# Bid-Ask Spread Management In A Market Without Asymmetric Information

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Much has been learned about the workings of financial markets over the past two decades through the efforts of researchers focusing on market microstructure. Most of these efforts have focused on equity markets and were aided by the availability of increasingly more detailed data sets and more powerful computing systems. The results have been greater insights into the actions of traders who provide the capital and expertise in a complex, yet efficient, market process.

Traders who take on the "dealer" function in equity markets are entrepreneurs who invest their capital with the expectation of profits from commissions on trades and from successful arbitrage trading. The ultimate consumers of dealer's services are investors whose goals include a target rate of risk adjusted return over an expected time horizon. Also trading in these markets are traders who seek to arbitrage price and trading site differences, and traders who speculate on future price changes. The more complicated the trading process, and the more market-affected variables involved, the more complex the process becomes, which provides greater opportunities for arbitrage and "knowledge based" trading.

While straight forward in concept, modeling these trading processes is difficult, particularly for equities, because of multiple markets and the multiple combinations of investments available. In addition, there is not unanimity as to the theoretical basis on which to model the trading "business". Two models are generally used to model these markets. The first is the theory of the firm model where the dealer conducts business as a shopkeeper and customers buy the dealer's services. The second is a game

theoretic model in which traders compete in a game where there are winners and losers. Central to the game theoretic model is knowledge based trading where traders with superior information take advantage of less informed traders. Because game theoretic models provide an ability to analyze behavior when there is asymmetric information, they have been used extensively to model equity markets.

In contrast to the complex stock and options markets are the debt markets where there are terminal pay offs, predictable cash flows, and outside evaluation of default risk. As a result, debt markets have less asymmetric information and fewer opportunities for information based trading. Nonetheless, the dollar volume of trading in debt markets is very large. For instance, the T-Bill market is one of the largest markets when measured in dollars traded, yet it is the least complicated of the large financial markets due to the absence of factors that make other financial markets more complicated.[1] Consequently, the Treasury-debt market provides an opportunity to analyze trading activity that is limited to the buying and selling a commodity for which the parameters are well-know by all of the participants. Because of the absence of asymmetric information about future cash flows and discount rates, dealers focus narrowly on providing liquidity to the market.[2] The simplicity of the Treasury-debt market, coupled with its lack of asymmetric information about the value of future cash flows, results in trading more compatible with the theory-of-the-firm model than a game

[1] Fleming and Remolona (1999) note that between April and August of 1994 (a time period in the middle of our sample) dealers traded an average of $125 billion per day of US Treasury securities. More currently, Fleming (2003) estimates the US Treasury market activity at $296 billion per day during the first half of 2001.

[2] Barclay, Hendershott, and Kotz (2006) state '…there are no difference in the payoff-relevant information for on- and off-the-run securities. Therefore, we can hold the level of informational asymmetry constant and focus on the matching function…" (p. 2404). This statement suggests there is little or no asymmetric information about intrinsic value in the Treasury bill market. It also suggests that dealers match orders and allows for liquidity-based information in order flow, which is the point of this paper.

theory model.

Our focus in this paper is to analyze dealer behavior in a market with a minimum or no value-based asymmetric information. To achieve this end, we employ the theory-of-the-firm model to analyze the bid-ask spread management of securities dealers trading in the off-the-run one-month T-bills. The combination of (1) a short time period, (2) virtually zero default risk, and (3) robust liquidity in the T-Bill market creates an environment where asymmetric information and speculative trading activities are very minor relative to the management of inventory and spreads. Profitable trading in this environment requires close attention be paid by dealers to spreads and inventory management. Moreover, because the downside risk of holding inventory is mitigated by maturity payoffs, investors bear the cost of distress sales prior to maturity.

Because the topic of this paper and the empirical testing differ from that used in the extant literature, it is important to provide detail on those differences. Hence, the following section is devoted to an explanation of the importance of the topic and demonstrating that the off-the-run one-month T-bill market provides an experimental setting by which to observe market activity in an environment that is void of asymmetric information between the dealers and investors about the value of future cash flows.

### 1.1. The Economic Question

The difficulties in determining the motivation for trades in equity and option markets by dealers and market-makers were recognized early on by researchers. In such complex markets, there are multiple trading niches with multiple trading participants. The participants engage in trades for different reasons among which are: (1) to control inventory; (2) to exploit asymmetric information and, (3) to satisfy

customers. However, it is difficult to determine from the data which factor is motivating the trading activity. Hasbrouck (1988, p. 229-231) discusses the difficulties inherent in categorizing a trader's activities as inventory control actions or asymmetric-information actions, the two factors that most interested researchers investigating equity markets. He notes that they are not competing paradigms since they occur concurrently and he provides some empirical evidence that delineates between inventory control and asymmetric information activities.

Although inventory control and asymmetric information are inextricably linked, the preponderance of researchers has focused on asymmetric information trading. The focus on asymmetric information is understandable because of the emphasis on financial efficiency in the pricing process and, because the trading structure in equity and derivative markets lends itself to the game theory model. [3, 4]

Hasbrouck's (1988, p. 229-231) observation regarding the difficulties of separating the motives for a trader's activities between inventory control actions and asymmetric-information exploitation suggests that we select a trading environment where asymmetric information about the value of future cash flows is minimal or non existent to investigate inventory-control trading. In such a market, all, or most, of the parameters of the market have to be well known by all investors and there is little opportunity to make information-based trades. The off-the-run T-Bill market provides just such a trading environment.

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[3] An example of this focus is the structure of O'Hara's (1995) textbook: *Market Microstructure Theory*. The book is divided into nine chapters with five chapters devoted to information issues and one chapter devoted to inventory issues.

[4] In contrast, Benveniste, Marcus, and Wilhelm (1992) explore markets where "the specialist actively differentiates between informed and uniformed traders and has the power to sanction traders exploiting private information." They find that this action "improves on the terms of trades faced by uniformed

## 1.2. Off-The-Run One-Month T-Bills as the Experimental Setting

Hasbrouck (1999) notes that bid-ask spreads include components to cover market making costs, inventory costs, and asymmetric information costs. However, there has been a lack of consistency in cost allocations across studies. Since there is not consistency in disentangling inventory costs from other costs in the complex equity and option markets, we take the approach of analyzing these costs in a market that is less complex and where inventory costs are the predominate factor. The off-the-run T-Bill market is an example of this type of market and is the choice of market for our analysis.

The T-Bill market is one of the largest markets when measured in dollars traded, yet it the least complicated of the large financial markets because factors that make other financial markets more complicated are absent in the T-Bill market.[5] Asymmetric information problems about the value of future cash flows are minimal to non-existent. The timing of expiration of old issues and the issuance of new issues is known with certainty although the quantity of new issues is not. Credit quality issues are non-existent; however, the T-bill market is not immune from economic shocks both internal to the US and external from the foreign markets.

The activities of T-Bill dealers within this framework can be viewed as a simple business model of buying T-Bills, selling T-Bills and holding an inventory of T-Bills. As with dealers of other financial instruments, T-Bill dealers quote bid-ask spreads that reflect their evaluation of market conditions and their respective inventory positions. To

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traders."

[5] Fleming and Remolona (1999) note that between April and August of 1994 (a time period in the middle of our sample) dealers traded an average of $125 billion per day of US Treasury securities. More currently, Fleming (2003) estimates the US Treasury market activity at $296 billion per day during the first

supply liquidity, dealers must maintain inventory or access to inventory to meet expected sales. The buying and selling activities of dealers are straightforward except in episodes of liquidity crises, an issue detailed later in this paper. However, inventory management differs from that of other financial markets due to the short duration of T-Bills. Because the T-Bills held in a dealer's inventory will mature in a relative short period, there is a minimum of "spoilage." The opportunity cost of holding a T-Bill for the dealer is mitigated by the redemption by the Treasury and the existence of an active repo market. This factor influences the bid-ask spreads of dealers because it reduces, or eliminates, distress sales of instruments by dealers and greatly increases the cost of liquidity for a distress sale by an investor.

