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Liquidity Provision during Circuit Breakers and Extreme Market Movements

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01-00

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January 15, 2000

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We gratefully acknowledge the helpful comments from seminar participants at Babson College, the NBER Microstructure conference, the NYSE conference on U.S. Equity Markets in Transition and MIT. We also thank Jeff Bacidore, James Cochrane, Robert Engle, Simon Gervais, Joseph Kenrick, Bruce Lehmann, Mark Lipson, Elizabeth Odders-White, Maureen O'Hara, Craig MacKinlay, Patrik Sandås, George Sofianos and Chester Spatt. In addition, we thank Katherine Ross of the NYSE for the excellent assistance she provided retrieving and explaining the data. All remaining errors are our own. This paper was initiated while Michael Goldstein was the Visiting Scholar at the New York Stock Exchange. 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.

Liquidity Provision during Circuit Breakers and Extreme Market Movements

On October 27, 1997, circuit breakers caused the New York Stock Exchange (NYSE) to halt trading for the first time in history as the Dow Jones Industrial Average (DJIA) lost 554 points. The next day, the NYSE traded a record 1.2 billion shares as the DJIA increased by 337 points, the largest single-day point gain to date. Using data on the limit order books and specialists' quotes, we examine liquidity provision by limit order traders and floor members during these extreme market movements. We find evidence that specialists fulfilled their obligations to 'lean against the wind' even though liquidity provision by limit order traders declined precipitously. An analysis of activity during the circuit breaker reveals that limit order traders generally either remained inactive or withdrew liquidity during the market-wide trading halt.

Following declines in international equity markets, stock prices on the New York Stock Exchange (NYSE) declined precipitously on Monday, October 27, 1997. By 2:36 PM, the Dow Jones Industrial Average (DJIA) had lost 350 points from the previous day's close. This decline caused 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. Trading resumed at 3:06 PM, but the market continued to fall. 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 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.[1]

Monday, October 27th and Tuesday, October 28th marked the most turbulent two-day period in the market in over a decade. Such extreme market movements could be due to the market's rapid readjustment of expectations of underlying fundamental variables. Alternatively, these extreme movements could be due to failures in the usual liquidity provision process. In either case, examining liquidity provision during extreme market movements is particularly important for a number of reasons. First, market rules and regulations are designed to assist in liquidity provision precisely during such times of extreme market movements. Second, little is known about the workings of markets – or the strategies of liquidity providers – during extreme market movements since most theoretical models of trading do not account for trading behavior under these circumstances. Third, due to a lack of data, empirical research on previous stock market breaks has been confined to studying price and volume data across stock, futures and options

[1] 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.

markets.[2] Finally, despite the existence of market-wide trading restrictions since late 1988, the October 1997 market break provides the first opportunity to analyze the performance of a systematic, market-wide trading halt on U.S. equity markets.

During periods of extreme market movements, the provision of liquidity and its management through market-wide regulation are of paramount concern for both market participants and regulators. Since by their very nature extreme market movements are quite rare, one cannot hope to create a statistically significant sample of "extreme" market movements. As such, we examine the most recent example, both to analyze the effect of the first-ever execution of market-wide circuit breakers and to control for the many market- and economy-wide changes that have occurred since 1987 and 1929.

We therefore examine liquidity provision surrounding the October 1997 market break with three goals in mind. The first goal is to understand how liquidity providers react during extreme movements, in particular, their strategic choices, including the extent and nature of their supply of liquidity, or whether they exit the market altogether. The second goal is to compare the actions of limit order traders and floor members in order to highlight differences in liquidity providers' actions. The third goal is to investigate how liquidity providers react to market-wide trading halts.

In order to examine these issues, we investigate the behavior of liquidity providers (floor members as well as limit order traders) by estimating the relative contributions to liquidity provision by each group. We use data on the quoted spread and quoted depth as well as data on the limit order book spread, depth and composition to ascertain how liquidity providers react to high degrees of adverse selection risk and price uncertainty. We separately examine floor member behavior, since, unlike limit order traders, some members of the floor – specialists – are required to maintain a presence in the market while simultaneously

[2] For example, Kleidon (1988), Blume, MacKinlay and Terker (1989), Harris (1989) and Bertero and Mayer (1990). For an overview of the issues concerning financial markets during extreme market movements as well as a summary of the official government reports concerning the 1987 market break, see Kamphuis, Kormendi and Watson (1989), Litan and Santomero (1998) and Stoll (1998).

maintaining narrow bid-ask spreads, reasonable market depth, and price continuity. At issue is how well these functions are performed in the market's time of liquidity need.

In addition to investigating liquidity provision, we take the unique opportunity to examine the impact of the first implementation of the market-wide circuit breakers since their inception. There has been much debate about the advisability of closing the market temporarily during extremely volatile periods.[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, time to reenter the market to absorb a further decline. In addition, they argue the break provides time for market participants to 'catch-up mentally'. Others, such as, Coursey and Dyl (1990), Grossman (1990) and Subrahmanyam (1994, 1995) suggest that a temporary market closure at best postpones market activity until trading can again generate information and, at worst, exacerbates the problem by inducing traders to exit the market before it closes. We examine order flow surrounding the circuit breaker in order to understand how liquidity providers reacted to the closure in order to bring some evidence to bear on the circuit breaker debate.

Our results show that a substantial liquidity drain occurs not on the day of the market break (Monday, October 27, 1997) but rather on the following day (Tuesday, October 28, 1997) as limit order traders are reluctant to replace expired day limit orders. The liquidity drain is characterized by significantly wider limit order book spreads as well as significantly diminished depth throughout the limit order book. Specialists, with the aid of floor brokers, performed their function as liquidity providers of last resort by maintaining narrow spreads and normal depth, despite the significantly diminished liquidity provision by the limit order traders. The analysis of the order flow activity reveals that limit order traders adjust their behavior to the extreme circumstance by repositioning their orders to account for large price changes in the posted quotes. In particular, both buy and sell limit orders are repositioned at lower limit

[3] See Harris (1998) for an overview of the circuit breaker debate.

prices as the market falls -- the buy orders "running away" from the market and the sell orders "chasing" the market.

Market activity leading up to the circuit breaker displays some characteristics consistent with a 'magnet effect' (an increased demand for sellside immediacy) in that market sell orders become more numerous and larger on average and limit buy orders are cancelled with greater intensity. However, these effects are difficult to distinguish from a simple increase in trading activity associated with a large downward movement in prices. Furthermore, market activity during the circuit breaker reveals that more market participants took the opportunity to cancel limit orders than to place new orders, although the orders cancelled were much further away from the quotes than the orders placed. The consequence of these actions 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.

The remainder of the paper is organized as follows. Section I describes the data, time period investigated, and procedure used in constructing the estimates of the limit order books. Section II provides summary statistics for the market break period. Section III details the behavior of the liquidity providers during this time period. Section IV investigates the impact of the circuit breakers on the market and Section V concludes.

I. Data and Methodology

We use order data and quote data provided by the NYSE to conduct our analysis.[4] 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

[4] We thank the NYSE for providing the data for this study.

Quotes (TORQ) database at the time the data was collected, November 1997.[5] While slightly over-weighted towards larger stocks, these 100 stocks are reasonably well distributed across the stocks on the NYSE in terms of market capitalization.

We define the period surrounding the October 1997 market break as Friday, October 24, 1997 to Wednesday, October 29, 1997. 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). 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 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.

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. Th 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

[5] The 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 counter parties and the specialist's quotes. For more information about the TORQ database see Hasbrouck (1991).

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.

We create a sequence of "snapshots" of the limit order book by sequentially updating the limit order book estimates. Limit order books are estimated at thirty-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 PM, 3:00 PM 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. Results are equally-weighted averages across these thirty minute snapshots.

II. Trading during the Market Break Period and the Demand for Liquidity

In order to examine the behavior of liquidity providers during this period, it is important to understand both the timing of events and the demands placed upon liquidity providers. A brief chronology of events surrounding the October 1997 market break can be found in Table 1. In addition, Chart 1 displays the minute-by-minute DJIA over the market break period. Table 1 highlights the timing of the implementation of the various trading restrictions, while Chart 1 demonstrates the impact of these

restrictions, as well as the impact of trading pressures, on the DJIA.[6] Together, Table 1 and Chart 1 provide evidence of the turbulent nature of the period in question.

Table 2 provides statistics on the demand for liquidity by analyzing SuperDOT market orders submitted over this period. Panel A of Table 2 provides data on the event period while Panel B provides data on the control periods. For both Panels A and B, the day is broken up into three two-hour periods: morning (10:00:00 AM to 11:59:59 AM), midday (12:00:00 Noon to 1:59:59 PM) and afternoon (2:00:00 PM to 4:00:00 PM). In addition, Monday afternoon, in both the market event period and the control period, is further subdivided to map into the time periods surrounding the two market-wide trading halts: a pre-period from 2:00 PM to the execution of the trading halt at 2:36 PM, the period of the first market-wide trading halt from 2:36 PM to 3:06 PM, and the resumption of trading period from 3:06 PM to 3:36 PM. At 3:36 PM, the circuit breaker was triggered for the second time and trading ceased for the remainder of the day.

