THE EFFICIENCY OF FINANCIAL

FUTURES MARKETS

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PREFACE

The idea that unfettered markets are necessary for efficient selection, production, and distribution of goods is as common to most economists as it is foreign to others. Most people believe in a fair price, fixed by the moral laws of nature, ungoverned by the revealed preferences of men. Many are convinced that the items they own are underpriced, while the opposite is true of the items they desire. Many believe that the ill effects of market restrictions are small and temporary, for free markets do not trumpet their beneficence any more than do electrons proclaim their existence. The benefits of free markets are buried from plain sight, are only with difficulty uncovered. The consequences of interference with them, as of with electrons, can sometimes be devastating.

That we do not more often abandon free markets is more remarkable than the enumeration of their restriction. Perhaps an untapped approach to the biography of mankind might concentrate on the episodic establishment and disestablishment of free markets; on the factors that have lead to the emplacement of restrictions on markets, given the ever present desire to do so; and on the principles that have allowed the relaxation of those restrictions. For the birth of market restrictions is rare enough to be newsworthy, while the brevity of their existence allows convenient study. The historical record with regard to free markets is that we cannot be long without them. In light of the services they render, this is of no small comfort.

The report that follows attempts to measure the degree to which three futures markets approach pricing perfection. Such measurement is possible because futures are entirely derivative assets, being only rights to buy or sell an underlying asset during a specific interval of time. Of all possible alternatives, it is easiest to identify the proper price of derivatives. Even here, it is not a trivial enterprise. The right to buy an asset is not exactly equivalent to the actual purchase of an asset, and a composite asset having most of the characteristics as another asset is not the other asset. The only perfect equivalent to a can of peas is another can of peas, of the same brand, of the same age, on the same shelf, at the same store, at the same time. All else is substitution. But within very small tolerances, the markets studied in this investigation perfectly price their commodities.

The implications of the Efficient Markets Hypothesis are extremely important, although too numerous to begin to recount here, bearing on questions from macroeconomic policy to securities regulation to investment counsel. Also numerous are the people who helped form and stimulate my interest in markets. Some of them are many years departed: Diocletian, with his edicts to control prices (he failed, or course); Adam Smith, with his Laffer curves; Maynard Keynes, with his elegant prose and imaginative analysis; Don Patinkin, with his elegant analysis and imaginative prose; Richard Nixon and Jimmy Carter, with their phases and entitlements to control prices (they failed, of course).

No one can name those to whom he is intellectually indebted. To try is at once exhausting in scope and humbling in contemplation. But I would like to at least thank those of most recent recall:

First, and paramount, my parents, Ralph C. Gamble, and Eloise Gamble, for their gentle encouragement, stimulating conversation, and demonstration in so many ways that devotion to duty is the primary attribute of humanity, and the requisite of love;

my very dear wife, Loretta, and daughter, Adria, for their forbearance of an absent husband and father, lost again in economic abstraction, who

my collegues in the Economics and Finance department at Fort Hays State University, Preston Gilson, Len Martien, Carl Parker, Bill Rickman, Dan Rupp, and Jack McCullick (still at heart an economist), for their fellowship and fraternity, and for their demonstration that diversity is strength;

my professors at Oklahoma State University, Janice and Joe Jadlow, Richard Leftwich, Michael Edgmand, Kent Olson, Ron Moomaw, Rudolf Trenton, Gerald Lage, and John Rea, for many hours of classroom delight;

my dissertation committee, Mary Gade, Ed Price, and John Wingender, for their efforts on my behalf;

and my dissertation committee chairman, Frank Steindl, who most cheerfully gave so generously of his time and insight in order to bring this project to fruition. His care and clear vision have imbued this work with any quality it may contain. To him I dedicate this work. May his desk ever be cluttered with effusions of praise from grateful students;

To these and more - my sincere thanks and appreciation.

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CHAPTER I

INTRODUCTION

The existence of informational efficiency in financial markets is an important issue. If financial futures markets are efficient, then there is little need to worry about the degree of regulation they enjoy. The effect of over-regulation is to make the market over-safe, with returns efficiently skewed toward the over-volatile investments that remain. If financial markets are efficient, then the activities of arbitrageurs yield the socially convenient virtue of providing liquidity to the market. If financial markets are efficient, then investors can economize on their purchases of special information, forecasts, techniques, tips, reports, and services in efforts to earn greater than normal rates of return at lower risk than that required by such return. If financial markets are efficient, then we need not fear the consequences of the introduction of new financial instruments, different systems of dispensing financial intermediation, new participants in financial markets, but can welcome them.

Tests of the efficiency of financial futures markets may provide some evidence on the efficiency of financial markets in general. Certainly, if some participants in financial futures willingly provide liquidity services to others by buying some of the risk inherent in investing, one or both parties is better off. This is an inescapable conclusion of voluntary exchange. If, however, financial futures markets increase the level of risk in the process of allocating that risk, it is possible that greater regulation might result in higher overall welfare.

With regard to Treasury bill futures, the market is efficient, according to some studies, since no arbitragable profits exist. For instance, Poole (1978), Dale and Workman (1981), and Dale (1981) find the bill futures market to be efficient. According to others, the market is only quasi-efficient, since portfolio returns can be enhanced by the use of the bill futures market, even though transactions costs make arbitrage unprofitable. Studies by Rendleman and Carabini (1979) and Cornell (1981) find this type of partial efficiency. Still others maintain the inefficiency of the market, since profits available through arbitrage exist for an appreciable time, and are not quickly eliminated. Examples of studies that purport to show the inefficiency of the market are those by Puglisi (1978), Capozza and Cornell (1978), Lang and Rasche (1978), Vignola and Dale (1979), Elton, Gruber and Rentzler (1984), and Monroe and Cohn (1986).

However, none of these studies has properly accounted for a risk differential inherent in ownership of a bill-futures combination. The time path of actual returns from the combination has a different distribution than that of the bill itself. This risk differential has not been accounted for by any previous test methodology employed on the financial futures markets. The differential in the returns distribution is able to explain a good deal of the apparent arbitrage profit that the market does not quickly eliminate. This means that what appears to be uncaptured arbitrage profit may be entirely due to the risk premium paid to owners of the more variable instrument. In other words, all previous studies which have found the Treasury bill futures market to be inefficient are at best inconclusive, and at worst incorrect.

What is true for the bill futures market is more forcefully so for the Treasury note and Treasury bond futures markets. However, there have been few attempts to test for the efficiency of these markets, for two reasons. First, it is more nearly obvious in the bond and note complexes that the arbitrage involves instruments having different characteristics. Second, the bond and note futures contracts do not require the delivery of a unique instrument. Unlike the bill futures contract, which requires the delivery of a specific bill in contract fulfillment, the bond contract allows the delivery of any Treasury bond having at least 15 years remaining to maturity or earliest call. The note contract allows the delivery of any Treasury note having 6 1/2 to 10 years remaining to maturity or call. Since an arbitrage requires the sale of an asset in one market and its offsetting purchase in another, the bond and note contracts do not facilitate arbitrage.

The purpose of this study is to examine properly the hypothesis of financial market efficiency, concentrating on three financial futures markets; the Treasury bill futures contract of the Chicago Mercantile Exchange, and the Treasury note and Treasury bond futures contracts of the Chicago Board of Trade. Chapter II presents the theory of interest rate arbitrage, as applied to the futures markets. The results from the literature are summarized in Chapter III. Chapter IV is a presentation of empirical findings. Chapter V is a summary.

CHAPTER II

THEORY OF EFFICIENT MARKETS

Informational Efficiency

The notion of market efficiency is closely related to the concept of rational expectations, although somewhat easier to describe than to specify. In general, a market is efficient in pricing an item if currently available information cannot be used to gain larger than normal profits from <u>future</u> prices of the item. Clearly, the operative words in the definition are adjectives, not nouns, hence the difficulty in specification.

Abnormally large profits occur when the rate of return exceeds the opportunity cost of the capital at risk. This concept is indistinguishable from that of economic profit. In terms of investments, the opportunity cost of capital at risk depends on the characteristics of the investment. To the extent that those characteristics are identifiable by theoreticians and testable by econometricians, they are based on the maximization of expected utility given the expected distribution of returns.[1] The attributes that are assumed to matter to investors are expected return and absence of risk.

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[1] See Hirschleifer (1961) for the classic article using indifference curves, and Friedman-Savage (1948) using total utility curves.

Risk

According to Robichek (1969; 513-514) risk "relates to the possibility that actual returns may vary from expected returns." There are numerous reasons for this, ranging from war, lightning, flood, and pestilence downward in severity and upward in likelihood. Intuition might indicate that investors are concerned only when actual returns turn out to be lower than expected returns. But in investment theory, risk is typically modelled in the literature as the variance.[1]

That this is so can be seen from the capital asset pricing model [CAPM] developed by Sharpe, Markowitz, Lintner, Fama and others. In Sharpe (1964), the underlying utility function is given as

$$U = \Phi(E_W, \beta_W),$$

where E_W is the expected value of future wealth, and β_W is the predicted standard deviation of the possible divergence of actual future wealth from E_W. Utility is assumed to increase with greater E_W and decrease with greater β_W. In CAPM, this proxy for risk is used in the sense of total risk, since investors are able, through diversification, to combine individually risky securities whose variances are at least somewhat unrelated to that of other securities to decrease the total variance of the portfolio. The set of <u>efficient</u> portfolios is that set of portfolios which offer the least variation,

[1] Markowitz for one has recognized the dichotomy of investor concern with regard to actual outcomes versus expected returns, suggesting the semi-variance as the proper measure of riskiness. See Sharpe (1964; 427). There was quite a lively debate as to the statistical measure of the appropriate proxy for risk. According to Fama (1968; 30), Tobin (1958) showed that "the mean-standard deviation framework is appropriate whenever distributions of returns on all assets and portfolios are of the same type and can be fully described by two parameters." But Fama was concerned that investment returns seemed to be distributed as members of the stable Paretian class, of which the only one with finite variance is the normal. The argument turned out a sterile victory for Fama - the standard deviation still models risk today.

given expected return, and/or maximum return, given expected variation.[2] Efficient portfolios are, in addition, perfectly correlated and perfect substitutes.[3] According to CAPM, the existence of a riskless lending/borrowing opportunity, together with the set of efficient portfolios, implies that, in equilibrium, the expected return of a risky asset i, $E(R_i)$, as a member of the market portfolio (M) of all existing securities will be

$$E(R_i) = R_F + \lambda \operatorname{cov}(R_i, R_M),$$

where R_F is the risk-free return rate, R_M is the return rate on the market portfolio in equilibrium[4], and λ is

$$[E(R_M) - R_F][1/\beta 2(R_M)],$$

where $\beta 2(R_M)$ is the variance of the market portfolio itself.

This is the basic equation for the testing of hypotheses regarding efficient markets. Since, in a market portfolio of many assets, the term λ does not depend more than trivially on asset i, λ can be considered invariant with respect to E(Ri). The equation is often put in terms of a risk premium equation:

$$E(R_i) - R_F = \lambda \operatorname{cov}(R_i, R_M),$$

in order to show that the differences in risk premia for various assets, when held in equilibrium, depend only on their covariation with the market portfolio. According to Fama, "The coefficient λ can be thought of as the

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[2] Here the word "efficient" is used in the sense of performance; an efficient portfolio yields best return performance given risk, and vice versa.

[3] See Fama (1968: 33-35). The word "efficient" is here used in the sense of fulfilling the boundary condition. The marginal rate of transformation of risk for expected return required for asset substitution is equal to the marginal rate of substitution along (homogeneous) investors' indifference curves.

[4] If the market is efficient, then it will be in equilibrium at all times, excepting the time taken for the receipt of unexpected information to be absorbed.

market price per unit of risk so that the appropriate measure of the risk of asset i is $cov(R_i,R_M)$."[5]

Jensen (1969), by introducing the relative risk concept, is able to show that his famous "beta",

$$\beta_j = [cov\ (R_j,R_M)]/[\beta 2(R_M)],$$

is the proper benchmark for the performance of portfolios, since it indicates the riskiness of portfolios relative to the (efficient) market portfolio. If the portfolio is the market portfolio of all existing securities, then

$$\beta_M = [cov\ (R_M,R_M)]/[\beta 2(R_M)] = [\beta 2(R_M)]/[\beta 2(R_M)] = 1.$$

Jensen's insight allows the expected return formulation of Sharpe-Lintner to be rewritten as

$$E(R_j) = R_F + \beta_j[E(R_M) - R_F],$$

or in an *ex post* sense, to measure the performance of portfolio j by whether or not the actual return is significantly above its expected value,

$$E(R_j) = R_F + \beta_j[R_M - R_F].$$

It is therefore immediately apparent that traders and portfolio managers ought to be able to earn greater positive returns than the value-weighted average of positive returns (the market return, R_M) by choosing portfolios of greater total risk than that of the market portfolio. But it is just as apparent that those more volatile portfolios will have lower negative returns when R_M happens to be negative. It is the return on the asset or portfolio after adjustment for risk that properly measures performance.

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[5] Fama (1968; 35).

Can traders and portfolio managers earn greater than normal returns, given the riskiness of their selections, by buying and selling, or diversifying and leveraging, and thus varying the riskiness of their portfolios at the "right" times? Not if the market efficiently processes new information, which is to say, if prices incorporate new knowledge concerning the relative riskiness of assets. Mandelbrot and Samuelson, says Jensen, have "rigorously demonstrated that prices in such a market will follow a submartingale."[6]

This means that an efficient market so incorporates past information in present prices that no useful clue remains to suggest the course of prices yet to come. The best estimate of future prices is today's price plus any prospective normal return. In terms of conditional expectation,

$$E[P(t+\tau) \mid \Phi(t)] = \phi(\tau)\, P(t),$$

where $E[P(t+\tau)]$ is the expected value of the future price of the asset at time $t+\tau$, $P(t)$ is the price today, $\phi(\tau)$ is a growth function, and $\Phi(t)$ is the set of information known at time t.[7] If $\Phi(t)$ includes only the series of past prices of the asset, the efficiency hypothesis is known as the weak form; if $\Phi(t)$ includes all public information disclosed up to time t, the hypothesis is semi-strong; and if $\Phi(t)$ includes all information extant at time t, the hypothesis is known as the strong form of the efficient market hypothesis.[8] Obviously, the strong form of the efficient market hypothesis is not testable.

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6 See Jensen (1969; 168).

7 See Jensen (1969; 169). In the special case where $\phi(\tau) = 0$, $E[P(t+\tau))$ is a random walk with no drift.

8 Again, see Jensen (1969; 170). Jensen is usually credited with the weak and strong efficient market dichotomy; but Jensen credits "Harry Roberts, who used it in an unpublished speech entitled 'Clinical vs. Statistical Forecasts of Security Prices,' given at the Seminar on the Analysis of Security Prices sponsored by the Center for Research in Security Prices at the University of Chicago, May, 1967." See Jensen (1969; 170, footnote).

From the above discussion, it is apparent that any empirical investigation which merely demonstrates the existence of a profitable albeit risky investment strategy fails to adequately test the Efficient Markets Hypothesis. Empirical work must always take into account any difference in risk, for what may appear to be profit from an investment strategy, trading rule, or information acquisition may in fact be a premium due to extraordinary risk.

The same is true for a Treasury instrument futures market. If returns from a "security" composed of a futures position in combination with a Treasury instrument are more variable than those from its real equivalent, then a premium for differential risk is in order. If we let the return on the artificial instrument, β_A, be equal to the return on Jensen's asset j, and that of the market portfolio the real equivalent, then

$$\beta_A = [\mathrm{cov}\ (R_A, R_R)]/[\beta 2(R_R)],$$

and

$$E(R_A) = R_F + \beta_A[E(R_R) - R_F],$$

where β_A is the relative risk "beta" of the artificial instrument, $\beta 2(R_R)$ is the variance of the real equivalent, $E(R_A)$ is the expected or *ex ante* rate of return on the artificial bill, and R_F is the rate of return on the risk free alternative of the Sharpe-Lintner model.

Interest Rate Arbitrage

Treasury Bills

A lender can provide short term funds to the federal Treasury in several different ways. One of them is to purchase a Treasury bill, hold it until maturity or earlier, and receive cash upon its maturity or sale. Barring default by the Treasury, a specific return is guaranteed only at maturity. If the bill is sold before maturity, short term interest rates may have risen, and the price will be lower than expected. The result will be a low or perhaps negative realized yield.

For example, if the short-term interest rate is 7%, a one million dollar 91-day bill may be purchased for $982,305.56, but will fetch only $982,250.00 twenty days hence if, in the interim, the short-term interest rate has risen to 9%.[9] On the other hand, if the short-term rate has fallen instead of risen, the bill will actually yield more than expected. In the instance above, if twenty days has seen a fall of 50 basis points, then the bill can be sold for $987,180.56, for an actual yield of 9.1% annually over the twenty day period.

The analysis applies to all instruments outstanding; an investor may as easily lend for 20 days by holding a 20-day instrument until maturity, a 90-day instrument for 20 days, or an 7-year instrument for 20 days. Only the former guarantees the investor a certain yield, and only then if the investor does not require cash prior to maturity. However, this is true only because the selling price of the instrument is fixed. By virtue of its maturity, it returns exactly $1,000,000. Were the selling price of another instrument to be fixed at some future date, then its yield would also be certain on that date. In effect, a Treasury instrument futures contract

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[9] The price (P) of a $1 million Treasury bill is:
$P = \$1{,}000{,}000[1 - (dt/360)]$
where d = the bankers' discount yield, or rate of discount, and
t = the number of days to maturity.
It can be seen by inspection that P remains the same if the percentage-change in d and t are equal in value and of opposite sign. See Stigum (1981; 28).

performs the function of fixing the future price of a particular instrument at a date prior to its maturity.

A long position in a Treasury bill futures contract is a promise to purchase, at the expiration of the contract, a $1 million bill of 91-day maturity. The value of the contract is the price of the bill, discounted at the current bankers' discount yield. Were the discount yield to be higher (lower) at contract expiration, the bill's price would be lower (higher), and so would the value of the contract, by the same dollar amount. Thus a long position guarantees the future purchase price of the bill to be delivered at a price determined today. While it is common to refer to a long futures position as guaranteeing a specific yield to future investors, it does not. Only an investor holding the purchased instrument to maturity is guaranteed a specific yield.

A short position in a Treasury bill futures contract is a promise to sell, at the expiration of the contract, a $1 million bill of 91-day maturity. The value of the contract is the price of the bill, discounted at the current bankers' discount yield. Were the discount yield to be higher (lower) at contract expiration, the bill's price would be lower (higher), and so would the value of the contract, by the same dollar amount. Thus a short position guarantees the future sale of the bill to be delivered at a price determined today. In other words, the short side of the futures contract, by fixing the sale price of the for-delivery instrument, guarantees a specific yield - for current owners of the instrument who do not require cash prior to contract expiration. And by a simultaneous purchase of a for-delivery instrument and futures contract short, an artificial instrument is created that "matures" with certain yield at contract expiration.

For example, suppose a Treasury bill futures contract expires in 22 days, and that a Treasury bill exists which matures in 113 days. This is the delivery bill for a Treasury bill futures contract. Since the bill discount is fixed by virtue of the hedge, so is the yield on the 113-day bill held for 22 days. An instrument consisting of the 113-day bill and a short futures position taken on the same day therefore has 22 days to maturity.

Suppose another Treasury bill exists which matures in 22 days. An investor taking a long futures position and simultaneously buying the 22-day bill would have created an artificial instrument having 113 days to maturity.[10]

Thus an investor can be certain of a specific 22-day yield in two ways; by purchasing the 22-day bill and holding it to maturity, or by purchasing the 113-day bill and entering a short futures position. An investor can also be certain of a specific 113-day yield in two ways; by purchasing the 113-day bill and holding it to maturity, or by purchasing the 22-day bill and entering a long futures position.

In general, if X is the number of days until maturity of an instrument or until the expiration of a futures contract requiring the delivery or acceptance of an N period instrument, the positions and durations of the real and artificial instruments are as shown in Table 1, where the equivalent strategy involving the creation of an artificial bill is noted "A".

[10] In brokers' parlance, this is a "strip;" the previous instrument - short positioning a bill for delivery - is a "strap."

TABLE 1

COMPOSITION AND TIME TO MATURITY OF TREASURY BILL STRATEGIES

Strategy	Position	Maturity
I	Long an X day instrument	X days
IA	Long an X+N day instrument, and Short a futures contract	X days
II	Long an X+N day instrument	X+N days
IIA	Long an X day instrument, and Long a futures contract	X+N days

Since the artificial instrument and the real instrument both return fixed dollar amounts on the same day, and are held for the same interval, their after-transactions-costs yields should also be equal. This is the basis for an arbitrage in Treasury bills. If the real instrument yield exceeds that of the artificial instrument (after transactions costs), then it can be purchased, and the artificial instrument simultaneously sold, for a profit. On the other hand, if the artificial instrument yield (after transactions costs) exceeds that of the real instrument, then simultaneous artificial instrument purchase and real instrument sale results in a profit. The capture of arbitrage profits removes any difference between the real instrument yield and the artificial instrument yield. By the Law of One Price, then, the two yields must be equal. If they are not, then arbitrage profits remain uncaptured, and the market is presumed inefficient. This is the basis of previous investigations of the efficiency of the Treasury bill futures market.

However, arbitrage tests are valid only if the instruments are identical, or else perfect substitutes. They are not, of course, identical since one of them contains a futures position, while the other does not. Whether or not they are practical equivalents is an empirical issue. The degree of substitution cannot be settled on *a priori* grounds. It is therefore fallacious first to assume perfect substitutability, predict equal yields, demonstrate nonequality of yields, and thereby infer inefficient markets.

In terms of the strategies of Table 1, if the market is perfectly efficient, and if risk is equivalent vis-a-vis the two equivalent strategies, then the yield from lending via Strategy I will be set equal to that from Strategy IA, and the yield from lending via Strategy II equal to that from Strategy IIA. If the yields are momentarily not equal, then profit can be earned by simultaneously buying the strategy with the higher yield (lower price) and selling the strategy with the lower yield (higher price). The profit will be realized when and if the yields (prices) again become equal.

As an example, assume that X is 80 days. A $1 million face value Treasury bill will, 80 days hence, pay the holder $1 million. The buyer will pay the asked price, which is face value less discount. The bill's discount from face value will be calculated by the following method:[11]

Discount(I) = (80/360) ($1,000,000) (asked-discount-yield).

The price of the bill, and thus the price of $1,000,000 to be delivered 80 days hence by Strategy I is:

Price(I) = $1,000,000 - Discount(I).

Using Strategy IA, a lender may also buy dollars to be received 80 days hence. Assume that a contract exists that expires in 80 days with the

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[11] See Stigum (1981; 27-32) for yield and pricing formulas on discount securities.

delivery of a 91-day bill. If the deliverable bill exists, then today its time remaining until maturity will be (80 + 91) = 171 days, and its discount and price will be:

$$\text{Discount(IA bill)} = (171/360)(\$1{,}000{,}000)\,(\text{asked-discount-yield}),$$

and

$$\text{Price(IA bill)} = \$1{,}000{,}000 - \text{Discount(IA bill)}.$$

To this is added the round-turn contract commission, $60, and the margin requirement, $1,500. The price of the strategy is:

$$\text{Price(IA)} = \text{Price(IA bill)} + \$1{,}560.$$

Let F be today's futures contract discount. Eighty days hence, when the bill is delivered, Strategy IA will return

$$\text{Cash(IA)} = \$1{,}500 + [\$1{,}000{,}000 - F(91/360)(\$1{,}000{,}000)],$$

because in 80 days the lender using Strategy IA receives the deposited margin in addition to the cash invoiced from the delivery of the bill. If in the interim there have been changes in discount yields, there are gains (or losses) posted to the lender's margin account. These are offset by losses or gains in the invoiced value of the bill when delivered.

The 80 day (unannualized) yields from the two strategies are:

$$\text{Yield(I)} = \{[(\$1{,}000{,}000 \;/\; \text{Price(I)}] - 1]\}$$

$$\text{Yield(IA)} = \{[(\text{Cash(IA)} \;/\; \text{Price(IA)}] - 1]\}.$$

If the two yields are not equal, then under the assumption stated above - that the risks inherent in the two strategies are equal - the efficient market should <u>make</u> them equal. Suppose that momentarily the yield on Strategy I exceeds the yield on Strategy IA. Potential lenders would then prefer Strategy I to IA. At the margin, would-be-purchasers and current owners of the near bill will be driving its price up, and its discount down. Meanwhile, current and would-be-owners of the deliverable bill will be driving its price down and its discount up. In the futures market, contractors increase the price of a contract; the futures discount F falls.

These movements continue as long as the yields on the two strategies differ. The movements are equilibrating: the increase in the near bill's price lowers the yield on Strategy I; the fall in the price of the far bill and the increase in the futures discount serve to increase the yield on Strategy IA, both by decreasing the price of the strategy and by increasing the amount received from the delivery of the bill.

In addition, another factor might serve to bring the yields to equality - arbitrage. For example, if Yield(I) exceeds Yield(IA), the profitable arbitrage would be to borrow and sell 171 day bills, use the proceeds to buy 80 day bills, and sell futures contracts.[12] In effect, the trader is selling Strategy IA and buying Strategy I, and this will tend to move the yields toward equality.

In a similar fashion, it can be shown that under the assumption of like risk, the market should equalize the yields from Strategies II and IIA. Suppose that X is 80 days, that a deliverable bill exists, and that the risks of non-fulfillment accrue equally to the instruments underlying Strategies II and IIA.

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[12] Properly speaking the trade is not a pure arbitrage, but a spread. The trader earns profit if the expectation is correct that, just prior to expiration, the future's price will become equal to the delivery bill's price. It would be a pure arbitrage if, for instance, the trader bought bills in Chicago and simultaneously sold them in New York. In fact, unless the market is efficient, and unless the position is maintained until expiration of the futures contract, there is no guarantee that the arbitrage will be profitable.

Strategy II requires the purchase and holding to maturity of a bill of time to maturity of (X + N) or 171 days, which returns $1,000,000. The bill's price and 171 day yield are:

$$\text{Price(II)} = \$1{,}000{,}000\ [(1-(171/360)(\text{Asked Discount})],$$

and

$$\text{Yield(II)} = [\$1{,}000{,}000/\text{Price(II)}] - 1.$$

Strategy IIA requires the purchase of an 80 day bill and a futures contract. When the near bill matures, the trader will use the proceeds to buy the delivered bill, which will be matured. There will be money left over, which will be re-invested at concurrent yield. Alternatively, the investor may be assumed to purchase the required fraction of an 80 day bill to return at maturity the funds needed to buy the delivered bill. The funds needed to buy the delivered bill, 80 days hence, will be:

$$\text{Funds(IIA)} = \$1{,}500 + \$60 + \{\$1{,}000{,}000\ [1 - 91/360(\text{Futures Discount})]\}.$$

Since a bill returns $1,000,000, the fraction to be bought today to return Funds(IIA) 80 days hence is:

$$\text{Fraction(IIA)} = \text{Funds(IIA)} / \$1{,}000{,}000.$$

The price of Strategy IIA is therefore:

$$\text{Price(IIA)} = [(\text{Fraction(IIA)})(\$1{,}000{,}000)(1 - 80/360(\text{Asked Discount}))].$$

Eighty days hence, the investor will accept delivery of the contracted bills, pay for them, and have no cash left over. After another 91 days, the delivered bill will mature, and margin will be returned, bringing in:

$$\text{Cash(IIA)} = \$1{,}000{,}000 + \$1{,}500.$$

So the 171 day yield for Strategy IIA is:

$$\text{Yield(IIA)} = [\$1{,}001{,}500 / \text{Price(IIA)}] - 1.$$

If the yield from Strategy II is not equal to the yield from Strategy IIA, and if the risks and quality are identical, then market participants would buy only the strategy offering the greater yield. As in the previous example, arbitrageurs would enter positions. Suppose that momentarily the yield from Strategy IIA exceeds the yield from Strategy II. There is profit to be earned by borrowing and selling a deliverable bill, using the proceeds to buy an X day bill, and entering into a long contract position. These actions would help to lower the price and raise the yield of Strategy II, while the increased demand for the near bill would raise its price and thus the cost of Strategy IIA. The increased demand for long futures positions would raise the futures index and thus the price of the delivered bill. This would also serve to lower the yield from Strategy IIA. But again, profit can be assured only if the position is held until futures expiration, and only if the prices of the two strategies do in fact converge near expiration.

Under the assumptions stated above, namely, that the various strategies entail equal risk, it would seem that to be efficient, the market must set Yield(I) equal to Yield(IA), and Yield(II) equal to Yield(IIA). Almost all previous studies have based their empirical conclusions on the presence or absence of this equality.

For example, Poole (1978, p. 18), using the first eight Treasury bill contracts to be traded, shows "that the Treasury-bill futures market is closely linked to the spot market in Treasury bills. Unexploited arbitrage opportunities between the two markets rarely exist."

Capozza and Cornell (1978, p. 513) maintain that "Since arbitrage is possible between the spot and futures markets, appropriately defined returns in both markets should be identical." They then show that after-transactions returns are not identical. However, they recognize that the difference may be caused by shorting costs and/or institutional constraints, and so do not conclude that the market is inefficient.

Rendleman and Carabini (1979, p. 912) included the shorting costs mentioned by Capozza and Cornell, and show that "no pure arbitrage opportunities were available in the market during the sample period...Therefore, the Treasury bill futures market appears to have been highly efficient...)

Puglisi (1978, p. 66) shows that the "...returns on the bills-only strategy are less than those on the bills-futures strategies" and concludes "that the T-bill futures market is inefficient." Vignola and Dale (1979, p. 78), applying Puglisi's means tests to daily returns, claim that "...although the mean difference between these returns on average are small and their standard deviations large, there are distinct arbitrage returns from using the futures market. Moreover, these returns may be substantial on a given day, even though the mean return for all days of a particular contract is zero."[13] They conclude that "the futures market has remained inefficient."

Other examples could perhaps be presented. However, all previous studies are based on the prior assumption of the perfect substitutability of the spot instrument with its futures equivalent. They are incomplete tests if the prior assumption is incorrect, and their conclusions are, though illuminating, irrelevant. If the instruments are not perfect substitutes then, using the criterion of equivalence in yields of the real bill and the artificial bill, a test of the efficiency of the market is specious.

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[13] If some daily returns are substantial, yet the mean return is zero, do not some days necessarily offer negative returns? Vignola and Dale offer no clue as to the determination of tomorrow's return, however, and do not recognize that the distribution of returns may be quite different.

Default Risk. In neither case are the two strategies equivalent with regard to risk, here considered as capital risk, or the uncertainty as to principal return, or risk of default. There is clearly less risk of default inherent in ownership of an X day Treasury instrument – guaranteed by the Treasury – than in ownership of the combination of an X+N day Treasury instrument and a private agreement to sell it in X days. Although no financial futures contract has yet been prohibited from trading, other contracts (for instance, Maine potatoes) have. Although Treasury contracts have not precipitated large margin calls, silver futures and stock market index futures have. Although Treasury contracts are insured by adequate collateral and re-collateralized daily,[14] and may be in practice as sure of fulfillment as the Treasury is sure to pay cash, there will exist a differential in the minds of investors, as long as contract fulfillment is not guaranteed by the Treasury.

Furthermore, the two strategies involving instruments and futures (IA and IIA) are asymmetric with regard to possible loss in earnings from default. If Strategy IA is followed, and the futures contract defaults, the investor owns an X + N period instrument that must be sold at the market price then prevailing, and not at the price guaranteed by the futures contract. The return may be greater or less than anticipated as money rates have fallen or increased in the interim. The return may be less than zero; and if rates rise, the investor will not have the amount of cash at maturity

[14] Perhaps "almost every day" might be more accurate language. There is not yet good information available as to the number of firms driven into technical insolvency by margin requirements on index futures losses in the October 1987 crash. Many firms' long index futures position losses were fully hedged by offsetting profits on their put options baskets that, however large, were not obtainable by means other than liquidation. See the Wall Street Journal; November 11, 1988; page C1.

that was planned. The artificial instrument owner is vulnerable to an increase in interest rates.

The lender using Strategy IIA faces a different problem upon default; the inability to take delivery of the contracted instrument. The investor must instead purchase an instrument in the open market. If rates have fallen during the time the contract is owned, the investor will pay more than anticipated for the instrument, more than will be received from the sale of the X period instrument. The investor is therefore vulnerable to a decrease in interest rates.

However, there are still N periods in which to acquire the extra cash the investor anticipates needing. Principal cannot be lost, since the long position in the near instrument is guaranteed by the Treasury. The situation at default is certainly not as immediate as in the case of default to an investor using Strategy IA, and clearly not as serious.

One would expect an efficient market to compensate for this asymmetry with a yield on Strategy IA greater than the implicit forward rate, and a yield on Strategy IIA lower than the implicit forward rate. Since the lender by Strategy IA sells contracts, while the lender by Strategy IIA buys contracts, compensation requires that the futures price be higher (the contract discount lower) than that which would prevail were futures rates equal to implicit forward rates.

Early Settlement. Another risk differential exists and should be accounted for. A lender may have a firmly held expectation about the time during which cash will not be required. However, that expectation may not be correct. The X period lender may need to convert to cash before maturity, or the lender may find that cash is not needed after all at maturity. In the latter event, no harm is done; the lender simply rolls over, although at an uncertain rate. But if cash is needed prior to maturity, a real instruments strategy is superior to an artificial instruments strategy. At the short maturities to which money market rates apply, bills certainly are unlikely to sell for less than that for which they were bought, unless settlement is required very soon after their purchase. But the same cannot be said of an artificial bill strategy. Futures rates often move anomalously with respect to their underlying instruments; they are stochastic. Only at contract expiration is unwinding a position sure to return the cash for which the strategy was purchased. Prior to expiration, the artificial instrument strategy can produce a low return or even a loss of principal, which may be sizable. For example, on September 27, 1978, a profitable arbitrage existed in Treasury bills, which required purchasing a bill of maturity of March 22, 1979, and selling a December 1979 contract and bill.[15] If an arbitrageur unwound 20 days later, on October 17, the arbitrage would have lost $2,018, since on that date the bill futures discount was almost 50 basis points below that of the lowest profitable arbitrage. Using the March, 1981 contract, if an arbitrage was entered at the first profitable opportunity and unwound in 138 days, the loss would have been $9,302. To the extent that a lender is aware of a potential distribution of cash need outcomes prior to maturity, and depending on the aversion to risk, compensation is likely to be required for lending via the artificial instrument strategy that is not required of the strategy involving only real instruments. The effect of this differential in risk is to raise the Strategy IA yield above that of Strategy I.

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[15] Equivalent to simultaneously buying Strategy IA and selling Strategy I.

For an X+N period lender, early need or desire for cash involves different considerations. The lender via Strategy II holds an X+N period instrument, which, in the event of a requirement for cash, must be sold or used as collateral for a loan at market rates. But the lender via Strategy IIA holds only an X period bill and a contract which requires the purchase an N period instrument. Cash will be received at contract expiration, which, if t is the number of days after positioning, occurs in X-t days. Cash can be acquired earlier by selling the contract and the X day bill. Given the uncertainties of the future course of rates in general, Strategy IIA involves less risk of loss from unexpected early settlement than Strategy II, and the market should compensate by setting the Strategy IIA yield lower than that of Strategy II.

The possibility of early settlement may render the instruments imperfect substitutes. If cash is required prior to maturity, then the investor holding the nearer-to-maturity instrument is less likely to suffer low or negative yield. Given identical near term yields, the near term investor prefers the real instrument to the artificial instrument. Given identical longer term yields, the longer term investor prefers the artificial instrument to the real instrument.

These asymmetrical preferences result in a higher (lower) yield for the near term (longer term) artificial instrument compared to its real counterpart. The near term artificial instrument involves a future sale; thus the higher yield occurs as the future sale price is higher, or the futures contract discount is lower, than that of equivalence. The longer term artificial instrument involves a future purchase; thus the lower yield occurs as the future sale price is higher, or the futures contract discount is again lower, than that of equivalence. *A Priori*, then, the futures contract discount yield is expected to be lower than the implicit forward rate – perhaps low enough so that observers report inefficiency when it is not implied.

Variability of Interest Rates. Another reason exists for exercising caution in interpreting the equivalence of yield as indicating efficiency. The preference for holding the near term bill would disappear if, all else constant, interest rates were invariant, or amenable to forecasting with zero error, or if the probability of requiring cash prior to maturity were zero. It follows then that the futures discount yield would approach the implicit forward rate. Put another way, the more variable or unpredictable are interest rates, and the higher the probability of prior-to-maturity cash requirements, the more the futures discount yield will diverge - downward - from the implicit forward rate.

The investor holding the (hedged) longer term instrument owns an asset whose price varies more than that of the shorter term instrument. If the expected variability of interest rates increases, an efficient market compensates with a relative increase in expected returns for those investors. This requires a higher futures price, or a lower discount yield, since the investment involves selling the longer term instrument by means of the futures contract.

If short-term rates were expected to fall in the near future, however, the effect would be lessened; perhaps reversed. Given a decrease in money market rates, the longer term bill would appreciate in price more than the near term bill. If money market investors expect a fall in money market rates, then, the longer term bill would become more attractive. The asymmetry in preferences noted above would diminish, tending to bring the futures discount more in line with the implicit forward rate.

Inflationary Expectations. An increase in the expected level of inflation induces marginal investors to seek higher nominal yields, and lenders to offer it – the well known inflation premium in the Fisher equation. By increasing the probability of early cash requirement, it may also induce a further negative divergence in the futures discount yield. Also, given a constant standard error of expectations, higher levels of interest rates involve greater absolute variation in those rates. For these reasons[16] one expects higher inflation rates to be negatively correlated with the divergence of the futures discount yield from the implicit forward rate, other things equal. This is essentially a static consideration.

But one state does not instantly become another. Higher levels of inflationary expectations sooner or later translate into higher overall nominal yields. First though, expectations of future inflation generate movements toward nearer term instruments, and away from those of longer duration, with a concomitant decrease in nearer term rates and a more positively inclined yield curve.

In addition, it is difficult to successfully model expectations of future inflation rates. Commonly, information imbedded in past inflationary rates is used to extrapolate forward in time – expectations are adaptive or ARIMA processes. But if investors are rational, they consider all relevant predictive information, or at least information whose expected marginal cost of acquisition is not greater than the expected gain of its inclusion.

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[16] And many others. The skittishness of the financial markets is a commonplace. Probably any new information casting doubt on old expectations quickly affects premia through a widening of the confidence bands of forecasts.

Monetary Regime. Prior to October 6, 1979, the Open Market Committee announced no target intentions with regard to monetary aggregates; but after that date, target ranges for M1-3 have been announced - and often missed - as the Federal Reserve shifted from a federal funds to a nonborrowed reserves operating procedure.

In October, 1982 the Fed replaced the nonborrowed reserves procedure with a borrowed reserves procedure. February, 1982 saw the adoption of (almost) contemporaneous reserve requirements. Probably the most important differences in these regimes occurred as the Fed shifted from interest rate to aggregate targeting, although other effects from changes in operating procedures cannot be ruled out. There is no certainty as to the weights placed by the Fed on the various aggregates and interest rates during the post-1979 regime. Investors must form some expectation, however uncertain, of the intentions of the Fed. It may be that changing perceptions of the Fed's intentions influence the divergence of the futures yield from the implicit forward rate.

For example, suppose the expected increase is less than the actual increase in M1. If an easier-money regime is ahead, near term yields will decline, and there will be less reason to fear losses if early settlement is required. The divergence of the futures yield from the implicit forward rate becomes smaller in absolute value, which means less negative, or perhaps even positive. Therefore, if the difference between the actual increase in M1 and the expected increase rises, and induces expectations of "easier" money ahead, the divergence of the futures yield from the implicit forward rate - normally negative - should increase.

This effect may be viewed in terms of an equation,

$$[F - (U+L)/2] = f[\Delta M1 - E(\Delta M1), Z],$$

where F is the actual futures yield, U is the highest futures yield consistent with unprofitable arbitrage, L is the lowest futures yield consistent with unprofitable arbitrage, $\Delta M1$ is the actual change in M1, $E(\Delta M1)$ is the expected change in M1, and Z is a vector of other relevant factors. The bracketed term on the left-hand side,

$$D = [F - (U+L)/2],$$

is the divergence (D) of the futures contract discount yield from the midpoint, or average, of the arbitrage bounds. Since the average of the arbitrage bounds,

$$(U+L)/2,$$

is that futures discount yield that would result in unprofitable arbitrage under the assumption of zero transactions cost, it is also the implicit forward rate.

The first bracketed term in the function,

$$S = [\Delta M1 - E(\Delta M1)],$$

is the divergence (S) of the actual growth of M1 from the expected growth of M1. The partial derivative of D with respect to S will tend to be positive if greater than expected money growth signals higher rates of money growth ahead.

However, if greater than expected money growth indicates a correction lies ahead, and if $E(\Delta M1)$ initially incorporates perceptions of the Fed's operative targets, then f_1 will tend to be negative. For if $\Delta M1 > E(\Delta M1)$, future correction involves a slowing of reserve growth, and higher near-term rates. If early settlement is required[17] at higher near-term

[17] It may be that the likelihood of early settlement requirements is itself positively related to future tightening.

rates, loss is more likely if the near term bill is not held, and in compensation F is lowered further below the implicit forward rate.

A priori, it is not possible to predict the sign of f_1, since the sign depends on the magnitude of the correction expectation (negative tendency) relative to the faster-growth expectation (positive tendency). But since the sign of f_1 depends on the relative magnitudes of the two effects, if f_1 is positive, then the faster-growth expectation has more impact than the correction expectation; whereas if f_1 is negative, the correction expectation has more impact than the faster-growth expectation. It is entirely possible that f_1 is positive under one monetary regime, and negative under another.

Transactions Costs. An instruments-only strategy requires very low positioning costs.[18] But an instruments-futures strategy requires at least a round turn commission on the futures contract and at least one more commission on the instruments than the instruments only strategy. For the X period lender in Treasury bills using Strategy IA, the lender incurs a buy commission on the X+N period bill, a $60 round turn commission on the futures contract trade, and a sell commission after X days, when the bill is sold. In addition, margin may be required, or securities posted to the trading account, in which case the services rendered by the cash at margin or the securities posted are lost. Even in the case where the trading entity is a bond dealer, the implicit cost of commission remains, for a dealer makes a market in instruments which, if posted, are no longer available by which to earn.

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[18] In the case of a lender buying Treasury instruments at auction, zero nominal costs.