Off-the-run T-bills provide a trading environment that is even simpler. This market has less uncertainty than on-the-run T-bills market due to several factors. First, the volume outstanding in off-the-run T-bills is known while on-the-run T-bills are newly issued T-Bills and the volume is not known until the Treasury makes it weekly auction announcement. Second, the primary market price of the new on-the-run T-bill is determined in an auction dominated by a few dealers so the market must match new T-bills with the secondary market demand before a market equilibrium price is determined. The off-the-run period follows the on-the-run period for each T-bill, so off-the-run T-bills have been through the process of arriving at the equilibrium secondary market price during the on-the-run period. Thus, the off-the-run T-bills market has the least uncertainty of all money market instruments with the remaining uncertainty being attributable to changes in future interest rates. In this market with few parameters, the

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half of 2001.

primary dynamic that dealers must manage is the level of inventory, and over the life of the off-the-run T-bill, dealers reduce inventory holdings as trading declines.

### 1.3. Summary of Results

To gain insights into the activities of dealers in a security market, it is helpful to have events where such individuals dramatically change behavior. These behavioral shifts occur when there is a substantial change in supply or demand, or an event that disrupts normal market making activities such that dealers stop their market-making function and retire to the sidelines by reducing the incentives to trade. Ideally, the investigator would like a shift in supply, a shift in demand, and a serious market disruption such that each event results in market makers holding no inventory and merely clearing buy and sell orders. Each of these events would lead the dealer to change their bid-ask spreads to accommodate the market, protect their income streams, and retain their capital.

The period from June 1988 to June 2001 contains two market events that resulted in shocks. The first event is the Salomon Brothers attempt to corner the Two-Year Treasury Note market which produced a supply shock; and; the second event is the collapse of Long Term Capital Management (LTCM) which produced a demand shock. The first event resulted in dealers charging a premium over previous spreads to hold inventory and facilitate trades. The second event resulted in dealers reducing inventory while continuing to facilitate trades.

The results show that, in the absence of asymmetric information, dealers change bid-ask spreads to manage their inventory. The results also reveal that dealers manage their bid-ask spreads so that they are compensated for their market-making activities

when market conditions change. We also find that dealers respond to market supply/demand conditions by altering the bid-ask spread.

## 2. Regime Shifts in Bid-Ask Spread, Major Market Events, and Changes in the Bid-Ask Spread

Shifts in the bid-ask spread are crucial to this study because each shift signals changes in dealer behavior and changes in behavior allow us to examine how the spread is changed and thus, we can infer how dealers manage their inventory. Therefore, in this section we identify the significant shifts in the bid-ask spread, link the timing of these shifts to important market events, and discuss the effect of the market events on the supply or demand for T-bills.

### 2.1. Regime Shifts

The first step in the process of investigating inventory management is to examine the data for structural breaks. Figure 1 plots the daily spreads for off-the-run one-month T-bills for the period covering 6/13/88 through 6/30/01 inclusive. The plot suggests three distinct breaks (regime shifts) in daily spreads. The first break is between May and June of 1991, the second between October and November of 1996, and the third break is between September and October 1998.

Next we employ a Chow test to determine if the observed regime shifts in the daily spread are statistically significant. Following Jordan and Jordan (1996), we test whether bid-ask spreads in the six weeks before the identified break are significantly different from those in the six weeks following the break using OLS with White's (1980) adjustment for heteroscedasticity.[6]

Our model is:

[6] We use the variant suggested by Jordan and Jordan (1996) who examine the Salomon Brothers' May 1991 attempt to corner the Treasury note market.

$$Spread_t = a_{Mon}D1 + a_{Tu}D2 + a_{Wed}D3 + a_{Th}D4 + a_{Fri}D5 + c(Break) + \varepsilon_t \quad (1)$$

where

*Spread*$_t$ = bid-ask spread on day t,

Di = 0/1 dummy variable that where D1 = 1 on Monday, D2 = 1 on Tuesday, D3 = 1 on Wednesday, D4 = 1 on Thursday and D5 = 1 on Friday,

*Break*$_t$ = 0/1 dummy variable that equals 0 for the six weeks before the break and equals 1 for the six weeks following the break.

We discuss the results, but do not present the results in Table form (available upon request) in the interest of brevity. The first break point (month-end 5/91) is positive and significant at the 5% level with the parameter estimate suggesting the average spreads increased 1.8 basis points following the break.[7] The second break point (month-end 10/96) is negative and significant at better than the 1% level with the parameter estimate suggesting the average spreads decreased 3.2 basis points. The third break point (month-end 9/98) is positive and significant at better than the 1% level with the parameter estimate suggesting the average spreads increased by 2.0 basis points.

## 2.2. Major Market Events at the Identified Break Points in the Bid-Ask Spread

Having determined that there are three significant regime shifts, we next determine if there was an associated major market event. The standard approach to this process is a Lexus/Nexis or Wall Street Journal index search. However, we break

[7] A minor adjustment was made to the May 1991 month-end data to conform with the findings of Park and Reinganum (1996). Without the adjustment, the results remain significant at the 5% level and the average spread increase is 1.5 bps.

from tradition here and chose to discuss the break dates with a senior officer in the Fixed Income area of a major brokerage house who traded US government securities throughout our sample period. The officer quickly identified the break point dates as coinciding with: (1) the Salomon Brothers attempts to corner the Two-Year Treasury Note market at the May 1991 auction, (2) the Asian financial crisis, and (3) the collapse of Long Term Capital Management (LTCM). Details of these three events are briefly presented below.

In the May 1991 two-year note auction, the US Treasury sold $12.29 billion in two-year notes. In subsequent testimony before Congress, Salomon Brothers' executives reported controlling 94% of the notes sold through competitive bids and 86% of all the notes sold in the auction, which substantially exceeded the 35% limit for a single bidder in a Treasury auction.[8] Jordan and Jordan (1996) examine the price impact of Salomon's actions and estimate that the notes were overpriced by 16 basis points for approximately six weeks following the auction.[9]

The Asian financial crisis has been well documented in the financial press and academic finance journals.[10] Many authors document market events related to the financial problems in Asia throughout 1997 and 1998. Others have referred to these events as the Asian financial crisis of 1997 (see, Pan, Chan, and Wright (2001)). The 1997 date reflects the fallout of the crisis, not the beginning of the crisis. The evidence

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[8] See, U.S. Department of the Treasury, Securities and Exchange Commission and Board of Governors of the Federal Reserve System, 1992, *Joint Report on the Government Securities Market,* Washington D.C., U.S. Government Printing Office.

[9] Jordan and Jordan (1996) consider this to be a conservative estimate.

[10] A search of the Economics Literature Database using 'Asian financial crisis' showed 75 published articles on the topic through 2003.

reveals that the crisis began at the end of 1996 which coincides with the second break in our data. However, delving deeper into the issue reveals there was also a change in the source of our data around this same date. Prior to this break the Federal Reserve collected the data on T-bill yields and provided the data to the Wall Street Journal. At the break point, the Fed discontinued its data collection because it determined that the data were readily available from other sources and the Wall Street Journal switched to Cantor Fitzgerald as its source of T-bill yields. We are unable to determine whether the break in the spread data is a response to the Asian Financial Crisis or the result of the change in the data source, nor were we able to obtain the necessary data from an alternative source. Accordingly, we remove this break point from any further analysis.

In the late summer and early fall of 1998, Long Term Capital Management (LTCM) was in the financial news due to its impending collapse. At the time, LTCM held $125 billion in assets on a capital base of only $4 billion, and the Federal Reserve was concerned about adverse market consequences should the hedge fund be forced to liquidate its assets to meet its current obligations. To prevent market liquidity problems, the Federal Reserve Bank of New York contacted major creditors and counterparties of LTCM to begin discussions that led to private sector parties providing $3.5 billion of additional capital in exchange for 90% of the equity of LTCM. The re-capitalization of LTCM occurred on September 23, 1998.[11] While the problems and re-capitalization of LTCM were prominent in the financial news, LTCM was not an isolated problem. It was part of a global financial crisis that Fleming (2000) and the Committee on the Global Financial System (1999) argue lead to a flight to quality and to liquidity.