Table 2 displays the numbers of market orders submitted, the average order size, as well as the bid-ask spread and relevant depth quote at the time the order was submitted, broken down by buy and sell orders. The results in Table 2 show that the quoted bid-ask spread is significantly higher over the entire three day period with both buy and sell market orders being placed during periods of increased quoted bid-ask spreads. In addition, the quoted bid depth is significantly smaller than the quoted bid depth in the control periods, while the quoted ask depth is significantly smaller during Friday and Wednesday afternoons and is significantly larger from the implementation of the first circuit breaker through the close of trading on Tuesday. These results suggest that market sell orders faced less liquidity overall compared to market buy orders throughout the entire break period.

The aggressiveness of liquidity demanded is revealed through the number and size of the market orders submitted over this period. Friday and Wednesday are characterized by heavy liquidity demand on

[6] For an extensive description of the NYSE trading activity over this period see Ross and Sofianos (1998).

both the buy and sell sides of the market. Monday is characterized by an increased number of larger than average sell orders, while on Tuesday, the number of buy orders is substantially above the control group's number of buy orders and dwarfs the number of sell orders. However, the average size of these buy orders is less than half the average size of the control group. It is puzzling that market participants who wished to purchase shares aggressively by submitting market orders in the face of large bid-ask spreads chose only to transact a small number of shares when far more were available. One possibility is that retail customers, who cannot purchase large number of shares, bought most of the shares on Tuesday.

In summary, the heightened activity during the market break period was characterized by aggressive liquidity demand with both buy and sell market orders being submitted in the face of larger than average spreads. In general, selling pressure (characterized by large sell orders) dominated Monday's activity as well as the final hours of trading each day, while buying pressure (characterized by many small buy orders) dominated Tuesday's activity. The effect of these and other market wide pressures for liquidity sent the DJIA falling on Monday and rebounding on Tuesday.

III. Liquidity Providers

Given the demand pressures on Monday and Tuesday, we need to analyze the relative contributions to liquidity provision by limit order traders and floor members. Our focus is to identify whether specific aspects of the liquidity provider's behavior impacts, or is impacted by, activity during these extreme circumstances. By comparing the sequence of order and quote data surrounding the October 1997 market break with the sequence of order and quote data during the control periods, we analyze the level and nature of liquidity provided, and the dynamic changes in strategy made by traders in this turbulent market.

A. Limit Order Traders

Limit order traders are faced with many risks when supplying liquidity: the risk that they trade with someone possessing superior information, the risk that the specialist passes on undesirable order flow, and the risk associated with price uncertainty. During periods of extreme market movements these risks are heightened. As a result, 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, even if they were willing to do so previously. Indeed, in the face of this turbulent market, some traders may strategically move their orders from the limit order book to the floor, and may in fact become liquidity *demanders* instead of liquidity *suppliers*.

We investigate liquidity provision by the limit order book in two ways. First, we analyze the limit order book spread, i.e., the spread between the best buyside and sellside 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.[7] Second, we investigate the characteristics of the flow of limit orders over these periods. Specifically, we follow the number of limit orders placed, whether they were eventually, executed, canceled, expired or still active, the size of those orders, and where on the limit order book they were positioned.

Chart 2 provides snapshots of the limit order book at 1:00 PM on Friday (October 24th), Monday (October 27th), Tuesday (October 28th) and Wednesday (October 29th). The data were calculated by averaging the cumulative depths across the sample stocks in increments of sixteenths as far away as two

[7] 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. Note that this definition is different than if measured from the midpoint of the bid-ask spread or from the quoted bid and quoted ask respectively. As we will see later, the best buy or sell price on the limit order book retreated quite far from the specialists' quotes. Thus, our definition of cumulative depth is quite conservative as it measures only changes in the limit order book itself, and not the relation between the limit order and the specialists' quotes.

dollars from the best buyside and sellside limit prices. These averages are then placed the appropriate dollar distance from the average best buyside and sellside limit prices. The right (left) side of Chart 2 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. The sloped lines on each side of the limit order book spread represents the cumulative depth on the sellside (buyside) as limit prices rise (fall). Consequently, Chart 2 displays the average demand (buyside) and supply (sellside) schedules for shares of stock in our sample.

As indicated by Chart 2, limit order books on Monday, October 27th did not indicate any significant decrease in liquidity as of 1:00 PM with bid-ask spreads and depth levels remaining relatively unchanged. In fact, the cumulative depths on the limit order books on both Friday, October 24th and Monday, October 27th at 1:00 PM were not significantly different from the cumulative depths of the two control periods at that time. In contrast, the 1:00 PM limit order books on Tuesday, October 28th, the day *after* the significant market drop, are significantly different from the limit order books in the control period at the 5% level. Most striking is the large range of prices – from $36 3/8 to $39 5/8 – on Tuesday, October 28th where there were *no* limit orders, either to buy or to sell. Indeed, Monday's range of $38 13/16 to $39¼ is subsumed completely in Tuesday's range, indicating that limit orders were much less willing to provide liquidity on the day after the market drop than they were on the day of the drop itself.

Chart 3 provides a more comprehensive view of the time series of average cumulative depth for both the buyside and sellside of the market. The chart displays the time series of half-hour cumulative limit order book depth observations between Friday, October 24, 1997 at noon to Wednesday, October 29, 1997 at 4:00 PM. The data for Chart 3 are calculated in the same manner as Chart 2; however, Chart 3 cumulates the series of half-hour cumulative depth charts across time. (Chart 2 merely contains the cutouts for 1:00 PM from Chart 3). Therefore, the right (left) side of Chart 3 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 buyside (sellside) as limit prices rise (fall). Consequently, Chart 3 displays the time series of average demand (buyside) and supply (sellside) schedules for stocks in our sample. In addition, Table 3 is included to accompany Chart 3 by providing limit order book spread and cumulative depth values and significance information for select time periods.

Chart 3 and Table 3 reveal that the limit order book spreads over the three days vary dramatically. The average limit order book spreads on Monday, Tuesday and Wednesday were $0.75, $2.90, and $0.57 respectively. While the values on Monday and Wednesday are not significantly different from the limit order book spreads of the control sample, the values for Tuesday are significantly different from the control sample at the 5% level throughout the entire day. The pattern of cumulative depth on the limit order book as shown in Chart 3 and Table 3 is also revealing during this time. There is a distinct drop in cumulative depth from Friday's close to Monday's open. Despite this drop and 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 buyside price and a quarter or more away from the best sellside price. Surprisingly, the depths at the best buyside and sellside 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 buyside at some point on Monday or Tuesday, while the control samples only had four cases. Although the limit order book spread reverts to a normal range on Wednesday, the diminished cumulative depth shown on Tuesday continues. Although not shown, cumulative depths on Wednesday afternoon are statistically smaller than the control sample for

limit prices an eighth away from the best buyside price and within an eighth of the best sellside price.[8]

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 maintained their normal level of liquidity provision *until* the market-wide trading halt. In contrast, Tuesday displays an extreme liquidity drain, as the limit order book spread is significantly larger and cumulative depth series significantly smaller than the corresponding series in the control sample. Wednesday shows some signs of recovery as the limit order book spread returns to normal levels; however, the lower cumulative depth persists. Overall the behavior of the limit order books surrounding the market break reveals that surprisingly, the liquidity drain surrounding this market break occurs not on the day of the drop but rather on the subsequent days after there had been a market closure.

Liquidity providers' response of reducing liquidity provision during times of excessive price uncertainty and adverse selection risk is consistent with the theoretical predictions of Rock (1990) and Seppi (1997), as well as the empirical findings of Lee, Mucklow, and Ready (1993), Bremer, Hiraki and Sweeney (1997), Chung, Van Ness and Van Ness (1999) and Kavajecz (1999). As Tuesday's results clearly indicate, limit order traders respond to extreme volatility by providing fewer shares and by placing those shares at less aggressive prices. An interesting puzzle, however, is that this predicted behavior happened on Tuesday *after* the extreme market movement, rather than on Monday. These results suggest that adverse selection costs are extremely high after a day of extreme market movements or potentially after a market closure.

One reason for this result is the expiration of day limit orders on Monday that were never replaced on Tuesday morning, as shown in Chart 3 and Table 3 by the widened limit order book spread and sharp drop in depth at the open on Tuesday. Limit order traders were perfectly capable of replacing their expired

[8] The aggregate results of a wide limit order book spread on Tuesday accompanied by diminished depth on Tuesday and Wednesday holds uniformly across the individual stocks in the sample. Even stocks as liquid and frequently traded as Boeing, IBM, Phillip Morris and AT&T, display these results.

limit orders had they wished to do so, yet they chose not to provide liquidity the following day. A complicating factor in this analysis is the first-ever implementation of the circuit breaker and the potential for further halts. Given the limitations in the data, we cannot determine whether the reaction of limit order traders are common to all market breaks or whether their reaction was a response to the potential for further market-wide trading halts on Tuesday.

