INFORMATION IN THE TREASURY BILL AUCTION RESULTS

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 1993

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PREFACE

Trading of Treasury bills occurs in the weekly auction market and the daily secondary market. After the auction occurs on Monday, the outcome of the auction is publicized. The information in the auction results is examined in this study.

Conclusions from examining information in the auction results include the following. First, the secondary market is slightly semi-strong form inefficient with respect to the percent of competitive auction bids accepted, the percent of unaccepted auction bids, the tail spread (high - low accepted auction discount rate) and the change in the Federal funds rate.

Next, the auction price was examined and found to be downward biased. The bidding adjustment which occurs due to the downward biasing is not found, however, to be determined by the auction results. The return in Tuesday's secondary

market, on the other hand, is determined by the price level in the auction.

Third, the Monday auction rate, which acts as a forward rate for a bill to be delivered on Thursday, is found to be a biased expectation of Thursday's spot rate. Finally, the auction results are not found to be determinants of the change in the secondary market bid-ask spread.

I wish to express my sincere gratitude to my committee members who assisted me in completing this dissertation, Drs. Ronald K. Miller, Tim Krehbiel, Janice W. Jadlow, and Tim C. Ireland. In particular, I wish to thank my chairman, Dr. Ronald K. Miller, for his guidance, knowledge, and especially his encouragement to always achieve what I thought was impossible.

Other individuals were highly instrumental in my completion of this dissertation. Thanks to my husband, Jim, for his love and support and for "enjoying the process" with me (or at least trying to). Thanks to Dimmick and Pauline

Bymaster and Richard and Ann Kenny for their continued love, prayers, and belief that Jim and I could earn these degrees. Thanks also to my parents for their many days of help on this project. Thanks to Dr. James Tripp, Dr. Carolyn Tripp, and Dr. Danny Reeder for their support, encouragement, and most of all for their friendship.

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CHAPTER I

INTRODUCTION

The purpose of this study is to examine the information in the Treasury bill auction results. Four methods are used to evaluate the information content of the Treasury bill auction results. The first method examines the efficiency of the Treasury bill secondary market with regard to information in the auction results. The next method examines whether or not the information in the Treasury bill auction explains the downward biased auction results. The third method examines whether the auction rate is an unbiased expectation of the asked rate on Thursday in the secondary market, given the information in the auction market on Monday. The last method examines the information in the Treasury bill auction market as a determinant of the secondary market bid-asked spread.

Scope of Study

The first question addressed is whether the Treasury bill secondary market is efficient with respect to the information carried in the announcement of the Treasury bill auction results. This is one aspect of the Treasury bill secondary market which has not been examined extensively.

The information used for this question relates to the strength of demand and the dispersion of information. Increased demand may not only show up as an increase in the dollar quantity demanded but also may show up in the form of more aggressive bids (Lumpkin, 1986). The dispersion of information, strength of demand, and aggressiveness of bidders can be seen in three pieces of information from the announcement of the auction results: the tail spread, the competitive bids accepted percentage, and the bids not filled percentage.

The dispersion of auction prices and aggressiveness of bidders can be seen through the Treasury bill auction tails and the tail spread. Two tails can be calculated using the average bid price accepted. The high tail is the difference between the highest price accepted (lowest discount rate) of the accepted bid and the average price of the accepted bids. The low tail is the difference between the lowest price accepted (highest discount rate) and the average price of the accepted bids. The tail spread is the sum of the low tail and the high tail. The tail spread can be calculated and used as one variable from the announcement of the auction results to examine the efficiency of the Treasury bill secondary market.

Two other pieces of information which can be calculated from the announced auction results and used in the examination of secondary market efficiency are the

percent of competitive bids accepted and the percent overbid. The percent of competitive bids accepted can be calculated as the dollar volume of competitive bids accepted divided by the total dollar volume of bids accepted. The percent overbid is the percent of total bids submitted which were not filled in the Treasury bill auction. The percent of competitive bids accepted and the percent overbid would give an idea of the strength of demand for the Treasury bills in the weekly auction. These, along with the tail spread, may be used in an empirical investigation to determine if the variables are significant pieces of information in predicting the change in the asked rate on Treasury bills in the secondary market in a semi-strong form efficiency study.

The second area addressed is based on auction theory. Cammack (1991) notes that the average auction rate tends to be less than the rate on similar bills in the secondary market near the time of the auction. The auction rate can, therefore, be said to be downward biased. Given this downward biasing, Cammack suggests a bidding adjustment occurs. This bidding adjustment is measured by the difference between the auction price and the secondary market price. The expected components of the auction results variables concerning the dispersion of opinion and the number of bidders are considered to be determinants of the bidding adjustment. With the announcement of the

auction results late Monday, the unexpected components of these auction results variables are considered to be determinants of the Tuesday secondary market return. This portion of the study uses the models from Cammack's study (1991) to examine downward biasing of auction prices and Treasury bill auction information.

After market efficiency and the downward biasing of the auction rate are examined, the relationship between the Treasury bill auction rate and the Treasury bill secondary market rate on Thursday is studied. Since the bills from Monday's auction are not issued until Thursday, it is anticipated that the average auction rate reflects the Treasury bill rates expected to prevail when the bills are issued. If the two rates are not significantly different, then the Treasury bill auction rate is an unbiased expectation of Thursday's Treasury bill secondary market rate.

If the announcement of Treasury bill auction results resolves uncertainty or adds uncertainty, these auction results are also expected to affect the bid-asked spread in the secondary markets. The final question addressed by this study is whether the auction results variables -- percent competitive, percent overbid, and tail spread -- have a significant impact on the change in the bid-asked spread. If these variables do have a significant impact, then the

auction results can be considered a determinant of the Treasury bill secondary market bid-asked spreads.

Four areas have been presented which are examined. In order to conduct the research, data concerning the Treasury bill auction and secondary markets was gathered for the time period August 1985 to August 1990. The data is then used with regression methodology to examine the four main areas.

Justification for the Study

Every Monday and Tuesday new information is released concerning the results of the Treasury bill auction which may impact or be related to factors in the Treasury bill secondary market. This information can be used to examine Treasury bill secondary market efficiency, determinants of the downward biased auction prices and secondary market returns, the auction rate as an unbiased expectation, and determinants of the secondary market bid-asked spread.

An efficient market is one in which current market prices reflect all information and fully and instantaneously reflect any new, relevant information. The typical assumptions given for an efficient market include: transactions costs are zero for all participants; information is costless for all participants; and information is available to all market players at the same time. The justification for questioning market efficiency comes from an examination of the breakdown of the

assumptions of market efficiency. Market inefficiency in the Treasury bill secondary market could be due to: not all market players being able to interpret information; not all market players having access to the same information; and information being costly to obtain.

There will be diverse abilities among traders to access and interpret information in the auction and secondary markets. Sales of new Treasury bills occur only through the Treasury bill auction. One class of bidders in the auction submits noncompetitive bids, and these bidders are usually investors who are less informed of what the true rates on Treasury bills should be. The second class of bidders, competitive bidders, submit bids which compete to win new Treasury bills based on prices bid. Each competitive bidder has information which is different from other competitive bidders. This fact is evidenced by the range of prices submitted as bids in the auction.

Most of the competitive bids in the auction each week come from dealers. These dealers are thought to have superior information, because their firms typically have a research department which monitors events affecting the Treasury bill markets. They also communicate among themselves which gives them access to information regarding the current conditions in the Treasury bill market. Not all dealers, however, will have the same information as witnessed by varying bid-asked quotes from different dealers

(Garbade, Pomrenze, and Silber; 1979). Non-dealers and some noncompetitive bidders do not have such immediate access to this information nor the specialized abilities to interpret the information. Consequently, the Treasury bill secondary market may not be fully efficient since not all participants in the market have the same access to the same information nor equal abilities to interpret it.

Another factor which allows for the breakdown of market efficiency in the Treasury bill secondary market is the fact that information is not free. The competitive bidders choose to obtain current market and economic information, but in doing so incur costs. Verification of information being costly is seen in dealers maintaining a bid-asked spread in the secondary market as a way to recoup the costs incurred to obtain information. If information was not costly and if all market players including non-dealers had the same information, the bid-asked spread would not exist.

Given that information is costly to obtain and difficult to interpret, uninformed market players may look to the informed players for information rather than incur the cost. The uninformed market players can obtain information on Treasury bill rates and the strength of demand for Treasury bills. The informed players' information can be proxied through the current prices in the secondary market, the prices realized in the auction (the tail spread = high auction discount rate - low auction

discount rate), the percent of competitive bids (competitive bids accepted/total bids accepted in the auction), and the percent overbid (bids not accepted/total bids in the auction). If the Treasury bill secondary market is efficient, the secondary market rates should fully reflect the information of the auction's competitive bidders prior to the announcement of the results.

The information from the auction results -- percent competitive bids accepted, percent overbid, and tail spread -- can also be examined as determinants of the change in the bid-asked spread in the secondary market for Treasury bills. The dealers' bid-asked spreads in the Treasury bill secondary market exist for dealers to recover costs they incur and to offset losses due to exchanges with traders who have better information. The dealers will alter their spreads as they receive new information regarding factors such as supply and demand conditions, competitors' actions, informed trader activity, and Federal Reserve policy. The percent competitive bids accepted, percent overbid, and tail spread from the auction results will provide information to the dealer concerning the strength of demand for auctioned Treasury bills and the number of informed traders participating or desiring to participate in the auction market. This information may then be used by the dealers in changing their bid-asked spreads in the secondary market.

The Treasury bills which are purchased in Monday's auction are not issued until Thursday. The new bills issued on Thursday can then be traded in the secondary market. Bidders realize that the auctioned bills they purchase on Monday and receive on Thursday will be similar to the Treasury bills already trading in the secondary market on Thursday. If the Treasury bill auction is a fair game, a bidder in the auction expects to earn no more by bidding in the auction than by waiting until Thursday and buying in the secondary market (ignoring transactions costs). The auction rates can be thought of as forward rates for the expected spot rates to prevail on Thursday in the secondary market.

Summary of Previous Studies

Information in a market is generally considered as disbursed among the informed market participants while some participants are considered to be uninformed (Green, 1977; Salop and Stiglitz, 1977). Those that do not obtain information can use the prices of securities traded by informed traders as proxies for information (Grossman, 1976; Green, 1977; Diamond and Verrecchia, 1981). In an auction market, the auction mechanism serves as an aggregator of bidders' private information which is relayed through the auction prices attained (Wilson, 1977; Milgrom, 1979; Bikhchandani and Huang, 1989). The cited articles justify

questioning whether the results from the Treasury bill auction carry information.

The efficiency of Treasury bill markets has been examined previously with the results being mixed as to the efficiency of the secondary market. Fama (1975) and Hamburger and Platt (1975) found the U.S. Treasury bill market is weak form efficient with respect to past interest rate data. Mills and Stephenson (1985) found the U.K. Treasury bill market to be efficient in regard to the use of information concerning inflation expectations, however inflation was not perfectly expected. Chandy and Cross (1984), on the other hand, found there was inefficiency in the U.S. Treasury bill market in capturing all of the information regarding expected changes in purchasing power during high inflationary periods. Wachtel and Young (1987) found government security interest rates increased when the announced projected federal deficit increased indicating semi-strong form efficiency did not exist with respect to projected federal deficits. Schirm, Sheehan, and Ferri (1989), on the other hand, found interest rates were not influenced by the unexpected component of regularly scheduled debt announcements indicating a semi-strong efficient market. Wachtel and Young (1990) also found the Treasury bill secondary market to be semi-strong efficient but with respect to the announcement of the upcoming Treasury auction. In looking at the auction results

announcements, however, they found inefficiency in the market when there was a "surprise" about demand for the bills auctioned. All of the studies cited above lend support to questioning the efficiency of the Treasury bill secondary market.

The question of whether the information in the Treasury bill auction explains the downward biased auction results was examined by Cammack (1991). The differences between the downward biased auction rate and the secondary market rate was found to be determined by the expected component of the low tail. The return earned in Tuesday's secondary market was determined by the unexpected components of the low tail, percent competitive, and percent noncompetitive.

Another relevant category of literature relates to unbiased expectations. Several studies examine unbiased expectations for futures markets and forward rates using regressions of the form $y_{t+1} = \alpha + \beta x_t + \epsilon_{t+1}$ (Frenkel, 1981; Bilson, 1981; Edwards, 1983; Lumpkin, 1986; Chiang, 1988; Wong and Henderson, 1990; and Cole, Impson, and Reichenstein, 1991). Unbiased expectations are said to exist if α is not significantly different than 0 and β is not significantly different from 1.

In regard to the bid-asked spread in the Treasury securities markets, few studies are found. There are several studies, however, concerning bid-asked spreads in other markets. The cited studies found the term to

maturity, volume outstanding, market volatility, interest rate outlook, perceived demand and supply conditions, market uncertainty, inventory position, dealer costs, timing of new information, new issues, liquidity-motivated investors, and information motivated investors will affect the bid-asked spreads (Roll, 1970; Bagehot, 1971; Branch and Freed, 1977; Garbade and Rosey, 1977; Hamilton, 1978; Federal Reserve Bank of New York, 1978; Stoll, 1978 and 1989; Garbade, Pomrenze, and Silber, 1979; Glosten and Milgrom, 1985; Venkatesh and Chiang, 1986; Mann and Seijas, 1991; McInish and Wood, 1992; Ma, Peterson, and Sears, 1992).

The following articles provide additional reasons for including the selected auction information variables. Several authors have found the array of competitive prices in the auction results to be an indication of demand characteristics (Brimmer, 1962; Bolten, 1973; Boatler, 1975; Ryan, 1987). Lumpkin (1986) specifically used the quantity weighted average yield on accepted tenders, low tail, and tail spread to look at the dispersion of auction prices. Wann (1989) tested an auction's success by looking at the amount oversubscribed and the spread of accepted tenders. The submission of noncompetitive bids and their impact was discussed by Brimmer (1962), Smith (1966), Mullineaux (1973), and Bolten (1973). All of these articles lend support to percent overbid, percent noncompetitive, and tail spread as explanatory variables and to the a priori

expectations of relationships between these variables and the dependent variables.

The literature supports the rationale for conducting this research. Existing Treasury bill secondary market studies of semi-strong efficiency have found mixed results. There is a paucity of studies in the area of bid-asked spread determinants in the Treasury bill secondary market. And no literature was found which questions whether the auction rate is an unbiased expectation of the Thursday secondary market rate.

Statement of Research Hypotheses

There are six basic hypotheses this research addresses. The first hypothesis considers the Treasury bill secondary market efficiency with respect to the information from the auction results -- percent competitive, percent overbid, and tail spread. The hypotheses for this question concern whether the estimated coefficients for the auction information variables are significantly different from zero. The null hypothesis is stated as:

$$H_{01}: \quad \beta_0 \ldots \beta_j = 0.$$

The null hypothesis for this question is rejected if the group of estimated coefficients for the auction information variables are significant in explaining the change in the asked rate in the Treasury bill secondary market. The

secondary market for Treasury bills then is not considered fully efficient.

Three additional hypotheses are related to the downward biasing of the auction prices. Auction theory predicts the average auction rate to be downward biased in auctions where information is not equally dispersed and the number of bidders is finite, such as the Treasury bill auction. The first of these hypotheses addresses whether the auction results information is a determinant of the bidding adjustment which occurs due to downward biasing of the auction price. The null hypothesis suggesting the expected component of each of the auction results variables is not a determinant is:

$$H_{02}: \quad \beta = 0.$$

The relationships between the expected components of the auction results variables and the bidding adjustment are examined individually. If an expected component of an auction results variable is statistically significant, the null hypothesis is rejected and the expected component of the auction results variable is considered a determinant of the bidding adjustment.

The unexpected components of the auction results variables may also carry information (Cammack, 1991). The second area related to downward biasing addresses the relationship of the Tuesday secondary market return with the unexpected components of the auction results variables. The

null hypothesis suggesting the unexpected component of each of the auction results variables is not related to the Tuesday secondary market return is:

$$H_{03}: \quad \beta = 0.$$

The relationships between the unexpected components of the auction results variables and the secondary market return are examined individually. If any of the auction results variables are significantly related to the Tuesday secondary market return, they are considered to be determinants of the Tuesday return.

The auction results variables could be just proxies for the auction price level (Cammack, 1991). To control for this, the third hypothesis related to downward biasing includes a price level comparison variable in the model with the auction results variables. The null hypothesis for this model is the auction results variables and the price level comparison variable do not determine Tuesday secondary market returns and takes the form:

$$H_{04}: \quad \beta = 0.$$

If any of the auction results variables are statistically significant with the price level variable included in the model, it is said the auction results variables do carry information other than price level information.

The fifth area suggests Monday's average auction rate is an unbiased expectation of the Thursday secondary market asked rate. The joint null hypothesis is the average

auction rate is an unbiased expectation and is stated as:

$$H_{05}: \quad \beta_0 = 0, \ \beta_1 = 1.$$

The joint null hypothesis is rejected if (i) the estimated intercept term is not zero and (ii) the estimated coefficient for the average auction rate is not equal to one in the model explaining the secondary market asked rate on Thursday.

The last hypothesis deals with the bid-asked spread. The null hypothesis is the bid-asked spread in the Treasury bill secondary market is not determined by the information from the auction results carried in the percent competitive, percent overbid, and tail spread. The null hypothesis is:

$$H_{06}: \quad \beta_0 \ldots \beta_j = 0.$$

If the group of estimated coefficients relating to the auction information variables is significant in explaining the change in the bid-asked spread, the null hypothesis that the information variables are not determinants of the bid-asked spread is rejected.

Organization of the Study

This dissertation is divided into five chapters. The current chapter introduces the scope of study, provides the justification for the study, presents a summary of previous studies, and proposes the hypotheses to be studied.

Chapter II reviews the literature relating to Treasury bill markets, efficient markets, bid-asked spreads, and

forward rates. This literature provides the foundation for the development of the hypotheses and the methodology used.

In Chapter III, the research methodology is explained. This includes the data for the research, a discussion of the techniques used, and the disadvantages and advantages of these techniques.

Chapter IV presents the results of the study and a discussion of the results. Last, Chapter V focuses on the conclusions which may be drawn from this research, implications which may be useful for the field of finance, and future research which may be suggested by the study.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Literature relevant to this study can be classified in the following groupings: description and importance of Treasury bills, description of Treasury bill markets, sources of bids and influence on demand for Treasury bills, auction theory and evaluation of the markets, theory of efficient markets, informed/uninformed traders in the markets, bid-asked spreads in dealer markets, and forward rates in markets. The methodological issues related to an examination of Treasury bill secondary market efficiency, downward biased auction prices, bid-ask spreads, and forward rates are illustrated through the review of this literature.

Description and Importance of Treasury Bills

Treasury bills, notes, and bonds are the three types of securities issued by the U.S. government. Treasury bills were first introduced to the auction market in December 1929 in 30, 60 and 90 day maturities (Federal Reserve Bank of Richmond, 1964). They were initially introduced to

lessen the impact on the money market from the operations of the Treasury (Federal Reserve Bank of St. Louis, 1960). The government also believed the use of Treasury bills would help to reduce errors in the pricing of bonds, and the shorter maturities of Treasury bills would allow closer matching with the length of time for which funds were needed (Henning, Pigott, and Scott; 1984). In the early 1930's, bill maturities of 182 to 273 days were also sold. In 1937, the Treasury began issuing only 91-day bills at the weekly auctions. In 1958 the Treasury added 182 day bills at the weekly auctions (Federal Reserve Bank of Richmond, 1964).

The Treasury bill market is an important component of the U.S. money market. As of April 30, 1993, $642 billion of Treasury bills were held by the public (compared to $482 held in December of 1990) (Bureau of the Public Debt, 1990 and 1993). Treasury security markets are the arena in which the Federal Reserve conducts open market operations for the purpose of achieving monetary policy goals. The Treasury bill rate is often used as a barometer of credit market conditions, because the Treasury bill is a major money market instrument; and it indicates the return which can be earned on liquid investments by large lenders who often use Treasury bills to meet requirements of keeping certain funds in liquid form (Henning, Pigott, and Scott; 1978). At this particular point in time, the study of Treasury securities garners additional interest because investors are trading

Treasury securities as they become more concerned with safety in investments (Sullivan, 1990). Due to these factors, it is pertinent to know that the Treasury bill markets are efficient.

Description of the Treasury Bill Markets

To illustrate the potential for information from Treasury bill auctions to affect secondary market outcomes, each market will be described. This includes a description of the auction market including the types of bids for Treasury bills in the auction market and the process of issuance for newly auctioned Treasury bills followed by a description of the secondary market for Treasury bills.

The Auction Market

The primary market for Treasury bills is a weekly auction carried out by the Federal Reserve. Currently, Treasury bills can be bought in these auctions in denominations starting at $10,000 and increasing in units of $5,000 thereafter (Rahmani, et. al., 1987). These bills are available to subscribers in book-entry form only.

The issuance of new 91-day and 182-day Treasury bills follows a standard procedure. During the week prior to issuance, the Treasury publishes the volume of Treasury bills to be sold and invites bids for these bills. It then accepts bids for both the 91-day and 182-day Treasury bills

on the following Monday. Except for dealers, commercial banks, and large regular bidders, payment for the bills is required at the time of bidding (Cammack, 1991).[1] This requirement favors the regular, more informed competitive bidders by not requiring payment in advance and allowing them to use their money for the extra three days.

The Federal Reserve accepts both competitive and non-competitive bids for the weekly Treasury bill auction. Competitive bids state the discount rate the bidder is tendering for a specified quantity of bills. The competitive bidder tenders the highest discount the bidder believes will be accepted and still provide the desired quantity of bills (Federal Reserve Bank of Richmond, 1960). The bidder may tender several bids having different quantities and/or discounts. Currently, the competitive portion of the Treasury bill auction is conducted through bids quoted on a bank discount basis to two decimal places.[2] Generally, the source of competitive bids will be from subscribers who are in continual contact with the money market. There are approximately 40 regular, competitive

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[1]Payment made at the time of bidding is for the full face value of the bids submitted. After the price is determined from the auction results, the Treasury refunds the amount overpaid to the winning bidders and a full refund to the losing bidders.

[2]Radcliffe (1987) defines the bank discount method. Let P=price, F=$100 face, D=dollar discount on $100 face value, t=time to maturity, and d=quoted yearly discount rate. D is calculated as $D = Fd[t/360]$. The price is then $P = F - D$.

The example given by Radcliffe is for a three month bill with a quoted discount of 8.55%.

$D = \$100 \times 0.0855 \times (91/360) = \$2.16125$.

Then $P = \$100 - 2.16125 = \$97.83875$.

bidders in a Treasury bill auction "who are mainly primary dealers and large financial institutions" (Bikhchandani and Huang, 1989).

There are primarily two types of competitive bids for Treasury bills. First, there are the "sure bids" which are generally tendered by government securities dealers. These bids are at a price high enough that the probability of the bids not being accepted is very low. The second type of bid, the "scale-out bid", is a bid at a low price, tendered in hopes of receiving bargain prices and earning a higher profit (Bolten, 1973). Dealers often submit "scale-out" bids in order to pick up extra bills for their inventories at low prices. Bolten (1973) suggests this part of the dealers' demand will increase in a market with rising yields and decrease in a market with falling yields. The demand curve for Treasury bills may be elastic for the sure-bid portion but inelastic for the scale-out portion (Boatler, 1975).

The second type of bid in the auction is the noncompetitive bid. Noncompetitive bids are submitted by stating only the quantity of bills desired. They are noncompetitive in the sense they do not compete on the basis of price. These bids are filled at a weighted average price and acceptance is restricted to amounts between $10,000 and $1 million. Noncompetitive bids by volume (number) make up the majority of Treasury bill bids tendered each week

(Federal Reserve Bank of St. Louis, 1960). By dollar amount, however, the majority of bills are sold on a competitive basis. Historical data has not been collected by the Treasury concerning the composition of noncompetitive bidders, but the Federal Reserve Bank of New York (1978) found that "85 percent of the total number of noncompetitive tenders came from individuals" which represented "70 percent of the total dollar volume of such tenders" (Sivesind, 1978, p. 35). Because of the size restrictions on non-competitive bids, it is likely these bids represent demand for bills from market participants who are not major players in the Treasury bill markets.

There are standard times for submitting both types of bids and issuing the bills. Noncompetitive bids must be submitted to the U. S. Treasury or the Federal Reserve banks by noon Eastern time on Monday, and competitive bids must be submitted by 1:00 p.m. Eastern time on Monday (Wall Street Journal, March 27, 1991). Typically by 5:00 p.m. Eastern Time on Monday, the Treasury updates an 800 phone line announcing the highest bid, lowest bid, and average bid from the auction which allows bidders to know what quantity of bills they have been awarded (Chicago Board of Trade, 1991). The bills are then issued on Thursday of the auction week. Given that the bills are purchased in the auction on Monday but not received until Thursday, a question raised is

whether the average auction rate is an unbiased expectation of Thursday's secondary market rate.

The Treasury bill auction process described is considered a discriminatory auction. The auction discriminates by selling the identical security to different competitive bidders at different prices (Garbade, 1982). The discriminatory auction process follows a standard procedure. Each weekly auction starts with the noncompetitive bids being filled from the supply of bills available. The remaining bills, total bills available - bills sought by noncompetitive bid - Fed purchases of bills (Cammack, 1991), are used to fill the orders of the competitive bids by ranking the tenders starting with the lowest discount first. The competitive bids are accepted at increasing discount rates until all bills are sold. The highest discount bid accepted in the weekly auction is the stop-out rate. The bids submitted at the stop-out rate are filled on a prorated basis of the total amount accepted at the stop-out rate (Scott, 1965).

After the competitive bids are filled, the rate for the noncompetitive bids is determined. The noncompetitive bids will be allotted at an average rate of the accepted competitive bids weighted by the amount of bills sold at each competitive rate (Brimmer, 1962). By reducing the supply of bills to competitive bidders, the existence of

noncompetitive bids has an indirect impact on prices in the Treasury bill market (Smith, 1966).

The week's demand schedule for each type of Treasury bill can also be noted after the competitive bids have been ranked (Bolten, 1973; Boatler, 1975). When the demand at an auction for a Treasury bill issue is not great enough, there is a "price concession" in the form of the Treasury accepting more low price bids (Ryan, 1987). This means the tail spread (high - low accepted auction discount rate) gives an indication of demand for Treasury bills since it is correlated with the Treasury accepting lower price bids.

Milgrom and Weber (1982) note that after completion of an auction additional information is conveyed than the information available to the winning bidders. That is, after the auction the maximum and minimum value of the auctioned goods are also known which provides the upper and lower boundaries on all the bids. They state that the price derived from this auction is a good aggregator of the bidders' private information. If this idea is applied to the Treasury bill markets, the announcement of the auction results will release more than any individual bidder's private information.

The Secondary Market

The secondary market for Treasury bills is an over-the-counter dealer market. Dealers may be dealer departments of

commercial banks or nonbank dealers (Federal Reserve Bank of New York, Winter 1977-78). There are approximately 40 primary dealers and 300-500 secondary dealers (Chicago Board of Trade, 1991).

One function of the primary dealers is to aid the Federal Reserve in implementing monetary policy through the Federal Reserve's open market operations. Primary dealers provide by, 11:00 a.m. each business day, the New York Federal Reserve Bank with insights into the daily state of the Treasury bill market by supplying information concerning trading activity, financial positions, and inventory (Chicago Board of Trade, 1991). In exchange for providing this information, primary dealers have direct access to the New York Federal Reserve trading desk, through which the dealers continue to gain information, and are awarded all Federal Reserve repos and reverse repos through a bidding process (Chicago Board of Trade, 1991). This indicates primary dealers have information which others do not and, hence, the assumption for an efficient market that all participants have access to the same information is violated.

Within the secondary market for Treasury bills, there are two components: the interdealer market and the customer market (Campbell and Kracaw, 1993). The interdealer market is composed of trades between dealers either directly or through brokers. The customer market is all nondealer

trades. There is an automated quotation system in the interdealer market which provides automated execution of trades and gives all of the primary dealers' bid and ask quotes. In contrast, in the customer market there is a billboard system giving only the average bid and asked quotes. Again, a divergence of information availability can be noted between dealers and other investors since they do not have access to the same information. Since there exists this asymmetric information, the efficiency of the secondary market comes into question as the requirements for an efficient market break down.

Sources of Bids and Influences on Demand for Treasury Bills

The majority of bids come from dealers and commercial banks (money centers). Other demand for Treasury bills comes from money market mutual funds, foreign investors, insurance companies, state and local governments, trust accounts, pension funds, individual investors, and corporations. The demand for Treasury bills will vary from week to week for different reasons. The strength of this demand impacts the percent overbid, percent competitive, and tail spread. Is the secondary market for Treasury bills semi-strong form efficient with respect to these auction results? Do the auction results have a material impact on dealer bid-ask spread in the post-auction period?

Dealers are interested in holding Treasury bills for inventory needs. They are faced with two types of uncertainty in submitting bids in the auction (Smith, 1966). They are uncertain of the range of bids which will be accepted and, hence, how low a discount rate (high price) they must bid to win the bills they need for their inventories. Second, they are uncertain of the price at which they will be able to resell the Treasury bills in the secondary market. Both of these uncertainties affect the dealers' demand and bids for bills. Auction results summarize the responses of auction participants to their information set(s) at the time of bidding. The release of the auction results would be anticipated to affect secondary market prices in a less than perfectly efficient market in which all participants do not share the same information set or in which information is costly to produce.

During periods in which the Federal Reserve is exhibiting a lenient monetary policy, the dealers are able to obtain funds at favorable rates from the New York money market banks through call-loan privileges in order to participate in the Treasury bill market (Scott, 1965). When the Federal Reserve has a tight monetary policy and call-loan rates are no longer favorable, dealers may not be able to maintain a positive carry.[3] "Thus precisely at the time

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[3]A positive carry occurs when dealers obtain rates of return on Treasury bill transactions which are higher than the interest rate the dealer pays on borrowed funds to finance the bill inventory (Scott, 1965).

when markets are thin anyway because of rising interest rates, the cost and availability of local accommodations further discourage the dealer from holding government securities" (Scott, 1965, p.167). This provides one basis for the expectation of a smaller percent overbid (due to fewer dealers submitting many bids) to actually cause an increase in the dealer's secondary market bid-ask spread in order to recover higher costs.

The demand for noncompetitive bids is derived mainly from small savers seeking liquidity. Often, corporations and individuals are placed into this category (Bolten, 1973). The Fed purchases bills at the noncompetitive rate as well.

The small savers as noncompetitive bidders are attracted to the Treasury bill market because they are somewhat disadvantaged in making other similarly low-risk security investments which require large cash investments (e.g. commercial paper typically issued in multiples of $100,000) (Mullineaux, 1973). Some additional investors may be attracted to the Treasury bill primary market during periods of increasing bill rates. These investors may submit noncompetitive bids, instead of buying the bills in the secondary market and incurring the dealer's charge during these periods of increasing bill rates (Brimmer, 1962; Mullineaux, 1973).

Auction Theory and Evaluation of the Markets

The demand for Treasury bills is met in part through the discriminatory auction process used to auction Treasury bills in the primary market and in part through the secondary market. A review of auction theory is useful as a preliminary guide for examining market efficiency.

According to Engelbrecht-Wiggans (1980) and Rasmusen (1989), the number of players, the utility functions of the players, and the number of objects being sold in an auction are important descriptive factors. The number of players in an auction is an indication of the strength of demand for the good(s). According to their definitions, the Treasury bill auction is best described as an auction with a random number of bidders having random utility functions bidding on a finite number of identical, indivisible objects having a known maturity value. Once the Treasury bill auction is over, however, the percent competitive and the percent overbid serve as proxies for the number of bidders and, hence, the strength of demand.

These auction theories also suggest the number of bidders will impact an auction's outcome. As the number of bidders increase and the bidders realize with how many other bidders they are competing, auction prices will be driven up. In an auction in which the bidders do not know the number of other bidders, one alternative for estimating this

information is to look at previous similar auctions. In a similar situation, the Treasury bill secondary market dealers can look at the number of bidders in the auction market (proxied by the percent competitive and percent overbid) to help determine the number of players that will be participating in the post-auction secondary market.

Baron (1976) notes three types of information which bidders may possess. First, undisclosed information describes information which only an individual bidder knows. Second, confidential information refers to information which only the bidder knows but of which other bidders are aware of that bidder knowing. Last, there is common information, such as the rate of inflation, which is available to all bidders. In terms of the Treasury bill markets, dealers most likely possess most of the undisclosed and confidential information. The non-competitive bidders and secondary market participants have available to them the common information. Although this information is available, the costs (e.g. time, financial) which may be involved in obtaining it may mean not all bidders possess the common information. The existence of asymmetric, costly information violates the assumptions of an efficient market.

Harsanyi defined an auction as a game with incomplete information (Engelbrecht-Wiggans, 1980). With multiple bidders competing in the Treasury bill auction, it is also a game with asymmetric information. Each player has

information different from the other players and bids without knowing the other players' bids and information. A bidding strategy is chosen by each player in an auction to place bids using the information which the bidder observes. Bidders with undisclosed information may have an advantage and bidders with "uniformly worse" information should stay out of the Treasury bill auction or submit noncompetitive bids (Rasmusen, 1989).

In this type of theoretical setting, one inefficient outcome faced by bidders is the possibility of suffering the "winner's curse." This occurs when the "winner's" payoff is negative, because the winner has overbid. If players scale down their bids, the chances of falling into the winner's curse are reduced (Rasmusen, 1989). If bidders do suffer the winner's curse because they have overbid, however, it can be questioned whether the auction information is reflective of the value of the bills auctioned. For Treasury bill dealers, another inefficient outcome faced in this setting of asymmetric information is not winning enough bills through the auction.

Some argue there may be problems associated with the use of a discriminatory auction such as second-best outcomes and dealer collusion which can provide other reasons for Treasury bill secondary market inefficiency. Smith (1966) found the submitted bids in discriminatory sealed-bid

auctions will be lower than the bids in competitive auctions while others found collusion in the auctions.

Milton Friedman (1959), Boatler (1975), and Scott and Wolf (1979) suggest the Treasury's discriminatory auction practices leads to collusion among bidders. Friedman's evidence of collusion was the fact in many periods there was no overlap between the highest and lowest bid accepted in one week versus the following week. Boatler (1975) also finds significant evidence of collusion during 1952-1972. Scott and Wolf (1979) believe the dealer collusion comes in the form of dealers exchanging views on the likely stop-out price in an effort to determine potential demand for the bills and to narrow their own assessments of the stop-out price shortly before the cut-off time for bidding.

Wilson (1977) and Milgrom (1979) each examine the winning bids of a sealed bid auction. In this type of auction, it is assumed one object was being auctioned with an unknown true value (V) under a non-cooperative game with incomplete information. There are n bidders each possessing a bidding strategy (p_{nk}) developed on information received through a private signal (s_k) to that bidder (k). Each bidders' bid, $p_{nk}(s_k)$, is then based on expectations about V and s_k. Milgrom denotes the winning bid as $W_n = \max p_{nk}(s_k)$ with k less than or equal to n. Both Milgrom and Wilson show the same result, W_n should converge to V as the number of bidders gets large. The auction mechanism under this

scenario serves as an aggregator of all the bidder's private information which is relayed through the price. Applying this to the current study, Treasury bill auctions, having a large number of bidders, should have auction prices which aggregate the competitive bidders' private information. This information can in turn be evaluated by secondary market participants when the results of the auction are announced.

Wilson's and Milgrom's suggestion that prices tend toward the true value as the number of bidders increases implies that prices would be downward biased when the number of bidders is low. In the current study, the percent overbid is a direct indication of the dollar volume of competitive bids. If there is a positive relationship between dollar bidding volume and the number of bidders, one would expect that, as the percent overbid gets larger, the auction price will tend toward the true value.

French and McCormick (1984) examine auction markets which incorporate precontract sunk costs and sealed bids. They suggest sunk costs determine the number of bidders, and expected profits are inversely related to the number of bidders. The sunk costs "on average," however, are recovered. With application to this study, an increase in the percent overbid in an auction means the dealers' expected profit from the auction will be less. The dealers,

in turn, may adjust the secondary market bid-ask spread in an effort to recover the costs.

Along with sunk costs, French and McCormick (1984) discuss the potential for duplicate information to be produced when there are several bidders revealing information in the sealed-bid auction. With this potential, the asset owner may be better off producing information to increase efficiency. Prior to the Treasury bill auction, the U.S. government announces the volume of bills to be sold and the amount of new money to be raised. The more information the bidders must produce, the lower will be the price paid to the owner.

French and McCormick note that the Treasury reduces the production of duplicate information in the Treasury bill auction by allowing non-competitive bids since these bidders do not have to produce any information. These noncompetitive bidders, in effect, receive a free ride from the information gathered by the competitive bidders. Both the noncompetitive and competitive bidders have reduced incentives to obtain information in the Treasury bill auction due to the fact the noncompetitive bidders are guaranteed to pay an average price without any information search. In this scenario, information is asymmetrically distributed between the noncompetitive and competitive bidders. Is the information possessed by the competitive bidders then passed along through the release of the auction

results? If it is, does the fact that more competitive bidders desired bills in the auction, as measured by percent overbid, mean the competitive bidders had information making the bills more desirable which may then affect the secondary market bid and asked prices?

Cammack (1991) evaluates the existence of downward biasing of auction prices and the presence of imperfect information in the U.S. Treasury bill markets. Cammack suggests traders in the different Treasury bill markets (auction, secondary, and forward) have different information and hypothesizes that these markets do not incorporate the information in the same manner.

If the secondary and auction markets incorporate the information from the auction in the same manner, then the mean price from the auction of 91 day bills (P_A) and the price from the secondary market for 91 day bills would differ only by a risk premium. The risk premium would exist because the market participants purchase the bills through different market mechanisms, the auction market or the secondary market. The announcement of auction results should not affect secondary market prices under this scenario.