[11] See, the report from the Committee on the Global Financial System titled “A Review of Financial Market Events in Autumn 1998”, which is available from the Bank for International Settlement. (October 1999).

## 2.3. Prices Changes from Exogenous Supply and Demand Shocks

Significant structural breaks in the time series of daily bid-ask spreads have been identified and linked to important market events. Next we describe the effect of each market event on the supply or demand for T-bills and discuss how dealers would be expected to respond to these exogenous shocks in setting bid and ask prices. Standard economic theory suggests that, in the absence of perfect substitutes, an exogenous shock to either supply or demand changes the market-clearing price.[12] Accordingly, we discuss the market events in terms of a supply or demand shock, and demonstrate the expected price effect from the shock. It is important when evaluating the price effect to recall which economic factor is causing the price change. Since we examine T-bills with one-month remaining until maturity, a supply or demand shock is unlikely to alter the intrinsic value of the T-bill because the only cash flow from the bill is due in one-month, and payment of the expected cash flow is considered certain. Instead, an exogenous supply or demand shock alters only the liquidity (inventory management) component of the price.

Salomon Brothers attempted to corner the May 1991 two-year note auction by controlling 94% of the notes sold through competitive bids and 86% of all the notes sold in the auction. This action restricted the supply of these T-notes available in the market. If this event is strictly an isolated in the two-year T-note market then we would expect no change in the behavior of T-bill dealers. Our results on regime shifts suggest that T-bill spread patterns changed at this time which suggests that the effects from Salomon's actions were not isolated in the T-note market. Instead, the actions by one dealer to control the supply on one Treasury security created concerns among the remaining dealers about the supply issues across other Treasury securities.[13] These concerns

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[12] Simon (1991 and 1994) provides evidence that market participants do not considered adjacent T-bills as perfect substitutes.

[13] Specifically, the two-year note that Salomon squeezed went 'fails' in the repo market. This meant that

would manifest in prices in a manner similar to a reduction in supply with a resulting increase in the price.

Since a reduction in supply increases the price of an asset (and we are assuming that the reduction in supply does not alter the intrinsic value of a T-bill with one month to maturity), the price increase must alter the liquidity component of the price. Specifically, such a supply shock would increase the ask price, therefore increasing the bid-ask spread as dealers to increase the price of having inventory available for sale.

The collapse of LTCM saw a flight to quality and to liquidity. A flight to quality is evident in Figure 2 where the spread between risk classes of commercial paper increases while the yield on T-bills falls following the collapse of LTCM. However, a flight to quality and a flight to liquidity are potentially offsetting effects for dealers in the T-bill market. Treasury securities are default-free so a flight to quality should be a flight toward T-bills which would result in an increase in investor demand that T-bill dealers could capture through an increase in the ask price. However, Scholes (2000) notes that during this time liquidity providers are unwilling to take long-horizon positions (hold inventory). If T-bill dealers are unwilling to hold inventory they will lower their bid price. Thus, we expect to see an increase in the bid-ask spread following the collapse of LTCM. However, the side of the spread that will change depends on which effect dominates.

## 3. Primary Data Set and Basic Descriptive Statistics

The off-the-run one-month T-bill spread data plotted in Figure 1 covers from 6/13/88 through 6/30/01 and represents the primary data set for our analysis. During this sample period, new Treasury bills were *not* issued with four-week terms to maturity in the regular auction process, so all of the data are for T-bills originally issued with at

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dealers wishing to sell short treasuries (either directly or through repos) could not be sure the other Treasury securities were not free of squeezes and they reacted by increasing prices.

least 13 weeks to maturity.[14] In addition, since T-bills are only issued one day per week, a true one-month bill is only available one day per week. Accordingly, our primary data set is for the T-bill closest to one-month from maturity.

We collect data daily for off-the-run T-bills. The data from 8/1/89 through 10/15/96 were collected from Treasury security quote sheets compiled by the Federal Reserve Bank of New York. The Fed quote sheet data were collected from market participants (Treasury securities dealers) that the Fed believes to be reliable. The Fed produced its daily quote sheet prior to 8/1/89, but we do not have access to those sheets. Instead, from 6/13/88 through 7/31/89 we collect data from the Wall Street Journal. For the period from 6/13/88 through 7/31/89 the Wall Street Journal reporting format is identical to the Fed quote sheets. Beginning on 8/1/89 we have access to both the Fed daily quote sheet and the Wall Street Journal and random comparisons between the Wall Street Journal and the Fed quote sheets find the two sources to be identical on each day examined. Data for the period from 10/16/96 through 6/30/01 were also collected from the Wall Street Journal. For the period from10/16/96 through 6/30/01 the Federal Reserve did not produce its daily quote sheet so the Wall Street Journal had to find an alternative source for its Treasury securities data. The data reported in the Wall Street Journal during this period was provided by Cantor Fitzgerald.[15]

In addition to the off-the-run one-month T-bill data, we collected 'on-the-run' three-month T-bill data from the Fed quote sheets. Finally, starting on 7/31/01 (8/2/01)

[14] We note that during our sample the Treasury issued cash management bills as needed and some cash management bills might have been issued with one month to maturity, but if this happened it would be unusual and irregular.

[15] When the Fed stopped providing its delay quote sheet it made the following statement. "The Federal Reserve Bank of New York has ended publication of the daily treasury securities price quotes. The final issue was posted to the ftp site on October 15, 1996. This reflects the Fed's decision to discontinue daily collection and compilation of treasury prices from its trading counterparties. No other Federal Reserve statistical releases will be affected. There are various sources that provide similar information on the internet."

the Treasury began auctioning (issuing) T-bills with an initial maturity of four weeks. We collected data from the Wall Street Journal from 8/2/01 through 6/28/02 for the on-the-run one-month (four-week) T-bill. For all bills, we collected the daily closing values of the annualized bid and ask yields.

Table 1 Panel A provides summary statistics for off-the-run T-bills for the entire sample on: (1) bid yields, (2) ask yields, and (3) the bid-ask spread. For our sample, the mean bid yield is 4.92%, while the mean ask yield is 4.85%. Thus, the mean bid-ask spread is 7 basis points (bps). An average spread of 7 bps is 5 bps larger than the minimum spread for a round trip in the T-bill market and is also 5 bps larger than the average spread for the on-the-run three-month T-bill spread for the period of 8/1/89 through 10/15/96. In addition, after removing the first 21 trading days for the new one-month T-bill, the following 193 trading days have spreads of 1 bp 93% of the time (179 out of 193 observations). A spread of 1 bp implies that dealers are not anticipating round trip trading in new one-month T-bills.[16] The substantial difference in spreads between the on-the-run and the off-the-run T-bills provides prima facie evidence that liquidity is a concern for dealers in off-the-run market. These results re-enforce Fleming's (2002) findings that dealers increase the spread for off-the-run T-bills. The difference in spreads between on-the-run and off-the-run T-Bills reflects that dealers are compensated for their liquidity services.[17]

Table 1 Panel B provides the frequencies of the various bid-ask spreads for the off-the-run T-bill with one month until maturity across our sample. The most frequently

[16] The first 21 trading days of the new one-month bill clearly comprise a start-up period and the bid-ask spread is 8 bps for each of the 21 days. After the start-up period there are only 13 days where the spread is not 1 bp. On those 13 days the spreads are 3 days at 2 bps, 2 days at 3 bps, 5 days at 5 bps, and 1 day each at 6 bps, 10 bps, and 15 bps.