Table 3 and Charts 2 and 3 allow us to analyze liquidity at a particular moment in time. Although this static analysis of limit order books displays the levels of the bid-ask spread and levels of various depth figures, it does not capture the speed at which liquidity is entering and leaving the market. While an asset may have a wide bid-ask spread and/or diminished cumulative depth at a particular moment in time, equally important is the potential for rapid replacement of executed orders which may result in a large *flow* of liquidity provision ***over*** time. Since the rate at which limit orders are placed, executed and cancelled impacts the overall flow of liquidity in a market, we analyze the flow of SuperDOT limit orders to investigate how limit order traders collectively manage their limit orders over this time period.

To examine the order management decisions of limit order traders, Tables 4 and 5 provide data on the order flow characteristics of limit orders for the buy and sell sides of the market respectively. In particular, Tables 4 and 5 provide information on the number of orders placed, their average size, and the dispersion of the order at the time of submission. Buyside (Sellside) dispersion is defined as the dollar difference between the limit price of the order and the quoted bid (ask) at the time.[9] In addition, the average size of executed limit orders as well as the average size and dispersion of cancelled limit orders is shown. Panel A displays the results for the event period while Panel B shows the results for the control

[9] Note that this definition does not take into account any changes in the bid-ask spread and thus focuses only on the aggressiveness of limit orders relative to the quoted price on that side of the market. By defining dispersion relative to the same side quote, rather than relative to the bid-ask midpoint, we do not capture the increase in the bid-ask spread as shown in Table 2. Thus, our definition of dispersion is conservative as it is biased against finding a statistically significant change during the market event period.

periods.

Table 4 shows the behavior of buyside order flow. Prior to the triggering of the first circuit breaker on Monday, the number of buy limit orders placed exceeds the number submitted in the control periods. The average size of buyside limit orders was in general in line with the control periods for most of the market break period; however, buy orders were statistically larger the half- hour prior to the initial market wide trading halt and on Tuesday morning. In contrast, buy orders were statistically smaller *during* the first market wide trading halt. Although the market was "halted", specialists were still accepting orders since the market was not "closed". It is possible that the low number of orders placed during the halt could be due to few market participants understanding this distinction.

The dispersion calculations indicate that the locus of placement for buy orders on Friday and on Monday morning was almost identical to that of the control group. The buy limit orders, submitted surrounding the trading halts on Monday and on Tuesday and Wednesday mornings, were generally placed farther from the quoted bid. These results suggest that buyside limit order traders were supplying liquidity at crucial times during the markets fall, but protected themselves somewhat by becoming less aggressive. One potential explanation for this behavior is that traders wishing to buy, who would otherwise demand immediacy by submitting market orders, switched to using limit orders placed slightly behind the bid. In a falling market, this strategy maintains its high probability of immediacy but also generates a profit, relative to a market order, for the provision of liquidity.

The pattern of executed buy limit orders suggests that the buy limit orders took on more of the selling pressure on Tuesday, given that statistically more buy limit orders shares executed, and less on Wednesday, given statistically fewer buy limit orders shares executed. In general, larger orders on average were cancelled both Monday and Tuesday, except for the half-hour of the circuit breaker. While in general the dispersion of these cancelled orders was not significantly different than the control group, the orders that were cancelled, from the initiation of the first circuit breaker on Monday through Tuesday morning,

were on average farther away from the bid than usual. Thus at least some buy limit orders took the opportunity to flee as the market fell, although those that did so were not close to the quoted bid at the time they were cancelled.

Although the amount of buy orders cancelled was not unusually large during the half-hour of the circuit breaker, the amount placed was unusually small, resulting in a net loss of liquidity. Despite the net loss, the dispersion characteristics indicate that during the half-hour of the circuit breaker, buy orders were cancelled far away from the quote while new orders were positioned much closer to the quote. This shift in the cumulative depth closer to the quoted bid could help support prices after the market re-opened, but did not provide liquidity at still lower prices.

In summary, Table 4 shows that buyside limit order traders were actively managing their exposure over the market break period by not only adjusting the size of their orders but also managing the relative distance to the quoted bid price. Over the initial halt period, there was a net reduction of liquidity, although some of the orders cancelled were farther away from the current price than the new ones that were submitted. Therefore, buyside limit order traders dynamically and strategically altered their liquidity provision over this turbulent period.

Table 5 shows the same information for sell limit order flow. As in the case of the buy limit orders, there are more sell orders submitted relative to the control in almost every period, although notable exceptions are the half-hour of the initial market wide trading halt and part of Tuesday. In general, submitted sell limit orders are larger on average over the market break period, particularly during the initial hours of trading each day. This result coincides with the larger than average executed sell limit orders that occur during the initial hours of trading each day. Thus, these results suggest that submissions of sell limit orders tend to be concentrated in the most active trading periods.

The dispersion of placed sell limit orders shows that in general, sell limit orders were placed statistically closer to the ask than submissions in the control periods, from late Friday afternoon through

noon Tuesday except for the initial market halt. In particular, sell orders were extremely aggressive for the half-hour between the first market halt and the second. In fact, they were placed *in front of* the ask, resulting in a negative dispersion. This aggressive placement strategy could be due to the high level of competition among sellside liquidity providers to supply liquidity to the few buyers present in the market. In contrast, the dispersion of the cancelled sell limit orders reveals that the sell limit orders being cancelled on Monday are statistically farther from the ask than in the control period. Furthermore, in comparing the dispersions of placed and cancelled sell limit orders over this period, the results show that in aggregate, sell limit orders are cancelled when they are far from the ask and placed close to the quoted ask price. Thus, after placing a sell limit order, traders find their sell order far from the market as the quoted ask falls; to adjust, traders cancel their order and reposition it closer to the market.

In summary, liquidity providers continuously placed, canceled and repositioned their orders throughout the day to adjust to the decline in quoted prices. Upon being placed, a buy limit order was chased by the quoted prices, while a sell limit order chased the quoted prices.

A. Floor Members

As liquidity providers, floor members (specialists and floor brokers) also have an incentive to decrease the amount of liquidity they provide to the market during extreme market movements. Unlike floor brokers who need not maintain a presence in the market, specialists have an overriding fiduciary responsibility to maintain a presence in the market despite the difficult trading circumstances. Specifically, specialists are charged with maintaining a 'fair and orderly' market, and are bound by a number of exchange mandated requirements. Price continuity, a narrow bid-ask spread, and reasonable quoted depth are just a few of the elements of these requirements. Because it is precisely in times of excessive volatility or extreme market movements when specialists, as liquidity providers, are most wanted, the question of how they behave during these circumstances is paramount. Unfortunately, we cannot partition the

behavior of the specialist and floor brokers because having only data on quoted prices and depths and the SuperDOT limit orders does not allow us to differentiate between specialists adding liquidity for their own account and specialists reflecting the interest of floor brokers within the quotes.[10] Despite this data limitation, the analysis to follow investigates whether specialists, with the potential aid of floor brokers, fulfill their obligation as liquidity providers of last resort. Alternatively, the analysis can be thought of as the benefit of having a floor-based trading mechanism during extreme trading circumstances.

Chart 4 provides a comparison of the average quoted spread and the average limit order book spread. The vertical bars represent the average quoted spread (centered on the average bid-ask spread midpoint) and the vertical lines represent the average limit order book spread (centered on the average limit order book spread midpoint). A striking feature of the chart is the dramatic increase in the limit order book spread on Tuesday as was seen in Charts 2 and 3. In stark contrast to the limit order spread, the *quoted* spread remained relatively constant over this period, averaging $0.22, $0.25 and $0.25 for Monday, Tuesday and Wednesday respectively. Furthermore, unlike the limit order spreads, the quoted spreads over these three days were not significantly different from the quoted spread in the control sample.[11]

Further evidence concerning the liquidity provision of floor members can be seen in Table 6 which shows the relative contribution to liquidity by the floor members (specialists and floor brokers) and the limit order book. Columns 1 and 4 display the percentage of time within the sample that floor members are contributing to liquidity by either providing additional depth beyond that supplied by the limit order book or bettering the best limit order book price. Columns 2 and 5 display the average level of depth contribution by floor members at the best available prices, while columns 3 and 6 display the average level of depth contribution of limit orders at the best available prices.

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[10] For an analysis of floor brokers actions see Sofianos and Werner (1997).

[11] The quoted depth figures, however, did show somewhat lower levels as there were intermittent periods of statistically lower quoted depth on both the buyside and sellside throughout Tuesday and Wednesday.