When the lender wishes to lend for an expected X+N periods, the instruments-futures strategy is potentially more costly. The lender buys an X-day bill and a contract, takes delivery of the N-period instrument, and holds it to maturity. Since the long futures position is not covered by a matching security, margin is likely to be required; at least more likely than with Strategy IA. These differences are small; they amount to only a few basis points at most, and can have only a minor role in explaining the divergence of futures rates from implicit forward rates.

Tax Differences. After 1978, a long futures position was treated by the IRS as a long term capital position if held six months or longer, while a short futures position was treated as a short term capital position no matter what the holding period. Prior to a tax ruling in November 1978, both short and long futures positions were treated the same by the IRS; they were undefined. Lenders could not know what the tax treatment would be prior to the November 1978 IRS ruling.

However, the interest earned on Treasury instruments themselves is taxed as ordinary income,[19] so that a lender who maximizes the risk-return LaGrangian and whose utility is based on after tax returns should require a higher marginal return on instruments-only strategies than on strategies involving both instruments and futures. This could be a factor in the note and bond complexes, but not in bills, since no arbitragable instruments of longer maturity than six months have existed since the inception of the Treasury bill futures market.

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[19] See Cornell (1981) and Interest Rate Futures Contracts: Federal Income Tax Implications, a customer's brochure published by the Chicago Mercantile Exchange.

Treasury Bonds

It is possible to lend to the U.S. Treasury for a long period of time in two equilavent ways. First, the lender may purchase a long term Treasury bond, at issue or on the open market. Second, the lender may purchase a combination, consisting of a Treasury bill and a Treasury bond futures contract, taking delivery of the contracted bond and making payment with the proceeds from the maturation of the Treasury bill. The purchased bill can be chosen from existing bills so that it matures in the same week that the bond contract expires, so that cash is available with which to purchase the contracted bond. In this way, an artificial bond is created. The artificial bond has approximately the same time to maturity as the real bond. Chicago Board of Trade (CBT) Treasury bond contracts allow the delivery of many different bonds in fulfillment of contract obligations, and the choice of which bond to deliver is up to the owner of the short contract position. The party owning the long futures contract position must accept any bond offered, as long as it fulfills the contract specifications, which require only that the Treasury bond have longer than fifteen years to maturity or earliest call. Still, as long as the lender does not care which bond is received, an approximately equivalent method exists by which cash can be foregone to the Treasury, long term. And if they are equivalents, their yields should be equal.

In the same manner, a lender may consider two methods of lending cash to the Treasury for a short time period; one of them involves a bond future contract position. First, a lender may purchase a Treasury bill and hold it to maturity. Second, the lender may purchase a Treasury bond, and simultaneously enter a CBT bond contract in order to deliver the bond in the same week that the bill matures. The two methods may therefore be considered equivalents, if their holding periods and yields are equal.

The following assignments will be helpful in keeping track of the options open to the lender. Strategy I indicates the purchase of a Treasury bill at time (t) which matures at time (t + n), so that the number of days to maturity is (t + n) – t = n. Its equivalent, Strategy IA, indicates the purchase of a deliverable Treasury bond and opening of a short bond futures position, both at time (t). The expiration of the bond contract occurs at time (t + n), so that the maturity of the combination is also n days. Strategy II will refer to the outright purchase of a Treasury bond at time t. The bond matures in y years. Strategy IIA will refer to the simultaneous purchase of a Treasury bill and opening of a (long) futures position at time (t). The maturity of the bill will coincide with the expiration of the futures contract, at time (t + n). At that time, a Treasury bond will be delivered against the long position. The bond matures in z years.

These strategies are summarized in Table 2.

TABLE 2

COMPOSITION AND TIME TO
MATURITY OF TREASURY
BOND STRATEGIES

Strategy	Position	Maturity
I	Long an n day Treasury bill	n days
IA	Long a Treasury bond, and Short a Treasury bond contract	n days
II	Long a Treasury bond	y years
IIA	Long an n day Treasury bill, and Long a futures contract	z years

The strategies are similar to the equivalent bill strategies in the preceding section, but some important differences exist. In Treasury bill contracts, only one particular bill exists that fulfills the delivery conditions of the contract; that bill having 91 days to maturity upon contract expiration. No other bill may be delivered. The conditions of the bond contract allows the short - the holder of the right to make delivery - to select the bond for delivery among all U.S. Treasury bond which have a time to maturity or earliest call greater than 15 years. Many deliverable bonds exist for each bond contract, with time to maturities from 15 to 30 years, and coupon rates that vary widely. Although the CBT bond contract invoicing methodology employs a conversion factor to adjust bond prices for the differences in coupon rate and time-to-maturity, the (converted) contract price most closely reflects the price of a single security. That security is the bond which can be purchased most cheaply by the short in order to deliver in contract fulfillment to the long. The bond is termed in the literature the "cheapest-to-deliver". It follows, then, that all other deliverable bonds can be sold more dearly on the spot market than via futures contract delivery.

A long position in a Treasury bond futures contract is a promise to purchase, at the expiration of the contract, a $100,000 bond of no less than 15 years to maturity or, if callable, to earliest call date. The value of the contract is the price of a theoretical bond of 8% coupon, priced to yield the contract yield, net of accumulated interest. Were the yield to be higher (lower) at contract expiration, the theoretical bond's price would be lower (higher), and so would the value of the contract, by the same dollar amount. Thus a long position guarantees the yield of the theoretical bond that will be received at contract expiration.[20]

The theoretical bond, of 8% coupon, did not exist after August 15, 1981. After that date, the 8% August 15, 1996-2001 Treasury bond had less than 15 years to earliest call. CBT contract rules specify a conversion factor for different coupons and times to maturity or earliest call. By multiplying the conversion factor for a particular bond by the contract price, the principal invoice price is attained. Accrued interest since last coupon is added, and the result is the dollar amount payable to the short by the long.[21]

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[20] This statement is true if the theoretical bond is the only bond, or if it is cheapest-to-deliver for the life of the contract.

[21] The invoicing methods and pricing may be obtained from various Chicago Board of Trade publications. Of particular relevance to the present point, see Interest Rate Futures for Institutions (Undated), and CBOT Financial Instruments Guide (1987).

Since the short chooses the bond for delivery, the long cannot know the amount of cash required for settlement, *ex ante*. The long must be prepared to accept any Treasury bond that exists, of any existing coupon, and having any time-to-maturity greater than 15 years. Depending on the bond delivered, and therefore on the conversion factor and accured interest, and the current yield, the long may be liable for as much as $200,000 per contract or as little as $50,000. This is illustrated in CBT's own literature, in fact. In the publication Interest Rate Futures for Institutional Investors, the first of the two examples on page 12 gives a principal invoice price of $102,912.00; the second, a principal invoice price of $61,824.00. Other examples could easily be constructed to illustrate much wider ranges. The salient point remains, however, that the long cannot know in advance what amount of cash will be required for settlement, what the delivered bond's actual maturity will be, nor what the delivered bond's coupon rate will be. All those factors are determined by the short.

A short position in a Treasury bond futures contract is a promise to deliver, at the expiration of the contract, a $100,000 face value Treasury bond having at least 15 years until maturity or earliest call. The value of the contract, after multiplication by the conversion factor for the particular bond owned by the short, is the price the short will receive, net of accumulated interest. Were the yield to be higher (lower) at contract expiration, the bond's price would be lower (higher), and so would the value of the contract, by approximately the same dollar amount.[22] Thus a short position guarantees the yield of the Treasury bond that is held during the life of the contract. The short side of the futures contract, by fixing the

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[22] Only if the short's bond is the cheapest-to-deliver, or if the short's bond correlates perfectly with the cheapest-to-deliver bond, will the magnitude of the dollar changes be exactly offset.

sale price of the for-delivery instrument, guarantees a specific yield - for current owners of the instrument who do not require cash prior to contract expiration. By a simultaneous purchase of a Treasury bond for delivery and sale of a futures contract, an artificial bond is created that "matures" with certain yield at contract expiration.

Of course, that yield may not be the greatest obtainable, either at the initiation nor the expiration of the contract, from an investment in Treasury bonds. The short may decide to hold the bond past contract expiration, buying a cheaper bond to deliver against the contract. The short is also free to sell the original bond any time a deliverable bond becomes cheaper than the original, in effect pocketing as profit the difference in dollar amounts. This freedom of decision belongs to the short by virtue of the difference in kind between Treasury bill and Treasury bond futures, in that the former requires one specific instrument for delivery, while the latter does not.

Now such freedom of decision cannot be conveyed costlessly, if markets efficiently price asset claims. The freedom to choose the bond to be delivered is a potentially valuable right, for which shorts should be willing and able to pay. From another perspective, the uncertainty about which bond will be delivered is a risk of being long, to be compensated by market participants.

A similarity to the bill contract should be mentioned here. The possibility of early settlement would leave the long, after contract liquidation, the owner of a Treasury bill. Early settlement would leave the short, after contract liquidation, the owner of a Treasury bond. At first glance, it would appear that, like the early settlement in the bill complex, the long in the bond complex would be better off than the short, having only a Treasury bill to dispose of - but this is not so. Early settlement would mean a profit or loss on the bond contract approximately equal to the profit or loss on the bond the short owns. The short in effect has hedged the ownership of the bond the short plans to deliver. The long is not covered by the offsetting bond ownership, having planned to strip the yield on the bill and take delivery of the offered bond, whatever it may be. The long owns only a Treasury bill. Any profit or loss on the bond contract at early settlement will not likely to be offset by any change in the bill's price, because the difference between long term interest rates and short term rates – the yield curve – is not likely to be perfectly immobile. This asymmetry is due to the differences in the maturities of the instruments underlying the two positions. It is a comparison of short term investment goals with long term investment goals, both of which are unfulfilled, and is not a valid comparison.

A few examples of an actual trades are valuable at this point, both to demonstrate the calculations and illustrate the variability of actual returns. The formula for bond invoice price calculation can be expressed as

$$V = P + (c/2)(d/n),$$

where V is the invoice price per $100 face value of the bond, P is the asked-price of the bond, c is the coupon rate expressed as a percent, d is the number of days since last (semi-annual) coupon payment, and n is the number of days in a Treasury half-year.[23] On June 7, 1979, the price of the 8% Treasury bond of 2001 was 91 30/32 asked. On that date, there had been 112 days since last coupon, so the cost of buying $100,000 face value of the bond would have been $91,938 plus approximately ($8,000/2) times (112/182.5) in accrued interest, or $94,393. If an investor had on that date

[23] See Stigum (1981) Chapter 8, especially pages 87-92.

approximately equal, since period y will not in general exactly equal period z. In this sense Strategy IIA is less desirable than Strategy II. The long term investor using Strategy II can choose the coupon and maturity desired; the Strategy IIA investor must accept the coupon and maturity of the bond delivered. Strategy IIA should therefore carry a higher yield than Strategy II, due to the additional uncertainty inherent in Strategy IIA. However, the Strategy IIA investor who must settle early owns a Treasury bill to dispose of, after profit or loss from closing the futures contract are tabulated. The Strategy II investor owns a Treasury bond, which must be sold in the spot market upon early settlement requirement. The variability in actual return rates is likely to be very large, in both cases. It is an empirical question whether or not early settlement of Strategy II investment is more or less variable than that of Strategy IIA, but a first guess might be that Strategy IIA is the more variable. The bond futures price is most closely tied to the bond that is cheapest-to-deliver, which is likely to be a different bond at different interest rates. The bond futures price therefore varies as interest rates change, and more than that of any particular bond, since there is additional variation in futures price due to the changing identity of the tracked (cheapest-to-deliver) bond. However, there is probably a measure of positive covariation in the combination of a bill and a long bond future position that lessens the variation of the combination. It is therefore not clearly evident that Strategy IIA is the more variable of the two.

Inasmuch as the pleasures of symmetry demand it, one is tempted to argue in the same manner for short term investments. It is difficult to make similar argument concerning Strategies I and IA, however. The short term investor using Strategy I owns a Treasury bill. The short term investor using Strategy IA buys a Treasury bond, and opens an offsetting bond contract short position. He may, if early settlement demands it, sell the bond and close the bond contract. If the price of the bond owned is always perfectly and negatively correlated with the price of the bond contract, then the daily variation in the value of the combination will be low. This is not the case, since the bond owned is not in general cheapest-to-deliver both at purchase and at sale. In the short term, realized yield from early settlement of Strategy IA is much more variable than that of Strategy I - so much more variable that there is some doubt as to whether Strategy IA is even a viable investment option, except for the bond that is cheapest-to-deliver.

In the case of Treasury bills (see Table 1) the bill owned in Strategy I is <u>the</u> deliverable instrument. At contract expiration, the closing contract price will be, through arbitrage, the very same as that unique bill. In the case of Treasury bonds, the bond owned in Strategy I is <u>one of many</u> deliverable instruments. At contract expiration, the closing contract price will be, through arbitrage, the same as that deliverable bond that is cheapest-to-deliver at that time. Only if the yield to maturity of the bond held and the cheapest-to-deliver bond were always identical would Strategy IA be viable, since Strategy IA requires the delivery of the bond. Since the bond is purchased spot and sold in delivery against the contract at the contract price, a loss is virtually guaranteed.

The mechanism that ties contract prices to the underlying security is the potential for arbitrage in the final few days prior to contract expiration. In the case of Treasury bill contracts, the underlying security is the deliverable bill. If the bill can be purchased at spot and sold more dearly at future settlement, then arbitrage will occur, lowering the future price to equivalence. If the bill can be sold at spot and bought more cheaply at future settlement, then the opposite arbitrage will occur, raising the future price to equivalence.

In the case of Treasury bond contracts, the underlying security is that single deliverable bond which can be purchased most cheaply at spot and sold most dearly at future settlement. If any bond can be purchased at spot and sold more dearly at future settlement, arbitrage will occur, lowering the future price to equivalence. If, a few days later, another bond can be purchased at spot and sold more dearly at future settlement, more arbitrage will occur, lowering the future price further, to a new equivalence. However, if it should occur that a particular bond can be sold at spot more dearly than the future price would seem to allow its purchase, <u>no</u> arbitrage will take place to raise the future price. In order for arbitrage to occur, the anticipated future bond delivery must be the particular bond sold short at spot, and there is no reason for this particular bond to be delivered. In fact there is every reason not to expect its delivery, since it is not cheapest-to-deliver.

This one-sided arbitrage, in the last few days of contract existence, puts an upper limit on bond futures contract prices. The future contract price could conceivably be lower than that of the cheapest-to-deliver bond. Presumably, the lack of supply of short-side contract participants would bring it up to equivalence. There might also be speculators who would wager that a futures purchase and spot sale of any bond, perhaps even the cheapest-to-deliver, might result in a profitable outcome. However, the fact remains that the purchase of a bond and its prospective future sale is not and cannot be perfectly hedged, because its price is not tied through arbitrage to the contract price.

Treasury Notes

The preceding arguments apply with equal validity to the market for Treasury note futures, since the delivery requirements are the same, with one exception: there is both a lower and upper limit to the time until maturity or earliest call allowed to deliverable instruments. Any note which has at least six and one-half years but less than ten years until maturity or earliest call may be delivered in fulfillment of a Treasury note contract. The calculations for settlement and conversion factors are the same for both contracts. The note future settlement price is tied through one-way arbitrage to the price of the cheapest-to-deliver note, but not to other notes, although, as in the case of bonds, its correlation may be quite high with respect to most notes. Two medium term investment options are open to the investor, and two non-equivalent short term options, as in bond market. Table 3 summarizes those options.

TABLE 3

COMPOSITION AND TIME TO
MATURITY OF TREASURY
NOTE STRATEGIES

Strategy	Position	Maturity
I	Long an n day Treasury bill	n days
IA	Long a Treasury note, and Short a Treasury note contract	n days
II	Long a Treasury note	s years
IIA	Long an n day Treasury bill, and Long a Treasury note contract	t years

As in the case of Treasury bonds, an investor sensitive only to yield may acquire a Treasury note through Strategy II outright, or through Strategy IIA. However, since there is no way to guarantee the note owned will be cheapest-to-deliver both at purchase and at sale, Strategy IA is not a viable alternative to Strategy I for participants interested in short term lending. As in the case of Treasury bonds, the possibility of the deliverance of many different notes makes efficiency tests difficult to interpret in this market.

Summary

Previous efforts to ascertain the efficiency of the financial futures markets have recognized that the instruments entail different transactions costs. Poole (1978) was the first to incorporate those different transactions costs in efficiency tests of the Treasury bill futures market, and studies after Poole's have invariably done so. Cornell (1981) recognized the differential effects of taxation, and included that difference in testing for efficiency in financial futures. The differential taxation effect was not found to be important. As will be shown in Chapter III, many tactics - some quite ingenious - have been employed in testing for the existence of pricing efficiency of financial markets. However, all are based on the same general approach.

First, the underlying instrument and its hedged equilavent are assumed to be perfect substitutes. Second, account is taken of the difference in transactions costs. Third, observations are made on the characteristics of the distributions of the underlying instrument and its hedged equivalent. Finally, if the distributions are significantly different, either in yield or in variability (the first or second moments), the market is declared inefficient, at the customary confidence level.

One could with equal validity view an identical empirical process, but with the assumption and the conclusion reversed. First, the market would be assumed perfectly efficient. Second, different transactions costs would be incorporated. Third, observations would be collected. Finally, if distributions were significantly different, the instrument and its hedged equivalent would be declared imperfect substitutes. The latter process is, of course, logically circular; but so is the former.

Stated in this way, it becomes obvious that all of the previous studies which have *a priori* assumed perfect substitutability of the underlying instrument for its hedged equivalent have not correctly examined the efficient markets hypothesis.[24] A proper examination of the hypothesis

[24] Actually, this statement is a bit too strong. In the event that the underlying instrument and its hedged equivalent are in fact perfect substitutes, the standard methodology is a correct procedure. But the

would involve an additional stage, wherein the impact of the different distribution of returns of the hedged equivalent - its differential risk - on its apparent rate of return would be taken into account. That is the purpose of the present work.

It is the return on assets after adjustment for risk that properly measures performance. In reference to Tables 1-3 above, lenders using Strategy I and Strategy IIA both hold near term instruments, and face different price risk than lenders using Strategies IA and II. The possibility of default or early settlement exposes these lenders to differences in expected outcomes which result in higher expected yields for Strategies IA and II, and lower the futures rate below the implicit forward rate. Factors which affect the probabilities of default or early settlement, or which alter the expected outcomes in the event of either, change the expected distributions of returns, and thereby affect the divergence of the futures rate from the implicit forward rate.

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reader will soon discover that the distributions are so different that the assumption of perfect substitutability is extremely unlikely.

CHAPTER III

PREVIOUS TESTS OF EFFICIENCY IN FINANCIAL FUTURES MARKETS

The investigation of the Efficient Markets Hypothesis (EMH) has taken many specific forms, and involved many different markets, although the basic approach for all of the studies surveyed is identical. Hardly a market where data have been obtainable has been disregarded, and work continues to go on apace in many areas, from markets in commodities to those in thirty year bonds. In this survey, attention is restricted in general to markets for financial instruments, although the reader may question whether or not foreign exchange is in fact a financial instrument. Also included is a recent study of the Rotterdam oil market, for reasons that will be evident. As to categorization . . .

There are three levels of abstraction[1] with regard to the efficiency of markets, financial or otherwise, in processing information. First, a market is weakly efficient if observations of past occurrences in the market alone hold no unexploited clue to its future behavior. Most of the

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[1] See Fama (1970) and Jensen (1969). Jensen is often credited with the original division of efficiency into its three parts. However, Jensen credits Harry Roberts with the description. See Jensen (1969; 170; footnote).

empirical work in the area of the Efficient Markets Hypothesis [EMH] is performed on the level of weak-form testing.

Second, a market is strongly efficient if observations of past occurrences in <u>any</u> market or forum hold no unexploited clue to its future behavior. No effort by any finite-lived researcher can prove the strong-form hypothesis. However, the hypothesis is often said to be disproved if a non-spurious correlation is shown between any information set and future market behavior. The validity of this approach is open to some question. In an infinite set of time series processes, an infinite subset of process realizations will exhibit significant correlation with any one particular process realization over an infinite subset of finite intervals. Most market observers recognize this intuitively, and put little value in hemline indicators, or NFL indicators, or tipsters of insiders, no matter how strong the apparent correlation.[1]

Third, a market is semi-strong form efficient if no publicly available information allows the future behavior of the market to be predicted. This approach encompasses the remaining portion of the empirical tests. Results must be examined carefully, with regard to the fact that information, although public, is never free. Even costless information must be read, heard, or seen. As the availability of costless information proliferates, an increasing amount of the investor's time is consumed in its assimilation, and there is some point at which the further assimilation of such information by individual investors is less than beneficial.[2]

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[1] A rise in women's hemlines, it is said, presages a rise in share prices. A victory by the National Football League's representative to the Superbowl, it is claimed, will be followed by a higher closing average share price at year's end.

[2] In other words, the utility of costless information is strictly concave.

In the studies that are summarized below, three major methods of testing for efficient markets are identifiable. First, the absence of profitable trading rules is employed as an indication of weak-form efficiency. To be adequate tests, however, such methodologies must first recognize the cost of capital employed, and the remuneration of risky exposure to capital loss undertaken in trading positions. Some studies attempt to do so; many do not. Further, there is some question as to whether trading rules which may yield paper profits in one period might not yield greater than normal losses in another.

Second, some tests attempt to show the existence of significant serial crosscorrelation (semi-strong) and autocorrelation (weak-form) and thereby expose informationally inefficient markets. Such tests are valid for time series processes that are essentially random walks, or martingales. Care must be taken to recognize that such tests are joint tests of market efficiency and the validity of the martingale model.

A third methodology involves testing the variance of the process against the variance that should result if the process is in fact generated by the hypothesized (efficient) model. The warning here is essentially the same as that above. In fact a *genus caveatus* should be applied, that all tests of EMH are in fact joint tests of EMH and the hypothesized market model, whether such models are explicitly stated or not.

This survey is organized in the following manner. First, all empirical tests of EMH as applied to Treasury bill futures and Treasury note futures markets are summarized. Next, theoretical arguments as to the applicability of the three types of tests are summarized. In the following sections, representative tests involving markets for fixed coupon investments, short term interest rates, common stock, foreign exchange, and spot gas oil, respectively.

Studies of the Efficiency of the Treasury Bill Futures Market

Puglisi (1978) found the futures market to be inefficient. Margin costs were ignored, round-turn commission assumed to be $60, and daily closing prices on both bills and futures were gathered from the Wall Street Journal. Puglisi used only asked-prices to determine his arbitrage limits, so his results differ a small amount from that of the present study. The study encompasses the first six contract months, and a signs test is employed to show that bills-futures strategies return a higher yield than bills-only strategies. He recognizes that early settlement can be costly (page 67) but states that "As long as there are portfolios that have the capacity to maintain a position to expiration, however, such an argument lacks sufficient merit to support continued inefficiencies in the market." If Puglisi's statement is true, then liquidity has no value, and there is no possibility of futures contract default. Arbitrage profit, or higher yield from bills-futures strategies can only be certainly realized near the expiration of the contract.

Capozza and Cornell (1978) report on the first thirty months of trading in the CME futures market. The authors used weekly data (Wednesdays) collected from the Wall Street Journal, and averaged the bid and asked quotes. They also used only bid prices but found no difference (see their note 5, page 515). Implicit forward rates using spot instruments and futures were calculated and compared. Rates were included when actual delivery bills did not exist. The authors found inefficiency but most was explained by the costs of borrowing bills for shorting. An interesting pattern emerged from the time series of deviations presented in the paper. For longer time periods, when the arbitragable bill did not exist, the futures rate exceeded the implicit forward rate. But the deviation declined with time, and for time periods when the actual bill did exist, the deviation was negative. The futures rates became less than the implicit forward rate.

Poole (1978) found that futures rates do in fact reflect implicit forward rates, and that "unexploited arbitrage opportunities rarely exist" (p. 10). Poole used the first six futures contracts, beginning with March, 1976, and ending with the June, 1977 contract. Data were collected from the Wall Street Journal, and included daily bid and asked bill quotes and daily futures closing quotes. Poole presents a t-test of the proposition that futures rates are depressed below the implicit forward rates. The test is significant for all contracts save June, 1977. However, the depressed futures rates are insufficient to allow profitable arbitrage, because of the existence of margin costs and commissions on contracts, and bid/asked spreads on bills. Of the six contracts Poole examined, only three show periods when the futures rate is above or below the arbitrage limits: January, in the March, 1976 contract; September to October, in the December, 1977 contract; and four days in May, in the June, 1977 contract. In each of the periods, the futures rates were below the lower arbitrage limit. Poole's article was one of the first to investigate the efficiency of the Treasury bill futures market. The six contracts available for study at the time of Poole's paper did not show the decrease in the futures rate relative to the implicit forward rate that has been observed in some of the more recent studies.

Cornell (1983) investigated the efficiency of the Treasury bill futures market with regard to the tax advantage that long futures positions enjoyed relative to holding bills for the individual investor. The period of study was September, 1976 to March, 1980. Cornell does not name his data source. Contrary to what would be expected if tax considerations mattered, he found that the bill futures market did not exhibit anomalies at six months to maturity - the time that a contract could no longer be held for six months and thus qualify as a capital asset. According to Cornell, marginal investors are dealers, whose trading profits and losses are taxed as ordinary income. Thus the market, while efficient, offers individual portfolio managers opportunities for increased returns from futures strategies relative to bills-only strategies.

Rendleman and Carabini (1979) used last-daily-trade price data on futures contracts, provided by the CME, and the Federal Reserve Bank of New York's Composite Closing Quotations for U.S. Government Securities (CCQ) for bid and asked bill discount yields. The period of study was January 6, 1976 through March 31, 1978. When the actual deliverable bill for a particular contract had yet to be auctioned by the Treasury, the authors used the existing bill nearest in maturity to the deliverable bill. Once again, the study is not directly comparable to others. They found that potential arbitrage profits existed for investors who did not have to pay short fees (50 basis points per year), but not when those fees were taken into account. According to the authors, the inefficiencies present are not profitable enough to attract portfolio managers. They also recognize the risk differences in strategies: "...recent default on the Maine potato contract ... may cast doubt on the Exchange members' guarantee. Thus, a portion of the apparent quasi-arbitrage opportunities that we observe may actually reflect a premium for default risk." (p. 913, note)

Dale and Workman (1980) test various moving average trading rules in the Treasury bills futures market. None of them is profitable. The market appears to be a random walk.

Dale (1981) tests for levels of resistance and support in the Treasury bills futures market, and finds no price congestion or reflecting barriers. He also finds the same volume behavior associated with the markets for shares.

Lang and Rasche (1978) selected thirty quote dates at random in the periods of March 1 to November 30, 1976; December 1 to July 31, 1977; and August 1, 1977 to March 31, 1978. Data on futures was collected from the Daily Information Bulletin of the IMM; spot bill rates from the New York Federal Reserve Bank's CCQ. When the actual delivery bill had not yet been auctioned, a linear interpolation was calculated between the two bills nearest to the maturity of the delivery bill. Lang and Rasche observed the pattern mentioned above: that for longer maturities, when the deliverable bill had not yet been auctioned, futures rates exceeded implicit forward rates; for shorter maturities, just the opposite. The increase in the divergence of futures rates over implicit forward rates with time was explained by the increased cost of default at longer maturities. The authors did not explain why futures rates would tend to be lower than implicit forward rates near contract expiration, other than to tentatively accept Poole's idea of lower transaction costs for contracted bills than spot purchases.

Vignola and Dale (1979) verified the inefficiency that Puglisi reported; however, they found that the market has not become more efficient with time, as Puglisi concluded, but has remained inefficient. They found that using only bid yield-discounts in calculations produced greatly different conclusions, in four of the eight contracts studied, than using only asked yield-discounts. Their charts show that yields from bills-futures strategies increase with time relative to bills-only yields. Once again, the arbitrage is artificial; if an actual arbitragable bill did not exist, the authors substitute the one-year bill nearest in maturity to the non-existent instrument. They show that bills-futures strategies offer greater return than bills-only strategies; a few days before expiration, on the order of 100 basis points or more, indicating unexploited arbitrage opportunities and market inefficiency.

Monroe and Cohn (1986) used the following procedure to test for efficiency in the Treasury bill futures market. First, the implied forward rate of return is calculated for any two contracts from the formula

$$F_{t,f} = F_{t,n}(1 + IR_{n,f}),$$

where $IR_{n,f}$ is the implicit unannualized forward rate, $F_{t,f}$ is the longer term futures price and $F_{t,n}$ is the near term contract price. Normal backwardization will usually result in a higher price for $F_{t,f}$ than for $F_{t,n}$ due to storage costs and the foregone yield of employed capital, less any convenience yield from ownership of the commodity itself. In efficient markets, the researchers argue, $IR_{n,f}$ should be no greater than the opportunity cost of capital employed at like risk. For the gold futures market, they argue that the proper alternative rate is the Bankers' Acceptance [BA] rate, since a BA is created when a trader borrows to finance the gold purchase.

Suppose $IR_{n,f}$ were to be assumed to normally equal to the BA rate. If two futures contracts diverged in price more than that indicated appropriate by the formula above, a trader could buy the underpriced contract and sell the overpriced contract, earning profit when and if their prices again were near the appropriate divergence. But the simultaneous purchase and sale of equal numbers of contracts of different maturities is a spread, and is vulnerable to a change in the price of the commodity itself. In fact, that is probably the major reason for most positions in spreads. However, if a trader bought and sold unequal numbers of near and far contracts, a "tail" could be created which leaves the position exposed only to a change in the implicit forward rate $IR_{n,f}$. The proper ratio is given by

$$q_n = q_f(1 + IR_{n,f}),$$

where q_n is the number of near term contracts to buy (sell) and q_f the number of far term contracts to sell (buy).

For example, suppose it is November, and the December gold contract settles at $500 per ounce, while the March contract settles at $525. The BA rate is 12% per year, or 3% per quarter. The implied forward rate for gold futures is 5% per quarter. A trader believing it will fall to 3% buys 1.05 December contracts for each March contract that is sold. In this way, the position is made invulnerable to a narrowing in the spread due to a change in anything other than the implicit forward rate itself.

The same analysis is applied to Treasury bill futures, expect that the costs of carry are argued to be lower for bills than for gold. Consequently, the implicit forward rate for Treasury bills [IR_B] should be lower than the implicit forward rate for gold [IR_G]. Indeed, there should be some "normal" ratio between the IR_G and IR_B such that

$$IR_G - IR_B = N$$

which is maintained by efficient market forces. If IR_G or IR_B diverge from their normal relationship, an efficient market will quickly bring them back. This is the basis for the efficiency tests of the researchers.

Each basis point change in the CME Treasury bill discount results in a contract value change of \$25, while each basis point change in the annualized IR_G causes an approximate gold contract value change of

$$100F_{t,n}N_G(.01)/4,$$

where N_G is the number of gold contracts per bill contract positioned. The proper quantities of Treasury bill futures contracts and gold contracts can be cross-hedged for profit, whenever $IR_G - IR_B \neq N$, by employing the following hedge ratio:

$$N_G = (100)/.01F_{t,n}.$$

For example, if $F_{t,n}$ is \$500, then N_G is 20, so that about 20 gold contracts should be bought for each bill contract.

The researchers used the Chicago Mercantile Exchange computer tapes, with data from March 1976 through July 1982. Two trading strategies were simulated. First, whenever $IR_G - IR_B < 0$, the cross-commodity hedge was positioned, and was closed out the following day. This simulation resulted in positive but small gross profit, covering less than half the estimated \$20 per contract positioning cost.

The second strategy consisted of two tactics. A sixty day moving average of $IR_G - IR_B$ was formed. A take-position signal was given when, on a given day, $IR_G - IR_B$ was more than one standard deviation above or below the moving average. The assumption was that it would return to the moving average. Tactic one called for closing out the cross hedge on the following day. Results: positive profit, but averaging only about \$16 per contract. Tactic two called for holding the cross hedge until a "reversal" occurred, and taking an opposite cross hedge only on the opposite signal. The researchers did not make it clear whether a reversal was indicated when the daily value of $IR_G - IR_B$ came within one standard deviation of the moving average, became equal to the moving average, or moved past one standard deviation beyond the moving average in the opposite direction. At any rate, one of the methods produced quite large simulated profits, averaging some \$80 per contract. Although the settle-tomorrow tactic produced simulated profits that averaged \$16 per contract, the hold-until-reversal tactic resulted in profits that were large enough to more than cover estimated transactions costs. According to the researchers, this test indicates an inefficient market, and is not a joint test, since no market model is jointly tested, but only the existence of informationally generated trading profit opportunities. But the researchers note that profitable opportunities are fairly quickly eliminated, and that almost all the profit is generated by the gold contracts. There is therefore some question as to whether or not the bill futures market is efficient - a question that is perhaps not addressed at all by this methodology.

The search for the perfect simulation was undertaken by Elton, Gruber and Rentzler (1984). Two "trading rules" were promulgated by the researchers. Investors may choose between holding a real bill to maturity, or creating a pseudo bill of a combination of futures contract sale and delivery bill purchase. In determining potential "profit" from holding the lower priced security to maturity, the price of the futures contract trading just prior to the cash bill quote is used. Immediate execution is said to occur when a cash position is taken at a price equal to that used in calculating potential profit, while a futures position is executed at a price equal to that of the following trade. Delayed execution is said to occur when the cash bill is traded at the price subsequent to the price used in calculating profit, and the futures position is taken at the price of the following trade.

The researchers believe that, although previous studies have been "simultaneous test(s) of efficiency and the appropriateness of a pre-specified valuation model," their study is not, since no valuation model at all is specified. Their claim is that only efficiency is examined. But the reader may wonder if any discussion of differential "profit" is not made meaningless, since any observed difference in potential or actual return may be due to differences in liquidity, price risk, or default risk. If no valuation model is specified, we cannot know. The researchers do in fact <u>imply</u> by their non-specification of a market model that the cash bill and pseudo bill are exact equivalents and perfect substitutes. Otherwise, why not use real estate returns less cash bill yields as the measure of differential "profit?" But enough . . . let us seek the comfort of the data.

The period of the test was January 6, 1976 through December 22, 1982. Transactions costs are neglected in the tables presented by the researchers. In general the data show that the pseudo bill offered greater return than the cash bill. Whether the trade was - using the researchers' terminology - immediate or delayed made little difference, for actual and potential excess return were quite close. On any given day, an investor could have reasonably expected that his actual return from a given investment would be within a few dollars of the anticipated return - at maturity. Much is made of this by the researchers. But the result follows naturally from the fact that discounted bills, whether cash or pseudo, always pay certain return at maturity, and did not default during the period in question.

However, having the futures contract gains or losses marked-to-market on a daily basis induces variation in the realized return. The researchers report that, under immediate execution, marking-to-market effects range from -$45 to $35 more than 80 percent of the time, while under delayed execution, only 32 percent of the time, with some losses as high as $2,152 and gains as large as $1,797. The researchers make light of this risk.[3] But since these gains and/or losses can be greater than the margin requirement of $1,500 itself, and do not occur in the case of the cash bill strategy, one may wonder again at the use of the non-modelled equivalency assumption.

The researchers present tables which show that owners of cash bills could have swapped them for pseudo bills and gained - on average - positive returns. The use of small filters to trigger such swaps results in an increase in average "profit" from swaps, at least, until the filter size exceeds $800 in expected "profit." The same is true for an arbitrage strategy, where the higher-priced instrument is shorted or repoed out to finance the purchase of the lower-priced instrument. But the use of mean "profit" averaged over many contracts tends to obscure the fact, not noted by the researchers, that the differential return tends to be eliminated as the maturity date approaches; a fact which is responsible for the existence of the researchers' "profit."

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[3] See Elton, Gruber and Rentzler (1984; 135).

Interest Rates and Money Supply Growth Rates

Studies of forecasting of interest rates have yielded mixed results, similar to shares research with regard to EMH. The evidence with regard to long rates is more indicative of market efficiency than short term instruments. Long term interest rates seem to follow a random walk process, while short term rates do not.

However, Pesando (1979) has maintained that, while long rates must exhibit the random walk characteristic if term premiums are constant across time and EMH holds, "by contrast, the proposition that short-term rates follow a random walk in an efficient market can be obtained only by direct assumption." In a further important *caveat* to EMH students, Pesando shows that autocorrelation in long term levels is not necessarily indicative of inefficiency; and that the appropriate variables in testing for EMH are changes in interest rates.

In a later paper Pesando (1981) examines the accuracy of three widely disseminated forecasts of long and short term Canadian and U.S. interest rates. For long term instruments, a random walk (non)prediction was not significantly worse, in terms of root mean square error (RMSE) than forecasts of Data Resources of Canada, the conference board of Canada, or the McLeod, Young, Weir and Company, Ltd. surveys of 35-40 financial market participants. However, the same cannot be said for forecasts of 90-day Treasury bills or finance paper.

According to Pesando, both results are consistent with the joint hypotheses of the equilibrium market model and EMH. One thing, however, is puzzling. According to Pesando, EMH does not require that "the short-term rate follow a martingale, nor does empirical evidence suggest that this is the case. There is no arbitrage opportunity through which agents could eliminate any serial dependence in the short-term rate..." (1981, p. 307, bottom.) Is Pesando then denying the arbitrage opportunities available in stripping out yields via futures contracts?

Mishkin (1982) employs the EMH, the theory of rational expectations, and the hypothesis of exogenous money supply determination to conclude that unanticipated increases in money growth are associated with unanticipated increases in short term interest rates. The hypotheses are jointly confirmed. Interestingly, Mishkin found that the risk premium based on a measure of variability of six month Treasury bill yields did not affect the results when eliminated - as it was in much of the present study.

In an earlier paper, Mishkin (1981) had shown that long term Treasury bond rates also responded positively to unanticipated increases in M1 and M2 growth rates when those variables were not seasonally adjusted, although not when seasonally adjusted values were used in expectations modelling. In the case of seasonally adjusted values, neither M1 nor M2 innovations were associated with changes in long term yields.

Urich and Wachtel (1984) also report a positive influence of contemporary unanticipated monetary innovations on short term rates. Using MMS survey data to model anticipated changes in the money stock, and concentrating on IMM Treasury bill futures rates from three through twelve months maturity, as well as Federal Funds rates (FFR), they found that anticipated changes in either the M1 growth rate or inflation rate had no significant effect on FFR or futures rates prior to October, 1979. However, they report the "anomalous coefficient" whereby, in the reserve targeting regime, anticipated changes in M1 had a significant (negative) effect on the nearby futures contract rate. If EMH is correct, anticipated information is not capable of affecting asset prices. Therefore the results of Urich and Wachtel cast some doubt on EMH. However, they mention two factors that may have biased this coefficient. First, MMS data reports survey medians rather than means. Second, MMS data is collected on Tuesday, and reported on Thursday, while actual M1 changes are reported on Friday. It is possible that anticipations change somewhat in three days. In fact, Urich and Wachtel report that a correction for this learning reduces the size of the anticipated money growth coefficient, but does not eliminate its significance.

Laffer and Ranson (1978) report on the efficiency of various markets, and maintain that efficiency exists in markets for Treasury bills, foreign currencies, and capital assets (common stock). According to Laffer and Ranson, only contemporaneous monetary shocks are capable of affecting GNP, since "increases in money supply that lead to delayed increases in GNP would imply exceptional expected profit opportunities." In addition, real GNP should show no periodicity other than the pseudo-cycles generated by random processes.

Markets for Foreign Exchange

Evidence for semi-strong form market efficiency is presented by Caves and Feige (1980). In addition, the monetary approach to exchange rate determination is tested and found wanting. Using changes in the Canadian/U.S. exchange rate, and growth rates of the two national money supplies, the researchers first showed that the foreign exchange market was weak-form efficient, in that the Box-Pierce Q-statistic for autocorrelation through lag twenty five was not significantly nonzero. The Canadian price of U.S. money was essentially a random walk during the two data periods, 1953.1 - 1962.4 and 1970.7 - 1975.8. Including past monetary changes through lag six did not substantially alter the expectation of the exchange rate, and neither did relative (U.S. minus Canadian) monetary changes. Hence, the hypothesis of semi-strong form foreign exchange market efficiency was not rejected. The researchers also present evidence that the money supplies are not exogenous, at least in the earlier period. Future values of exchange rates "cause" monetary changes.

However, as the researchers show, the fact of acceptance of the incremental efficiency of exchange rates implies lack of causality of exchange rates by lagged monetary values, in the Granger-Sims sense. Hence semi-strong form efficiency precludes acceptance of any past monetary influence on exchange rates, so that it is not possible to distinguish between market efficiency and the invalidity of the monetary approach. The only method of ascertaining the possible validity of the monetary approach left to researchers, in the presence of market efficiency, is the influence of contemporaneous monetary changes on exchange rates, assuming at least part of any present period monetary change is unexpected. The researchers point out that, although only one of the zero lag monetary coefficients was significant, all four had the expected signs. An increase in the growth rate of Canadian money was contemporaneously associated with its depreciation, but not significantly so, in general. However, since the researchers do not attempt to differentiate expected monetary changes from innovations, their contention that the simple monetary approach is invalid is less than convincing.

In addition, Stein (1980) shows that tests of foreign exchange market efficiency which rely on lack of serial autocorrelation for acceptance of the hypothesis may suffer a problem of false rejection. The reason is because the spot exchange rate follows a process which in general is not a martingale; so exchange rate changes are not in general rationally expected to be zero. The spot rate $p(t)$ is proposed by Stein to equilibrate the stock of short term claims, while the long term equilibrium exchange rate $y(t)$ serves to simultaneously equilibrate the stock demand and supply of money and fulfill the doctrine of purchasing power parity. The difference $p(t) - y(t)$ is a determinant of basic balance, and thus affects the change in the stock of short term claims. Since there is feedback from $p(t)$ to $p(t+j)$, the spot rate cannot be a martingale, and $E[(1-B)p(t)]$, where B is the backshift operator, cannot be zero.

The same conclusion would seem to apply to forward rates, to the extent that they reflect rationally derived prices of current spot currency purchases carried forward - the process known as normal backwardization. Thus the market efficiency found by Caves and Feige (1980) is seen to be quite remarkable evidence of the semi-unity of the U.S. and Canadian economies rather than verification of exchange market efficiency.