[17] Fabozzi (2001) notes that analysis of data from GovPX, Inc., indicates that in 1998, 71% of trading activity in the Treasury market was in *on-the-run* issues. Brandt and Kavajecz (2004, Table 1) show that net order flow for *on-the-run* T-bills with maturities of six months or less is about double the net order flow of similar T-bills that are just *off-the-run*.

observed spread for the off-the-run T-bills is 4 bps, which is observed 38.90% of the time. A close second is a spread of 10 bps, which is observed 33.57% of the time. The third most popular spread is 8 bps, which is observed 13.83% of the time. Each of the remaining spreads appears less than 5% of the time. The concentration of spreads on even numbers is suggestive of dealer spread management. There is a similarity between spread management in this market and the spread management of NASDAQ dealer who avoid the odd 8$^{th}$ quotes (see, Christie and Schultz (1994) and Christie, Harris and Schultz (1994)).

The spread frequencies reported in Table 1 clearly show spread clustering which is consistent with spread management. The earlier break point regression analysis indicated significant breaks in spreads around the two identified major market events. Accordingly, the remainder of the paper focuses on analysis around the Salomon Brothers squeeze and the collapse of Long Term Capital Management (LTCM). Because we are examining price behavior around major market events, we isolate each event by examining spreads from six month on either side of each event. Using spreads minimizes the affect of any trend in the level of interest rates and using six months of data provides a sufficient number of observations for our tests while limiting the distance from each event.

For the focused event analysis, we use data for the T-bill closest to 30 days to maturity. We use additional data on the T-bill closest to 45 days to maturity and the T-bill closest to 30 days, but less than 30 days to maturity. The 45 day bill data are collected because this bill will mature at a different time in the calendar month than the bill closest to 30 days.[18] The bill closest to 30 days (but less than 31 days) is collected to determine if 30 days to maturity is an important break point in T-bill maturities.[19]

[18] This is necessary because the last bill to mature in a month trades at a yield discount to adjacent bills (Park and Reinganum (1986)).

[19] Griffiths and Winters (2005) find year-end preferred habitats in one-month money market security yields, but not in three-month yields.

## 4. The Salomon Brothers Attempt to Corner the Treasury Market (Event month equals May 1991)

Jordan and Jordan (1996) examine the price impact of Salomon's attempt to corner the two-year T-note market in May 1991 and find that the notes from this auction were overpriced by about 16 basis points for approximately six weeks following the auction. Although Salomon's actions directly affected only this one auction of two-year Treasury notes, our initial analysis suggests that their actions had much farther reaching implications by creating a general concern among dealers about the availability of Treasury securities. These concerns are evident from our preliminary analysis of daily bid-ask spreads in off-the-run one-month T-bills. In this section we provide a more detailed analysis of the bid-ask spread around the Salomon squeeze.

We divide our analysis into two parts. We begin with a detailed frequency analysis of spreads to determine where the dealers manage the spread. Then we use regression analysis on change in spreads and changes in the bid and the ask to determine how the dealers manage the spread.

### 4.a. Spread Analysis

Table 2 provides spread frequencies for the T-bill with maturity closest to 30 days and for the T-bill with a maturity closest to 30 days but not exceeding 30 days. The difference in these two spread series is that the series for the bill closest to 30 days includes bills with 31 days until maturity which are not in the other series because it is limited to 30 days or less. The result is that each series contains the same value on four of five trading days in a normal work week with the exception being the day of the week where the first series contains the yield on a T-bill with 31 days to maturity (the other series contains the yield on a 24-day T-bill). Using these two series allows us to determine if 30 days to maturity is an important break point in time to maturity in T-bills.

Panel A of Table 2 provides frequencies for both series around the Salmon squeeze. There is a stark contrast between the pre and post Salomon squeeze. Before the squeeze 72.95% of the spreads for the T-bill closest to 30 days are 2 bps with 22.13% at 4 bps. A spread of 2 bps is the minimum spread on a round trip in this market and is consistent with dealers simply process orders and moving T-bills in a highly liquid market. After the squeeze 84.43% of the spreads are 10 bps with 15.57% at 4 bps. These spread frequencies suggest that dealers increased their spreads. A spread increase is consistent with concern about available supplies. The T-bill closet to 30 days but with 30 days or less shows a similar increase in the spread following the Salomon squeeze. However, after the squeeze this bill shows a 10 bps spread 91.80% of the time.

Panel B and C of Table 2 provide matrices of spreads for the two series before and after the Salomon squeeze. The matrices are designed so that the diagonal are the number of observations where the spread for the two series are the same on a given day. The off-diagonal items represent the days when the two series have different spreads. By definition the off-diagonal observations must be the days when the series closest to 30 days has observations for a 31 day bill because on all other days the two series are the same. Thus, these matrices are designed to determine if 30 days to maturity is an important break point in the maturity series of T-bills. For example, Panel B shows 25 days where both series have a spread of 4 bps and two days where the bill closet to 30 days has a spread of 4 bps while the series of 30 days or less has a spread of 2 bps. On these two days the 31 day bill has a spread of 4 bps while the 24 day bill has a spread of 2 bps.

Panel B shows that before the Salomon squeeze the two series have the same spreads on all but four days and the four days are evenly distributed above and below the diagonal. The even distribution suggests that 30 days to maturity is not a break point before the Salomon squeeze. Panel C shows the series differ on 9 days and for

each of the 9 days the bill closets to 30 days has a spread of 4 bps and the series of closest 30 days but with 30 days or less has a spread of 10 bps. On these 9 days the first series has a bill with 31 days to maturity and the second series has a bill with 24 days to maturity, so the results suggest that following the Salomon squeeze 30 days to maturity became a significant break point in the dealers' management of the spread and the dealers increase the spread at 30 days until maturity.

We do not report the spread frequencies on the 45 day series in table form. We find that 87.70% of the spreads are 2 bps before the Salomon squeeze and 97.96% are 4 bps following the Salmon squeeze. In general, T-bill spreads increased following the Salomon squeeze but the increase is larger at the 30 day break point revealing concerns about the availability of T-bills across maturities and the price for liquidity is higher in the shorter bills.

### 4.b. Regression Analysis

The frequency analysis suggests that the size of the spread increased following the Salmon squeeze in the two-year note and that 30 days to maturity is a important break point in the maturity of T-bills. These results suggest that dealers actively manage the T-bill spread after the Salomon squeeze. In this section we extend our analysis to regression analysis in an attempt to determine the specifics on how the dealers manage their spreads.

To examine the spread change behavior by the dealers, we estimate regressions on the daily spread changes. We believe day-of-the-week controls are indicated because Gibbons and Hess (1981) and Flannery and Protopapadakis (1988) find day-of-the-week effects in T-bill returns. Hence, we include day of the week dummies in analyzing daily spread changes the following regression:

$$Spread_t - Spread_{t-1} = b_{Mon}D1 + b_{Tu}D2 + b_{Wed}D3 + b_{Th}D4 + b_{Fri}D5 + d\left(TB_t - TB_{t-1}\right) + \varepsilon_t \quad (2)$$

where

Di = 0/1 dummy variable that where D1 = 1 on Monday, D2 = 1 on Tuesday, D3 = 1 on Wednesday, D4 = 1 on Thursday and D5 = 1 on Friday,

$TB_t$ = annualized yield for the on-the-run three-month T-bill on day t, which is included to control for changes in the general level of short-term interest rates.[20]

All regressions are estimated using OLS with White's (1980) adjustment for heteroscedasticity and estimated separately for the six-month period before and after the Salomon squeeze. The regression results from equation (2) are reported in Table 3.

Panel A of Table 3 report results from before the squeeze with the first set of results on the series of bills closest to 30 days and the second set on the series of bills closest to 30 but with 30 days or less. Our frequency analysis suggests that dealers did not actively manage the spread before the Salomon squeeze, so we do not expect to find any significant pattern in spread changes. The model has no explanatory power with no significant parameter estimates. This results support dealers are not managing the spread based on days to maturity before the squeeze.