Table 6 shows that floor members were particularly crucial in providing liquidity during periods of extreme market stress. Floor members provided liquidity beyond the limit order book significantly more frequently during the extreme stress periods of Monday afternoon and all day Tuesday. Moreover, they also provided statistically more shares on the buyside at the low point of the market Tuesday morning and the close Tuesday afternoon. Consistent with the data in Chart 2 and 3, Table 6 also shows that the depth contributed by the limit order book was statistically smaller than the depth in the control sample.

The results on floor member liquidity provision suggest that specialists, with the potential aid of floor brokers, performed their functions of 'leaning against the wind' well. Floor members not only maintained a market presence, but also preserved normal quoted bid-ask spread while filling in gaps in the limit order book depth. In particular, during moments of extreme stress, floor members provided significant liquidity to the market at the exact times when limit order traders stepped away from the market and were unwilling to indicate publicly their willingness to provide liquidity via standing limit orders. Thus, either specialists performed their job of maintaining fair and orderly markets, or limit orders shifted to the floor, or both.

The results in Table 6 and in Chart 4 may also help explain the next day "bounce back" that is a feature of almost all significant one day declines.[12] One factor that may contribute to the "bounce back" is the relative size and position of the quoted and limit order book spreads. When limit order book spreads are extremely wide and specialists' quotes are positioned in the lowest portion of the limit order book spread, specialists are aided by the remaining buyside limit orders while they are unaided by sellside limit orders. Thus, once liquidity demanders start to buy shares, the limit order book provides little resistance against a sharp increase in prices. In particular, the buyside of the limit order book provides some added support against further price declines while the sellside of the limit order book is too distant to be of any

[12] For example, this pattern has occurred in the market breaks of 1929, 1987, and 1997.

immediate use to the specialist.[13] As shown in SEC (1998), once the market reversed itself on Tuesday morning, the increase in prices was quite rapid and far outpaced the speed of the downturn during any time on Monday.

Furthermore, work by Kavajecz and Odders-White (1999) shows that specialists' reactions are stronger to order flow in the absence of a limit order book than in the presence of a limit order book. Therefore, the specialist is likely to increase prices more in response to buy orders than he is likely to decrease prices in response to sell orders. Thus, while the limit order liquidity provision results of Table 6 and Chart 4 cannot explain Monday's decline, they may help explain Tuesday's record-breaking rise.

IV. Market-wide Trading Restrictions

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.[14] Much of the analysis focused on market-wide trading restrictions aimed at decreasing volatility in the market. These trading restrictions took many forms: margin requirements, program trading restrictions, price limits and coordinated market-wide trading halts. In this section, we turn our attention from the behavior of liquidity providers over the entire four day period to an analysis of the impact of the market-wide trading restriction, known as NYSE Rule 80B, more commonly known as circuit breakers.[15] Specifically, Rule 80B 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, Rule 80B stated

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[13] Similarly, floor brokers with sell orders receive liquidity from the remaining buyside limit orders. However, floor brokers with buy orders do not receive benefit from even the best sellside limit orders, since the best sellside limit orders may be as far away as $3 from the current prices, as shown in Chart 4.

[14] 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 U.S. Securities and Exchange Commission* and *Report of The Presidential Task Force on Market Mechanisms*.

[15] For an analysis of the other types of trading restrictions see, Kupiec (1997) for margin requirements, Kuserk, Locke and Sayers (1992) for program trading restrictions and McMillan (1991) for price limits.

that a 350 (500) point drop in the DJIA would trigger a market-wide trading halt of 30 (60) minutes. Subsequently, 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.

Since the October 1987 crash, the debate continues on the cost and benefits of circuit breakers.[16] Some argue that circuit breakers allow the market to somehow 'catch-up', or at least catch their breath, while others suggest that circuit breakers do nothing more than prevent consenting adults from trading. Since Rule 80B had never been triggered prior to October 1997, examining the effectiveness and performance of circuit breakers has been difficult. Some, such as Greenwald and Stein (1991), Kodres and O'Brien (1994), and Subrahmanyam (1994), rely on theoretical models to examine circuit breakers, while others, such as Courney and Dyl (1990) and Ackert, Church, and Jayaraman (1999) use experimental techniques. Greenwald and Stein (1991) and Kodres and O'Brien (1994) each develop a model that indicates that properly designed circuit breakers may mitigate uncertainty by reducing transactional risk and therefore, help the market achieve optimal outcomes. In contrast, Courney and Dyl (1990), Subrahmanyam (1994) and Ackert, Church and Jayaraman (1999) argue that the existence of circuit breakers may have the perverse effect of increasing price volatility prior to the triggering due to the 'magnet effect'. 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 actually exacerbate the problem by pressing the price closer to the circuit breaker trigger level.

Others have empirically examined the effectiveness of circuit breakers on foreign markets. For example, Lauterbach and Ben-Zion (1993) examine the effects of trading halts on the Tel Aviv Stock market during the October 1987 crash, finding that the circuit breakers helped reduce price losses the

[16] For example, see Cochrane (1998) and Lucchetti and Ip (1998).

following day but had little long-term effect. In addition, Bertero and Mayer (1990) examine the effects of market structure, including circuit breakers, on stock market performance on 23 markets around the world during the October 1987 crash.[17]

In a related literature, researchers such as Lee, Ready and Seguin (1994), Edelen and Gervais (1997) and Corwin and Lipson (1999) have investigated the effect of halting trade on individual stocks. Individual halts, although somewhat different from market-wide trading halts due to the discretionary nature of their implementation, can be informative about how liquidity providers react to trading restrictions. Lee, Ready and Seguin (1994) argues that individual trading halts *increase*, rather than *decrease*, both volume and volatility. They conclude that individual trading halts do not facilitate the transmission of information to market participants as proponents argue. In contrast, Edelen and Gervais (1997) model individual trading halts in a principle-agent framework and argue that halts are beneficial to exchanges in that they facilitate the monitoring of specialists' actions in order to curb potentially abusive pricing behavior. In closely related work, Corwin and Lipson (1999) show that limit order traders are reluctant to supply liquidity during unusual trading periods resulting in diminished limit order book depth and active repositioning of their orders.

We investigate the first implementation of the circuit breakers on Monday, October 27, 1997. Our analysis is done from the perspective of liquidity providers and its focus is on bringing evidence to bear on two issues. First, we investigate whether the circuit breaker trigger mechanism creates the magnet effect hypothesized by Subrahmanyam (1994). We analyze the flow of orders during three half-hour periods in order to investigate whether market participants moved quickly to exit the market. Second, we investigate how liquidity providers reacted during and after the market wide trading halt. On one hand, if circuit breakers allow liquidity providers the time to 'catch-up,' the market will be stabilized. On the other hand, if circuit breakers induce liquidity providers to cancel limit orders because of a lack of information they

[17]For an overview and discussion of research on circuit breakers see Harris (1998).

will have a destabilizing effect.

A. The Magnet Effect

Under the magnet effect hypothesis, market participants should have an increasing demand for liquidity on the buyside of the market as prices approach the halt trigger level. The magnet effect could manifest itself in a number of ways. First, market sell orders should be submitted at an increasing rate and increasing sizes as the trigger approaches. Second, limit order traders wishing to sell may 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 may decide to cancel or reposition their limit orders in anticipation of the approaching market wide halt.

On Monday, October 27, 1997, the DJIA approached the initial trigger level on two separate occasions. 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.[18] In order to investigate whether there is a gravitational pull toward the circuit breaker trigger level, we analyze three half-hour periods, one that was not close to the circuit breaker trigger (12:59-1:29PM), one that came close to the circuit breaker trigger but did not trigger a halt (1:29-1:59PM), and one that actually triggered the initial circuit breaker (2:06-2:36PM). We analyze these three half-hour periods to control for the possibility that any effects we find are an artifact of a rapidly declining market and not due to the circuit breaker itself. 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 actual impact of triggering the market wide trading halt. The third period is used to examine the actual triggering of the circuit breaker. Therefore, if the magnet hypothesis holds, we would

[18] 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.

expect to find evidence consistent with the magnet effect in the two periods that came close to triggering the market wide halt but not in first period far from the trigger level.

Table 7 measures aspects of 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 cancellation rates. The results of Table 7 show that there are relatively more market sell orders in the last nine minutes of panels B and C than in 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 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 to 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. Thus, the phenomenon of increased average market sell order size is at least partially a product of an active declining market and not due to the pending activation of the circuit breaker.

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 panels 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 in Panel A. Thus, despite the fact that sell limit orders do not diminish in their average size, their placement effectively converts them from limit

orders to market orders. Furthermore, this effect again seems more due to the declining day than due to the circuit breaker.