The market studies affected by the feedback problem are not limited to exchange rates, although problems there have been most recognized. Stein discusses five studies marred by the feedback problem.[4] But the preceding applies with equal force to any market where there is feedback to

[4] Dooley and Shafer (1976), Cummins, et. al. (1976), Levich (1978), Kaserman (1973) and Frenkel (1977).

a causal variable from other, endogenous variables. To paraphrase Stein's Proposition 2 (page 577), "an examination of the time-series per se of market prices which incorporate feedback cannot reveal whether or not the market is efficient."

Even though examination of the time series is purported to be valueless for efficiency tests of foreign exchange markets, other tests remain. For example, Huang (1984) has examined the variance of spot exchange rates with the aim of testing the monetary approach and EMH. Huang writes the basic monetary approach to exchange rate determination under rational expectations (or what amounts to the same thing, EMH) in logarithmic form as

$$s_t = (m - m^*)_t - \beta(y - y^*)_t + a[E_t(s_{t+1}) - s_t],$$

where s, m, and y are the logarithms of the spot exchange rate, money stock, and real income. In this equation, the asterisk (*) indicates a foreign value; β is the income elasticity of money demand; a is the (nominal) interest elasticity of money demand; and E is the expectations operator. Today's expectation of tomorrow's spot rate $[E_t(s_{t+1})]$ is assumed to depend on expectations of future changes in domestic and foreign money stocks and real incomes. Let $x = (m - m^*) - \beta(y - y^*)$, and let A_t be a properly weighted moving average of all future changes in domestic and foreign money stocks and real incomes, $A_t = \Sigma w^i(Dx_{t+i})$, summed from i=1 to infinity. The w^i are the weights $[w = a/(1-a)]$ and D is the difference operator. Huang is able to write the monetary model as

$$(s_t - x_t) = A_t - \mu_t,$$

where μ_t is the real forecast error $[\mu_t = A_t - E_t(A_t)]$ and is not correlated with any currently obtainable relevant information. Therefore

$$Var(A_t) = Var(\mu_t) + Var(s_t - x_t) \geq Var(s_t - x_t).$$

By the smoothing properties of moving average filters,

$$Var(A_t) \leq [w/(1-w)]^2 Var(Dx_t),$$

so that by assuming probable values for a and ß, the magnitude of the variances,

$$Var(s_t - x_t) \leq [w/(1-w)]^2 Var(Dx_t),$$

becomes a testable hypothesis. Huang found that, using monthly data for Germany, Britain, and the U.S. from March, 1973, to March, 1979, the hypothesis was refuted quite soundly. Spot exchange rates were significantly more variable than a rational and efficient market would allow, given the correctness of the researcher's modelling of the monetary approach.

The methodology employed by Huang has been used by others, and in contexts of both stock and bond price variances.[5] But the methodology has not displaced the practice of examination of residuals for autocorrelation. For example, Murfin (1984), using sixteen monthly U.S. Dollar exchange rates from September 1978 through September 1983, employs evidence of residual autocorrelation in the estimated equation

$$lnS_t = a + \beta ln_{t-1}F_t + U_t$$

to "undermine the joint assumption of rational expectations and risk neutrality which underlies the simplest model of exchange market efficiency." Durbin-Watson statistics indicate significant (positive) first order autocorrelation for all save three of the exchange rate series using OLS regressions, and for all sixteen using the Zellner regression technique. The researcher then models spot rates using the autocorrelation information in forward rates, estimating

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[5] See Huang (1981), Shiller (1979b), Shiller (1979a), Leroy and Porter (1979) and Singleton (1979).

$$\ln S_t - \ln_{t-1}F_t = a + \beta[\ln S_{t-1} - \ln_{t-2}F_{t-1}] + U_t$$

over the twenty most recent months for each one-period-ahead forecast, and finding β to be significant and positive for all currencies. According to the researcher, "... this simple forecasting model implicitly represents a stronger test of the efficiency of the foreign exchange market than the unbiasedness of the forward rate." The statement is true if profitable speculation is thereby possible. But the researcher's monthly data are averages of daily rates, so that in order to reap the forecasting model's speculative harvest, the trader must be able to purchase (or sell) currency forward and simultaneously sell (or buy) currency spot after the end of a month at precisely the average of the daily prices observed over the previous month. This will not in general be possible. Since the series are not martingales, by the time go-long signals are observed, prices have already moved out of profitable range, if the market is efficient.

The Rotterdam Spot Oil Market

A similar problem exists in the "profitable" simulation performed by Gjølberg (1985). In examining the Rotterdam spot market for crude oil, Gjølberg first employed runs tests and regressions in finding that the market was weak-form inefficient. The series of daily price changes from 1978 through 1983 showed significantly fewer runs than 99 of 100 random series drawn from a white noise generator, or a larger than expected number of reversals. The same result holds for weekly and monthly price changes overall, but not for every year in the test interval. In addition, in the regression of daily and weekly percentage change in spot price on its lagged values, by year,

$$P_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + a_3 P_{t-3} + e_t,$$

a_1 was for all six years significantly greater than zero when the series of daily price changes was examined, but only so for 1980 and 1982 when weekly price changes were examined. The value of a_1 seems to have declined after 1981, the year in which International Petroleum Exchange futures contracts on gas oil began trading, indicating that the market perhaps became more efficient as a result. Gjølberg reports the values of the Durbin-Watson statistic (DW) in his regression results, although it imparts little information when lagged dependent variables are used as predictors, as is here the case. The researcher then formulates a trading rule, and tests its performance over the six remaining months of the test period, January through June, 1984. The trading rule allows only long positions, as follows: buy (or hold) 1,000 tons of crude if today's price exceeds yesterday's; if not, sell. According to the simulation, after deduction of line-of-credit capital costs of 10% per year and neglecting any other possible insurance, transportation, transactions, brokerage, or storage fees, a tidy profit of some $20,000 remains after eleven round turn trades, thus implicating the price series as a process of an inefficient market of the weak kind. However, it is problematic to suppose that rational risk-averse investors would - or could - employ such a trading method, for the following reasons:

First, the purchase of 1,000 tons of crude would have required the payment, in 1984, of some one-quarter million dollars. The sum would have had to remain at risk until receipt of a like sum from the sale of the asset. All sorts of scenarios can be imagined that would have prevented delivery and/or payment, but these aside, the commodity trader was undertaking an investment of a risky nature, to be compared with the returns from similarly risky ventures, not that of risk-free capital costs. The existence of positive simulated returns from trading ventures requiring the risk of capital is to be expected, if capital market theory is correct and markets are efficient processors of information. The existence of returns significantly exceeding those from investments of like risk is the proper measure of inefficient markets.

Second, this simulation, along with almost all of its counterparts, assumes the ability of purchasing the commodity at the price that has just given the signal to buy, and selling at the price giving the signal to sell. The impossibility of selling for more than the bid price and purchasing at less than the asked price is well known, but is similar in nature to the avoidance of transactions costs, and so is neglected here. But it is in general not possible to buy and/or sell at yesterday's price. It is more likely to be possible the more nearly the price process approaches a martingale – but then, of course, no one would want to. There is a paradox involved in the testing of small price-change filter trading rules of this sort. The simulated profit largely exists by virtue of being able to buy and sell today at yesterday's price, which by being greater than the previous closing, has signaled a buy. If today's price is higher still, a future "profit" accrues. If the same, the trader is out with no loss. If lower, the trader is out with a loss – but in general a small one. In order to lose simulated profits, a reversal of a specific kind must occur. A run must be followed by such a powerful reversal that all previously accrued gains are more than erased. But if the variance of the process is reasonably constant, such an occurrence is quite unlikely. Thus such filters amount to hardly more sophisticated advice than i.e. "Cut your losses and let your profits run," the wisdom of which has long been recognized.

Summary

In this sample of the literature many hours of research by serious students of financial futures markets have been summarized. Much thought entered into the performance and presentation of that research, and the considered opinions of diligent scholars is always valuable. Yet there is no consensus.

Many students believe that their research has shown financial futures markets to be less than perfectly efficient. Many others, employing the same assumptions and methodology, disagree. There is no clearly defined dominance of views. It is ironic that the very question of market efficiency is answered efficiently.

To some, because of uncaptured arbitrage profits, the market is inefficient. To others, because the time path of price or returns are not markedly different from random walks, the market is efficient. To still others, because the variability of prices or returns are inconsistent with those implied by random walk realizations, the market is inefficient. It cannot be both. As a pendulum in a randomly moving elevator sometimes does - and sometimes does not - indicate the gravitational constant, something important is missing. Something is overlooked. The experiment is flawed.

The flaw in the researches surveyed is common to all. The *a priori* assumption that assets are perfect substitutes because they have identical costs and identical returns is not necessarily valid. The distributions of the returns may be different enough to render the assumption incorrect. At times, in the examination of some markets, the assumption may be justified, and the researcher may perhaps conclude that the market is efficient. At other times, or in other markets, the assumption may not be valid, and the researcher may conclude the opposite. It is conceivable, though the occurrence must be rare indeed, that the incorrect assumption of perfect substitution would be sufficiently offset by an inefficient market so that the conclusion of efficiency would result.

In summary, therefore, it is not possible to judge from the historical record of past research whether or not financial futures markets are efficient. Past research has not accounted for the difference in variability of the futures-based instruments, and is commonly flawed. In a catholic sense, the present study reconciles the disparate results of past research. For the first time, the question of the efficiency of financial futures markets is adequately addressed.

CHAPTER IV

EMPIRICAL TESTS OF FINANCIAL FUTURES MARKETS

Treasury Bond Futures

Unlike that of the Treasury bills futures market, adequate testing for efficiency in the bond futures market is not possible, since in the bond futures market, no unique instrument exists for delivery. However, the performance of the market may be examined in some detail. In general, the market assures that yields from maturing a Treasury bond, versus purchasing a Treasury bill and accepting a bond through a long futures settlement, are virtually identical. In the following performance analysis, the bond in question is the August 15, 2001 Treasury bond of 8% coupon yield, callable in 1996. The period of analysis begins in January,1978 - at which time the Chicago Board of Trade opened trading in the Treasury bond futures contract. The test period ends with the June, 1981 contract. After that time the bond had less than 15 years until earliest call, and therefore was no longer deliverable. The particular bond was chosen for use in the data set because, being an 8% bond, no conversion factor calculations were necessary.[1] In all of what follows, however, yields are strictly approximate, since there is no way to guarantee that this particular bond will be in fact delivered in settlement.

Treasury bill data were collected from daily editions of the Wall Street Journal. Treasury bond future contract settling prices were provided by the Chicago Board of Trade. Bid and Asked prices for the 8% August 15 2001-2006 Treasury bond was downloaded from the Micro Quote database, a part of the Compuserve Information Services database collection.

In the calculations of descriptive statistics that are presented in this chapter, the SAS application MEANS procedure was used. Regression coefficients were obtained by using the SAS SYSREG procedure as well as the SPSS-X REGRESSION command. Regressions requiring corrections for serial correlation were performed using the SAS AUTOREG procedure and the SPSS-X AREG command.

The extreme variability of actual annual yields from Strategy IA settled early may be seen in the box plots of Appendix D, and for each bill and bond contract, Appendix G. In Table 4 below, summary statistics are presented for each business day that it was possible to make observations on two prospective yields: the yield to maturity from outright purchase of a particular Treasury bond (YIIB), and the yield to maturity from the purchase and maturation of a Treasury bill and the 8% August 2001 Treasury bond delivered in fulfillment of a bond future contract (YIIAB). The naming convention will be obvious upon referral to Table 2 in Section II above. The variable named (LONGPREM) is the difference in yields, YIIAB - YIIB. Notice

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1 In actual fact, a slight correction is needed in alternate quarters. However, since the conversion factor is either 1.0000 or .9998, and results in a converted price difference of approximately half a tick (1/2 of 1/32), it is ignored in the calculations. See Chicago Board of Trade Conversion Factors, Publication No. 765, Revised (1985, pp. 17-19).

that the values in the table are based on an assumption, since there is no actual reason that this particular Treasury bond will be delivered. Yields are approximate, and are calculated using Stigum's method [see Stigum (1981; 136-139)], which is, for the former yield,

$$y1 = (cY + 1 - P)/[Y - (1 - P)(2Y + 1)/4],$$

where y1 is the approximate yield to maturity, c is the coupon yield, Y is the number of years to maturity, and P is the price of the bond. In calculating yield YIIB, c is 8%, and P is the asked price of the bond purchased.

In calculating yield YIIAB, we assume payment of round turn futures contract commission ($60) and subtraction of the opportunity cost of margin posted to the account ($1,500) while the contract is in force. A Treasury bill is purchased and held for the number of days until contract expiration, at which time the bond is delivered to the long by the short. The formula used to calculate the approximate yield to maturity is therefore weighted by the relative length of time each instrument is held. The calculation of approximate yield YIIAB is given by the formula

$$y2 = [X/(X+Y)][(1 - Pb)/Pb] + [Y/(X+Y)][(cY + 1 - F)/[Y - (1 - F)(2Y + 1)/4],$$

where y2 is the approximate yield to maturity, X is the number of years the Treasury bill is held, Pb is the asked price of the bill, Y is the number of years the bond will have to maturity upon its delivery, and F is the futures contract price.

The two yields are equivalent to the yields from Strategy II and Strategy IIA, assuming that the bond delivered in contract fulfillment is the same bond to be held outright. In general, the delivered bond, and thus the Strategy IIA yield, will not be the same, even if it is cheapest-to-deliver, and therefore the yields are only approximately comparable. However, to the extent the yields are satisfactory proxies for what might actually occur, the Strategy IIA yield appears to be slightly more variable than its counterpart. It also appears to yield slightly more than yield from Strategy II, as would be expected. But perhaps the most striking indication from the table is the near equivalence of the two yields.

TABLE 4

AVERAGE YIELD TO MATURITY OF BOND BOUGHT OUTRIGHT AND BOND BOUGHT THROUGH BOND FUTURES CONTRACT

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN
YIIB	880	9.741026	1.2541752	8.035840	12.553994	0.0422782
YIIAB	880	9.808090	1.2671826	8.069554	12.587870	0.0427167
LONGPREM	880	0.067064	0.0516621	-0.130098	0.378190	0.0017415

The reader can verify that the yields to maturity are close and highly correlated be referring to the charts in Appendix C. Usually, but not always, the Strategy IIA yield is a few basis points higher than that of Strategy II. The two tend to move together, but the spread does widen and narrow at times, indicating less than perfect correlation. Care is advisable in interpreting the yields, however. It is unknown how much of the apparent premium in the Strategy IIA yield is due to the greater variability, and how much is an arithmetic artifact, due to the calculation of yield from the assumed purchase of a bond which will not actually be delivered in futures contract settlement. Since the actual bond to be delivered will in all probability be a different, cheaper bond than the 8% of August 2001, the yield to maturity will probably be less than it appears in the data. A proper test would mandate the collection of data on the actual delivery bond at contract expiration. However, except for investors who are perfectly prescient, the identity of the delivery bond remains unknown, *ex ante*. Another possibility would be to collect daily data on all existing delivery bonds, find the cheapest-to-deliver bond, and assume that the bond would still be the cheapest-to-deliver bond that would actually be delivered on contract expiration.

Even with the problems in interpretation, one may easily infer that the yields to maturities are highly correlated. The regression results in Table 5 indicate the high degree of correlation of the yield of the combination bill-bond futures with the yield of the bond alone. The t-statistic for the null hypothesis that the regression parameter on YIIB is unity is 7.3; thus the null hypothesis can be rejected at the 1% significance level, indicating that the yield of Strategy IIA exceeds that of Strategy II. The root mean squared error is only 5 basis points. The residuals are highly correlated, however, as can be seen from the Durbin-Watson statistic, which may bias the standard error of the parameter estimates, but enough robustness certainly remains to indicate the high degree of tracking of the bond by the bond futures contract.

The variable named DAYTOEXP is the number of days remaining before contract expiration. The variable's influence is negative, and significant at the 10%, though not the 5% level; but it has only a very small influence on the yield to maturity of the combination instrument. Even 90 days from contract expiration, the influence on the yield of Strategy IIA would be only -.008 percent per year.

TABLE 8

AVERAGE DAILY YIELD OF BILL-BOND
FUTURES COMBINATION AND
BOND BOUGHT OUTRIGHT
AFTER 21 DAY HOLDING
PERIOD

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN
ERLYIIB	395	-1.71310073	59.36466501	-177.8458288	241.0635954	2.98696046
ERLYIIAB	395	2.42171507	48.10000369	-135.8145644	183.1384083	2.42017384

Both yields are highly variable. The standard deviation of the yield from the combination of the bill and futures contract settled early is slightly less than that of the bond held alone, due to the stable positive earnings of the bill at times offsetting some of the loss on the futures contract, and contributing a smaller increment to total profit. In this period of generally rising interest rates, neither of the investment strategies did particularly well. The average annual yield from holding the bond for 21 days is in fact negative, and the average yield from holding the combination is less than that of the bill alone. This is due to the particular realization of interest rates in the approximately 3 1/2 years of the test. In a period of generally falling interest rates, the bond strategy will average higher annual yields. However, due to the extreme variability of yields from both strategies settled early, neither is advisable if there is an appreciable probability of early need for cash.[2]

2 They may be good speculative vehicles, for those participants with tastes for the distributions they offer, and constraints that do no prohibit their exercise. This can be seen in the range of the annual yields. A speculator with the right timing could have earned 241 percent per year, at least for 21 days, from Strategy II and 183 percent per year from Strategy IIA. Speculators with poor timing could have lost 178 (136) percent per year over 21 days from Strategy II (IIA).

In Table 9, the results from regressing the early settlement yield from Strategy IIA on the early settlement yield from Strategy II (ERLYIIB) and the number of days to contract expiration (DAYTOEXP). Correction for serial correlation in the residuals is via the Cochrane-Orcutt method. A large portion of the variation in the early settlement yield of Strategy IIA is accounted for by the variation in the Strategy II early settlement yield, and the autoregressive error process. The results are not unlike those from the previous regression, except for two things: the large mean squared error, and the significance of the DAYTOEXP variable. The first is a natural result of the extreme variation in the realized yield from owning bonds or bond futures that are settled only 21 business days after inception. The second is most likely a statistical artifact - the parameter estimate, although significantly negative, is still quite small.

TABLE 9

REGRESSION OF DAILY YIELD OF BILL-BOND FUTURES COMBINATION ON BOND BOUGHT OUTRIGHT AFTER 21 DAY HOLDING PERIOD

RHO		.43697474	STANDARD ERROR OF RHO		.04548834
R-SQUARED		.95885178	STANDARD ERROR		5.8587772
DURBIN-WATSON		2.2775016			
	DF	SUM OF SQUARES	MEAN SQUARE		
REGRESSION	2	311945.69	155972.84		
RESIDUALS	390	13386.86	34.33		
	B	SEB	BETA	T	SIG T
ERLYIIB	.7933621	.00837510	.97569592	94.728724	.00000000
DAYTOEXP	-.0972234	.02652901	-.03774701	-3.664795	.00028203
CONSTANT	6.6744382	.94150226	.	7.089137	.00000000

Table 10 presents the results from regressing the change in the early settlement yield from Strategy IIA (DEYIIAB) on the early settlement yield from Strategy II (DEYIIB) and the number of days to contract expiration (DAYTOEXP). The early settlement yields, although not tied as closely together as the yields to maturity (see Table 4), are closely related.

TABLE 10

REGRESSION OF DAILY YIELD OF BILL-BOND
FUTURES COMBINATION ON YIELD OF
BOND BOUGHT OUTRIGHT AFTER
21 DAY HOLDING PERIOD:
FIRST DIFFERENCES

MODEL: MODEL01		SSE	18281.16	F RATIO	689.42
		DFE	391	PROB>F	0.0001
DEP VAR: DEYIIAB		MSE	46.754891	R-SQUARE	0.7791
DURBIN-WATSON D STATISTIC = 2.9369					
FIRST ORDER AUTOCORRELATION = -0.4698					
VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	-0.014846	0.695256	-0.0214	0.9830
DEYIIB	1	0.739775	0.019988	37.0112	0.0001
DAYTOEXP	1	0.0007103723	0.020401	0.0348	0.9722

Even though the results are contaminated by the fact that the test instrument may not be at all times cheapest-to-deliver, and therefore not the bond actually delivered, one may easily infer that the yields to maturities are highly correlated. The regression results in Tables 4-10 indicate the high degree of correlation of the expected yield of the combination bill-bond futures with the yield of the bond alone. The results also indicate the close association of the simulated early settlement yields note futures combination is more variable than the real-note equivalent, and to a greater degree of difference than that of the bond contracts. Some of the difference in variability is due to the different test interval, but how much is not clear.

TABLE 11

AVERAGE YIELD TO MATURITY OF
NOTE BOUGHT OUTRIGHT AND
NOTE BOUGHT THROUGH
NOTE FUTURES
CONTRACT

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN
YIIN	735	11.96565	1.0265695	9.95051	14.73250	0.0378656
YIIAN	735	12.59879	1.0992306	10.63155	15.21567	0.0405457
LONGPREM	735	0.63314	0.4452687	-0.15875	1.42272	0.0164240

This note and the futures settling price are quite closely related, as can be seen from Table 12. The root mean squared error is 45 basis points, much higher than that of the bond contracts - but then the term to maturity is shorter for the note than for the bond. The note futures market clearly tracks the test note less accurately than the bond contract tracked the test bond (see Table 5). That this is so can also be seen by referring to Appendix B (Treasury note contracts) and Appendix C (bond contracts) together. The regression results in Table 12 are not corrected for autocorrelation of the residuals.

TABLE 12

REGRESSION OF YIELD TO MATURITY OF
BILL-NOTE FUTURES COMBINATION
ON YIELD OF NOTE BOUGHT
OUTRIGHT

MODEL: MODEL01		SSE	145.018348	F RATIO	1872.37
		DFE	732	PROB>F	0.0001
DEP VAR: YIIAN		MSE	0.198112	R-SQUARE	0.8365
DURBIN-WATSON D STATISTIC = 0.0178					
FIRST ORDER AUTOCORRELATION = 0.9897					
VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	0.907845	0.194201	4.6748	0.0001
YIIN	1	0.979451	0.016006	61.1943	0.0001
DAYTOEXP	1	-0.000656869	0.0007018878	-0.9359	0.3497

After correction for serially correlated residuals, the results reported in Table 13 are obtained. The serial correlation correction procedure lowers the R^2 statistic slightly, and makes the estimate of the effect of the actual note's yield (YIIN) higher, although slightly less significant. Approximately 80 percent of the variation in the prospective Strategy IIA yield to maturity is captured by the concurrent note yield (and the autocorrelation in YIIAN itself). However, most of the reduction in the mean squared error is seen to be due to the autocorrelation term; the value of RHO is very high, although the hypothesis the YIIAN is a random walk, with RHO=1, can be rejected at the 10%, although not at the 5% level of significance. Clearly much of the predictive power of the model is due to the autoregressive process. It is evident, however, that there remains a close connection between the yields, and that the number of days prior to contract expiration is of no significant influence on the bill-note future yield.

TABLE 13

REGRESSION OF YIELD TO MATURITY OF BILL-NOTE FUTURES COMBINATION ON YIELD OF NOTE BOUGHT OUTRIGHT, CORRECTED FOR RESIDUAL AUTO-CORRELATION

RHO		.9916953	STANDARD ERROR OF RHO		.0047568
R-SQUARED		.7972975	ADJUSTED R-SQUARED		.79646447
STANDARD ERROR		.05560177	DURBIN-WATSON		2.6530568
	DF	SUM OF SQUARES	MEAN SQUARE		
REGRESSION	2	8.8768998	4.4384499		
RESIDUALS	730	2.2568361	.0030916		
	B	SEB	BETA	T	SIG T
YIIN	1.1808700	.02203870	.89286711	53.581666	.00000000
DAYTOEXP	.0001458	.00019037	.01276489	.766031	.44390559
CONSTANT	-1.2663224	.35209138	.	-3.596573	.00034439

Taking first differences of the yield variables does not change the results appreciably. In Table 14, the value of the autoregressive coefficient is smaller, but the root mean square error is about the same. The dependent variable is the first difference of the yield to maturity of the Treasury bill and the test note purchased via contract ownership, DYIIN is the first difference of the yield to maturity of the test note, and DAYTOEXP is the number of days until contract expiration. DAYTOEXP remains insignificant, and DYIIN significantly positive. The implication again is the close connection of the futures price and the price of the test note.

TABLE 14

REGRESSION OF YIELD TO MATURITY OF
BILL-NOTE FUTURES COMBINATION
ON YIELD OF NOTE BOUGHT
OUTRIGHT: FIRST
DIFFERENCES

ESTIMATES OF THE AUTOREGRESSIVE PARAMETERS

LAG	COEFFICIENT	STD ERROR	T RATIO
1	0.34299254	0.03476646	9.865615

SSE	1.996362	DFE	730
MSE	0.002734743	ROOT MSE	0.05229477
SBC	-2226.35	AIC	-2244.74
REG RSQ	0.8457	TOTAL RSQ	0.8213

VARIABLE	DF	B VALUE	STD ERROR	T RATIO	APPROX PROB
INTERCPT	1	0.00233435	0.003105780	0.752	0.4525
DYIIN	1	1.20187944	0.019039654	63.125	0.0001
DAYTOEXP	1	5.07943E-07	0.0000628212	0.008	0.9936

In the event of early settlement, the yields from the note positions, as in the case of bonds, are quite variable, although slightly less variable than for the bond futures market. The artificial note yield, settled early, is presented in Table 15 as ERLYIIAN, and is more variable than the early-settlement yield from the test note, ERLYIIN. This is not true of the bond futures market with early settlement. Unlike the bond futures market, the mean early-settlement yield of the note exceeds -slightly - that of the bill-futures combination. However, the pooled standard error of the mean, for the note futures market, is approximately 1.75. The hypothesis that the two means are equal cannot be rejected. The same is true in the bond futures market, where the pooled standard error of means is 2.7. The insignificant differences in yields may be due to the different interest rate environments in the two test periods.

TABLE 15

AVERAGE EARLY SETTLEMENT YIELD OF NOTE
BOUGHT OUTRIGHT AND BILL-NOTE
FUTURES COMBINATION AFTER
21 DAY HOLDING PERIOD

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN
ERLYIIN	430	16.337	31.19810	-49.853	104.732	1.50451
ERLYIIAN	430	16.042	41.25412	-68.416	127.409	1.98945

The test note is connected quite closely to the futures contract, as may be seen from Table 16. The variables are as defined in Table 15, and the regression correction, by the Cochrane-Orcutt grid method of the SPSS-X AREG procedure, corrects for significant serial autocorrelation. The yield from early note sale is positively and significantly related to the yield from early bill sale and closure of the note contract. The root mean squared error is large, at 477 basis points, although smaller than that of the bond contract test. The DAYTOEXP variable is significantly and positively related to ERLYIIAN, indicating that, during the test period, as the expiration date of a particular contract approached, and DAYTOEXP declined, the early settlement yield tended to decline, at the rate of about 11 basis points per day, ± 5 basis points. This is so much smaller than the root mean squared error value, however, that the effect does not indicate a profitable opportunity. The opposite is the case for the bond contracts. There, as DAYTOEXP declined, the early settlement yield tended to increase. This leads to the conclusion that the relationship in both cases is spurious, significant only because of the particular interest rate environment.

TABLE 16

REGRESSION OF EARLY SETTLEMENT YIELD
OF BILL-NOTE FUTURES COMBINATION
ON ACTUAL NOTE YIELD AFTER
21 DAY HOLDING PERIOD

ESTIMATES OF THE AUTOREGRESSIVE PARAMETERS

LAG	COEFFICIENT	STD ERROR	T RATIO
1	-0.67890623	0.03557332	-19.084704

SSE	9700.49	DFE	426
MSE	22.7711	ROOT MSE	4.771908
SBC	2585.103	AIC	2568.848
REG RSQ	0.9318	TOTAL RSQ	0.9867

VARIABLE	DF	B VALUE	STD ERROR	T RATIO	APPROX PROB
INTERCPT	1	-8.46446045	1.06214418	-7.969	0.0001
ERLYIIN	1	1.31233050	0.01778393	73.793	0.0001
DAYTOEXP	1	0.10711007	0.02741682	3.907	0.0001

In Table 17, the dependent variable is the first difference of the early settlement yield of the artificial instrument composed of a Treasury bill and a long Treasury note futures position. The regression results are corrected for first-order serially correlated residuals. The regression is significant, and the concurrent early settlement yield of the note is a significant and positive influence, in the first differences, on the artificial instrument yield. The number of days that remain before contract expiration (DAYTOEXP) remains a significant predictor, but with an even smaller coefficient. The unexplained variation is quite large, even though 70% of the total variation is accounted for by the regression - the root mean squared error is 695 basis points. In the case of Treasury notes, it seems, the Treasury bill, sold before maturity, is influenced in the same manner as the Treasury note contract, but in an opposite manner in the case of the bond contracts. This is one way to account for the higher variation of the artificial note position versus the real note position, and the regression coefficient larger than one, whereas the opposite is the case for the Treasury bond market. However, at least some of the differential variation is due to the different interest rate environment.

TABLE 17

REGRESSION OF EARLY SETTLEMENT YIELD
OF BILL-NOTE FUTURES COMBINATION
ON ACTUAL NOTE YIELD AFTER
21 DAY HOLDING PERIOD:
FIRST DIFFERENCES

ESTIMATES OF THE AUTOREGRESSIVE PARAMETERS

LAG	COEFFICIENT	STD ERROR	T RATIO
1	0.13613710	0.04805552	2.832913

SSE	20548.18	DFE	425
MSE	48.34865	ROOT MSE	6.953319
SBC	2901.545	AIC	2885.299
REG RSQ	0.7015	TOTAL RSQ	0.6959

VARIABLE	DF	B VALUE	STD ERROR	T RATIO	APPROX PROB
INTERCPT	1	-1.13096025	0.657797939	-1.719	0.0863
DALYIIN	1	1.32283249	0.042153623	31.381	0.0001
DAYTOEXP	1	0.06541466	0.020190001	3.240	0.0013

Bond Futures and Note Futures:

A Summary

As is the case in the bond complex, the particular note used as the test instrument may not be at all times (or even momentarily) cheapest-to-deliver, and therefore not the note actually delivered. However, the results do indicate that the yields to maturity are highly correlated. The regression results in Tables 12-17 indicate the high degree of correlation of the expected yield of the combination instrument (long Treasury bill - short Treasury note futures) with the yield of the note alone. The results also indicate the close association of the simulated early settlement yield levels of the two note instruments; though clearly the association is not as close as in the case of Treasury bonds (compare Tables 5 and 6 with Tables

9 and 10). The correlation of first-differenced yields is high in both cases, but higher in the case of notes than bonds, as may be seen by comparing Tables 7 and 14. Compared to bonds, the mean yields on the real note and the artificial note are quite significantly different. In the bond complex, the *ex ante* yields are only 5 basis points apart, and the difference is not significant. In the case of notes, the yield on the artificial instrument exceeds the yield on the real note by 63 basis points, or approximately 16 standard deviations (compare Table 4 with Table 11). What can account for these similarities and differences?

Short term interest rates are often seen to change in isolation from long term rates. Thus early settlement of the artificial bond instrument, composed of a bill and a bond futures position, contains a degree of unsystematic risk, *vis-a-vis* the real bond. However, Treasury notes, being shorter-term obligations, are influenced by the same information that influences Treasury bills. Yields on notes are less often observed to fluctuate randomly with respect to bills than are yields on bonds. The degree of unsystematic variation is lower in the case of the artificial note instrument than in the case of bonds.

That this is so is evident in the data. A comparison of Table 8 with Table 15 shows that, upon simulated early settlement, the statistics of variation for the actual bond yield (ERLYIIB) are higher than those of the artificial bond (ERLYIIAB). The standard deviation of ERLYIIB is 23 percent higher than that of ERLYIIAB. The range, or interval between maximum and minimum values, is 31 percent higher, and the standard error of the mean is 24 percent higher. The opposite is true in the case of notes. For the note complex, the variation of the simulated early settlement yield of the artificial note (ERLYIIAN) exceeds that of the real note (ERLYIIN). The standard deviation of ERLYIIAN is 32 percent higher than that of ERLYIIN. The range, or interval between maximum and minimum values, is 26 percent higher, and the standard error of the mean is 33 percent higher.

By the theory developed in Chapter II, we are lead to expect that an asset that is more variable than its functional counterpart will, if the market is efficient, offer a higher yield to investors. The existence of a different distribution of returns makes the assets imperfectly substitutable. This is what is observed in the data.

The data also offer the inference of a corollary: the more the distribution of returns of an artificial asset differs from that of its functional counterpart, the greater the difference in ex ante yields, if the market is efficient. Recognizing that the instruments are imperfect substitutes, therefore, the data are consistent with the hypothesis that the Treasury note and Treasury bond futures markets are efficient.

Treasury Bill Futures

Treasury bill and Treasury bill futures data were collected from the Wall Street Journal. The data begins on January 6, 1976, when contract trading began, and extends through December, 1985. All existing arbitragable opportunities are included.

Table 18 displays the date and number of days until contract expiration that the last profitable arbitrage could have been entered, for each contract. An H indicates the futures discount is above the upper arbitrage limit; an L, that it is below the lower arbitrage limit. Since an L indicates that a contract's discount is too low, or that its price is too dear to prevent profitable arbitrage, the capture of profit implies the purchase of Strategy IA financed by the sale of Strategy I. If the contract discount is above the upper limit for successful arbitrage, an H is displayed, indicating the profitable purchase of Strategy IIA financed by the sale of Strategy II. Of the 40 contracts displayed, 27 involve the former arbitrage, while 13 involve the latter. Interestingly, 8 of the latter arbitrage opportunities occurred in the October, 1979 – 1982 period of nonborrowed reserve management.

TABLE 18

NUMBER OF DAYS PRIOR TO CONTRACT EXPIRATION OF LAST PROFITABLE FUTURES CONTRACT ARBITRAGE

Obs	Expdate	Nowdate	Hi/Lo	Days
1	18MAR76	09MAR76	L	48
2	24JUN76	23JUN76	L	34
3	23SEP76	22SEP76	L	83
4	23DEC76	22DEC76	L	23
5	24MAR77	23MAR77	H	72
6	23JUN77	22JUN77	L	34
7	22SEP77	21SEP77	L	24
8	22DEC77	20DEC77	L	16
9	23MAR78	22MAR78	L	17
10	22JUN78	21JUN78	L	1
11	21SEP78	19SEP78	L	24
12	21DEC78	19DEC78	H	6
13	22MAR79	21MAR79	L	34
14	21JUN79	19JUN79	H	2
15	20SEP79	19SEP79	H	1
16	20DEC79	19DEC79	H	1
17	20MAR80	19MAR80	L	1
18	19JUN80	17JUN80	H	8
19	18SEP80	16SEP80	H	10
20	18DEC80	16DEC80	H	2
21	19MAR81	17MAR81	H	2
22	18JUN81	16JUN81	H	2
23	24SEP81	22SEP81	L	6
24	24DEC81	14DEC81	H	13
25	18MAR82	16MAR82	L	13
26	17JUN82	15JUN82	L	10
27	16SEP82	14SEP82	H	2
28	16DEC82	14DEC82	L	7
29	17MAR83	15MAR83	L	20
30	16JUN83	08JUN83	L	23
31	15SEP83	31AUG83	L	15
32	15DEC83	13DEC83	L	2
33	15MAR84	13MAR84	L	7
34	14JUN84	06JUN84	L	8
35	13SEP84	11SEP84	L	2
36	13DEC84	11DEC84	L	3
37	14MAR85	12MAR85	L	6
38	13JUN85	05JUN85	H	8
39	12SEP85	10SEP85	L	2
40	12DEC85	27NOV85	L	15

In Table 19, the mean futures discount (Mean-C) is compared to the mean upper (Mean-U) and lower (Mean-L) arbitrage limits, for each contract.

The reader will notice that the first seven contracts and the March and June, 1979 and September, 1980 contracts give evidence of efficiency, but for others, the mean futures discount is outside - and lower than - the mean arbitrage limits.

TABLE 19

MEAN UPPER AND LOWER ARBITRAGE
LIMITS AND MEAN BILL FUTURES
CONTRACT DISCOUNT-YIELD

OBS	Expdate	Mean-U	Mean-L	Mean-C	N
1	18MAR76	5.3535	5.0300	5.1100	43
2	24JUN76	5.6927	5.3795	5.4814	64
3	23SEP76	5.5915	5.3529	5.4387	63
4	23DEC76	5.0555	4.8369	4.8435	62
5	24MAR77	4.9521	4.7287	4.8070	63
6	23JUN77	5.2303	4.9873	5.0484	64
7	22SEP77	5.7676	5.5366	5.5835	63
8	22DEC77	6.6157	6.3818	6.2771	63
9	23MAR78	6.8564	6.6246	6.5708	62
10	22JUN78	7.0296	6.7689	6.7575	64
11	21SEP78	7.6962	7.4071	7.3311	62
12	21DEC78	9.1381	8.7331	8.6853	62
13	22MAR79	9.6735	9.3600	9.4110	62
14	21JUN79	9.6099	9.3144	9.3784	63
15	20SEP79	9.7106	9.4109	9.3775	64
16	20DEC79	12.0225	11.5555	11.4172	61
17	20MAR80	13.3282	12.9099	12.6466	61
18	19JUN80	10.8446	10.2663	10.2156	61
19	18SEP80	8.9878	8.5609	8.7487	63
20	18DEC80	13.5624	13.0902	12.8198	61
21	19MAR81	13.9075	13.2794	12.8946	120
22	18JUN81	14.4683	14.0311	13.9730	63
23	24SEP81	15.4261	15.0219	14.3922	63
24	24DEC81	14.2802	13.7204	13.0755	118
25	18MAR82	13.6551	13.1098	12.6562	122
26	17JUN82	12.9195	12.5058	12.2538	63
27	16SEP82	11.3883	10.9949	10.9386	63
28	16DEC82	9.0768	8.7635	8.2428	61
29	17MAR83	8.3395	8.0431	7.9575	63
30	16JUN83	8.5749	8.3461	8.3422	59
31	15SEP83	9.5981	9.3697	9.3542	55
32	15DEC83	9.1921	8.9817	8.9578	60
33	15MAR84	9.4024	9.2188	9.1711	61
34	14JUN84	10.2918	10.1035	10.0592	59
35	13SEP84	10.9092	10.7293	10.5652	62
36	13DEC84	9.8481	9.6699	9.3446	61
37	14MAR85	8.5019	8.3747	8.2622	60
38	13JUN85	8.3839	8.2335	8.0676	59
39	12SEP85	7.3628	7.2226	7.1002	63
40	12DEC85	7.5513	7.4054	7.1330	53

TABLE 20

NUMBER OF DAYS CONTRACT DISCOUNT IS OUTSIDE LIMITS OF PROFITABLE ARBITRAGE

OBS	EXPDATE	NUMHI	NUMLO	NUMTOTAL
1	18MAR76	0	7	43
2	24JUN76	0	8	64
3	23SEP76	0	3	63
4	23DEC76	0	29	62
5	24MAR77	1	8	63
6	23JUN77	1	12	64
7	22SEP77	0	12	63
8	22DEC77	0	53	63
9	23MAR78	0	45	62
10	22JUN78	0	37	64
11	21SEP78	0	38	62
12	21DEC78	5	36	62
13	22MAR79	0	14	62
14	21JUN79	2	14	63
15	20SEP79	1	35	64
16	20DEC79	2	42	61
17	20MAR80	3	44	61
18	19JUN80	2	38	61
19	18SEP80	9	8	63
20	18DEC80	1	49	61
21	19MAR81	2	90	120
22	18JUN81	10	37	63
23	24SEP81	0	61	63
24	24DEC81	2	101	118
25	18MAR82	1	101	122
26	17JUN82	0	47	63
27	16SEP82	18	36	63
28	16DEC82	0	53	61
29	17MAR83	0	43	63
30	16JUN83	1	34	59
31	15SEP83	0	29	55
32	15DEC83	0	34	60
33	15MAR84	0	48	61
34	14JUN84	1	47	59
35	13SEP84	1	55	62
36	13DEC84	0	60	61
37	14MAR85	0	51	60
38	13JUN85	3	53	59
39	12SEP85	0	59	63
40	12DEC85	0	53	53

TABLE 21

MEAN DIVERGENCE OF FUTURES
DISCOUNT FROM IMPLICIT
FORWARD RATE

OBS	EXPDATE	DIVMEAN	DIVSTD	T	N
1	18MAR76	-0.08173	0.0129258	-6.323	43
2	24JUN76	-0.05468	0.0091710	-5.962	64
3	23SEP76	-0.03349	0.0055807	-6.001	63
4	23DEC76	-0.10263	0.0092079	-11.145	62
5	24MAR77	-0.03343	0.0084525	-3.954	63
6	23JUN77	-0.06038	0.0107172	-5.634	64
7	22SEP77	-0.06860	0.0078258	-8.765	63
8	22DEC77	-0.22160	0.0129246	-17.145	63
9	23MAR78	-0.16969	0.0120800	-14.047	62
10	22JUN78	-0.14175	0.0160805	-8.815	64
11	21SEP78	-0.22048	0.0252463	-8.733	62
12	21DEC78	-0.25025	0.0376301	-6.650	62
13	22MAR79	-0.10577	0.0146055	-7.242	62
14	21JUN79	-0.08373	0.0122920	-6.812	63
15	20SEP79	-0.18326	0.0267643	-6.847	64
16	20DEC79	-0.37181	0.0379681	-9.793	61
17	20MAR80	-0.47247	0.0552499	-8.552	61
18	19JUN80	-0.33988	0.0393096	-8.646	61
19	18SEP80	-0.02563	0.0225577	-1.136	63
20	18DEC80	-0.50650	0.0381696	-13.270	61
21	19MAR81	-0.69885	0.0515867	-13.547	120
22	18JUN81	-0.27669	0.0451986	-6.122	63
23	24SEP81	-0.83177	0.0443761	-18.744	63
24	24DEC81	-0.92480	0.0521686	-17.727	118
25	18MAR82	-0.72623	0.0449641	-16.151	122
26	17JUN82	-0.45881	0.0399605	-11.482	63
27	16SEP82	-0.25306	0.0655882	-3.858	63
28	16DEC82	-0.67735	0.0822631	-8.234	61
29	17MAR83	-0.23388	0.0192823	-12.129	63
30	16JUN83	-0.11831	0.0132719	-8.915	59
31	15SEP83	-0.12974	0.0127521	-10.174	55
32	15DEC83	-0.12906	0.0112528	-11.469	60
33	15MAR84	-0.13945	0.0094078	-14.823	61
34	14JUN84	-0.13847	0.0105049	-13.181	59
35	13SEP84	-0.25407	0.0209572	-12.123	62
36	13DEC84	-0.41437	0.0192559	-21.519	61
37	14MAR85	-0.17610	0.0161852	-10.880	60
38	13JUN85	-0.24107	0.0242486	-9.942	59
39	12SEP85	-0.19254	0.0095985	-20.059	63
40	12DEC85	-0.34535	0.0086907	-39.737	53

It is clear that the contract discount is usually below the lower limit for arbitrage. In Table 22 the reader may ascertain the significance of that occurrence. The mean divergence of each contract's discount below the lower arbitrage limit (DIVLOW_M), the standard error of each (DIVLOWSE) and the Student's t-statistic for each (DIVLOW_T) under the hypothesis that each is zero are presented. Only those dates where the futures discount is lower than the lower arbitrage limit are included. For all contracts, the mean divergence of the contract discount is significantly lower than the lower arbitrage limit.