Following the Salomon squeeze our frequency analysis suggests dealer increased the size of the spread and actively managed the spread around 30-days to maturity. Accordingly, we expect to find a spread change pattern associated with 30 days to maturity. Panel B of Table 3 reports results for the six-month period following the Salomon squeeze. Here, both models provide some explanatory power on daily spread changes. For the spread series on bills closets to 30 days until maturity we find

[20] Note, we collected data on the bid and ask yield for on-the-run three-month T-bills for only a portion of the entire sample period covered by our off-the-run data. So, for our regression analysis we collected daily secondary market yields for three-month T-bills for the entire sample period from the FRED database at the Federal Reserve Bank of St. Louis. We chose 3-month T-bills as a proxy for the general level of short-term interest rates because Musto (1997) and Griffiths and Winters (1997a) both find no evidence of regularities in this instrument. We recognize that by using a 3-month yield to proxy for the general level of 1-month rates we are mismatching maturities.

a significant [at better than the 1% level] and negative parameter estimate on Mondays.[21] The data series construction is such that a typical week has the 31 day bill on Monday, the 30 day bill on Tuesday, and so on until the 27 day bill on Friday. The result is that Monday captures the weekly maturity break where the series jumps from 27 days to maturity up to 31 days to maturity. The negative parameter estimate suggests smaller spread on 31 day bill than 27 day bill, which is consistent with the dealers increasing the spread around the 30 day maturity break point. The insignificant parameter estimates for the remainder of the week suggest a positive drift in the spread across the remained of the week. A positive drift is necessary to keep the negative Monday spread change from driving the spread to zero.

The regression in Panel B for the spread series of closest to 30 but with 30 days or less has a significant [at better than the 1% level] and negative parameter estimate on Tuesdays. In this series the typical week has 24 days until maturity on Monday, 30 days until maturity on Tuesday, 29 days until maturity on Wednesday, and so on. This means that Tuesday is the break point in the maturity series for this spread. A detailed analysis of the 24 day spread indicates that all 24 days spreads during this period are 10 bps. Not all 30 day spreads are 10 bps. Instead some are 4 bps, so the negative parameter estimates captures that on some Tuesdays the 30 day spread is not 10 bps.

In an attempt to see how the dealers change the spread we re-estimate the regression model (equation (2)) with the change in the bid and the change in the ask as the dependent variable and we do these estimation on the data series of the T-bill closest to 30 days to maturity. Recall, that the Salomon squeeze is a supply restriction, so we expect dealers managing their spread will increase their ask price (decrease ask yield) to earn compensation for making T-bills available for sale. The results are reported in Table 4.

[21] Note, the yield data is recorded as percent yields so, for example, the parameter estimate for the Monday spread change of -0.0244 represents 2.44 basis points.

Panel A of Table 4 provides the regression results on the bid and ask for the six month period before the Salomon squeeze. All previous results suggest dealers are not managing the spread before the Salomon squeeze, so we do not expect to find a pattern in these results. No day-of-the-week parameter estimate are significant at better than the 5% level.

Panel B of Table 4 provides the regression results on the bid and ask for the six month period after the Salomon squeeze. All previous results suggest dealers are managing the spread after the Salomon squeeze, so we do expect to find a pattern in these results. One day-of-the-week parameter estimate is significant [at better than the 5% level] and that parameter is a positive Monday parameter on the ask. A significant parameter estimate on the Monday ask without a significant parameter estimate on the Monday bid suggests that when the 31 day bill has a 4 bps spread its because the ask yield increased (ask price decreased) narrowing the spread relative at a 27 day T-bill. This suggests that the positive drift in the spread across the week comes from drift down in the ask yield (up in the ask price) across the week to accommodate the Monday effect in the data. A positive drift in the price suggests that dealers are increasing their price for making inventory available following an inventory squeeze. That is, dealers increase what they charge for their market making function for T-bills with 30 days or less until maturity.

## 5. Collapse of Long Term Capital Management (Event month is September 1998))

The daily spreads plot in figure 1 show the end of September 1998 as the last break in the T-bill spread data and suggests a change from a one spread market to a two spread market. Our regime shift regression confirms a significant change in the average bid-ask spread around the re-capitalization of LTCM. Accordingly, this section reports the results of our detailed analysis on the collapse of Long Term Capital

Management (LTCM). We follow the methods we used to analysis the Salomon squeeze.

### 5.a. Spread Analysis

Panel A of Table 5 shows the spread frequencies for the six month on either side of the collapse of LTCM. The panel provides spreads for the series of closest to 30 days to maturity followed by the series of closest to 30 days but with 30 days or less to maturity. The T-bill closest to 30 days exhibits a one spread market with 97.50% of its spreads at 4 bps before the collapse. After the collapse we see a two spread market with 22.13% of the spreads at 4 bps and with 77.87% of the spreads at 8 bps. The series on the bill closest to 30 days but with 30 days or less exhibit a one spread market on both sides of the collapse. Before the collapse 96.67% of the spreads are 4 bps and after the collapse 97.54% of the spreads is 8 bps. This spread increases suggests that dealers increased their spread following the collapse of LTCM.

Recall that the difference in the two series is that the series of bills closest to 30 days to maturity includes T-bills with 31 days to maturity while the other series does not. Accordingly, the differences in the spread frequencies following the collapse must be the 31 day bills and they appear to have a 4 bps spread when the other series has an 8 bps spread. This suggests that following the collapse of LTCM 30 days to maturity becomes a significant break point in the maturity series of the T-bills.

Panels B and C of Table 5 provide the spread pairs for the two data series. Panel B reports spreads from before the collapse and shows that the spreads are same across the two series on all but one day. Panel C reports the spread pairs after the collapse of LTCM and shows that there are 24 days when the spread on the series closest to 30 days is 4 bps while the spread on the other series is 8 bps.[22] This means

[22] Note, that the difference between the two series at 31 days occurs one time per week and we have 24 occurrences which means 24 weeks. We only analyze six months of data on either side of the event, so these 24 occurrences represent every week in the sample, post event.

31 day bills have smaller spreads and suggests that following the collapse that 30 days to maturity becomes a significant break point in the maturity of T-bills and that spreads increased at this break point.

We also examine the spread frequencies for the 45 day maturity series. Prior to the collapse of LTCM over 95% of the spreads in this series are 4 bps. Following the collapse over 95% of the spreads in this series are 4 bps. This suggests that following the collapse of LTCM the spread increased at 30 days to maturity but not in the longer terms as was seen previously in the Salomon squeeze. The different treatments of spreads around the two events strongly suggest that dealers actively manage their spreads to manage their inventory.

### 5.b. Regression Analysis

Next we estimate our regression model (equation (2)) around the collapse of LTCM and report the results in Table 6. We estimate the regression model on both 30 day series and divide the estimation into before (Panel A) and after (Panel B) the collapse of LTCM.

In Panel A we report only one statistically significant parameter estimate [at the 5% level or better] and that is for Mondays in the series with maturity closest to 30 days. Since the frequencies suggest a one spread market before the collapse a significant parameter estimate for one of the days of the week is surprising (and potentially spurious). However, size of the parameter is only one-third of a basis point which is not economically significant. Accordingly, we do not attach any importance to this parameter estimate and move on to the regression results from after the collapse.

Panel B of Table 6 provides the regression results for both series for the six months following the collapse of LTCM. The regression results on the series with maturity closest to 30 days have four significant parameter estimates on the day-of-the-week variables while the regression results on the series closest to 30 days but 30 days

of less have two significant parameter estimates on the day-of-the-week variables. The significant parameter estimates on the series for closet to 30 days to maturity are negative parameters on Monday and Friday with positive parameters on Tuesday and Wednesday. The Monday parameter estimate represents the data series break from 27 days back up to 31 days and suggests that the 31 days spread is about 4 bps less than the 27 day spread, on average. The Tuesday parameter estimate is the move from 31 days to maturity to 30 days and suggests that the 30 day spread is about 4 bps higher than the 31 day spread. This again suggests that following the collapse of LTCM the 30 days to maturity is an important break point to the maturity time series of T-bills. The Wednesday and Friday parameter estimates represent one-half basis point or less and therefore are not economically significant. The statistically significant parameter estimates on the series of closest to 30 days but with 30 days or less represent about one-half basis point and therefore are not economically significant. The lack of any economically meaningful day-of-the-week parameter estimates on the data series of closest to 30 days but with 30 days or less suggest a one spread market once the maturity is 30 days or less, which is consistent with our frequency results.