Cammack states that according to auction theory and the imperfect information assumption, the average auction price would be a "downward biased" estimate of the value of a 91 day Treasury bill if it matters in which market the bills

are purchased. The potential for downward biasing occurs when the number of bidders is finite and bidders' information is diverse. To examine the concept of downward biased auction prices, Cammack defines her variables of interest as:

1) P_A = quantity-weighted average auction price (Mon. 6:00 p.m.)

2) ${}_{91}P_M$ = secondary market price from Monday for 92 day bill adjusted to a 91 day maturity calculated as ${}_{91}P_M = F \times (P_M/F)^{S/T}$

3) P_T = mean of the bid-ask prices from the Tuesday secondary market for a 91-day bill (Tues. 3:00)

4) Tail = log(P_a - low auction price)

5) N = ($ amount of competitive bids placed)/($ amount of competitive bids accepted)

6) NC = ($ amount of noncompetitive bids)/($ amount of 91-day bills sold in the auction)

7) Monday Bidding Adjustment [Mon. BA] = $100 \times \ln({}_{91}P_M/P_A)$

8) Tuesday Bidding Adjustment [Tues. BA] = $100 \times \ln(P_T/P_A)$

9) Tuesday Return [Tues. Ret.] = $100 \times \ln(P_T/P_M)$

10) Monday Return = $100 \times \ln(P_M/P_F)$

11) P_F = Friday's secondary market mean of bid-ask price

Variables 1, 2, and 3 indicate the prices on 91 day bills in the auction and secondary markets. Variables 4, 5, and 6 are used to indicate bidders' dispersion of opinions and number of bidders in the auction. Variables 7 and 8 are

used in examining the downward biasing of auction prices. If the bidding adjustment variables are greater than zero, the average auction price is less than the secondary market price. Finally, variables 9, 10 and 11 are used to measure the percentage change in prices caused by a reaction to the auction results in the secondary market from Friday to Monday and Monday to Tuesday.

In Cammack's analysis, Cammack groups the data into subperiods based upon announced Federal Reserve policy changes (from targeting interest rates to targeting monetary aggregates) and the start of Treasury bill futures trading. Cammack then calculates the unexpected and expected components for the variables using the full sample and subsamples.

Once the expected and unexpected components are determined, Cammack's first set of regressions are estimated with the expected components of the variables. The equations estimated were:

$$\text{Mon. } BA_t = \alpha + \beta ETail_t + \epsilon_t$$

$$\text{Mon. } BA_t = \alpha + \beta EN_t + \epsilon_t$$

$$\text{Mon. } BA_t = \alpha + \beta ENC_t + \epsilon_t.$$

These are used to examine the expected gain from the auction in relation to the expected number of bidders and the expected dispersion of opinions. Cammack finds a positive, significant relationship between the expected tail and the Monday bidding adjustment in these regressions and no

relationship between the number of bidders and the Monday bidding adjustment. This indicates the greater the dispersion of opinions in the auction (as measured by the expected tail), the greater the downward bias of the auction rate.

Cammack's second series of regressions examines the secondary market's reaction to the unexpected component of the announced auction results. The regressions,

$$\text{Tues. Ret.}_t = \alpha + \beta \text{UTail}_t + \epsilon_t$$

$$\text{Tues. Ret.}_t = \alpha + \beta \text{UN}_t + \epsilon_t$$

$$\text{Tues. Ret.}_t = \alpha + \beta \text{UNC}_t + \epsilon_t$$

show the unexpected dispersion of opinion variable generates the strongest reaction of the Tuesday return. The unexpected number of competitive bidders, as measured by N, also causes a reaction in Tuesday's return but not as statistically significant. For both cases, the majority of explanatory power is found in the first sample period, January 1973 to January 1976.

The last regression Cammack runs is to examine the possibility that price levels from the auction are proxied by the unexpected components of the auction variables. According to Cammack, the Tuesday secondary market price drops may be caused by a higher than expected tail. This drop in secondary market prices would have to occur if all the bills sold in the auction were at lower prices. Cammack, therefore, includes a price level comparison

variable, A%Δ, calculated as 100 x ln(low auction price/P_M). The following regression is then run:

$$\text{Tues. Ret.}_t = \alpha + \beta \text{UTail}_t + \delta \text{UN}_t + \Theta \text{UNC}_t + \phi A\%\Delta + \epsilon_t.$$

The unexpected component of the tail is not as significant as in the previous regressions, and the unexpected component of N is no longer significant. The A%Δ variable is statistically significant and affects the Tuesday return due to the price level news from the auction.

Overall Cammack's results show: (1) unanticipated dispersion of opinion in the auction market causes the prices in the secondary market to decrease; (2) greater unanticipated participation in the auction yields an increase in secondary market prices; and (3) auction rates are downward biased rates of the Tuesday secondary market rates. Based on these results, Cammack concludes the auction and secondary markets do incorporate information differently from traders, and the secondary market contains less than perfect information.

Theory of Efficient Markets

Another major area of literature examined deals with market efficiency. First a general development of market efficiency is presented (Fama, 1970; Garbade, 1982). Next studies relating to market efficiency in the Treasury bill secondary market are discussed. Fama (1975) finds weak form efficiency in the Treasury bill secondary market did exist

while Hamburger and Platt (1975), Schirm, Sheehan, and Ferri (1989), and Wachtel and Young (1990) find evidence of semi-strong form efficiency. Mills and Stephenson (1985) find semi-strong form efficiency in a market similar to the US Treasury bill secondary market, the UK Treasury bill secondary market. Chandy and Cross (1984) confirm Fama's weak form efficiency results but find semi-strong inefficiency in the Treasury bill secondary market with respect to changes in the purchasing power. Other studies indicate Treasury bill secondary market semi-strong form inefficiency also: Wachtel and Young (1987) with respect to announced future expected government deficits; Schirm, Sheehan, and Ferri (1989) with respect to the announcement of cash management bills; and Wachtel and Young (1990) with respect to the post-auction announcement.

General Market Efficiency

Fama (1970) provides a definition and a classification scheme for the concept of market efficiency. There are three main classifications of market efficiency which were developed originally by Fama with the stock market: weak form efficiency, semi-strong form efficiency, and strong form efficiency. Weak form efficiency suggests all past price information is reflected in current prices. Semi-strong market efficiency suggests all publicly available information is reflected in the security prices. Strong

form efficiency suggests all public and private information is reflected in security prices. The inclusiveness of the information sets is what distinguishes among the three classifications. Fama (1976, p.186) states, "the value of a market is in providing accurate signals for resource allocation, which means setting prices that more or less fully reflect available information. If the market ignores the information from so obvious a source (such as past inflation rates), its effectiveness is seriously questioned."

The semi-strong form market efficiency is the most relevant form for the major portion of the current study. In looking at semi-strong market efficiency, this study is considering the following type of scenario Garbade (1982) describes.

Let: Φ = some information set
ϕ = an observation from Φ
P'= price in next auction
P = price in current auction
U = another information set over all publicly available information
u = an observation from U.

If (1) $\text{Exp}[P' \mid u,\phi] = \text{Exp}[P' \mid \phi]$, the market is said to be efficient with respect to U as the added information from u does not change the expected price.

If R is the return on a security between auctions, then: $R = \frac{P' - P}{P}$.

Then the expected return given ϕ is

$$\mu(\phi) = \frac{\text{Exp}[P' \mid \phi] - P}{P},$$

and the price in the current auction can be written as the discounted expected future value:

$$P = \frac{Exp[P' | \phi]}{1 + \mu(\phi)}.$$

If market efficiency holds as in (1), we can then write

$$P = \frac{Exp[P' | u, \phi]}{1 + \mu(\phi)} \quad \text{and}$$

$$\mu(u,\phi) = \frac{Exp[P' | u, \phi] - P}{P}.$$

Therefore, $\mu(u,\phi) = \mu(\phi)$ and information from U does not alter expected returns, and the market is efficient with respect to U.

Putting the semi-strong efficiency portion of the current study in similar terms, U would be the complete set of information from the auction. The specific observations from U would be the tail spread, percent of competitive bids accepted, and the percent overbid.

Treasury Bill Market Efficiency

The concept of semi-strong market efficiency has been widely studied in the stock markets. Semi-strong form market efficiency in the U.S. Treasury bill secondary market has been studied less. Most studies of U.S. Treasury bill secondary market efficiency have been weak form studies.

Fama (1975) Fama explores the weak form efficiency of the Treasury bill market by asking if interest rates of one to six month Treasury bills from 1953 to 1971 incorporated accurate information on future inflation rates. Fama examines this by determining if all past information on

inflation, which embodies expected future inflation, was used by the market in valuing the real return on Treasury bills.

In setting up the inquiry, Fama approximates the real return on a Treasury bill (r_t) as the nominal return (R_t) plus the rate of change in purchasing power (Δ_t) during the period: $r_t = R_t + \Delta_t$.

The hypotheses given are:

> H_o: R_t summarizes all information available about the expected rate of change in purchasing power.
>
> H_a: R_t does not summarize all information available about the expected rate of change in purchasing power.

By recognizing the best predictor of the rate of change in purchasing power will be the nominal Treasury bill interest rate, Fama set up two regressions to examine efficiency given the above relationship:

1) $\Delta_t = \alpha_o + \alpha_1 R_t + \epsilon_t$ and

2) $\Delta_t = \alpha_o + \alpha_1 R_t + \alpha_2 \Delta_{t-1} + \epsilon_t$.

The data obtained to calculate the purchasing power rate of change is the consumer price index.

The first equation is used to test whether the expected real return is constant (the null hypothesis). This would mean $\alpha_o = E(\tilde{r})$ and $\alpha_1 = -1.0$. Also since R_t summarizes all information about the expected rate of change in purchasing power, there should not be any way to use the past series of disturbance terms to predict a future disturbance term $[E(\tilde{\epsilon}_t | \epsilon_{t-1}, \epsilon_{t-2}, \ldots) = 0.0]$. Therefore, the autocorrelations

of the disturbances from the above regression should be zero.

To test the alternative hypothesis, a second independent variable (Δ_{t-1}) is added to equation 1 to reflect the market's use of information from the previous period's rate of change in purchasing power to set R_t. If the market is efficient, $\alpha_2 = 0$ and $E(\tilde{\epsilon}_t | \epsilon_{t-1}, \epsilon_{t-2}, \ldots) = 0.0$. If the expected real return is constant, $\alpha_o = E(\tilde{r})$ and $\alpha_1 = -1.0$.

Through examination of the results of the regressions, Fama determines the null hypothesis cannot be rejected. The Treasury bill secondary market real rates do incorporate all information concerning rates of change in purchasing power. Therefore, the secondary market is efficient with respect to the information concerning the rates of change in purchasing power.

Hamburger and Platt (1975) Hamburger and Platt look at the efficiency of the U.S. Treasury bill market in combination with the expectations hypothesis for the period 1961 to 1971. They state that forward rates follow a martingale sequence under the expectations hypothesis and the efficient market model. They suggest information regarding the validity of both concepts may be gained by comparing forecast errors with actual rate changes over three month spans.

The authors posit the difference between the forward rate and the future spot rate could be explained by using

the expectations hypothesis and the efficient market hypothesis together. This concept is developed from the expectations hypothesis stated as: ${}_{t+j}F_{k,t} = E_t({}_{t+j}R_k)$ and the efficient market model (assuming perfect information availability) stated as: ${}_{t+j}R_k - E_t({}_{t+j}R_k) = \mu_{t,j}$. The forward rate is ${}_{t+j}F_{k,t}$. $E_t({}_{t+j}R_k)$ is the market's expectation at time t of the rate on k to prevail at time t + j. ${}_{t+j}R_k$ is the future spot rate. $\mu_{t,j}$ is information regarding the future spot rate represented by a random number. Putting the two hypotheses together yielded the following equation: ${}_{t+j}R_k - {}_{t+j}F_{k,t} = \mu_{t,j}$. The difference between the future spot rate and the forward rate, therefore, is simply a random number representing the arrival of new information.

A weak form market efficiency test is first performed for the period 1961 to 1971. The authors find past interest rate data was reflected in current rates, and therefore the secondary Treasury bill market is weak form efficient.

Under the efficient market hypothesis and the expectations hypothesis, the following equation is formed:

$$ {}_{t+j}R_k - {}_{t+j}F_{k,t} = \mu_{t,j} $$

where:

${}_{t+j}R_k$	=	spot rate yield at time t+j on an instrument of maturity k
${}_{t+j}F_{k,t}$	=	forward rate on a k period security expected in period t+j which is implied by the yield curve at time t
$\mu_{t,j}$	=	random number representing information available at time t+j that was not available at time t regarding ${}_{t+j}R_k$.

Next a semi-strong form test is performed. They propose expectations of future rates are formed based on information from estimates of personal income and liquidity variables (including M1 money supply, the monetary base, and nonborrowed monetary base). From the initial results, it is determined the nonborrowed monetary base was the best measure of liquidity. This, combined with personal income on a lagged basis, is used in the regression to look for semi-strong form efficiency. The result is the Treasury bill secondary market was highly semi-strong efficient.

In attempting to detect any systematic nature in the forecasting errors, they find a constant was added to the actual change in rates. However, no significant forecasting ability using three month Treasury bill forward rates is evidenced. They conclude the three month Treasury bill rate which prevailed when the forecast of the three month Treasury bill forward rate was made is almost equal to the three month Treasury bill forward rate, and the three month Treasury bill forward rate is a poor predictor of the future spot rate. Based on the semi-strong tests, better predictions can be made with information from the personal income and money supply variables.

Chandy and Cross (1984) In their study, Chandy and Cross advance the work with interest rates and inflation in examining the efficiency of the U.S. Treasury bill market. Two of Fama's results (from 1975, 1976, and 1977 studies)

are confirmed in this study: past purchasing power rates of change did carry information about future rates, and one month Treasury bill expected real returns were constant.

In the one-month Treasury bill secondary market, however, they found inefficiency in the market in capturing all of the information regarding expected changes in purchasing power during high inflationary periods. The authors offered that Fama's results of market efficiency may be dependent upon a period of low inflation, as was the case during the time of Fama's studies. They also noted measurement bias could have occurred due to individual investor differences and the use of only one proxy for inflation and interest rates.

Mills and Stephenson (1985) Mills and Stephenson investigate the semi-strong form efficiency of the U.K. Treasury bill market. In their study, market efficiency deals with the use of information concerning inflation expectations to determine the nominal rate of return on a Treasury bill.

In conducting the test of the U.K. Treasury bill market, they use a quarterly interest rate series with the rate used being the average rate from the auction. The bills examine were 91 day maturity bills during the time frame 1952 to 1982. The inflation rate for each quarter is estimated using the retail price index. Based on their initial work, they decided any seasonal component should be

removed from the inflation rate in the development of a model of interest rates and examination of market efficiency.

The authors then use two models to test for market efficiency. With the following definitions,

π = rate of inflation over period t
p_t = expected real rate of return
R_t = nominal interest rate on a bill

The Fama model used is:

$$p_t = \beta_o + \beta_1 R_t + u_t.$$

The Mundell-Tobin model used is:

$$p_t = \beta_o + \beta_2 \pi_{t-1} + u_t$$

They combine these models to form:

$$p_t = \beta_o + \beta_1 R_t + \beta_2 \pi_{t-1} + u_t.$$

The combined model is the only one which did not exhibit serial correlation and therefore indicates secondary market efficiency. Given the above results, Mills and Stephenson proceed to develop a model of the U.K. Treasury bill market. The model for the U.K. Treasury bill market is formed by adding an integrated MA(1) process for expected inflation. The empirical results from the completed model yield the conclusion the U.K. market is semi-strong form efficient.

Wachtel and Young (1987) The announcement effect of future expected government deficits on government security interest rates are examined by Wachtel and Young. They hypothesize a larger than expected increase in the deficit should lead to higher interest rates. They use regression

methodology to measure the effect of the anticipated and unanticipated elements of the deficit and the unanticipated elements of the money supply announcements. The results of their study indicate statistically significant increases in interest rates occurred for government securities with longer maturities (greater than 90 days) when the projected deficit increased. This indicates market inefficiency in the sector of the market for longer maturity Treasury bills.

Schirm, Sheehan, and Ferri (1989) In a similar study, Schirm, Sheehan, and Ferri examine the effects of Treasury debt announcements. They state that the Treasury attempts to minimize the effect of a deficit announcement (debt funding announcements) by making weekly announcements and consulting with primary dealers concerning the timing and maturity of new issues. However, the Treasury believes there is still some effect on the markets from such announcements. The authors hypothesize the unexpected component of debt announcements affects financial markets. Using the period January 1977 to December 1985, regression results indicate only the announcement of cash management bills and not the unexpected component of regular scheduled debt announcements influence the interest rates. This means semi-strong form market inefficiency with respect to the announcement of cash management bills.

Wachtel and Young (1990) A second study by Wachtel and Young examines the Treasury auction announcements. In this

study, the authors look at effects on interest rates both before and after the Treasury auction. First, they examine the effects from the Treasury's announcement concerning the upcoming auction. The announcement concerning an upcoming auction tells the maturities, volume of new bills to be auctioned, and the new cash expected to be raised. They initially hypothesize the auction announcement might carry surprises about the "debt management policy" or "deficit financing requirements" of the Treasury. Their results indicate there was no significant information in this announcement which affected the interest rates. Consequently, they do not reject market efficiency.

Their next hypothesis is a post-auction announcement indicating a weak demand leads to higher interest rates. They use three measures of demand for Treasury issues to examine this:

1) the high tail from the auction,
2) the cover (total tenders received/total tenders accepted), and
3) percent noncompetitive (noncompetitive tender/total tenders received).

Two equations are developed to look at the effects from an auction announcement. The first is an attempt to explain the daily change in yields with a measure of money surprise and either the tail, cover, or percent noncompetitive. The regression equation formulated is:

$$R_i = a_o + a_1 M^u + a_2 I^u$$

where R_i = daily change in yield on the i^{th} maturity

M^u = portion of money stock announcement which was unanticipated, and

I^u = tail, cover, and percent noncompetitive.

The second equation incorporates the effect of auction announcements on the term structure. This is handled by adding the change in yields on a three month bill as an explanatory variable to the regression.

Their examination of the effects from the announcement of the auction results shows a slight but positive, significant impact on interest rates. This occurs when the announcement conveys a "surprise" about demand for the securities auctioned. This leads to the conclusion the Treasury bill secondary market is not fully efficient.

Prices as Information

The following section reviews the existing research on markets which incorporate the existence of both informed and uninformed market participants and the pricing systems in these markets. The Treasury auction process sorts bids into two categories, competitive bids from "informed" traders and non-competitive bids from "uninformed" traders. Salop and Stiglitz (1977) suggest that most people do not even understand simple probabilities, as a result it is unlikely all market participants would ever be considered informed. The informed participants are generally said to have private

information which they obtain through an information gathering process which is costly (Milgrom and Weber, 1982). Do the auction results then pass on information from the informed bidders to the secondary market participants? The discussion of the use of information, informational efficiency, and informed/uninformed traders is presented by Hayek (1945), Grossman (1976), Green (1977), Grossman and Stiglitz (1980), and Bikhchandani and Huang (1989).

Hayek (1945) was one of the first to discuss the use of information. Hayek states "in a system where the knowledge of the relevant facts is dispersed among many people, prices can act to coordinate the separate actions of different people..." Hayek describes the pricing system in a market as a means of passing along information and hence indicating change. Auction results release a summary of the informed bidders information. One factor found as a result of the auction which indicates the level of prices in the auction is the tail spread. The Treasury bill secondary market participants may examine the tail spread as a means of gaining information concerning auction prices and informed bidders' information.

Green (1977) furthers Hayek's suggestions by stating that the information to be obtained is costly, and some market players choose to obtain the costly information, while others do not. Similar to Hayek's suggestion of prices aggregating information, Green says that those who do

not obtain the information can use the prices of the securities traded by informed players as proxies for the information. Green argues these systems, however, are usually inefficient because of this process of information transfer. This indicates the Treasury bill secondary market may be inefficient if the secondary market traders are using auction prices as proxies for information.

Grossman (1976) and Grossman and Stiglitz (1980) also proffer the informed participants have obtained information which is used to make trades, and this information is then partially reflected in the prices of the securities. The uninformed see only the prices of the securities and use those in decision-making. Not all informed traders will be able to earn returns by obtaining information if the pricing in the market is "over-informationally" efficient, but the fact the prices contain only partial information permits the informed traders to earn a return to offset the cost of obtaining information.

Under this scenario, Grossman (1976) and Grossman and Stiglitz (1980) develop models of these markets. Grossman (1976) concludes an equilibrium will exist in a market when there is some noise in the system so that it is profitable for the informed trader to continue to obtain the information. Grossman and Stiglitz (1980) find the price system becomes more informative as the cost of information decreases; the proportion of informed traders increases as

noise increases; and the percentage of informed traders decreases as costs increase. In the Treasury bill market, bidders must not all choose to incur the costs of becoming informed since not all bidders submit competitive bids. Since the same traders submitting bids participate in the secondary market, there are both informed and uninformed bidders in the secondary market as well. With information being costly and unequally distributed, the assumptions of market efficiency are violated. Is the Treasury bill secondary market then inefficient?

The scenario modeled by Grossman (1976) and Grossman and Stiglitz (1980) may hold true in the Treasury bill markets for dealers with noise existing in both markets. Combining this with Diamond and Verrecchia's (1981) suggestion that prices cannot be fully revealing with noise in a system, the question can be posed whether the auction prices are fully revealing. If the auction prices are not fully revealing, then they may not be unbiased expectations of Thursday's spot rate.

In an examination of auctions with resale markets, Bikhchandani and Huang (1989) develop an exploratory model of the U.S. Treasury bill market. Their model assumes competitive bidders have information which is better than the information possessed by investors in the secondary market. The bids in the auction then convey this information to the secondary market. They speculate

secondary market prices will respond to the private information held by competitive bidders in the primary market.

A game-theoretic model linking the resale price and actions of competitive bidders is developed which has n risk-neutral bidders who are dealers and k identical, indivisible objects (n > k). The objects all have the same, true, but unknown value at bid time. The model assumes information on the highest losing bid and additional information can be passed to the secondary market between the bidding cutoff time and the opening of the secondary market. The price at which the winning dealers resell their objects is the "expected value of the object conditional on all publicly available information" in a discriminatory auction with a resale market such as the Treasury bill market.

The model developed by Bikhchandani and Huang (1989) suggesting that secondary market prices will respond to the private information held by competitive bidders gives rise to a semi-strong form efficient Treasury bill market study. Do asked rates in the Treasury bill secondary market react to the announcement of auction results using the percent overbid as a proxy for private information held by competitive bidders?

The current study questions the semi-strong efficiency of the Treasury bill secondary market. The majority of the

results described in the existing literature support a weak form efficient Treasury bill secondary market (Fama, 1975; Hamburger and Platt, 1975; Phillips and Pippenger, 1976; Mills and Stephenson, 1985). Chandy and Cross (1984), however, found weak form inefficiency during high inflationary periods. Most studies also failed to reject the semi-strong efficiency of the Treasury bill market. Table I summarizes the results of the market information and semi-strong form efficiency studies of the Treasury bill secondary market. The results of these studies, in particular Wachtel and Young (1990) and Cammack (1991), lend relevance to the present study's question of announced auction results having an impact in the Treasury bill secondary market.

Forward Rates and Unbiased Expectations in Markets

Bids placed on Monday are for bills to be received on Thursday. As a result, purchasing a Treasury bill in the auction market could be viewed as purchasing a forward contract for a 91-day Treasury bill to be delivered in three days (Lumpkin, 1986). Monday's auction bid rates can be considered as unbiased expectations of the spot rate to prevail in the secondary market on Thursday. This type of relationship has been examined in studies dealing with the Treasury bill futures market and the foreign exchange

TABLE I

SUMMARY OF RESULTS OF SEMI-STRONG

TREASURY BILL SECONDARY MARKET

EFFICIENCY STUDIES

Authors:	Market Efficiency with Respect to:	Results:
Hamburger and Platt (1975)	Estimates of personal income and liquidity (nonborrowed monetary base)	Semi-strong efficient
Chandy and Cross (1984)	Expected changes in purchasing power	Market inefficiency during high inflationary periods
Mills and Stephenson (1985)	Expected inflation in the U.K. Treasury bill market	Semi-strong efficiency in U.K. Treasury bill market
Wachtel and Young (1987)	Expected government deficits announcements	Semi-strong inefficient for the longer-term maturity segment of the market
Schirm, Sheehan, and Ferri (1989)	Unexpected components of the Treasury debt announcements and cash management bills announcements	Semi-strong efficient except with respect to cash management bills announcement
Wachtel and Young (1990)	Announced auction results - demand surprise	Semi-strong inefficiency

market. To develop the appropriate methodology for the current study, literature relating to (1) the foreign exchange market and forward rates is reviewed (Frenkel, 1981; Bilson, 1981; Edwards, 1983; and Chiang, 1988) and (2) Treasury bill futures and unbiased expectations (Wong and Henderson, 1990; Cole, Impson, and Reichenstein, 1991).

The concept of unbiased expectations has been studied with forward rates in the foreign exchange market. The model developed and used in many of these studies provides the model to examine the auction rate as an unbiased expectation of Thursday's secondary market rate in the current study.

Trades of foreign currencies in the foreign exchange market occur both at rates established in the spot market and at rates established by forward contracts. One concept which has been questioned due to the existence of these two outlets for foreign currency trades is whether the forward rate is an unbiased expectation of the future spot rate.

Current spot foreign exchange rates will reflect all relevant information at the time the spot rate is set in an efficient foreign exchange market, and forward rates should reflect expectations about future spot rates (Frenkel, 1981; Edwards, 1983). In examining forward exchange rates as unbiased expectations of future spot rates, the basic model used takes the form (Frenkel, 1981; Bilson, 1981; Edwards, 1983; Chiang, 1988):

$$s_{t+1} = \alpha + \beta F_t + \epsilon_{t+1}$$

where s_{t+1} = spot rate at time t1+1 or ln of spot rate

F_t = forward rate at time t or ln of forward rate

ϵ_{t+1} = white noise.

Testing the unbiased expectations hypothesis is a joint hypothesis test:

H_o: $\alpha = 0$ and $\beta = 1$

H_a: $\alpha \neq 0$ and $\beta \neq 1$.

If the null hypothesis is not rejected, then the forward rate is considered an unbiased expectation of the future spot rate.

Both studies from the Treasury bill futures market included in the literature review use models similar to the foreign exchange market models to examine unbiased expectations. Wong and Henderson (1990) examine the efficiency of the Treasury bill futures market. One part of their study also involves determining if futures prices are unbiased forecasts of Treasury bill spot prices during the time period March 1976 to December 1986. In order to conduct their study, the following regression model is developed:

$$S_n = a + bFT_{m,n} + U_m$$

where S_n = spot price at time n

U_m = forecast error [$S_n - E_m(S_n)$]; and

$FT_{m,n}$ = futures price at time m, to be delivered at time n.

If the futures price is an unbiased forecast of the spot price, then the two should not be significantly different and U_m should be approximately zero. The hypothesis tested is:

H_o: $b = 1$

H_A: $b \neq 1$

In testing this hypothesis, Wednesday bid prices are used for the S_n variable and the 3, 6, and 9 month futures were used for $FT_{m,n}$. The results of the regression lead to a failure to reject the null hypothesis in most cases since b was not significantly different from one at the 95 percent confidence level. The only cases in which the null hypothesis is rejected are the futures having terms to delivery of 1, 4, 25 and 27 weeks.

Cole, Impson, and Reichenstein (1991) look at the possibility of Treasury bill futures rates being rational expectations of the spot rates to prevail on the contract delivery date. They test futures prices for the characteristics of rational expectations.

In studying this question, Cole, Impson, and Reichenstein suggest one of the following would hold. (1) A combination of factors, such as term premia; differences in transactions costs and margin regulations; and location, timing and delivery options contained in futures contracts, could lead to rational expectations not being able to describe the futures rate. In this case, there would be a significant difference between the futures rate and expected

spot rate. (2) Rational expectations can be used to describe the futures rate when these combined factors are not significantly reflected in the expectation. In this case, the futures rate is a rational expectation of the spot rate.

In determining whether the futures rates are consistent with rational expectations, their study includes a test of unbiasedness. In doing the study, futures rates are compared with a "no-change" scenario in which actual bill rates are used from the same day the futures rate is obtained. The test for unbiasedness is performed using the following regression.

$$r_t = \alpha + \beta r_{t-s} + e_{st}$$

where r_t = actual bill rate at time t

r_{t-s} = forecast at time t-s of the bill rate expected to prevail at time t

The results of the tests indicate Treasury bill futures rates are consistent with unbiased rational expectations.

With Monday's auctioned Treasury bills not being issued until the following Thursday, the auction rate is similar to a forward or futures rate. Is the auction rate from Monday an unbiased expectation of the rate to prevail in Thursday's secondary market? To examine this question, the same model and hypotheses used in the foreign exchange market studies and Treasury bill futures market studies are used in the current study.

Bid-Ask Spreads in Dealer Markets

The last area of the current study examines the determinants of the Treasury bill secondary market bid-ask spread around the time of the auction results announcement. Bid-ask spreads exist to compensate dealers for inventory costs, transactions costs, asymmetric information costs, and risk (Bagehot, 1971; Branch and Freed, 1977; Hamilton, 1978; Stoll, 1978 and 1989; ; Mann and Seijas, 1991; and McInish and Wood, 1992). Security dealers continually monitor new information and evaluate their risks and costs to set bid and ask quotes (Hamilton, 1978). The information set monitored will include inventory positions, competitors' supply and demand schedules, purchase and sale orders, volatility and arrival of new market information (Hamilton, 1978; Garbade, Pomrenze, and Silber, 1979).

In the over-the-counter stock market, Stoll (1989) examines three of the determinants of the bid-ask spread. Stoll argues the true value of a stock will be bracketed by the bid-ask spread if the spread is compensation only for order processing. If the spread is instead compensation for inventory holding costs, dealers will alter their bid-ask spread in order to attract or discourage trades depending on how near the dealers are to their perceived optimal inventory positions. Last if dealers are being compensated for adverse information costs, dealers will alter their bid-ask spreads after transactions with other dealers under the

assumption the other dealers have superior information. The adverse information cost is a result of the dealer being put in the position of trading with individuals who have more information than the dealer.

Using data from NASDAQ/NMS from 1984, Stoll found 43 percent of the realized spread was compensation for adverse information costs, 10 percent for holding costs, and 47 percent for order costs. Since compensation for adverse information costs is a significant portion of the spread in the over-the-counter stock market, this compensation is likely a significant portion of the spread in the Treasury bill market as well.

Treasury bill dealers cannot discern between transaction orders generated by traders with liquidity needs and orders generated by traders with superior information. Liquidity-motivated investors are interested in being able to make timely exchanges of securities for cash, and information-motivated investors make exchanges based on the possession of "special" information which the market maker may not have (Bagehot, 1971; Copeland and Galai, 1983; and Glosten and Milgrom, 1985). The market maker gains from transactions with the liquidity-motivated investor and attempts to minimize losses to information-motivated investors by altering the bid-ask spread. The larger the spread is, the smaller will be the market maker's loss due to adverse selection from these information-motivated

investors. The spread, however, cannot be too large as it would discourage trades by the information-motivated investors (Bagehot, 1971). Bagehot also notes the more liquid the market, the smaller the spread.

Based on the theory there are expected losses to informational traders and expected gains from liquidity traders, Glosten and Milgrom (1985) and Copeland and Galai (1983) develop models of bid-ask spreads. Glosten and Milgrom extract the following propositions from their model. 1) If all traders, along with the market maker, had equivalent information, there would be one price between the bid and ask prices. 2) A martingale is formed by the prices at which the transactions occur. 3) The variance of underlying uncertainty partially determines the bound on the size of the spread. 4) Insiders' information is reflected in market prices. 5) Bid prices decrease and ask prices increase when (a) insiders get better information; (b) there becomes many more informational traders as opposed to liquidity traders; (c) for the liquidity trader, there is an increase in elasticity of expected supply and demand.

The fourth and fifth propositions are the most useful for this study. If insider information is reflected in market prices, the tail spread will convey "insider" information from the Treasury bill auction to the secondary market. Dealers will alter their bid-ask spreads to reflect

the arrival of this "insider" information in the post-auction period.

The bid-ask spread should be wider, according to the fifth proposition of Glosten and Milgrom, when there are more informational traders. The question is does the announcement of the auction results including the percent competitive and percent overbid reduce some uncertainty concerning the number of informational traders and result in changes to the bid-ask spread.

Previous studies model determinants of the bid-ask spread of the over-the-counter stock market dealers and NYSE specialists. Linear regression models are developed in a format similar to:

$$s_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + e_i$$

where s_i represents the bid-ask spread as an average or as a percentage relative to the stock price or average bid-ask spread and the X's represent the hypothesized determinants of the bid-ask spread (Branch and Freed, 1977; Hamilton, 1978; and McInish and Wood, 1992). Stoll (1978) uses a similar model, but in log linear form, to explore bid-ask spread determinants. The dependent variables included as determinants in these models are able to significantly explain the bid-ask spread of OTC dealers and NYSE specialists (R^2s from .3 to .82.).

Branch and Freed (1977) find dealers' risk (as measured by the percentage change in closing price of stock from

previous day), competition, and volume are significant determinants of the bid-ask spread. In the Treasury bill market, dealers' risk may change as a result of the auction outcome and, therefore, the bid-ask spread in the secondary market is affected according to Branch and Freed's results. The level of competition and volume may also change in the secondary market as a result of the auction outcomes. If dealers are able to buy more bills in the auction, competition to sell the bills in the secondary market will increase.

Hamilton (1978) finds the difference between highest and lowest bid price for a stock, the number of OTC dealers quoting prices for a stock, the number of shareholders, and the average share price were determinants of the bid-ask spread. The difference between highest and lowest bid price for stock is similar to the tail spread information from the auction. The tail spread is then expected to be related to the change in the secondary market bid-ask spread.

Stoll's (1978) log linear model finds dealer risk aversion, stock return variance, volume, adverse information costs (proxied by turnover), stock price, and the degree of competition were all determinants of the over-the-counter stock market bid-ask spread. The volume, degree of competition, and price are negatively related to the bid-ask spread while the variance and adverse information costs are positively related to the spread. The relationship of

volume, degree of competition and adverse information costs to the bid-ask spread are expected to be the same in the Treasury bill secondary market.

The intraday bid-ask spread in the futures markets is shown to be related to both the "timing of information arrival and the uncertainty of the information flow" (Ma, Peterson, and Sears, 1992). Ma, Peterson, and Sears suggest that bid-ask spread changes signal the arrival of new information. If Treasury bill dealers change their bid-ask spread in the post-auction period due to the announcement of the auction results, it would be said the auction results announcement is an arrival of new information. If the coefficients on the auction results variables are statistically significant, then they would be considered determinants of the change in the spread.

Venkatesh and Chiang (1986) specifically examine the arrival of new information and information events. In a study of the over-the-counter stock market, they note the dealer should widen the spread in anticipation of an information event which will give informed traders an advantage. The information events studied are dividend and earnings announcements. The results of their study show, judging by the dealer's increase in spread, there is an increased amount of information asymmetry (more than "normal asymmetry") between the uninformed dealers and the informed traders at the time of a second announcement of dividends or

earnings. Applying this idea to the Treasury bill secondary market, dealers may reduce their spreads after the auction if they believe there is reduced information asymmetry due to the announced auction results.

One study of bid-ask spreads specifically dealing with Treasury issues is Garbade and Rosey's (1977). Two models are used by Garbade and Rosey to examine bid/asked spreads for U.S. Treasury coupon issues. The time frame for the study was 1961 to 1974 which is subdivided into pre- and post-1966. The spreads during these years are collected in mid-February, mid-May, mid-August, and mid-November.

Garbade and Rosey's first model compares bid/asked spreads to characteristics of the U.S. Treasury coupon issues. The model is formulated as:

$$\ln(S) = ao + bo\ln(TRM) + co\ln(VOL) + doFlwr + eoNew$$

where:
- S = bid/ask spread in percent of par value
- TRM = term to maturity
- VOL = volume outstanding
- Flwr = a dummy variable equal to one if the security could be used to pay estate taxes and zero otherwise, and
- New = dummy variable equal to one if the security had been issued within three months before the observation date and zero otherwise.

The results of the first regression indicate all of the coefficients are significant. The term to maturity and the flower variable have a positive relationship with the bid/ask spread. The outstanding volume variable and the new variable have a negative relationship with the spread.

The second model examines the bid/ask spread as compared to yield volatility. The change in the Federal funds rate is used as a proxy for yield volatility. The model is:

$$\ln(S) = ao + a1|\Delta FF| + bo\ln(TRM) + b1|\Delta FF|\ln(TRM) + co\ln(VOL) + c1|\Delta FF|\ln(VOL) + doFlwr + eoNew.$$

With the second regression, they find that in the post-1966 time frame, dealers' spreads on U.S. Treasury coupon issues varied directly with volatility in the market. A model similar to this will be used in the current study and the change in the Federal funds rates will be included as an explanatory variable.

Roll (1970) examines bid-asked spreads on 13 week maturity Treasury bills. Roll discusses the sharp changes in the spreads on the 13 week bills which occur at the time of a new issue.

Roll provides three explanations for these changes. First, the Treasury bill secondary market may have trouble absorbing the new issue. If the market is able to absorb the new issue without any problems, the decrease in spreads should be smoother. An alternative explanation for the sharp decrease in spreads is that dealer collusion may be occurring in the secondary market in an attempt to provide low priced newly issued bills for government purchases in the secondary market. The sharp drop in spreads from 12 to 13 weeks and from 25 to 26 weeks supports this alternative

explanation. Roll's final explanation is in the 1 to 13 week Treasury bill market, the dealer costs are less and this is reflected in the smaller yield spreads. This explains the upward shifts in spreads from 14 to 26 weeks but not the drops in spreads. Roll also notes the market for new issues of 13 and 26 week bills is very active. Costs are lower in more active markets.