TABLE 22

MEAN DIVERGENCE OF FUTURES
DISCOUNT BELOW LOWER
ARBITRAGE LIMIT

OBS	EXPDATE	DIVLOW_M	DIVLOWSE	DIVLOW_T	N
1	18MAR76	-0.03656	0.0092427	-3.956	7
2	24JUN76	-0.01685	0.0054172	-3.111	8
3	23SEP76	-0.02302	0.0042293	-5.442	3
4	23DEC76	-0.04620	0.0059738	-7.733	29
5	24MAR77	-0.06650	0.0141661	-4.694	8
6	23JUN77	-0.04132	0.0092295	-4.477	12
7	22SEP77	-0.04849	0.0082407	-5.884	12
8	22DEC77	-0.13138	0.0075618	-17.374	53
9	23MAR78	-0.08970	0.0100636	-8.913	45
10	22JUN78	-0.08908	0.0102346	-8.703	37
11	21SEP78	-0.20978	0.0196940	-10.652	38
12	21DEC78	-0.25660	0.0257003	-9.984	36
13	22MAR79	-0.10795	0.0411029	-2.626	14
14	21JUN79	-0.05238	0.0086811	-6.034	14
15	20SEP79	-0.17542	0.0285746	-6.139	35
16	20DEC79	-0.30572	0.0317770	-9.621	42
17	20MAR80	-0.46619	0.0454316	-10.261	44
18	19JUN80	-0.21308	0.0301956	-7.057	38
19	18SEP80	-0.11961	0.0315173	-3.795	8
20	18DEC80	-0.36990	0.0322014	-11.487	49
21	19MAR81	-0.62012	0.0461577	-13.435	90
22	18JUN81	-0.28330	0.0337694	-8.389	37
23	24SEP81	-0.65351	0.0371695	-17.582	61
24	24DEC81	-0.78351	0.0421209	-18.601	101
25	18MAR82	-0.57398	0.0375560	-15.283	101
26	17JUN82	-0.38202	0.0299402	-12.759	47
27	16SEP82	-0.41623	0.0391413	-10.634	36
28	16DEC82	-0.60654	0.0826545	-7.338	53
29	17MAR83	-0.16273	0.0131248	-12.399	43
30	16JUN83	-0.06850	0.0105379	-6.501	34
31	15SEP83	-0.08568	0.0154895	-5.532	29
32	15DEC83	-0.07518	0.0093867	-8.009	34
33	15MAR84	-0.07159	0.0059983	-11.935	48
34	14JUN84	-0.06827	0.0081982	-8.327	47
35	13SEP84	-0.19955	0.0147057	-13.570	55
36	13DEC84	-0.33109	0.0179388	-18.456	60
37	14MAR85	-0.13395	0.0313797	-4.269	51
38	13JUN85	-0.20429	0.0151125	-13.518	53
39	12SEP85	-0.13294	0.0077182	-17.224	59
40	12DEC85	-0.27243	0.0091152	-29.887	53

Although the futures discount appears significantly different from the implicit forward rate, it is not independent of that rate. In a regression of the Treasury bill futures discount (F) on the implicit forward rate (IMPLICIT) and the number of days until contract expiration (N), the parameter estimates shown below were obtained. All predictors are significantly nonzero and are shown after correction for autocorrelation. Standard errors of the regression parameters are in parentheses below their respective values.

$$\underset{(.40)}{F = .85} + \underset{(.08)}{.84\text{IMPLICIT}} - \underset{(.0005)}{.003N}$$

$$R2 = .77 \qquad RMSE = .06$$

Arbitrage may be occurring, but since the arbitrage is asymmetric with regard to the risk of default and costs of early settlement, the implicit forward rate overstates the equilibrium futures discount by the amount of the compensation for this differential in risk.

To see the effects of different monetary regimes on the divergence of futures discounts from the implicit rate, the data are divided into three sub-periods corresponding to the different regimes: prior to October 1979; October 1979 to December 1982; and post-1982; and assume that the divergence depends, among other things, on the current inflation rate and the expected and unexpected changes in the money stock. The regression equation assumed is

$$D = a_0 + aP + bMe + cMu + e,$$

where D is the divergence of the futures discount from the implicit rate, P is the actual inflation rate, Me is the expected change in the money stock (the MMS median), Mu is the unexpected change in the money stock (the actual change in M1 minus Me), and e is an error term. The actual inflation rate variable (P) is formed as an annualized three-month moving average of the growth rate of the Consumer Price Index. Regression results are reported in Table 23.

TABLE 23

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT FROM IMPLICIT FORWARD RATE ON ACTUAL INFLATION, EXPECTED MONEY GROWTH AND UNEXPECTED MONEY GROWTH

Period	RMSE	R^2	Inflation	MMS	Unexpected
Pre -1979	.08	.003	.006	.002	-.005
1979-1982	.26	.012	-.02**	-.01	-.02*
Post-1982	.08	.015	.009	.010	.001

Expected changes in the money stock, as implied in the MMS median forecasts, seem to have no impact on the divergence of the futures discounts from the implicit rate, in any of the sub-periods. However, during the period when the Federal Reserve was using nonborrowed reserves as its response variable, both unexpected money increases and inflation rate increases were associated with a larger divergence of contract discounts from the implicit forward rate. It is possible that, during this period, increases in inflation rates could have prompted expectations of monetary tightening, decreasing the slope of the yield curve and making futures strategies more attractive. Also, if unexpected monetary increases promised compensatory tightening by the Federal Reserve during the middle period, similar processes could have depressed contract discounts further below implicit forward rates.[3] However, the effects are not powerful; only a small part of the total variation of the divergence is explained by current inflation rates and monetary surprises. If the hypothesized relationships do in fact exist, they are not well captured in contemporaneous values of the variables in question.

Table 24 presents the results of individual regressions for each contract, for periods when both Treasury bill data and MMS data are available. Lag1(L) is the lower arbitrage limit, lagged one day. UNEX represents the unexpected component of the weekly change in the money stock, interpolated to yield daily changes. DAYTOEXP is the number of days until contract expiration, and INT is the intercept term. An asterisk indicates at least the .05 confidence level.

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[3] It is also possible that the observed relationships between inflation and the divergence, and/or unexpected monetary changes and the divergence are simply spurious. The middle period saw inflation rates peak and then decline, and both interest rates and monetary growth rates become much more volatile. The problem of spurious relationships in time series cannot be ruled out, but also is not unique to the present study.

TABLE 24

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT BELOW IMPLICIT FORWARD RATE ON LAGGED LOWER ARBITRAGE LIMIT, UNEXPECTED MONEY GROWTH AND NUMBER OF DAYS UNTIL CONTRACT EXPIRATION

OBS	EXPDATE	ST.DEV	Log1(L)	UNEX	DAYTOEXP	INT
1	22DEC77	0.042469	-0.36228*	-0.001326	-0.000816*	2.1304*
2	23MAR78	0.037253	-0.18199*	0.000115	-0.001753*	1.1200*
3	22JUN78	0.083915	-0.60404*	-0.000930	-0.000342*	3.9640*
4	21SEP78	0.084607	-0.08324*	0.036316*	-0.006081*	0.6996*
5	21DEC78	0.162765	-0.61458*	-0.006008	-0.009909*	5.5679*
6	22MAR79	0.081965	-0.18158*	-0.022154*	-0.001331*	1.6299*
7	21JUN79	0.067355	-0.03891	-0.024469*	-0.002243*	0.3882
8	20SEP79	0.073203	-0.22300*	0.001113	-0.010738*	2.4104*
9	20DEC79	0.278794	0.01198	0.112029*	-0.002322	-0.4225
10	20MAR80	0.226040	-0.02768	-0.016545	-0.015718*	0.5798
11	19JUN80	0.220659	-0.06469	0.057426*	0.002968	0.2429
12	18SEP80	0.145052	0.10938	-0.027097*	-0.000228	-0.9109
13	18DEC80	0.243930	0.27888*	-0.018807	0.019242*	-5.0475*
14	19MAR81	0.528629	-0.20553*	-0.082548*	-0.003655*	2.3752*
15	18JUN81	0.259741	-0.10561*	-0.027454	-0.012206*	1.7695*
16	24SEP81	0.155478	-0.21379*	0.013953	-0.013477*	3.0101*
17	24DEC81	0.282498	-0.23982*	-0.020909	-0.002443*	2.6114*
18	18MAR82	0.199988	-0.05171*	-0.005037	-0.008021*	0.7013*
19	17JUN82	0.259495	-0.28624*	-0.012910	-0.000844	3.1683*
20	16SEP82	0.196245	-0.23522*	-0.003469	0.000708	2.3176*
21	16DEC82	0.367698	-0.27372*	-0.000513	-0.009977*	2.2029*
22	17MAR83	0.099473	0.03919	0.006877	-0.004265*	-0.3568
23	16JUN83	0.089392	0.13054	0.007274	-0.002327*	-1.0982
24	15SEP83	0.084734	-0.01083	-0.024394*	0.002292*	-0.1563
25	15DEC83	0.066902	-0.06532	0.006340	-0.002023*	0.5580

In Table 24, of the thirteen contracts of the middle period, which includes December 1979 through December 1982, ten of the unexpected money-change coefficients are negative. However, only two are significantly so. In the same period, three coefficients are positive; two are significantly greater than zero. But the regressions are not corrected for autocorrelation, which is of significant concern, and do not include the effects of inflation.

In Table 25, correction is performed for autocorrelation, and an inflation rate regressor (INFLP) is included. INFLP is formed by smoothing the monthly Consumer Price Index changes, so that the latest monthly rate is expected to continue for the entire year.

TABLE 25

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT FROM IMPLICIT FORWARD RATE ON ACTUAL INFLATION, EXPECTED MONEY GROWTH AND UNEXPECTED MONEY GROWTH: CORRECTED FOR RESIDUAL AUTOCORRELATION

OBS	INFLP	MMSP	UNEXP	EXPDATE
1	0.00496	-0.012557	0.005329	22DEC77
2	0.10756*	-0.001034	0.031268*	23MAR78
3	-0.01800	-0.026770*	0.012295	22JUN78
4	0.01281	-0.028456	0.021526	21SEP78
5	-0.00296	0.062566	-0.029525	21DEC78
6	0.05171*	0.046659*	-0.014980	22MAR79
7	-0.03199*	0.006979	-0.029388*	21JUN79
8	-0.12529*	0.038935	-0.018713	20SEP79
9	-0.04743*	0.049452	0.071810	20DEC79
10	-0.01190	0.117407	-0.071384	20MAR80
11	-0.02677*	0.069317	0.075616*	19JUN80
12	0.05031*	0.094126*	-0.047156*	18SEP80
13	0.02549	0.025929	-0.028158	18DEC80
14	-0.05233	0.054973	-0.066416	19MAR81
15	0.10508*	-0.044542	-0.024597	18JUN81
16	-0.04415*	-0.048317	-0.010297	24SEP81
17	-0.04086*	-0.075075	0.036853	24DEC81
18	-0.00912	-0.052711	0.000811	18MAR82
19	0.00544	0.042014	0.015102	17JUN82
20	-0.20928*	0.021939	-0.009680	16SEP82
21	-0.08627*	0.009340	-0.022209	16DEC82
22	0.02161	0.047119	-0.005281	17MAR83
23	-0.05108*	-0.017591	-0.006699	16JUN83
24	-0.10688*	0.003279	-0.016091	15SEP83
25	-0.00435	-0.009611	0.007571	15DEC83

After correction for autocorrelation and including the inflation regressor, 15 of the 25 estimated monetary innovation coefficients are negative. Only two are significantly so, however, and an equal number are significantly positive. The evidence presented in Table 25 indicates that the unexpected monetary change regressor is of little help in predicting the contemporaneous divergence of the futures discounts from the implicit forward rates.

Table 26 presents the results of regressions for each contract of the divergence when a past profit regressor (MAVSUMPL) is included. MAVSUMPL is formed as the five day moving average of profit earned from the appropriate arbitrage taken as early as possible and settled during the preceding five days. It is included as a proxy for the expected outcome of an unobservable distribution of potential early settlements. It is a significant regressor and is of the expected sign.[4] In 11 of the 25 contracts the unexpected money change regressor is significant.

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[4] The higher the expected profit on the artificial bill, given early settlement, the more the contract discount rises toward the implicit forward rate.

TABLE 26

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT FROM IMPLICIT FORWARD RATE ON ACTUAL INFLATION, EXPECTED MONEY GROWTH, UNEXPECTED MONEY GROWTH, AND LAGGED ARBITRAGE PROFIT

OBS	EXPDATE	INFL	MMS1	UNEX	MAVSUMPL
1	22DEC77	0.013098*	0.01208	-0.006897	0.000080539*
2	23MAR78	0.055631*	0.00130	0.015444	0.000066853*
3	22JUN78	-0.028865*	-0.00549	0.022254*	0.000057213*
4	21SEP78	-0.017887	0.03824*	0.001729	0.000088055*
5	21DEC78	-0.025007*	-0.01217	-0.093437*	0.000076863*
6	22MAR79	0.035006*	0.05020*	-0.011105	0.000022099*
7	21JUN79	-0.028336*	0.00637	-0.031474*	0.000032743*
8	20SEP79	-0.050197*	0.03466*	-0.049442*	0.000055785*
9	20DEC79	0.006664	0.07416	0.061471*	0.000063741*
10	20MAR80	-0.000903	0.06881	-0.005350	0.000074081*
11	19JUN80	-0.027716*	0.07463	0.106105*	-0.000032063
12	18SEP80	0.061911*	0.11792*	-0.051737*	-0.000020392
13	18DEC80	-0.038957	0.00180	-0.072717*	0.000054146*
14	19MAR81	-0.027623	0.07953	-0.042500	0.000044982*
15	18JUN81	0.088780*	-0.04263	-0.019428	0.000019375
16	24SEP81	0.003928	0.08090	-0.028981	0.000115156*
17	24DEC81	-0.053084*	-0.16108*	0.088330*	0.000076615*
18	18MAR82	-0.032118	-0.05125*	0.049674*	0.000111116*
19	17JUN82	0.014345*	-0.06838*	0.016507	0.000110011*
20	16SEP82	-0.060705	-0.01568	0.043330	0.000076977*
21	16DEC82	-0.006637	-0.00540	0.000570	0.000063620*
22	17MAR83	-0.005156	0.03232*	-0.011786	0.000082304*
23	16JUN83	-0.038019*	-0.01442	-0.000494	0.000044422*
24	15SEP83	-0.055747	0.00916	-0.023541*	0.000029866*
25	15DEC83	-0.015395	-0.00258	0.002333	0.000069556*

In Table 27, which presents the results of the previous regression after correction for residual autocorrelation, only 8 are significantly nonzero. The difference in significance may be due to autocorrelation, or to the methodology employed in forming the regressors. Since data for inflation and the unexpected monetary innovations are only available on a monthly and weekly basis respectively, while Treasury bill data exists for every non-holiday business day, the regressors have been formed by interpolation heretofore.

TABLE 27

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT FROM IMPLICIT FORWARD RATE ON ACTUAL INFLATION, EXPECTED MONEY GROWTH, UNEXPECTED MONEY GROWTH, AND LAGGED ARBITRAGE PROFIT: CORRECTED FOR RESIDUAL AUTOCORRELATION

OBS	INFLP	MMSP	UNEXP	MAVSUMP	EXPDATE
1	0.01602*	0.00827	0.001994	0.000065042*	22DEC77
2	0.06905*	0.00108	0.022355*	0.000058868*	23MAR78
3	-0.02058	-0.02279	0.014524	0.000035776*	22JUN78
4	-0.00183	0.00405	0.003499	0.000057967*	21SEP78
5	-0.02302	0.03173	-0.070186*	0.000049490*	21DEC78
6	0.03767*	0.04458*	-0.011903	0.000000001*	22MAR79
7	-0.03194*	0.00868	-0.030827*	0.000000000	21JUN79
8	-0.05009*	0.03476*	-0.049629*	0.000055930*	20SEP79
9	-0.00505	0.06314	0.060235	0.000052213*	20DEC79
10	0.00155	0.09140	-0.019025	0.000058918*	20MAR80
11	-0.02912*	0.07521	0.104648*	-0.000039882	19JUN80
12	0.06674*	0.12780*	-0.055125*	-0.000028708	18SEP80
13	-0.02564	0.01020	-0.064667*	0.000049233*	18DEC80
14	-0.03729	0.09723	-0.067904	0.000027453*	19MAR81
15	0.09254*	-0.04368	-0.021283	0.000014323	18JUN81
16	-0.01145	0.03769	-0.018469	0.000088961*	24SEP81
17	-0.04841*	-0.14012*	0.075284*	0.000064349*	24DEC81
18	-0.03126	-0.05775	0.029980	0.000083012*	18MAR82
19	0.01076	-0.02715	0.023077	0.000086317*	17JUN82
20	-0.06835	-0.01212	0.040691	0.000073826*	16SEP82
21	-0.01163	-0.01270	0.004660	0.000061808*	16DEC82
22	-0.00351	0.03117	-0.010097	0.000076607*	17MAR83
23	-0.05142*	-0.01834	-0.005341	0.000000000	16JUN83
24	-0.10345*	0.00630	-0.021350	0.000000000	15SEP83
25	-0.00460	-0.01077	0.005937	0.000000000	15DEC83

In an effort to discover the influence of the interpolation methodology, further regressions were performed wherein the unexpected monetary change regressor was not interpolated. The results are presented in Table 28. The results lack robustness, since only about one-fifth of each contract's data coincide, but the effect of interpolation is apparent. In Table 28, eight of the inflation rate coefficients are significant, and six have the expected sign. Only four unexpected monetary change regressors are significant; however, all carry the sign expected if greater-than-forecast monetary innovation is indicative of future monetary correction by the Federal Reserve.

TABLE 28

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT FROM IMPLICIT FORWARD RATE ON ACTUAL INFLATION, UNEXPECTED MONEY GROWTH, AND TIME REMAINING TO CONTRACT EXPIRATION

OBS	EXPDATE	INFL	UNEX	DAYTOEXP	MSE
1	22DEC77	-0.08877*	0.00441	-0.01121*	.0005
2	23MAR78	-0.15294*	-0.02352*	-0.01066*	.0011
3	22JUN78	-0.07127	0.01603	-0.00506	.0127
4	21SEP78	0.03297	0.02466	-0.00845*	.0101
5	21DEC78	-0.03784	-0.03823	-0.00742	.0499
6	22MAR79	-0.06929*	-0.00514	-0.00644*	.0031
7	21JUN79	-0.02043	-0.02689*	-0.00311*	.0048
8	20SEP79	0.01107	0.01063	-0.00886*	.0062
9	20DEC79	0.27747	0.07135	-0.00105	.0653
10	20MAR80	0.00591	-0.01294	-0.01239*	.0495
11	19JUN80	0.08075	0.04783	-0.00961	.0810
12	18SEP80	0.02046	-0.01920	-0.00335	.0198
13	18DEC80	0.70100	-0.16723*	-0.00522	.1019
14	19MAR81	0.60996*	-0.08258*	-0.00166	.2390
15	18JUN81	0.14219	-0.03673	-0.00664*	.0259
16	24SEP81	-0.50581	0.00216	0.01089	.0327
17	24DEC81	-0.23578*	0.05670	0.01013	.2566
18	18MAR82	-0.05392	0.01304	-0.00725*	.0504
19	17JUN82	0.04376	0.01232	0.00142	.0864
20	16SEP82	-0.07591	0.02212	-0.01194	.0706
21	16DEC82	1.07682*	-0.11234	-0.11934*	.1733
22	17MAR83	-0.06890*	0.00437	-0.00786*	.0035
23	16JUN83	-0.02530	0.00528	-0.00380*	.0064
24	15SEP83	0.12039	-0.00418	0.00109	.0063
25	15DEC83	-0.29041*	0.01248	0.00946	.0021
26	15MAR84	0.15171	0.02481	0.00987	.0026

It is likely that market participants' expectation of future Federal Reserve behavior depends not only on the most recent monetary outcome, but on some perceived trend in outcomes. In an effort to capture these expectations, we form an unexpected monetary innovation regressor as a forward weighted moving average of the three most recent errors in the MMS median forecasts. In the equation and tables below, UNEXP is the unexpected monetary innovation regressor. It is filtered, or smoothed, by a weighted moving average process given by the equation

$$UNEXP_t = [5Me_t + Me_{t-1} + Me_{t-2}]/7,$$

where $UNEXP_t$ is the smoothed regressor, and Me_t, Me_{t-1}, and Me_{t-2} are the present, one-, and two-period lagged unexpected money growth respectively. Me is the actual money growth minus the MMS median forecast. The regression results are presented in Tables 29 and 30.

Of the 25 contracts examined, six past-inflation regressors (INFLP) were significant; four were negative, as we would expect if the prospect of monetary tightening is made more likely by the same factors which lead to increased inflationary expectations. Nine of the coefficients on the unexpected monetary growth regressors (UNEXP) are significant; six have the expected negative sign. The remaining three, which have positive signs, all occur in contracts which expired in the period before monetary aggregate targeting was initiated by the Federal Reserve. Sixteen of the coefficients on the time remaining until contract expiration regressors (DAYSP) are significantly negative, and nine coefficients on the past early settlement profit regressors (MAVSUMP) are significantly positive. Overall, the regression model accounts for a good deal of the variation in the futures contract divergence, with an average RMSE of thirteen basis points and average R^2 of .52.

TABLE 29

REGRESSION OF DIVERGENCE OF FUTURES DISCOUNT FROM IMPLICIT FORWARD RATE ON SMOOTHED INFLATION, EXPECTED MONEY GROWTH, UNEXPECTED MONEY GROWTH, DAYS REMAINING TO CONTRACT EXPIRATION, AND LAGGED ARBITRAGE PROFIT

OBS	EXPDATE	INFLP	MMSP	UNEXP	DAYSP	MAVSUMP
1	22DEC77	-0.00218	-0.01226	0.02642*	-0.004702*	0.000000
2	23MAR78	0.02240	0.01586*	0.03873*	-0.003188*	0.000000
3	22JUN78	-0.05199*	0.00755	0.02914*	-0.002646*	0.020799
4	21SEP78	-0.00488	-0.00860	0.03380	-0.005772*	0.005805
5	21DEC78	-0.01117	-0.03529	-0.11778*	-0.006931*	0.020068
6	22MAR79	0.04330	0.07883*	-0.03086*	-0.000187	0.000001*
7	21JUN79	-0.00356	0.00795	-0.04843*	-0.002843*	0.000000
8	20SEP79	-0.04565*	0.01745	-0.02314	-0.004617*	0.000000
9	20DEC79	0.03023	0.22412*	0.04388	-0.000795	0.070907*
10	20MAR80	-0.01596	0.03153	0.01192	-0.013635*	0.008289
11	19JUN80	-0.02142	0.18014*	0.03285	-0.007520*	-0.000000
12	18SEP80	0.06056*	0.03359	-0.04432*	0.003324	-0.003962
13	18DEC80	-0.02960	-0.10059*	-0.07715*	-0.003825*	0.059347*
14	19MAR81	0.00436	0.08370	-0.01750	-0.001934	0.043030*
15	18JUN81	0.19301*	-0.04436	0.01573	-0.000431	-0.015042
16	24SEP81	-0.01022	0.07421*	-0.00026	-0.010207*	0.033897*
17	24DEC81	-0.01458	-0.05872	0.04861	-0.004514*	0.066811*
18	18MAR82	-0.01190	-0.02309	0.02032	-0.007483*	0.000000
19	17JUN82	0.00315	-0.04505*	-0.00302	-0.003894	0.078142*
20	16SEP82	-0.12087	-0.02342	-0.01412	-0.005757	0.041596*
21	16DEC82	-0.01467	0.01225	0.05803	-0.007064*	0.037708*
22	17MAR83	-0.00155	0.02052	-0.00644	-0.004835*	0.000000
23	16JUN83	-0.08580*	-0.01868	0.00320	0.001598	0.000000
24	15SEP83	-0.26142*	0.00378	-0.04926*	-0.001737	0.000000
25	15DEC83	-0.00936	-0.02080	0.01073	-0.002888*	0.000000

TABLE 30

REMAINING ERROR AND R-SQUARE FOR REGRESSIONS IN TABLE 29

Date	DFE	RMSE	R^2
DEC77	44	0.03	0.77
MAR78	50	0.03	0.64
JUN78	51	0.04	0.50
SEP78	49	0.06	0.39
DEC78	49	0.13	0.53
MAR79	50	0.04	0.43
JUN79	51	0.06	0.64
SEP79	52	0.06	0.85
DEC79	48	0.19	0.47
MAR80	48	0.21	0.67
JUN80	49	0.22	0.31
SEP80	50	0.14	0.25
DEC80	48	0.18	0.51
MAR81	107	0.35	0.14
JUN81	50	0.27	0.51
SEP81	50	0.16	0.74
DEC81	105	0.21	0.57
MAR82	110	0.18	0.71
JUN82	50	0.12	0.66
SEP82	50	0.18	0.76
DEC82	48	0.16	0.79
MAR83	51	0.06	0.53
JUN83	47	0.06	0.23
SEP83	43	0.07	0.20
DEC83	48	0.05	0.26
Average	56	0.13	0.52
Maximum	110	0.35	0.85
Minimum	43	0.03	0.14

Systematic Risk Premium

In Chapter II it is argued that the risks inherent in the artificial bill strategies exceed those of the real bill. Early settlement, if required by exigencies or unforeseen opportunities, may require conversion of bills into cash. Even if early settlement is not required, during the holding period the value of the artificial bill will vary more than value of the real bill. The real bill is less variable in price than the artificial bill and therefore, given equal inter-bill covariances, the covariance of the artificial bill with the market portfolio exceeds that of the real bill. The efficient market thus compensates investors who bear the increased (systematic) risk of including the artificial bill in their portfolios by increasing the expected yield to maturity, or decreasing the discount of the futures contract so that it may be sold at what has appeared to previous students to afford an unjustifiable profit.

In this section the differential risk hypothesis is examined directly, by two methods. In the first method, a simulation is performed of the effect on the *ex post* annualized rate of return if settlement or portfolio revaluation occurs prior to the maturity of the instrument(s). If market participants are rational, then a measure of the mean historical difference in actual realized returns should affect *ex ante* yields. The effect of the differential yields on the divergence of the contract discount from its perfectly efficient transactionless expected value is then evaluated.

In the second method, the value of the additional covariance of the artificial bill (with respect to the market portfolio) over and above that of the real bill is estimated. Using this information, the effect on the divergence of the contract discount from its perfectly efficient transactionless expected value is evaluated.

In the first methodology, for each day of trading, the difference in the mean annualized yield for the real bill and its artificial counterpart,

$$DIFM_{t-1} = \mu_A - \mu_R,$$

is simulated, where μ_R is the mean annualized yield from owning the real (near) bill for the past seven business days, and μ_A is the mean annualized yield for the artificial bill - the combination of the short futures position

TABLE 31

EARLY SETTLEMENT YIELD DIFFERENTIALS
AFTER 7 DAY HOLDING PERIOD

OBS	EXPDATE	RMSE	A	B
1	18MAR76	0.064320	-0.04419	0.005836
2	24JUN76	0.074348	-0.04110	0.012151*
3	23SEP76	0.040588	-0.01664	0.008447
4	23DEC76	0.072077	-0.08185	0.013121
5	24MAR77	0.041073	0.01150	0.028526*
6	23JUN77	0.064986	-0.06633	0.022731*
7	22SEP77	0.048112	-0.03548	0.034802*
8	22DEC77	0.074973	-0.15382	0.100388*
9	23MAR78	0.084076	-0.14006	0.032017*
10	22JUN78	0.114742	-0.10725	0.055009*
11	21SEP78	0.161115	-0.15748	0.028339*
12	21DEC78	0.298555	-0.20932	0.021889*
13	22MAR79	0.054136	-0.01989	0.045244*
14	21JUN79	0.096982	-0.03496	0.029856*
15	20SEP79	0.154190	-0.10917	0.012078*
16	20DEC79	0.245971	-0.27066	0.040960*
17	20MAR80	0.413838	-0.39464	-0.026429*
18	19JUN80	0.311165	-0.31108	0.000125
19	18SEP80	0.163078	0.05761	0.022410*
20	18DEC80	0.218081	-0.41887	0.048767*
21	19MAR81	0.445694	-0.70380	0.035008*
22	18JUN81	0.358552	-0.21723	0.050358*
23	24SEP81	0.352754	-0.76146	0.007447*
24	24DEC81	0.537848	-0.91040	0.034802*
25	18MAR82	0.425257	-0.70769	-0.039461*
26	17JUN82	0.238154	-0.33565	0.068175*
27	16SEP82	0.432825	-0.07637	0.065854*
28	16DEC82	0.356596	-0.46922	0.031783*
29	17MAR83	0.141160	-0.21476	0.000334
30	16JUN83	0.091645	-0.08347	0.034353*
31	15SEP83	0.079516	-0.08429	0.034068*
32	15DEC83	0.092039	-0.12469	-0.002096
33	15MAR84	0.059739	-0.16328	-0.016181*
34	14JUN84	0.085938	-0.14231	-0.007606
35	13SEP84	0.142540	-0.18912	0.026913*
36	13DEC84	0.156807	-0.40230	0.002246
37	14MAR85	0.131719	-0.17845	-0.002295
38	13JUN85	0.171739	-0.21797	-0.044939*
39	12SEP85	0.068700	-0.14267	0.047030*
40	12DEC85	0.054842	-0.34745	0.009435

* Significant at .10 level or better.

TABLE 32

REGRESSION OF EARLY SETTLEMENT YIELD DIFFERENTIALS AFTER 7 DAY HOLDING PERIOD ON DIFM AND DAYTOEXP

OBS	EXPDATE	RMSE	A	B
1	18MAR76	0.049497	0.06343	0.016173
2	24JUN76	0.074237	-0.01988	0.014029*
3	23SEP76	0.040371	-0.03184	0.006394
4	23DEC76	0.047935	0.01409	0.018960
5	24MAR77	0.041289	0.02160	0.031370*
6	23JUN77	0.064902	-0.05077	0.021299*
7	22SEP77	0.043642	0.00164	0.036133*
8	22DEC77	0.042751	-0.02086	-0.051735*
9	23MAR78	0.038309	-0.01219	0.034804*
10	22JUN78	0.073749	0.04082	0.039895*
11	21SEP78	0.101476	0.07392	0.010031*
12	21DEC78	0.210668	0.16045	0.011426
13	22MAR79	0.048932	0.01950	0.044238*
14	21JUN79	0.070010	0.09137	0.034498*
15	20SEP79	0.065353	0.12851	-0.001082
16	20DEC79	0.247459	-0.30700	0.040765*
17	20MAR80	0.216456	0.23193	0.010382
18	19JUN80	0.235932	0.08202	0.013770*
19	18SEP80	0.152505	0.15697	0.017314*
20	18DEC80	0.218803	-0.37450	0.049120*
21	19MAR81	0.445258	-0.62371	0.034814*
22	18JUN81	0.275076	0.18966	0.044270*
23	24SEP81	0.155049	-0.15933	-0.012408*
24	24DEC81	0.338685	-0.08707	0.040969*
25	18MAR82	0.191800	0.04898	0.015115
26	17JUN82	0.211315	-0.13745	0.053918*
27	16SEP82	0.224668	0.66712	0.000364
28	16DEC82	0.173944	0.08415	0.019334*
29	17MAR83	0.069252	0.03015	0.021356*
30	16JUN83	0.062266	0.05495	0.032751*
31	15SEP83	0.080410	-0.08684	0.033830*
32	15DEC83	0.064859	0.01259	0.012238*
33	15MAR84	0.040497	-0.07687	-0.009590*
34	14JUN84	0.083254	-0.07726	0.000983
35	13SEP84	0.140700	-0.24299	0.027049*
36	13DEC84	0.147045	-0.29157	0.006691*
37	14MAR85	0.132920	-0.16738	-0.001889
38	13JUN85	0.154568	-0.03884	-0.020590
39	12SEP85	0.062618	-0.10307	0.018296
40	12DEC85	0.055472	-0.34365	0.009720

* Significant at .10 level or better.

The next empirical test involves the following methodology. First, the covariance of the artificial bill's rate of return with that of the real bill,

$$C_{A,R} = \text{cov}[R_A, R_R],$$

is estimated, where R_A is the annualized return of the artificial bill (composed of the short futures position and the ownership of the delivery bill), and R_B is the annualized return of the real bill which matures at the time of expiration of the futures contract, when both are assumed to have been settled early. The covariation in returns declines as the time of expiration (or maturity in the case of the real bill) approaches. Therefore the *ex ante*, or expected covariation in returns is postulated as follows:

$$C^t_{A,R} = f(N_t),$$

where N is the number of calendar days until contract expiration at time t, $C^t_{A,R}$ is the expected covariance of actual return of artificial bill with the real bill if both are converted to cash at time t, and where time t is seven days after the purchase of the instruments. Assuming a linear form, the following equation is estimated by OLS regression:

$$C^t_{A,R} = a + b(N_t) + e_t.$$

Once the values of the *ex ante* relative differential variances are estimated, statistical tests of the effect of the relative riskiness of the artificial bill on its *a priori* return (as a result of the operation of efficient market forces) can be performed. In the equation

$$D_t = -[F_t - (U_t + L_t)/2],$$

where F_t is the contract discount at time t, and U_t and L_t are Poole's (1978) upper and lower arbitrage limits respectively at time t, the annualized premium that the artificial bill enjoys is approximated by

$$P_t \cong \{[D_t(N_t/360)]/[1 - D_t(N_t/360)]\}[365/N_t],$$

TABLE 33

REGRESSION OF ANNUALIZED YIELD DIFFERENCE (A-R) ON $C^{t}_{A,R}$ (COV_HAT)

OBS	EXPDATE	RMSE	INTERCEPT	COV_HAT
1	18MAR76	0.05687	0.01884	0.00099587*
2	24JUN76	0.07952	0.05059	0.00008220
3	23SEP76	0.04087	0.03512	-0.00014801
4	23DEC76	0.05014	0.04774	0.00099004*
5	24MAR77	0.04679	0.02241	-0.00014784
6	23JUN77	0.07243	0.06890	0.00028283
7	22SEP77	0.05393	0.04001	0.00036535*
8	22DEC77	0.04801	0.13345	0.00192580*
9	23MAR78	0.04552	0.08996	0.00142613*
10	22JUN78	0.09537	0.04579	0.00194127*
11	21SEP78	0.11138	0.03893	0.00288161*
12	21DEC78	0.23275	0.02474	0.00444156*
13	22MAR79	0.07698	0.06360	0.00050775*
14	21JUN79	0.08193	0.01528	0.00122183*
15	20SEP79	0.06842	-0.00596	0.00283051*
16	20DEC79	0.32665	0.38604	-0.00040214
17	20MAR80	0.26751	0.09456	0.00829963*
18	19JUN80	0.27330	0.13765	0.00428934*
19	18SEP80	0.16408	-0.06923	0.00147343*
20	18DEC80	0.35090	0.57457	0.00052271
21	19MAR81	0.90082	0.84301	0.00160687*
22	18JUN81	0.32976	0.03673	0.00472481*
23	24SEP81	0.24678	0.53230	0.00795501*
24	24DEC81	1.29536	0.18687	0.00926849*
25	18MAR82	0.82810	-0.15939	0.00804625*
26	17JUN82	0.31635	0.27894	0.00421461*
27	16SEP82	0.24679	-0.28112	0.00981234*
28	16DEC82	0.40401	0.13991	0.00999762*
29	17MAR83	0.08117	0.10422	0.00241047*
30	16JUN83	0.08568	0.04020	0.00146113*
31	15SEP83	0.09600	0.17908	-0.00042154
32	15DEC83	0.07185	0.06368	0.00119667*
33	15MAR84	0.04527	0.10429	0.00096155*
34	14JUN84	0.08583	0.10688	0.00057677*
35	13SEP84	0.15576	0.26037	-0.00046187
36	13DEC84	0.16589	0.37656	0.00100261*
37	14MAR85	0.15049	0.17623	0.00029656
38	13JUN85	0.15258	0.09806	0.00218858*
39	12SEP85	0.06714	0.14755	0.00095293*
40	12DEC85	0.06114	0.36639	0.00020843

* Significant at .10 level or better.

Summary

These results indicate quite clearly that at least one specification of the expected differential risk of the two investment alternatives has a significant impact on the yields and prices of the alternatives. These results are consistent with the dual hypotheses that the cash bill is an imperfect substitute for the hedged deliverable bill, due to the difference in the returns distribution, and that the Treasury bill futures market is efficient.

The cash bill is an asset owned by an investor. The deliverable, longer-term bill is also an asset owned by an investor. However, the deliverable bill is hedged with an offsetting short futures contract position, in order to create an artificial asset with the same expiration date as the cash bill. Unexpected information affects the values of both assets; but the change in the value of the real bill is not necessarily equal to the change in the value of the artificial bill. Perhaps this accounts for the difference in the returns distribution.

Also, the change in value of the real asset is only a paper profit or loss, unless the investor liquidates the position by selling the asset. The investor is not required to liquidate. However, the artificial bill contains a futures contract. Provisions of both IMM and CBT contracts call for daily marking-to-market. The investor owning the artificial asset has no choice in this matter. The mark-to-market requirement means that the daily change in the value of the artificial asset is not a paper profit or loss, but is in fact an <u>actual</u> profit or loss, posted each day to the investor's account. Perhaps this accounts for the difference in the returns distribution.

Perhaps the reason for the difference in the returns distribution are immaterial. The data examined in Chaper IV indicate that the real asset possesses a different returns distribution than that of the artificial asset. The real asset is observed to be, on average, less variable than the artificial asset. This observation is neither difficult nor costly for market participants to make, and is useful information concerning the expected future values of the assets. Rational investors would not ignore such information. Thus the assumption that the assets are treated as perfect substitutes, in view of the observed differences in the variability of their returns, is an assumption that investors are irrational.

The data examined in Chapter IV show that the prices of the real assets and their artificial counterparts are related to the predictable portion of their differential variabilities. This is consistent with the efficient market hypothesis. Since expected differential variation is significantly related to *ex ante* yields and prices of the derivative instruments, it follows that statistical tests which do not in some way include a specification of the expected differential risk are incomplete. Their results are therefore suspect, and can lead to an incorrect acceptance or (more likely) rejection of the efficient market hypothesis. Since no examination of the efficiency of financial futures markets has heretofore included a specification of the expected differential risk, previous empirical examinations of financial futures markets should be regarded with suspicion.

CHAPTER V

SUMMARY AND

CONCLUSION

It is important to know whether or not financial futures markets result in efficient derivative instrument pricing. The social purpose of financial futures markets is to reduce the cost of shifting risk from one investor to another. A reduction in a country's cost of risk transfer, by increasing the net return per unit of risk, increases the rate of capital formation in that country, from both domestic and foreign sources, and may affect domestic relative prices, exchange rates, trade patterns, and productivity growth rates. However, if financial futures markets are inefficient pricing mechanisms, a country may be quite adversely affected. Thus the question of the efficiency of financial futures markets encompasses more than the probable profits or losses of traders, and has generated extensive (and intensive) research in proper proportion to its importance.

In a sense, empirical testing of the efficiency of financial futures markets is not difficult. A long futures position at expiration results in the purchase of the underlying instrument. An artificial instrument is created by the combination of a long futures position and the short-term investment of sufficient funds to purchase the underlying instrument at contract expiration. The price or volatility of the underlying instrument is compared to that of the artificial instrument. If they are significantly different, the hypothesis of market efficiency is rejected.

The unstated assumption that accounts for the relative ease of empirical tests is the assumption that the underlying instrument is a perfect substitute for the artificial instrument. If that assumption is abandoned, empirical testing is more difficult; so is the rejection of the hypothesis of efficient markets. One major result of the present study is that the assumption of perfect asset substitution is invalid, and should be abandoned. The empirical work in Chapter IV shows that the returns distribution of the artificial instrument is quite different from that of the underlying instrument.

The studies summarized in Chapter III are based on the assumption of perfect substitutability of real for artificial instruments. Some of the studies find markets to be efficient; others do not. But since all are based on a questionable assumption, their conclusions are themselves questionable. Thus a second result of the present study is to indicate the present degree of certainty concerning the efficiency of financial futures markets. It is small.

If investors are aware of a probability distribution of likely gains or losses from early settlement, they will incorporate these expectations into investment decisions. Similarly, if investors value the option of getting cash before contract expiration with greater certainty of return, the market should make yields adjust so that the option has a positive price. One cannot measure investors' expectations; they can only be estimated, using an expectations hypothesis. Furthermore, any test of market efficiency must simultaneously test both the expectations hypothesis and the hypothesis of efficiency.

In the present study it is assumed that investors are aware of the potential gains and losses from investments that are converted to cash prior to settlement, and that the distribution of those gains and losses matters to them. Perhaps they use the process of past early settlement gains and losses to forecast those of the future. If expectations are formed in this manner, and if expectations of future early settlement outcomes matter to investors, then the time series of past early settlement outcomes affects futures prices and future contract discounts. However, those past outcomes do not enable investors to earn more than normal rates of return, given the added riskiness of their investment in the artificial instruments, if the market is efficient.

This hypothesis - and that of market efficiency - has been tested by calculating the settlement profit that an investor or arbitrageur would have realized on each market day, assuming a position was taken on the first day that arbitrage was potentially profitable, and after accounting for the differential variability of the artificial instrument. Since almost all of the time the lower arbitrage limit is above the futures contract discount, the assumed arbitrage consists of the following: short a near-term Treasury bill, buy the instrument for delivery, and sell a futures contract. If previous early settlement has been profitable, arbitrages are more likely to occur, and therefore it is expected that a smaller divergence of the contract discount below the implicit forward rate to be associated with higher early settlement profitability. This is supported by the data.