Table 7 reports estimations of equation (2) on changes in the bid and the ask of the T-bill series with maturity closest to 30 days. Panel A reports the results from the six months before the collapse of LTCM and finds significant parameter estimates for both the bid and the ask on Mondays and Thursdays. The parameter estimates for Mondays are positive for both the bid and the ask and the difference in the size between the two parameter is consistent with the one-third basis point change in the spread report in Table 6 Panel A. Both Thursday parameter estimates are negative and the size of the parameter estimates are almost identical which is consistent with no change in the spread.

Panel B of Table 7 reports the results from after the collapse of LTCM. Both the bid and the ask have significant and positive parameter estimates on Mondays. The

positive parameter estimates suggest that yields rise and prices fall on Mondays. Mondays capture the break in the data series when the maturity switches from a 27 day bill on Friday to a 31 day bill on Monday. Since T-bills are discount instruments, the price should increase as maturity declines, ceteris paribus. Accordingly, the parameter estimates capture a purely mechanical process and therefore we do not attach any economic significance to these parameters. None of the other day-of-the-week parameter estimates are statistically significant. However, on Tuesday the size of the parameter estimates are almost 4 bps apart which is consistent with the almost 4 bps change in the spread reported in Table 6. Specifically, the parameter estimates suggest that the bid yield increased about 3.9 bps while the ask yield is unchanged. An increase in the bid yield means a decrease in the bid price which suggests that following the collapse of LTCM dealers lowered their bid price at the 30 day break point to avoid acquiring inventory. This is consistent with Scholes' (2000) statement that following the collapse of LTCM providers of liquidity were unwilling to take the long positions necessary to keep the market liquid.

The results around the collapse of LTCM suggest that dealers actively manage their spreads to manage their inventory. Specifically, the results suggest that dealers manage their spread to avoid accumulating inventory. Additionally, the differences in the spread management behavior around the two events suggest that dealers tailor their spread management to the market conditions prevailing at the time.

## 6. Further Discussion and Analysis of Spread Changes

At this point, we have provided strong economic and statistical support for dealer bid-ask spread management in a manner consistent with dealer inventory management in response to changes in market liquidity. In this section, we address some issues that potentially could affect our study. One issue is the quality of the data. Our data come from two sources. A major portion of the data comes from the Federal Reserve daily

quote sheets that are generated by the Federal Reserve which surveys dealers who actively trade with the Federal Reserve. Since the Fed is an important portion of these dealers' business it is possible that the dealers provided quotes consistent with what they thought the Fed wanted to hear as opposed to quotes that reflect actual market conditions. We consider the possibility of dealers not reporting accurately to be small because the Federal Reserve buys and sells securities for its own portfolio and would have almost as much information as the dealers about rates. Moreover only the Salomon Brother event analysis is based on the Fed data. The LTCM event analysis is based on Wall Street Journal data obtained from Cantor Fitzgerald.[23] Hence, the potential for data bias is very small.

The second issue is the change in behavior of the spread in the primary data set (T-bills closest to 30 days to maturity) around the two economic break points. In a financial market that is the least complicated of all the financial markets, the break points are so stark as to raise concerns about the reliability of the results. To address this issue we collected additional data from the six months on either side of the two break points. One of the additional data sets contains the bid and ask prices for the T-bills with–approximately 45 days remaining until maturity. These bills do not mature during the same time of the month as the bills in the original data source. The second data set contains bid and ask prices for the bills less than 31 days but closest to 30 days to maturity. This additional data was collected to determine if 30 days to maturity is a break point in T-bill pricing. As we detailed above, The results show there is a clear break point at 30 days in the maturity series of T-bills following each of the two events and that the 45 day bill are managed differently around the two events.

## 7. **Summary and Discussion**

[23] Cantor Fitzgerald is a brokerage service for Wall Street's fixed income inter-dealer community. They provide the Wall Street Journal summary information based on the market transactions.

The liquidity services that dealers provide by buying, selling, and holding inventory are crucial to the efficient functioning of markets. However, it is difficult to examine empirically dealer inventory practices in most markets because it is difficult to isolate inventory price effects from asymmetric information price effects. We isolate the inventory price effects by examining prices in a market with minimal or no asymmetric information, and find that dealers do set bid-ask spreads to manage inventory and receive compensation for their liquidity services.

Specifically, we examine daily bid-ask spreads in the market for off-the-run one-month T-bills. During our sample period, there are two significant structural breaks in the time series of spreads that we can unambiguously link with a major market liquidity event. The first break aligns with Salomon Brothers' cornering of the two-year T-note auction in May of 1991. This event is a restriction in the supply of a Treasury security and we find that dealers respond by increasing the ask price to receive additional compensation for making T-bills available. The second break aligns with the collapse of LTCM in September 1998. The financial market problems concurrent with the collapse of LTCM resulted in the providers of liquidity withdrawing from the market and the dealer responded by lowering their bid prices to avoid acquiring inventory and thus limiting their liquidity services.

In conclusion, our results support a fundamental proposition in finance that liquidity is an important component in the price of financial assets. Further, our results reveal that dealers alter the liquidity component of the bid-ask spread in response to changes in liquidity conditions in the market. Dealers manage the spread by increasing

the ask price when the supply of T-bills is a concern and by decreasing the bid price when there is concern about providing liquidity.

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**Table 1 Descriptive Statistics on Bid yields, Ask yields, and Bid-ask Spreads for Off-the-Run One-Month T-bills**

**Panel A: Summary Statistics**

| | Mean | Median | Mode | Inter-quartile range |
|---|---|---|---|---|
| **Bid** | 4.92% | 4.88% | 4.86% | 4.01% - 5.47% |
| **Ask** | 4.85% | 4.82% | 4.82% | 3.93% - 5.39% |
| **Spread** | 0.07% | 0.08% | 0.04% | 0.04% - 0.10% |

**Panel B: Spread Frequencies [Primary data set]**

| Bid-ask Spread (bps) | Count | Percentage |
|---|---|---|
| **2 bps** | 110 | 3.35% |
| **3** | 3 | 0.10% |
| **4** | 1212 | 38.90% |
| **5** | 4 | 0.13% |
| **6** | 70 | 2.25% |
| **7** | 135 | 4.33% |
| **8** | 431 | 13.83% |
| **9** | 1 | 0.03% |
| **10** | 1046 | 33.57% |
| **12** | 83 | 2.66% |
| **greater than 12** | 20 | 0.85% |

**Table 2 Spread Frequencies for Six Months Before and After Salomon Brothers' Attempt to Corner of the T-Note Market**

**Panel A:**

| | **T-bill closest to 30 days** | | **T-bill of 30 days or less** | |
|---|---|---|---|---|
| **Spread (bps)** | **Before** | **After** | **Before** | **After** |
| **2** | 72.95% | 0.00% | 72.95% | 0.00% |
| **4** | 22.13 | 15.57 | 22.13 | 8.20 |
| **6** | 2.46 | 0.00 | 2.46 | 0.00 |
| **8** | 0.82 | 0.00 | 0.82 | 0.00 |
| **10** | 0.82 | 84.43 | 1.64 | 91.80 |
| **12** | 0.82 | 0.00 | 0.00 | 0.00 |

**Panel B: Before Break**

| N=122 | **30 days or less** | | | | | |
|---|---|---|---|---|---|---|
| | Basis points | **2** | **4** | **6** | **8** | **10** |
| **Closest to 30 days** | **2** | *87* | *2* | 0 | 0 | 0 |
| | **4** | *2* | *25* | 0 | 0 | 0 |
| | **6** | 0 | 0 | *3* | 0 | 0 |
| | **8** | 0 | 0 | 0 | *1* | 0 |
| | **10** | 0 | 0 | 0 | 0 | *1* |