However, consistent with the magnet effect, there is a concentration of significantly larger buyside cancellations in panels B and C in the last 9 minutes of each respective period with no corresponding effect in panel A. The pattern of buyside cancellations suggests 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 and not by the potential magnet effect, Panels B and C of Table 7 do present some evidence consistent with a magnet effect toward an oncoming DJIA trigger level. The results suggest that although there is an increase in the number of orders and in the average order size across the three panels, this effect is most pronounced in the last ten minutes of panels B and C. In addition, the increased marketability of sell limit orders as well as the heightened buy limit cancellation rates in the last ten minutes of panels B and C, represent evidence consistent with the existence of the magnet effect.

B. Liquidity Provision During and After the Circuit Breaker

The other important issue we investigate is how liquidity providers react during and after a market wide trading halt has been triggered. At issue is whether or not liquidity providers used the time during the halt to reenter the market and submit buy limit orders, or whether they used the time to exit the market. We measure changes 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. In addition, we measure the flow of orders between these points in time to gauge how liquidity providers reacted to the halt.

Table 8 provides information on the change in the spread, depth and composition of the limit order book. Complementing Table 8 is Chart 5, which displays the cumulative depth on the limit order book

surrounding the market wide circuit breakers. At the initiation of the first circuit breaker, none of the results in Table 8 were significantly different from the control group, although the results at the end of the first circuit breaker and the initiation of the second circuit breaker are different at the 5% level. While the quoted spread dropped from $0.21 to $0.19 and the quoted depth declined a small amount during the half-hour that the circuit breaker went into effect, the composition of the book remained relatively unchanged. The limit order book spread increased from $0.65 to $0.71 over this period. In addition, cumulative depth $1/8^{th}$ and 1/2th away from the best limit order on the sellside dropped by a few thousand shares. On the buyside, the cumulative depth $1/8^{th}$ away from the best buyside limit order increased, but the depth 1/2th away decreased slightly. The lack of change in the cumulative depth is also evident in comparing the first two panels of Chart 5.

On the buyside of the limit order book, the average number of orders remained constant at the beginning and end of the circuit breaker, although the total number of shares on the buyside of the limit order book dropped from 109,138 shares to 107,163 shares. Buyside limit orders at the end of the circuit breaker were slightly more dispersed across prices in the limit order book. While only four of the 100 stocks had no buy limit orders on them at the beginning of the circuit breaker, 15 stocks did not have any limit orders on the buyside of the limit order book at the end of the circuit breaker. Similarly, for the sellside, the average number of orders remained constant, there was a slight drop in the total number of shares and these shares were slightly more dispersed at the end of the circuit breaker relative to the beginning. However, 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 there was active trading and during which the market continued to plunge, ultimately triggering the circuit breaker a second time. Panel 3 of Chart 5 shows that by the time the second circuit breaker was triggered, the limit order book spread had jumped to $0.83, and both the depth at the best prices on the

limit order book and the cumulative depths had dropped as compared with the beginning of that half-hour just before trading resumed.

Overall, during the half-hour that the circuit breaker stopped trading, order placement and order cancellation numbers were significantly below comparable time periods. Activity seems to have dropped off precipitously in the absence of trade. Thus, rather than allow traders time to place buy orders, the market essentially paused and waited until trading resumed to conduct business. Unfortunately, we cannot distinguish this from an alternate scenario in which market participants did not know that they could submit and cancel orders even though actual trading was halted.

V. Conclusion

Surprisingly, even though Monday, October 27, 1997 had the largest point drop in history, the results in this paper indicate that the unusual day – from a liquidity perspective – was Tuesday and not Monday. In fact, despite the large drop in prices, liquidity provision for most of the day on Monday was not statistically different from our control period. Thus, we find little evidence that the significant drop in prices on Monday, October 27, 1997 was due to a lack of liquidity provision by the market.

Upon the first execution of a circuit breaker halting the market, liquidity provision and the limit order books were not significantly different from the limit order books in more normal times. However, little liquidity, if any, was provided to the market during the half-hour "cooling off" period. While there was some removal of limit orders during this time, the most notable feature of the first circuit breaker period is the lack of order submission, cancellation or change in the limit order book. We should note, however, that we cannot distinguish between the case where market participants knew they could submit or cancel orders and chose not to, and the observationally equivalent case, where market participants were unaware that they could continue to submit orders while the circuit breaker was in effect. In any case, the fact remains that the NYSE received little order flow (either submissions or cancellations) during this time.

As such, we do not find any evidence that the execution of the NYSE circuit breaker had beneficial effects in terms of liquidity provision.

Tuesday, October 28, 1997 saw the most dramatic liquidity drain of the period as liquidity providers off the floor either withdrew their standing limit orders or changed their trading strategies to utilize the trading floor. The aggregate limit order book on Tuesday was uncharacteristically thin and empty, providing little help to floor members trying to maintain a "fair and orderly" market. In particular, limit order spreads – although within normal limits on Monday – widened dramatically on Tuesday. The lack of limit orders on the sell side may help explain the record breaking rise in the DJIA on Tuesday, as there was little or no resistance to rising prices by the limit order book to abate the buying pressure.

Despite the lack of liquidity provision by limit orders on Tuesday, quoted spreads remained in the normal range. Most – if not all – of the depth of the quoted spread came from floor participants, and not from limit orders. By their actions, floor participants enabled the continuation of a "fair and orderly" market even in the absence of limit orders. This result may be due to specialists committing capital to fulfill their obligations to stabilize the market and maintain price continuity and tight bid-ask spreads. Alternatively, off-floor liquidity providers such as large institutions may have strategically switched their method of liquidity provision from limit orders to using the more flexible (but more expensive) floor brokers.

While it is admittedly difficult to make inference with only a single observation, the rarity of extreme market movements makes it impossible to create a sample large enough for statistical significance. Despite this drawback, the sharp results of this analysis make compelling arguments for the behavior of liquidity providers around market breaks. Furthermore, the results in this paper for a market-wide trading halt are consistent with the results found for individual stock halts found in Corwin and Lipson (1999). Overall, we find that an extreme drop in prices does not significantly affect limit order liquidity provision while the drop is taking place. However, after a market closure, particularly prior to the market finding a

stable trading level, limit order traders withdraw their liquidity provision via limit orders to re-evaluate their risk. The provision of liquidity shifts from the limit order book to the floor of the NYSE not during the market break itself, but the following day. In addition, the location of the quoted spread relative to the limit order book spread on Tuesday suggests that the limit order book provided protection against a drop in prices but no such protection against a rise in prices. Thus, these results on liquidity provision during extreme market movements, while they cannot explain the initial drop, may help explain the "bounce back" phenomenon that is increasingly common to large price decreases.

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Table 1

Chronology of Events
October 27, 1997 through October 28, 1997

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 repealed.
	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.

Table 2

SuperDOT Market Order Flow Characteristics

This table presents data on the market orders submitted for the 100 stocks in our sample for the four days surrounding the market break of late October 1997 as well as the control periods July 18-23, 1997 and September 12-17, 1997. The bid-ask spread and the ask (bid) depth refer to the dollar quoted bid-ask spread and the quoted depth outstanding at the time the market order was submitted. Values in **bold** are significant at the 5% level for both parametric and non-parametric tests.

	Buy Orders				Sell Orders			
	Number Of Orders	Average Size	Bid-Ask Spread	Ask Depth	Number Of Orders	Average Size	Bid-Ask Spread	Bid Depth
A. Market Break Period								
Friday, October 24, 1997								
12 – 2	3871	786	**0.13**	**9259**	2450	1751	**0.13**	6061
2 – 4	4141	**2625**	**0.13**	**8501**	3636	**5721**	**0.13**	**6133**
Monday, October 27, 1997								
10 – 12	3946	5204	0.13	9574	5519	**1508**	**0.14**	**7327**
12 – 2	3624	2780	**0.14**	8435	5235	**1860**	**0.14**	**6285**
2:00-2:36	1873	602	**0.16**	**5896**	1871	**1067**	**0.16**	**8728**
2:36-3:06	700	**353**	**0.15**	**17120**	640	**651**	**0.16**	**4843**
3:06-3:40	2071	723	**0.21**	**12832**	2641	**1508**	**0.21**	**6368**
Tuesday, October 28, 1997								
10 – 12	12220	591	**0.33**	**15447**	3338	1458	**0.30**	**7294**
12 – 2	6338	**675**	**0.16**	**37800**	1927	924	**0.15**	**6242**
2 – 4	6088	504	**0.15**	**12704**	1450	**2711**	**0.15**	**6255**
Wednesday, October 29, 1997								
10 – 12	9084	1219	**0.14**	11897	5211	**1275**	**0.14**	**5651**
12 – 2	4316	**664**	**0.13**	**8399**	4137	1286	**0.13**	**6348**
2 – 4	5170	**572**	**0.13**	**7288**	4692	**1491**	**0.14**	**5894**
B. Control Periods								
Friday								
12 – 2	2256	819	0.10	14115	2136	1925	0.11	9589
2 – 4	3769	986	0.11	13895	3202	1555	0.11	9817
Monday								
10 – 12	3122	1283	0.14	8493	3211	941	0.13	9710
12 – 2	1784	1026	0.10	9349	2106	1065	0.10	12573
2:00-2:36	658	1112	0.11	8702	811	2892	0.10	11367
2:36-3:06	627	618	0.11	7852	1706	858	0.11	8686
3:06-3:40	952	700	0.11	8815	1213	1040	0.11	8208
Tuesday								
10 – 12	3813	2161	0.12	12880	3266	1927	0.11	9313
12 – 2	2608	1942	0.10	11688	2431	1407	0.10	10134
2 – 4	5410	1380	0.11	11993	3900	940	0.11	10648
Wednesday								
10 – 12	3754	950	0.11	19919	3541	2615	0.11	12196
12 – 2	2283	1668	0.10	19947	2354	1317	0.10	11783
2 – 4	3037	2003	0.11	10203	3225	941	0.11	8816

