, limit order traders did not replace expired day limit orders from the day before but instead moved their trading to the floor of the NYSE. As a result, the limit order books on Monday, October 27th displayed normal spreads and depth up to the market wide circuit breaker. Near the execution of the circuit breaker, market participants changed their behavior such that limit order book spreads became significantly wider and depth significantly smaller through the end of trading Monday and all day Tuesday, October 28th. The results suggest that extreme uncertainty concerning the ability to trade continuously caused market participants to change their behavior in such a way that it effectively shut down liquidity provision via the electronic limit order book.

The results also show that market participants moved to the exchange floor, causing record transaction volume as well as normal quoted spreads and depth on Tuesday, October 28th. Moreover, the most dramatic deterioration in the limit order books and the largest difference between quoted and limit order book spreads and depth occurred in the most frequently traded (DJIA) stocks. These results suggest that while all market participants prefer the flexibility of trading on the floor to trading through the electronic limit order book, traders of infrequently traded stocks do not have view the exchange floor as a feasible alternative given the lack of a trading crowd. Therefore, despite common preferences for flexibility across traders, traders of infrequently traded stocks do not enjoy the same flexibility imparted to traders of frequently stocks. Finally, the results demonstrate that market participants altered the timing of their actions to avoid (take advantage of) constrained (expanded) trading possibilities surrounding the implementation of the market wide circuit breaker. Specifically, the results show an acceleration of activity approaching the market wide circuit breaker that is consistent with the ‘magnet

effect' and a curtailment of activity (order placement) during the market wide circuit breaker.

These results have important implications on many different dimensions. The results demonstrate that during periods with heightened uncertainty, the value of the free option associated with supplying liquidity via an electronic limit order book becomes so high that market participants protect themselves by withdrawing depth and where possible, transferring their trading interest to the floor where contingencies can be handled via discretionary trading. Given our results, the numerous electronic limit order book systems currently in place (e.g. foreign systems in Paris, Taiwan and Toronto as well as domestic systems such as Archipeligo ECN, Island ECN, Instinet, the limit order books on the NYSE and regional exchanges, and Nasdaq's SuperMontage) may be vulnerable to extreme liquidity drains during periods of extreme market movements. A direct way of addressing this vulnerability is to make available alternative mechanisms by which market participants are able to trade with discretion, although recent electronic attempts to do so (such as Optimark) have not been successful. While the presence of an exchange floor mitigates these effects, the availability of other human interactive systems such as a telephone markets or the availability of contingency limit orders may do so as well.

While extreme market movements play a role in our results, so too does the impact of market wide closures. Consequently, our results also have strong regulatory policy implications. After the market break of 1987, there were a number of official government reports that analyzed what took place, what went wrong, and what could be done to prevent market breaks in the future.²³ Much of the analysis focused on market-wide trading restrictions aimed at decreasing volatility in the market, ultimately resulting in NYSE Rule 80B. Since then, there has been much debate about the reactions of market participants if the market is closed temporarily during extremely volatile periods. Our results suggests that uncertainty associated with the disruption of continuous trading markets caused by market closures is larger than the uncertainty associated with a sharp declines in market prices during an open market. This finding underscores an often overlooked benefit of having financial markets open in that it provides a constant flow of information to market participants such that traders are willing to supply liquidity without the need for contingencies. Thus, our results suggest that the implementation of the market wide circuit breaker potentially altered market participants' choices of venue, order type and timing in such a way as to exacerbate the very problem it was meant to alleviate.