**Panel C: After Break**

| N=122 | **30 days or less** | | | | | |
|---|---|---|---|---|---|---|
| | Basis points | **2** | **4** | **6** | **8** | **10** |
| **Closest to 30 days** | **2** | *0* | 0 | 0 | 0 | 0 |
| | **4** | 0 | *10* | 0 | 0 | **9** |
| | **6** | 0 | 0 | *0* | 0 | 0 |
| | **8** | 0 | 0 | 0 | *0* | 0 |
| | **10** | 0 | 0 | 0 | 0 | *103* |

**Table 3 Spreads Results for the Six Months Before and After Salomon's Attempt to Corner the Market**

**Panel A: Before Break**

| | Closest to 30 | | 30 days or less | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | -0.0002 | 0.9620 | -0.0010 | 0.7224 |
| Tuesday | 0.0032 | 0.3326 | 0.0032 | 0.2644 |
| Wednesday | -0.0036 | 0.2635 | -0.0028 | 0.3162 |
| Thursday | 0.0040 | 0.2244 | 0.0040 | 0.1619 |
| Friday | -0.0012 | 0.5695 | -0.0018 | 0.5136 |
| 3-mth TB | -0.0182 | 0.5186 | -0.0179 | 0.4663 |
| F-stat | 0.74 | 0.6220 | 0.89 | 0.5059 |
| Adj R-sq. | -0.0133 | | -0.0056 | |

**Panel B: After Break**

| | Closest to 30 | | 30 days or less | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | -0.0244 | **<0.0001** | 0.0003 | 0.9444 |
| Tuesday | 0.0070 | 0.1343 | -0.0147 | **0.0002** |
| Wednesday | 0.0068 | 0.1378 | 0.0068 | 0.0765 |
| Thursday | 0.0048 | 0.3184 | 0.0047 | 0.2407 |
| Friday | 0.0023 | 0.6206 | 0.0023 | 0.5590 |
| 3-mth TB | -0.0208 | 0.7016 | -0.0317 | 0.4803 |
| F-stat | 5.13 | 0.0001 | 3.31 | 0.0049 |
| Adj R-sq. | 0.1690 | | 0.1019 | |

**Table 4** **Bid and Ask Results for the Six Months Before and After Salomon's Attempt to Corner the Market on the T-bill Closest to 30 days until Maturity**

**Panel A:** **Before Break**

| | Bid | | Ask | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | 0.0369 | 0.1607 | 0.0371 | 0.1730 |
| Tuesday | 0.0102 | 0.6924 | 0.0070 | 0.7920 |
| Wednesday | -0.0499 | 0.0535 | -0.0463 | 0.0829 |
| Thursday | -0.0017 | 0.9466 | -0.0057 | 0.8304 |
| Friday | -0.0093 | 0.7134 | -0.0074 | 0.7752 |
| 3-mth TB | 0.4949 | 0.0277 | 0.5131 | 0.0273 |
| F-stat | 2.19 | 0.0484 | 2.02 | 0.0691 |
| Adj R-sq. | 0.0559 | | 0.0480 | |

**Panel B:** **After Break**

| | Bid | | Ask | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | 0.0354 | 0.2510 | 0.0597 | **0.0547** |
| Tuesday | -0.0159 | 0.5806 | -0.0230 | 0.4276 |
| Wednesday | -0.0124 | 0.6591 | -0.0193 | 0.4963 |
| Thursday | -0.0263 | 0.3739 | -0.0311 | 0.2951 |
| Friday | 0.0328 | 0.2552 | 0.0305 | 0.2917 |
| 3-mth TB | 1.3585 | <0.0001 | 1.3792 | <0.0001 |
| F-stat | 3.87 | 0.0015 | 4.67 | 0.0003 |
| Adj R-sq. | 0.1238 | | 0.1528 | |

**Table 5 Spread Frequencies for Six Months Before and After the Collapse of Long Term Capital Management (LTCM)**

**Panel A:**

| | T-bill closest to 30 days | | T-bill of 30 days or less | |
|---|---|---|---|---|
| **Spread (bps)** | **Before** | **After** | **Before** | **After** |
| **2** | 1.67% | 0.00% | 1.67% | 0.00 |
| **4** | 97.50 | 22.13 | 96.67 | 2.46 |
| **6** | 0.00 | 0.00 | 0.00 | 0.00 |
| **8** | 0.83 | 77.87 | 1.67 | 97.54 |
| **10** | 0.00 | 0.00 | 0.00 | 0.00 |
| **12** | 0.00 | 0.00 | 0.00 | 0.00 |

**Panel B: Before Break**

| N=122 | 30 days or less | | | | | |
|---|---|---|---|---|---|---|
| | Basis points | **2** | **4** | **6** | **8** | **10** |
| **Closest to 30 days** | **2** | *2* | 0 | 0 | 0 | 0 |
| | **4** | 0 | *116* | 0 | 1 | 0 |
| | **6** | 0 | 0 | *0* | 0 | 0 |
| | **8** | 0 | 0 | 0 | *1* | 0 |
| | **10** | 0 | 0 | 0 | 0 | *0* |

**Panel C: After Break**

| N=122 | 30 days or less | | | | | |
|---|---|---|---|---|---|---|
| | Basis points | **2** | **4** | **6** | **8** | **10** |
| **Closest to 30 days** | **2** | *0* | 0 | 0 | 0 | 0 |
| | **4** | 0 | *3* | 0 | **24** | 0 |
| | **6** | 0 | 0 | *0* | 0 | 0 |
| | **8** | 0 | 0 | 0 | *95* | 0 |
| | **10** | 0 | 0 | 0 | 0 | *0* |

**Table 6 Spreads Results for the Six Months Before and After the Collapse of Long Term Capital Management**

**Panel A: Before Break**

| | Closest to 30 | | 30 days or less | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | -0.0031 | **0.0181** | -0.0003 | 0.9130 |
| Tuesday | -0.0004 | 0.7410 | -0.0041 | 0.0656 |
| Wednesday | 0.0009 | 0.4193 | 0.0016 | 0.4813 |
| Thursday | 0.0003 | 0.8171 | 0.0010 | 0.6563 |
| Friday | 0.0022 | 0.0692 | 0.0025 | 0.2828 |
| 3-mth TB | 0.0557 | <0.0001 | 0.0938 | 0.0003 |
| F-stat | 3.67 | 0.0022 | 3.63 | 0.0025 |
| Adj R-sq. | 0.1171 | | 0.1153 | |

**Panel B: After Break**

| | Closest to 30 | | 30 days or less | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | -0.0399 | **<0.0001** | 0.0003 | 0.8834 |
| Tuesday | 0.0384 | **<0.0001** | 0.0047 | **0.0222** |
| Wednesday | 0.0040 | **0.0396** | 0.0023 | 0.2525 |
| Thursday | -0.0000 | 0.9794 | -0.0001 | 0.9462 |
| Friday | -0.0050 | **0.0112** | -0.0051 | **0.0157** |
| 3-mth TB | -0.0023 | 0.8388 | -0.0065 | 0.5946 |
| F-stat | 137.06 | <0.0001 | 2.20 | 0.0477 |
| Adj R-sq. | .8700 | | 0.0558 | |

**Table 7** **Bid and Ask Results for the Six Months Before and After the collapse of Long Term Capital Management (LTCM) on the T-bill Closest to 30 days until Maturity**

**Panel A:** **Before Break**

| | Bid | | Ask | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | 0.0532 | **0.0087** | 0.0563 | **0.0066** |
| Tuesday | 0.0049 | 0.7796 | 0.0053 | 0.7678 |
| Wednesday | -0.0080 | 0.6537 | -0.0090 | 0.6235 |
| Thursday | -0.0516 | **0.0047** | -0.0519 | **0.0054** |
| Friday | -0.0244 | 0.1861 | -0.0265 | 0.1583 |
| 3-mth TB | 0.3324 | 0.1004 | 0.2768 | 0.1793 |
| F-stat | 4.97 | 0.0001 | 4.70 | 0.0003 |
| Adj R-sq. | 0.1646 | | 0.1549 | |