Furthermore, if the variance of the actual rate of return from early settlement of the artificial instrument is not expected to be significantly greater than that of its real counterpart, the divergence of the contract discount below the implicit forward rate is expected to be smaller. The data indicate that this is true as well. Whether or not early settlement or default results in loss or lower yield should depend, in addition, on the actions of the Federal Reserve in the interval between positioning and unwinding. If monetary tightening occurs, short term interest rates will be driven up relative to longer term rates, resulting in losses or lower yields for arbitrageurs. But if a more expansionary monetary policy is followed, arbitrageurs need not fear loss from early settlement, since prices of the assets they own are more likely to rise than fall. The present study attempts to capture the expectations of lenders with regard to Federal Reserve intentions by smoothing the unexpected component of weekly monetary changes. Although not completely satisfactory, indications that the phenomenon occurs are evident in the data. This, too, lends credence to the dual conclusion that the assets are imperfect substitutes, and that financial futures markets are efficient.

The results may properly be viewed as preliminary. Further testing of the hypothesis - that early settlement returns matter to investors - should be performed, using different markets and methods than those done in the present study. Different models of the expectation forming process should be examined. The distribution of early settlement probabilities should be ascertained. Different intervals for the holding period will result in different estimates of the covariances of actual and artificial instrument yields, some of which may result in more adequate models.

With regard to the Treasury bond and note futures markets, some method must be found of connecting a particular instrument to the futures contract, or of predicting the identity of the cheapest-to-deliver instrument. One possible method might be to collect data on all existing deliverable bonds and notes, ascertain the cheapest-to-deliver, and assume that costless transactions allow the arbitrager to always trade the owned instrument for the new cheapest-to-deliver. Another arbitrage that this study suggests might be to find the dearest-to-deliver instrument, short it on the assumption that it will be the last to be delivered, and go long a futures contract. These are interesting lines for further research.

The evidence examined in the present study indicates the correctness of the hypothesis that financial futures markets are efficient processors of even quite subtle information; that the distribution of returns given early settlement are important to investors; that this is particularly the case for investments having short term maturities, and that tests of market efficiency which do not incorporate them are incomplete, and likely to be erroneous.

Empirical methodology cannot prove null hypotheses; it can only reject or fail to reject them. Financial futures markets can be shown by empirical methods to be less than perfectly efficient; they cannot be proven efficient. The efficient market is but one of two nested null hypotheses that every empirical test of markets jointly rejects or fails to reject. Additionally, the required data are not sufficiently detailed to allow precise statistical testing. However, the present study has shown that the rejection of the efficient market hypothesis is premature, unless account is taken of the different distribution of returns of the underlying instrument and its derivative. Certainly little valid evidence remains of the gross inefficiency of financial futures markets.

A careful consideration of the data examined and evidence presented in the present study leads to the following conclusion: After properly accounting for the differential riskiness of futures-based instruments, pricing mechanisms in financial futures markets are efficient.

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APPENDIXES

APPENDIX A

INTERNATIONAL MONETARY MARKET (IMM)

TREASURY BILL FUTURES

CONTRACTS

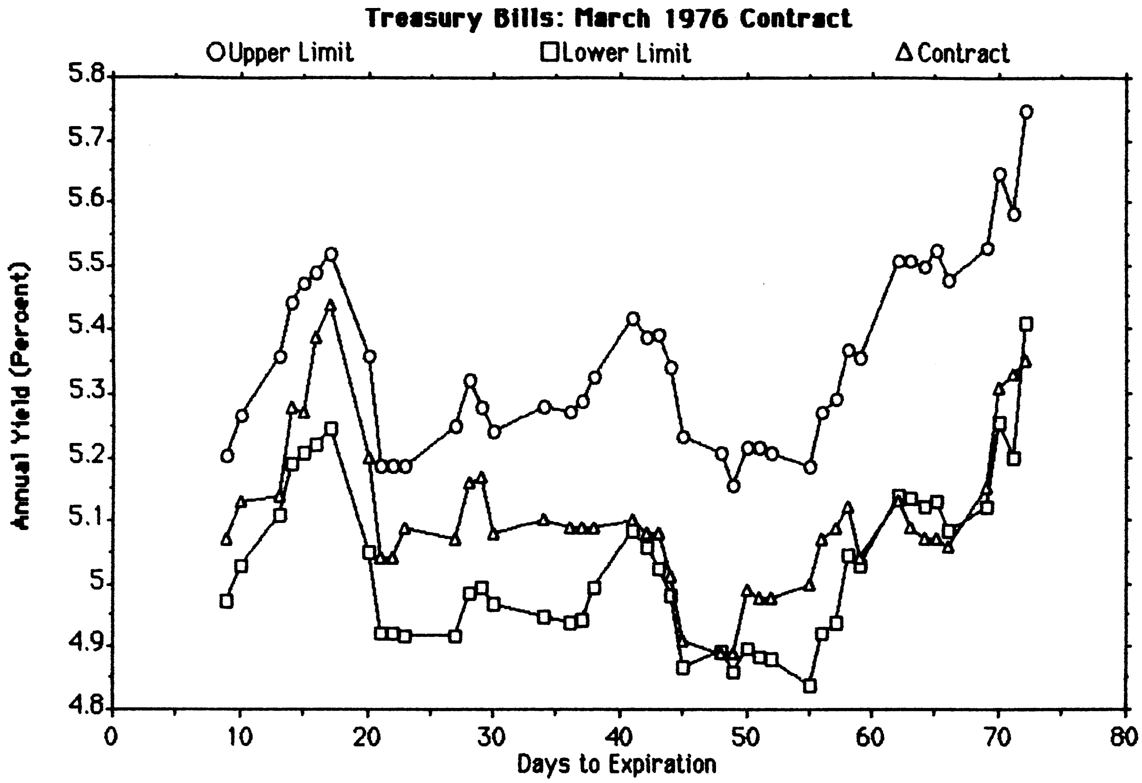
Contract index upper (Upper Limit) and lower (Lower Limit) arbitrage limits, assuming $1,500 margin and $60 round-turn commission, and actual settlement indices (Contract).

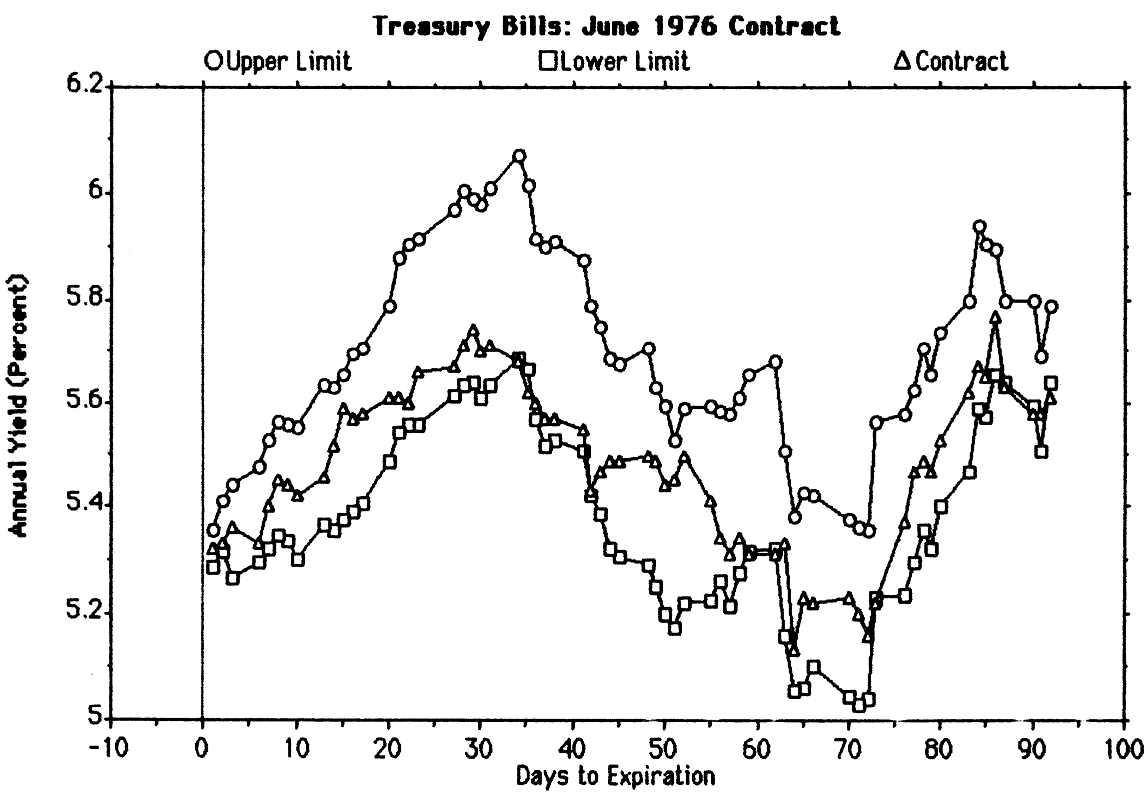
Sampling Interval: Daily.

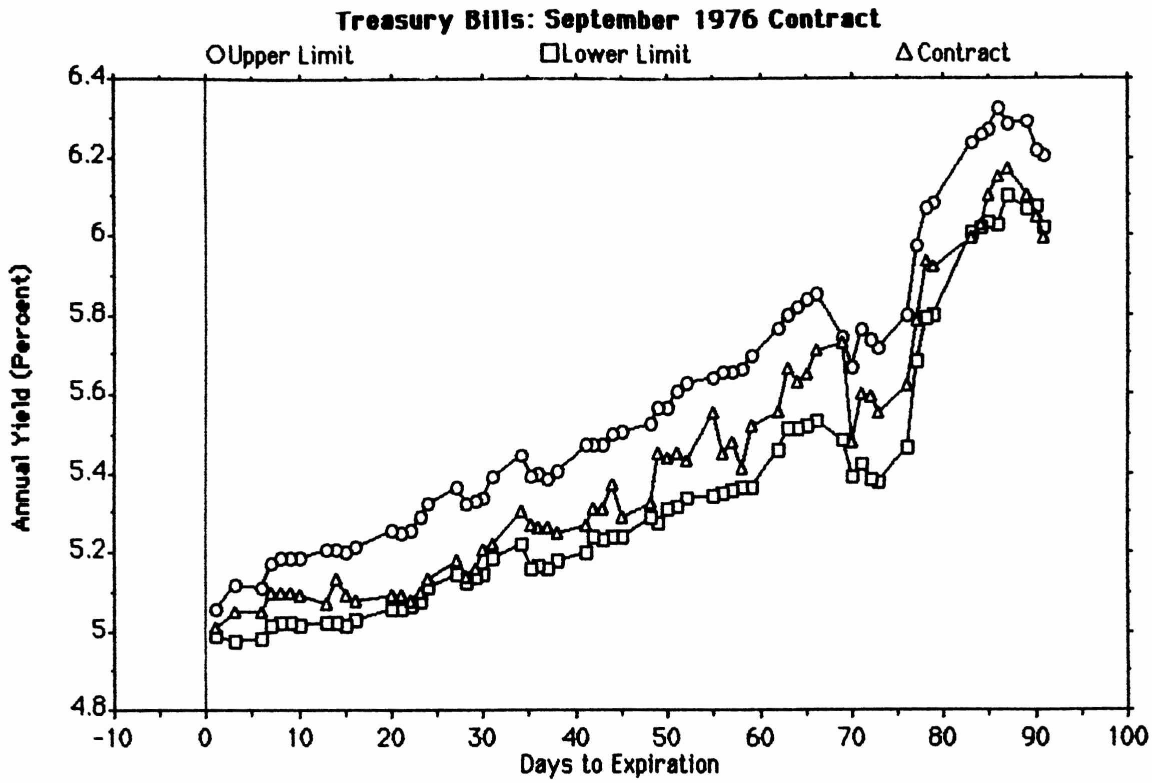
Sample Duration: March, 1976 contract through December, 1985 contract.

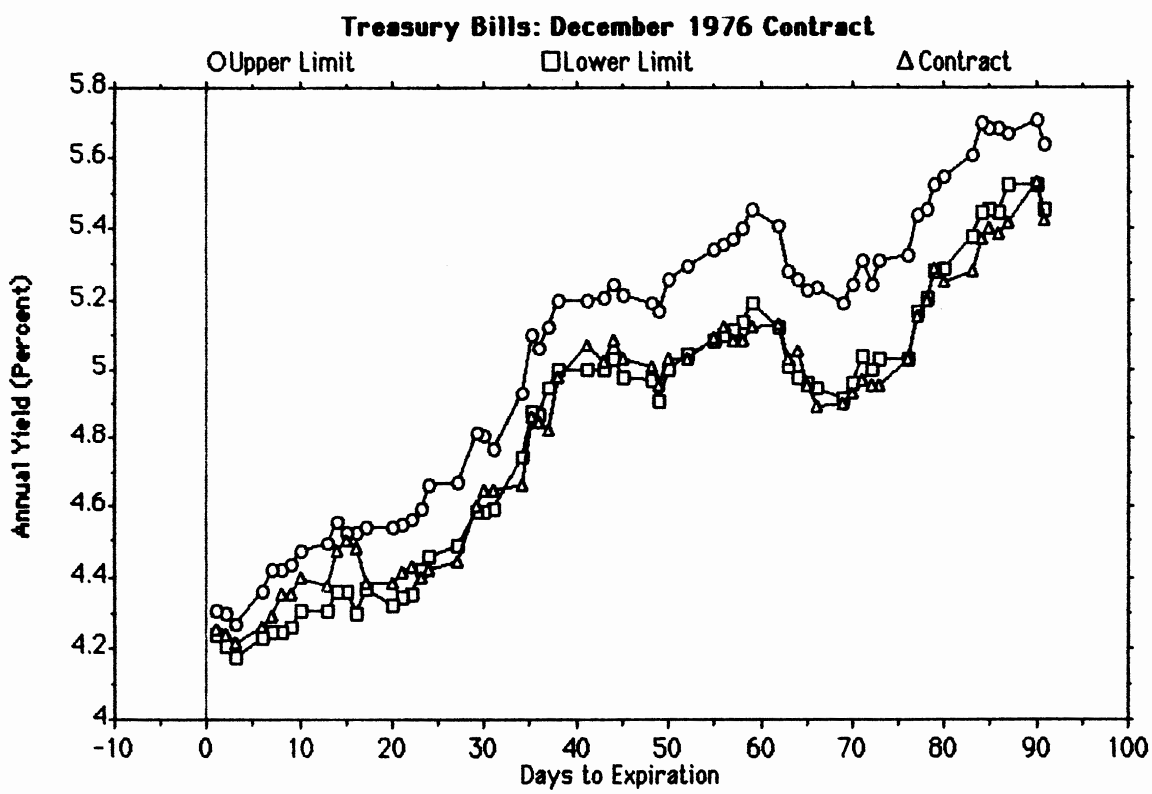
Source of Data:	Futures Contract:	Wall Street Journal.
	Treasury Bill:	Wall Street Journal.

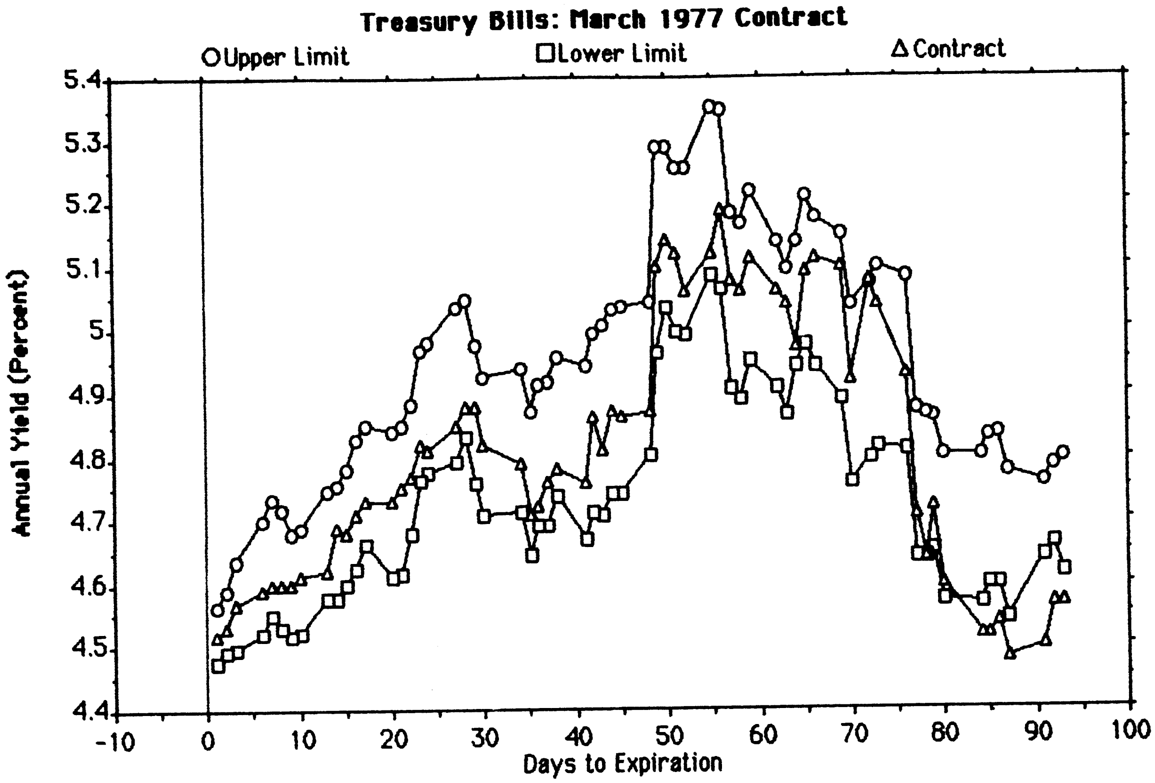
Description: Each chart in this appendix shows three values for each business day - the upper arbitrage limit (Upper Limit), lower arbitrage limit (Lower Limit), and the contract settlement (Contract). The lower arbitrage limit is calculated by finding the contract settlement that would result in identical yield from Strategy II and Strategy IIA, after payment of required commission ($60) and subtraction of the opportunity cost of margin posted to the account ($1,500). The upper arbitrage limit is calculated by finding the contract settlement that would result in identical yield from Strategy I and Strategy IA, after payment of required commission ($60) and subtraction of the opportunity cost of margin posted to the account ($1,500). For descriptions of these investment strategies, see Section II, Table 1.

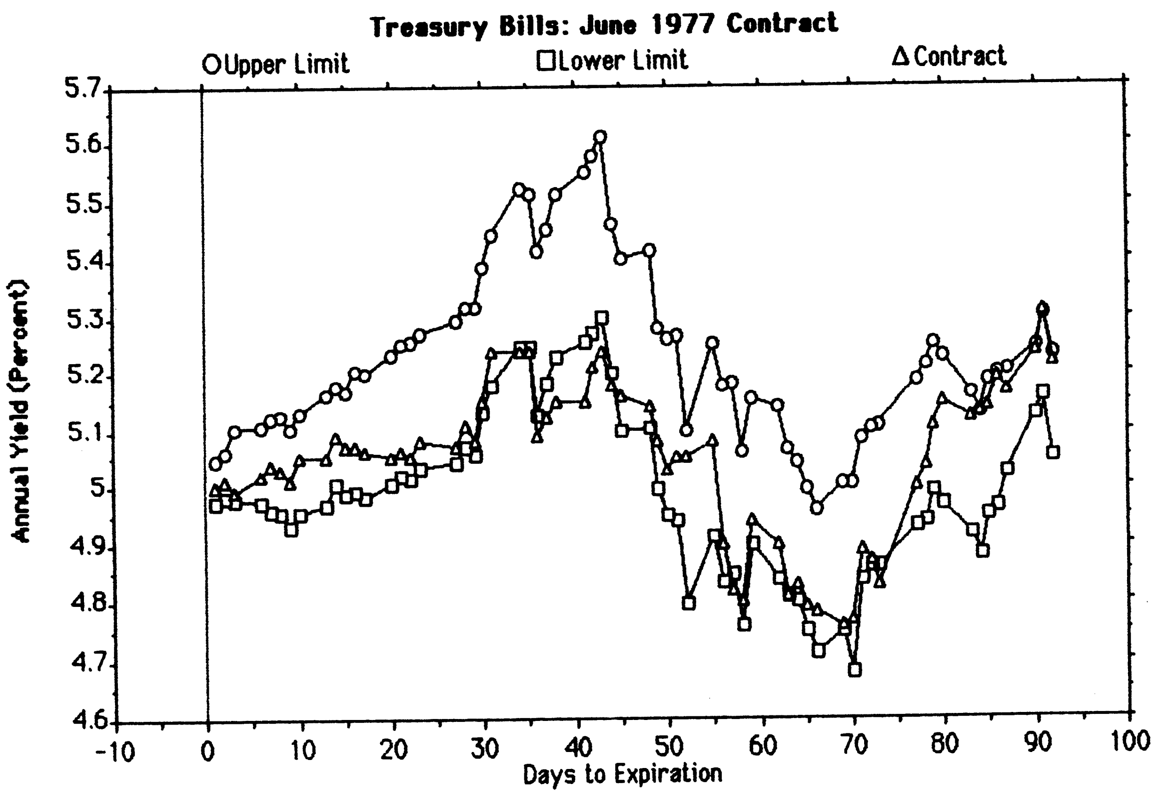

Treasury Bills: March 1976 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
0
10
20
30
40
50
60
70
80
Days to Expiration

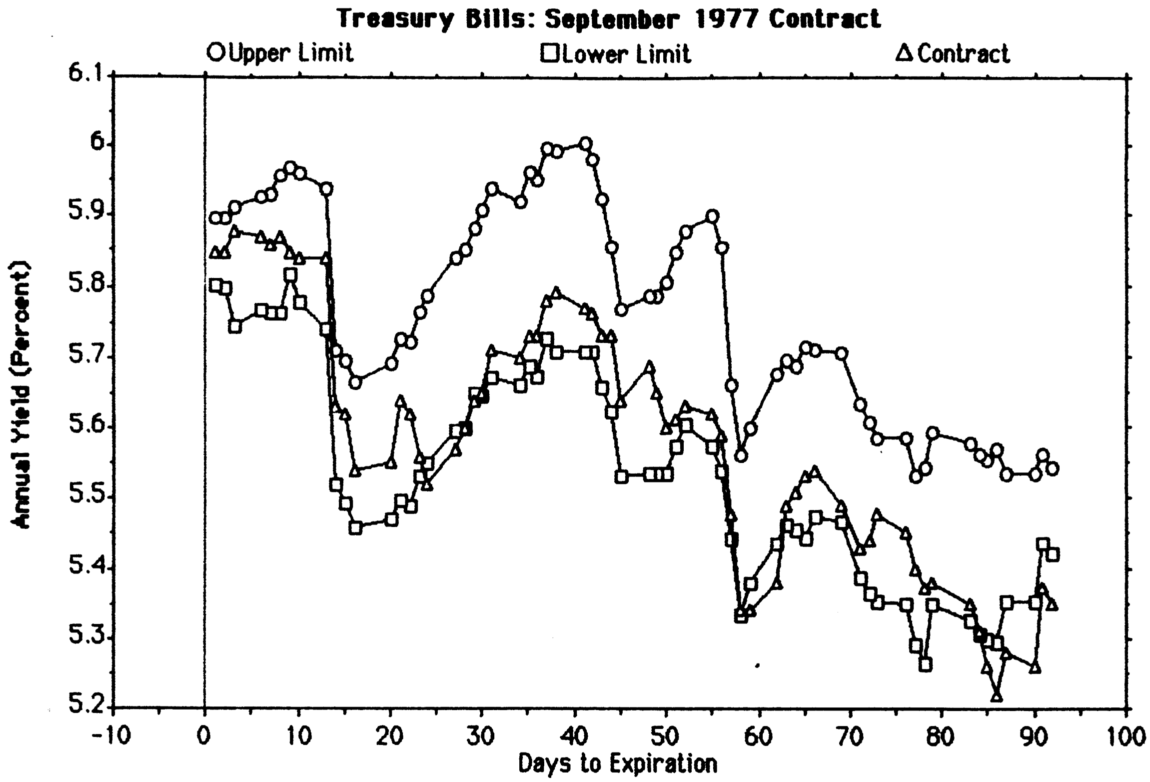

Treasury Bills: June 1976 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
6.2
6
5.8
5.6
5.4
5.2
5
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

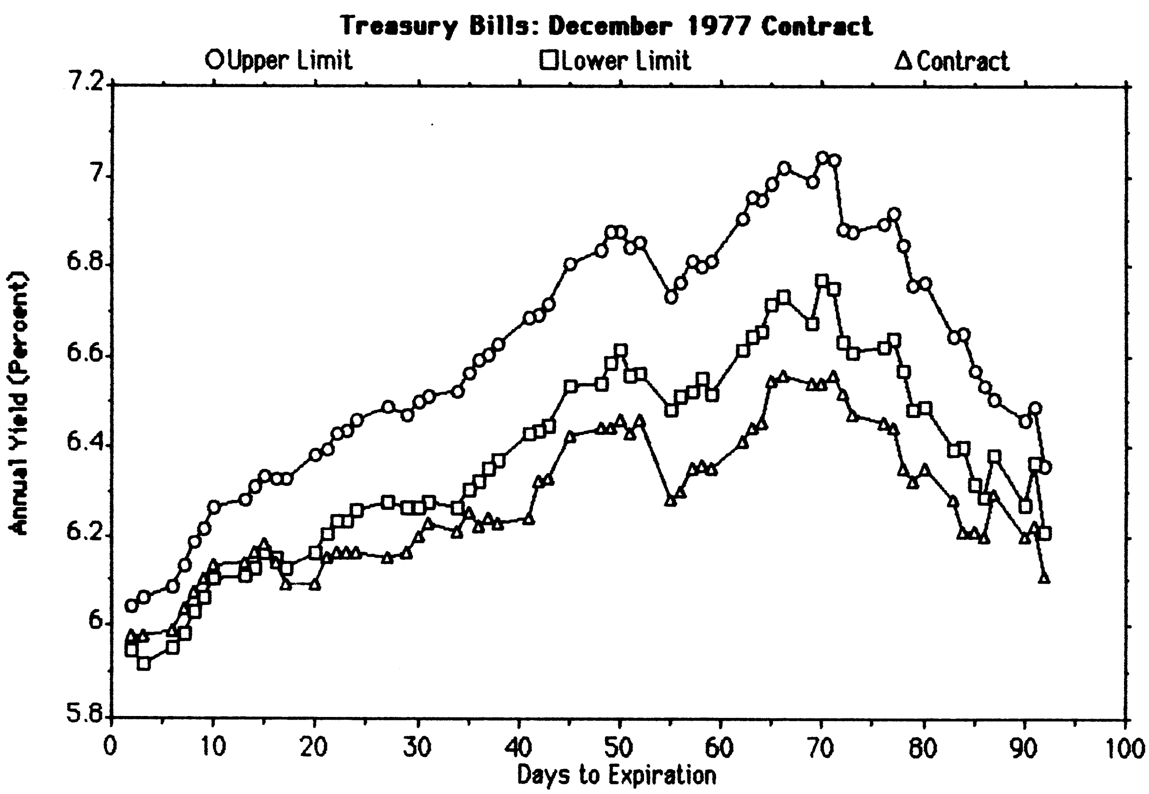

Treasury Bills: September 1976 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
-10
0
10
20
30
40
50
60
70
80
90
100

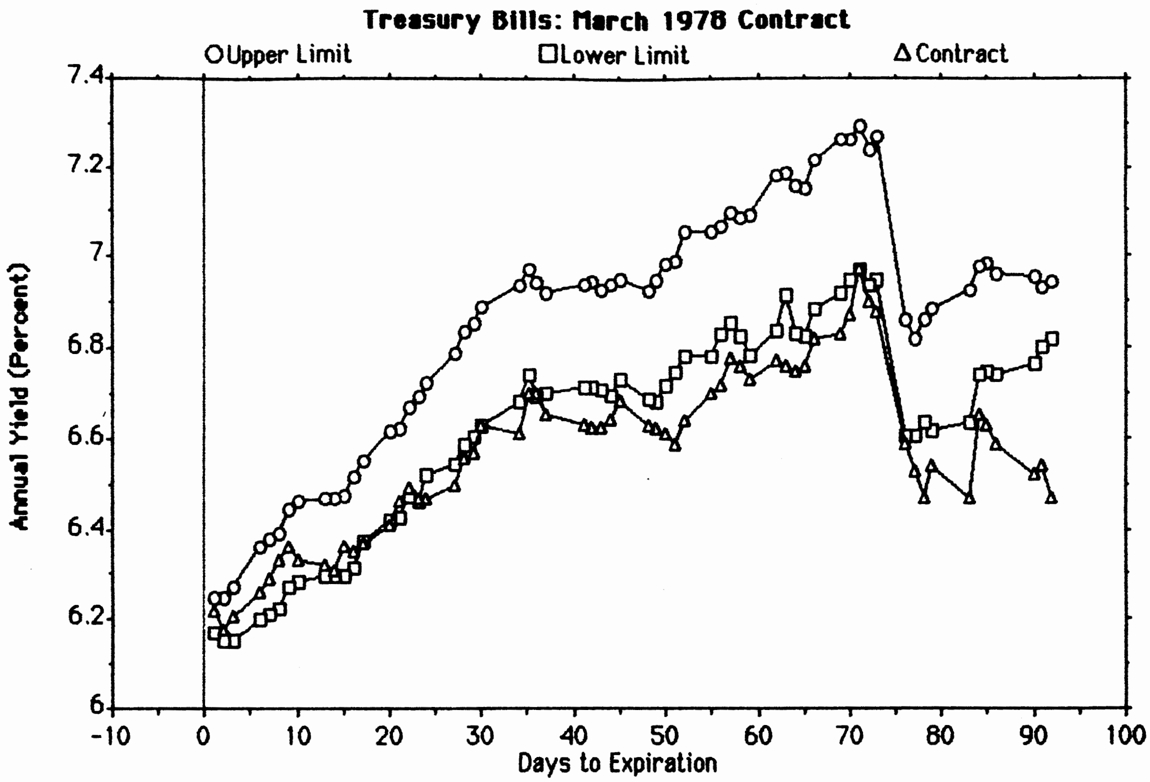

Treasury Bills: December 1976 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
-10
0
10
20
30
40
50
60
70
80
90
100


Treasury Bills: March 1977 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

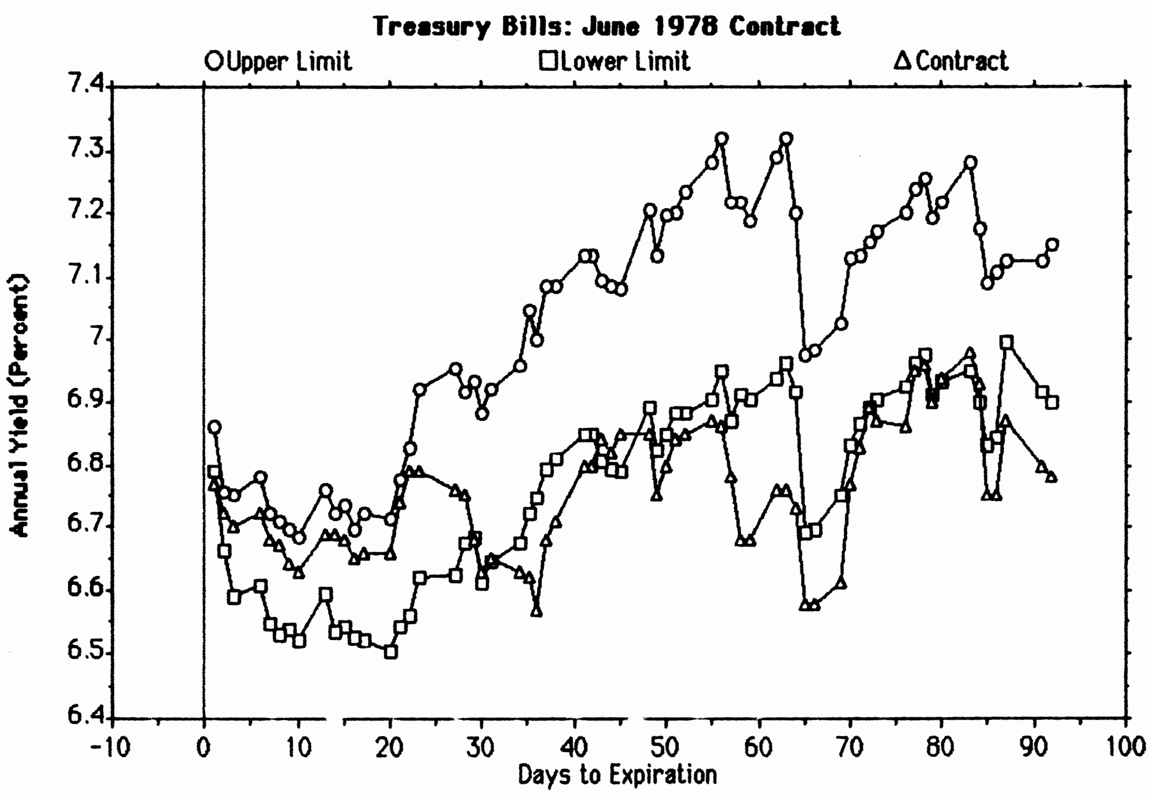

Treasury Bills: June 1977 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration


Treasury Bills: September 1977 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
-10
0
10
20
30
40
50
60
70
80
90
100

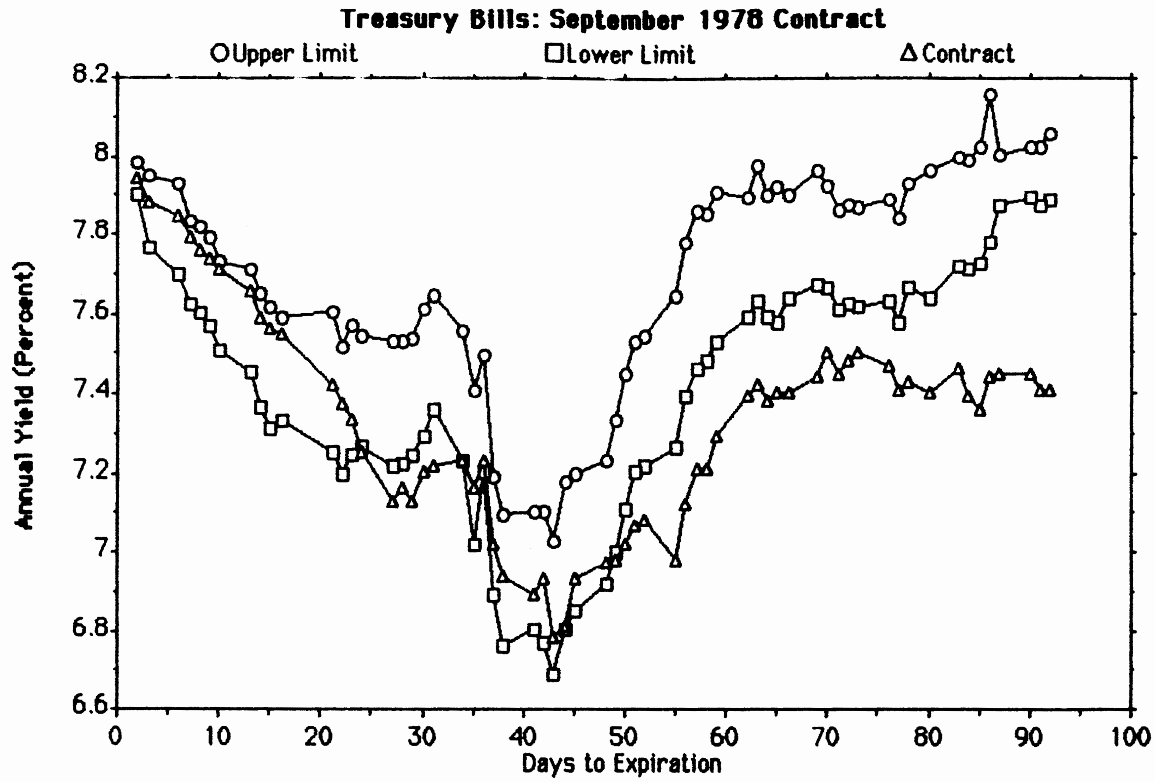

Treasury Bills: December 1977 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
7.2
7
6.8
6.6
6.4
6.2
6
5.8
0
10
20
30
40
50
60
70
80
90
100

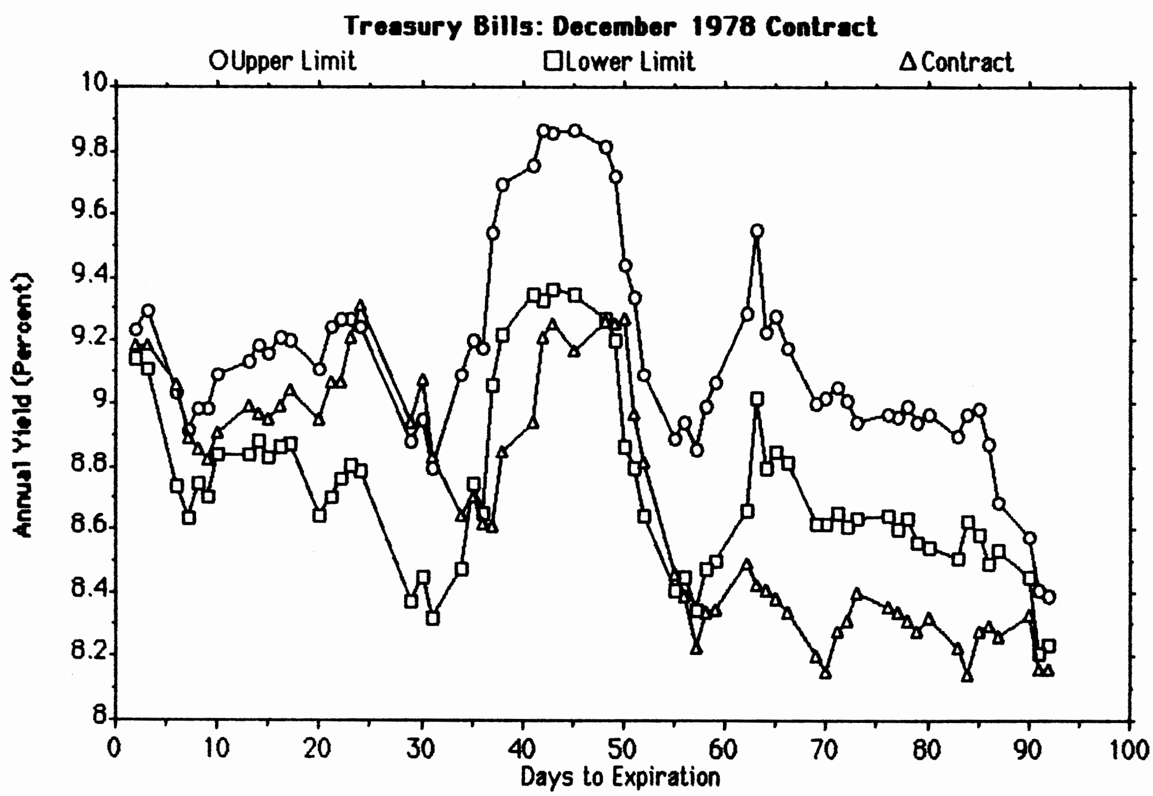


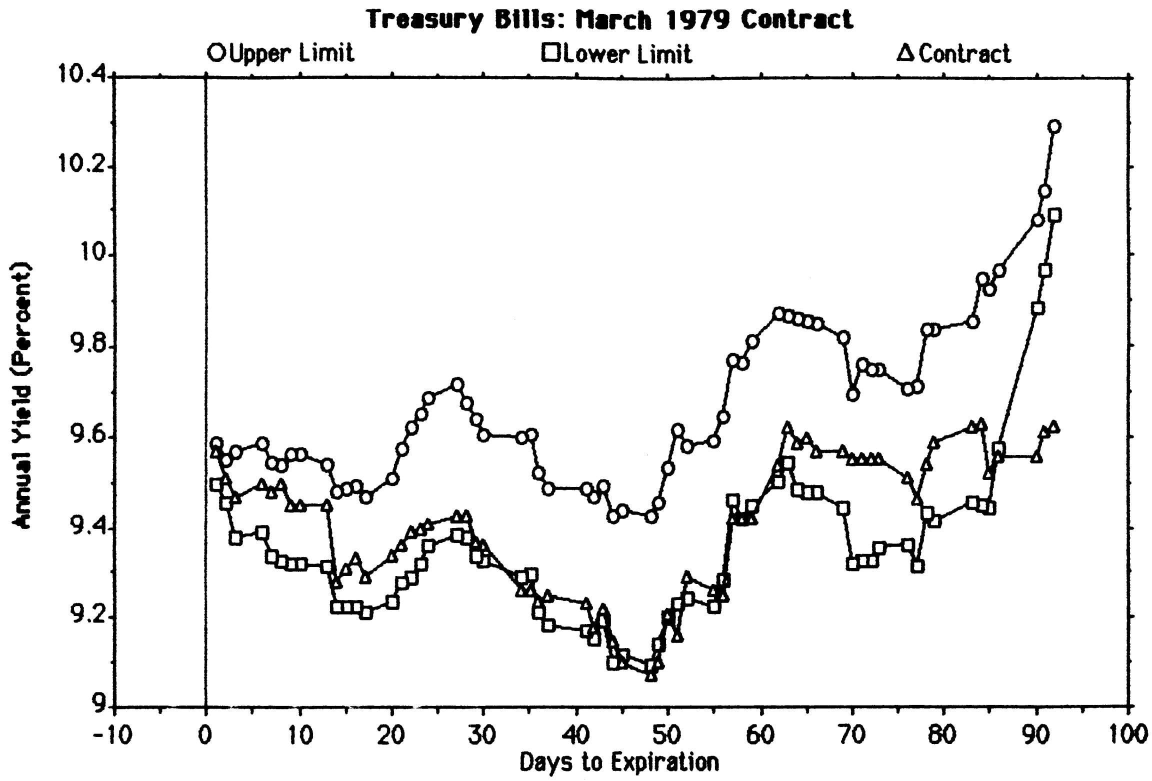
Treasury Bills: March 1978 Contract
O Upper Limit
□ Lower Limit
Δ Contract
Annual Yield (Percent)
7.4
7.2
7
6.8
6.6
6.4
6.2
6
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