Table 3

Limit Order Book Spread and Cumulative Depth
October 27, 1997 through October 28, 1997

This table presents data on the limit order book spread as well as the cumulative depth on the buyside and sellside 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 30 minutes. The LOB spread is the spread between the best buyside and sellside 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** are significantly different from the control periods July 18-23, 1997 and September 12-17, 1997 at the 5% level for both parametric and non-parametric tests.

Time	Buyside				LOB Spread	Sellside			
	At Best Limit order price	1/8 away	1/4 away	1/2 away		At Best Limit order price	1/8 away	1/4 away	1/2 away
A. Monday, October 27, 1997									
Open	2315	6129	7985	13566	1.21	3880	6430	9484	13273
10:30	2790	**5811**	**8539**	15566	0.79	2570	8313	13552	19342
11:30	3920	9811	13092	17399	1.05	4153	7392	12168	16827
12:30	3642	8936	12143	16491	0.57	4509	9854	14842	19113
1:30	4604	9668	14103	21202	0.48	**3023**	**6829**	11769	18211
2:36	5257	7652	11363	16249	0.65	3501	10417	15120	21745
3:06	5148	**7992**	11275	**14911**	0.72	3511	**8644**	**11850**	**17714**
3:36	4422	**6490**	**8962**	**11375**	**0.84**	**2564**	**5486**	**8221**	**14588**
B. Tuesday, October 28, 1997									
Open	2631	**3972**	**6175**	9901	**2.12**	3805	6488	8128	10819
10:30	3175	**4205**	**5158**	**8936**	**2.91**	5037	6746	**8299**	**10610**
11:30	3678	**6054**	**7698**	**11379**	**2.90**	5548	7935	**9398**	**15050**
12:30	3154	6974	**9434**	13357	**2.93**	5304	9481	11093	**14577**
1:30	5029	7445	**9418**	**13171**	**2.96**	4563	9306	10810	**14194**
2:30	3227	**6428**	**8870**	**13217**	**3.00**	4619	8444	10856	**14712**
3:30	3001	**4972**	**6497**	**9666**	**3.13**	4673	**7452**	**11667**	**15634**
Close	3218	**7026**	**8837**	**12762**	**3.09**	6003	**10538**	**16257**	**20195**

Table 4

Buyside Limit Order Flow Characteristics

This table presents data on the buyside limit order flow for the 100 stocks in our sample for the four days surrounding the market event of late October 1997 as well as the control periods July 18-23, 1997 and September 12-17, 1997. N represents the number of orders that were placed. Shares represents the average order size for placed, executed and cancelled orders respectively. Dispersion is defined as the average dollar difference between the limit order price of the placed or cancelled order and the current posted bid price. Values in **bold** are significant at the 5% level for both parametric and non-parametric tests.

	Placed			Executed	Cancelled	
	N	Shares	Dispersion	Shares	Shares	Dispersion
			A. Market Event Period			
Friday, October 24, 1997						
12 – 2	7674	1947	0.13	1996	2046	0.23
2 – 4	8891	2238	0.08	2183	**2332**	0.12
Monday, October 27, 1997						
10 – 12	9634	1915	0.08	1973	1852	0.09
12 – 2	8985	2085	**0.25**	1804	**2454**	0.35
2:00-2:36	3315	**2337**	0.19	1934	**2903**	0.18
2:37-3:05	720	**1321**	**1.79**	**1074**	2874	**4.44**
3:06–3:36	2055	2691	**0.38**	2213	**4416**	**0.46**
Tuesday, October 28, 1997						
10 – 12	6799	**1935**	**0.74**	**2276**	**2477**	**0.92**
12 – 2	4753	1830	**0.63**	**2217**	**2454**	0.33
2 – 4	4857	1891	0.38	1888	**2376**	0.20
Wednesday, October 29, 1997						
10 – 12	9927	**1658**	**0.34**	**1749**	1690	0.22
12 – 2	7642	**1556**	0.18	**1574**	**1689**	0.09
2 – 4	9149	**1519**	0.17	**1581**	**1585**	0.13
			B. Control Periods			
Friday						
12 – 2	4720	1944	0.13	1747	2187	0.26
2 – 4	7724	2203	0.08	2162	2159	0.17
Monday						
10 – 12	6351	1891	0.08	1913	1891	0.19
12 – 2	3694	1990	0.16	1890	2188	0.29
2:00–2:36	1461	1899	0.14	1788	2173	0.29
2:37-3:05	1388	2006	0.12	1807	2341	0.25
3:06–3:36	2194	2046	0.04	1901	2252	0.13
Tuesday						
10 – 12	6557	1723	0.11	1794	1644	0.25
12 – 2	4732	1841	0.12	1923	1809	0.27
2 – 4	9938	1821	0.05	1826	1781	0.15
Wednesday						
10 – 12	6618	1894	0.10	2015	1788	0.21
12 – 2	4391	1885	0.12	1830	2053	0.27
2 – 4	6229	2024	0.04	1997	2105	0.12

Table 5

Sellside Limit Order Flow Characteristics

This table presents data on the sellside limit order flow for the 100 stocks in our sample for the four days surrounding the market event of late October 1997 as well as the control periods July 18-23, 1997 and September 12-17, 1997. N represents the number of orders that were placed. Shares represents the average order size for placed, executed and cancelled orders respectively. Dispersion is defined as the average dollar difference between the limit order price of the placed or cancelled order and the current posted ask price. Values in **bold** are significant at the 5% level for both parametric and non-parametric tests.

	Placed			Executed	Cancelled	
	N	Shares	Dispersion	Shares	Shares	Dispersion
			A. Market Event Period			
Friday, October 24, 1997						
12 – 2	5030	**2389**	0.10	**2406**	**2405**	0.12
2 – 4	9214	2204	**0.04**	2172	2103	0.12
Monday, October 27, 1997						
10 – 12	8270	**2143**	**0.03**	**2246**	1998	0.21
12 – 2	9237	**2099**	**0.02**	2064	2124	**0.17**
2:00-2:36	3446	**2448**	**0.03**	**2379**	**2452**	**0.16**
2:37-3:05	267	3019	**0.56**	2202	3146	0.43
3:06–3:36	3801	**2225**	**-0.04**	2226	**2183**	**0.23**
Tuesday, October 28, 1997						
10 – 12	4979	**2081**	**0.04**	**2255**	1855	0.18
12 – 2	3410	**1812**	0.11	1979	1649	0.15
2 – 4	2952	**2604**	0.21	**2470**	2576	0.25
Wednesday, October 29, 1997						
10 – 12	10024	**2178**	0.09	2179	**2256**	**0.22**
12 – 2	8628	**1959**	**0.04**	2040	**1929**	0.15
2 – 4	7706	2056	0.05	2043	2143	0.15
			B. Control Periods			
Friday						
12 – 2	4351	1907	0.10	2044	1820	0.14
2 – 4	6611	2307	0.09	2335	2139	0.14
Monday						
10 – 12	5324	1842	0.12	1845	1868	0.21
12 – 2	3788	1922	0.08	1904	2009	0.10
2:00–2:36	1404	1941	0.08	1966	1985	0.10
2:37-3:05	1546	1976	0.06	1865	2111	0.06
3:06–3:36	2102	1923	0.05	2002	1908	0.10
Tuesday						
10 – 12	5640	1923	0.10	1973	1888	0.13
12 – 2	4170	2098	0.10	2031	2225	0.12
2 – 4	7497	2242	0.08	2041	2327	0.09
Wednesday						
10 – 12	6558	1969	0.09	2041	1966	0.16
12 – 2	4539	2111	0.08	2029	2312	0.13
2 – 4	6009	2094	0.08	2054	2216	0.15

Table 6

Liquidity Provision by Floor Members and the Limit Order Book
October 27, 1997 through October 28, 1997

This table presents data on the percentage of time the floor is contributing depth to the market as well as the average share contribution to the market depth for 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 30 minutes. % Floor Depth displays the percentage of time floor members are supplying at least some of the depth at the posted quotes. Floor (LOB) Depth corresponds to the average number of shares provided by floor members (limit order book) at the posted quotes. Floor members encompass both the specialists' own interest as well as the interest of floor brokers. Values in **bold** are significantly different from the control periods July 18-23, 1997 and September 12-17, 1997 at the 5% level for both parametric and non-parametric tests.