With the exceptions of Roll's (1970) article and Garbade and Rosey's (1977) article, this paper differs from other studies presented here in that it examines the Treasury bill secondary market bid-ask spreads. It uses more current data and questions whether auction results are determinants of the post-auction secondary market bid-ask spreads. Although the spreads should be smaller on the 91 day bills used in this study, Roll (1970) provides an argument for examining the determinants of bid-ask spreads in the secondary market. It would appear the secondary market is reacting to something associated with the auctioning of new bills given the sharp change in spreads at the time of new issues.

According to the Federal Reserve Bank of New York (Winter 1977-78, p. 40), "Spreads ... widen--sometimes dramatically--when new developments generate caution or uncertainty in the market." Do the announced auction results lessen uncertainty and cause a reduction in secondary market bid-ask spreads in the post-auction period?

Are the secondary market bid-ask spreads on Treasury bills determined by the information from the auction results: tail spread, percent competitive, and percent overbid?

Summary of Study as Related to the Literature

The literature review supports the development of the hypotheses and selection of methodology to test the hypotheses. The first group of literature discusses the auction and the secondary markets. This sets up the justification for the examination of information flow between the two markets through the announced auction results and the examination of the auction rate as a downward biased estimate of the true value of a Treasury bill.

The next area of the literature review concerns market efficiency. This literature states that if markets are semi-strong form efficient, then the announcement of new information will not affect the market prices. Studies are presented which use regression methodology to test relationships similar to the semi-strong form Treasury bill secondary market efficiency being tested in this paper. The studies specifically examining Treasury bill secondary market efficiency are mixed in their results. Semi-strong form market efficiency is found in the United States and United Kingdom Treasury bill secondary markets with respect

to estimates of personal income and liquidity, expected inflation, and unexpected components of Treasury debt announcements (Hamburger and Platt, 1975; Mills and Stephenson, 1985; Schirm, Sheehan, and Ferri, 1989). This study examines the semi-strong market efficient of the Treasury bill secondary market with respect to components of the announced auction results not previously studied.

The Cammack (1991) study provides the justification and models for hypotheses two through four. These hypotheses look at models of a bidding adjustment and secondary market returns which occur as a result of the downward biasing of the auction price.

The studies presented support the methodology for testing the fifth hypothesis concerning unbiased expectations. These studies examine unbiased expectations in forward and futures markets all using similar regression models and hypotheses. The model and hypotheses are used in the current study to test the Treasury bill auction rate as an unbiased expectation of Thursday's secondary market rate.

Bid-ask spreads are discussed in the last area of the literature review. In other markets, studies find determinants of the bid-ask spread to include asymmetric information costs, transactions costs, volatility, supply and demand schedules, risks, volume, and competitors. This study examines components of the Treasury bill auction results as determinants of the secondary market bid-ask

spread. These components encompass information regarding asymmetric information, demand, risk, volume, and competitors.

CHAPTER III

MODELS AND HYPOTHESES, METHODOLOGY, AND DATA SOURCES

Introduction

This chapter presents the models, hypotheses, methodology, and data sources for this study. The chapter is divided into three sections. In the first section, six models are presented along with the hypotheses examining the models. In the second section, the methodology is discussed for testing the hypotheses. The required data and data sources employed to conduct the hypotheses testing are introduced in the last section.

Models and Hypotheses

Market Efficiency

The first hypothesis concerns whether the Treasury bill secondary market is semi-strong efficient with respect to a given information set. If the changes in Treasury bill secondary market asked rates follow a fair game, the Treasury bill secondary market can be said to be semi-strong efficient with respect to the given information set. A

stochastic process, x_t, is a martingale with respect to a sequence of information sets, ϕ_t, if x_t has the property $E_t(x_{t+1}|\phi_t) = x_t$ and is said to be a fair game if x_{t+1} has the property $E_t(x_{t+1}|\phi_t) = 0$. It follows that the change in a martingale process $(x_{t+1} - x_t)$ is a fair game and is not predictable given the sequence of information sets, ϕ_t.

Applying this theory to the Treasury bill secondary market, the change in the Treasury bill discount rate from time period t-1 to time period t is not predictable if the Treasury bill rate follow a martingale process. An analysis of the following model is appropriate in questioning whether changes in the discount rates follow this fair game, systematic, linear relationship:

$$R_t - R_{t-1} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_j X_j + \epsilon_t.$$

where R_t = the discount rate on a Treasury bill at time t,

X_j = component j of the information set,

ϵ_t = random error terms which are identically, independently distributed.

If changes in Treasury bill rates are a fair game, then coefficients $\beta_0 \ldots . \beta_j$, which are linked to the information set, will not be significantly different from zero. The Treasury bill secondary market would then be considered semi-strong efficient with respect to the information set.

The information set of interest in this study, ϕ_t, includes the Treasury bill auction announcement variables

(percent competitive, percent overbid, and tail spread) and the change in the Federal funds rate. The percent overbid, the percent competitive, and the tail spread are proxies for the strength of demand and the degree of participation in the auction market by informed and uninformed traders.

The first auction results variable discussed is the percent overbid. The percent overbid (POVER) is calculated as the ratio of the dollar volume of competitive bids not accepted to the total dollar volume of bids in the auction. When the volume of competitive bids exceeds the supply of bills available to competitive bidders, demand has exceeded supply. This excess demand can be measured by the percent overbid. When the competitive bidders demand is not met in the auction market, the demand is expected to move to the secondary market. Because the competitive bidders have better information than other traders in the secondary market, transactions with competitive bidders increases the dealers' risk in the secondary market (Bikhchandani and Huang, 1989). It is anticipated that dealers reduce asked rates (increase prices) in response to the increased risk and the greater demand.

The percent competitive, the second auction results variable, reflects the number of informed traders winning bills in the auction market. The percent competitive (PCOMP) is the ratio of the dollar volume of competitive bids accepted to the dollar volume of total bids accepted.

The largest group of informed traders is dealers. A larger percent of competitive bids filled in an auction suggests dealers will have a larger inventory of 91 day bills once the bills are issued. The dealers may increase their asked rates (lower prices) in order to bring their inventory of 91 day bills to an optimal level.

The bids filled in an auction are either competitive or noncompetitive bids, by definition. The percent of total bids filled through competitive bids (PCOMP), therefore, indirectly indicates the demand for bills from noncompetitive bidders in the auction market. Since noncompetitive bids reduce the supply of bills available to competitive bidders, a lower percent competitive variable may indicate there could be more competitive bidders seeking bills in the secondary market. More competitive bidders seeking bills in the secondary market would be associated with a reduction in asked rates (higher bill prices).

The study's last auction information variable is the tail spread. The tail spread (TAILSPR) is the difference between the high and low accepted bid rates. Boatler (1975) states that an approximate demand schedule for Treasury bills is produced by the ranking of bid prices and quantities. This demand schedule can be represented by the spread between the high and low prices. The more aggressive the demand, the smaller the tail spread.

Market prices aggregate the private information of market participants (Hayek, 1945; Grossman, 1976; Green, 1977; Milgrom, 1979; Diamond and Verrecchia, 1981; and Lumpkin, 1986). The tail spread (TAILSPR) reflects the prices achieved in an auction. This implies the tail spread is not only a reflection of the dispersion of prices but is a means of passing along bidders' private information. Reduced demand from competitive bidders, a wider disparity of information among competitive bidders, or less aggressive competitive bidders are all factors which could result in a larger tail spread. As the tail spread gets larger, an increase in the secondary market asked rate (lower bill prices) is expected.

The fourth variable in the information set is the change in the Federal funds rate (CHFF). The Federal funds rate is included to account for activities of the Federal Reserve which affect Treasury bill rates. The purchase or sale of Treasury bills by the open market desk of the Federal Reserve Bank of New York is used to adjust reserves in the banking system. While a measure of open market transactions to account for Federal Reserve activities which could influence interest rates might be more appropriate for the estimated model, the data was not available. The Federal funds rate was selected as an explanatory variable to act as a proxy for the influence of the Federal Reserve on Treasury bill rates.

The first reason the Federal funds rate acts as a proxy is the Federal funds rate provides a measure of the Federal Reserve's pressure on the money supply and the pressure on the money market. The Federal Reserve Bank of San Francisco (1961) states that a restrained monetary policy, which leads to increasing Federal funds rates, will be seen in an economic boom. In this situation, commercial banks may have to reduce their holdings of Treasury bills in order to fill their customers' loan demand and meet reserve requirements. Also as the Federal funds rate increases, there is a reduction in the money supply available for bank purchases of Treasury bills to hold as secondary reserves. This results in a reduced demand for Treasury bills.

A second reason for selecting the Federal funds rate as a proxy is the Federal funds rate can be used for predicting future rates on other money market instruments, since it is most quickly influenced when the Fed changes its policy (Jones, 1986; Bernanke and Blinder, 1989; Simon, 1989). Cook and Hahn (1988) find the change in the Federal funds rate is a statistically significant explanatory variable for the change in the three month Treasury bill rate. Given the two reasons for using the Federal funds rate as a proxy, a Federal funds rate increase is anticipated to result in an increase in the Treasury bill secondary market asked rate (lower bill price).

Using the information set consisting of the auction results variables and the change in the Federal funds rate, the first relationship modeled is:

Model I

$$CHASK_t = \beta_0 + \beta_1 POVER_t + \beta_2 PCOMP_t + \beta_3 TAILSPR_t + \beta_4 CHFF_t + \epsilon_t.$$

The variables used are defined as follows:

CHASK: the change in the discount rate ($R_t - R_{t-1}$) on a Treasury bill with approximately 91 days to maturity;

POVER: the ratio of the bids not accepted to the total bids in the auction;

PCOMP: the ratio of competitive bids accepted to the total bids accepted in the auction;

TAILSPR: the low auction tail plus the high auction tail (difference between the highest and lowest auction discount rates accepted); and

CHFF: the change in the Federal funds rate.

Model I examines whether the Treasury bill secondary market is semi-strong form efficient with respect to the auction results variables and the change in the Federal funds rate. The null and alternative hypotheses to test this are:

H_{O1}: $\beta_0 \ldots \beta_j = 0$

H_{A1}: $\beta_0 \ldots \beta_j \neq 0$.

If the null hypothesis is rejected, the Treasury bill

secondary market is not considered fully efficient with respect to the auction results information and the changes in the Federal funds rate.

Initially, Model I uses the change in the Treasury bill asked discount rate (CHASK) from Friday to Monday, because information concerning Monday's auction may be used by Monday's secondary market participants. There is only a short time, however, between the 1:00 p.m. cutoff of Monday's auction and the collection at approximately 3:00 p.m. Monday of secondary market trading information. The high, low and average rates accepted in the auction are not announced until 5:00 p.m. Monday. The timing, therefore, allows secondary market trades on Monday to be based only on the bidders' perceived auction results and on information transmitted between auction bidders during the two hour time span from 1:00 to 3:00 p.m..

With the Treasury release of the auction information not occurring until near 5:00 p.m., there is no time Monday for the secondary market to react to the announced auction results. It is more likely that a change in the asked rate due to information contained in the announced auction results would occur from Monday to Tuesday. The next regression, consequently, will use the change in the Treasury bill asked discount rate from Monday to Tuesday. Additional Model I regressions use Tuesday to Wednesday data, Wednesday to Thursday data, and Thursday to Friday

data. These regressions attempt to see if the market waits until the bills are issued to incorporate the auction results information.

Downward Biased Estimates

Auction theory suggests auction rates are downward biased estimates of the true value of the Treasury bills (Reece, 1978; Milgrom and Weber, 1982; French and McCormick, 1984; and Cammack, 1991). As a result, Monday's secondary market price will differ from the auction price and an excess return could be earned due to a bidding adjustment. Components of the auction results can be considered as determinants of the bidding adjustment and secondary market returns. To examine this, the models developed by Cammack (1991) are replicated using the current data from the time period August 1985 to August 1990.

According to auction theory, this downward biasing of the auction prices is a function of the number of auction bidders and the dispersion of opinion among auction participants (Reece, 1978; Milgrom and Weber, 1982; Cammack, 1991). Downward biased auction rates occur when bidders realize there are fewer bidders in the auction and their chance of winning a bid is greater. The bidder can lower his bid and realize a greater return. A simple comparison of the auction rates and the secondary market rates is

conducted to verify that the relationship predicted by auction theory is correct.

Once the comparison confirms downward biasing exists, the hypothesis that the downward biased auction rate is determined by the number of bidders and dispersion of opinion is examined. The degree of downward biasing is measured using a variable termed the Monday bidding adjustment (MONBA) which is 100 x $\ln({}_{91}P_M/P_A)$ (Cammack, 1991). ${}_{91}P_M$ is the 92-day Treasury bill price traded in Monday's secondary market adjusted to 91 days to maturity. The formula to make this adjustment is ${}_{91}P_M = 100 \times (P_M/100)^{91/92}$. P_A is the quantity-weighted average price from Monday's auction.[4]

Three auction variables are used to measure the dispersion of opinion and the number of bidders. The low tail (LOTAIL) is a proxy for the dispersion of opinion.[5] The number of competitive bidders in an auction (C) is examined by looking at the fraction of unsuccessful competitive bids.[6] The number of noncompetitive bidders (NC) is measured with the fraction of the dollar volume of

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[4]The prices are calculated from the discount rates given in the auction and secondary markets using the following formula: P = 100 - (days to maturity x discount rate)/360.

[5]LOTAIL = $\ln(P_A$ - low auction price).

[6]C = dollar volume of competitive bids submitted/dollar volume of competitive bids accepted.

noncompetitive bids in the auction.[7]

These three auction variables are decomposed into expected and unexpected components using a first-order autoregressive process. Each auction variable of interest is estimated using an iterative process with ten data points for each iteration. The model used to determine the expected component for each variable takes the form:

$$\text{Variable}_t = \beta_0 + \beta_1 \text{Variable}_{t-1} + \epsilon_t.$$

β_0 and β_1 are estimated for the model first using data points for t = 2 through 11. The estimated equation is used to forecast the variable at t = 12 which is then considered the expected component for the variable at t = 12. The unexpected component for t = 12 is then calculated by subtracting the forecasted component from the actual value at t = 12. This estimation process is repeated through the study period by dropping the i^{th} observation and adding the i^{th} plus ten observation each time until the end (n) of the data set is reached (t = 3 through 12, 4 through 13, ..., n - 10 through n - 1). This estimation process produces unexpected and expected components for the auction results variables for n - 11 time periods.

The process outlined for finding the unexpected and expected components differs from Cammack's process in that Cammack used a data set including the entire time frame

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[7]NC = dollar volume of noncompetitive bids/dollar volume of accepted bids.

rather than an iterative process with ten data points in each estimation period. The process used for this study was chosen because it should provide better estimates for the unexpected and expected components of the auction variables. This improvement should occur because the time period used in estimating the expected components is closer in proximity to the time period being estimated.

The model used to examine the relationship of the expected components of the auction independent variables with the bidding adjustment due to the downward biasing is (Cammack, 1991):

Model II

$$MONBA_t = \alpha + \beta X_t + \epsilon_t$$

where: MONBA = Monday's bidding adjustment

X = ELOTAIL (expected component of the low tail); EC (expected component of the number of competitive bidders); or ENC (expected component of the number of noncompetitive bidders)

The hypotheses tested in conjunction with this model are:

H_{O2}: $\beta = 0$.

H_{A2}: $\beta \neq 0$.

The expected components are used in this model, because the Monday secondary market price cannot react to the unexpected components of the auction results. This is true because the calculation of the unexpected components cannot occur until

after the secondary market prices are recorded at 3:00 p.m. Monday and the auction results are announced at 5:00 p.m. If there is a relationship, the bidding adjustment should be related to the expected portion of the auction results.

The null hypothesis for this question is rejected if an individual expected component of an auction results variable is statistically significant in explaining the bidding adjustment. ELOTAIL is expected to have a positive sign since the dispersion of prices is related to expected profit (Cammack, 1991). The number of bidders, as proxied by EC and ENC, should be also positively related to the bidding adjustment (Cammack, 1991).

The next model, as presented by Cammack (1991), examines whether the unexpected components of the auction results variables are determinants of the return which can be earned in Tuesday's Treasury bill secondary market. Any adjustment of the secondary market prices due to unexpected information and the bidding adjustment will likely occur on Tuesday. This is due to the announcement of the auction results occurring on Monday after the secondary market prices are recorded for the day. The model which uses each of the auction results variables individually to examine this relationship is stated as:

Model III

$$TUESRET_t = \alpha + \beta X_t + \epsilon_t$$

where: TUESRET = the percentage change in price on a Treasury bill from Monday (P_M) to Tuesday (P_T) in the secondary market;

$100 \times \ln(P_T/P_M)$

X = ULOTAIL (unexpected component of the low tail); UC (unexpected component of the number of competitive bidders); or UNC (unexpected component of the number of noncompetitive bidders).

The hypotheses tested in conjunction with this model are:

H_{O3}: $\beta = 0$.

H_{A3}: $\beta \neq 0$.

If any of the auction results variables are statistically significant, they are considered to be determinants of the Tuesday return.

The auction results variables in the third model may simply be proxies for the price level in the auction (Cammack, 1991). The fourth model, therefore, includes a price level comparison variable (denoted A%D) to determine whether the auction results variables only convey information about the price level in the auction. This model is presented as (Cammack, 1991):

Model IV

$$TUESRET_t = \alpha + \beta_1 ULOTAIL_t + \beta_2 UC_t + \beta_3 UNC_t + \beta_4 A\%D_t + \epsilon_t$$

where A%D = $100 \times \ln(\text{low auction price}/P_M)$.

The set of hypotheses for the examination of each individual variable is:

H_{O4}: $\beta = 0$.

H_{A4}: $\beta \neq 0$.

If any of the individual auction results variables are statistically significant in this model, then they are not just proxies for the auction price level and are determinants of Tuesday's secondary market return.

Unbiased Expectations

Buyers of Treasury bills in Monday's auction market do not receive the bills until Thursday. For Treasury bill auction markets to be truly efficient, the auction must produce an unbiased estimate of the secondary market rate prevailing when the new bills are delivered. Lumpkin (1986) notes the purchase of a Treasury bill in the auction market could be viewed as a purchase of a forward contract for a 91-day Treasury bill to be delivered in three days. Forward rates can be examined as unbiased expectations of future spot rates.

Unbiased expectations in the auction rate are in contrast to the auction rate being downward biased. The examination of whether the auction rate is a downward biased estimate of the true rate requires a comparison of almost identical bills selling in two different markets on the same day. The law of one price argues the rates in the two

markets should be the same for similar products. The argument for downward biased auction rates, however, stems from auction theory and the fact that when there is less competition and greater disparity of information bidders can place lower price bids.

This is in contrast to an examination of whether the auction rate is an unbiased expectation of Thursday's secondary market rate. The unbiased expectations examination looks at a comparison of similar instruments selling in two different markets on two different days. The argument for unbiased expectations stems from market efficiency and forward rate theories. If the auction rate is a downward biased estimate of the Treasury bills true value in the secondary market on Monday and Tuesday, then the auction rate may not be an unbiased expectation.

The average auction rate (being similar to a forward rate) should be an unbiased expectation of Thursday's secondary market asked rate. This relationship is stated as:

$$A_{M,Th} = E_M(R_{Th})$$

where $A_{M,Th}$ is the auction rate on Monday (M) for a bill to be issued on the following Thursday; and $E_M(R_{Th})$ is the Monday auction market's expectation of Thursday's spot rate (R_{Th}).

To address the question of whether the auction's average discount rate ($A_{M,Th}$) is an unbiased expectation of

Thursday's spot rate (R_{Th}), the following regression model suggesting the two rates are equal (except for white noise, ϵ_t) is used:

Model V

$$R_{Th} = \beta_0 + \beta_1 A_{M,Th} + \epsilon_t.$$

The model is consistent with that used by Hamburger and Platt (1975); Frenkel (1981); Bilson (1981); Edwards (1983); Chiang (1988); Wong and Henderson (1990); and Cole, Impson, and Reichenstein (1991) in testing for unbiased expectations.

The joint hypotheses associated with this model question whether the average auction discount rate ($A_{M,Th}$) is an unbiased expectation of Thursday's secondary market rate (R_{Th}) are:

H_{O5}: $\beta_0 = 0$ and $\beta_1 = 1$.

H_{A5}: $\beta_0 \neq 0$ and $\beta_1 \neq 1$.

If the estimates of the coefficients are not significantly different from zero and one, respectively, then the null hypothesis cannot be rejected. It would then be said $A_{M,Th}$ is an unbiased expectation of R_{Th}. Failure to reject the joint null hypothesis implies that all relevant information for predicting Thursday's secondary market rate is contained in the auction rate (Chiang, 1988).

Bid-Asked Spreads

The last set of hypotheses for the study involves the determinants of the change in the bid-asked spread in the Treasury bill secondary market. In general, market spreads will change as new information arrives and increases or lessens uncertainty (Garbade, Pomrenze, and Silber, 1979; Glosten and Milgrom, 1985; and Ma, Peterson, and Sears, 1992). Spreads in the Treasury bill secondary market have been found to be explained by dealer costs, volume, term to maturity, and new issue status (Roll, 1970; and Garbade and Rosey, 1977). It is expected the Treasury bill auction results contain information which the dealers in the secondary market incorporate into their bid-asked spreads. The explanatory variables considered as determinants of the secondary market change in bid-asked spreads include three auction results variables (percent overbid, percent competitive, and tail spread) and the change in the Federal funds rate.

The first auction result variable considered as a determinant of the change in the bid-asked spread is the percent overbid (POVER). One argument for including the percent overbid as an explanatory variable stems from the theory dealers increase bid-asked spreads when their risks and costs are increased. The percent overbid acts as a signal of the level of excess demand from information motivated traders in the auction. These more informed

traders may demand bills in the secondary market, because they were unable to purchase bills in the auction market (Glosten and Milgrom, 1985; Bagehot, 1971; and Mann and Seijas, 1991). Recognizing that trades may be occurring with information motivated traders, the dealers increase their bid-asked spreads to reflect the potential risk and recoup the cost of transacting with informed bidders. The change in the spread should be positive when the percent overbid increases.

Another argument supporting the inclusion of the percent overbid (POVER) as a determinant of the bid-asked spread is based on the cost of obtaining information. As this cost increases, fewer market traders will choose to incur the cost of obtaining information needed to participate in the auction as a competitive bidder. The result is a smaller percent overbid. With fewer information motivated traders having unmet demand in the auction, the chance of suffering a loss in an exchange with these traders in the secondary market is reduced. Dealers can therefore reduce their bid-asked spreads when the percent overbid is smaller.

The second determinant of the bid-asked spread included in the model is the percent competitive (PCOMP). Mullineaux (1973) notes that looking at the ratio of noncompetitive bids to total bills sold is a good measure of small saver activity in the primary Treasury bill market. Accordingly,

if the small saver activity was increasing, there would be a lower amount of competitive bids being accepted in the auction market. Consequently, the current study's use of the percent competitive (which is one minus the ratio of noncompetitive bids to total bills sold) should give a measure of the informed traders success in purchasing bills in the auction market. This, in turn, indicates the number of informed bidders which will enter the secondary market.

Another reason for suggesting the percent competitive (PCOMP) is a determinant of the bid-asked spread stems from the possibility competitive bidders may have specialized information. A lower percent competitive may indicate traders have specialized information and are willing to trade in the secondary market and incur the transactions costs rather than submit competitive bids in the auction. Dealers would realize this and in turn increase their bid-asked spread to protect themselves against trades with information motivated traders.

The last component of the auction results which is considered as a determinant of the secondary market bid-asked spread is the tail spread (TAILSPR). The support for inclusion of this variable is based on the tail spread being a measure of the dispersion of information and a measure of the range of auction market prices. Glosten and Milgrom (1985) propose that market prices convey inside information. If the tail spread reduces uncertainty for the dealers

concerning "inside" information of the auction market participants, the dealers will alter their bid-asked spreads. Also, McInish and Wood (1992) note the difference between the highest and lowest bid prices explain over-the-counter stock market bid-asked spreads. Although in a different market, the tail spread is the difference between the highest and lowest auction bid rates and, as such, is similar to McInish and Wood's stock market bid-asked spread variable.

Support for including this variable in the model of determinants of the bid-asked spread is also derived from Boatler (1975, 1985). The tail spread was larger as less experienced bidders, tendering less informed bids, were drawn into the market during periods of low bill prices and high interest rates. If there are more uninformed participants in the market, which can be judged by a larger tail spread, the dealers have the opportunity to narrow their bid-asked spreads without as much concern for losing profits to informational traders.

Last, justification for including the tail spread (TAILSPR) in Model VI is found in Bolten (1973). Bolten notes higher prices in this week's Treasury bill auction would give some expectations of a lower price in next week's auction. Trading volume in the post-auction secondary market would be reduced if market participants have expectations of prices being lower in next week's auction.

Reduced trading volume would lead dealers to increase their secondary market bid-asked spreads (McInish and Wood, 1992; Copeland and Galai, 1983; Branch and Freed, 1977; Stoll, 1978). If this occurs in the Treasury bill markets, then a smaller tail spread would lead dealers to increase their bid-asked spreads.

The change in the Federal funds rate (CHFF) is the last explanatory variable included as a determinant of the secondary market bid-asked spread. The justification for including this variable is the same as presented in the development of Model I. The Federal funds rate was said to be a predictor of money market rates and a proxy for Federal Reserve activities which affect the Treasury bill rates. Garbade and Rosey (1977) also find in a study of Treasury coupon issues that the Federal funds rate acts as a proxy for yield volatility in determining bid-asked spreads. As such, it had a positive relationship to the change in the bid-asked spread.

Using the variables calculated from the auction results (the percent overbid, percent competitive bids accepted, and the tail spread) and the change in the Federal funds rate, the last question addressed concerns whether these variables explain the Treasury bill secondary market bid-asked spread. This question is examined using the following model:

Model VI

$$CHSPR_t = \beta_0 + \beta_1 POVER_t + \beta_2 PCOMP_t + \beta_3 TAILSPR_t + \beta_4 CHFF_t + \epsilon_t$$

where CHSPR = the change in the secondary market bid-asked spread.

The set of hypotheses for this examination are:

H_{O6}: $\beta_0 \ldots \beta_j = 0$.

H_{A6}: $\beta_0 \ldots \beta_j \neq 0$.

If the group of estimated coefficients relating to the auction information variables and the change in the Federal funds rate is statistically significant in explaining the change in the bid-asked spread, the null hypothesis is rejected. Rejecting the null hypothesis would mean the auction results variables and the change in the Federal funds rate are determinants of the secondary market bid-asked spreads.

Methodology

The hypotheses are examined using linear regression models. Regression is a common means of examining and explaining the relationship between variables. With regression, a dependent variable is related to one or more independent variables. The independent variables are tested to determine whether they have explanatory power of the dependent variable using F-tests and t-tests. The

regression methodology used is consistent with that used by Fama (1975); Hamburger and Platt (1975); Chandy and Cross (1976); Mills and Stephenson (1985); Wachtel and Young (1987, 1990); Schirm, Sheehan and Ferri (1989); and Cammack (1991). In setting up the regression models, some basic assumptions are made.[8]

Regression Methodology Considerations

When working with linear regression models, there are potential problems with the use of time series data and the use of the standard regression model for which tests must be conducted. First, the functional form of the equation can be difficult to define. The test for market efficiency is also a test of the equation used to examine market efficiency. Second autocorrelation, heteroskedasticity, multicollinearity, and nonstationarity are problems with the use of time series data in a study.

The error terms must be independent and identically distributed if the assumptions of the linear model are not to be violated. For each of the regressions, the residuals are used to conduct a Durbin-Watson test for

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[8] Basic Assumptions of the Linear Model

1) The dependent variable may be expressed as a linear combination of the independent variables plus a disturbance term.
2) On average the disturbance terms will be zero.
3) The disturbance terms have equal variances (homoskedastic) and are pairwise uncorrelated.
4) The independent variables are not linearly related.
5) The disturbance terms have Normal distribution.
6) The independent variables form a nonstochastic matrix.

autocorrelation. The d-statistics are reported in the results' tables for each regression.

The linear model assumes the error terms are homoskedastic. There is the possibility, however, that the error terms are heteroskedastic. In this study two tests are conducted to check for heteroskedasticity. The first is a visual inspection of a graph of the residuals. The second is the White test.

Both autocorrelation and heteroskedasticity lead to nonspherical disturbances which cause "unbiased but inefficient estimation" (Johnston, 1984) and invalid t-tests. If autocorrelation or heteroskedasticity are found to be present, the regression can be altered to help counteract these problems. It is possible an autoregressive process, a moving average process, or a combination of both may provide a better model.

Multicollinearity is also a possible problem with regression analysis. The variable correlation and the regression coefficients' standard errors are examined in this study to check for the possibility of multicollinearity.

Finally, nonstationarity of the time series of the variables may be a problem. A visual inspection of time series graphs for the variables and the Augmented Dickey-Fuller test are used to check for stationarity. If any

variables are found to be nonstationary, the assumptions of the standard least squares model are not met.

If the variables are nonstationary and cointegrated, the standard least squares model is again inappropriate, but a technique for testing the parameters exists. The Engle-Granger cointegration test is used to check for cointegration. If the variables are found to be cointegrated, the Johansen technique will be used to estimate the parameters and perform hypotheses tests.

Data Sources

For this study, data is obtained concerning the Treasury bill discount rates, the results of the auction, and the Federal funds rate. The data used covers the time period from August 1985 through August 1990. The Treasury bill discount rates are obtained from back issues of the Wall Street Journal from the "Treasury Bonds, Notes, and Bills" column. The rates for bills with approximately 91 days to maturity are used in order to include bills which are similar to those from the auction. The discount rate used for this study is the asked rate, since that is the rate at which market players can purchase bills in the secondary market. A comparison, therefore, is being made between the rate at which bills are purchased in the auction

market and the rate at which bills are purchased in the secondary market.[9]

Results of the weekly auctions are also obtained. These come from the Treasury Bulletin. In the "Offerings of Bills" table from the "Public Debt Operations" section of this report, the partial results of each weekly auction which occurred during the quarter are listed. Data concerning the following are included: issue date, maturity date, number of days to maturity, amount of bids tendered, total amount of bids accepted, total amount of bids accepted on a competitive basis, total amount of bids accepted on a noncompetitive basis, amount maturing on issue date of new offering, total unmatured issues outstanding after new issues, the average price per hundred on total bids accepted, the average discount rate on total bids accepted, the average investment rate on total bids accepted, the high and low discount rate on competitive bids accepted, and the high and low price per hundred on competitive bids accepted.

Last, the Federal funds rate is obtained. This variable is found in the Wall Street Journal in the "Money Rates" column.

Due to changes in factors affecting variables, it may be necessary to divide the data into subperiods. Cammack divided the 1973 - 1984 data into groups according to the

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[9]The asked rate given in the Wall Street Journal is the lowest rate for which a dealer was willing to sell the bill of interest during the day.

Federal Reserve changes in targets for implementing monetary policy and the introduction of Treasury bill futures trading. During the time frame of the current study, there are no such changes which would necessitate partitioning the data.

The models presented in this chapter are estimated using the data obtained. The results of these estimations and the description of the data set used are presented in Chapter IV.

CHAPTER IV

DATA DESCRIPTION AND RESULTS

Introduction

This chapter presents a description of the auction and bid-asked data used in this study, and the results of the tests of hypotheses. Figures showing the time series plots for the variables are included in this section. Also included in this section is a test to check for time period differences in the data.

Description of the Data

Auction Rates

Auction rate data consists of the high, low and average discount rates. The high and low discount rates accepted in each auction are obtained for the 260 weeks covered in the time period August, 1985 to August, 1990. For the low discount rate accepted, the range is from 5.00 percent (occurring 10/26/87) to 9.05 percent (occurring 3/27/89). For the high discount rate accepted, the range is 5.08 percent (occurring on 10/6/86) to 9.11 percent (occurring on 3/27/89).

Friedman (1959), Boatler (1975), and Scott and Wolf (1979) argue that dealer collusion occurs in the auction. Friedman's conclusion is drawn, because there was no overlap evidenced between the highest and lowest bids accepted one week and the highest and lowest bids accepted the next week (e.g. week one: highest rate = 8.0 percent and lowest rate = 7.0 percent; week two: highest rate = 9.0 percent and lowest rate = 8.2 percent). In comparing the highest and lowest bids for the current study from one week to the next, there is some degree of overlap but only in 22 percent of the weeks (58 out of 260 auctions). More recent studies argue the lack of overlap is simply due to market factors during the week.

The Treasury calculates the average auction rate based on a weighted average of the accepted competitive auction bid rates. The average auction rates differ very little from week to week. There are, however, only seven occurrences where the average auction rates are exactly the same from week to week. During the five year time frame, the average auction rate ranged from a low of 5.08 percent on 10/9/86 to a high of 9.10 percent on 3/27/89.

The low tail, high tail, and tail spread are calculated using the low discount rate accepted, high discount rate accepted, and the average discount rate. The low tail ranged from 0 to .12 percent, and the high tail ranged from 0 to .89 percent. The calculated tail spread ranged from 0

(on 10/30/89, 7/17/89, 7/20/89, and 3/30/86) to .95 percent (on 8/21/89) (see Appendix A). Figure 1 presents a time series plot of the tail spread data (see Appendix E).[10]

Bid and Asked Rates

Information concerning the Treasury bill secondary market is obtained from the Wall Street Journal. The bid and asked rates reported in the Wall Street Journal are as of the official close of trading in the Treasury bill secondary market, which occurs at 3:00 p.m. every weekday. The bid-asked spread, the change in the asked rate, and the change in the spreads are calculated from the bid and asked rates (See Appendix B). Some rates are not available due to holidays and those dates are not included.[11] The time series plots of the independent variables (the change in the asked rate and the change in the spread) are shown in Figures 2 and 3 respectively (see Appendix E).

An examination of the bid-asked spreads reveals the bid-asked spread ranges from 0 to .25 percent. Table II shows the proportion of increases and the proportion of decreases in bid-asked spreads from one trading day to the next. The bid-asked spread did not change from one trading

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[10]Outliers were noted for some of the data points in the figures, but the numbers were verified from the data sources. It is possible the data sources contained typographical errors. The regression models were estimated with and without the outliers. The results were not significantly different.

[11]Cammack (1991) notes the occurrence of holidays did not have a significant impact on results.

day to the next for 60 percent of the data points during the five year study period. For the Friday to Monday time frame, the bid-asked spread changes in 39.04 percent of the weeks. For the weekly Monday to Tuesday data points, there is a change in 64.68 percent of the weeks. During the Tuesday to Wednesday time frame, the bid-asked spread changes in 29.80 percent of the weeks. For the Wednesday to Thursday data points, there is a change in 30.65 percent of the weeks; and for Thursday to Friday data points, there is a change in 36.93 percent of the weeks. For the Monday to Tuesday group, the number of changes in the bid-asked spread

TABLE II

CHANGE IN THE BID-ASKED SPREAD

	Proportion of Increases	Proportion of Decreases
Friday to Monday (n = 228)	17.11%	21.93%
Monday to Tuesday (n = 235)	8.94%	55.74%
Tuesday to Wednesday (n = 255)	14.90%	14.90%
Wednesday to Thursday (n = 248)	15.32%	15.32%
Thursday to Friday (n = 241)	16.18%	20.75%

Note: There is no change in the bid-asked spread for the remainder of the data points.
n = number of weeks in the sample

is much greater than for any of the other days, and the majority of changes are decreases. These decreases in the bid-asked spread occur much more frequently than for any of the other days. (86 percent of the total changes are decreases.)

Tests for differences in the proportion of increases versus the proportion of decreases are conducted with this data. The set of hypotheses for these tests are:

H_0: $p_1 - p_2 = 0$

H_A: $p_1 - p_2 \neq 0$.

The results of these tests for a difference in proportion suggest for the Monday to Tuesday data there is a statistically significant difference between the proportion of decreases and the proportion of increases at a 99 percent confidence level (Z-calculated = 12.5247, $z_{.005} = 2.575$).

The Monday to Tuesday proportion of decreases in bid-asked spreads to total observations is also significantly different from all the other proportions of decreases at a 99 percent confidence level (see Table III). Looking at Table III, only one other proportion is significantly different from one of the other proportions but not at a 99 percent confidence level.

Based on this information, there appears to be some significant event occurring during the Monday to Tuesday time frame driving the reduction in secondary market bid-asked spreads. This lends justification to examining

whether auction results variables from Monday are determinants of the bid-asked spread using Model VI.

TABLE III

CALCULATED Z-VALUES FOR COMPARISON OF PROPORTIONS OF THE NEGATIVE CHANGES TO TOTAL OBSERVATIONS

	MON-TUE	TUE-WED	WED-THU	THU-FRI
TUE-WED	10.38*			
WED-THU	10.19*	.13		
THU-FRI	8.41*	1.70	1.56	
FRI-MON	7.97*	1.99**	1.85	.31

* = significantly different in proportions at 99 percent confidence level
** = significantly different in proportions at 95 percent confidence level

Percent Competitive and Percent Overbid

The percentage of total bids accepted in the form of competitive bids (PCOMP) and the percent oversubscribed (POVER) are also calculated from the auction results (See Appendix C). The percent of competitive bids accepted during the 260 week period ranged from 72.63 percent (on 9/11/89) to 99.04 percent (on 7/7/86) (see Figure 4 in Appendix E). Noncompetitive bids accounted for between 1 percent and 28 percent of the bills purchased in auctions

from August 1980 to August 1985. This is near the historic range of 10 percent to 25 percent (Chicago Board of Trade, 1991). The percent oversubscribed ranged from 59.15 percent (on 12/2/85) to 93.03 percent (on 8/15/88) (see Figure 5 in Appendix E).

Federal Funds Rate

The Federal funds rates are obtained for each day and the change in the rates (CHFF) calculated (see Appendix D). The largest change occurred on 3/6/89 and is an increase of 5.38 percent.