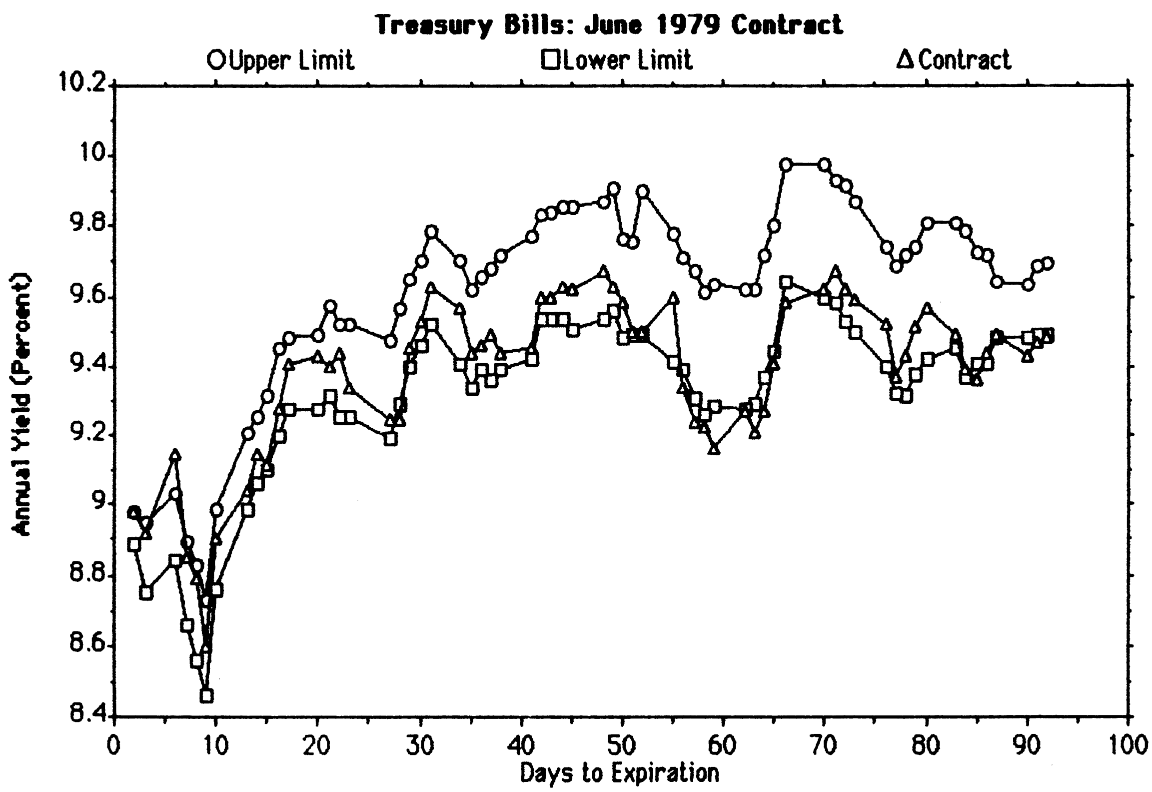


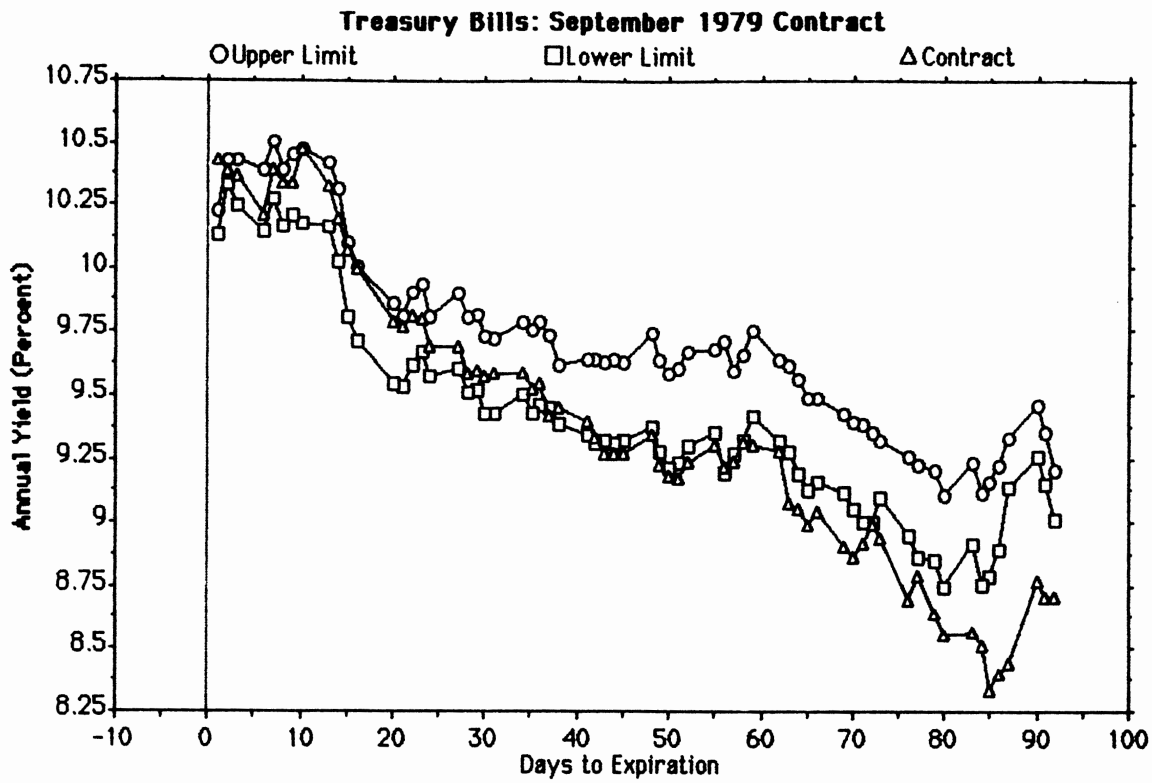
Treasury Bills: June 1978 Contract
O Upper Limit
□ Lower Limit
Δ Contract
Annual Yield (Percent)
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

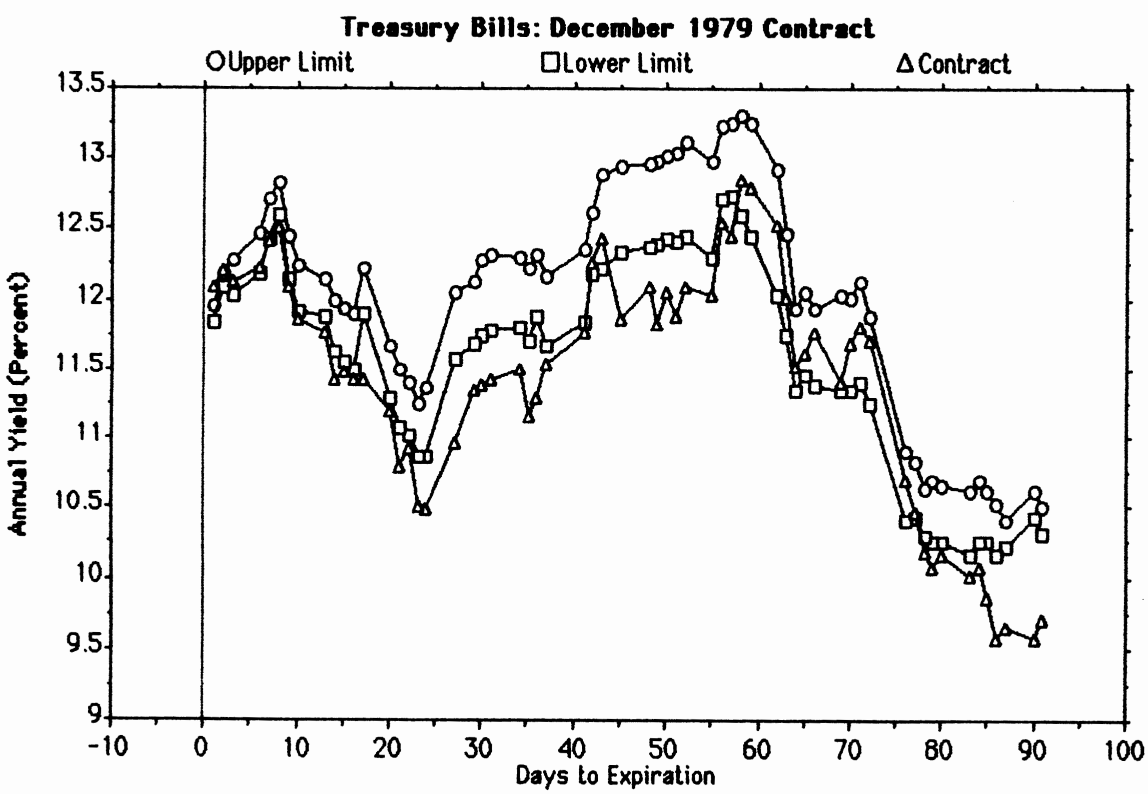

Treasury Bills: September 1978 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
0
10
20
30
40
50
60
70
80
90
100

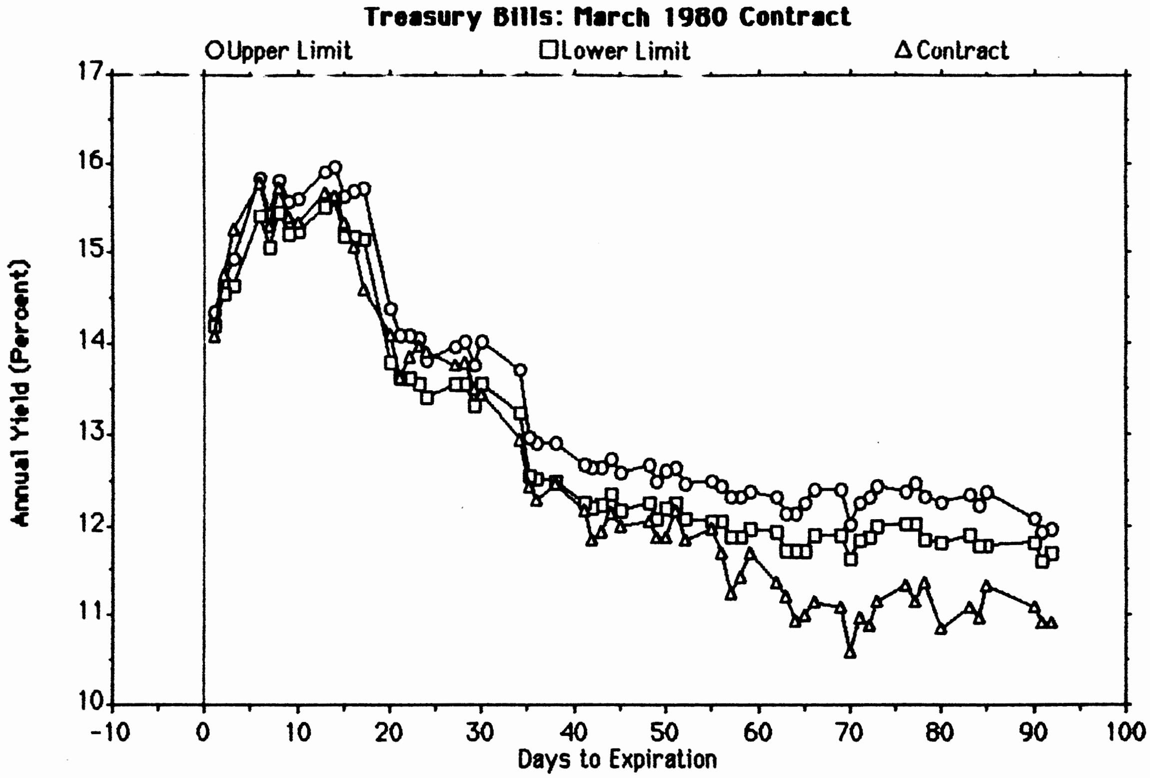

Treasury Bills: December 1978 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
10
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
0
10
20
30
40
50
60
70
80
90
100

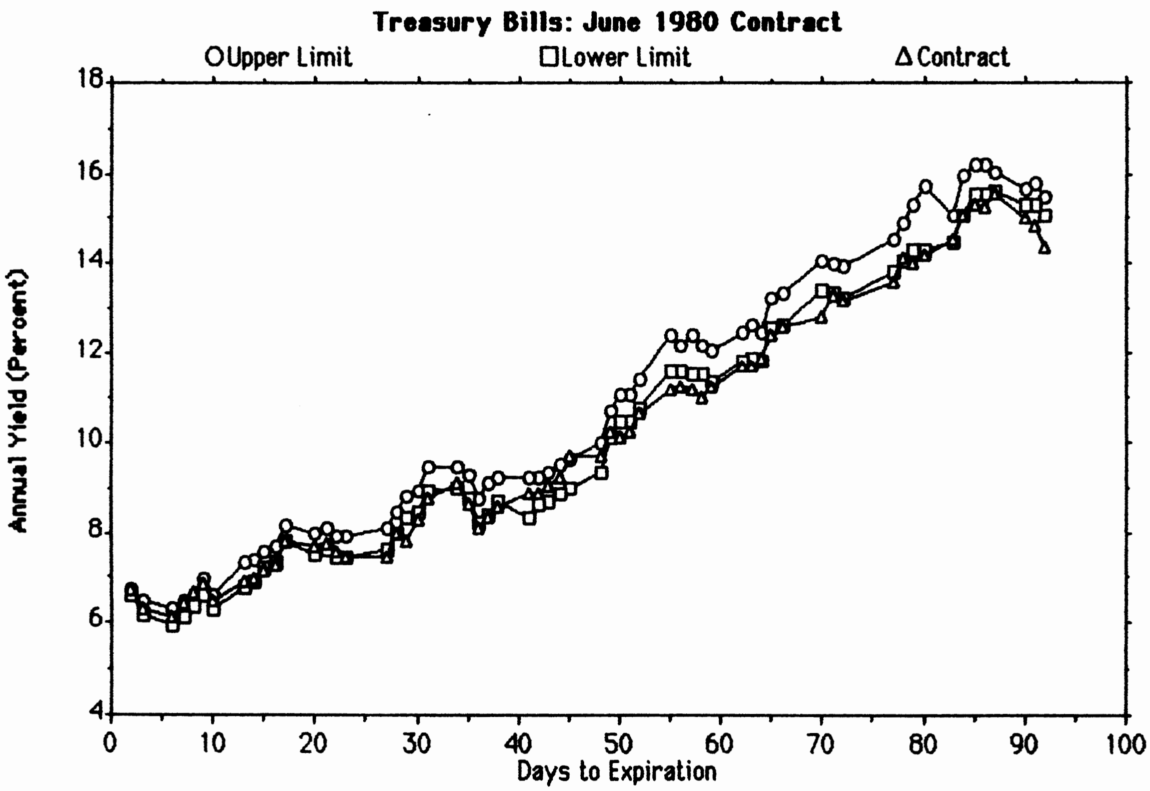

Treasury Bills: March 1979 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration

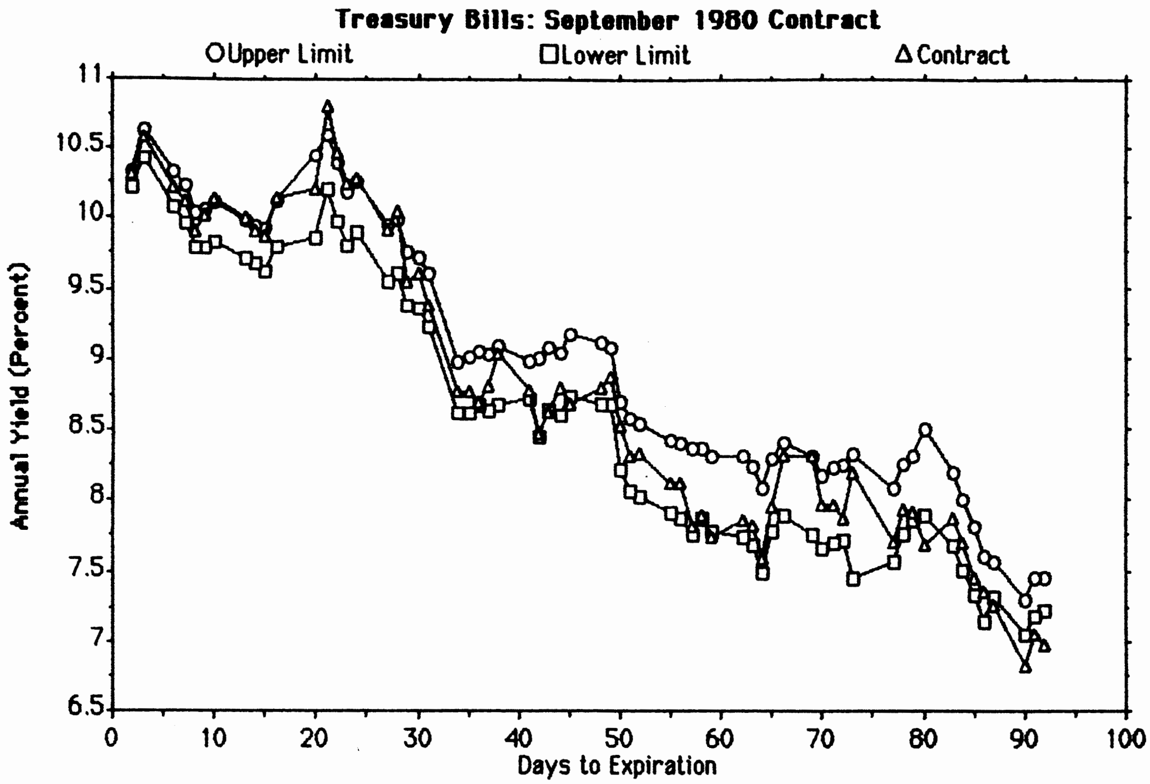

Treasury Bills: June 1979 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration

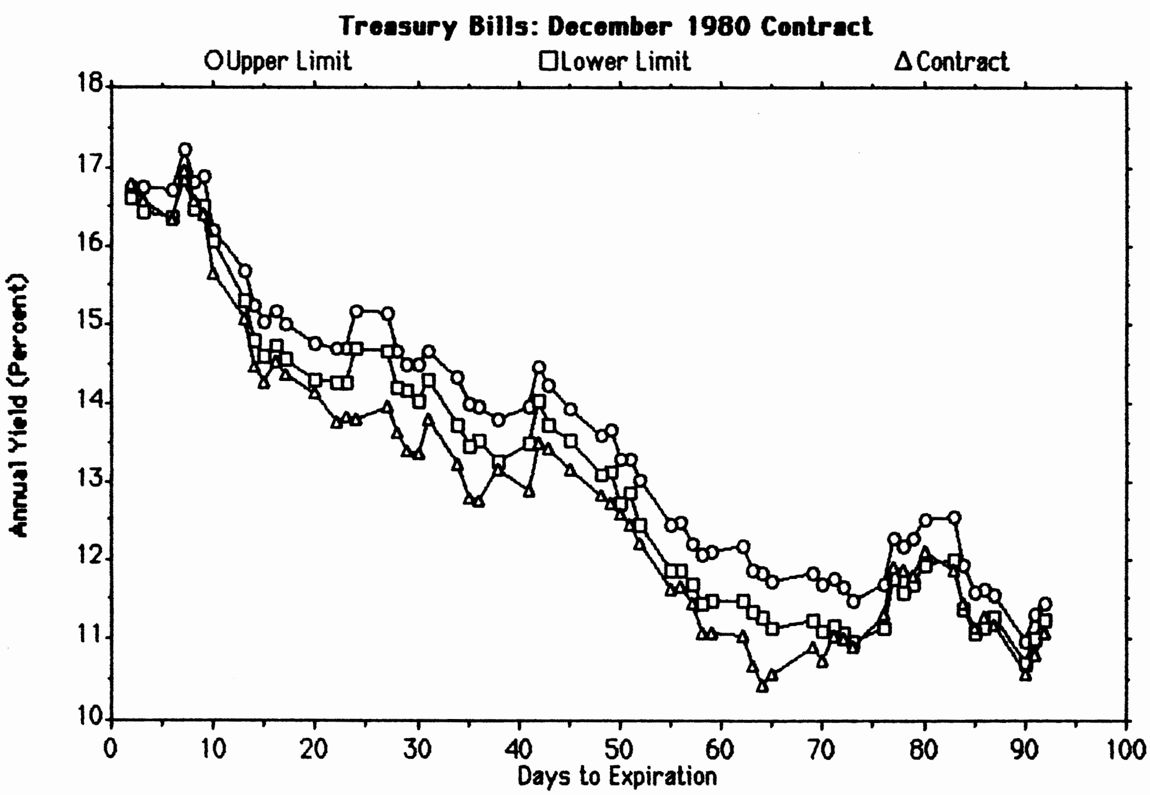

Treasury Bills: September 1979 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
10.75
10.5
10.25
10
9.75
9.5
9.25
9
8.75
8.5
8.25
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

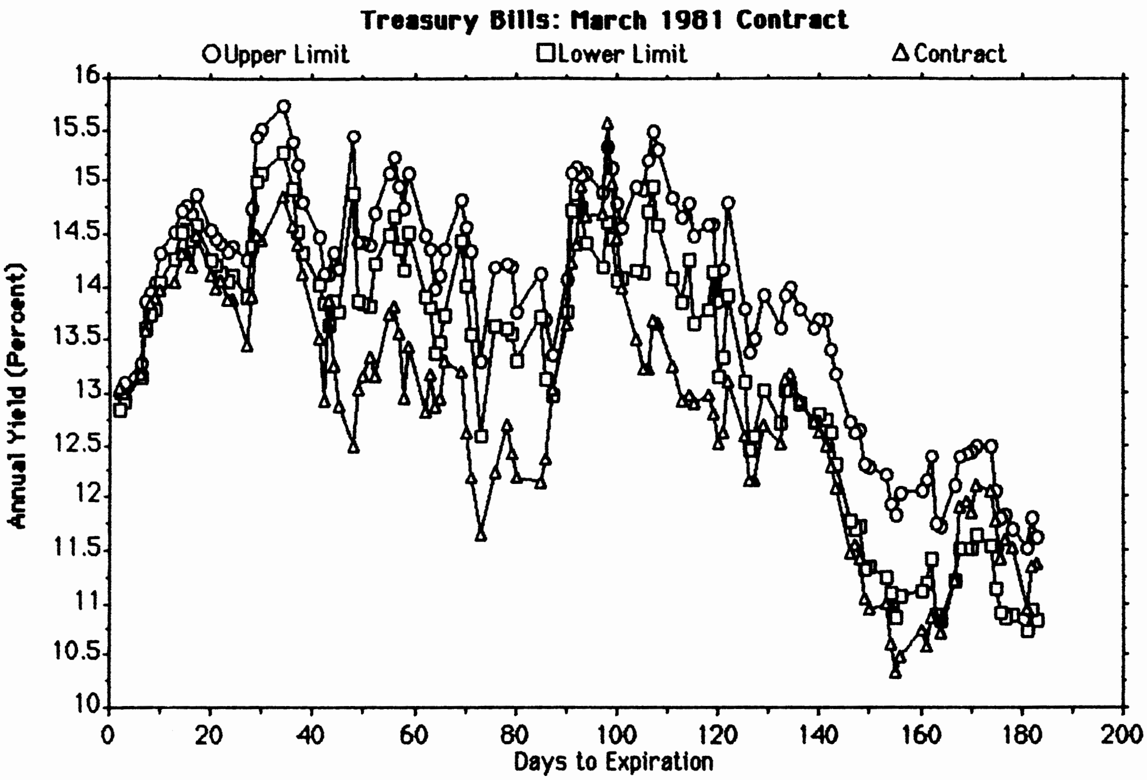

Treasury Bills: December 1979 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
-10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

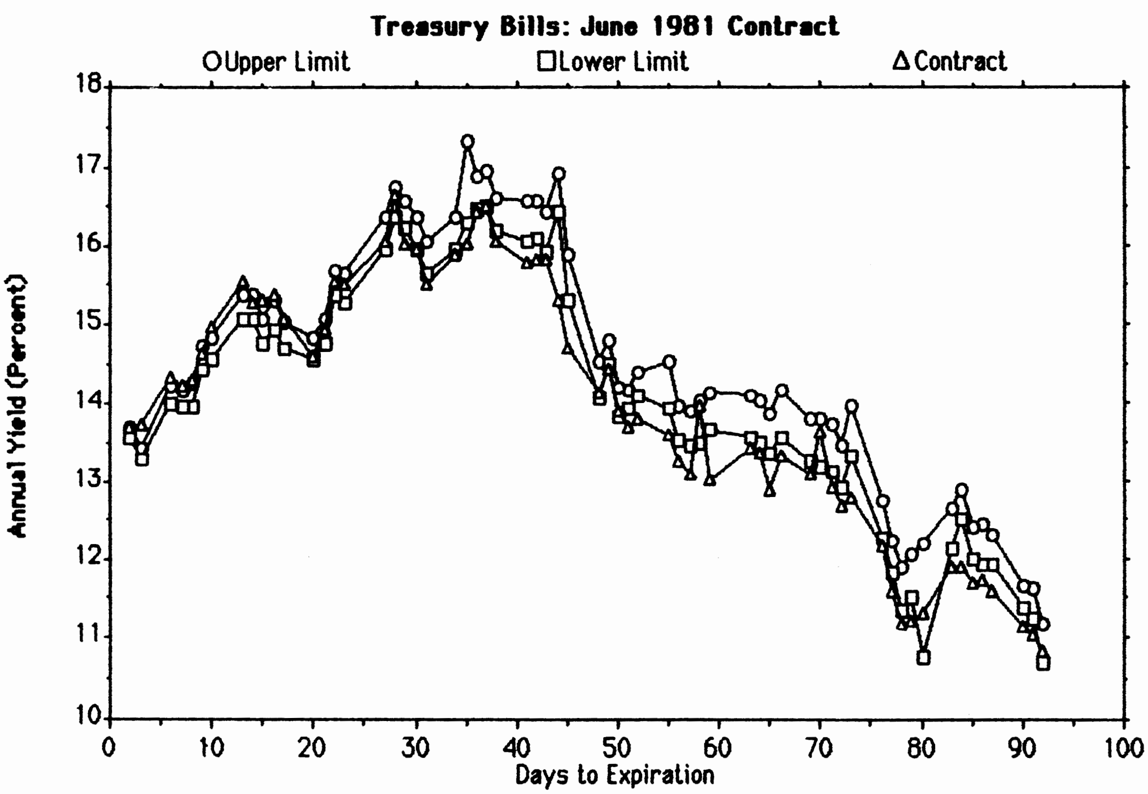

Treasury Bills: March 1980 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
17
16
15
14
13
12
11
10
-10
0
10
20
30
40
50
60
70
80
90
100

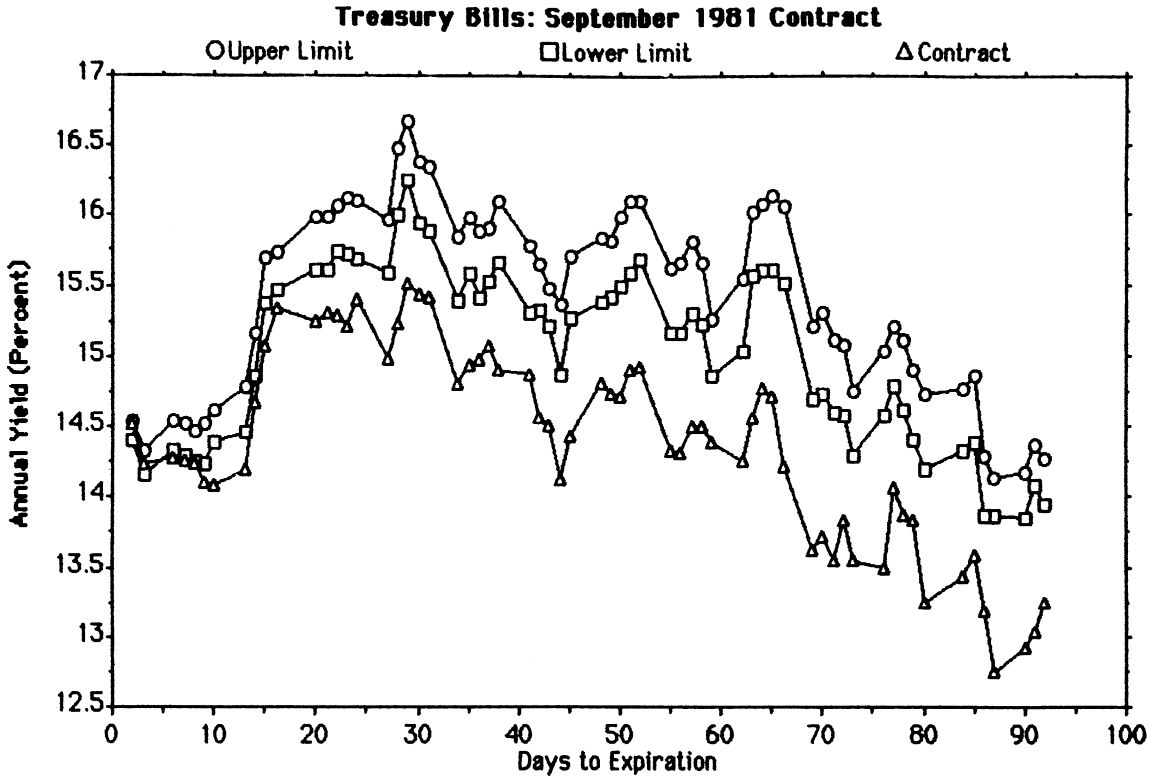

Treasury Bills: June 1980 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
18
16
14
12
10
8
6
4
0
10
20
30
40
50
60
70
80
90
100

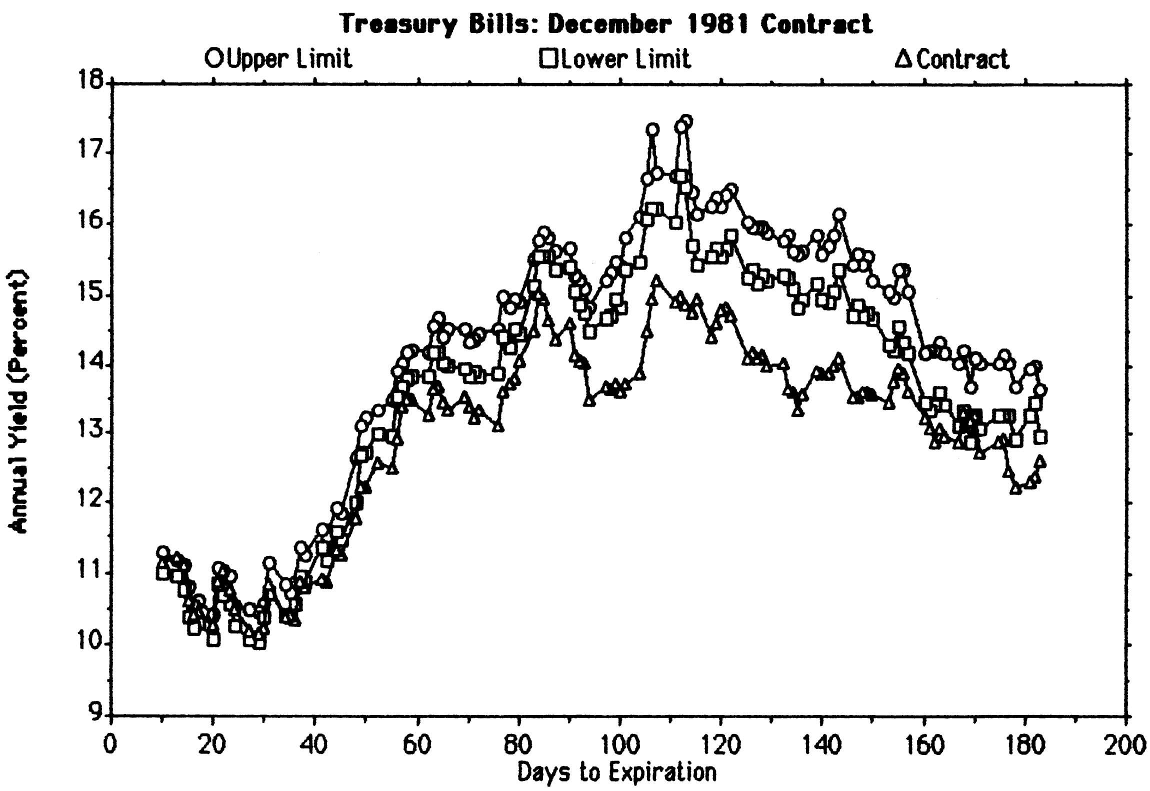

Treasury Bills: September 1980 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
0
10
20
30
40
50
60
70
80
90
100

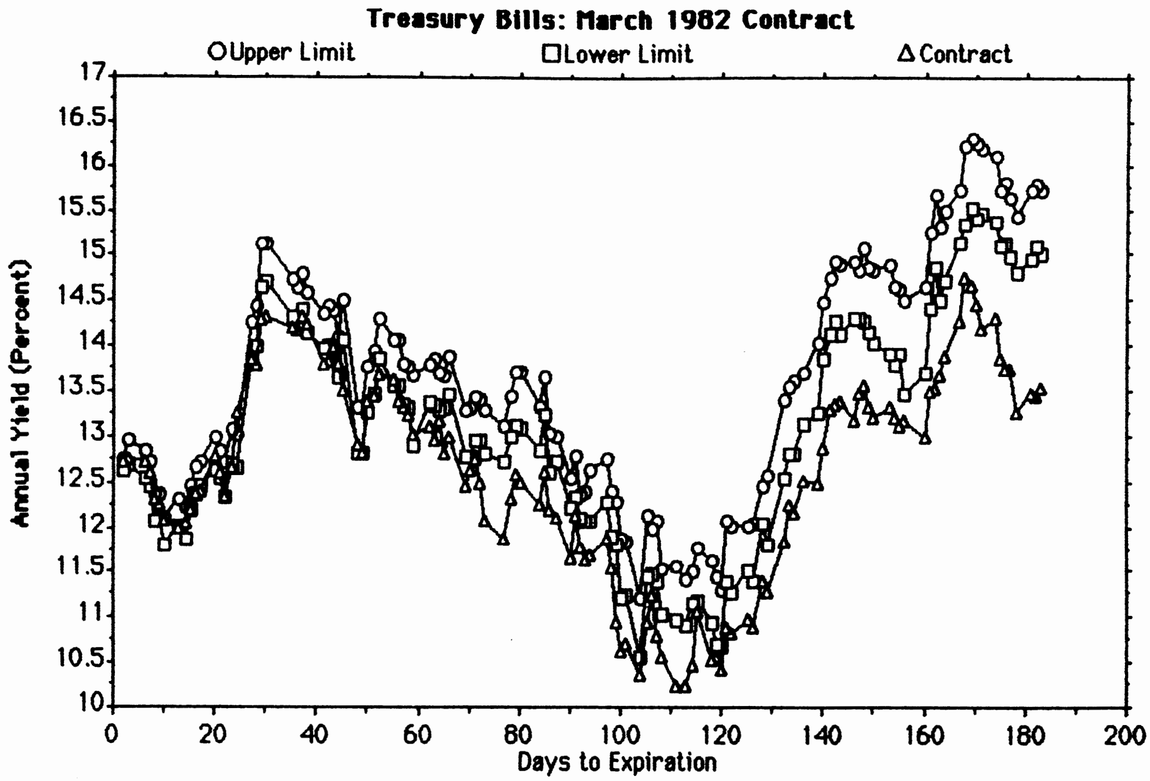

Treasury Bills: December 1980 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
18
17
16
15
14
13
12
11
10
0
10
20
30
40
50
60
70
80
90
100

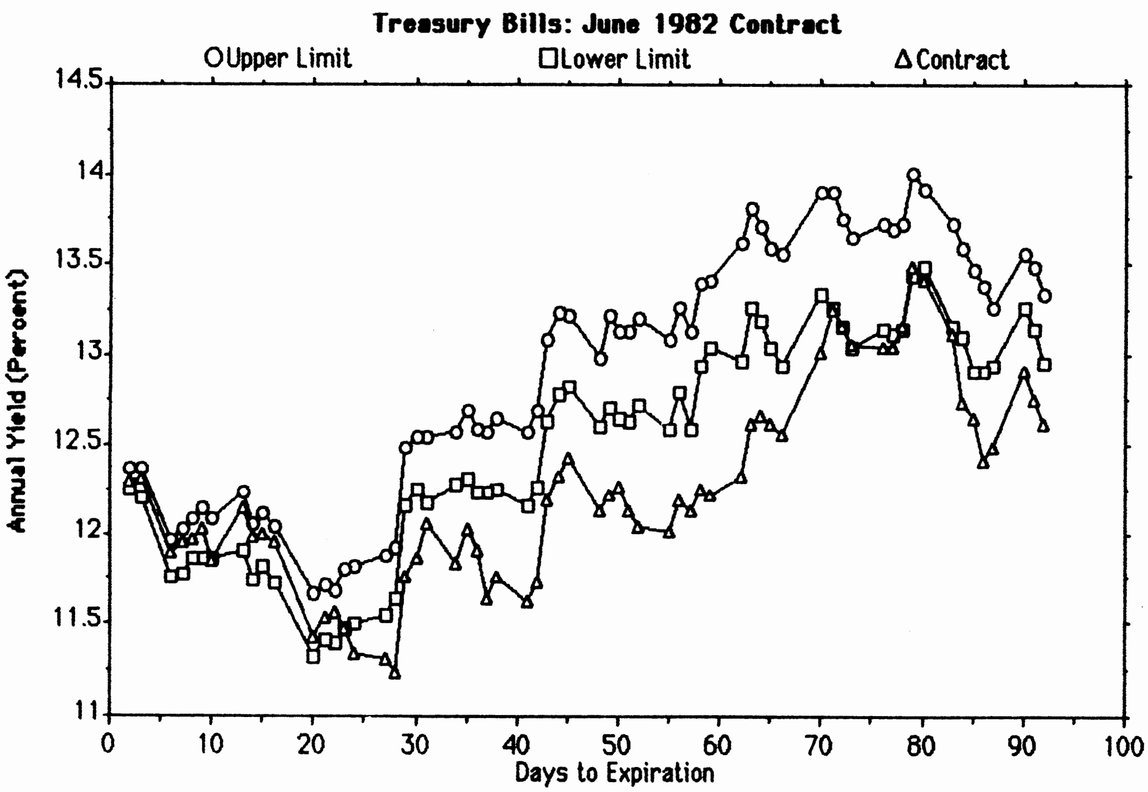

Treasury Bills: March 1981 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
0
20
40
60
80
100
120
140
160
180
200
Days to Expiration

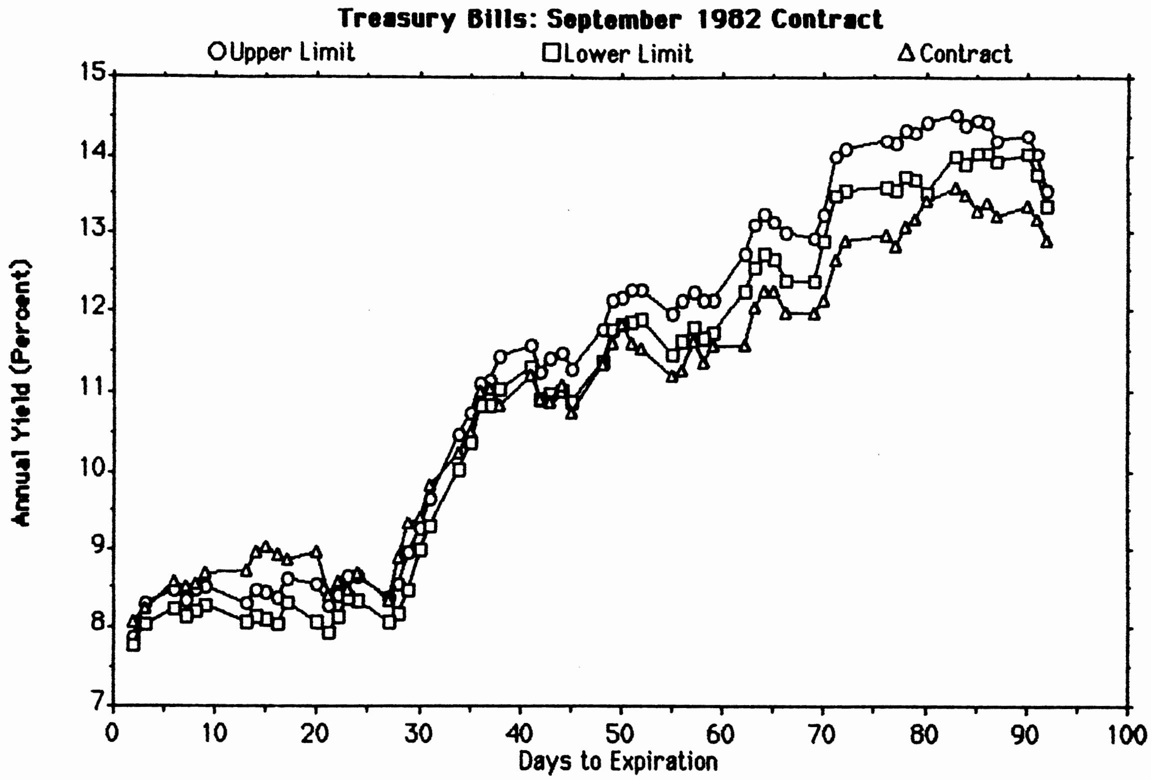

Treasury Bills: June 1981 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
18
17
16
15
14
13
12
11
10
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