	Buyside			Sellside		
Time	% Floor Depth	Floor Depth	LOB Depth	% Floor Depth	Floor Depth	LOB Depth
			A. Monday, October 27, 1997			
Open	0.64	844	1509	0.72	1162	2289
10:30	0.44	773	1979	0.57	1712	1238
11:30	0.43	**636**	2932	0.64	1887	2258
12:30	0.43	**777**	2690	0.63	2589	2140
1:30	0.34	616	3672	0.61	2299	1646
2:36	0.45	932	4450	0.57	1809	1805
3:06	**0.52**	1033	4452	**0.73**	2736	1428
3:36	**0.46**	605	3678	0.61	1698	**1249**
			B. Tuesday, October 28, 1997			
Open	0.52	661	2166	**0.87**	2792	1548
10:30	**0.75**	**3158**	**964**	**0.91**	2411	**464**
11:30	**0.76**	**2881**	**1194**	**0.80**	1715	**827**
12:30	**0.69**	2157	**1440**	**0.84**	4481	1230
1:30	**0.78**	2194	2233	**0.81**	3153	**542**
2:30	**0.82**	1245	**499**	**0.76**	2739	**898**
3:30	**0.81**	**2166**	**1125**	**0.80**	1787	**1104**
Close	**0.77**	**2100**	**1177**	**0.79**	**5484**	**1175**

Table 7

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 – 1:29PM and 1:29 – 1:59PM as well as the period 2:06 – 2:36PM. 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 ten 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 significant at the 5% level for both parametric and non-parametric tests.

		Monday, October 27, 1997					Control Periods				
		Market Sell Orders		Limit Orders			Market Sell Orders		Limit Orders		
	Change in DJIA	Number	Volume	Sell Placed	Sell Disp.	Buy Cancels	Number	Volume	Sell Placed	Sell Disp.	Buy Cancels
A. 12:59 – 1:29 PM (DJIA starts at 7530 and ends at 7458; loss of 72)											
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
B. 1:29 – 1:59 PM (DJIA starts at 7458 and ends at 7372; loss of 86)											
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 8

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 buyside and sellside 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** are significant at the 5% level for both parametric and non-parametric tests.

	2:36 PM	3:06 PM	3:35 PM
A. Quoted Price Schedule			
Spread	0.2144	0.1900	0.2350
Ask Depth	5299	5076	3478
Bid Depth	3608	3711	**2766**
B. Limit Order Book			
LOB Spread	0.6458	0.7145	**0.8345**
Ask Depth	3501	3511	**2564**
Sell Cum. Depth 1/8 away	10417	**8644**	**5486**
Sell Cum. Depth 1/2 away	21745	**17714**	**14588**
Bid Depth	5257	5148	4422
Buy Cum. Depth 1/8 away	7652	**7992**	**6490**
Buy Cum. Depth 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

Chart 1

Dow Jones Industrial Average Minute-by-Minute

The chart depicts the Dow Jones Industrial Average minute-by-minute over the two day period, Monday, October, 27, 1997 through Tuesday, October, 28, 1997.

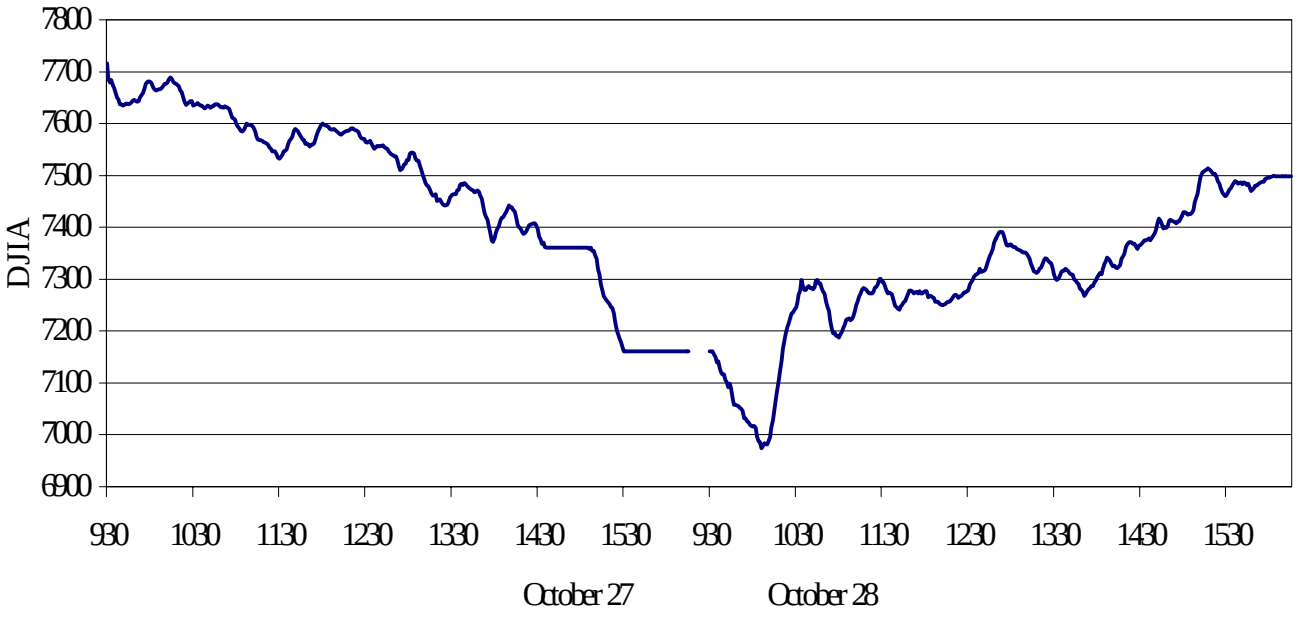
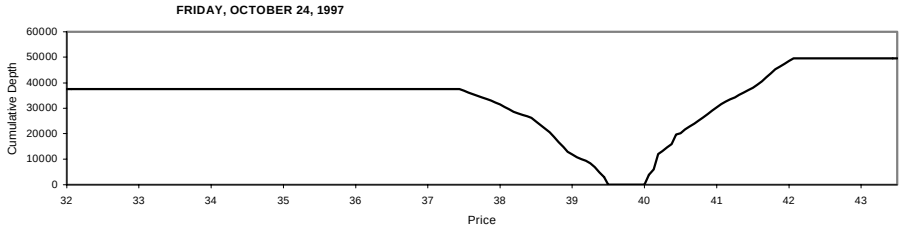
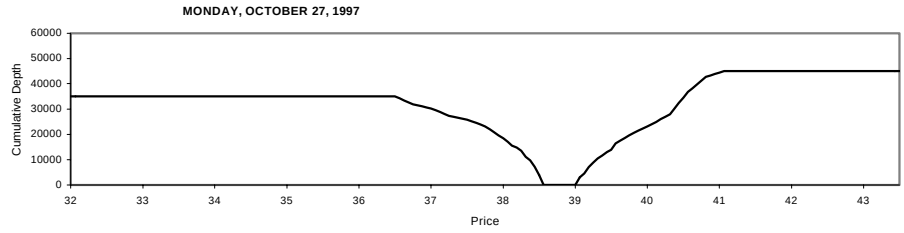


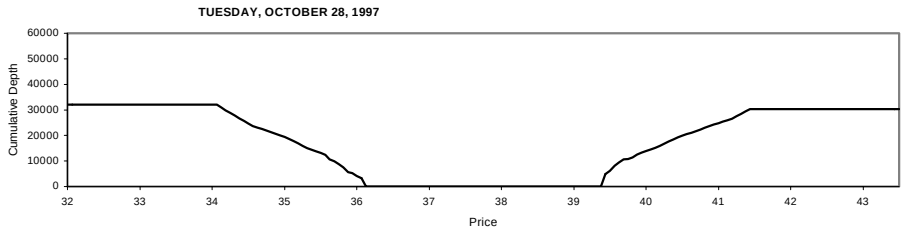
Chart 2

Cumulative Limit Order Book Depth at 1:00 PM

The chart depicts the average cumulative limit order book depth for the 100 stocks in our sample. Limit order books (LOB) were estimated using the technique described in Kavajecz (1999). Cumulative depth is the sum of all shares available at a particular price or better on the limit order book up to $2.00 away. Cumulative depth is measured from the best limit order price on the limit order book on that side of the market. The left portion of each chart represents the cumulative buyside limit orders while the right portion of each chart represents the cumulative sellside limit orders. The portion of each chart that has zero cumulative depth represents the average limit order book spread.