Stationarity Test and Cointegration

The Augmented Dickey-Fuller (ADF) test and a visual examination of the time series plots of the variables is used to check for stationarity. The ADF test values and the associated critical values are shown in Table IV. As the ADF test values indicate, all of the variables are stationary with the exception of Thursday's asked rate and the average auction rate.

Since both the Thursday asked rate and the average auction rate are included in Model V, cointegration is considered. Using the Engle-Granger cointegration test, it is determined the average auction rate and Thursday's asked rate have one cointegrating vector. Based on these results,

TABLE IV

Augmented Dickey-Fuller Test Results

	t-statistic
CHASK	-9.8576
CHSPR	-11.2001
POVER	-6.7538
PCOMP	-7.9911
TAILSPR	-10.5501
CHFF	-9.6298
A(M,Th)	-1.2526*
R(Th)	-1.0894*
C	-6.7178
NC	-6.8204
LOTAIL	-9.2239
TUESBA	-9.6860
TUESRET	-10.0194
MONBA	-8.2953
MONRET	-6.4278
A%D	-9.1578

Note: Critical t-value is -2.87.
* = Nonstationary.

the Ordinary Least Squares method for evaluating Model V is deemed inappropriate and the Johansen Method used in its place.

Data Subperiods Test

The standard least squares model assumes the estimated parameters are constant over the time period examined. If the parameters do not remain constant during the period for which the data was collected, the estimated parameters will be inefficient and the t-tests unreliable. One solution to time-varying parameters is to group the data into subperiods during which the parameters do not vary. Federal Reserve policy changes represent an exogenous variable for this study that would affect Treasury bill rates and auction results. During this study's time frame, there are no major Federal Reserve policy changes. To verify there are no other changes that would necessitate the data being placed in subsets, the total sample is divided in two halves. The means and standard deviations for all variables are computed on both subsets (see Table V), and the results compared.

The hypotheses for examining the data subsets for each variable are:

H_0: μ for first half of data = μ second half of data

H_A: μ for first half of data $\neq \mu$ second half of data.

Two-tailed tests for a difference between means are

TABLE V

COMPARISON OF DATA SUBSETS

FOR POTENTIAL GROUPING

	First half of data		Second half of data		Full data set	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
P_A-low rate	.03	.018	.036	.023	.033	.021
High-low (tail spread)	.046	.083	.046	.031	.046	.063
LOTAIL	-3.722	.865	-3.548	.733	-3.635	.805
C	4.137	.682	4.123	.832	4.130	.759
NC	16.864	2.825	15.532	2.376	16.198	2.689
PCOMP	83.218	2.927	84.464	2.371	83.841	2.731
POVER	71.647	4.262	71.545	5.145	71.596	4.715

conducted at a 1 percent alpha level. As Table VI shows, there are no statistically significant differences between the means for six of the seven variables. This leads to the failure to reject the null hypothesis. Consequently the data is not divided into subperiods, and the analyses are done using the sample as a whole.

TABLE VI

CALCULATED T-VALUES FOR THE COMPARISON OF SUBSET MEANS

P_A-low	2.342
High-low (tail spread)	0.00
LOTAIL	1.7498
C	.1484
NC	1.5763
PCOMP	3.7716*
POVER	.1741

with α = 1 percent, t - stat = 2.576
* significant difference between means at α = 1 percent.

Regression Results

Hypothesis One

The hypothesis tested by Model I examines whether the Treasury bill secondary market is efficient with respect to the information carried in the announced auction results (percent overbid, percent competitive, tail spread) and the

change in the Federal funds rate. Table VII presents the estimation results for Model I.

The F-statistics used to test the null hypotheses indicate the set of independent variables is significant in explaining the change in the asked rate for the Wednesday to Thursday data and the Thursday to Friday data at a 95 percent confidence level. The percent competitive (PCOMP), tail spread (TAILSPR), and change in the Federal funds rate (CHFF) were each statistically significant for the Wednesday to Thursday data. For the Thursday to Friday data, the percent overbid (POVER) is statistically significant. Given these results, the Treasury bill secondary market cannot be said to be efficient with respect to the percent overbid, percent competitive, tail spread, and change in the Federal funds rate. The overall explanatory power of the model, however, is very weak with R-squareds of 7.7 percent and 5.9 percent.

The Durbin-Watson test is conducted on each regression to check for autocorrelation. This test is run to determine if the autocorrelation parameter, ρ, is zero. As long as the d-statistic calculated from the regression residuals is within the bounds for the Durbin-Watson test, the test is inconclusive. Only if the d-statistic falls outside the bounds can a conclusive statement about autocorrelation be made. When the d-statistic is greater than the upper bound, one can conclude the parameter, ρ, is equal to zero. In

TABLE VII

PARAMETER ESTIMATES FOR SEMI-STRONG

MARKET EFFICIENCY HYPOTHESIS:

MODEL I

Change in Asked Rate From:	INTERCEPT	POVER	PCOMP	TAILSPR	CHFF	R^2	F-stat	d-stat
Friday-Monday	-.194 (-.477)	-.004 (-1.429)	.006 (1.271)	.063 (.353)	.011 (.555)	.024	1.254	2.083
Monday-Tuesday	0.034 (.149)	-.001 (-.318)	0 (.049)	.088 (.818)	0.009 (.836)	.007	0.329	1.961
Tuesday-Wednesday	-.185 (-1.171)	0.0 (-.454)	0.003 (1.493)	-.147 (-1.939)	0.002 (.857)	.026	1.644	1.798
Wednesday-Thursday	.270 (1.7)	0 (.227)	-.003 (-2.003)*	-.158 (-2.197)*	-.008 (-2.479)*	.077	4.60*	2.255
Thursday-Friday	-.066 (-.333)	.004 (2.757)*	-.002 (-1.005)	.139 (1.529)	.027 (1.748)	.059	3.64*	1.75

* significant at 95 percent level
Note: Numbers in parentheses below the coefficients are t-values
POVER = number of competitive bids not accepted/total number of bid submitted
PCOMP = number of competitive bids accepted/total number of accepted bids
TAILSPR = difference between the high and low auction discount rates
CHFF = the change in the Federal funds rate.

three of the regressions, the d-statistic is above the upper boundary of 1.799 and two fall between the lower and upper boundary. There is no evidence of autocorrelation from these results.

A White heteroskedasticity test is also conducted with each regression. None of the resulting F-statistics from the White tests called for rejection of the null hypothesis of no heteroskedasticity.

Last, the collinearity of the independent variables is considered. Correlations are calculated for the explanatory variables, and the standard errors of the estimated parameters are examined to check for multicollinearity. The correlations, presented in Table VIII, are not large, and the standard errors of the estimated parameters are very small. Multicollinearity, therefore, is not expected to be a problem.

TABLE VIII

PEARSON CORRELATION MATRIX

	PCOMP	POVER	TAILSPR
PCOMP	1.000		
POVER	0.020	1.000	
TAILSPR	0.008	-.253	1.000

Hypotheses Two, Three and Four:

The next regressions simulate Cammack's study (1991), but differ in two respects. One exception, noted earlier, is the data is not subsetted in the current study. Cammack presents results for the full sample 1/1973 to 12/1984 plus four subsets of the sample which corresponded to changes in Federal Reserve policies of targeting interest rates versus targeting monetary aggregates and the introduction of Treasury bill futures.

The other exception is the method used to compute the expected and unexpected components. Cammack determines the expected and unexpected components of the auction variables using univariate models. An ARMA(1,1) process is employed for the low tail (LOTAIL) and for the participation of competitive bidders variable (C). An AR(1) process is used for the participation of noncompetitive bidders variable (NC). The current study uses information from the previous 10 time periods for each variable in order to predict the following time period's expected and unexpected components.

Table IX and X give general statistical descriptions of the explanatory and dependent variables used in this portion of the study. The descriptive statistics for the dependent variables are presented in Table IX. Compared to Cammack's study (1991), this study's dependent variables have fewer autocorrelation coefficients which are greater than two standard errors.

TABLE IX

DATA DESCRIPTION FOR MEANS, STANDARD DEVIATIONS, AND AUTOCORRELATIONS OF THE BIDDING ADJUSTMENTS

	MEAN	STD DEV	SE	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5
MONBA	0.005230	0.013967	0.069	0.068	0.184*	0.088	0.158*	0.14*
TUESBA	0.004178	0.023037	0.069	-0.056	0.071	-0.059	0.141*	0.019
TUESRET	0.017945	0.021308	0.069	-.045	0.067	-.064	.026	.076
MONRET	0.015901	0.033173	0.069	.121	-.036	-.056	.017	.014

* greater than two standard errors.

Table IX allows a comparison of the bidding adjustment and return data which occur as a result of the downward biased auction prices. For the current data, the mean Monday bidding adjustment and the mean Tuesday bidding adjustment are .005 and .004 percent, respectively. For Cammack's full sample data, both bidding adjustments are .01 percent. For this study, the mean auction price is only slightly less (1.6 to 2 basis points less) than the mean secondary market prices from Monday and Tuesday and not the four basis points Cammack finds.

A slight downward bias in the auction rate, however, is still evidenced. To determine if the Monday bidding adjustment is different from zero the t-statistic was calculated as 5.79. The statistical significance of the Monday bidding adjustment suggests it is different from zero.

In the 8/85 through 8/90 time period, the Monday and Tuesday average bidding adjustments are .008 and .007 respectively. The only portion of Cammack's bidding adjustment data similar to this study is in the 1/76 to 1/79 subperiod (Fed targeting interest rates) during which time both the Monday bidding adjustment and Tuesday bidding adjustment had averages of .004. The next closest bidding adjustment averages from Cammack's data are in the 10/82 to 12/84 subperiod when the Fed again was targeting interest rates.

The standard deviations of the bidding adjustments for this study are also compared to those from Cammack's data. The standard deviation of the Monday bidding adjustment is significantly less than the standard deviation of the Tuesday bidding adjustment. The difference in Cammack's data is even greater with the standard deviation for Monday's bidding adjustment being half as much as Tuesday's. Cammack suggests this is because Monday's secondary market price is observed at 3:00 p.m. which is approximately the same time as the Monday auction bid price is observed at 1:00 p.m. The Tuesday secondary market, as a result, has much more time to incorporate additional information. The difference in the current data and Cammack's data is the variables have about half as much variance during 8/85 to 8/90.

Table X shows the descriptive statistics for the auction variables for Models II, III and IV. The average low tail (P_A - low) during the time from August 1985 to August 1990 is .003 compared to .009 during Cammack's time frame (1/73 to 12/84). The average total tail spread (High-Low) is .012 for the 8/85 to 8/90 data, which is less than half the average tail spread during Cammack's time frame. The means of the other variables are similar. The standard deviations for the variables measuring the number of bidders (C and NC) are much less than Cammack's, while the standard deviation for low tail is slightly more.

TABLE X

DATA DESCRIPTION FOR MEANS, STANDARD

DEVIATIONS, AND AUTOCORRELATIONS

OF THE AUCTION VARIABLES

	MEAN	Std DEV	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9	ρ_{10}	$SE_{\rho_{10}}$	Q(10)
PA-Low	0.00343	.01517	.007	.015	-.011	-.002	-.012	.008	.01	.01	-.024	-.006	.067	.314
Hi-Lo	.01175	.01691	.032	.049	-.018	.019	-.043	.020	.09	.019	-.061	-.011	.067	4.112
LOTAIL	-5.36483	4.68136	.015	.116	-.022	.001	.085	-.111	-.046	-.006	.128	.140*	.066	16.65
C	4.15703	0.74507	.339*	.283*	.195*	.220*	.096	.137*	.116	.123	.120	.131	.066	85.75**
NC	16.16224	2.74965	.396*	.273*	.304*	.251*	.219*	.242*	.176*	.129	.129	.189*	.066	137.6**

Notes: Q (10) is the Box-Pierce Statistic for 10 Lags.

* greater than two standard errors

** greater than $X^2(10)\ 95 = 18.3$

PA-Low = average auction price - low auction price

Hi-Lo = highest auction price accepted - lowest auction price accepted

LOTAIL = ln(PA-Low)

C = fraction of competitive bids submitted to competitive bids accepted

NC = fraction of noncompetitive bids to total bids accepted

Table XI shows the correlations of the bidding adjustment variables (MONBA and TUESBA) and the auction variables. The first section of the table shows correlations using the actual auction variables. For this study's data, all of the correlations of the actual auction variables with the bidding adjustment variables had the same sign for both Monday and Tuesday. For most of the variables in each subperiod of Cammack's data, the signs of the correlations of the Monday bidding adjustment with the actual auction variables were opposite the signs of the correlations of the Tuesday bidding adjustment with the actual auction variables. Cammack notes the expected scenario would be correlations with the same sign since both bidding adjustments are examining similar relationships. This expected relationship was found with the current data.

The second section of Table XI presents the correlations of the bidding adjustment variables (MONBA and TUESBA) with the expected components of the auction results (ELOTAIL, EC, ENC). The expected component correlations have opposite signs for the Monday bidding adjustments versus the Tuesday bidding adjustments whereas with Cammack's data the signs are more similar. Since both Monday and Tuesday bidding adjustments are measuring similar relationships, the correlations should carry similar signs. Cammack states that the similar signs found with the expected components indicate "the time-series models are

TABLE XI

CORRELATIONS OF BIDDING ADJUSTMENTS

AND ACTUAL AUCTION VARIABLES

	MONBA	TUESBA	LOTAIL	C	NC
MONBA	1				
TUESBA	0.416499	1			
LOTAIL	-0.00141	-0.01694	1		
C	0.000764	0.106302	-0.37070	1	
NC	0.001153	0.030722	-0.04781	0.137459	1

CORRELATIONS OF BIDDING ADJUSTMENTS AND

EXPECTED COMPONENTS OF

AUCTION VARIABLES

	MONBA	TUESBA	ELOTAIL	EC	ENC
ELOTAIL	0.017630	-0.04884	1		
EC	-0.05174	0.057103	-0.14320	1	
ENC	0.020996	-0.01859	0.035984	0.045932	1

CORRELATIONS OF BIDDING ADJUSTMENTS AND

UNEXPECTED COMPONENTS OF

AUCTION VARIABLES

	MONBA	TUESBA	ULOTAIL	UC	UNC
ULOTAIL	-0.02803	0.021734	1		
UC	0.102144	0.061387	-0.21758	1	
UNC	0.014654	0.046235	-0.05325	0.181366	1

successful in extracting the expected portion of the actual value" (p. 118). Since the current data has opposite signs on the correlations, the time series models in this study may not be as successful as Cammack's in extracting the expected portion of the auction variables or the relationship has changed.

The correlations for the bidding adjustment variables (MONBA and TUESBA) with the auction variables' unexpected components (ULOTAIL, UC, UNC) are presented in the last section of Table XI. The correlations for the Monday bidding adjustment versus the Tuesday bidding adjustment are the same sign except, for the tail component. This is in contrast to Cammack who found opposite signs for the bidding adjustment correlations with the unexpected portions of the auction variables for Monday versus Tuesday. The noncompetitive measure has the same sign for the correlations of both the expected and unexpected components with the Monday bidding adjustment. Cammack reasoned this relationship would indicate there must be some information about the auction which is not included in the expected component of the noncompetitive measure. For the correlations of the low tail unexpected component with Monday's and Tuesday's bidding adjustments, the opposite signs indicate there is some unexpected information from the auction concerning the tail which is being disbursed to the secondary market.

For the estimation of Model II examining the expected components of the auction variables (ELOTAIL, EC, ENC) as determinants of Monday's bidding adjustment (MONBA), the results are presented in Table XII. There are no statistically significant parameters in the estimation of Model II. Cammack had found the expected component of the low tail produced statistically significant results for the Model II regressions. Using the current data, the null hypothesis cannot be rejected for any of the auction variables. This suggests that none of the auction variables are significant in explaining the Monday bidding adjustment.

Table XIII presents the regression results for Model III, which tests whether the unexpected components of the auction results (ULOTAIL, UC, UNC) are determinants of Tuesday's secondary market return (TUESRET). The results indicate the unexpected portion of the number of noncompetitive bidders (UNC) is statistically significant. This leads to rejection of the null hypothesis suggesting that the unexpected number of noncompetitive bidders (UNC) does not explain the Tuesday secondary market returns. The unexpected portion of the low tail (ULOTAIL) and competitive bidders (UC) variables are not significant. In contrast to Cammack's results, Cammack finds all three independent variables are statistically significant pieces of information which determine Tuesday secondary market

TABLE XII

REGRESSIONS OF MONDAY BIDDING ADJUSTMENT

ON ELOTAIL, ENC, AND EC:

Model II

	α	β
$MONBA_t = \alpha + \beta ELOTAIL_t + \epsilon_t$		
Coefficient	.00544	0.000049
t-statistic	3.4519	0.229173
SE	(.001576)	(.0002158)
R^2	.000252	
Durbin-Watson	1.86	
SE Regression	.014008	
$MONBA_t = \alpha + \beta EC_t + \epsilon_t$		
Coefficient	.010984	-.0013894
t-statistic	1.4001	-.74876
SE	(.0078451)	(.0018557)
R^2	.002688	
Durbin-Watson	1.8565	
SE Regression	.013991	
$MONBA_t = \alpha + \beta ENC_t + \epsilon_t$		
Coefficient	.0038209	8.222E-05
t-statistic	.503056	.1770598
SE	(.0075953)	(.0004643)
R^2	.000151	
Durbin-Watson	1.865423	
SE regression	.014009	

n = 210
MONBA: Monday's bidding adjustment
ELOTAIL: expected portion of the low tail
EC: expected portion of the fraction of competitive bids placed to competitive bids accepted
ENC: expected portion of the fraction of noncompetitive bids placed to total bids accepted

TABLE XIII

REGRESSIONS OF TUESDAY RETURN ON

ULOTAIL, UC, AND UNC:

Model III

$TUESRET_t = \alpha + \beta\ ULOTAIL_t + \epsilon_t$

	α	β
Coefficient	.015866	-.0001902
t-statistic	6.952379	-.5381232
SE	(.0022821)	(.0003535)
R^2	.001315	
Durbin-Watson	1.808644	

$TUESRET_t = \alpha + \beta UC_t + \epsilon_t$

	α	β
Coefficient	.01588	.0045875
t-statistic	7.009	1.6267
SE	(.00227)	(.002862)
R^2	.011541	
Durbin-Watson	1.817144	

$TUESRET_t = \alpha + \beta UNC_t + \epsilon_t$

	α	β
Coefficient	.0159535	.0022306
t-statistic	7.117548	2.7610941*
SE	(.0022414)	(.0008079)
R^2	.033492	
SE regression	.033385	
Durbin-Watson	1.8217	

* = significant at 1 percent level
n = 222
TUESRET: Tuesday secondary market return
ULOTAIL: unexpected portion of the low tail
UC: unexpected portion of the fraction of competitive bids placed to competitive bids accepted
UNC: unexpected portion of the fraction of noncompetitive bids placed to total bids accepted

returns. The coefficient on the unexpected portion of noncompetitive demand carries a positive sign which is consistent, however, with Cammack's results.

The regression results of Model IV, which included all the unexpected components of the auction variables and the price level comparison variable, are shown in Table XIV. The results of this regression are similar to Cammack's in that the price level comparison variable, A%D, is statistically significant. However, Cammack also found the unexpected tail to be statistically significant. The statistical significance of the price level comparison variable leads to rejection of the associated null hypothesis suggesting the variable is not a determinant of the Tuesday secondary market return (TUESRET).

In summary, the lack of statistically significant parameter estimates for Model II leads to a failure to reject the null hypothesis for the expected components of all three auction variables. This indicates the expected components of the auction results variables (ELOTAIL, EC, ENC) cannot explain the Monday bidding adjustment (MONBA) which occurs due to the downward biasing of the auction rate. For Model III, the null hypothesis is not rejected for the unexpected components of the low tail (ULOTAIL) and the number of competitive bidders (UC). For the unexpected portion of the fraction of noncompetitive bidders to total

TABLE XIV

REGRESSION OF TUESDAY RETURN ON A%D,

ULOTAIL, UC, AND UNC:

Model IV

$$TUESRET_t = \alpha + \beta_1 ULOTAIL_t + \beta_2 UC_t + \beta_3 UNC_t + \beta_4 A\%D_t + \epsilon_t$$

	α	β_1	β_2	β_3	β_4
Coefficient	.015846	.00018	5.63E-05	.00037	.19466
t-stat	9.76248	.77477	.02959	.65954	2.8675*
OLS Std. Error	(.00162)	(.0002)	(.0019)	(.0006)	(.0679)
R^2	.04181				
Durbin-Watson	2.098				
SE of regression	.02119				
MA(1) Std. Errors	.015844	.00023	.001907	.00057	.06798

* = significant at alpha = 1 percent
ß's estimated using OLS
n = 209
TUESRET: Tuesday secondary market return
ULOTAIL: unexpected portion of the low tail
UC: unexpected portion of the fraction of
competitive bids placed to competitive bids accepted
UNC: unexpected portion of the fraction of
noncompetitive bids placed to total bids accepted
A%D = the difference between the low auction price and Monday's secondary market price.

bids accepted (UNC), however, the null hypothesis is rejected which suggests the unexpected portion of this variable is significant in explaining Tuesday's secondary market return (TUESRET). Last, the null hypothesis for Model IV is rejected for the price level comparison variable indicating the price level variable does explain the Tuesday secondary market return but the unexpected components of the auction variables do not.

Hypothesis Five

The fifth hypothesis examines the question of whether the weekly average Treasury bill auction rate ($A_{M,Th}$) is an unbiased expectation of Thursday's Treasury bill spot rate (R_{Th}). The method of examining Model V is altered due to the nonstationarity and cointegration of Thursday's asked rate and the average auction rate. Ordinary least squares cannot be used to obtain accurate results with data of this nature. The Johansen method, however, accounts for these problems in its estimation of the parameters.

Use of the Schwarz Criterion determines one is the appropriate number of lags to use with the Johansen method. The estimated parameters from the Johansen estimation method using one lag are presented in Table XV.

Tests on the parameter estimates are conducted for the joint null hypothesis, $\beta_0 = 0$ and $\beta_1 = 1$. The results of this test yielded a chi-square value with two degrees of

freedom equal to 44.8515. The critical value at a 95% confidence level for the chi-square(2) statistic is 5.991. Therefore, the joint null hypothesis is rejected. This indicates the auction rate ($A_{M,Th}$) is a biased expectation of the Thursday secondary market rate (R_{Th}).

The significance of the slope and intercept term for Model V is also examined individually. Using the Johansen method and the individual null hypotheses $\beta_0 = 0$, the test

TABLE XV

UNRESTRICTED PARAMETER ESTIMATES FOR THE JOHANSEN METHOD COINTEGRATION VECTOR

Model V

	INTERCEPT	AVERAGE AUCTION RATE
THURSDAY ASKED RATE	-.154	1.01

statistic chi-square(1) = 8.4922 was obtained. This indicates the null hypothesis is rejected at a 95% confidence level. The statistical significance of the intercept term, therefore, suggests it is different from

zero. With the null hypothesis being $\beta_1 = 1$, the resulting test statistic under the Johansen method is chi-square(1) = 3.5331. This indicates the slope term is not significantly different from one. Based on these results, the average auction rate ($A_{M,Th}$) is a biased estimate of Thursday's secondary market asked rate (R_{Th}) even though the slope term is not significantly different from one.

Hypothesis Six

The last null hypothesis suggests the auction results variables and the change in the Federal funds rate are not significant in explaining the change in the secondary market bid-asked spread. The results of the Model VI regressions to examine this hypothesis are presented in Table XVI. The Durbin-Watson test is also conducted for each of these regressions and no significant autocorrelation is found.

Although individually the parameter estimate for the percent competitive (PCOMP) is statistically significant for the Monday to Tuesday data and the Tuesday to Wednesday data, none of the F-tests call for rejection of the null hypothesis which jointly tests all of the independent variables. The auction results variables and the change in the Federal funds rate, therefore, are not significant in explaining the change in the secondary market bid-asked spread (CHSPR).

TABLE XVI

REGRESSION RESULTS EXAMINING

DETERMINANTS OF THE CHANGE

IN THE SECONDARY MARKET

BID-ASKED SPREAD:

Model VI

Bid-Asked Spread Change from:	CONSTANT	POVER	PCOMP	TAILSPR	CHFF	R^2	F-stat	d-stat
Friday-Monday	.005 (.026)	.002 (1.734)	-.002 (-.895)	.046 (.582)	.006 (.645)	.018	.948	1.791
Monday-Tuesday	-.942 (-1.957)	-.002 (-.477)	.013 (2.528)*	-.043 (-.194)	0 (.015)	.03	1.659	1.992
Tuesday-Wednesday	1.015 (2.374)*	-.001 (-.432)	-.011 (-2.462)*	.028 (.135)	.001 (.183)	.025	1.610	2.001
Wednesday-Thursday	-.047 (-.733)	0 (.275)	0 (.658)	.005 (.184)	0 (.08)	.003	0.546	2.012
Thursday-Friday	-.002 (-.035)	0 (.359)	0 (-.659)	-.005 (-.184)	.003 (.719)	.004	.216	2.019

* = Significant 95 percent confidence level.

Note: Numbers in parentheses below the coefficients are t-values

POVER = number of competitive bids not accepted/total number of bid submitted

PCOMP = number of competitive bids accepted/total number of accepted bids

TAILSPR = difference between the high and low auction discount rates

CHFF = the change in the Federal funds rate

CHAPTER V

CONCLUSIONS

Introduction

Chapter V provides a summary of the results. Using econometric techniques, six models are examined. The first model was used to question semi-strong form market efficiency in the Treasury bill secondary market with respect to auction results and the change in the Federal funds rate. Models II through IV are included to examine the determinants of the bidding adjustment and secondary market return caused by the downward biasing of auction prices. Next, Model V assumes auction rates are not downward biased and are instead unbiased expectations of Thursday's secondary market spot rate when the new bills are issued. Last, auction results and the change in the Federal funds rate are examined as determinants of the secondary market bid-asked spread using Model VI.

The chapter is presented in the following manner. The discussion of the results from the tests of hypotheses for models one through six is presented first. The analysis is broken down into four groups: Hypothesis One, Hypotheses Two through Four (Cammack Simulation), Hypothesis Five, and

Hypothesis Six. The remainder of the chapter discusses the implications of this work for the field of finance and the future potential studies related to this work.

Discussion of the Results

Hypothesis One

Three of the Model I regression results, support the null hypothesis of secondary market efficiency. The regressions which support secondary market efficiency are the Friday to Monday, Monday to Tuesday and Tuesday to Wednesday regressions. The F-statistic for each of these regressions suggests the set of independent variables does not explain the change in the asked rates (CHASK). This is consistent with the null hypothesis of the asked rate having no relationship with percent overbid (POVER), percent of competitive bids accepted (PCOMP), tail spread (TAILSPR), and change in Federal funds rate (CHFF). This indicates participation in the Treasury bill secondary market is participation in a fair game.

The release of the information regarding the auction results does not occur until near 5:00 p.m. Eastern time through a recording on an 800 number at the U.S. Treasury Department. It is up to individuals to call the 800 number to receive the auction information on Monday, and the major Treasury bill secondary market trading has ended for Monday by the time the auction information is available. This does

not give Monday's secondary market the opportunity to react to information prior to the secondary market results being reported. Due to this, it is feasible there would not be a statistically significant relationship between the auction results variables and the change in the asked rate for the Friday to Monday data.

The complete auction results are published on Tuesday morning, so any reaction by the Treasury bill secondary market to the auction results would likely occur on Tuesday. The F-statistic, however, did not call for rejecting the null hypothesis for the Monday to Tuesday data. This again is consistent with a semi-strong efficient secondary market with respect to the auction results variables and the change in Federal funds rate. From the Model I regression using the Tuesday to Wednesday data, the F-statistic also did not lead to rejection of semi-strong efficiency.

The Wednesday to Thursday data has a significant F-test statistic. The coefficients for percent competitive (PCOMP), tail spread (TAILSPR), and change in Federal funds rate (CHFF) all were statistically significant from the Model I regression. At the 95 percent confidence level the F-statistic called for rejection of the null hypothesis which jointly tested that all the estimated parameters are zero. This suggests the Treasury bill secondary market is inefficient in anticipating all the information in the auction results variables and change in Federal funds rate.

One possible explanation for this is the secondary market is reacting to auction results on Thursday when the auctioned bills are actually distributed and possibly begin trading in the secondary market.

All the statistically significant auction results variables for the Wednesday to Thursday time period carry negative signs. This indicates the asked rate will decrease (price increase) from Wednesday to Thursday as the percent competitive (PCOMP), tail spread (TAILSPR), and change in the Federal funds rate (CHFF) increase. The signs on these variables are all opposite of a priori expectations, and the significant results are also further from the time of the auction than was expected.

The negative sign for the percent competitive (PCOMP) may be a result of a reversal effect. A larger percent competitive in the auction may allow dealers to increase the asked rate (decrease prices) near the time of the auction since more of the informed bidders won bills in the auction. Near the auction's close, dealers may not see demand in the secondary market from these bidders. This reduces dealer's demand and risk of trading with informed traders which allows dealers to increase their asked rates. By Thursday, dealers may reduce their asked rates to reverse the asked rate changes they made near the time of the auction.

The negative sign on tail spread (TAILSPR) may be explained by considering what the tail spread indicates. A

larger tail spread would mean lower prices were accepted in the auction in order to sell all available bills. Since the Treasury auction accepted lower prices in the auction, dealers may have to accept lower prices in the secondary market during the days near the auction. From Wednesday to Thursday, the dealers may believe prices in the secondary market are similar enough to auction prices that the dealers can increase their prices again.

The change in the Federal funds rate (CHFF) also has a negative sign for the Wednesday to Thursday period. The variable's significance can be explained by the Thursday announcement of changes in Fed policy. If policy changes result in the Fed funds rate increasing from Wednesday to Thursday, Treasury bill dealers may find it necessary to increase prices in the secondary market to keep aligned with the Fed funds rate.

The F-test is statistically significant in the Thursday to Friday regression. The null hypothesis suggesting the auction results variables and the change in the Federal funds rate jointly affect the change in the asked rate, therefore, is rejected. On Thursday the auctioned bills are available to be traded in the secondary market, so the individuals who did not place winning bids in the auction can now purchase those same Treasury bills in the secondary market. These results also indicate the Treasury bill secondary market is not semi-strong efficient with respect

to the information carried in the auction results and the change in the Federal funds rate.

The estimated parameter for the percent overbid (POVER) is statistically significant and positive in the Thursday to Friday regression. This indicates as more competitive bidders are unsuccessful in winning bills in the auction, the asked discount rate is increased from Thursday to Friday (prices decreased). The competitive bidders who do not fulfill their demand for bills in the auction may seek to buy similar bills in the post-auction secondary market. With this increased demand in the secondary market, dealers keep their asked discount rates lower. When secondary market dealers take possession of the auctioned bills on Thursday, their supply of 91 day bills is increased. The dealers can then increase their asked rates in the secondary market. A higher percent overbid, therefore, results in an increase in the secondary market asked rate from Thursday to Friday.

The F-statistics led to the rejection of the joint null hypothesis for the Wednesday to Thursday data and the Thursday to Friday data. This means the Treasury bill secondary market cannot be considered efficient with respect to the independent variable set. For these relationships, a fair game is not evidenced in the results. It had been anticipated the null hypothesis for the Friday to Monday data, Monday to Tuesday data, or Tuesday to Wednesday data

would be more likely to be rejected, than for the Wednesday to Thursday data or the Thursday to Friday data. The secondary market, however, seems to react to the auction results around Thursday when the bills are actually issued.

Although the F-tests call for rejection of the null and suggest the Treasury bill secondary market is not semi-strong efficient, all of the regressions had low R-squareds (2.4 percent to 7.7 percent). This means the model has low explanatory power for the variations in the change in the asked rate, and the regression line is considered a poor fit (Pindyck and Rubinfeld, 1981). This is not unusual, since Model I was developed based on a martingale process. A martingale is expected to exist in an efficient Treasury bill secondary market (Glosten and Milgrom, 1985), and therefore the auction variables in Model I have difficulty explaining the change in the asked rates. Due to a lack of fit, the model would not be economically valid as a predictive model for use in trading Treasury bills.

Although this study uses different forms of the auction information variables and different models, the results obtained were consistent with those of Wachtel and Young (1990) in that a slight degree of semi-strong secondary market inefficiency was found with regard to the auction results information set. Wachtel and Young, however, had much larger R^2's indicating economical significance of their results.

One explanation for the decreased explanatory power of the auction information variables in the current study as compared to the Wachtel and Young (1990) study is found in Boatler (1985). In a study ten years after an initial study, Boatler concludes the cause of the change in explanatory power a variable related to the tail spread is due to market participants gaining experience in coping with price instability. This may be the case for the lack of explanatory power of the auction variables in the current study compared to Wachtel and Young's results. It may be over time the secondary market has learned to cope with the weekly price changes from the auction market. The market, consequently, has reduced the reaction to unexpected information carried in the auction results and further increased the efficiency of the secondary market.

Another relevant cause of the differences in results may be the different time periods studied. The supply and demand for Treasury bills has continued to increase over time. Market efficiency in incorporating all information into prices usually increases as trading volume increases. Using more recent data than Wachtel and Young, which involves increased supply and demand conditions, may show increased market efficiency. Also Wachtel and Young examined a more volatile time period.

Hypotheses Two, Three, and Four

The conclusions from the simulation of Cammack's (1991) study in some cases are contrary to Cammack's results. Cammack notes downward biasing of the auction rate is evident by an examination of the data. During the time frame August 1985 through August 1990, the data for this study finds downward biasing occurs but by only 1.6 to 2 basis points. The auction rate was approximately four basis points less than rates on similar bills in the secondary market during 1973 through 1984. The downward biasing which causes the bidding adjustment during August 1985 through August 1990 is statistically significant. Model II is used to further examine this relationship.

Using Model II to examine whether the secondary market bidding adjustment (MONBA) caused by the downward biased auction rates is explained by the expected portion of the auction results (ELOTAIL, EC, ENC), there are no statistically significant results. With no statistically significant results, the slight bidding adjustment which occurs due to downward biasing is not determined by the expected components of the auction results during August 1985 to August 1990; and no excess expected gain would be realized by traders using the auction information.

These results are consistent with Cammack's in two respects. Cammack finds the expected portion of the number of noncompetitive bidders (ENC) is not related to the

bidding adjustment (MONBA). Also, the expected portion of the ratio of competitive bids submitted to competitive bids accepted (EC) is not significant for the data sample as a whole. EC was only significant in two of Cammack's four subperiods. Cammack expected EC to have a positive relationship with the bidding adjustment, but EC carries a negative coefficient as it does in this study.

Cammack finds a strong significant positive relationship between the expected component of the tail (ELOTAIL) and Monday's bidding adjustment (MONBA) for the full sample (1973 to 1984) and three of the four subperiods. This means the greater the dispersion of opinion, the greater the expected gain due to more downward biasing. The expected component of the tail is not statistically significant in this study.

In Cammack's last subperiod (10/82 to 12/84) none of the auction variables are statistically significant. This subperiod ends only seven months prior to the beginning of this study's time frame. The results using this study's data, therefore, are all consistent with the results during Cammack's last subperiod.

For Model III questioning whether Tuesday's secondary market return (TUESRET) is explained by the unexpected components of the auction results, there was slight evidence of explanatory power. The relationship of the unexpected portion of the number of noncompetitive bidders (UNC) with

Tuesday returns had statistical significance. The unexpected component of the number of noncompetitive bidders (UNC) carried a positive relationship to the Tuesday return which is consistent with Cammack. This indicates unexpected demand from the less informed bidders in the auction market leads to higher prices in the secondary market.

The results differ from Cammack's in that Cammack also finds unexpected information concerning the dispersion of opinion (ULOTAIL) and the number of rejected bids (UC) to be statistically significant explanatory variables. Although not statistically significant in this study, the coefficients of these auction variables do have signs consistent with Cammack's.

From Model IV's regression examining whether the auction results simply convey information about the price level in the auction, the price level comparison variable (A%D) is the only statistically significant variable. Since the unexpected portion of the number of noncompetitive bidders (UNC) is no longer statistically significant as in the previous model, UNC is simply acting as a proxy for the price level in the auction.

There was a positive relationship of A%D with the Tuesday return (TUESRET) indicating information about the price level in the auction does affect Tuesday's secondary market returns. This is logical as the bills purchased in the auction market are similar to the bills being sold in

the secondary market. As a result, the prices in the two markets should be related. The overall equation, however, does not have much predictive value with an R^2 less than Cammack's.

This result is consistent with Cammack except the unexpected component of the low tail (ULOTAIL) is also significant in Cammack's results. This would indicate the low tail is conveying information to the secondary market other than simply serving as a proxy for the auction price level during Cammack's time frame.

The dissimilarities between Cammack's results and this study's results are most likely due to the time frame differences. The current study examines the August 1985 through August 1990 period, and Cammack is examining the January 1973 to December 1984 time frame.

The biggest difference in the market environment during these two time frames is the period of the late 70's through early 80's was a period of instability. Markets were much more volatile then than during the 1985 through 1990 time frame. This was evident in the comparison of the dependent and independent variable standard deviations which were much less during August 1985 through August 1990.

Another factor may be the changes in Fed targets. During Cammack's study period, the Fed changed from targeting interest rates to targeting the money supply then back to targeting interest rates. The Fed targeted interest

rates continuously during the August 1985 to August 1990 period.

Finally, two other factors may play a role in causing the discrepancies in results. First, Treasury bill futures trading was introduced during Cammack's time frame which may have had an initial unsettling impact on the Treasury bill secondary market. Second, the supply and demand for Treasury bills has continued to increase over time. This increased trading volume may have an impact on results.

The results from the last subperiod of Cammack's study provide justification for the time period differences being responsible for the discrepancies between the two studies. During the period 10/82 through 12/84, Cammack did not find any statistically significant results for Model II. This is consistent with the estimation results in this study, and the time frame difference is only seven months.