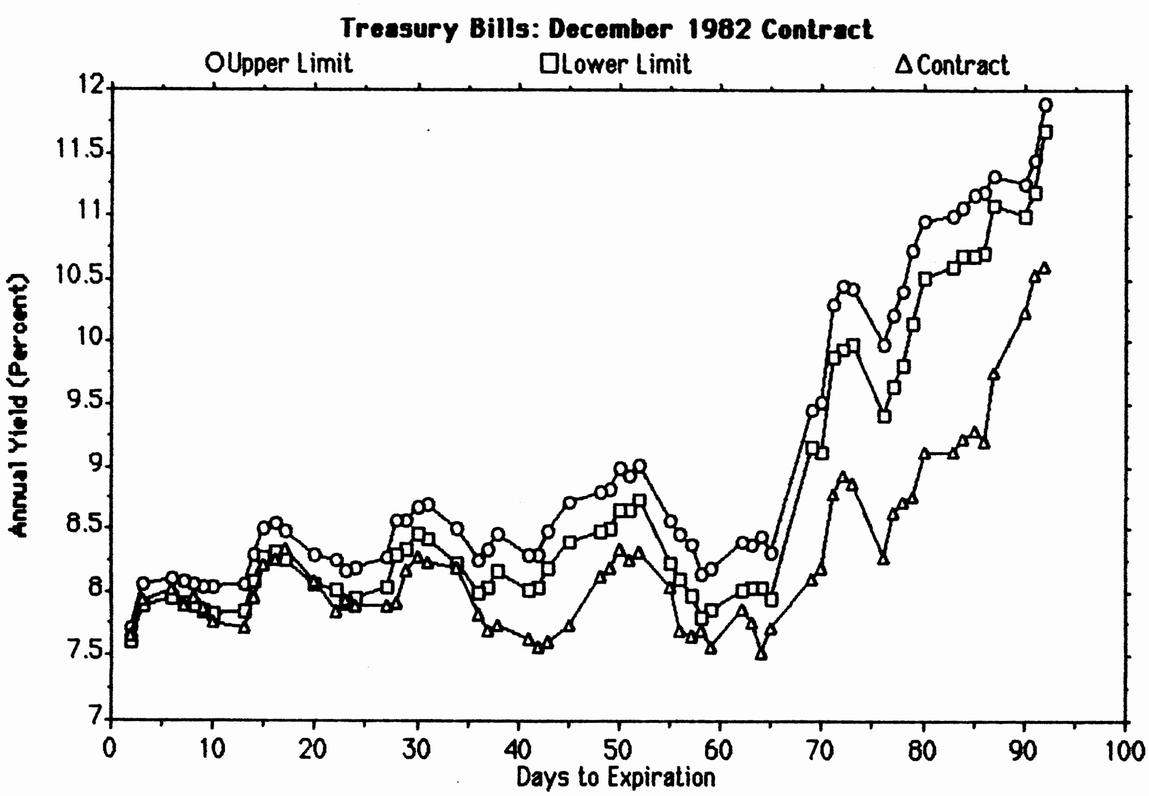

Treasury Bills: September 1981 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
Days to Expiration
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
0
10
20
30
40
50
60
70
80
90
100

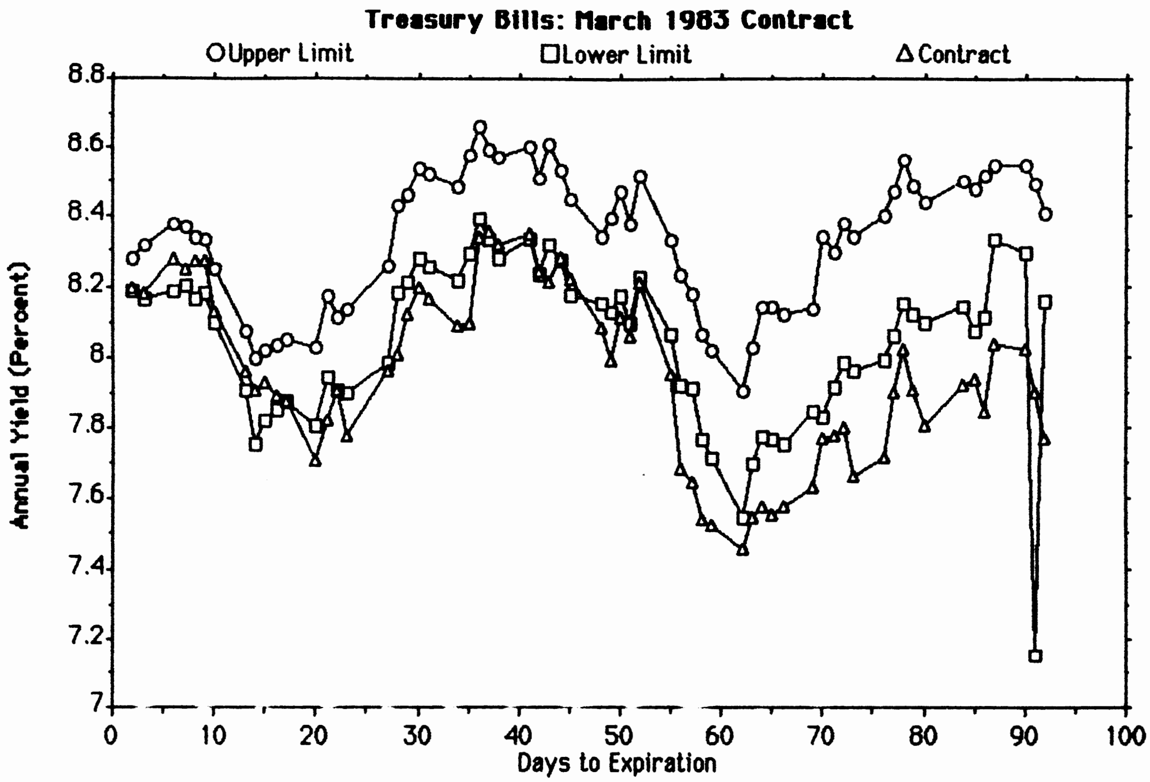

Treasury Bills: December 1981 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
Days to Expiration
18
17
16
15
14
13
12
11
10
9
0
20
40
60
80
100
120
140
160
180
200

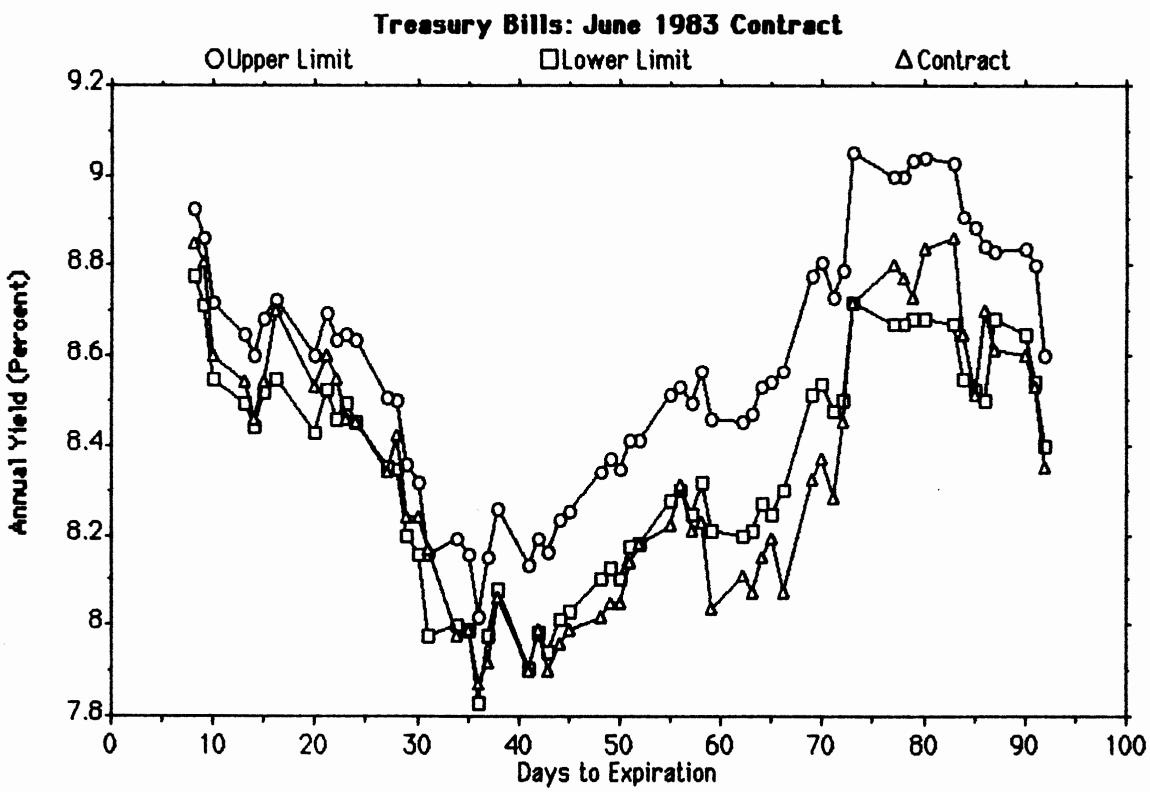

Treasury Bills: March 1982 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
0
20
40
60
80
100
120
140
160
180
200
Days to Expiration

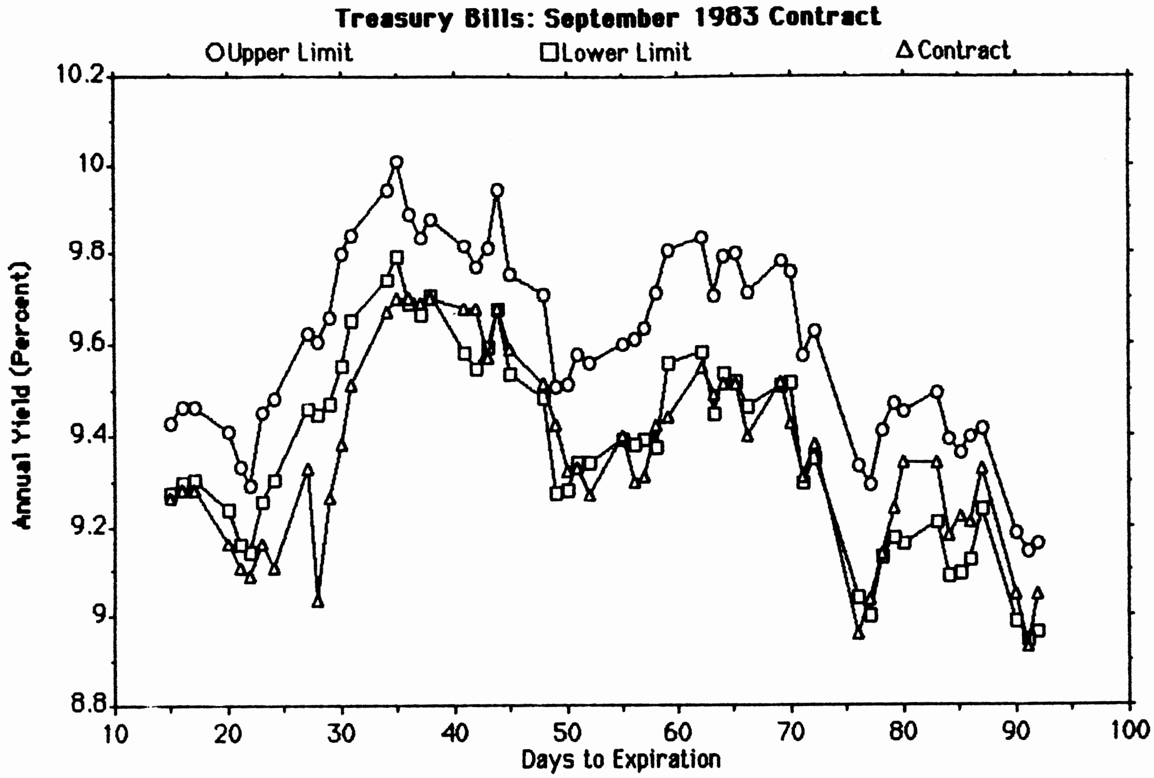

Treasury Bills: June 1982 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
14.5
14
13.5
13
12.5
12
11.5
11
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration


Treasury Bills: September 1982 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
15
14
13
12
11
10
9
8
7
0
10
20
30
40
50
60
70
80
90
100

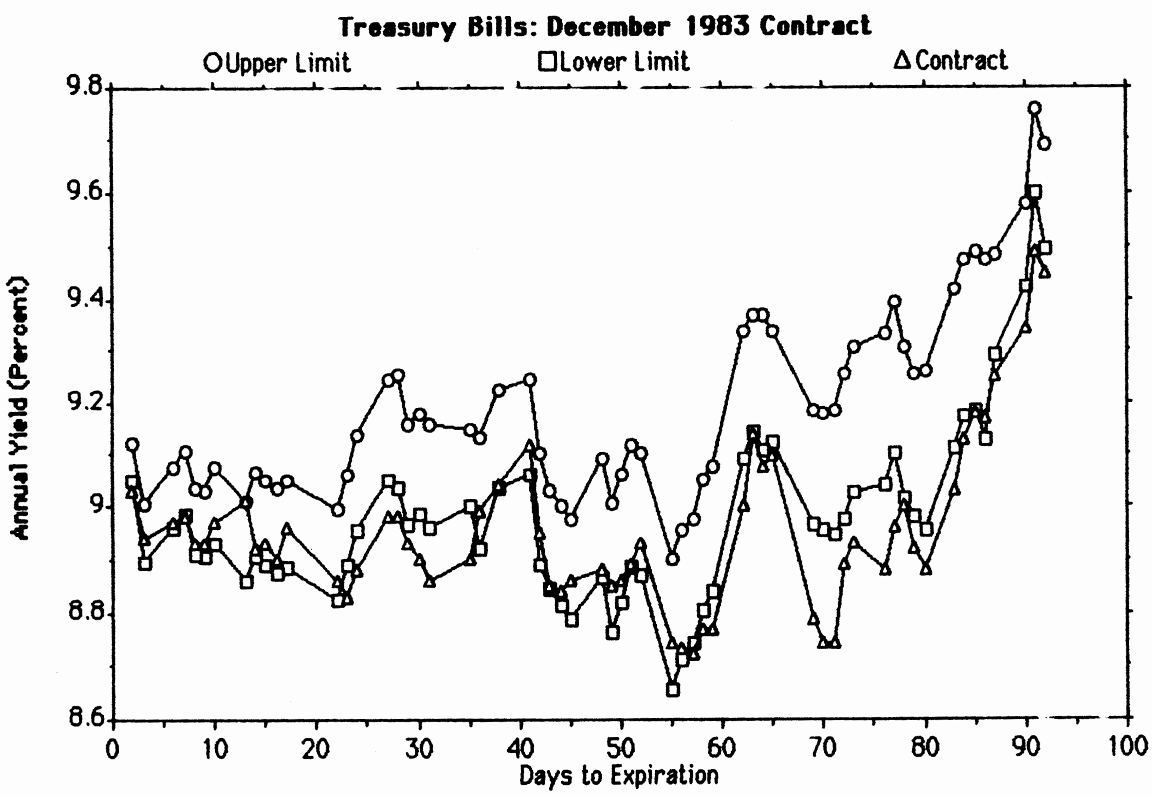

Treasury Bills: December 1982 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
0
10
20
30
40
50
60
70
80
90
100


Treasury Bills: March 1983 Contract
○Upper Limit
□Lower Limit
△Contract
Annual Yield (Percent)
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration

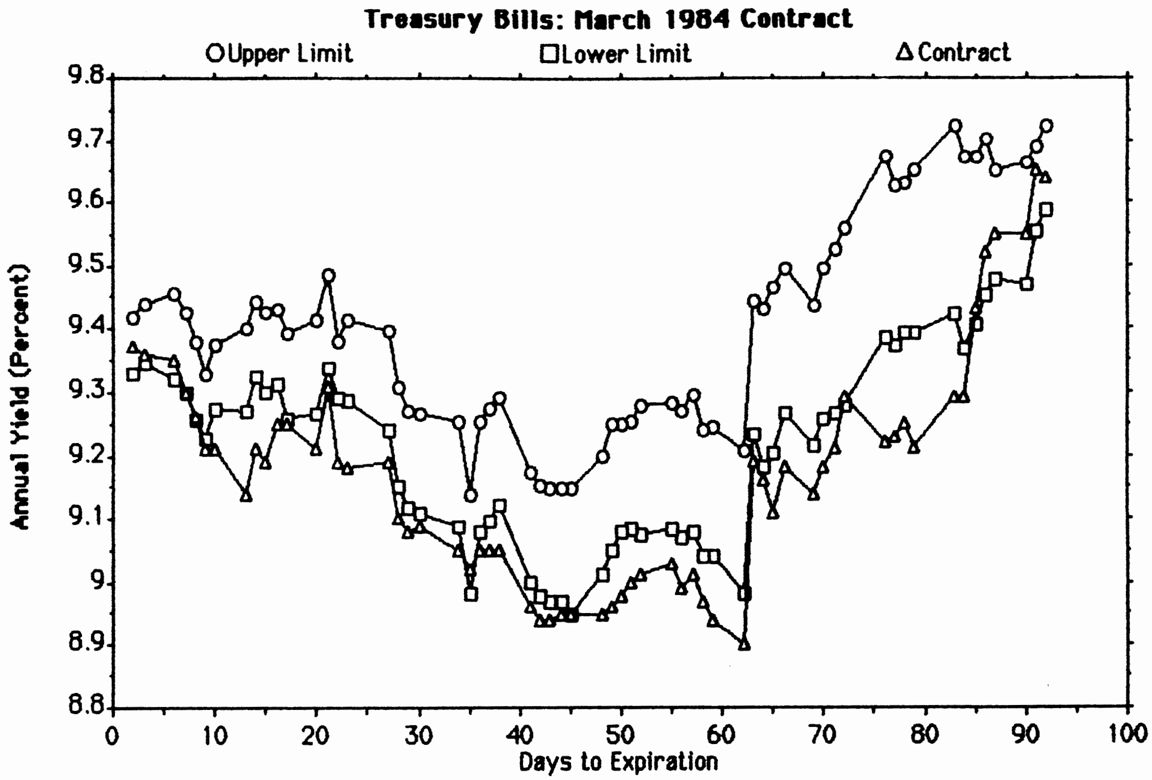

Treasury Bills: June 1983 Contract
○Upper Limit
□Lower Limit
△Contract
Annual Yield (Percent)
9.2
9
8.8
8.6
8.4
8.2
8
7.8
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration



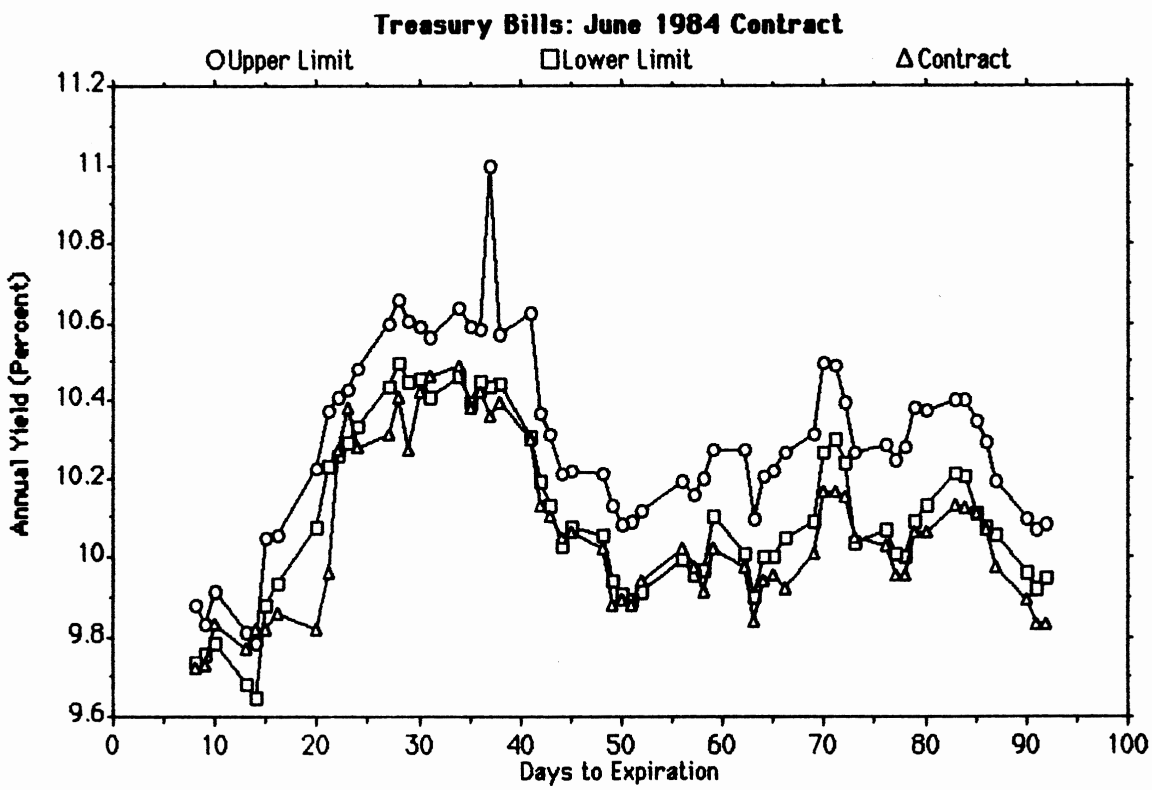
Treasury Bills: September 1983 Contract
OUpper Limit
□Lower Limit
ΔContract
10.2
10
9.8
9.6
9.4
9.2
9
8.8
10
20
30
40
50
60
70
80
90
100
Days to Expiration
Annual Yield (Percent)



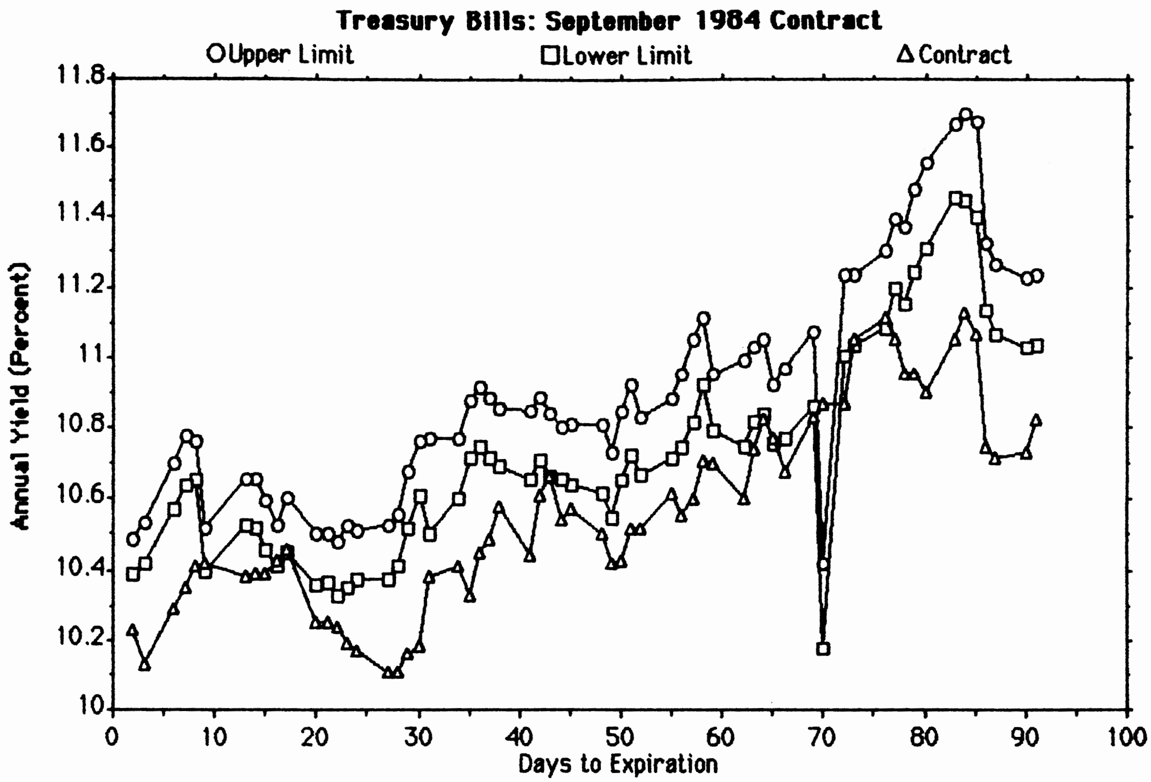
Treasury Bills: December 1983 Contract
OUpper Limit
□Lower Limit
ΔContract
9.8
9.6
9.4
9.2
9
8.8
8.6
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration
Annual Yield (Percent)

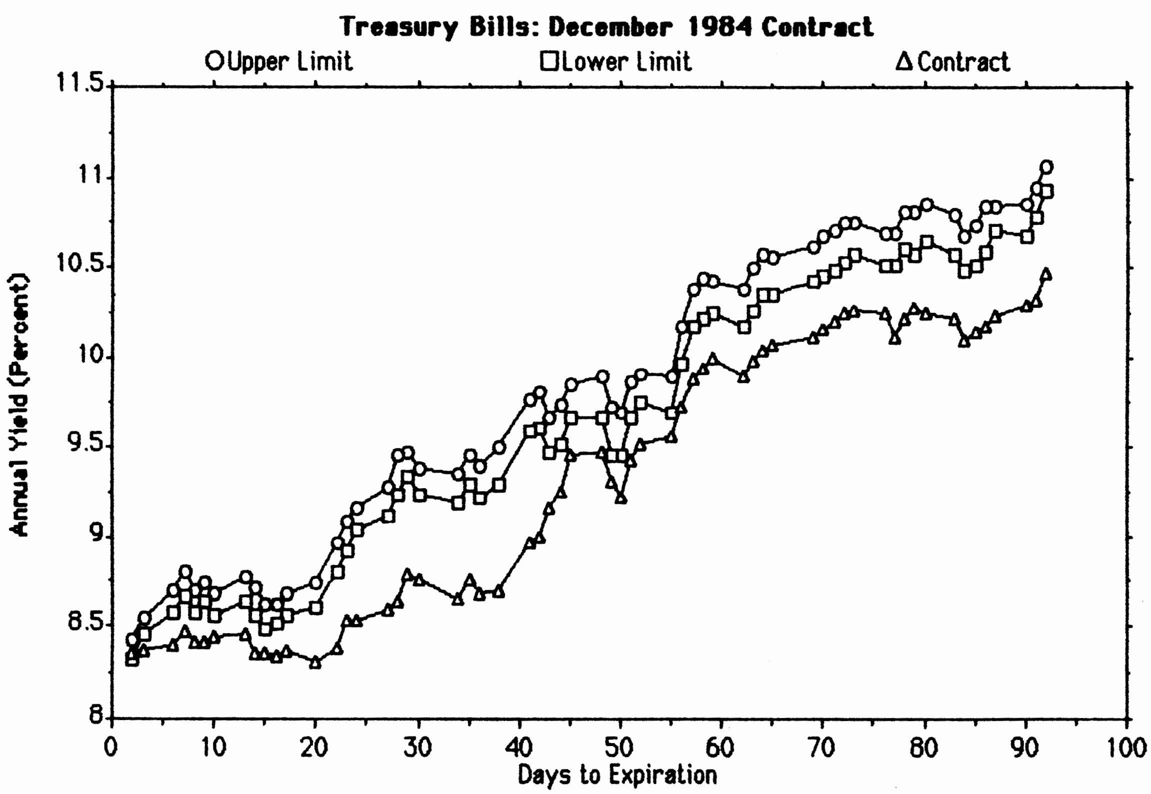


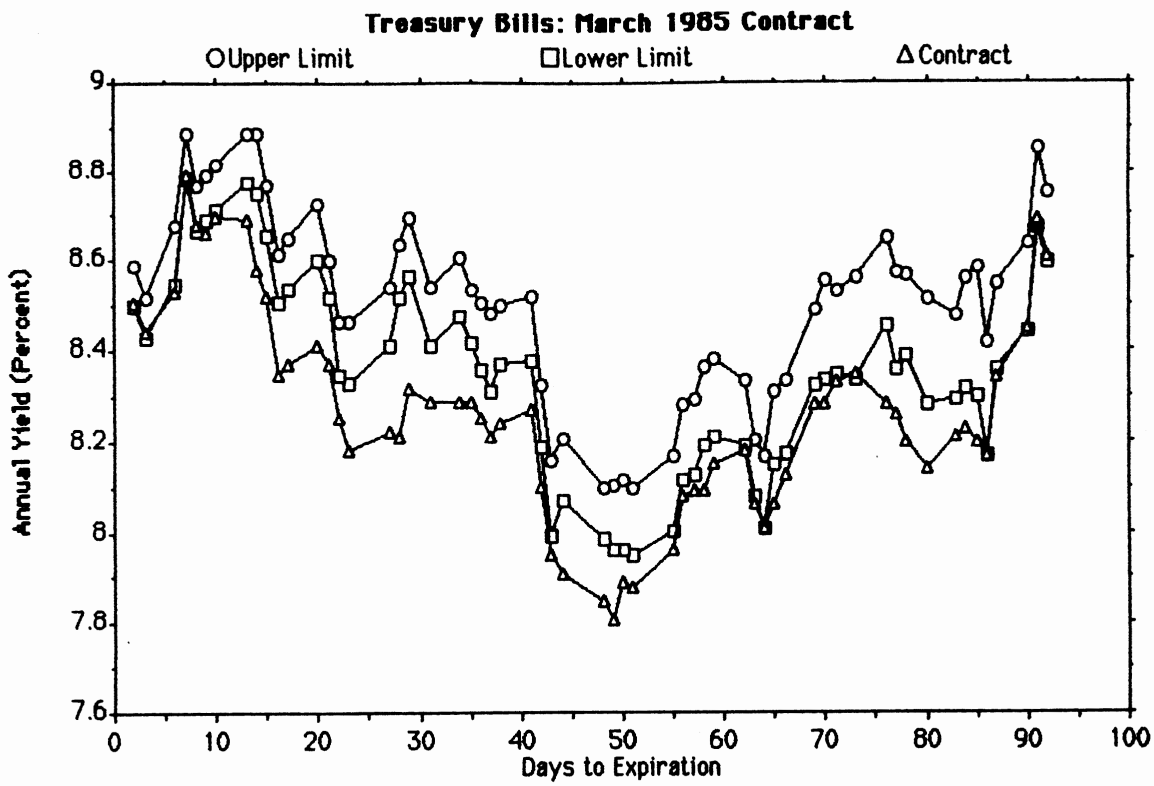
Treasury Bills: March 1984 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
Days to Expiration

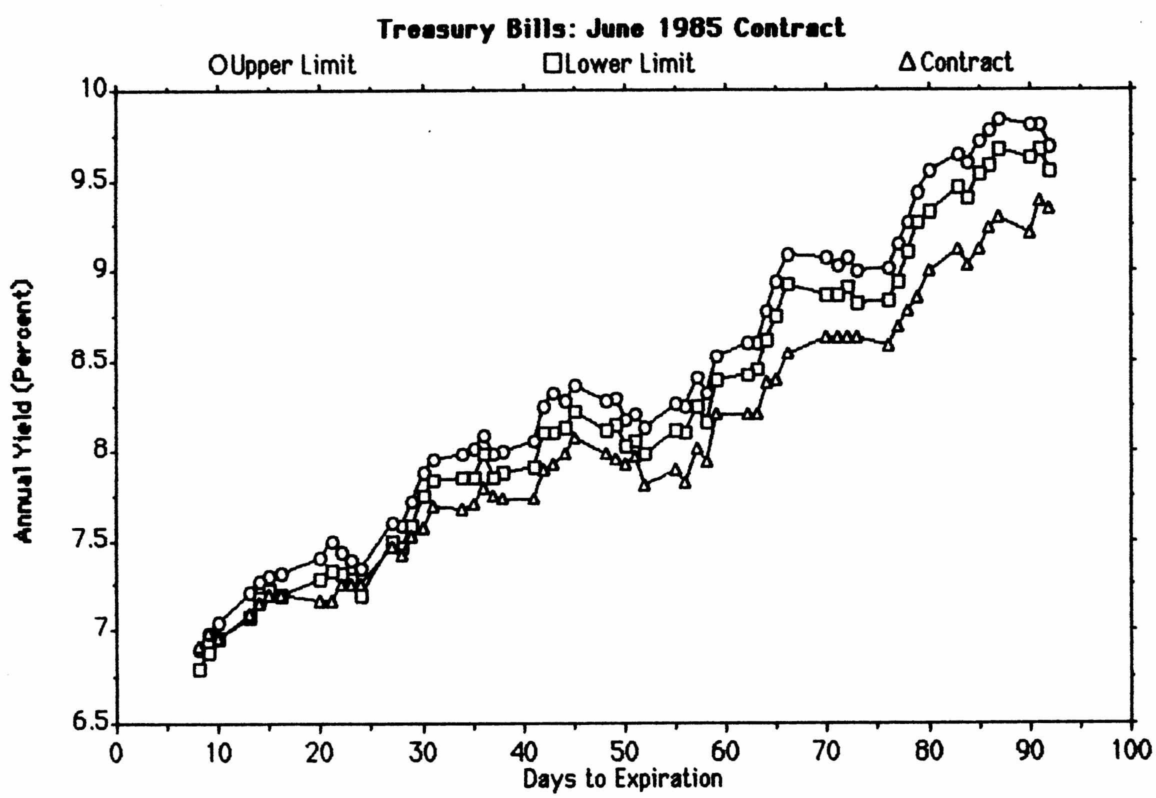


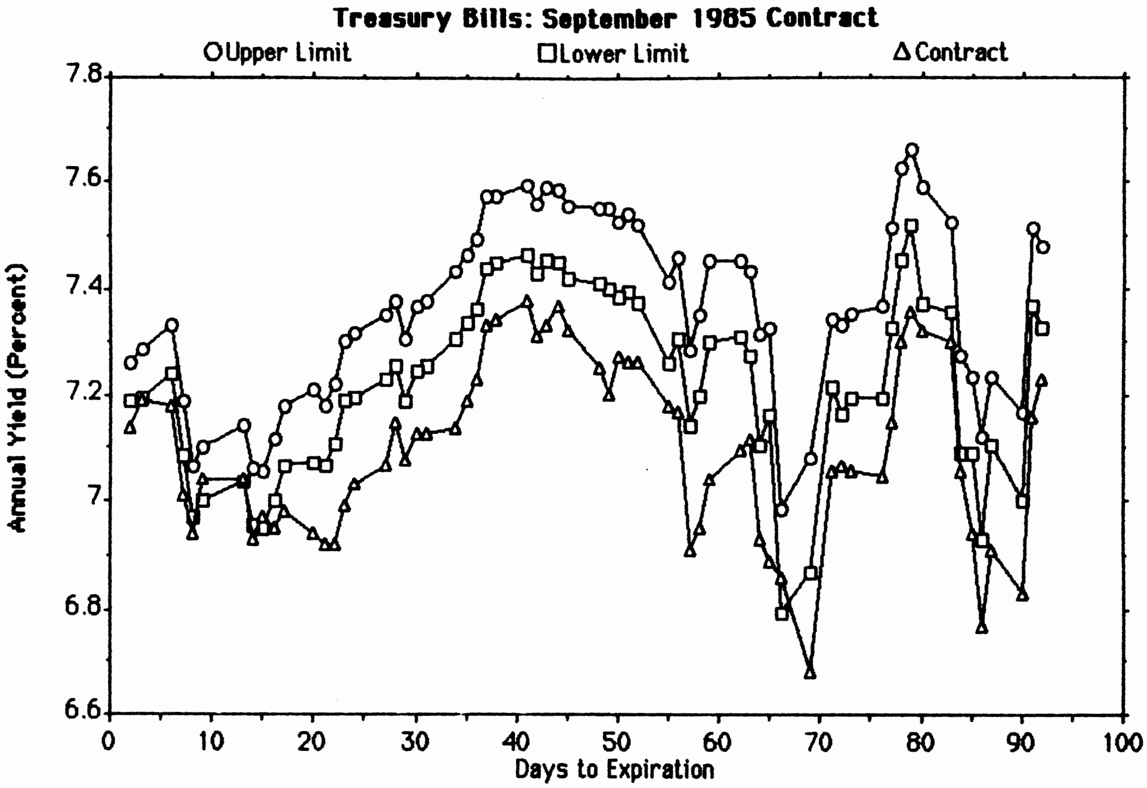
Treasury Bills: June 1984 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
Days to Expiration

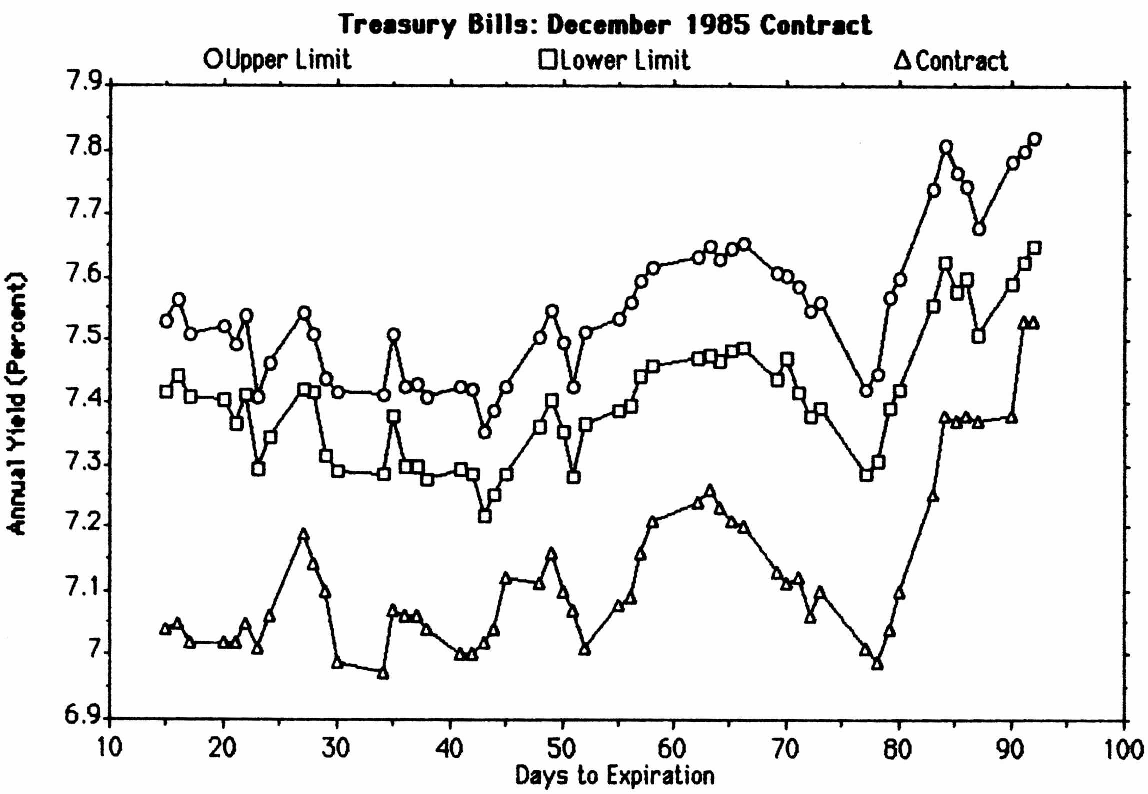

Treasury Bills: September 1984 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
10
0
10
20
30
40
50
60
70
80
90
100


Treasury Bills: December 1984 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
Days to Expiration
11.5
11
10.5
10
9.5
9
8.5
8
0
10
20
30
40
50
60
70
80
90
100


Treasury Bills: March 1985 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
9
8.8
8.6
8.4
8.2
8
7.8
7.6
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration


Treasury Bills: June 1985 Contract
OUpper Limit
□Lower Limit
ΔContract
Annual Yield (Percent)
10
9.5
9
8.5
8
7.5
7
6.5
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration


Treasury Bills: September 1985 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
7.8
7.6
7.4
7.2
7
6.8
6.6
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration


Treasury Bills: December 1985 Contract
Upper Limit
Lower Limit
Contract
Annual Yield (Percent)
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
6.9
10
20
30
40
50
60
70
80
90
100
Days to Expiration

APPENDIX B

YIELD TO MATURITY USING CHICAGO BOARD OF TRADE (CBT) TREASURY NOTE CONTRACTS

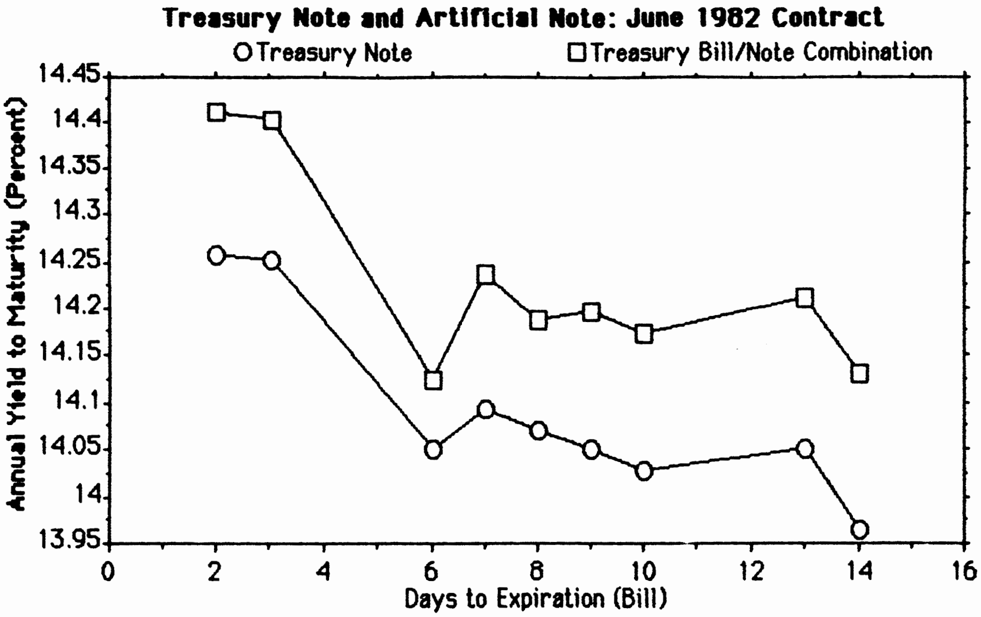
Prospective yield to maturity from outright purchase of a Treasury note (Treasury Note) versus prospective yield to maturity from purchase of a Treasury bill and Treasury note contract, with acceptance of delivered note at contract expiration (Treasury Bill/Note Combination).