**Panel B:** **After Break**

| | Bid | | Ask | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **estimate** | **p-value** |
| Monday | 0.1201 | **0.0028** | 0.1600 | **<0.0001** |
| Tuesday | 0.0386 | 0.2920 | 0.0002 | 0.9960 |
| Wednesday | -0.0330 | 0.3666 | -0.0369 | 0.3159 |
| Thursday | -0.0331 | 0.3680 | -0.0330 | 0.3727 |
| Friday | -0.0609 | 0.1032 | -0.0559 | 0.1378 |
| 3-mth TB | 0.8751 | 0.0001 | 0.8774 | 0.0001 |
| F-stat | 7.04 | <0.0001 | 8.52 | <0.0001 |
| Adj R-sq. | 0.2290 | | 0.2699 | |

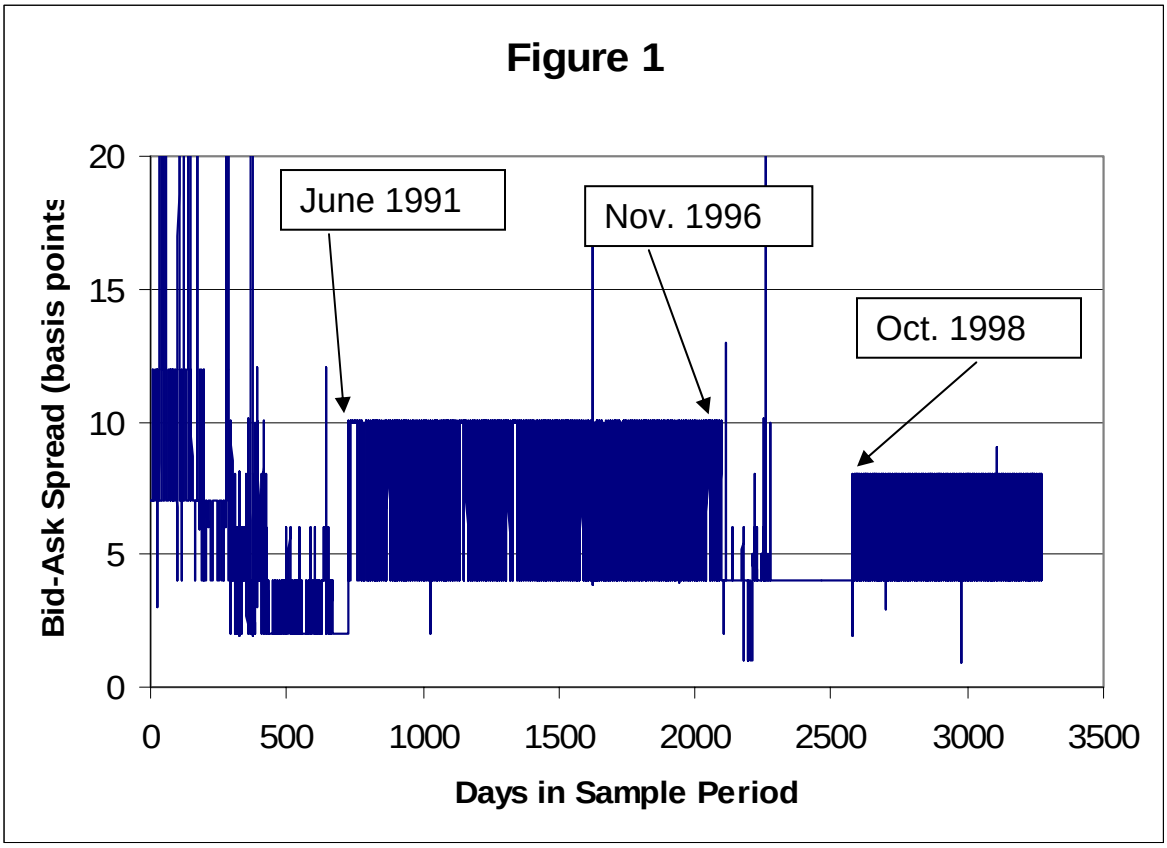
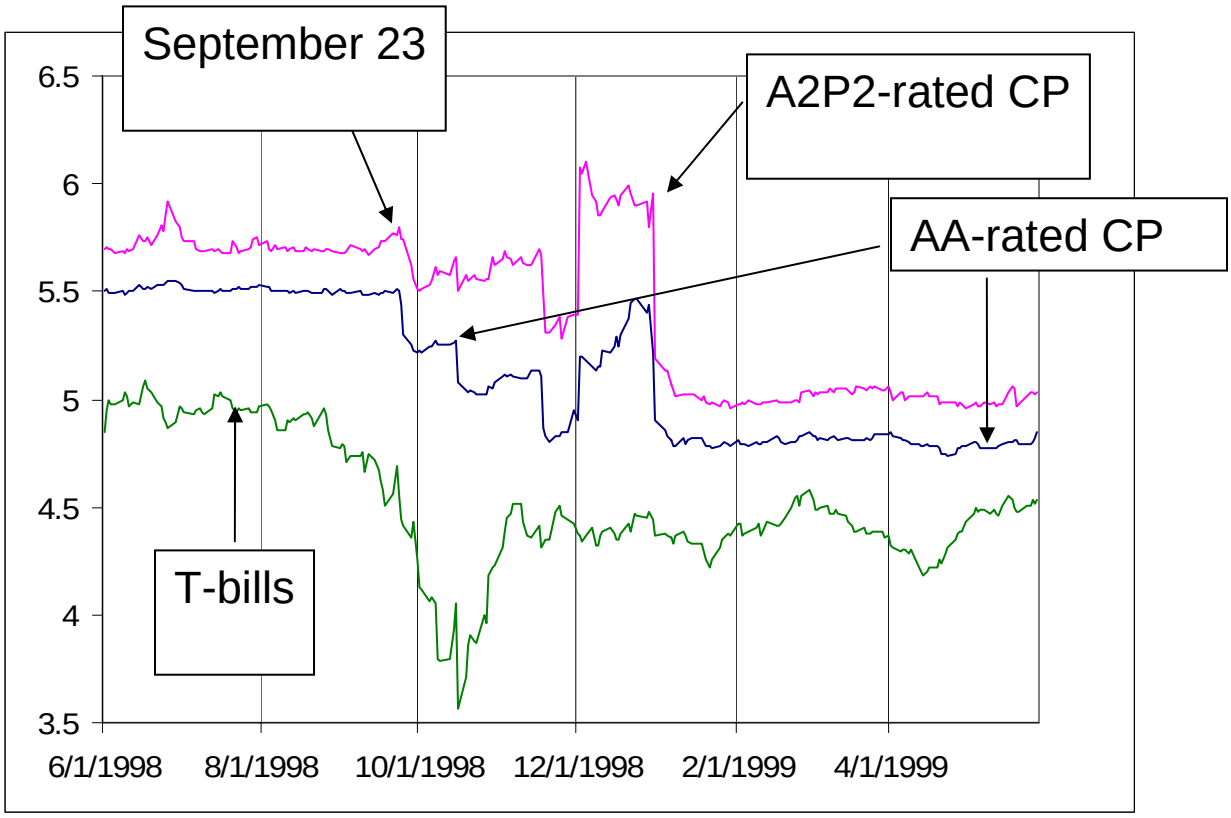


Figure 1
Bid-Ask Spread (basis points
20
15
10
5
0
June 1991
Nov. 1996
Oct. 1998
0
500
1000
1500
2000
2500
3000
3500
Days in Sample Period

**Figure 2**


September 23
A2P2-rated CP
AA-rated CP
T-bills
6.5
6
5.5
5
4.5
4
3.5
6/1/1998
8/1/1998
10/1/1998
12/1/1998
2/1/1999
4/1/1999