Hypothesis Five

The fifth hypothesis examines whether the weekly average Treasury bill auction rate ($A_{M,Th}$) is an unbiased expectation of Thursday's Treasury bill spot rate (R_{Th}). In examining the auction price and the price on a bill in Monday's secondary market, a slight downward biasing of the

auction prices was noted.[12] Since the auction price is downward biased, the testing of hypothesis five is relevant.

The Model V joint null hypothesis ($\beta_0 = 0$ and $\beta_1 = 1$) was rejected at a 95 percent confidence level. The statistical significance of the intercept term and slope term indicate jointly they are different from zero and one, respectively. Since the average auction rate and Thursday's asked rate differ by something other than white noise, the average auction rate is a biased estimate of Thursday's asked rate. The auction rate, therefore, does not contain all information relevant to predicting Thursday's secondary market asked rate prevailing when the bills are issued.

The estimated parameters for the slope and intercept are also tested individually. These tests indicate the slope term by itself is not significantly different from one, but the statistical significance of the intercept term suggests it is different from zero. This confirms the auction rate is a biased estimate of Thursday's secondary market asked rate, and it is the intercept term driving this conclusion.

The estimated intercept term has a negative coefficient in Model V which suggests the average auction rate ($A_{M,Th}$) is greater than Thursday's secondary market asked rate (R_{Th}). This indicates the auction price is lower than Thursday's

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[12]Monday's secondary market rate is adjusted to a 91 day rate which makes it similar to the bills issued on Thursday.

secondary market asked price. This supports the downward biasing of the auction price seen in the comparison with Monday's and Tuesday's secondary market prices.

Hypothesis Six

The auction information variables and the change in the Federal funds rate are examined as determinants of the change in the bid-asked spread in the secondary market. This is accomplished using the Model VI linear regression with the dependent variable being the change in the bid-asked spread (CHSPR).

The coefficient for the percent competitive (PCOMP) was statistically significant at the 95 percent level in explaining the change in the bid-asked spread from Monday to Tuesday and from Tuesday to Wednesday. The F-test, however, does not lead to the rejection of the null hypothesis that the set of independent variables is a determinant of the bid-asked spread for any of the combinations of days of the week.

The coefficient for the percent competitive is positive for the Monday to Tuesday change in the bid-asked spread. As the number of competitive bidders winning bills in the auction increases compared to the number of noncompetitive participants, the percent competitive increases. Dealers may feel there is more uncertainty concerning the potential to incur adverse information costs in the secondary market

from subsequent trades with the informed competitive bidders. Feeling this, dealers may be increasing their bid-asked spreads to reduce the potential losses from trades with more informed traders. The positive sign and significance of the percent competitive variable is consistent with results found by Roll (1970), Bagehot (1971), Copeland and Galai (1983), Glosten and Milgrom (1985), and Stoll (1989). This result is also consistent with the expectation that dealers alter their bid-asked spread once the results of the auction are known as evidenced by the significant number of changes in spreads from Monday to Tuesday (see Table II).

Other Conclusions

The visual inspection of the data indicates a significant number of decreases in the bid-asked spread occurring from Monday to Tuesday in the secondary market. This is consistent with Roll's (1970) findings of sharp decreases in bid-asked spreads on 13 week Treasury bills immediately following the auction and Cammack's similar finding (1991).

The decrease in the bid-asked spread is consistent with Monday's auction results announcement at the end of the day reducing uncertainty and hence dealers' risk. The Federal Reserve Bank of New York (Winter 1977-78) specifically notes the Treasury bill secondary market spreads should narrow

when uncertainty is lessened. Glosten and Milgrom (1985) suggest dealers' spreads are larger on Mondays due to uncertainty concerning Monday's auction results. The announcement of the results allows the dealers to reduce their spreads on Tuesday.

One alternative explanation stems from Stoll's (1989) discussion of bid-asked spread determinants. If it is inventory holding costs for which the dealer is compensated through the bid-asked spread, the dealers will alter their bid-asked spreads in order to encourage transactions to bring inventory levels to their optimum levels. The dealers will know to what levels their inventories of 91-day bills will be increasing once the auction results are announced. These newly auctioned bills have maturities similar to bills already available in the secondary market. Given dealers' inventories will be increasing significantly due to the purchase of bills in Monday's auction, dealers may reduce their bid-asked spreads on Tuesday. By reducing the costs of secondary market transactions to buyers, dealers will reduce inventories of bills similar to the new bills to be received. In this manner, dealers ensure their inventories will be near the optimum levels when they receive the new bills.

Another alternative explanation would be a Treasury bill secondary market anomaly in the form of a day-of-the-week effect. Studies have shown strong evidence for a

"weekend effect" in the stock markets in which the Friday-to-Monday return is negative (Bodie, Kane, and Marcus, 1993). A similar type of anomaly appears to be occurring in the Treasury bill secondary market with dealers frequently reducing their bid-asked spreads from Monday to Tuesday.

Summary and Financial Implications

Using the auction results variables, various conclusions are drawn. First, the Treasury bill secondary market is not semi-strong efficient with respect to the auction results variables (percent overbid, percent competitive, and tail spread) and the change in the Federal funds rate.

Second, downward biased auction prices are observed. Based on this the Monday bidding adjustment is examined but is not found to be determined by any of the expected components of the auction results (low tail, fraction of noncompetitive bidders, and fraction of competitive bids not accepted). The Tuesday return, however, is determined by the unexpected component of the fraction of noncompetitive bidders. This result is negated when a price level comparison variable is included in a model with the unexpected components of the auction results. This suggests Tuesday's return is just determined by the auction price level.

Next, the average auction rate is found to be a biased estimate of Thursday's secondary market rate. The auction price is less than Thursday's asked price. This supports the downward biasing observed in the comparison of the auction price with Monday and Tuesday's secondary market prices. Last, the bid-asked spread was not found to be determined by the set of auction variables (percent overbid, percent competitive, and tail spread) and the change in the Federal funds rate.

The results of this study also provide implications for the field of finance. The secondary market is found to be semi-strong inefficient with respect to the auction results variables and the change in the Federal funds rate. Although semi-strong inefficiency is found, the explanatory power of the models is very low. Due to this, the models cannot be used by market participants to earn any excess returns.

Future Work with Treasury Issues

One area of interest which has developed during the course of this study is with Treasury notes. With the Salomon Brothers illegal activities in the Treasury note auctions, the efficiency of the Treasury note auction could be examined. A study set up in a manner similar to the present study could be used. It would be interesting to determine if the market was less efficient during the time

frame of Salomon Brothers' bogus bidding in the Treasury note auction.

An extension of the current study using data from the past two years is another possibility. The Treasury bill rate has experienced drastic changes during this time period with the changes in the economy. It would be interesting to note whether there was more or less uncertainty in the market with the volatility in Treasury bill rates or if the market can better cope with volatility. This would provide a better comparison with Cammack's work.

Third, alternative explanatory variables could be considered. One possible relevant variable might be related to foreign purchases of Treasury bills. These purchases have become much more significant in recent years.

Last if intra-day data was available, market efficiency and primary dealers could be studied in more detail. There are specific times during the day, especially on Mondays, when events are occurring. It could be questioned whether primary dealers as "insiders" are able to gain excess profits.

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APPENDIXES

APPENDIX A

TAIL SPREAD DATA

DATE OF MONDAY'S AUCTION	TAIL SPREAD
07/30/90	0.02
07/23/90	0.04
07/16/90	0.04
07/09/90	0.03
07/02/90	0.01
06/25/90	0.04
06/18/90	0.02
06/11/90	0.03
06/04/90	0.01
05/28/90	0.02
05/21/90	0.02
05/14/90	0.01
05/07/90	0.03
04/30/90	0.03
04/23/90	0.03
04/16/90	0.04
04/09/90	0.03
04/02/90	0.05
03/26/90	0.05
03/19/90	0.03
03/12/90	0.02
03/05/90	0.03
02/26/90	0.05
02/19/90	0.03
02/12/90	0.04
02/05/90	0.02
01/29/90	0.02
01/22/90	0.06
01/15/90	0.07
01/08/90	0.04
01/01/90	0.02
12/25/89	0.14
12/18/89	0.07
12/11/89	0.08
12/04/89	0.10
11/27/89	0.09
11/20/89	0.06

DATE OF MONDAY'S AUCTION	TAIL SPREAD
11/13/89	0.03
11/06/89	0.04
10/30/89	0.00
10/23/89	0.07
10/16/89	0.12
10/09/89	0.06
10/02/89	0.02
09/25/89	0.05
09/18/89	0.04
09/11/89	0.03
09/04/89	0.03
08/28/89	0.02
08/21/89	0.95
08/14/89	0.02
08/07/89	0.06
07/31/89	0.01
07/24/89	0.04
07/17/89	0.00
07/10/89	0.03
07/03/89	0.07
06/26/89	0.03
06/19/89	0.04
06/12/89	0.02
06/05/89	0.02
05/29/89	0.05
05/22/89	0.04
05/15/89	0.02
05/08/89	0.04
05/01/89	0.04
04/24/89	0.05
04/17/89	0.06
04/10/89	0.02
04/03/89	0.09
03/27/89	0.06
03/20/89	0.03
03/13/89	0.05
03/06/89	0.01
02/27/89	0.06
02/20/89	0.03
02/13/89	0.02
02/06/89	0.05
01/30/89	0.05
01/23/89	0.05
01/16/89	0.03
01/09/89	0.02
01/02/89	0.03
12/26/88	0.11
12/19/88	0.05

DATE OF MONDAY'S AUCTION	TAIL SPREAD
12/12/88	0.04
12/05/88	0.02
11/28/88	0.03
11/21/88	0.02
11/14/88	0.10
11/07/88	0.05
10/31/88	0.05
10/24/88	0.05
10/17/88	0.03
10/10/88	0.06
10/03/88	0.01
09/26/88	0.06
09/19/88	0.02
09/12/88	0.02
09/05/88	0.06
08/29/88	0.07
08/22/88	0.03
08/15/88	0.04
08/08/88	0.02
08/01/88	0.04
07/25/88	0.07
07/18/88	0.02
07/11/88	0.04
07/04/88	0.01
06/27/88	0.04
06/20/88	0.04
06/13/88	0.03
06/06/88	0.03
05/30/88	0.03
05/23/88	0.01
05/16/88	0.01
05/09/88	0.05
05/02/88	0.05
04/25/88	0.04
04/18/88	0.02
04/11/88	0.03
04/04/88	0.03
03/28/88	0.06
03/21/88	0.04
03/14/88	0.03
03/07/88	0.02
02/29/88	0.03
02/22/88	0.04
02/15/88	0.06
02/08/88	0.01
02/01/88	0.03
01/25/88	0.01
01/18/88	0.03

DATE OF MONDAY'S AUCTION	TAIL SPREAD
01/11/88	0.03
01/04/88	0.07
12/28/87	0.07
12/21/87	0.06
12/14/87	0.04
12/07/87	0.15
11/30/87	0.12
11/23/87	0.04
11/16/87	0.02
11/09/87	0.04
11/02/87	0.13
10/26/87	0.15
10/19/87	0.18
10/12/87	0.12
10/05/87	0.11
09/28/87	0.06
09/21/87	0.00
09/14/87	0.06
09/07/87	0.05
08/31/87	0.04
08/24/87	0.03
08/17/87	0.05
08/10/87	0.04
08/03/87	0.03
07/27/87	0.03
07/20/87	0.00
07/13/87	0.08
07/06/87	0.03
06/29/87	0.02
06/22/87	0.03
06/15/87	0.05
06/08/87	0.03
06/01/87	0.06
05/25/87	0.08
05/18/87	0.10
05/11/87	0.08
05/04/87	0.11
04/27/87	0.07
04/20/87	0.02
04/13/87	0.07
04/06/87	0.01
03/30/87	0.04
03/23/87	0.04
03/16/87	0.03
03/09/87	0.03
03/02/87	0.04
02/23/87	0.04
02/16/87	0.02
02/09/87	0.02

DATE OF MONDAY'S AUCTION	TAIL SPREAD
02/02/87	0.01
01/26/87	0.03
01/19/87	0.01
01/12/87	0.03
01/05/87	0.03
12/29/86	0.05
12/22/86	0.06
12/15/86	0.03
12/08/86	0.07
12/01/86	0.04
11/24/86	0.04
11/17/86	0.03
11/10/86	0.04
11/03/86	0.06
10/27/86	0.02
10/20/86	0.02
10/13/86	0.05
10/06/86	0.06
09/29/86	0.02
09/22/86	0.04
09/15/86	0.02
09/08/86	0.04
09/01/86	0.01
08/25/86	0.03
08/18/86	0.04
08/11/86	0.06
08/04/86	0.01
07/28/86	0.06
07/21/86	0.02
07/14/86	0.04
07/07/86	0.02
06/30/86	0.04
06/23/86	0.03
06/16/86	0.05
06/09/86	0.06
06/02/86	0.04
05/26/86	0.04
05/19/86	0.06
05/12/86	0.02
05/05/86	0.02
04/28/86	0.04
04/21/86	0.03
04/14/86	0.02
04/07/86	0.04
03/31/86	0.04
03/24/86	0.05
03/17/86	0.04
03/10/86	0.01
03/03/86	0.00

DATE OF MONDAY'S AUCTION	TAIL SPREAD
02/24/86	0.10
02/17/86	0.03
02/10/86	0.01
02/03/86	0.05
01/27/86	0.02
01/20/86	0.04
01/13/86	0.05
01/06/86	0.04
12/30/85	0.07
12/23/85	0.07
12/16/85	0.09
12/09/85	0.02
12/02/85	0.04
11/25/85	0.05
11/18/85	0.01
11/11/85	0.04
11/04/85	0.07
10/28/85	0.04
10/21/85	0.03
10/14/85	0.03
10/07/85	0.04
09/30/85	0.02
09/23/85	0.14
09/16/85	0.04
09/09/85	0.05
09/02/85	0.05
08/26/85	0.03
08/19/85	0.05
08/12/85	0.03
08/05/85	0.01
07/29/85	0.02

APPENDIX B

BID RATES, ASK RATES, AND BID-ASK SPREADS DATA

Appendix B-1: Bid Rates from the Secondary Market

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
07/30/90	7.49	7.49	7.42	7.43	NA
07/23/90	7.49	7.53	7.56	7.58	7.52
07/16/90	7.62	7.61	7.55	7.54	7.54
07/09/90	7.81	7.80	7.78	7.68	7.60
07/02/90	7.73	7.70	NA	7.66	7.75
06/25/90	7.76	7.81	7.79	7.75	7.75
06/18/90	7.71	7.75	7.77	7.78	7.79
06/11/90	7.74	7.74	7.68	7.68	7.70
06/04/90	7.71	7.71	7.70	7.72	7.72
05/28/90	7.75	7.79	7.77	7.77	7.70
05/21/90	7.77	7.74	7.66	7.70	7.72
05/14/90	7.68	7.66	7.67	7.68	7.75
05/07/90	7.79	7.80	7.75	7.72	7.63
04/30/90	7.88	7.93	7.90	7.87	7.77
04/23/90	7.77	7.77	7.80	7.87	7.80
04/16/90	7.71	7.78	7.81	7.78	7.70
04/09/90	7.79	7.78	7.77	7.76	NA
04/02/90	7.85	7.83	7.76	7.77	7.77
03/26/90	7.84	7.97	7.85	7.89	NA
03/19/90	7.97	7.97	7.91	7.92	7.89
03/12/90	7.97	7.99	7.95	7.95	7.92
03/05/90	7.89	7.90	7.91	7.93	7.98
02/26/90	7.72	7.73	7.78	7.81	7.76
02/19/90	NA	7.79	7.79	7.73	7.68
02/12/90	7.70	7.59	7.62	7.71	7.70
02/05/90	7.83	7.81	7.82	7.82	7.81
01/29/90	7.77	7.76	7.76	7.77	7.81
01/22/90	7.67	7.68	7.68	7.70	7.70
01/15/90	7.59	7.72	7.70	7.80	7.75
01/08/90	7.54	7.56	7.52	7.58	7.50

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
01/01/90	NA	7.63	7.64	7.60	7.56
12/25/89	NA	7.53	7.74	7.70	7.56
12/18/89	7.64	7.67	7.57	7.57	7.60
12/11/89	7.63	7.69	7.63	7.65	7.63
12/04/89	7.50	7.58	7.67	7.71	7.62
11/27/89	7.61	7.66	7.66	7.61	7.54
11/20/89	7.62	7.66	7.59	NA	7.54
11/13/89	7.69	7.70	7.63	7.58	7.69
11/06/89	7.81	7.76	7.68	7.74	7.72
10/30/89	7.77	7.79	7.73	7.69	7.84
10/23/89	7.53	7.50	7.54	7.56	7.71
10/16/89	7.42	7.43	7.45	7.52	7.56
10/09/89	7.66	7.65	7.81	7.71	7.07
10/02/89	7.85	7.79	7.82	7.79	7.58
09/25/89	7.72	7.78	7.84	7.86	7.93
09/18/89	7.57	7.68	7.80	7.74	7.78
09/11/89	7.66	7.62	7.58	7.59	7.55
09/04/89	7.84	7.86	7.82	7.78	7.77
08/28/89	7.88	7.91	7.83	7.85	NA
08/21/89	7.98	8.07	8.01	7.90	7.97
08/14/89	8.08	8.03	7.94	7.95	7.88
08/07/89	7.95	7.93	7.91	7.85	7.96
07/31/89	7.69	7.69	7.55	7.61	7.88
07/24/89	8.10	8.02	7.92	7.80	7.87
07/17/89	7.92	7.94	7.98	8.00	8.13
07/10/89	7.77	7.75	7.74	7.75	7.85
07/03/89	NA	7.94	7.77	7.75	7.74
06/26/89	8.14	NA	8.03	7.94	7.99
06/19/89	8.21	8.17	8.24	8.23	8.07
06/12/89	8.16	8.13	8.13	8.16	8.15
06/05/89	8.16	8.19	8.11	8.09	8.21
05/29/89	NA	8.54	8.56	8.52	8.37
05/22/89	8.34	8.29	8.37	8.52	8.53
05/15/89	8.18	8.24	8.28	8.40	8.38
05/08/89	8.43	8.54	8.54	8.36	8.23
05/01/89	8.65	8.58	8.44	8.47	8.46
04/24/89	8.65	8.64	8.52	8.42	8.44
04/17/89	8.57	8.45	8.42	8.63	8.66
04/10/89	8.67	8.68	8.69	8.74	8.61
04/03/89	8.86	8.78	8.83	8.76	8.81
03/27/89	9.07	9.08	8.97	8.95	8.88
03/20/89	9.08	9.10	9.01	9.05	NA
03/13/89	8.68	8.72	8.69	8.71	8.86
03/06/89	8.65	8.64	8.63	8.69	8.76
02/27/89	8.70	8.72	8.66	8.67	8.65
02/20/89	NA	8.49	8.54	8.63	8.66

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
02/13/89	8.53	8.56	8.50	8.50	8.51
02/06/89	8.57	8.55	8.54	8.49	8.56
01/30/89	8.29	8.39	8.35	8.39	8.49
01/23/89	8.24	8.23	8.30	8.35	8.34
01/16/89	8.27	8.30	8.27	8.24	8.25
01/09/89	8.34	8.31	8.26	8.28	8.21
01/02/89	NA	8.23	8.25	8.29	8.30
12/26/88	NA	8.13	8.24	8.12	8.11
12/19/88	8.11	8.18	8.08	8.05	8.05
12/12/88	8.01	8.12	8.11	8.20	8.17
12/05/88	8.02	7.95	8.00	7.97	7.90
11/28/88	8.06	7.99	7.83	7.86	8.07
11/21/88	7.98	8.03	8.02	NA	8.05
11/14/88	7.83	7.96	7.94	7.93	7.96
11/07/88	7.51	7.60	7.59	7.66	7.66
10/31/88	7.38	7.36	7.38	7.43	7.48
10/24/88	7.51	7.46	7.42	7.40	7.40
10/17/88	7.35	7.39	7.43	7.46	7.46
10/10/88	7.28	7.28	7.29	7.34	7.34
10/03/88	7.24	7.25	7.24	7.32	7.30
09/26/88	7.31	7.33	7.32	7.31	7.29
09/19/88	7.22	7.21	7.19	7.22	7.24
09/12/88	7.21	7.18	7.17	7.19	7.16
09/05/88	NA	7.27	7.35	7.33	7.30
08/29/88	7.26	7.31	7.29	7.30	7.23
08/22/88	7.19	7.18	7.20	7.28	7.35
08/15/88	7.01	7.07	7.04	7.01	7.07
08/08/88	6.95	7.07	6.99	7.02	7.03
08/01/88	6.86	6.91	6.91	6.85	6.93
07/25/88	6.87	6.92	7.01	7.00	6.95
07/18/88	6.73	6.69	6.72	6.78	6.76
07/11/88	6.68	6.76	6.74	6.74	6.73
07/04/88	NA	6.55	6.54	6.56	6.67
06/27/88	6.55	6.62	6.60	6.56	6.56
06/20/88	6.47	6.58	6.53	6.53	6.51
06/13/88	6.47	6.36	6.35	6.30	6.39
06/06/88	6.48	6.44	6.41	6.45	6.46
05/30/88	NA	6.55	6.47	6.46	6.47
05/23/88	6.34	6.30	6.33	6.44	6.45
05/16/88	6.26	6.31	6.23	6.16	6.28
05/09/88	6.32	6.36	6.27	6.22	6.20
05/02/88	6.12	6.13	6.16	6.20	6.31
04/25/88	5.90	5.91	5.87	5.99	6.00
04/18/88	5.84	5.81	5.84	5.84	5.84
04/11/88	6.01	5.94	5.86	5.70	5.90

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
04/04/88	5.92	6.01	6.05	6.05	6.02
03/28/88	5.76	5.76	5.74	5.71	NA
03/21/88	5.79	5.79	5.84	5.82	5.69
03/14/88	5.64	5.62	5.64	5.61	5.72
03/07/88	5.78	5.75	5.75	5.74	5.75
02/29/88	NA	5.63	5.61	5.61	5.71
02/22/88	5.65	5.64	5.64	5.65	5.60
02/15/88	NA	5.73	5.75	5.70	5.67
02/08/88	5.67	5.61	5.61	5.65	5.76
02/01/88	5.69	5.71	5.69	5.66	5.66
01/25/88	5.83	5.81	5.75	5.68	5.65
01/18/88	5.90	5.98	5.82	5.84	5.81
01/11/88	5.88	5.82	5.80	5.84	5.88
01/04/88	5.89	5.94	5.85	5.79	5.81
12/28/87	5.58	5.83	NA	NA	NA
12/21/87	5.92	8.91	5.78	5.75	NA
12/14/87	5.97	5.95	5.95	5.95	5.89
12/07/87	5.86	5.88	5.86	5.92	5.90
11/30/87	5.40	5.59	5.46	5.37	5.48
11/23/87	5.78	5.74	5.70	NA	5.66
11/16/87	5.98	5.89	5.81	5.67	5.72
11/09/87	5.70	5.69	5.64	5.82	5.93
11/02/87	5.72	5.65	5.58	5.62	5.76
10/26/87	5.17	5.25	5.04	5.05	5.30
10/19/87	6.65	5.91	5.59	5.31	5.31
10/12/87	6.96	6.96	7.19	7.08	6.91
10/05/87	6.50	6.56	6.56	6.69	6.72
09/28/87	6.61	6.69	6.62	6.64	6.69
09/21/87	6.51	6.58	6.59	6.63	6.64
09/14/87	6.37	6.32	6.33	6.38	6.44
09/07/87	NA	6.41	6.44	6.34	6.36
08/31/87	6.20	6.13	6.09	6.20	6.39
08/24/87	6.18	6.21	6.26	6.28	6.24
08/17/87	5.99	6.02	6.08	6.11	6.10
08/10/87	5.93	5.93	5.95	5.96	5.96
08/03/87	5.95	5.85	5.86	5.74	5.85
07/27/87	5.93	6.03	6.06	6.08	6.07
07/20/87	5.51	5.64	5.66	5.62	5.93
07/13/87	5.60	5.55	5.58	5.58	5.56
07/06/87	5.60	5.60	5.57	5.61	5.61
06/29/87	5.78	5.65	5.73	5.66	NA
06/22/87	5.65	5.72	5.83	5.84	5.78
06/15/87	5.67	5.63	5.65	5.65	5.65
06/08/87	5.58	5.51	5.48	5.54	5.58
06/01/87	5.83	5.76	5.69	5.66	5.59

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
05/25/87	NA	5.70	5.76	5.85	5.81
05/18/87	5.92	5.78	5.69	5.53	5.62
05/11/87	5.59	5.60	5.53	5.72	6.01
05/04/87	5.78	5.81	5.50	5.53	5.48
04/27/87	5.78	5.82	5.71	5.53	5.67
04/20/87	5.68	5.50	5.42	5.49	5.76
04/13/87	5.99	5.92	5.68	5.56	NA
04/06/87	5.53	5.51	5.50	5.75	5.85
03/30/87	5.71	5.61	5.54	5.51	5.56
03/23/87	5.58	5.61	5.57	5.57	5.68
03/16/87	5.59	5.57	5.52	5.50	5.50
03/09/87	5.66	5.68	5.69	5.67	5.62
03/02/87	5.48	5.54	5.51	5.52	5.64
02/23/87	5.43	5.44	5.45	5.45	5.45
02/16/87	NA	5.68	5.60	5.45	5.43
02/09/87	5.74	5.82	5.86	5.72	5.65
02/02/87	5.60	5.59	5.63	5.59	5.66
01/26/87	5.46	5.49	5.47	5.48	5.60
01/19/87	NA	5.25	5.31	5.38	5.40
01/12/87	5.39	5.36	5.35	5.36	5.33
01/05/87	5.54	5.34	5.48	5.43	5.38
12/29/86	5.65	5.69	5.67	NA	5.49
12/22/86	5.49	5.55	5.57	NA	5.57
12/15/86	5.56	5.58	5.64	5.60	5.51
12/08/86	5.49	5.48	5.49	5.49	5.49
12/01/86	5.40	5.41	5.41	5.40	5.44
11/24/86	5.35	5.39	5.39	NA	5.39
11/17/86	5.40	5.35	5.33	5.38	5.36
11/10/86	5.40	5.40	5.40	5.40	5.40
11/03/86	5.22	5.25	5.26	5.26	5.32
10/27/86	5.18	5.20	5.20	5.18	5.20
10/20/86	5.30	5.31	5.30	5.26	5.27
10/13/86	NA	5.13	5.18	5.20	5.27
10/06/86	5.12	5.06	5.04	5.06	5.06
09/29/86	5.19	5.20	5.19	5.19	5.09
09/22/86	5.24	5.25	5.24	5.23	5.24
09/15/86	5.17	5.13	5.12	5.23	5.25
09/08/86	5.24	5.20	5.16	5.21	5.17
09/01/86	NA	5.14	5.24	5.19	5.23
08/25/86	5.35	5.29	5.32	5.29	5.17
08/18/86	5.62	5.57	5.50	5.37	5.36
08/11/86	5.64	5.61	5.57	5.59	5.56
08/04/86	5.72	5.72	5.72	5.72	5.70
07/28/86	5.87	5.86	5.85	5.79	5.77
07/21/86	5.70	5.73	5.81	5.81	5.81

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
07/14/86	5.78	5.77	5.77	5.75	5.71
07/07/86	5.85	5.94	5.88	5.85	5.75
06/30/86	5.99	5.99	6.00	5.91	NA
06/23/86	6.07	6.08	6.08	6.08	6.02
06/16/86	6.11	6.09	6.09	6.11	6.10
06/09/86	6.33	6.28	6.34	6.28	6.17
06/02/86	6.36	6.41	6.52	6.51	6.32
05/26/86	NA	6.16	6.19	6.30	6.30
05/19/86	6.22	6.22	6.20	6.20	6.18
05/12/86	6.09	6.09	6.09	6.17	6.21
05/05/86	6.06	6.05	6.04	6.04	6.05
04/28/86	6.07	6.09	6.10	6.11	6.15
04/21/86	5.86	5.95	6.09	6.11	6.14
04/14/86	5.86	5.81	5.77	5.84	5.87
04/07/86	6.20	6.13	6.01	6.02	5.96
03/31/86	6.35	6.34	6.34	6.33	6.23
03/24/86	6.36	6.38	6.41	6.34	NA
03/17/86	6.54	6.54	6.49	6.44	6.41
03/10/86	6.57	6.57	6.62	NA	6.54
03/03/86	6.92	6.84	5.85	6.69	6.61
02/24/86	6.99	7.05	7.07	7.03	7.02
02/17/86	NA	6.98	7.08	7.11	6.98
02/10/86	7.18	7.11	7.11	7.10	7.02
02/03/86	6.99	6.98	7.01	7.10	7.21
01/27/86	6.92	6.92	7.03	7.04	6.97
01/20/86	NA	7.00	7.00	6.97	6.97
01/13/86	7.24	7.24	7.19	7.08	7.11
01/06/86	7.06	7.03	7.17	7.18	7.21
12/30/85	7.03	7.05	NA	7.10	7.03
12/23/85	7.04	7.05	NA	7.01	6.96
12/16/85	7.00	7.06	7.13	7.10	7.05
12/09/85	7.20	7.19	7.04	7.08	6.98
12/02/85	7.23	7.23	7.22	7.26	7.26
11/25/85	7.17	7.20	7.18	NA	7.16
11/18/85	NA	7.21	7.25	7.23	7.23
11/11/85	NA	7.22	7.27	7.32	7.35
11/04/85	7.23	7.24	7.25	7.25	7.23
10/28/85	7.24	7.24	7.19	7.19	7.21
10/21/85	7.21	7.16	7.22	7.29	7.24
10/14/85	NA	7.23	7.21	7.19	7.20
10/07/85	7.14	7.16	7.19	7.22	7.19
09/30/85	7.04	7.03	7.02	6.98	6.99
09/23/85	6.80	6.84	6.87	6.94	NA
09/16/85	7.19	7.20	7.11	7.09	7.01
09/09/85	7.24	7.23	7.24	7.24	7.21

DATE OF AUCTION	TBILL MON BID RATE	TBILL TUES BID RATE	TBILL WED BID RATE	TBILL THURS BID RATE	TBILL FRI BID RATE
09/02/85	NA	7.11	7.05	7.13	7.26
08/26/85	7.08	7.05	7.06	7.04	7.14
08/19/85	7.13	7.12	7.04	7.03	7.04
08/12/85	7.14	7.14	7.09	7.19	7.11
08/05/85	7.29	7.26	7.18	7.17	7.16
07/29/85				7.27	7.31

Appendix B-2: Ask Rates from the Secondary Market

DATE OF AUCTION	TBILL MON ASK RATE	TBILL TUES ASK RATE	TBILL WED ASK RATE	TBILL THURS ASK RATE	TBILL FRI ASK RATE
07/30/90	7.47	7.47	7.40	7.41	NA
07/23/90	7.47	7.51	7.54	7.56	7.50
07/16/90	7.60	7.59	7.53	7.52	7.52
07/09/90	7.79	7.78	7.76	7.66	7.58
07/02/90	7.71	7.68	NA	7.64	7.73
06/25/90	7.72	7.78	7.75	7.72	7.72
06/18/90	7.69	7.72	7.75	7.75	7.75
06/11/90	7.69	7.72	7.66	7.66	7.66
06/04/90	7.69	7.69	7.66	7.69	7.69
05/28/90	7.72	7.75	7.75	7.75	7.66
05/21/90	7.75	7.72	7.63	7.66	7.69
05/14/90	7.66	7.63	7.63	7.66	7.72
05/07/90	7.75	7.78	7.72	7.69	7.58
04/30/90	7.84	7.91	7.88	7.84	7.75
04/23/90	7.75	7.75	7.78	7.81	7.78
04/16/90	7.69	7.75	7.78	7.75	7.66
04/09/90	7.75	7.75	7.75	7.72	NA
04/02/90	7.81	7.81	7.72	7.75	7.75
03/26/90	7.81	7.94	7.81	7.84	NA
03/19/90	7.94	7.94	7.88	7.88	7.88
03/12/90	7.94	7.97	7.91	7.91	7.88
03/05/90	7.88	7.88	7.88	7.91	7.94
02/26/90	7.69	7.69	7.75	7.78	7.72
02/19/90	NA	7.75	7.75	7.69	7.66
02/12/90	7.66	7.56	7.59	7.69	7.66
02/05/90	7.78	7.78	7.78	7.78	7.78
01/29/90	7.72	7.72	7.72	7.75	7.78
01/22/90	7.63	7.63	7.63	7.66	7.66
01/15/90	7.58	7.69	7.66	7.75	7.72
01/08/90	7.50	7.53	7.47	7.53	7.47
01/01/90	NA	7.59	7.59	7.56	7.53
12/25/89	NA	7.50	7.69	7.66	7.53
12/18/89	7.56	7.63	7.53	7.53	7.56
12/11/89	7.59	7.66	7.59	7.63	7.59
12/04/89	7.44	7.53	7.63	7.69	7.59
11/27/89	7.53	7.63	7.63	7.56	7.50
11/20/89	7.59	7.63	7.56	NA	7.50
11/13/89	7.63	7.63	7.59	7.53	7.66
11/06/89	7.75	7.69	7.63	7.69	7.69
10/30/89	7.72	7.75	7.66	7.63	7.81

DATE OF AUCTION	TBILL MON ASK RATE	TBILL TUES ASK RATE	TBILL WED ASK RATE	TBILL THURS ASK RATE	TBILL FRI ASK RATE
10/23/89	7.49	7.47	7.50	7.53	7.66
10/16/89	7.35	7.39	7.41	7.48	7.52
10/09/89	7.61	7.61	7.74	7.64	7.03
10/02/89	7.77	7.75	7.75	7.72	7.54
09/25/89	7.67	7.73	7.80	7.78	7.89
09/18/89	7.50	7.65	7.77	7.69	7.75
09/11/89	7.59	7.58	7.54	7.52	7.51
09/04/89	7.77	7.79	7.78	7.72	7.74
08/28/89	7.82	7.88	7.76	7.78	NA
08/21/89	7.92	8.08	7.97	7.84	7.93
08/14/89	8.02	7.99	7.88	7.89	7.8
08/07/89	7.89	7.89	7.83	7.79	7.92
07/31/89	7.65	7.65	7.49	7.55	7.84
07/24/89	8.06	7.98	7.86	7.74	7.83
07/17/89	7.86	7.90	7.94	7.96	8.09
07/10/89	7.73	7.71	7.70	7.69	7.81
07/03/89	NA	7.88	7.73	7.71	7.70
06/26/89	8.08	NA	7.97	7.88	7.95
06/19/89	8.17	8.13	8.18	8.17	8.03
06/12/89	8.12	8.09	8.09	8.12	8.11
06/05/89	8.12	8.15	8.07	8.05	8.17
05/29/89	NA	8.50	8.52	8.48	8.33
05/22/89	8.30	8.25	8.33	8.48	8.49
05/15/89	8.14	8.20	8.24	8.36	8.34
05/08/89	8.36	8.50	8.50	8.32	8.20
05/01/89	8.61	8.54	8.37	8.40	8.42
04/24/89	8.61	8.60	8.48	8.38	8.40
04/17/89	8.53	8.41	8.38	8.56	8.63
04/10/89	8.63	8.64	8.65	8.70	8.57
04/03/89	8.82	8.74	8.79	8.72	8.77
03/27/89	9.03	9.05	8.94	8.92	8.85
03/20/89	9.04	9.06	8.98	9.02	NA
03/13/89	8.64	8.69	8.66	8.68	8.83
03/06/89	8.61	8.60	8.59	8.65	8.72
02/27/89	8.66	8.68	8.62	8.63	8.61
02/20/89	NA	8.45	8.50	8.59	8.62
02/13/89	8.49	8.52	8.46	8.46	8.47
02/06/89	8.53	8.51	8.51	8.45	8.52
01/30/89	8.25	8.35	8.31	8.35	8.45
01/23/89	8.20	8.19	8.26	8.31	8.30
01/16/89	8.23	8.26	8.23	8.20	8.21
01/09/89	8.30	8.27	8.22	8.24	8.17
01/02/89	NA	8.19	8.21	8.25	8.26
12/26/88	NA	8.09	8.20	8.08	8.07
12/19/88	8.07	8.14	8.04	8.01	8.01

DATE OF AUCTION	TBILL MON ASK RATE	TBILL TUES ASK RATE	TBILL WED ASK RATE	TBILL THURS ASK RATE	TBILL FRI ASK RATE
12/12/88	7.97	8.08	8.07	8.16	8.13
12/05/88	7.98	7.91	7.96	7.93	7.86
11/28/88	8.00	7.95	7.80	7.82	8.03
11/21/88	7.92	7.99	7.98	NA	8.01
11/14/88	7.79	7.92	7.90	7.89	7.92
11/07/88	7.47	7.56	7.55	7.62	7.62
10/31/88	7.32	7.32	7.34	7.39	7.44
10/24/88	7.47	7.42	7.38	7.36	7.36
10/17/88	7.31	7.35	7.39	7.42	7.42
10/10/88	7.22	7.22	7.25	7.30	7.30
10/03/88	7.20	7.21	7.20	7.28	7.26
09/26/88	7.25	7.29	7.28	7.27	7.23
09/19/88	7.15	7.17	7.15	7.18	7.20
09/12/88	7.15	7.14	7.13	7.15	7.12
09/05/88	NA	7.21	7.31	7.29	7.26
08/29/88	7.20	7.27	7.25	7.26	7.19
08/22/88	7.15	7.14	7.16	7.24	7.31
08/15/88	6.97	7.03	7.00	6.97	7.03
08/08/88	6.89	7.03	6.95	6.98	6.99
08/01/88	6.80	6.87	6.87	6.81	6.89
07/25/88	6.81	6.88	6.97	6.96	6.91
07/18/88	6.66	6.65	6.68	6.74	6.72
07/11/88	6.61	6.72	6.70	6.70	6.69
07/04/88	NA	6.48	6.50	6.52	6.63
06/27/88	6.48	6.58	6.56	6.52	6.52
06/20/88	6.40	6.54	6.49	6.49	6.47
06/13/88	6.40	6.32	6.31	6.26	6.35
06/06/88	6.41	6.40	6.37	6.41	6.42
05/30/88	NA	6.48	6.43	6.42	6.43
05/23/88	6.27	6.26	6.29	6.40	6.41
05/16/88	6.19	6.27	6.19	6.12	6.24
05/09/88	6.25	6.32	6.23	6.18	6.16
05/02/88	6.05	6.09	6.12	6.16	6.27
04/25/88	5.83	5.87	5.83	5.95	5.96
04/18/88	5.77	5.77	5.80	5.80	5.80
04/11/88	5.94	5.90	5.82	5.66	5.86
04/04/88	5.85	5.97	6.01	6.01	5.98
03/28/88	5.72	5.72	5.70	5.69	NA
03/21/88	5.72	5.75	5.80	5.78	5.65
03/14/88	5.57	5.58	5.60	5.57	5.68
03/07/88	5.71	5.71	5.71	5.70	5.71
02/29/88	NA	5.59	5.57	5.57	5.69
02/22/88	5.58	5.60	5.60	5.61	5.56
02/15/88	NA	5.66	5.71	5.66	5.63
02/08/88	5.60	5.57	5.57	5.61	5.72