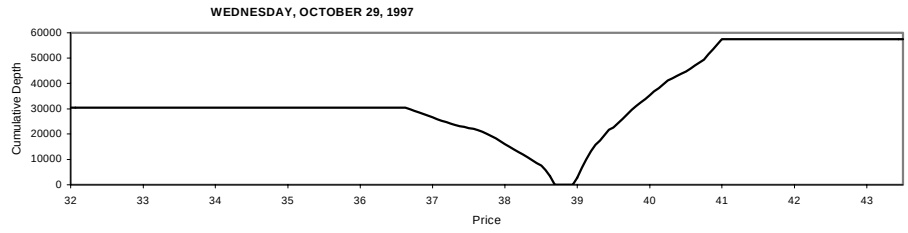


Chart 3

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, October 24, 1997 at Noon through the close Wednesday, October 29, 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 30 minutes. Cumulative depth is the sum of all shares available at a particular price or better on the limit order book up to $2.00 away. Cumulative depth is measured from the best limit order price on the limit order book on that side of the market. The left (lower) portion represents the cumulative buyside limit orders while the right (upper) portion of the chart represents the cumulative sellside limit orders. The valley in the center represents the average limit order book spread.

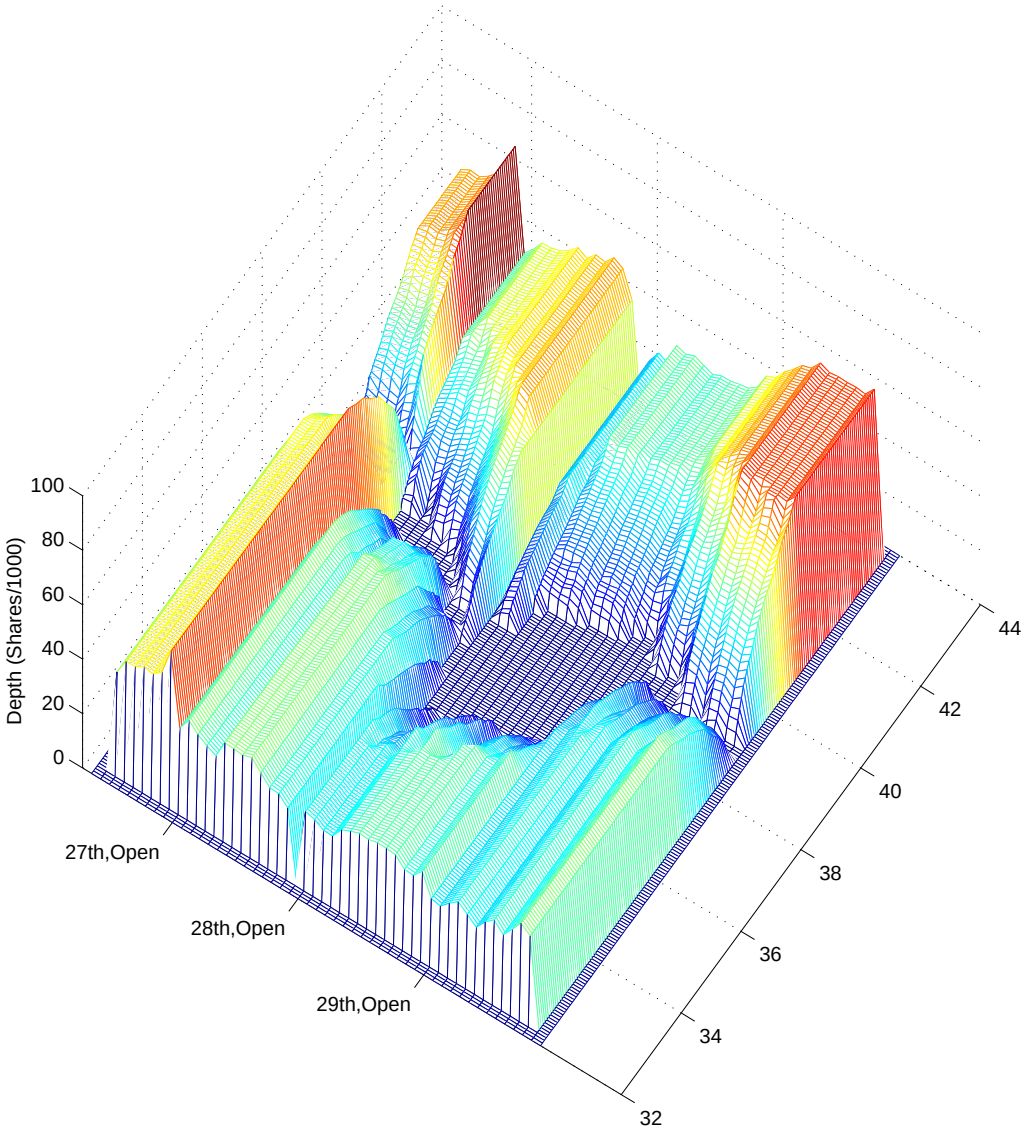


Chart 4

Quoted Spreads and Limit Order Book Spreads

The chart shows the average quoted spread (dark solid bar) and the average limit order book spread (narrow line) for the 100 stocks in our sample from Noon, Friday, October 24, 1997 through 4:00 PM, Wednesday, October 29, 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 30 minutes. The LOB spread is the spread between the best buyside and sellside limit order prices. The spreads are centered on the average quoted spread midpoint and the average limit order book spread midpoint respectively.

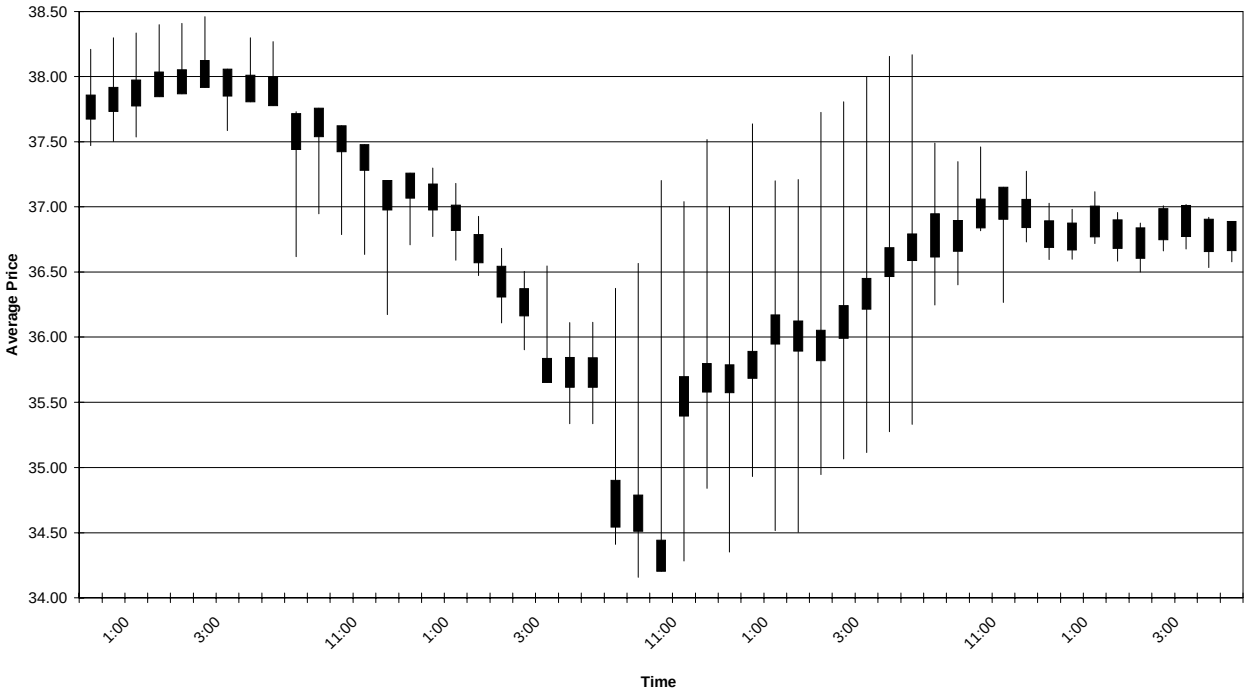


Chart 5

Cumulative Limit Order Book Depth Surrounding the Market Wide Trading Halts

The chart depicts the average cumulative limit order book depth for the 100 stocks in our sample. Limit order books (LOB) were estimated using the technique described in Kavajecz (1999). Cumulative depth is the sum of all shares available at a particular price or better on the limit order book up to $2.00 away. Cumulative depth is measured from the best limit order price on the limit order book on that side of the market. The left portion of each chart represents the cumulative buyside limit orders while the right portion of each chart represents the cumulative sellside limit orders. The portion of each chart that has zero cumulative depth represents the average limit order book spread.