In conclusion, we find that market participants alter their trading strategies during extreme market movements in such a way that they prefer human trading mechanisms over electronic ones and will alter the timing and choice of order type in such a way to maximize their trading flexibility. More importantly, we find that

²³ The official government reports concerning the 1987 market break include: *Financial Markets: Preliminary Observations on the October 1987 Crash*, *The October 1987 Market Break: A Report by the Division of Market Regulation US Securities and Exchange Commission* and *Report of The Presidential Task Force on Market Mechanisms* (1988). For an analysis of the other types of trading restrictions see, Kupiec (1997) for margin requirements, Kuserk et al. (1992) for program trading restrictions and McMillan (1991) for price limits.

flexibility is prized by market participants during uncertain times, hence their preference for trading venues that allow discretion (human-based trading systems), for order types that avoid inflexibility or that give away free options (choosing market orders over limit orders), and for timing their actions so that they trade during the least constrained periods (the magnet effect). Electronic markets that ignore these preferences during turbulent markets do so at their own peril.

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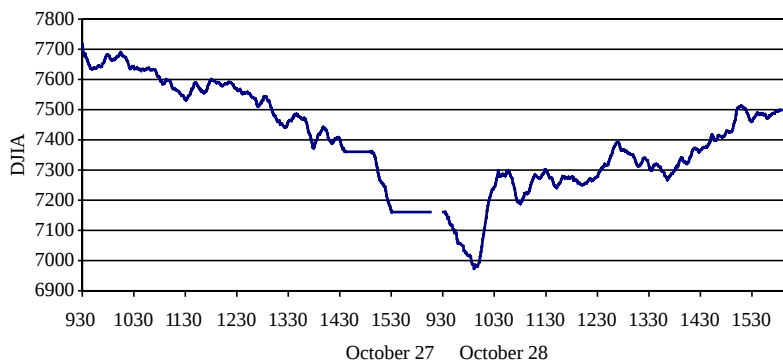


Chart A.1. This chart depicts the Dow Jones Industrial Average minute-by-minute over the two day period, Monday, October 27, 1997–Tuesday, October 28, 1997.

Appendix A. Chronology of Events: October 27, 1997–October 28, 1997

A.1. Dow Jones Industrial Average minute-by-minute

Chart A.1 depicts the Dow Jones Industrial Average.

Chronology of events

Date	Time	Event
October 24, 1997	4:00:00 PM	The Dow Jones industrial average (DJIA) closed at 7,715.
October 27, 1997	9:36:00 AM	The DJIA fell 50 points triggering Rule 80A (c), the index arbitrage sell restrictions. Under this rule, index arbitrage sells (including short sales and non-expiring derivative related program strategies) in S&P 500 stocks must be executed on a plus or zero-plus tick.
	11:00:00 AM	The nearby S&P 500 futures contract declined 12 points triggering Rule 80A (a), the five-minute sidecar. Under the sidecar, all SuperDot market orders that are part of a program trade for NYSE-listed S&P 500 stocks are diverted to a separate blind file. After the sidecar period ends, buy and sell orders within this file are paired off and executed.
	2:35:55 PM	The DJIA declined 350 points from the pervious day's close triggering Rule 80B, the 350-point circuit breaker, at which time trading was suspended, market-wide, for 30 minutes.

	3:06:00 PM	The market re-opened.
	3:30:00 PM	The DJIA declined 550 points from the previous day's close triggering Rule 80B, the 550-point circuit breaker, at which time trading was to be suspended for one hour. However, given that only 30 minutes of trading remained, trading was halted for the remainder of the day. The last value for the DJIA was 7,161. The NYSE volume of trade was 684.5 million shares
October 28, 1997	9:30:00 AM	The market opened with Rule 80A (a), the sidecar in effect because the nearby S&P 500 future contract was already down 12 points.
	9:41:00 AM	The DJIA declined 50 points triggering Rule 80A (c), the index arbitrage sell restrictions.
	10:06:00 AM	The DJIA fell 188 points to 6,973 the lowest point reached throughout the two days of trading.
	10:20:00 AM	Rule 80A (c), the index arbitrage sell restrictions were repeated.
	10:25:00 AM	Rule 80A (c), the index arbitrage buy restrictions were imposed. The rule restricts index arbitrage program buys in S&P 500 stocks to be executed on a minus or a zero-minus tick.
	4:00:00 PM	DJIA closes at 7,498. The NYSE volume of trade reached a record 1.2 billion shares.

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