DATE OF AUCTION	TBILL MON ASK RATE	TBILL TUES ASK RATE	TBILL WED ASK RATE	TBILL THURS ASK RATE	TBILL FRI ASK RATE
02/01/88	5.62	5.67	5.65	5.62	5.62
01/25/88	5.79	5.77	5.71	5.64	5.61
01/18/88	5.83	5.91	5.78	5.80	5.77
01/11/88	5.81	5.78	5.76	5.80	5.84
01/04/88	5.82	5.90	5.81	5.75	5.77
12/28/87	5.46	5.79	NA	NA	NA
12/21/87	5.85	5.87	5.74	5.71	NA
12/14/87	5.90	5.91	5.91	5.91	5.85
12/07/87	5.74	5.84	5.82	5.90	5.86
11/30/87	5.33	5.52	5.39	5.33	5.44
11/23/87	5.71	5.70	5.66	NA	5.62
11/16/87	5.91	5.82	5.74	5.60	5.65
11/09/87	5.63	5.62	5.57	5.75	5.86
11/02/87	5.65	5.58	5.51	5.55	5.69
10/26/87	5.10	5.18	4.97	4.98	5.23
10/19/87	6.58	5.84	5.52	5.24	5.24
10/12/87	6.84	6.92	7.15	7.04	6.87
10/05/87	6.38	6.52	6.52	6.65	6.68
09/28/87	6.49	6.65	6.58	6.60	6.65
09/21/87	6.47	6.51	6.52	6.59	6.60
09/14/87	6.12	6.22	6.29	6.34	6.40
09/07/87	NA	6.16	6.34	6.24	6.26
08/31/87	5.95	6.03	5.99	6.10	6.29
08/24/87	5.93	6.11	6.16	6.18	5.99
08/17/87	5.74	5.92	5.98	6.01	6.00
08/10/87	5.68	5.83	5.85	5.86	5.86
08/03/87	5.70	5.75	5.76	5.64	5.75
07/27/87	5.88	5.98	6.01	5.83	5.97
07/20/87	5.46	5.59	5.61	5.57	5.88
07/13/87	5.56	5.53	5.56	5.56	5.54
07/06/87	5.56	5.58	5.55	5.59	5.57
06/29/87	5.74	5.61	5.71	5.64	NA
06/22/87	5.63	5.70	5.81	5.82	5.76
06/15/87	5.63	5.61	5.63	5.63	5.63
06/08/87	5.54	5.49	5.46	5.52	5.53
06/01/87	5.81	5.74	5.67	5.64	5.55
05/25/87	NA	5.66	5.74	5.81	5.77
05/18/87	5.85	5.76	5.67	5.51	5.56
05/11/87	5.55	5.58	5.49	5.71	5.99
05/04/87	5.74	5.79	5.46	5.51	5.44
04/27/87	5.76	5.80	5.69	5.49	5.63
04/20/87	5.64	5.48	5.40	5.47	5.74
04/13/87	5.95	5.90	5.66	5.54	NA
04/06/87	5.49	5.49	5.48	5.73	5.83
03/30/87	5.67	5.59	5.52	5.49	5.52

DATE OF AUCTION	TBILL MON ASK RATE	TBILL TUES ASK RATE	TBILL WED ASK RATE	TBILL THURS ASK RATE	TBILL FRI ASK RATE
03/23/87	5.56	5.59	5.55	5.55	5.64
03/16/87	5.57	5.55	5.50	5.46	5.48
03/09/87	5.64	5.66	5.67	5.65	5.60
03/02/87	5.46	5.52	5.49	5.50	5.62
02/23/87	5.41	5.42	5.43	5.43	5.43
02/16/87	NA	5.66	5.58	5.43	5.41
02/09/87	5.72	5.80	5.84	5.70	5.63
02/02/87	5.58	5.57	5.61	5.57	5.64
01/26/87	5.44	5.47	5.45	5.46	5.58
01/19/87	NA	5.23	5.29	5.36	5.38
01/12/87	5.35	5.34	5.31	5.34	5.31
01/05/87	5.52	5.30	5.41	5.41	5.36
12/29/86	5.63	5.67	5.65	5.53	NA
12/22/86	6.47	5.53	5.55	NA	5.55
12/15/86	5.54	5.56	5.62	5.58	5.49
12/08/86	5.45	5.46	5.47	5.47	5.47
12/01/86	5.36	5.39	5.39	5.38	5.42
11/24/86	5.31	5.37	5.37	NA	5.37
11/17/86	5.36	5.33	5.31	5.36	5.34
11/10/86	5.38	5.36	5.38	5.36	5.38
11/03/86	5.18	5.23	5.24	5.24	5.30
10/27/86	5.16	5.18	5.18	5.16	5.18
10/20/86	5.28	5.29	5.28	5.24	5.25
10/13/86	NA	5.09	5.16	5.18	5.25
10/06/86	5.10	5.04	5.02	5.04	5.04
09/29/86	5.15	5.18	5.17	5.17	5.07
09/22/86	5.20	5.23	5.22	5.21	5.22
09/15/86	5.13	5.09	5.10	5.21	5.23
09/08/86	5.22	5.18	5.14	5.19	5.15
09/01/86	NA	5.10	5.22	5.17	5.21
08/25/86	5.33	5.22	5.30	5.27	5.13
08/18/86	5.60	5.53	5.46	5.35	5.34
08/11/86	5.60	5.59	5.55	5.57	5.54
08/04/86	5.68	5.68	5.70	5.70	5.66
07/28/86	5.83	5.81	5.83	5.77	5.75
07/21/86	5.68	5.71	5.79	5.79	5.79
07/14/86	5.76	5.73	5.75	5.71	5.69
07/07/86	5.81	5.92	5.86	5.83	5.73
06/30/86	5.95	5.97	5.98	5.89	NA
06/23/86	6.05	6.06	6.06	6.06	6.00
06/16/86	6.07	6.07	6.05	6.09	6.08
06/09/86	6.30	6.24	6.32	6.24	6.15
06/02/86	6.34	6.39	6.50	6.47	6.30
05/26/86	NA	6.12	6.17	6.28	6.28
05/19/86	6.20	6.20	6.18	6.18	6.16

DATE OF AUCTION	TBILL MON ASK RATE	TBILL TUES ASK RATE	TBILL WED ASK RATE	TBILL THURS ASK RATE	TBILL FRI ASK RATE
05/12/86	6.07	6.07	6.07	6.15	6.19
05/05/86	6.02	6.03	6.02	6.00	6.03
04/28/86	6.03	6.07	6.08	6.09	6.11
04/21/86	5.84	5.93	6.07	6.09	6.12
04/14/86	5.82	5.79	5.75	5.82	5.85
04/07/86	6.18	6.11	5.99	5.98	5.94
03/31/86	6.31	6.32	6.29	6.31	6.19
03/24/86	6.32	6.36	6.39	6.32	NA
03/17/86	6.52	6.52	6.45	6.42	6.39
03/10/86	6.53	6.55	6.60	NA	6.50
03/03/86	6.90	6.82	6.83	6.65	6.59
02/24/86	6.95	7.03	7.05	7.01	7.00
02/17/86	NA	6.94	7.06	7.09	6.94
02/10/86	7.14	7.09	7.09	7.08	6.98
02/03/86	6.97	6.96	6.99	7.08	7.19
01/27/86	6.88	6.90	7.01	7.02	6.95
01/20/86	NA	6.96	6.98	6.95	6.95
01/13/86	7.22	7.22	7.17	7.06	7.09
01/06/86	7.04	7.01	7.15	7.16	7.19
12/30/85	6.99	7.03	NA	7.08	7.00
12/23/85	7.00	7.03	NA	6.99	6.94
12/16/85	6.98	7.02	7.11	7.08	7.03
12/09/85	7.16	7.15	7.00	7.06	6.94
12/02/85	7.19	7.21	7.20	7.24	7.24
11/25/85	7.13	7.38	7.14	NA	7.14
11/18/85	NA	7.19	7.23	7.21	7.21
11/11/85	NA	7.20	7.23	7.30	7.33
11/04/85	7.19	7.22	7.23	7.23	7.19
10/28/85	7.20	7.19	7.17	7.17	7.17
10/21/85	7.17	7.14	7.20	7.23	7.22
10/14/85	NA	7.19	7.19	7.17	7.18
10/07/85	7.12	7.14	7.17	7.20	7.17
09/30/85	7.02	7.01	7.00	6.94	6.97
09/23/85	6.76	6.82	6.85	6.92	NA
09/16/85	7.15	7.18	7.07	7.07	6.99
09/09/85	7.20	7.21	7.22	7.22	7.17
09/02/85	NA	7.07	7.01	7.11	7.24
08/26/85	7.04	7.03	7.04	7.00	7.12
08/19/85	7.09	7.10	7.02	6.99	7.02
08/12/85	7.10	7.12	7.07	7.17	7.09
08/05/85	7.25	7.24	7.14	7.15	7.14
07/29/85				7.23	7.29

Appendix B-3: Bid-Ask Spreads in Secondary Market

DATE OF MONDAY'S AUCTION	BIDASK SPREAD ON MON	BIDASK SPREAD ON TUE	BIDASK SPREAD ON WED	BIDASK SPREAD ON THU	BIDASK SPREAD ON FRI
07/30/90	0.02	0.02	0.02	0.02	0.00
07/23/90	0.02	0.02	0.02	0.02	0.02
07/16/90	0.02	0.02	0.02	0.02	0.02
07/09/90	0.02	0.02	0.02	0.02	0.02
07/02/90	0.02	0.02	0.00	0.02	0.02
06/25/90	0.04	0.03	0.04	0.03	0.03
06/18/90	0.02	0.03	0.02	0.03	0.04
06/11/90	0.05	0.02	0.02	0.02	0.04
06/04/90	0.02	0.02	0.04	0.03	0.03
05/28/90	0.03	0.04	0.02	0.02	0.04
05/21/90	0.02	0.02	0.03	0.04	0.03
05/14/90	0.02	0.03	0.04	0.02	0.03
05/07/90	0.04	0.02	0.03	0.03	0.05
04/30/90	0.04	0.02	0.02	0.03	0.02
04/03/90	0.02	0.02	0.02	0.06	0.02
04/16/90	0.02	0.03	0.03	0.03	0.04
04/09/90	0.04	0.03	0.02	0.04	0.00
04/02/90	0.04	0.02	0.04	0.02	0.02
03/26/90	0.03	0.03	0.04	0.05	0.00
03/19/90	0.03	0.03	0.03	0.04	0.01
03/12/90	0.03	0.02	0.04	0.04	0.04
03/05/90	0.01	0.02	0.03	0.02	0.04
02/26/90	0.03	0.04	0.03	0.03	0.04
02/19/90	0.00	0.04	0.04	0.04	0.02
02/12/90	0.04	0.03	0.03	0.02	0.04
02/05/90	0.05	0.03	0.04	0.04	0.03
01/09/90	0.05	0.04	0.04	0.02	0.03
01/22/90	0.04	0.05	0.05	0.04	0.04
01/15/90	0.01	0.03	0.04	0.05	0.03
01/08/90	0.04	0.03	0.05	0.05	0.03
01/01/90	0.00	0.04	0.05	0.04	0.03
12/25/89	0.00	0.03	0.05	0.04	0.03
12/18/89	0.08	0.04	0.04	0.04	0.04
12/11/89	0.04	0.03	0.04	0.02	0.04
12/04/89	0.06	0.05	0.04	0.02	0.03
11/27/89	0.08	0.03	0.03	0.05	0.04
11/20/89	0.03	0.03	0.03	0.00	0.04
11/13/89	0.06	0.07	0.04	0.05	0.03
11/06/89	0.06	0.07	0.05	0.05	0.03
10/30/89	0.05	0.04	0.07	0.06	0.03
10/23/89	0.04	0.03	0.04	0.03	0.05
10/16/89	0.07	0.04	0.04	0.04	0.04
10/09/89	0.05	0.04	0.07	0.07	0.04

DATE OF MONDAY'S AUCTION	BIDASK SPREAD ON MON	BIDASK SPREAD ON TUE	BIDASK SPREAD ON WED	BIDASK SPREAD ON THU	BIDASK SPREAD ON FRI
10/02/89	0.08	0.04	0.07	0.07	0.04
09/25/89	0.05	0.05	0.04	0.08	0.04
09/18/89	0.07	0.03	0.03	0.05	0.03
09/11/89	0.07	0.04	0.04	0.07	0.04
09/04/89	0.07	0.07	0.04	0.06	0.03
08/28/89	0.06	0.03	0.07	0.07	0.00
08/21/89	0.06	0.01	0.04	0.06	0.04
08/14/89	0.06	0.04	0.06	0.06	0.04
08/07/89	0.06	0.04	0.08	0.06	0.04
07/31/89	0.04	0.04	0.06	0.06	0.04
07/24/89	0.04	0.04	0.06	0.06	0.04
07/17/89	0.06	0.04	0.04	0.04	0.04
07/10/89	0.04	0.04	0.04	0.06	0.04
07/03/89	0.00	0.06	0.04	0.04	0.04
06/26/89	0.06	0.00	0.06	0.06	0.04
06/19/89	0.04	0.04	0.06	0.06	0.04
06/12/89	0.04	0.04	0.04	0.04	0.04
06/05/89	0.04	0.04	0.04	0.04	0.04
05/29/89	0.00	0.04	0.04	0.04	0.04
05/22/89	0.04	0.04	0.04	0.04	0.04
05/15/89	0.04	0.04	0.04	0.04	0.04
05/08/89	0.07	0.04	0.04	0.04	0.03
05/01/89	0.04	0.04	0.07	0.07	0.04
04/24/89	0.04	0.04	0.04	0.04	0.04
04/17/89	0.04	0.04	0.04	0.07	0.03
04/10/89	0.04	0.04	0.04	0.04	0.04
04/03/89	0.04	0.04	0.04	0.04	0.04
03/27/89	0.04	0.03	0.03	0.03	0.03
03/20/89	0.04	0.04	0.03	0.03	0.00
03/13/89	0.04	0.03	0.03	0.03	0.03
03/06/89	0.04	0.04	0.04	0.04	0.04
02/27/89	0.04	0.04	0.04	0.04	0.04
02/20/89	0.00	0.04	0.04	0.04	0.04
02/13/89	0.04	0.04	0.04	0.04	0.04
02/06/89	0.04	0.04	0.03	0.04	0.04
01/30/89	0.04	0.04	0.04	0.04	0.04
01/23/89	0.04	0.04	0.04	0.04	0.04
01/16/89	0.04	0.04	0.04	0.04	0.04
01/09/89	0.04	0.04	0.04	0.04	0.04
01/02/89	0.00	0.04	0.04	0.04	0.04
12/26/88	0.00	0.04	0.04	0.04	0.04
12/19/88	0.04	0.04	0.04	0.04	0.04
12/12/88	0.04	0.04	0.04	0.04	0.04
12/05/88	0.04	0.04	0.04	0.04	0.04
11/28/88	0.06	0.04	0.03	0.04	0.04
11/21/88	0.06	0.04	0.04	0.00	0.04
11/14/88	0.04	0.04	0.04	0.04	0.04
11/07/88	0.04	0.04	0.04	0.04	0.04

DATE OF MONDAY'S AUCTION	BIDASK SPREAD ON MON	BIDASK SPREAD ON TUE	BIDASK SPREAD ON WED	BIDASK SPREAD ON THU	BIDASK SPREAD ON FRI
10/31/88	0.06	0.04	0.04	0.04	0.04
10/24/88	0.04	0.04	0.04	0.04	0.04
10/17/88	0.04	0.04	0.04	0.04	0.04
10/10/88	0.06	0.06	0.04	0.04	0.04
10/03/88	0.04	0.04	0.04	0.04	0.04
09/26/88	0.06	0.04	0.04	0.04	0.06
09/19/88	0.07	0.04	0.04	0.04	0.04
09/12/88	0.06	0.04	0.04	0.04	0.04
09/05/88	0.00	0.06	0.04	0.04	0.04
08/29/88	0.06	0.04	0.04	0.04	0.04
08/02/88	0.04	0.04	0.04	0.04	0.04
08/15/88	0.04	0.04	0.04	0.04	0.04
08/08/88	0.06	0.04	0.04	0.04	0.04
08/01/88	0.06	0.04	0.04	0.04	0.04
07/25/88	0.06	0.04	0.04	0.04	0.04
07/18/88	0.07	0.04	0.04	0.04	0.04
07/11/88	0.07	0.04	0.04	0.04	0.04
07/04/88	0.00	0.07	0.04	0.04	0.04
06/27/88	0.07	0.04	0.04	0.04	0.04
06/20/88	0.07	0.04	0.04	0.04	0.04
06/13/88	0.07	0.04	0.04	0.04	0.04
06/06/88	0.07	0.04	0.04	0.04	0.04
05/30/88	0.00	0.07	0.04	0.04	0.04
05/23/88	0.07	0.04	0.04	0.04	0.04
05/16/88	0.07	0.04	0.04	0.04	0.04
05/09/88	0.07	0.04	0.04	0.04	0.04
05/02/88	0.07	0.04	0.04	0.04	0.04
04/25/88	0.07	0.04	0.04	0.04	0.04
04/18/88	0.07	0.04	0.04	0.04	0.04
04/11/88	0.07	0.04	0.04	0.04	0.04
04/04/88	0.07	0.04	0.04	0.04	0.04
03/28/88	0.04	0.04	0.04	0.02	0.00
03/21/88	0.07	0.04	0.04	0.04	0.04
03/14/88	0.07	0.04	0.04	0.04	0.04
03/07/88	0.07	0.04	0.04	0.04	0.04
02/29/88	0.00	0.04	0.04	0.04	0.02
02/22/88	0.07	0.04	0.04	0.04	0.04
02/15/88	0.00	0.07	0.04	0.04	0.04
02/08/88	0.07	0.04	0.04	0.04	0.04
02/01/88	0.07	0.04	0.04	0.04	0.04
01/25/88	0.04	0.04	0.04	0.04	0.04
01/18/88	0.07	0.07	0.04	0.04	0.04
01/04/88	0.07	0.04	0.04	0.04	0.04
12/28/87	0.12	0.04	0.00	0.00	0.00
12/21/87	0.07	3.04	0.04	0.04	0.00
12/14/87	0.07	0.04	0.04	0.04	0.04
12/07/87	0.12	0.04	0.04	0.02	0.04
11/30/87	0.07	0.07	0.07	0.04	0.04

DATE OF MONDAY'S AUCTION	BIDASK SPREAD ON MON	BIDASK SPREAD ON TUE	BIDASK SPREAD ON WED	BIDASK SPREAD ON THU	BIDASK SPREAD ON FRI
01/11/88	0.07	0.04	0.04	0.04	0.04
11/23/87	0.07	0.04	0.04	0.00	0.04
11/16/87	0.07	0.07	0.07	0.07	0.07
11/09/87	0.07	0.07	0.07	0.07	0.07
11/02/87	0.07	0.07	0.07	0.07	0.07
10/26/87	0.07	0.07	0.07	0.07	0.07
10/19/87	0.07	0.07	0.07	0.07	0.07
10/12/87	0.12	0.04	0.04	0.04	0.04
10/05/87	0.12	0.04	0.04	0.04	0.04
09/28/87	0.12	0.04	0.04	0.04	0.04
09/21/87	0.04	0.07	0.07	0.04	0.04
09/14/87	0.25	0.10	0.04	0.04	0.04
09/07/87	0.00	0.25	0.10	0.10	0.10
08/31/87	0.25	0.10	0.10	0.10	0.10
08/24/87	0.25	0.10	0.10	0.10	0.25
08/17/87	0.25	0.10	0.10	0.10	0.10
08/10/87	0.25	0.10	0.10	0.10	0.10
08/03/87	0.25	0.10	0.10	0.10	0.10
07/27/87	0.05	0.05	0.05	0.25	0.10
07/20/87	0.05	0.05	0.05	0.05	0.05
07/13/87	0.04	0.02	0.02	0.02	0.02
07/06/87	0.04	0.02	0.02	0.02	0.04
06/29/87	0.04	0.04	0.02	0.02	0.00
06/22/87	0.02	0.02	0.02	0.02	0.02
06/15/87	0.04	0.02	0.02	0.02	0.02
06/08/87	0.04	0.02	0.02	0.02	0.05
06/01/87	0.02	0.02	0.02	0.02	0.04
05/25/87	0.00	0.04	0.02	0.04	0.04
05/18/87	0.07	0.02	0.02	0.02	0.06
05/11/87	0.04	0.02	0.04	0.01	0.02
05/04/87	0.04	0.02	0.04	0.02	0.04
04/27/87	0.02	0.02	0.02	0.04	0.04
04/20/87	0.04	0.02	0.02	0.02	0.02
04/13/87	0.04	0.02	0.02	0.02	0.00
04/06/87	0.04	0.02	0.02	0.02	0.02
03/30/87	0.04	0.02	0.02	0.02	0.04
03/23/87	0.02	0.02	0.02	0.02	0.04
03/16/87	0.02	0.02	0.02	0.04	0.02
03/09/87	0.02	0.02	0.02	0.02	0.02
03/02/87	0.02	0.02	0.02	0.02	0.02
02/23/87	0.02	0.02	0.02	0.02	0.02
02/16/87	0.00	0.02	0.02	0.02	0.02
02/09/87	0.02	0.02	0.02	0.02	0.02
02/02/87	0.02	0.02	0.02	0.02	0.02
01/26/87	0.02	0.02	0.02	0.02	0.02
01/19/87	0.00	0.02	0.02	0.02	0.02
01/12/87	0.04	0.02	0.04	0.02	0.02

DATE OF MONDAY'S AUCTION	BIDASK SPREAD ON MON	BIDASK SPREAD ON TUE	BIDASK SPREAD ON WED	BIDASK SPREAD ON THU	BIDASK SPREAD ON FRI
01/05/87	0.02	0.04	0.07	0.02	0.02
12/29/86	0.02	0.02	0.02	0.00	NA
12/22/86	NA	0.02	0.02	0.00	0.02
12/15/86	0.02	0.02	0.02	0.02	0.02
12/08/86	0.04	0.02	0.02	0.02	0.02
12/01/86	0.04	0.02	0.02	0.02	0.02
11/24/86	0.04	0.02	0.02	NA	0.02
11/17/86	0.04	0.02	0.02	0.04	0.02
11/10/86	0.02	0.04	0.02	NA	0.02
11/03/86	0.04	0.02	0.02	NA	0.02
10/27/86	0.02	0.02	0.02	0.10	0.02
10/20/86	0.02	0.02	0.02	NA	0.02
10/13/86	0.00	0.04	0.02	NA	0.02
10/06/86	0.02	0.02	0.02	0.15	0.02
09/29/86	0.04	0.02	0.02	0.06	0.02
09/22/86	0.04	0.02	0.02	0.02	0.02
09/15/86	0.04	0.04	0.02	0.00	0.02
09/08/86	0.02	0.02	0.02	0.00	0.02
09/01/86	0.00	0.04	0.02	0.12	0.02
08/25/86	0.02	0.07	0.02	0.00	0.04
08/18/86	0.02	0.04	0.04	0.02	0.02
08/11/86	0.04	0.02	0.02	0.02	0.02
08/04/86	0.04	0.04	0.02	0.02	0.04
07/28/86	0.04	0.05	0.02	0.02	0.02
07/21/86	0.02	0.02	0.02	0.02	0.02
07/14/86	0.02	0.04	0.02	0.04	0.02
07/07/86	0.04	0.02	0.02	0.02	0.02
06/30/86	0.04	0.02	0.02	0.02	0.00
06/23/86	0.02	0.02	0.02	0.02	0.02
06/16/86	0.04	0.02	0.04	0.02	0.02
06/09/86	0.03	0.04	0.02	0.04	0.02
06/02/86	0.02	0.02	0.02	0.04	0.02
05/26/86	0.00	0.04	0.02	0.02	0.02
05/19/86	0.02	0.02	0.02	0.02	0.02
05/12/86	0.02	0.02	0.02	0.02	0.02
05/05/86	0.04	0.02	0.02	0.04	0.02
04/28/86	0.04	0.02	0.02	0.02	0.04
04/21/86	0.02	0.02	0.02	0.02	0.02
04/14/86	0.04	0.02	0.02	0.02	0.02
04/07/86	0.02	0.02	0.02	0.04	0.02
03/31/86	0.04	0.02	0.05	0.02	0.04
03/24/86	0.04	0.02	0.02	0.02	0.00
03/17/86	0.02	0.02	0.04	0.02	0.02
03/10/86	0.04	0.02	0.02	0.00	0.04
03/03/86	0.02	0.02	na	0.04	0.02
02/24/86	0.04	0.02	0.02	0.02	0.02
02/17/86	0.00	0.04	0.02	0.02	0.04
02/10/86	0.04	0.02	0.02	0.02	0.04

DATE OF MONDAY'S AUCTION	BIDASK SPREAD ON MON	BIDASK SPREAD ON TUE	BIDASK SPREAD ON WED	BIDASK SPREAD ON THU	BIDASK SPREAD ON FRI
02/03/86	0.02	0.02	0.02	0.02	0.02
01/27/86	0.04	0.02	0.02	0.02	0.02
01/20/86	0.00	0.04	0.02	0.02	0.02
01/13/86	0.02	0.02	0.02	0.02	0.02
01/06/86	0.02	0.02	0.02	0.02	0.02
12/30/85	0.04	0.02	0.00	0.02	0.03
12/23/85	0.04	0.02	0.00	0.02	0.02
12/16/85	0.02	0.04	0.02	0.02	0.02
12/09/85	0.04	0.04	0.04	0.02	0.04
12/02/85	0.04	0.02	0.02	0.02	0.02
11/25/85	0.04	NA	0.04	0.00	0.02
11/18/85	0.00	0.02	0.02	0.02	0.02
11/11/85	0.00	0.02	0.04	0.02	0.02
11/04/85	0.04	0.02	0.02	0.02	0.04
10/28/85	0.04	0.05	0.02	0.02	0.04
10/21/85	0.04	0.02	0.02	0.06	0.02
10/14/85	0.00	0.04	0.02	0.02	0.02
10/07/85	0.02	0.02	0.02	0.02	0.02
09/30/85	0.02	0.02	0.02	0.04	0.02
09/23/85	0.04	0.02	0.02	0.02	0.00
09/16/85	0.04	0.02	0.04	0.02	0.02
09/09/85	0.04	0.02	0.02	0.02	0.04
09/02/85	0.00	0.04	0.04	0.02	0.02
08/26/85	0.04	0.02	0.02	0.04	0.02
08/19/85	0.04	0.02	0.02	0.04	0.02
08/12/85	0.04	0.02	0.02	0.02	0.02
08/05/85	0.04	0.02	0.04	0.02	0.02
07/29/85			0.00	0.04	0.02

Appendix B-4: Calculated Changes in the Ask Rates

DATE OF MONDAY'S AUCTION	CHANGE IN ASK M TO TU	CHANGE IN ASK TU TO W	CHANGE IN ASK W TO TH	CHANGE IN ASK TH TO F	CHANGE IN ASK FR TO M
07/30/90	0.00	-0.07	0.01	NA	NA
07/23/90	0.04	0.03	0.02	-0.06	-0.03
07/16/90	-0.01	-0.06	-0.01	0.00	0.08
07/09/90	-0.01	-0.02	-0.10	-0.08	0.21
07/02/90	-0.03	0.00	0.00	0.09	-0.02
06/25/90	0.06	-0.03	-.03	0.00	0.00
06/18/90	0.03	0.03	000	0.00	-0.06
06/11/90	0.03	-0.06	0.00	0.00	0.03
06/04/90	0.00	-0.03	0.03	0.00	0.00
05/28/90	0.03	0.00	0.00	-0.09	0.06
05/21/90	-0.03	-0.09	0.03	0.03	0.06
05/14/90	-0.03	0.00	0.03	0.06	-0.06
05/07/90	0.03	-0.06	-0.03	-0.11	0.17
04/30/90	0.07	-0.03	-0.04	-0.09	0.09
04/23/90	0.00	0.03	0.03	-0.03	-0.03
04/16/90	0.06	0.03	-0.03	-0.09	0.03
04/09/90	0.00	0.00	-0.03	NA	NA
04/02/90	0.00	-0.09	0.03	0.00	0.06
03/26/90	0.13	-0.13	0.03	NA	NA
03/19/90	0.00	-0.06	0.00	0.00	0.06
03/12/90	0.03	-0.06	0.00	-0.03	0.06
03/05/90	0.00	0.00	0.03	0.03	-0.06
02/26/90	0.00	0.06	0.03	-0.06	-0.03
02/19/90	0.00	0.00	-0.06	-0.03	0.00
02/12/90	-0.10	0.03	0.10	-0.03	0.00
02/05/90	0.00	0.00	0.00	0.00	0.00
01/29/90	0.00	0.00	0.03	0.03	-0.06
01/22/90	0.00	0.00	0.03	0.00	-0.03
01/15/90	0.11	-0.03	0.09	-0.03	-0.14
01/08/90	0.03	-0.06	0.06	-0.06	0.03
01/01/90	0.00	0.00	-0.03	-0.03	0.00
12/25/89	0.00	0.19	-0.03	-0.13	0.00
12/18/89	0.07	-0.10	0.00	0.03	0.00
12/11/89	0.07	-0.07	0.04	-0.04	0.00
12/04/89	0.09	0.10	0.06	-0.10	-0.15
11/27/89	0.10	0.00	-0.07	-0.06	0.03
11/20/89	0.04	-0.07	0.00	0.00	0.09
11/13/89	0.00	-0.04	-0.06	0.13	-0.03
11/06/89	-0.06	-0.06	0.06	0.00	0.06
10/30/89	0.03	-0.09	-0.03	0.18	-0.09
10/23/89	-0.02	0.03	0.03	0.13	-0.17
10/16/89	0.04	0.02	0.07	0.04	-0.17
10/09/89	0.00	0.13	-0.10	-0.61	0.58

DATE OF MONDAY'S AUCTION	CHANGE IN ASK M TO TU	CHANGE IN ASK TU TO W	CHANGE IN ASK W TO TH	CHANGE IN ASK TH TO F	CHANGE IN ASK FR TO M
10/02/89	-0.02	0.00	-0.03	-0.18	0.23
09/25/89	0.06	0.07	-0.02	0.11	-0.22
09/18/89	0.15	0.12	-0.08	0.06	-0.25
09/11/89	-0.01	-0.04	-0.02	-0.01	0.08
09/04/89	0.02	-0.01	-0.06	0.02	0.03
08/28/89	0.06	-0.12	0.02	NA	NA
08/21/89	0.16	-0.11	-0.13	0.09	-0.01
08/14/89	-0.03	-0.11	0.01	-0.05	0.18
08/07/89	0.00	-0.06	-0.04	0.13	-0.03
07/31/89	0.00	-0.16	0.06	0.29	-0.19
07/24/89	-0.08	-0.12	-0.12	0.09	0.23
07/17/89	0.04	0.04	0.02	0.13	-0.23
07/10/89	-0.02	-0.01	-0.01	0.12	-0.08
07/03/89	NA	-0.15	-0.02	-0.01	NA
06/26/89	0.00	0.00	-0.09	0.07	0.13
06/19/89	-0.04	0.05	-0.01	-0.14	0.14
06/12/89	-0.03	0.00	0.03	-0.01	0.01
06/05/89	0.03	-0.08	-0.02	0.12	-0.05
05/29/89	0.00	0.02	-0.04	-0.15	0.00
05/22/89	-0.05	0.08	0.15	0.01	-0.19
05/15/89	0.06	0.04	0.12	-0.02	-0.20
05/08/89	0.14	0.00	-0.18	-0.12	0.16
05/01/89	-0.07	-0.17	0.03	0.02	0.19
04/24/89	-0.01	-0.12	-0.10	0.02	0.21
04/17/89	-0.12	-0.03	0.18	0.07	-0.10
04/10/89	0.01	0.01	0.05	-0.13	0.06
04/03/89	-0.08	0.05	-0.07	0.05	0.05
03/27/89	0.02	-0.11	-0.02	-0.07	0.18
03/20/89	0.02	-0.08	0.04	NA	NA
03/13/89	0.05	-0.03	0.02	0.15	-0.19
03/06/89	-0.01	-0.01	0.06	0.07	-0.11
02/27/89	0.02	-0.06	0.01	-0.02	0.05
02/20/89	0.00	0.05	0.09	0.03	0.00
02/13/89	0.03	-0.06	0.00	0.01	0.02
02/06/89	-0.02	0.00	-0.06	0.07	0.01
01/30/89	0.10	-0.04	0.04	0.10	-0.20
01/23/89	-0.01	0.07	0.05	-0.01	-0.10
01/16/89	0.03	-0.03	-0.03	0.01	0.02
01/09/89	-0.03	-0.05	0.02	-0.07	0.13
01/02/89	0.00	0.02	0.04	0.01	0.00
12/26/88	8.09	0.11	-0.12	-0.01	-8.07
12/19/88	0.07	-0.10	-0.03	0.00	0.06
12/12/88	0.11	-0.01	0.09	-0.03	-0.16
12/05/88	-0.07	0.05	-0.03	-0.07	0.12
11/28/88	-0.05	-0.15	0.02	0.21	-0.03
11/21/88	0.07	-0.01	0.00	0.00	-0.09
11/14/88	0.13	-0.02	-0.01	0.03	-0.13
11/07/88	0.09	-0.01	0.07	0.00	-0.15

DATE OF MONDAY'S AUCTION	CHANGE IN ASK M TO TU	CHANGE IN ASK TU TO W	CHANGE IN ASK W TO TH	CHANGE IN ASK TH TO F	CHANGE IN ASK FR TO M
10/31/88	0.00	0.02	0.05	0.05	-0.12
10/24/88	-0.05	-0.04	-0.02	0.00	0.11
10/17/88	0.04	0.04	0.03	0.00	-0.11
10/10/88	0.00	0.03	0.05	0.00	-0.08
10/03/88	0.01	-0.01	0.08	-0.02	-0.06
09/26/88	0.04	-0.01	-0.01	-0.04	0.02
09/19/88	0.02	-0.02	0.03	0.02	-0.05
09/12/88	-0.01	-0.01	0.02	-0.03	0.03
09/05/88	0.00	0.10	-0.02	-0.03	0.00
08/29/88	0.07	-0.02	0.01	-0.07	0.01
08/22/88	-0.01	0.02	0.08	0.07	-0.16
08/15/88	0.06	-0.03	-0.03	0.06	-0.06
08/08/88	0.14	-0.08	0.03	0.01	-0.10
08/01/88	0.07	0.00	-0.06	0.08	-0.09
07/25/88	0.07	0.09	-0.01	-0.05	-0.10
07/18/88	-0.01	0.03	0.06	-0.02	-0.06
07/11/88	0.11	-0.02	0.00	-0.01	-0.08
07/04/88	0.00	0.02	0.02	0.11	0.00
06/27/88	0.10	-0.02	-0.04	0.00	-0.04
06/20/88	0.14	-0.05	0.00	-0.02	-0.07
06/13/88	-0.08	-0.01	-0.05	0.09	0.05
06/06/88	-0.01	-0.03	0.04	0.01	-0.01
05/30/88	0.00	-0.05	-0.01	0.01	0.00
05/23/88	-0.01	0.03	0.11	0.01	-0.14
05/16/88	0.08	-0.08	-0.07	0.12	-0.05
05/09/88	0.07	-0.09	-0.05	-0.02	0.09
05/02/88	0.04	0.03	0.04	0.11	-0.22
04/25/88	0.04	-0.04	0.12	0.01	-0.13
04/18/88	0.00	0.03	0.00	0.00	-0.03
04/11/88	-0.04	-0.08	-0.16	0.20	0.08
04/04/88	0.12	0.04	0.00	-0.03	-0.13
03/28/88	0.00	-0.02	-0.01	NA	NA
03/21/88	0.03	0.05	-0.02	-0.13	0.07
03/14/88	0.01	0.02	-0.03	0.11	-0.11
03/07/88	0.00	0.00	-0.01	0.01	0.00
02/29/88	NA	-0.02	0.00	0.12	NA
02/22/88	0.02	0.00	0.01	-0.05	0.02
02/15/88	0.00	0.05	-0.05	-0.03	0.00
02/08/88	-0.03	0.00	0.04	0.11	-0.12
02/01/88	0.05	-0.02	-0.03	0.00	0.00
01/25/88	-0.02	-0.06	-0.07	-0.03	0.18
01/18/88	0.08	-0.13	0.02	-0.03	0.06
01/11/88	-0.03	-0.02	0.04	0.04	-0.03
01/04/88	0.08	-0.09	-0.06	0.02	0.05
12/28/87	0.33	0.00	0.00	0.00	NA
12/21/87	0.02	-0.13	-0.03	NA	NA
12/14/87	0.01	0.00	0.00	-0.06	0.05
12/07/87	0.10	-0.02	0.08	-0.04	-0.12

DATE OF MONDAY'S AUCTION	CHANGE IN ASK M TO TU	CHANGE IN ASK TU TO W	CHANGE IN ASK W TO TH	CHANGE IN ASK TH TO F	CHANGE IN ASK FR TO M
11/30/87	0.19	-0.13	-0.06	0.11	-0.11
11/23/87	-0.01	-0.04	NA	NA	0.09
11/16/87	-0.09	-0.08	-0.14	0.05	0.26
11/09/87	-0.01	-0.05	0.18	0.11	-0.23
11/02/87	-0.07	-0.07	0.04	0.14	-0.04
10/26/87	0.08	-0.21	0.01	0.25	-0.13
10/19/87	-0.74	-0.32	-0.28	0.00	1.34
10/12/87	0.08	0.23	-0.11	-0.17	-0.03
10/05/87	0.14	0.00	0.13	0.03	-0.30
09/28/87	0.16	-0.07	0.02	0.05	-0.16
09/21/87	0.04	0.01	0.07	0.01	-0.13
09/14/87	0.10	0.07	0.05	0.06	-0.28
09/07/87	NA	0.18	-0.10	0.02	NA
08/31/87	0.08	-0.04	0.11	0.19	-0.34
08/24/87	0.18	0.05	0.02	-0.19	-0.06
08/17/87	0.18	0.06	0.03	-0.01	-0.26
08/10/87	0.15	0.02	0.01	0.00	-0.18
08/03/87	0.05	0.01	-0.12	0.11	-0.05
07/27/87	0.10	0.03	-0.18	0.14	-0.09
07/20/87	0.13	0.02	-0.04	0.31	-0.42
07/13/87	-0.03	0.03	0.00	-0.02	0.02
07/06/87	0.02	-0.03	0.04	-0.02	-0.01
06/29/87	-0.13	0.10	-0.07	NA	NA
06/22/87	0.07	0.11	0.01	-0.06	-0.13
06/15/87	-0.02	0.02	0.00	0.00	0.00
06/08/87	-0.05	-0.03	0.06	0.01	0.01
06/01/87	-0.07	-0.07	-0.03	-0.09	0.26
05/25/87	NA	0.08	0.07	-0.04	NA
05/18/87	-0.09	-0.09	-0.16	0.05	0.29
05/11/87	0.03	-0.09	0.22	0.28	-0.44
05/04/87	0.05	-0.33	0.05	-0.07	0.30
04/27/87	0.04	-0.11	-0.20	0.14	0.13
04/20/87	-0.16	-0.08	0.07	0.27	-0.10
04/13/87	-0.05	-0.24	-0.12	NA	NA
04/06/87	0.00	-0.01	0.25	0.10	-0.34
03/30/87	-0.08	-0.07	-0.03	0.03	0.15
03/23/87	0.03	-0.04	0.00	0.09	-0.08
03/16/87	-0.02	-0.05	-0.04	0.02	0.09
03/09/87	0.02	0.01	-0.02	-0.05	0.04
03/02/87	0.06	-0.03	0.01	0.12	-0.16
02/23/87	0.01	0.01	0.00	0.00	-0.02
02/16/87	NA	-0.08	-0.15	-0.02	NA
02/09/87	0.08	0.04	-0.14	-0.07	0.09
02/02/87	-0.01	0.04	-0.04	0.07	-0.06
01/26/87	0.03	-0.02	0.01	0.12	-0.14
01/19/87	NA	0.06	0.07	0.02	NA
01/12/87	-0.01	-0.03	0.03	-0.03	0.04
01/05/87	-0.22	0.11	0.00	-0.05	0.16

DATE OF MONDAY'S AUCTION	CHANGE IN ASK M TO TU	CHANGE IN ASK TU TO W	CHANGE IN ASK W TO TH	CHANGE IN ASK TH TO F	CHANGE IN ASK FR TO M
12/29/86	0.04	-0.02	-0.12	NA	NA
12/22/86	-0.94	0.02	NA	NA	0.92
12/15/86	0.02	0.06	-0.04	-0.09	0.05
12/08/86	0.01	0.01	0.00	0.00	-0.02
12/01/86	0.03	0.00	-0.01	0.04	-0.06
11/24/86	0.06	0.00	NA	NA	-0.06
11/17/86	-0.03	-0.02	0.05	-0.02	0.02
11/10/86	-0.02	0.02	-0.02	0.02	0.00
11/03/86	0.05	0.01	0.00	0.06	-0.12
10/27/86	0.02	0.00	-0.02	0.02	-0.02
10/20/86	0.01	-0.01	-0.04	0.01	0.03
10/13/86	NA	0.07	0.02	0.07	NA
10/06/86	-0.06	-0.02	0.02	0.00	0.06
09/29/86	0.03	-0.01	0.00	-0.10	0.08
09/22/86	0.03	-0.01	-0.01	0.01	-0.02
09/15/86	-0.04	.01	.11	0.02	-0.10
09/08/86	-0.04	-0.04	0.05	-0.04	0.07
09/01/86	NA	0.12	-0.05	0.04	NA
08/25/86	-0.11	0.08	-0.03	-0.14	0.20
08/18/86	-0.07	-0.07	-0.11	-0.01	0.26
08/11/86	-0.01	-0.04	0.02	-0.03	0.06
08/04/86	0.00	0.02	0.00	-0.04	0.02
07/28/86	-0.02	0.02	-0.06	-0.02	0.08
07/21/86	0.03	0.08	0.00	0.00	-0.11
07/14/86	-0.03	0.02	-0.04	-0.02	0.07
07/07/86	0.11	-0.06	-0.03	-0.10	0.08
06/30/86	0.02	0.01	-0.09	NA	NA
06/23/86	0.01	0.00	0.00	-0.06	0.05
06/16/86	0.00	-0.02	0.04	-0.01	-0.01
06/09/86	-0.06	0.08	-0.08	-0.09	0.15
06/02/86	0.05	0.11	-0.03	-0.17	0.04
05/26/86	NA	0.05	0.11	0.00	NA
05/19/86	0.00	-0.02	0.00	-0.02	0.04
05/12/86	0.00	0.00	0.08	0.04	-0.12
05/05/86	0.01	-0.01	-0.02	0.03	-0.01
04/28/86	0.04	0.01	0.01	0.02	-0.08
04/21/86	0.09	0.14	0.02	0.03	-0.28
04/14/86	-0.03	-0.04	0.07	0.03	-0.03
04/07/86	-0.07	-0.12	-0.01	-0.04	0.24
03/31/86	0.01	-0.03	0.02	-0.12	0.12
03/24/86	0.04	0.03	-0.07	NA	NA
03/17/86	0.00	-0.07	-0.03	-0.03	0.13
03/10/86	0.02	0.05	NA	NA	0.03
03/03/86	-0.08	0.01	-0.18	-0.06	0.31
02/24/86	0.08	0.02	-0.04	-0.01	-0.05
02/17/86	NA	0.12	0.03	-0.15	NA
02/10/86	-0.05	0.00	-0.01	-0.10	0.16
02/03/86	-0.1	0.03	0.09	0.11	-0.22

DATE OF MONDAY'S AUCTION	CHANGE IN ASK M TO TU	CHANGE IN ASK TU TO W	CHANGE IN ASK W TO TH	CHANGE IN ASK TH TO F	CHANGE IN ASK FR TO M
01/27/86	0.0	0.11	0.01	-0.07	-0.07
01/20/86	NA	0.02	-0.03	0.00	NA
01/13/86	0.00	-0.05	-0.11	0.03	0.13
01/06/86	-0.03	0.14	0.01	0.03	-0.15
12/30/85	0.04	NA	NA	-0.08	-0.01
12/23/85	0.03	NA	NA	-0.05	0.06
12/16/85	0.04	0.09	-0.03	-0.05	-0.05
12/09/85	-0.01	-0.15	0.06	-0.12	0.22
12/02/85	0.02	-0.01	0.04	0.00	-0.05
11/25/85	0.25	-0.24	NA	NA	-0.01
11/18/85	NA	0.04	-0.02	0.00	NA
11/11/85	NA	0.03	0.07	0.03	NA
11/04/85	0.03	0.01	0.00	-0.04	0.00
10/28/85	-0.01	-0.02	0.00	0.00	0.03
10/21/85	-0.03	0.06	0.03	-0.01	-0.05
10/14/85	NA	0.00	-0.02	0.01	NA
10/07/85	0.02	0.03	0.03	-0.03	-0.05
09/30/85	-0.01	-0.01	-0.06	0.03	0.05
09/23/85	0.06	0.03	0.07	NA	NA
09/16/85	0.03	-0.11	0.00	-0.08	0.16
09/09/85	0.01	0.01	0.00	-0.05	0.03
09/02/85	NA	-0.06	0.10	0.13	NA
08/26/85	-0.01	0.01	-0.04	0.12	-0.08
08/19/85	0.01	-0.08	-0.03	0.03	0.07
08/12/85	0.02	-0.05	0.10	-0.08	0.01
08/05/85	-0.01	-0.10	0.01	-0.01	0.11
07/29/85	0.00	0.00	NA	0.06	NA

Appendix B-5: Changes in the Bid-Ask Spreads

DATE OF AUCTION	CHANGE IN SPREAD M TO TU	CHANGE IN SPREAD TU TO W	CHANGE IN SPREAD W TO TH	CHANGE IN SPREAD TH TO F	CHANGE IN SPREAD FR TO M
07/30/90	0.00	0.00	0.00	-0.02	0.02
07/23/90	0.00	0.00	0.00	0.00	0.00
07/16/90	0.00	0.00	0.00	0.00	0.00
07/09/90	0.00	0.00	0.00	0.00	0.00
07/02/90	0.00	0.00	0.00	0.00	0.00
06/25/90	-0.01	0.01	-0.01	0.00	0.01
06/18/90	0.01	-0.01	0.01	0.01	-0.02
06/11/90	-0.03	0.00	0.00	0.02	0.01
06/04/90	0.00	0.02	-0.01	0.00	-0.01
05/28/90	0.01	-0.02	0.00	0.02	-0.01
05/21/90	0.00	0.01	0.01	-0.01	-0.01
05/14/90	0.01	0.01	-0.02	0.01	-0.01
05/07/90	-0.02	0.01	0.00	0.02	-0.01
04/30/90	-0.02	0.00	0.01	-0.01	0.02
04/23/90	0.00	0.00	0.04	-0.04	0.00
04/16/90	0.01	0.00	0.00	0.01	-0.02
04/09/90	-0.01	-0.01	0.02	0.00	0.00
04/02/90	-0.02	0.02	-0.02	0.00	0.02
03/26/90	0.00	0.01	0.01	0.00	0.00
03/19/90	0.00	0.00	0.01	-0.03	0.02
03/12/90	-0.01	0.02	0.00	0.00	-0.01
03/05/90	0.01	0.01	-0.01	0.02	-0.03
02/26/90	0.01	-0.01	0.00	0.01	-0.01
02/19/90	0.00	0.00	0.00	-0.02	0.00
02/12/90	-0.01	0.00	-0.01	0.02	0.00
02/05/90	-0.02	0.01	0.00	-0.01	0.02
01/29/90	-0.01	0.00	-0.02	0.01	0.02
01/22/90	0.01	0.00	-0.01	0.00	0.00
01/15/90	0.02	0.01	0.01	-0.02	-0.02
01/08/90	-0.01	0.02	0.00	-0.02	0.01
01/01/90	0.00	0.01	-0.01	-0.01	0.00
12/25/89	0.00	0.02	-0.01	-0.01	0.00
12/18/89	-0.04	0.00	0.00	0.00	0.04
12/11/89	-0.01	0.01	-0.02	0.02	0.00
12/04/89	-0.01	-0.01	-0.02	0.01	0.03
11/27/89	-0.05	0.00	0.02	-0.01	0.04
11/20/89	0.00	0.00	0.00	0.00	-0.01
11/13/89	0.01	-0.03	0.01	-0.02	0.03
11/06/89	0.01	-0.02	0.00	-0.02	0.03
10/30/89	-0.01	0.03	-0.01	-0.03	0.02
10/23/89	-0.01	0.01	-0.01	0.02	-0.01
10/16/89	-0.03	0.00	0.00	0.00	0.03
10/09/89	-0.01	0.03	0.00	-0.03	0.01

DATE OF MONDAY'S AUCTION	CHANGE IN SPREAD M TO TU	CHANGE IN SPREAD TU TO W	CHANGE IN SPREAD W TO TH	CHANGE IN SPREAD TH TO F	CHANGE IN SPREAD FR TO M
10/02/89	-0.04	0.03	0.00	-0.03	0.04
09/25/89	0.00	-0.01	0.04	-0.04	0.01
09/18/89	-0.04	0.00	0.02	-0.02	0.04
09/11/89	-0.03	0.00	0.03	-0.03	0.03
09/04/89	0.00	-0.03	0.02	-0.03	0.04
08/28/89	-0.03	0.04	0.00	0.00	0.00
08/21/89	-0.07	0.05	0.02	-0.02	0.02
08/14/89	-0.02	0.02	0.00	-0.02	0.02
08/07/89	-0.02	0.04	-0.02	-0.02	0.02
07/31/89	0.00	0.02	0.00	-0.02	0.00
07/24/89	0.00	0.02	0.00	-0.02	0.00
07/17/89	-0.02	0.00	0.00	0.00	0.02
07/10/89	0.00	0.00	0.02	-0.02	0.00
07/03/89	0.00	-0.02	0.00	0.00	0.00
06/26/89	0.00	0.00	0.00	-0.02	0.02
06/19/89	0.00	0.02	0.00	-0.02	0.00
06/12/89	0.00	0.00	0.00	0.00	0.00
06/05/89	0.00	0.00	0.00	0.00	0.00
05/29/89	0.00	0.00	0.00	0.00	0.00
05/22/89	0.00	0.00	0.00	0.00	0.00
05/15/89	0.00	0.00	0.00	0.00	0.00
05/08/89	-0.03	0.00	0.00	-0.01	0.04
05/01/89	0.00	0.03	0.00	-0.03	0.00
04/24/89	0.00	0.00	0.00	0.00	0.00
04/17/89	0.00	0.00	0.03	-0.04	0.01
04/10/89	0.00	0.00	0.00	0.00	0.00
04/03/89	0.00	0.00	0.00	0.00	0.00
03/27/89	-0.01	0.00	0.00	0.00	0.01
03/20/89	0.00	-0.01	0.00	0.00	0.00
03/13/89	-0.01	0.00	0.00	0.00	0.01
03/06/89	0.00	0.00	0.00	0.00	0.00
02/27/89	0.00	0.00	0.00	0.00	0.00
02/20/89	0.00	0.00	0.00	0.00	0.00
02/13/89	0.00	0.00	0.00	0.00	0.00
02/06/89	0.00	-0.01	0.01	0.00	0.00
01/30/89	0.00	0.00	0.00	0.00	0.00
01/23/89	0.00	0.00	0.00	0.00	0.00
01/16/89	0.00	0.00	0.00	0.00	0.00
01/09/89	0.00	0.00	0.00	0.00	0.00
01/02/89	0.00	0.00	0.00	0.00	0.00
12/26/88	0.00	0.00	0.00	0.00	0.00
12/19/88	0.00	0.00	0.00	0.00	0.00
12/12/88	0.00	0.00	0.00	0.00	0.00
12/05/88	0.00	0.00	0.00	0.00	0.00
11/28/88	-0.02	-0.01	0.01	0.00	0.02
11/21/88	-0.02	0.00	0.00	0.00	0.02
11/14/88	0.00	0.00	0.00	0.00	0.00
11/07/88	0.00	0.00	0.00	0.00	0.00

DATE OF MONDAY'S AUCTION	CHANGE IN SPREAD M TO TU	CHANGE IN SPREAD TU TO W	CHANGE IN SPREAD W TO TH	CHANGE IN SPREAD TH TO F	CHANGE IN SPREAD FR TO M
10/31/88	-0.02	0.00	0.00	0.00	0.02
10/24/88	0.00	0.00	0.00	0.00	0.00
10/17/88	0.00	0.00	0.00	0.00	0.00
10/10/88	0.00	-0.02	0.00	0.00	0.02
10/03/88	0.00	0.00	0.00	0.00	0.00
09/26/88	-0.02	0.00	0.00	0.02	0.00
09/19/88	-0.03	0.00	0.00	0.00	0.03
09/12/88	-0.02	0.00	0.00	0.00	0.02
09/05/88	0.00	-0.02	0.00	0.00	0.00
08/29/88	-0.02	0.00	0.00	0.00	0.02
08/22/88	0.00	0.00	0.00	0.00	0.00
08/15/88	0.00	0.00	0.00	0.00	0.00
08/08/88	-0.02	0.00	0.00	0.00	0.02
08/01/88	-0.02	0.00	0.00	0.00	0.02
07/25/88	-0.02	0.00	0.00	0.00	0.02
07/18/88	-0.03	0.00	0.00	0.00	0.03
07/11/88	-0.03	0.00	0.00	0.00	0.03
07/04/88	0.00	-0.03	0.00	0.00	0.00
06/27/88	-0.03	0.00	0.00	0.00	0.03
06/20/88	-0.03	0.00	0.00	0.00	0.03
06/13/88	-0.03	0.00	0.00	0.00	0.03
06/06/88	-0.03	0.00	0.00	0.00	0.03
05/30/88	0.00	-0.03	0.00	0.00	0.00
05/23/88	-0.03	0.00	0.00	0.00	0.03
05/16/88	-0.03	0.00	0.00	0.00	0.03
05/09/88	-0.03	0.00	0.00	0.00	0.03
05/02/88	-0.03	0.00	0.00	0.00	0.03
04/25/88	-0.03	0.00	0.00	0.00	0.03
04/18/88	-0.03	0.00	0.00	0.00	0.03
04/11/88	-0.03	0.00	0.00	0.00	0.03
04/04/88	-0.03	0.00	0.00	0.00	0.03
03/28/88	0.00	0.00	-0.02	0.00	0.00
03/21/88	-0.03	0.00	0.00	0.00	0.03
03/14/88	-0.03	0.00	0.00	0.00	0.03
03/07/88	-0.03	0.00	0.00	0.00	0.03
02/29/88	0.04	0.00	0.00	-0.02	-0.02
02/22/88	-0.03	0.00	0.00	0.00	0.03
02/15/88	0.00	-0.03	0.00	0.00	0.00
02/08/88	-0.03	0.00	0.00	0.00	0.03
02/01/88	-0.03	0.00	0.00	0.00	0.03
01/25/88	0.00	0.00	0.00	0.00	0.00
01/18/88	0.00	-0.03	0.00	0.00	0.03
01/11/88	-0.03	0.00	0.00	0.00	0.03
01/04/88	-0.03	0.00	0.00	0.00	0.03
12/28/87	-0.08	0.00	0.00	0.00	0.12
12/21/87	2.97	-3.00	0.00	0.00	0.00
12/14/87	-0.03	0.00	0.00	0.00	0.03
12/07/87	-0.08	0.00	-0.02	0.02	0.08

DATE OF MONDAY'S AUCTION	CHANGE IN SPREAD M TO TU	CHANGE IN SPREAD TU TO W	CHANGE IN SPREAD W TO TH	CHANGE IN SPREAD TH TO F	CHANGE IN SPREAD FR TO M
11/30/87	0.00	0.00	-0.03	0.00	0.03
11/23/87	-0.03	0.00	0.00	0.00	0.03
11/16/87	0.00	0.00	0.00	0.00	0.00
11/09/87	0.00	0.00	0.00	0.00	0.00
11/02/87	0.00	0.00	0.00	0.00	0.00
10/26/87	0.00	0.00	0.00	0.00	0.00
10/19/87	0.00	0.00	0.00	0.00	0.00
10/12/87	-0.08	0.00	0.00	0.00	0.08
10/05/87	-0.08	0.00	0.00	0.00	0.08
09/28/87	-0.08	0.00	0.00	0.00	0.08
09/21/87	0.03	0.00	-0.03	0.00	0.00
09/14/87	-0.15	-0.06	0.00	0.00	0.21
09/07/87	0.00	-0.15	0.00	0.00	0.00
08/31/87	-0.15	0.00	0.00	0.00	0.15
08/24/87	-0.15	0.00	0.00	0.15	0.00
08/17/87	-0.15	0.00	0.00	0.00	0.15
08/10/87	-0.15	0.00	0.00	0.00	0.15
08/03/87	-0.15	0.00	0.00	0.00	0.15
07/27/87	0.00	0.00	0.20	-0.15	-0.05
07/20/87	0.00	0.00	0.00	0.00	0.00
07/13/87	-0.02	0.00	0.00	0.00	0.02
07/06/87	-0.02	0.00	0.00	0.02	0.00
06/29/87	0.00	-0.02	0.00	0.00	0.00
06/22/87	0.00	0.00	0.00	0.00	0.00
06/15/87	-0.02	0.00	0.00	0.00	0.02
06/08/87	-0.02	0.00	0.00	0.03	-0.01
06/01/87	0.00	0.00	0.00	0.02	-0.02
05/25/87	0.00	-0.02	0.02	0.00	0.00
05/18/87	-0.05	0.00	0.00	0.04	0.01
05/11/87	-0.02	0.02	-0.03	0.01	0.02
05/04/87	-0.02	0.02	-0.02	0.02	0.00
04/27/87	0.00	0.00	0.02	0.00	-0.02
04/20/87	-0.02	0.00	0.00	0.00	0.02
04/13/87	-0.02	0.00	0.00	0.00	0.00
04/06/87	-0.02	0.00	0.00	0.00	0.02
03/30/87	-0.02	0.00	0.00	0.02	0.00
03/23/87	0.00	0.00	0.00	0.02	-0.02
03/16/87	0.00	0.00	0.02	-0.02	0.00
03/09/87	0.00	0.00	0.00	0.00	0.00
03/02/87	0.00	0.00	0.00	0.00	0.00
02/23/87	0.00	0.00	0.00	0.00	0.00
02/16/87	0.00	0.00	0.00	0.00	0.00
02/09/87	0.00	0.00	0.00	0.00	0.00
02/02/87	0.00	0.00	0.00	0.00	0.00
01/26/87	0.00	0.00	0.00	0.00	0.00
01/19/87	0.00	0.00	0.00	0.00	0.00
01/12/87	-0.02	0.02	-0.02	0.00	0.02
01/05/87	0.02	0.03	-0.05	0.00	0.00

DATE OF MONDAY'S AUCTION	CHANGE IN SPREAD M TO TU	CHANGE IN SPREAD TU TO W	CHANGE IN SPREAD W TO TH	CHANGE IN SPREAD TH TO F	CHANGE IN SPREAD FR TO M
12/29/86	0.00	0.00	0.00	0.00	-5.47
12/22/86	1.00	0.00	0.00	0.00	-1.00
12/15/86	0.00	0.00	0.00	0.00	0.00
12/08/86	-0.02	0.00	0.00	0.00	0.02
12/01/86	-0.02	0.00	0.00	0.00	0.02
11/24/86	-0.02	0.00	5.36	-5.36	0.02
11/17/86	-0.02	0.00	0.02	-0.02	0.02
11/10/86	0.02	-0.02	-0.12	0.12	0.00
11/03/86	-0.02	0.00	-0.08	0.08	0.02
10/27/86	0.00	0.00	0.08	-0.08	0.00
10/20/86	0.00	0.00	-0.06	0.06	0.00
10/13/86	0.00	-0.02	-0.14	0.14	0.00
10/06/86	0.00	0.00	0.13	-0.13	0.00
09/29/86	-0.02	0.00	0.04	-0.04	0.02
09/22/86	-0.02	0.00	0.00	0.00	0.02
09/15/86	0.00	-0.02	-0.02	0.02	0.02
09/08/86	0.00	0.00	-0.02	0.02	0.00
09/01/86	0.00	-0.02	0.10	-0.10	0.00
08/25/86	0.05	-0.05	0.00	0.00	-0.02
08/18/86	0.02	0.00	-0.02	0.00	0.00
08/11/86	-0.02	0.00	0.00	0.00	0.02
08/04/86	0.00	-0.02	0.00	0.02	0.00
07/28/86	0.01	-0.03	0.00	0.00	0.02
07/21/86	0.00	0.00	0.00	0.00	0.00
07/14/86	0.02	-0.02	0.02	-0.02	0.00
07/07/86	-0.02	0.00	0.00	0.00	0.02
06/30/86	-0.02	0.00	0.00	0.00	0.00
06/23/86	0.00	0.00	0.00	0.00	0.00
06/16/86	-0.02	0.02	-0.02	0.00	0.02
06/09/86	0.01	-0.02	0.02	-0.02	0.01
06/02/86	0.00	0.00	0.02	-0.02	0.00
05/26/86	0.00	-0.02	0.00	0.00	0.00
05/19/86	0.00	0.00	0.00	0.00	0.00
05/12/86	0.00	0.00	0.00	0.00	0.00
05/05/86	-0.02	0.00	0.02	-0.02	0.02
04/28/86	-0.02	0.00	0.00	0.02	0.00
04/21/86	0.00	0.00	0.00	0.00	0.00
04/14/86	-0.02	0.00	0.00	0.00	0.02
04/07/86	0.00	0.00	0.02	-0.02	0.00
03/31/86	-0.02	0.03	-0.03	0.02	0.00
03/24/86	-0.02	0.00	0.00	0.00	0.00
03/17/86	0.00	0.02	-0.02	0.00	0.00
03/10/86	-0.02	0.00	0.00	0.00	0.00
03/03/86	0.00	-1.00	1.02	-0.02	0.00
02/24/86	-0.02	0.00	0.00	0.00	0.02
02/17/86	0.00	-0.02	0.00	0.02	0.00
02/10/86	-0.02	0.00	0.00	0.02	0.00
02/03/86	0.00	0.00	0.00	0.00	0.00

DATE OF MONDAY'S AUCTION	CHANGE IN SPREAD M TO TU	CHANGE IN SPREAD TU TO W	CHANGE IN SPREAD W TO TH	CHANGE IN SPREAD TH TO F	CHANGE IN SPREAD FR TO M
01/27/86	-0.02	0.00	0.00	0.00	0.02
01/20/86	0.00	-0.02	0.00	0.00	0.00
01/13/86	0.00	0.00	0.00	0.00	0.00
01/06/86	0.00	0.00	0.00	0.00	0.00
12/30/85	-0.02	0.00	0.00	0.01	0.01
12/23/85	-0.02	0.00	0.00	0.00	0.02
12/16/85	0.02	-0.02	0.00	0.00	0.00
12/09/85	0.00	0.00	-0.02	0.02	0.00
12/02/85	-0.02	0.00	0.00	0.00	0.02
11/25/85	-0.22	0.22	0.00	0.00	0.02
11/18/85	0.02	0.00	0.00	0.00	-0.02
11/11/85	0.00	0.02	-0.02	0.00	0.00
11/04/85	-0.02	0.00	0.00	0.02	0.00
10/28/85	0.01	-0.03	0.00	0.02	0.00
10/21/85	-0.02	0.00	0.04	-0.04	0.02
10/14/85	0.00	-0.02	0.00	0.00	0.00
10/07/85	0.00	0.00	0.00	0.00	0.00
09/30/85	0.00	0.00	0.02	-0.02	0.00
09/23/85	-0.02	0.00	0.00	0.00	0.00
09/16/85	-0.02	0.02	-0.02	0.00	0.02
09/09/85	-0.02	0.00	0.00	0.02	0.00
09/02/85	0.00	0.00	-0.02	0.00	0.00
08/26/85	-0.02	0.00	0.02	-0.02	0.02
08/19/85	-0.02	0.00	0.02	-0.02	0.02
08/12/85	-0.02	0.00	0.00	0.00	0.02
08/05/85	-0.02	0.02	-0.02	0.00	0.02
07/29/85	0.00	0.00	0.04	-0.02	-0.02

APPENDIX C

PERCENT COMPETITIVE BIDS ACCEPTED

AND PERCENT OVERBID

DATE OF MONDAY'S AUCTION	%COMP ACCEPTED	% OVER SUBSCRIBED
07/30/90	88.66	68.84
07/23/90	83.70	68.84
07/16/90	83.81	65.27
07/09/90	82.95	61.19
07/02/90	82.55	74.78
06/25/90	81.69	66.28
06/18/90	85.75	74.16
06/11/90	82.37	66.21
06/04/90	83.31	73.28
05/28/90	84.16	70.46
05/21/90	83.14	71.63
05/14/90	79.34	74.10
05/07/90	81.39	65.77
04/30/90	88.25	70.19
04/23/90	81.56	64.87
04/16/90	82.60	69.03
04/09/90	79.76	71.75
04/02/90	81.42	70.05
03/26/90	80.63	63.53
03/19/90	84.54	71.00
03/12/90	80.00	71.11
03/05/90	82.26	69.76
02/26/90	83.38	96.18
02/19/90	81.30	67.59
02/12/90	87.59	66.44
02/05/90	80.59	75.73
01/29/90	87.37	82.31
01/22/90	81.13	64.91
01/15/90	82.45	69.86
01/08/90	80.94	68.53
01/01/90	82.88	71.41
12/25/89	85.50	62.76
12/18/89	87.27	68.94
12/11/89	83.81	66.04
12/04/89	84.44	62.65

DATE OF MONDAY'S AUCTION	%COMP ACCEPTED	% OVER SUBSCRIBED
11/27/89	85.01	59.65
11/20/89	83.10	68.82
11/13/89	81.54	67.74
11/06/89	84.70	71.05
10/30/89	93.96	79.08
10/23/89	83.47	67.62
10/16/89	85.27	66.71
10/09/89	81.91	67.56
10/02/89	82.85	73.26
09/25/89	84.69	68.98
09/18/89	87.92	71.26
09/11/89	72.63	69.71
09/04/89	83.29	72.11
08/28/89	83.14	67.49
08/21/89	83.69	66.75
08/14/89	81.49	74.43
08/07/89	81.54	71.34
07/31/89	76.71	77.02
07/24/89	78.29	69.36
07/17/89	81.17	73.43
07/10/89	79.88	69.23
07/03/89	80.28	74.07
06/26/89	81.96	74.07
06/19/89	84.81	73.10
06/12/89	80.23	79.10
06/05/89	80.19	79.21
05/29/89	81.92	71.26
05/22/89	82.03	69.77
05/15/89	76.02	73.16
05/08/89	80.72	72.23
05/01/89	81.85	70.54
04/24/89	82.00	65.64
04/17/89	82.00	68.98
04/10/89	78.85	72.84
04/03/89	79.14	68.86
03/27/89	82.58	71.03
03/20/89	85.60	73.55
03/13/89	79.73	68.06
03/06/89	79.63	79.73
02/27/89	80.69	72.53
02/20/89	80.39	72.07
02/13/89	92.06	74.87
02/06/89	81.07	69.74
01/30/89	80.52	70.12
01/23/89	81.32	69.22
01/16/89	81.49	70.78
01/09/89	77.11	74.86
01/02/89	81.58	75.05

DATE OF MONDAY'S AUCTION	%COMP ACCEPTED	% OVER SUBSCRIBED
12/26/88	84.77	69.81
12/19/88	87.29	71.95
12/12/88	82.74	74.68
12/05/88	82.18	74.81
11/28/88	84.27	74.42
11/21/88	82.46	76.48
11/14/88	84.50	67.82
11/07/88	83.91	70.27
10/31/88	83.42	73.86
10/24/88	84.37	71.18
10/17/88	86.83	75.59
10/10/88	82.51	70.08
10/03/88	84.00	74.58
09/26/88	87.16	68.58
09/19/88	90.12	75.90
09/12/88	84.69	76.15
09/05/88	85.53	69.62
08/29/88	85.20	69.81
08/22/88	85.59	71.50
08/15/88	34.49	93.03
08/08/88	83.20	72.44
08/01/88	82.60	70.78
07/25/88	84.75	68.46
07/18/88	86.29	79.67
07/11/88	82.61	73.70
07/04/88	83.58	82.07
06/27/88	86.27	73.46
06/20/88	90.51	72.52
06/13/88	83.37	75.09
06/06/88	84.83	75.29
05/30/88	84.57	76.20
05/23/88	85.06	76.81
05/16/88	83.39	77.44
05/09/88	83.00	73.09
05/02/88	83.72	75.08
04/25/88	84.46	71.05
04/18/88	86.20	76.46
04/11/88	81.32	75.73
04/04/88	84.31	76.88
03/28/88	86.67	74.01
03/21/88	91.22	72.90
03/14/88	82.27	77.64
03/07/88	83.94	78.70
02/29/88	84.03	76.92
02/22/88	86.24	74.27
02/15/88	80.70	68.91
02/08/88	81.33	77.21
02/01/88	82.37	74.28
01/25/88	81.95	77.58

DATE OF MONDAY'S AUCTION	%COMP ACCEPTED	% OVER SUBSCRIBED
01/18/88	74.56	71.68
01/11/88	79.59	77.98
01/04/88	82.74	70.50
12/28/87	89.36	72.26
12/21/87	91.08	71.77
12/14/87	85.03	71.56
12/07/87	85.89	68.23
11/30/87	85.71	69.81
11/23/87	85.01	69.60
11/16/87	84.84	77.92
11/09/87	84.15	74.52
11/02/87	81.62	68.24
10/26/87	82.05	68.36
10/19/87	88.45	67.50
10/12/87	81.85	65.93
10/05/87	81.82	69.83
09/28/87	84.48	71.65
09/21/87	0.00	0.00
09/14/87	84.66	73.39
09/07/87	85.72	71.82
08/31/87	84.33	77.32
08/24/87	86.01	74.59
08/17/87	85.37	73.68
08/10/87	85.08	74.07
08/03/87	83.09	79.22
07/27/87	91.14	73.50
07/20/87	0.00	0.00
07/13/87	84.01	72.91
07/06/87	83.72	75.11
06/29/87	86.53	81.89
06/22/87	85.86	75.00
06/15/87	84.58	76.96
06/08/87	84.10	74.54
06/01/87	84.06	75.00
05/25/87	83.40	71.69
05/18/87	83.44	70.15
05/11/87	82.72	68.36
05/04/87	82.54	70.78
04/27/87	83.21	69.79
04/20/87	82.68	77.35
04/13/87	81.54	74.44
04/06/87	80.98	79.90
03/30/87	83.84	73.98
03/23/87	84.32	76.59
03/16/87	82.72	73.32
03/09/87	83.94	78.40
03/02/87	82.73	77.41
02/23/87	84.89	77.74
02/16/87	83.07	78.11

DATE OF MONDAY'S AUCTION	%COMP ACCEPTED	% OVER SUBSCRIBED
02/09/87	85.46	80.01
02/02/87	83.77	84.22
01/26/87	85.42	75.40
01/19/87	84.58	81.22
01/12/87	83.54	80.14
01/05/87	8.37	-132.56
12/29/86	86.97	71.71
12/22/86	87.76	67.16
12/15/86	87.70	71.40
12/08/86	87.70	68.05
12/01/86	88.02	71.66
11/24/86	88.28	72.17
11/17/86	87.63	77.69
11/10/86	87.20	69.82
11/03/86	87.39	70.57
10/27/86	86.93	73.74
10/20/86	86.69	72.96
10/13/86	84.18	69.31
10/06/86	83.36	72.36
09/29/86	83.62	76.55
09/22/86	88.64	70.79
09/15/86	87.78	68.03
09/08/86	88.06	72.78
09/01/86	87.17	70.46
08/25/86	88.15	73.33
08/18/86	87.10	72.55
08/11/86	80.67	77.29
08/04/86	86.23	80.15
07/28/86	87.42	69.78
07/21/86	86.95	70.41
07/14/86	85.46	68.60
07/07/86	99.04	76.17
06/30/86	85.81	67.96
06/23/86	86.96	72.29
06/16/86	85.31	70.43
06/09/86	83.95	67.70
06/02/86	84.10	69.18
05/26/86	85.49	66.13
05/19/86	83.67	68.19
05/12/86	83.09	74.02
05/05/86	84.42	76.48
04/28/86	84.77	69.98
04/21/86	84.83	72.78
04/14/86	82.91	74.76
04/07/86	82.51	72.42
03/31/86	84.99	73.62
03/24/86	85.43	68.78
03/17/86	84.41	71.07
03/10/86	84.28	73.32

DATE OF MONDAY'S AUCTION	%COMP ACCEPTED	% OVER SUBSCRIBED
03/03/86	82.97	78.35
02/24/86	85.33	64.45
02/17/86	82.88	68.76
02/10/86	83.39	72.56
02/03/86	82.88	70.85
01/27/86	83.63	67.20
01/20/86	81.98	64.39
01/13/86	82.77	65.08
01/06/86	82.37	72.26
12/30/85	85.28	61.45
12/23/85	86.65	60.72
12/16/85	86.06	60.99
12/09/85	86.80	62.92
12/02/85	84.98	59.15
11/25/85	86.07	64.65
11/18/85	84.98	72.34
11/11/85	82.62	66.36
11/04/85	82.85	64.86
10/28/85	82.92	65.53
10/21/85	81.16	76.52
10/14/85	81.25	65.05
10/07/85	80.49	64.01
09/30/85	82.17	67.80
09/23/85	76.96	76.44
09/16/85	83.64	69.26
09/09/85	83.61	66.11
09/02/85	84.08	59.43
08/26/85	85.07	62.00
08/19/85	83.83	60.99
08/12/85	82.82	60.19
08/05/85	82.85	77.61
07/29/85	83.41	63.26

APPENDIX D

DAILY CHANGE IN THE FEDERAL FUNDS RATE

DATE OF MONDAY'S AUCTION	CHANGE IN FF M TO TU	CHANGE IN FF TU TO W	CHANGE IN FF W TO TH	CHANGE IN FF TH TO F	CHANGE IN FF FR TO M
07/30/90	NA	0.00	0.00	0.00	NA
07/23/90	-0.19	2.06	-2.00	0.00	0.13
07/16/90	-0.06	0.00	0.00	0.00	0.06
07/09/90	0.06	-1.38	1.31	-0.19	0.19
07/02/90	0.00	0.00	0.06	0.00	0.13
06/25/90	-0.13	-0.25	0.38	-0.88	0.88
06/18/90	0.06	-0.06	0.00	0.00	0.00
06/11/90	-0.06	3.81	-3.63	-0.06	-0.06
06/04/90	0.00	-0.06	0.13	0.00	-0.06
05/28/90	0.00	-1.00	1.06	0.00	0.00
05/21/90	0.06	0.00	0.00	-0.06	0.00
05/14/90	0.13	-1.38	1.25	0.00	0.00
05/07/90	-0.06	0.06	0.00	0.06	-0.06
04/30/90	-1.25	0.00	1.31	-0.06	0.00
04/23/90	-0.06	0.00	0.06	-0.13	0.13
04/16/90	-0.19	0.25	-0.25	-0.06	0.25
04/09/90	0.00	0.00	0.06	-0.50	0.44
04/02/90	-0.25	0.25	-0.25	-0.06	0.31
03/26/90	0.00	0.00	0.06	-0.25	0.19
03/19/90	-0.06	0.31	-0.25	-0.06	0.06
03/12/90	0.00	0.06	0.06	-0.13	0.00
03/05/90	0.00	0.63	-0.44	0.00	-0.19
02/26/90	-0.06	0.06	0.06	-0.19	0.13
02/19/90	0.00	0.19	-0.19	0.00	0.00
02/12/90	0.00	0.06	0.25	-0.31	0.00
02/05/90	-0.06	-0.13	0.19	0.06	-0.06
01/29/90	-0.06	0.06	0.00	-0.13	0.13
01/22/90	0.00	0.31	-0.25	0.00	-0.06
01/15/90	0.00	-0.13	-0.06	0.00	0.00
01/08/90	-0.06	-0.06	0.06	0.00	0.06
01/01/90	0.00	-0.25	-0.13	0.00	0.00
12/25/89	0.00	0.50	0.38	-3.13	0.00
12/18/89	-0.19	0.00	-0.19	-0.13	0.50
12/11/89	0.06	0.00	0.00	0.13	-0.19
12/04/89	0.00	-0.06	0.06	-0.13	0.13
11/27/89	-0.75	0.13	-0.19	-0.19	1.00
11/20/89	-0.06	-0.19	0.00	0.00	0.25
11/13/89	0.13	0.25	-0.19	-0.13	-0.06

DATE OF MONDAY'S AUCTION	CHANGE IN FF M TO TU	CHANGE IN FF TU TO W	CHANGE IN FF W TO TH	CHANGE IN FF TH TO F	CHANGE IN FF FR TO M
11/06/89	-0.25	0.00	0.00	0.00	0.25
10/30/89	0.19	0.06	-0.25	0.00	0.00
10/23/89	-0.06	0.13	-0.06	-0.06	0.06
10/16/89	-0.06	0.19	-0.19	0.06	0.00
10/09/89	0.00	-0.06	0.06	-0.13	0.00
10/02/89	-0.38	0.13	-0.13	-0.13	0.50
09/25/89	-0.19	0.06	0.50	-1.13	0.75
09/18/89	-0.13	1.00	-0.88	0.00	0.00
09/11/89	-0.06	0.00	0.06	0.06	-0.06
09/04/89	-0.06	-0.63	0.75	-0.06	0.00
08/28/89	0.00	0.00	0.13	0.00	0.00
08/21/89	0.06	1.50	-1.50	-0.13	0.06
08/14/89	0.06	-0.13	0.00	-0.06	0.13
08/07/89	0.00	0.69	-0.56	-0.06	-0.06
07/31/89	0.00	0.00	0.00	-0.06	0.06
07/24/89	0.00	-3.13	3.00	0.13	0.00
07/17/89	-0.06	0.00	0.00	-0.06	0.13
07/10/89	-0.13	0.50	-0.38	-0.19	0.19
07/03/89	0.00	0.25	-0.31	-0.19	0.00
06/26/89	-0.13	-0.13	0.25	-0.25	0.25
06/19/89	0.00	0.19	0.13	-0.38	0.06
06/12/89	-0.13	-2.25	2.88	-0.44	-0.06
06/05/89	-0.13	0.00	-0.06	-0.06	0.25
05/29/89	0.00	1.13	-1.13	-0.19	0.00
05/22/89	-0.06	0.06	0.00	-0.13	0.13
05/15/89	-0.44	0.75	-0.50	0.00	0.19
05/08/89	0.00	0.00	0.00	-0.06	0.06
05/01/89	-0.06	0.44	-0.25	-0.19	0.06
04/24/89	-0.06	0.06	0.00	0.06	-0.06
04/17/89	-0.44	4.50	-4.06	-0.13	0.13
04/10/89	-0.13	0.06	0.00	0.06	0.00
04/03/89	-3.38	-0.50	3.81	0.00	0.06
03/27/89	-0.06	0.00	0.06	0.00	0.00
03/20/89	-0.06	0.75	-0.56	-0.06	-0.06
03/13/89	0.00	0.13	-0.13	0.19	-0.19
03/06/89	-0.13	5.38	-5.19	0.00	-0.06
02/27/89	0.00	-0.06	0.00	-0.88	0.94
02/20/89	0.00	4.69	-4.31	0.06	0.00
02/13/89	0.13	0.13	-0.06	-0.19	0.00
02/06/89	0.50	1.25	-1.06	0.06	-0.75
01/30/89	0.00	-0.19	0.06	-0.06	0.19
01/23/89	-0.06	0.94	-0.81	0.00	-0.06
01/16/89	0.00	-0.31	0.13	-0.06	0.00
01/09/89	0.13	-0.25	0.19	-0.06	0.00
01/02/89	0.00	-1.00	-0.69	0.81	0.00
12/26/88	0.00	0.69	0.00	-3.13	0.00
12/19/88	-0.13	0.00	0.00	-0.88	1.00
12/12/88	-0.44	1.38	-0.25	-0.25	-0.44

DATE OF MONDAY'S AUCTION	CHANGE IN FF M TO TU	CHANGE IN FF TU TO W	CHANGE IN FF W TO TH	CHANGE IN FF TH TO F	CHANGE IN FF FR TO M
12/05/88	-0.13	-0.06	0.06	0.00	0.13
11/28/88	-0.56	na	na	-0.06	-0.19
11/21/88	0.00	-0.06	0.00	0.00	-0.13
11/14/88	0.25	-2.63	2.38	0.00	0.00
11/07/88	-0.06	0.00	0.00	0.00	0.00
10/31/88	0.00	0.19	-0.25	0.00	0.06
10/24/88	0.06	-0.19	0.06	0.06	0.00
10/17/88	-0.13	0.19	-0.19	-0.06	0.19
10/10/88	0.00	-0.13	0.06	0.31	0.00
10/03/88	-0.69	12.25	-11.69	-0.13	0.25
09/26/88	-0.06	0.00	0.31	0.00	-0.25
09/19/88	0.06	1.88	-1.75	-0.06	-0.13
09/12/88	0.00	0.00	0.13	-0.25	0.13
09/05/88	0.00	-0.13	0.63	0.00	0.00
08/29/88	0.00	0.00	0.13	-0.13	0.00
08/22/88	-0.25	0.25	0.25	-0.13	-0.13
08/15/88	-0.25	0.06	0.00	-0.13	0.31
08/08/88	-0.13	0.38	0.13	0.00	-0.38
08/01/88	-0.13	0.00	0.00	0.00	0.13
07/25/88	-0.19	-0.25	0.38	-0.06	0.13
07/18/88	-0.13	0.00	0.13	-0.13	0.13
07/11/88	-0.13	0.81	-0.50	0.06	-0.25
07/04/88	0.00	-0.06	-0.06	-0.13	0.00
06/27/88	-0.06	0.38	0.25	-0.50	-0.06
06/20/88	-0.19	0.13	0.06	-0.06	0.06
06/13/88	-0.13	2.75	-2.44	-0.13	-0.06
06/06/88	-0.13	-0.06	0.06	0.00	0.13
05/30/88	0.00	-0.13	-0.13	-0.06	0.00
05/23/88	-0.06	0.44	0.25	-0.50	-0.13
05/16/88	-0.69	-0.63	1.25	0.13	-0.06
05/09/88	0.00	-0.19	0.13	0.06	0.00
05/02/88	-0.38	0.13	0.38	0.06	-0.19
04/25/88	-0.13	0.50	-0.13	-0.25	0.00
04/18/88	0.25	1.25	-1.38	0.00	-0.13
04/11/88	-0.06	-0.13	0.06	0.25	-0.13
04/04/88	0.31	0.69	-0.63	-0.13	-0.25
03/28/88	-0.06	0.13	1.38	-1.25	-0.19
03/21/88	0.00	1.88	-1.63	0.00	-0.25
03/14/88	-0.13	-0.06	0.00	0.00	0.19
03/07/88	0.06	2.56	-2.38	0.00	-0.25
02/29/88	na	-0.13	-0.06	0.06	na
02/22/88	-0.13	0.25	-0.31	-0.06	0.25
02/15/88	0.00	-0.25	-0.13	0.06	0.00
02/08/88	-2.25	2.25	0.25	0.25	-0.50
02/01/88	0.00	-0.06	-0.25	0.00	0.31
01/25/88	-0.19	0.00	0.06	0.19	-0.06
01/18/88	0.00	-0.06	0.00	-0.13	0.00
01/11/88	-0.25	0.25	0.00	0.13	-0.13

DATE OF MONDAY'S AUCTION	CHANGE IN FF M TO TU	CHANGE IN FF TU TO W	CHANGE IN FF W TO TH	CHANGE IN FF TH TO F	CHANGE IN FF FR TO M
01/04/88	-0.13	-0.13	-0.19	0.00	0.44
12/28/87	0	0.00	0.00	0.00	7.13
12/21/87	-0.06	0.00	-0.06	0.00	0.00
12/14/87	0.00	-1.69	1.75	0.13	-0.19
12/07/87	-0.06	0.13	0.00	-0.06	0.00
11/30/87	-0.25	-1.00	0.88	-0.06	0.44
11/23/87	-0.13	0.00	0.00	0.00	0.19
11/16/87	-0.63	2.50	-2.19	-0.06	0.38
11/09/87	0.06	0.00	0.00	-0.06	-0.13
11/02/87	-1.88	-2.00	3.63	0.13	0.13
10/26/87	-0.63	-0.13	0.50	-0.38	0.63
10/19/87	-0.50	-0.25	0.75	-0.50	0.50
10/12/87	0.00	-0.19	0.25	-0.50	0.00
10/05/87	-0.13	0.19	0.25	-0.25	-0.06
09/28/87	0.00	0.50	0.25	-0.88	0.13
09/21/87	0.00	0.31	-0.50	0.00	0.00
09/14/87	0.13	-0.13	-0.13	0.06	0.06
09/07/87	0.00	-2.25	2.13	0.00	0.00
08/31/87	-0.06	-0.06	0.06	0.00	0.06
08/24/87	0.13	0.81	-0.88	-0.06	0.00
08/17/87	-0.25	0.00	0.06	0.00	0.19
08/10/87	-0.19	0.50	-0.25	0.25	-0.31
08/03/87	-0.06	-0.06	0.00	-0.13	0.25
07/27/87	-0.06	0.31	-0.13	0.00	-0.13
07/20/87	-0.13	0.00	0.13	0.06	-0.06
07/13/87	-0.75	0.88	-0.19	0.19	-0.13
07/06/87	0.00	-0.06	0.19	-0.19	0.06
06/29/87	0.00	-1.50	1.69	0.00	0.00
06/22/87	-0.19	0.06	0.06	-0.31	0.38
06/15/87	-0.13	0.06	0.00	-0.06	0.13
06/08/87	-0.13	0.13	0.00	0.06	-0.06
06/01/87	0.31	0.00	-0.25	-0.06	0.00
05/25/87	0.00	-0.25	-0.13	0.00	0.00
05/18/87	-0.13	0.50	-0.38	0.13	-0.13
05/11/87	-0.06	-0.06	0.13	-0.13	0.13
05/04/87	-0.06	0.13	-0.25	0.00	0.19
04/27/87	-0.25	1.25	-0.25	0.00	-0.75
04/20/87	-0.13	0.69	-0.50	0.00	-0.06
04/13/87	-0.06	0.00	-0.31	0.13	0.25
04/06/87	0.13	0.38	-0.38	0.13	-0.25
03/30/87	-0.13	0.25	-0.19	-0.13	0.19
03/23/87	0.00	0.31	-0.25	-0.06	0.00
03/16/87	-0.13	-0.06	0.25	0.06	-0.13
03/09/87	-0.13	0.00	0.06	0.00	0.06
03/02/87	-0.13	0.00	0.06	-0.06	0.13
02/23/87	0.00	0.00	0.00	0.13	-0.13
02/16/87	0.00	-0.63	-0.06	-0.06	0.00
02/09/87	-0.06	-4.25	4.13	0.00	0.19

DATE OF MONDAY'S AUCTION	CHANGE IN FF M TO TU	CHANGE IN FF TU TO W	CHANGE IN FF W TO TH	CHANGE IN FF TH TO F	CHANGE IN FF FR TO M
02/02/87	-0.31	-0.19	0.13	0.25	0.13
01/26/87	0.00	0.69	-0.44	0.13	-0.38
01/19/87	0.00	-0.13	0.13	-0.19	0.00
01/12/87	0.00	-3.19	3.00	0.00	0.19
01/05/87	-0.56	-0.25	0.00	0.00	0.81
12/29/86	6.75	-15.50	0.00	0.00	2.75
12/22/86	-0.13	-0.13	0.00	0.00	-0.13
12/15/86	-0.13	1.06	-1.19	-0.06	0.31
12/08/86	-0.06	-0.06	0.06	0.13	-0.06
12/01/86	-2.00	1.00	-1.00	-0.13	2.13
11/24/86	0.00	0.00	0.00	0.00	-0.25
11/17/86	-0.13	3.94	-3.81	-0.31	0.31
11/10/86	0.00	0.00	-0.06	0.00	0.06
11/03/86	-0.19	2.69	-2.50	-0.19	0.19
10/27/86	-0.25	0.06	0.31	-0.25	0.13
10/20/86	0.00	1.44	-1.13	-0.38	0.06
10/13/86	0.00	-0.06	0.00	0.00	0.00
10/06/86	-0.63	1.00	-0.13	-0.13	-0.13
09/29/86	0.13	0.13	-0.19	-0.44	0.38
09/22/86	-0.25	0.63	-0.38	0.06	-0.06
09/15/86	-0.13	0.00	-0.06	-0.06	0.25
09/08/86	0.13	0.88	-0.88	-0.06	-0.06
09/01/86	0.00	-0.13	0.00	0.00	0.00
08/25/86	-0.13	0.06	0.00	-0.06	0.13
08/18/86	0.06	-0.19	-0.19	-0.25	0.56
08/11/86	-0.06	-0.44	0.69	0.56	-0.75
08/04/86	0.00	0.06	0.00	0.06	-0.13
07/28/86	-0.06	0.06	0.06	-0.13	0.06
07/21/86	-0.13	0.00	0.00	0.13	0.00
07/14/86	0.06	0.00	0.06	-0.25	0.13
07/07/86	-0.06	-0.13	0.06	-0.56	0.69
06/30/86	-0.38	0.25	-0.56	0.00	0.00
06/23/86	-0.06	-0.69	0.81	-0.19	0.13
06/16/86	-0.19	0.19	0.00	-0.06	0.06
06/09/86	-0.19	0.06	0.00	0.00	0.13
06/02/86	-0.13	0.50	-0.44	-0.06	0.13
05/26/86	0.00	-0.31	0.00	0.06	0.00
05/19/86	0.00	0.06	0.13	-0.13	-0.06
05/12/86	-0.06	-0.06	0.38	-0.19	-0.06
05/05/86	-0.06	-0.19	0.38	-0.06	-0.06
04/28/86	0.13	0.56	-0.50	-0.31	0.13
04/21/86	-0.13	0.00	-0.06	-0.13	0.31
04/14/86	0.00	0.00	-0.25	0.13	0.13
04/07/86	0.00	0.00	0.06	-0.13	0.06
03/31/86	0.06	-0.56	0.31	-0.56	0.75
03/24/86	0.00	-0.13	0.25	-1.00	0.88
03/17/86	0.00	-0.25	0.13	-0.19	0.31
03/10/86	0.13	0.31	-0.38	-0.25	0.19

DATE OF MONDAY'S AUCTION	CHANGE IN FF M TO TU	CHANGE IN FF TU TO W	CHANGE IN FF W TO TH	CHANGE IN FF TH TO F	CHANGE IN FF FR TO M
03/03/86	-0.13	0.13	-0.13	-0.38	0.50
02/24/86	-0.13	0.00	0.13	0.00	0.00
02/17/86	0.00	-0.50	0.13	-0.19	0.00
02/10/86	0.94	-1.00	-0.06	-0.31	0.44
02/03/86	-0.44	0.31	-0.06	0.06	0.13
01/27/86	-0.25	0.00	0.38	0.00	-0.13
01/20/86	0.00	-0.38	0.13	-0.13	0.00
01/13/86	0.00	-2.00	1.88	0.00	0.13
01/06/86	0.00	-0.06	0.19	-0.13	0.00
12/30/85	-4.50	0.00	0.00	-1.63	na
12/23/85	-0.25	0.00	0.00	-1.00	1.25
12/16/85	-0.56	2.06	-1.63	0.00	0.00
12/09/85	-0.06	-0.06	0.06	-0.06	0.13
12/02/85	-0.75	0.13	-0.38	-0.25	1.25
11/25/85	-0.13	1.25	0.00	0.00	-1.63
11/18/85	-1.38	4.00	-1.88	-1.63	0.88
11/11/85	0.00	-0.25	0.38	0.13	0.00
11/04/85	0.00	0.25	-0.25	-0.25	0.25
10/28/85	-0.13	0.50	0.06	-0.19	-0.25
10/21/85	0.00	0.38	-0.38	-0.38	0.38
10/14/85	0.00	-0.50	0.13	0.13	0.00
10/07/85	0.00	0.38	0.00	0.13	-0.50
09/30/85	-1.50	-1.13	0.13	-0.38	2.88
09/23/85	-0.19	0.69	-0.63	-0.63	0.75
09/16/85	-0.13	0.06	0.63	-0.50	-0.06
09/09/85	0.19	0.19	-0.13	0.00	-0.25
09/02/85	0.00	-0.75	0.25	-0.13	0.00
08/26/85	0.13	-1.00	0.88	0.25	-0.25
08/19/85	-0.38	0.13	0.25	-0.25	0.25
08/12/85	0.19	0.63	0.00	-0.56	-0.25
08/05/85	-0.06	-0.06	0.06	-0.19	0.25
07/29/85	0.00	0.00	8.38	-0.75	NA

APPENDIX E

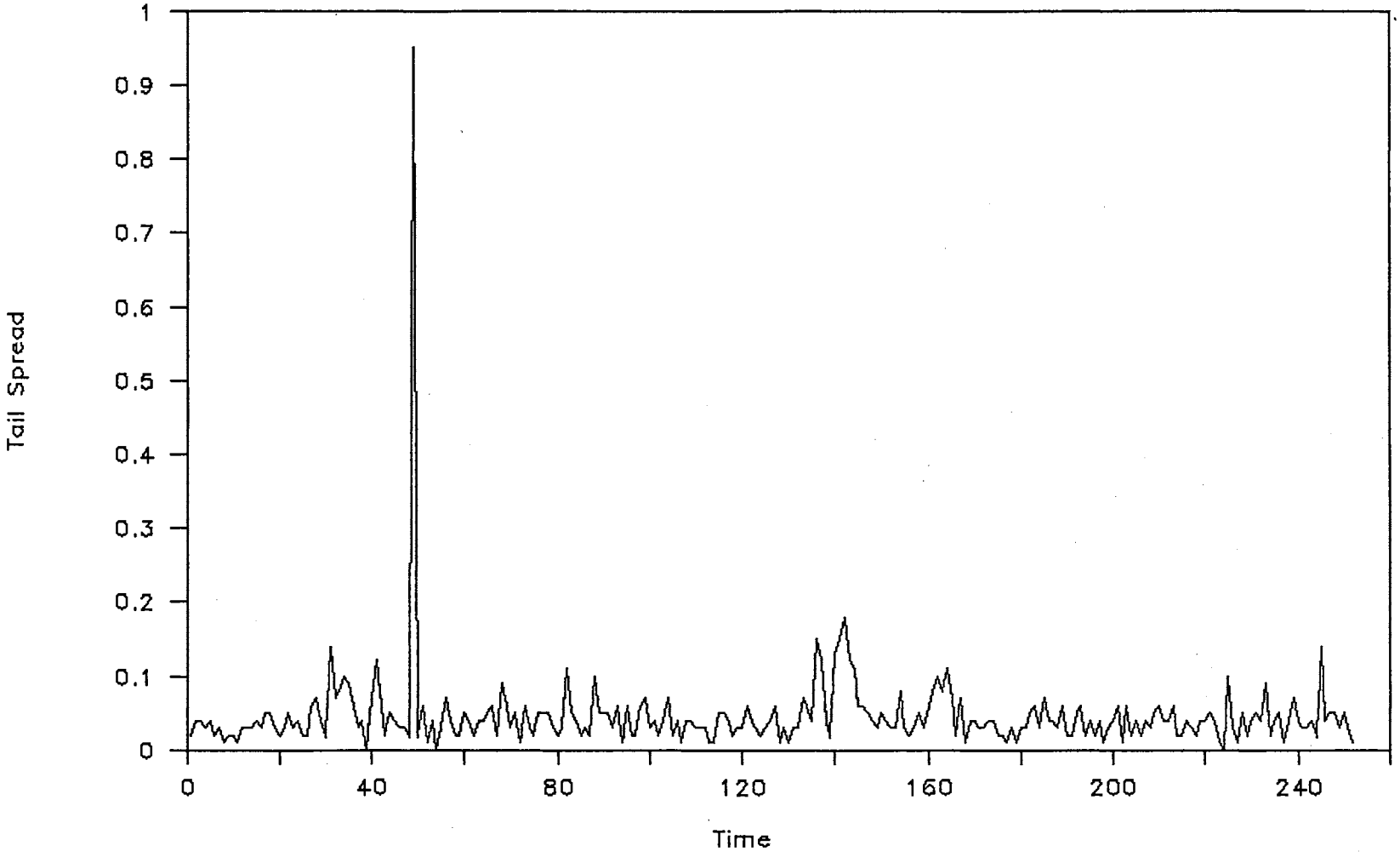

Figure 1. Time Series of the Tail Spread

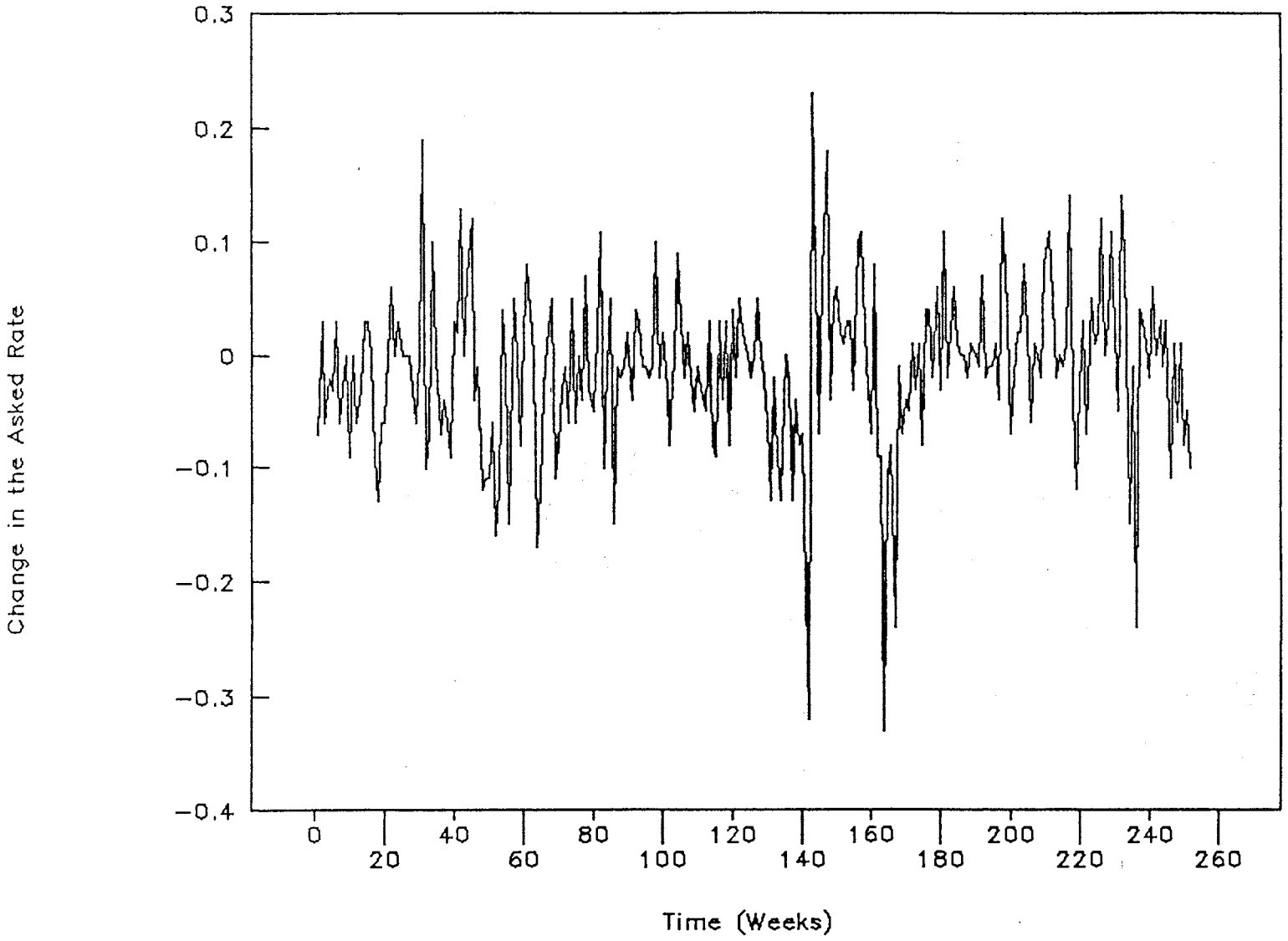

Figure 2. Time Series of the Change in the Asked Rate

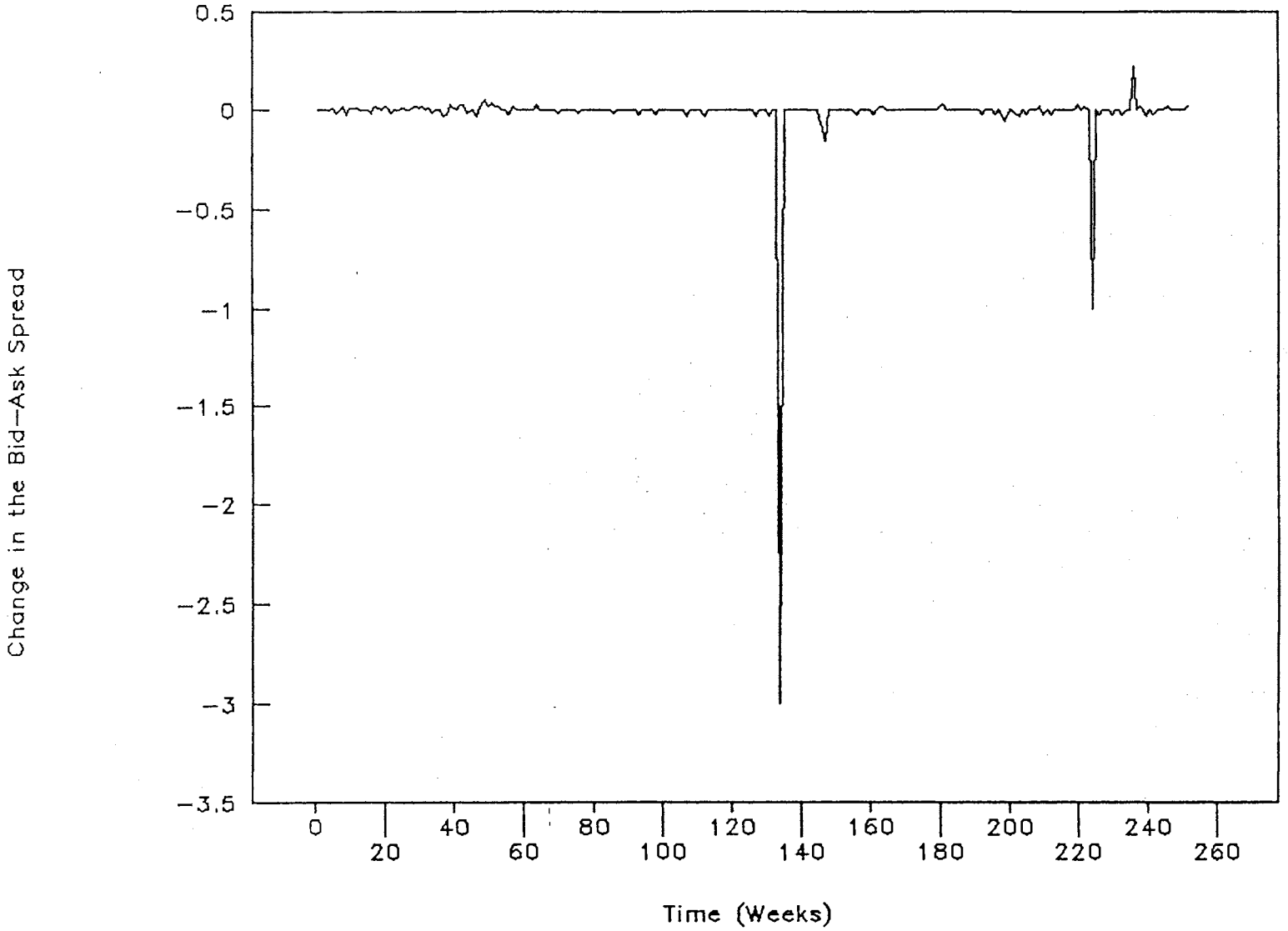

Figure 3. Time Series of the Change in the Bid-Ask Spread

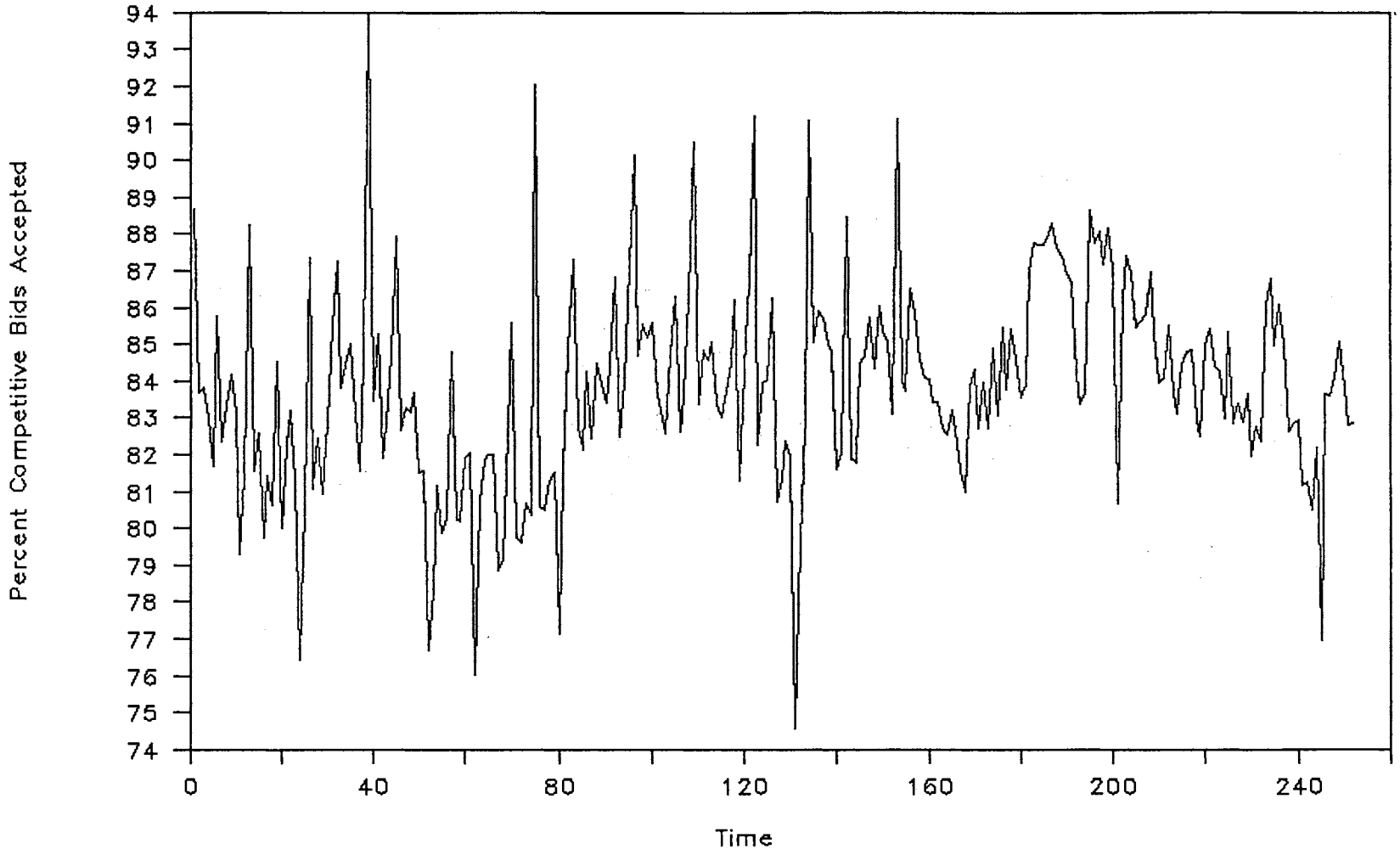

Figure 4. Time Series of the Percent Competitive

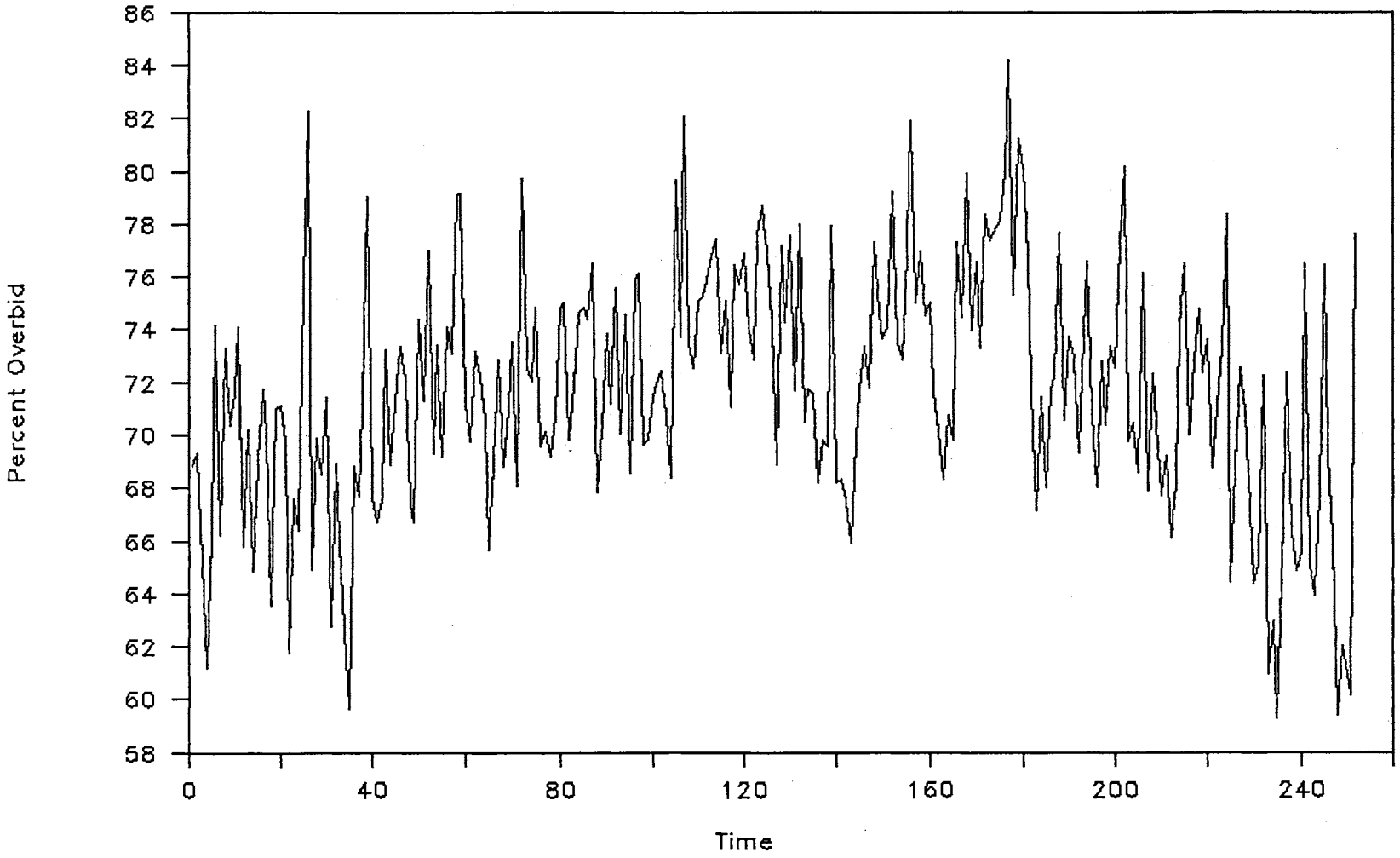

Figure 5. Time Series of the Percent Overbid

2

VITA

Peppi Bymaster Kenny

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