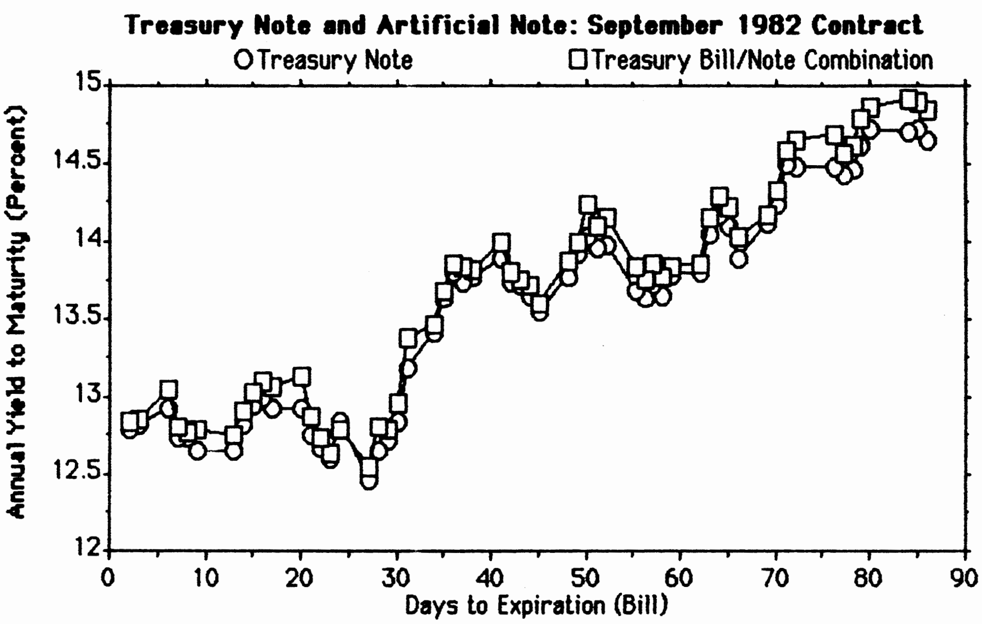
Sample Interval: Daily.

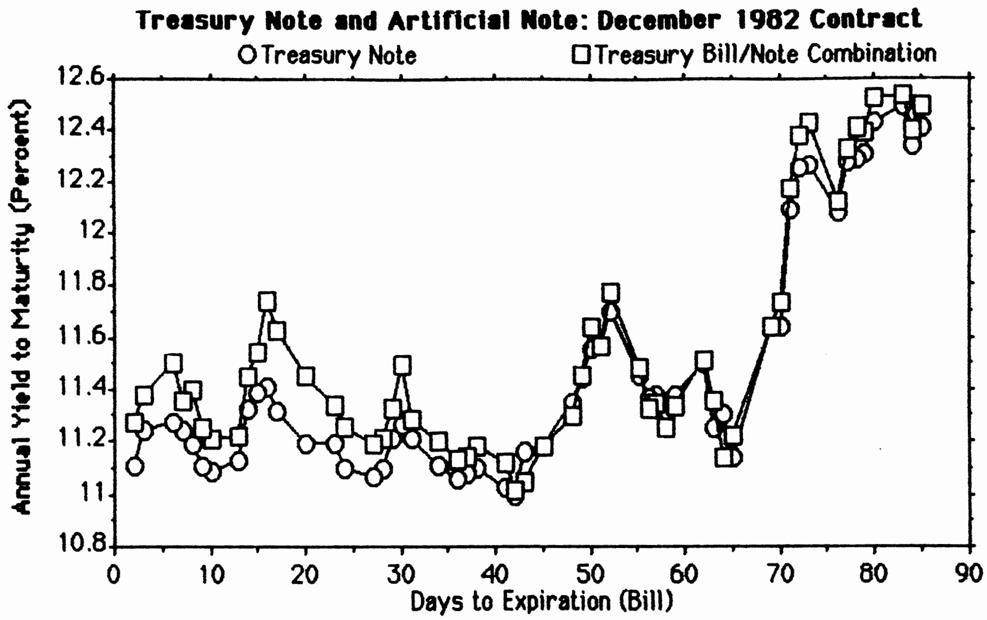
Sample Duration: June, 1982 contract through September, 1985 contract.

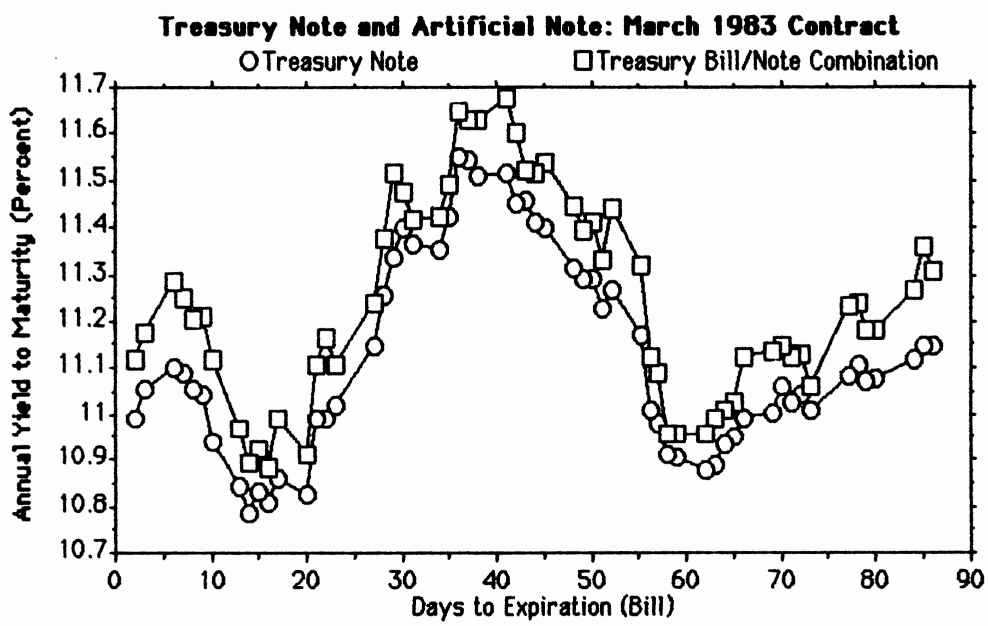
Source of Data:	Futures Contract:	Wall Street Journal.
	Treasury Bill:	Wall Street Journal.
	Treasury Note:	Wall Street Journal.

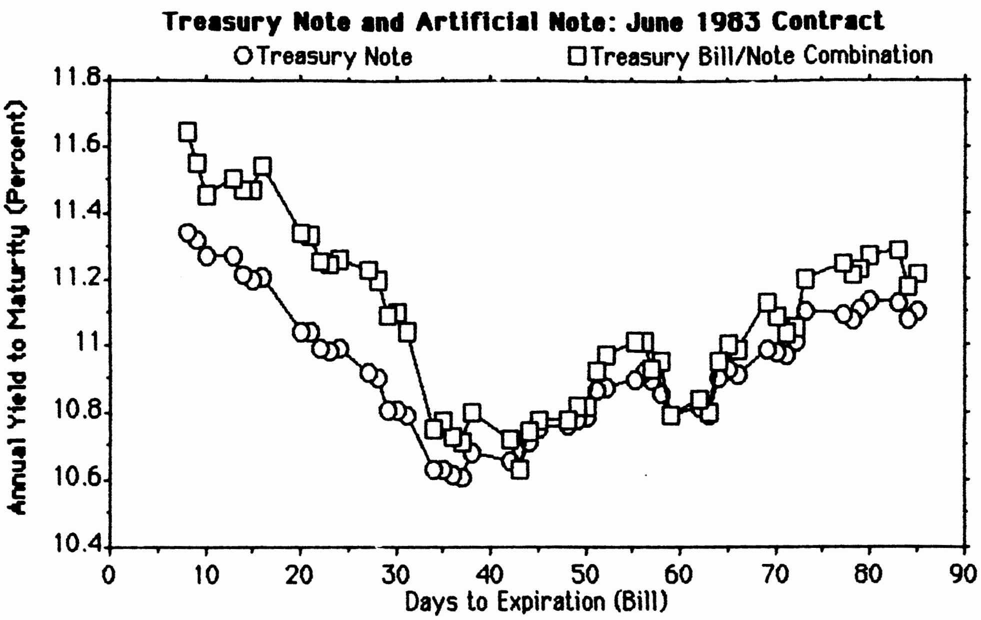
Description: Each chart in this appendix shows two values for each business day - the yield to maturity from outright purchase of a particular Treasury note (Treasury Note), and the yield to maturity from the purchase and maturation of a Treasury bill and delivery of a note via settlement of a Treasury note futures contract (Treasury Bill/Note Combination). Yields are approximate, and are calculated using Stigum's method [see Stigum (1981; 136-139)]. The latter yield assumes payment of required commission ($60) and subtraction of the opportunity cost of margin posted to the account ($1,500) while the contract is in force. The two yields are equivalent to the yields from Strategy II and Strategy IIA, assuming that the note delivered in contract fulfillment is the same note to be held outright. In general, the delivered note, and thus the Strategy IIA yield, will not be the same, since it is not cheapest-to-deliver (See Table 3, Section II). Therefore the yields are only approximately comparable. In all cases, the Treasury note used to create the charts is the February, 1992 14 5/8% note.

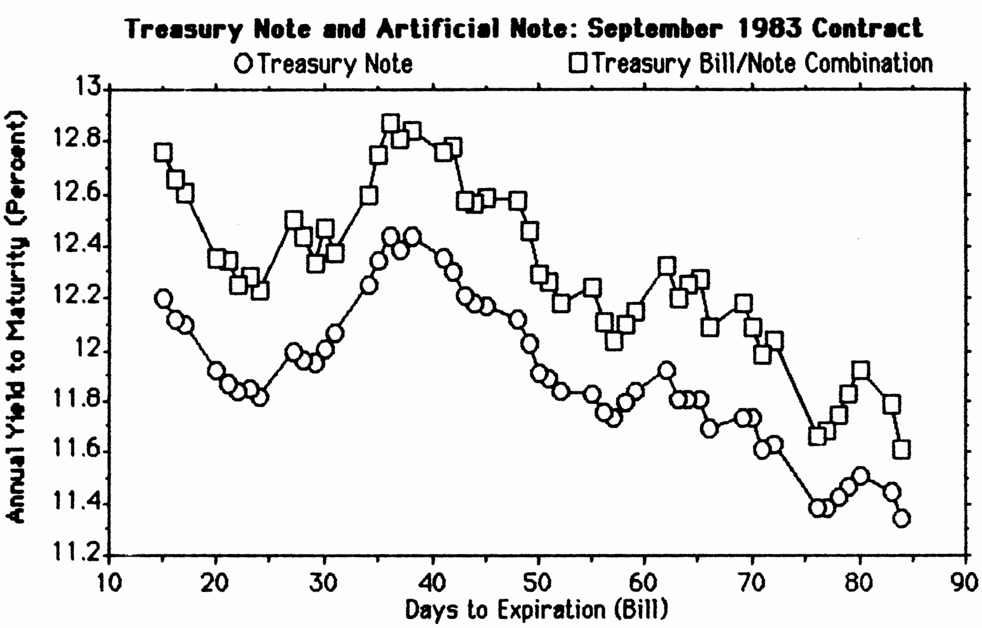

Treasury Note and Artificial Note: June 1982 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
14.45
14.4
14.35
14.3
14.25
14.2
14.15
14.1
14.05
14
13.95
0
2
4
6
8
10
12
14
16
Days to Expiration (Bill)

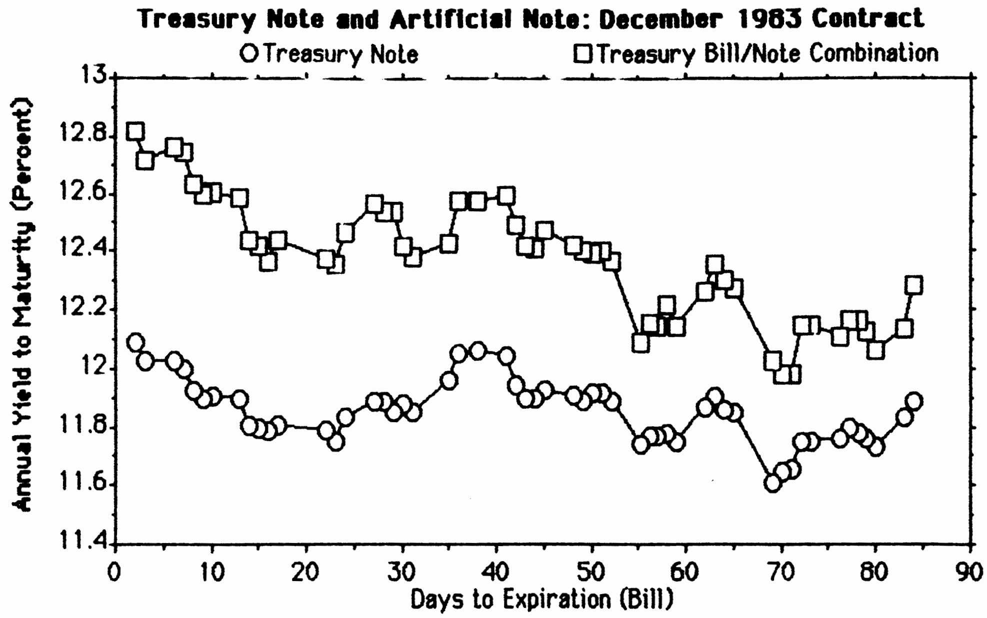

Treasury Note and Artificial Note: September 1982 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
15
14.5
14
13.5
13
12.5
12
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)


Treasury Note and Artificial Note: December 1982 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10.8
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)

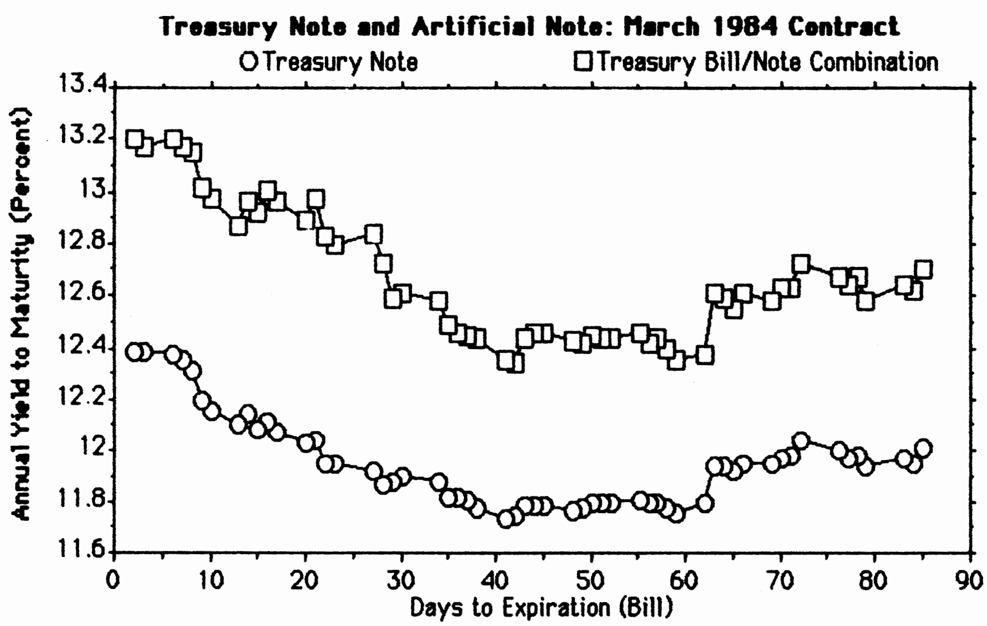

Treasury Note and Artificial Note: March 1983 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
11.7
11.6
11.5
11.4
11.3
11.2
11.1
11
10.9
10.8
10.7
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)


Treasury Note and Artificial Note: June 1983 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)

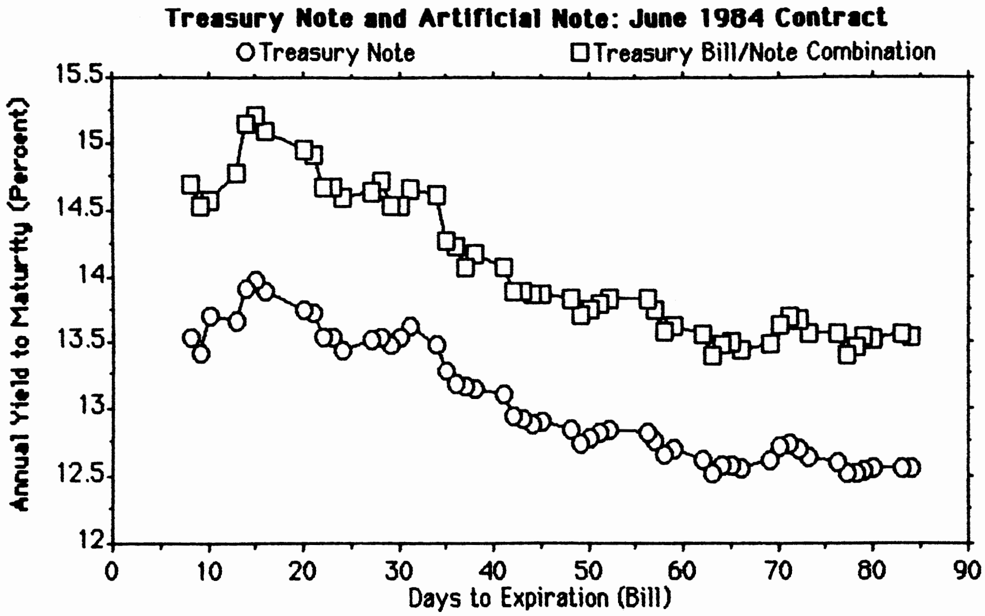

Treasury Note and Artificial Note: September 1983 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
13
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)

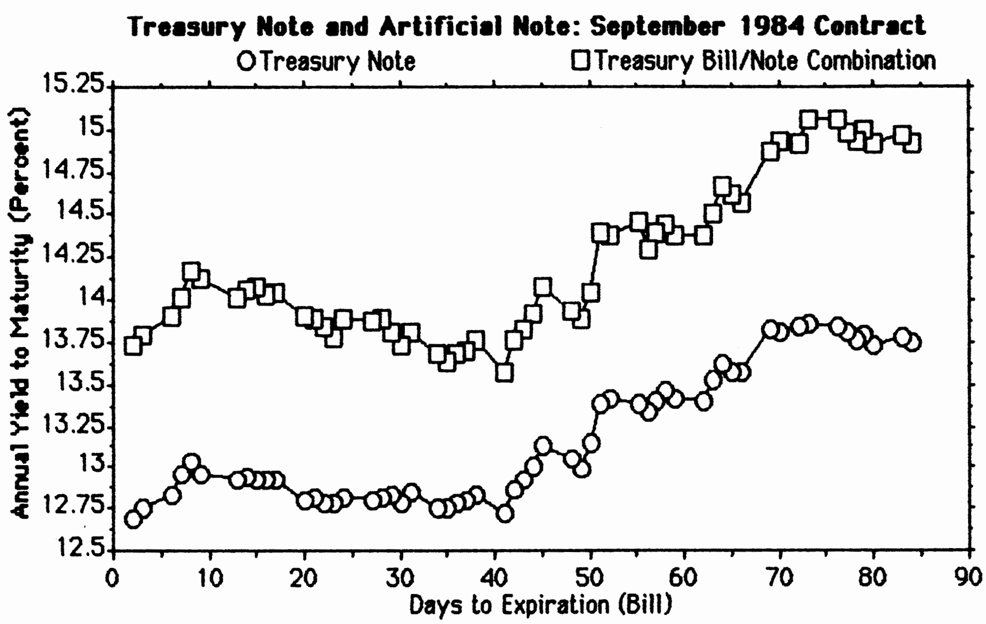


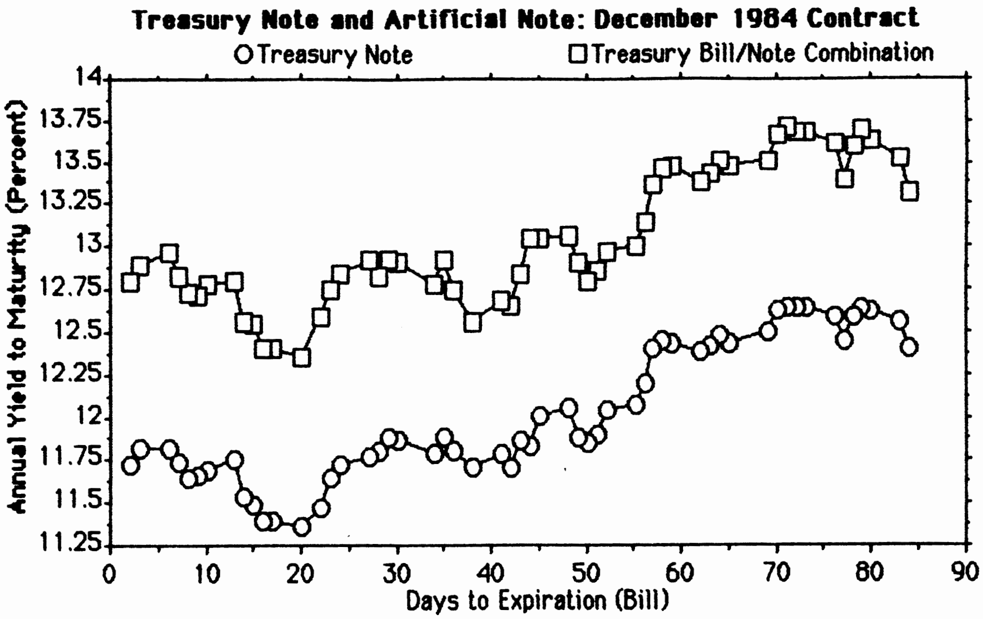
Treasury Note and Artificial Note: December 1983 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
Days to Expiration (Bill)
13
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
0
10
20
30
40
50
60
70
80
90



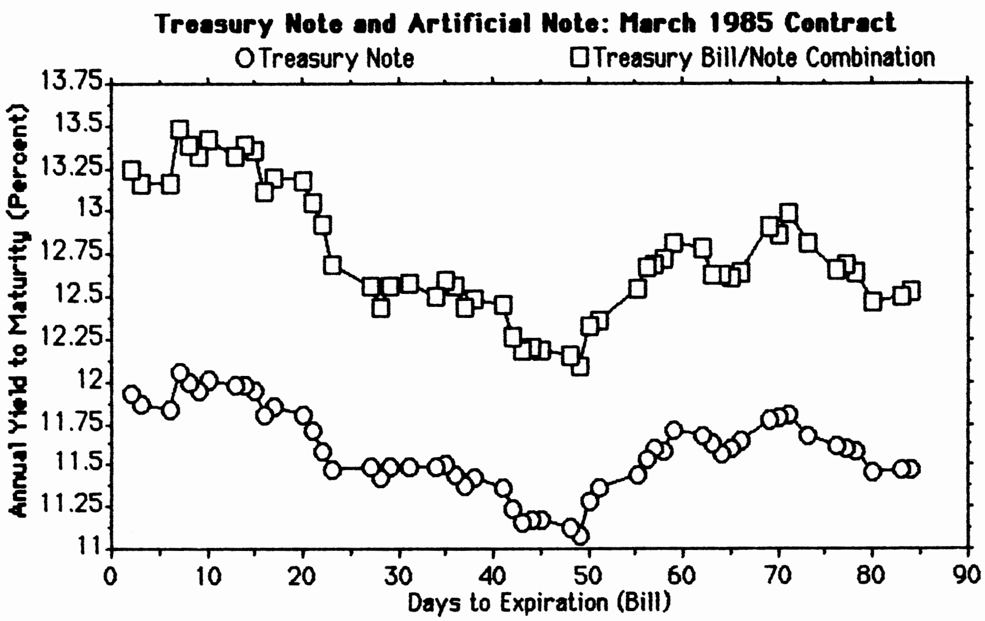
Treasury Note and Artificial Note: March 1984 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
Days to Expiration (Bill)
13.4
13.2
13
12.8
12.6
12.4
12.2
12
11.8
11.6
0
10
20
30
40
50
60
70
80
90


Treasury Note and Artificial Note: June 1984 Contract
O Treasury Note
□ Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
15.5
15
14.5
14
13.5
13
12.5
12
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)

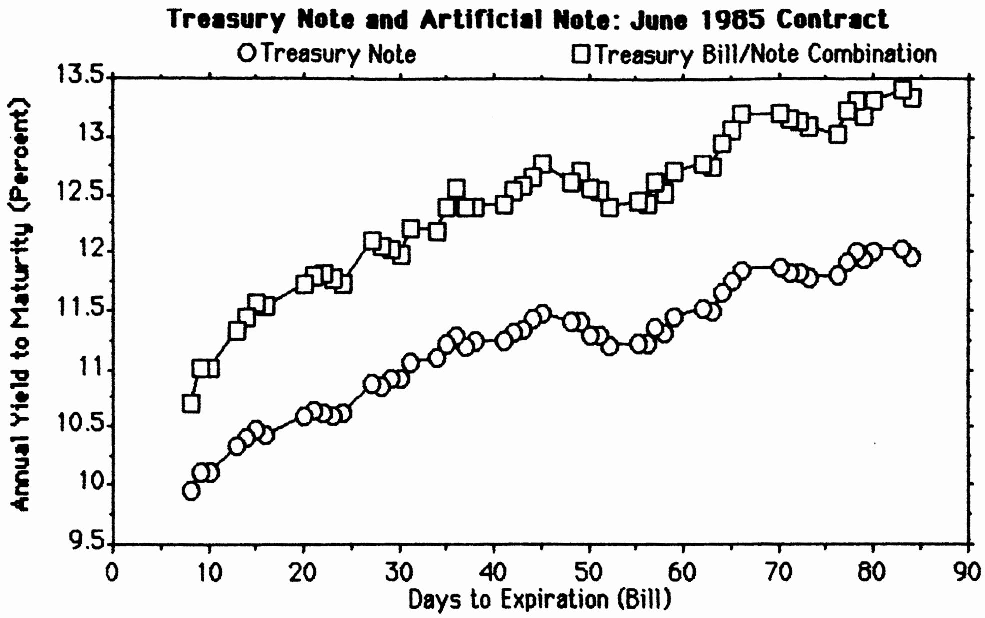

Treasury Note and Artificial Note: September 1984 Contract
O Treasury Note
□ Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
15.25
15
14.75
14.5
14.25
14
13.75
13.5
13.25
13
12.75
12.5
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)

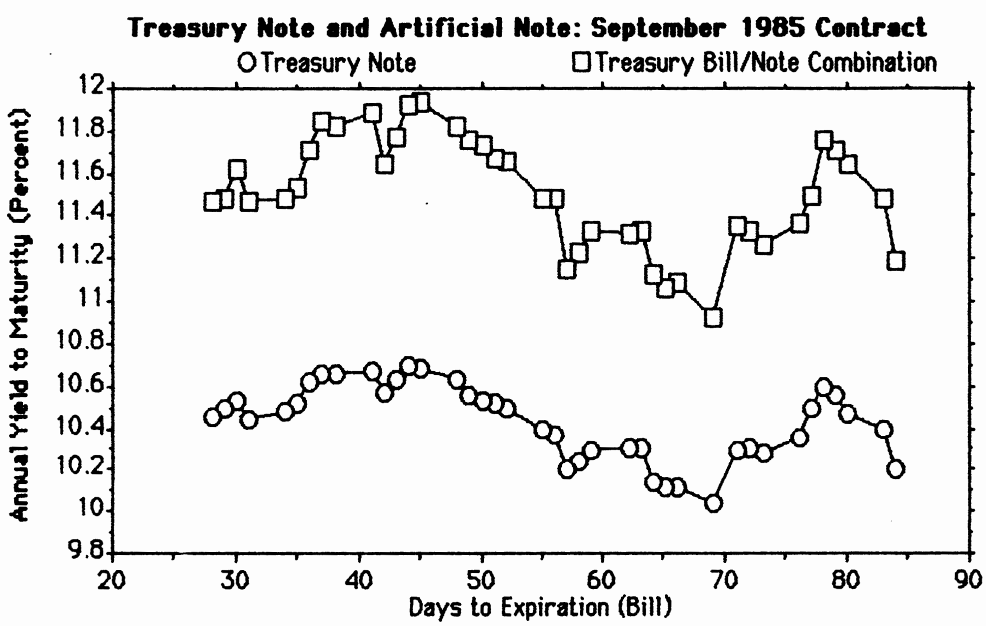


Treasury Note and Artificial Note: December 1984 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
14
13.75
13.5
13.25
13
12.75
12.5
12.25
12
11.75
11.5
11.25
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)



Treasury Note and Artificial Note: March 1985 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
13.75
13.5
13.25
13
12.75
12.5
12.25
12
11.75
11.5
11.25
11
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)


Treasury Note and Artificial Note: June 1985 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
13.5
13
12.5
12
11.5
11
10.5
10
9.5
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)


Treasury Note and Artificial Note: September 1985 Contract
Treasury Note
Treasury Bill/Note Combination
Annual Yield to Maturity (Percent)
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
10
9.8
20
30
40
50
60
70
80
90
Days to Expiration (Bill)

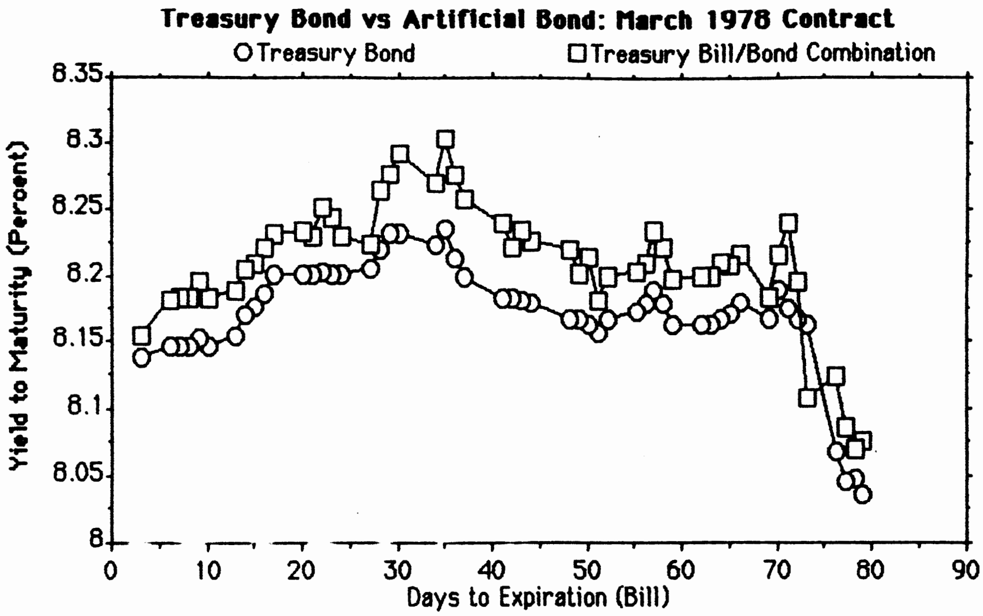
APPENDIX C

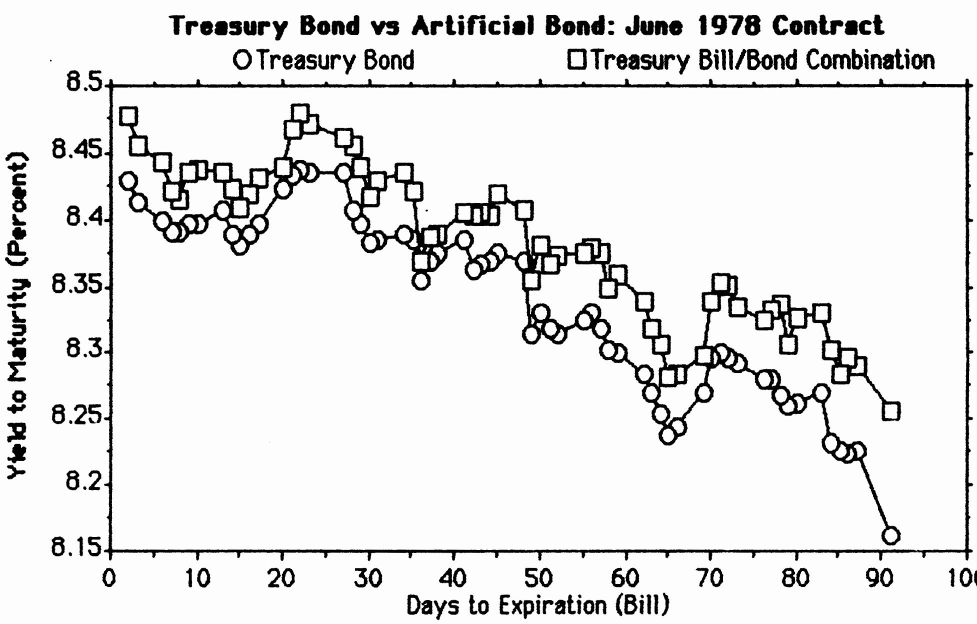
YIELD TO MATURITY USING CHICAGO BOARD OF TRADE (CBT) TREASURY BOND CONTRACTS

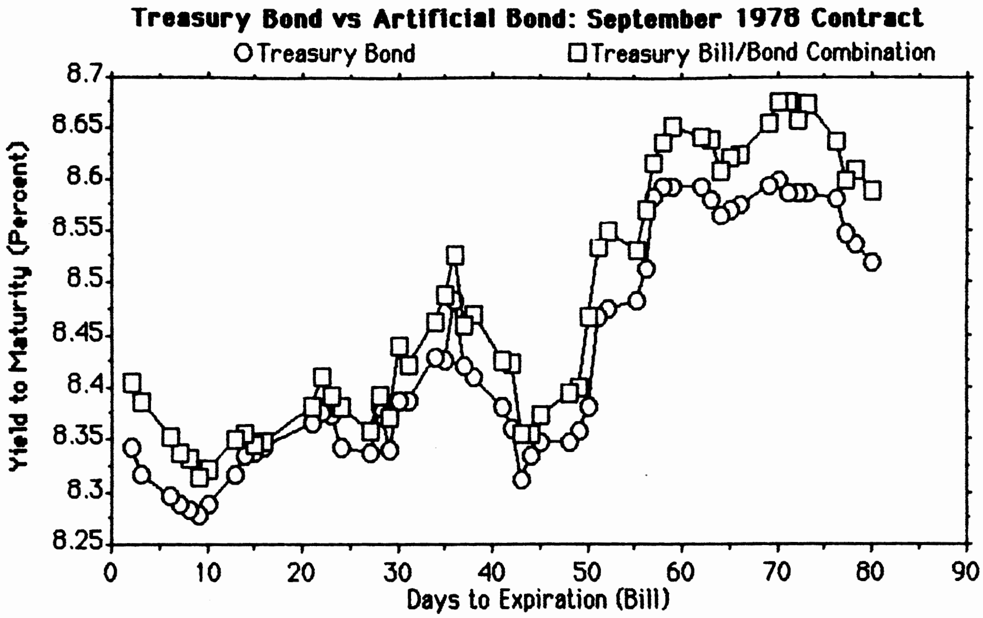
Prospective yield to maturity from outright purchase of a Treasury bond (Treasury Bond) versus purchase of a Treasury bill and Treasury bond contract, with acceptance of delivered bond at contract expiration (Treasury Bill/Bond Combination).

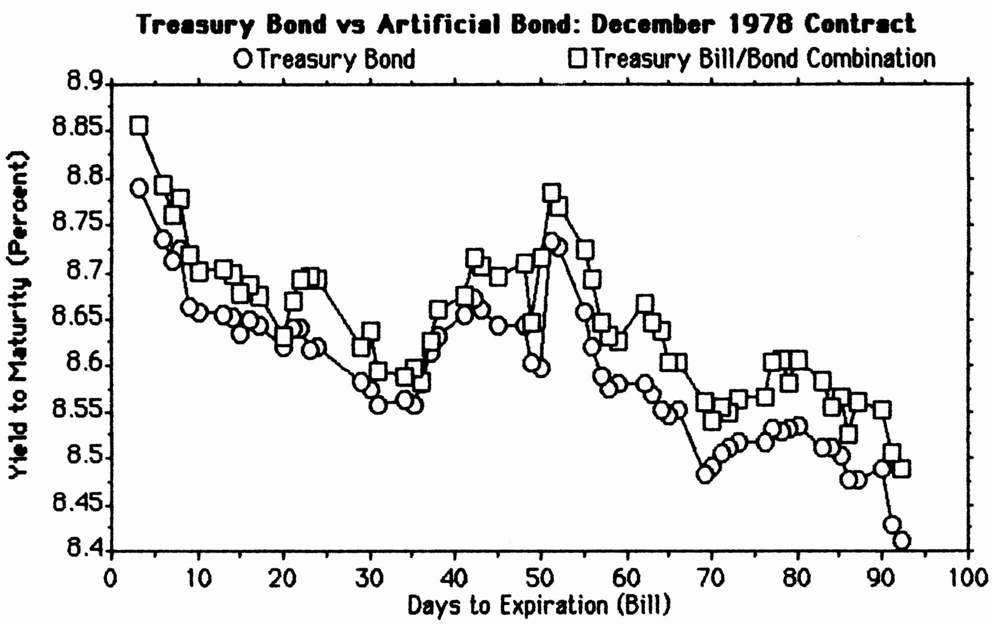
Sample Interval:	Daily.	
Sample Duration:	March, 1978 contract through June, 1981 contract.	
Source of Data:	Futures Contract:	Chicago Board of Trade.
	Treasury Bill:	Wall Street Journal.
	Treasury Bond:	Compuserve Information Services.

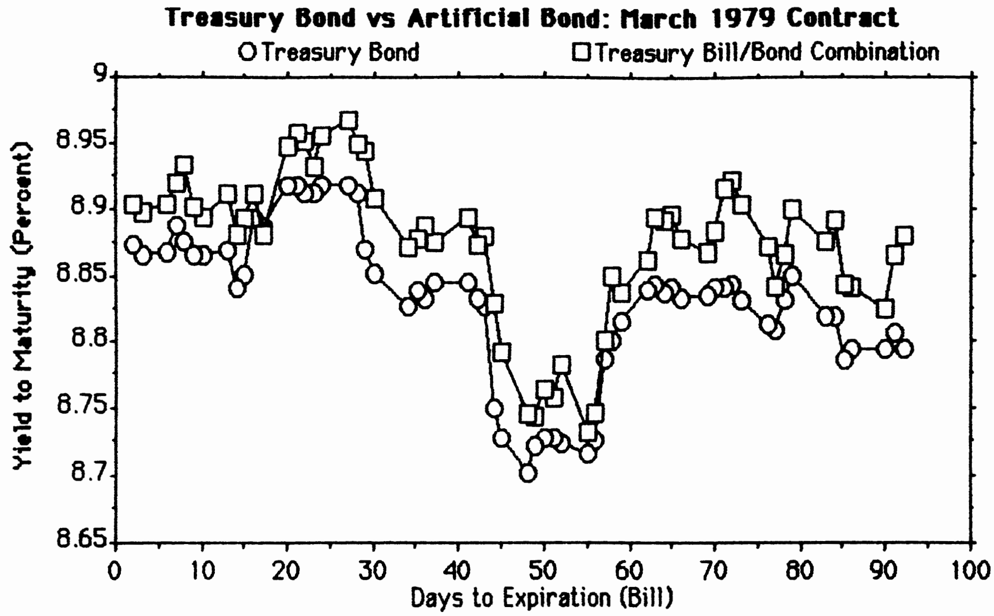
Description: Each chart in this appendix shows two values for each business day - the yield to maturity from outright purchase of a particular Treasury bond (Treasury Bond), and the yield to maturity from the purchase and maturation of a Treasury bill and a Treasury bond delivered in fulfillment of a bond future contract (Treasury Bill/Bond Combination). Yields are approximate, and are calculated using Stigum's method [see Stigum (1981; 136-139)]. The latter yield assumes payment of required commission ($60) and subtraction of the opportunity cost of margin posted to the account ($1,500) while the contract is in force. The two yields are equivalent to the yields from Strategy II and Strategy IIA, assuming that the bond delivered in contract fulfillment is the same bond to be held outright. In general, the delivered bond, and thus the Strategy IIA yield, will not be the same, even if it is cheapest-to-deliver, and therefore the yields are only approximately comparable (See Table 2, Section II). In all cases, the Treasury bond used to create the charts is the August, 1996-2001 8% bond.

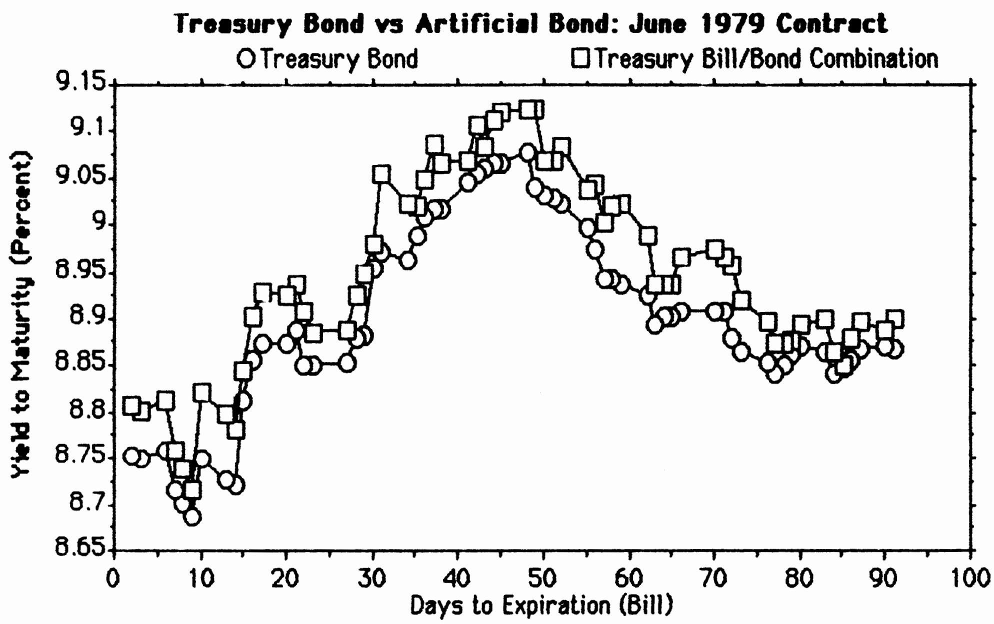

Treasury Bond vs Artificial Bond: March 1978 Contract
O Treasury Bond
□ Treasury Bill/Bond Combination
Yield to Maturity (Percent)
8.35
8.3
8.25
8.2
8.15
8.1
8.05
8
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)


Treasury Bond vs Artificial Bond: June 1978 Contract
O Treasury Bond
□ Treasury Bill/Bond Combination
Yield to Maturity (Percent)
8.5
8.45
8.4
8.35
8.3
8.25
8.2
8.15
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)

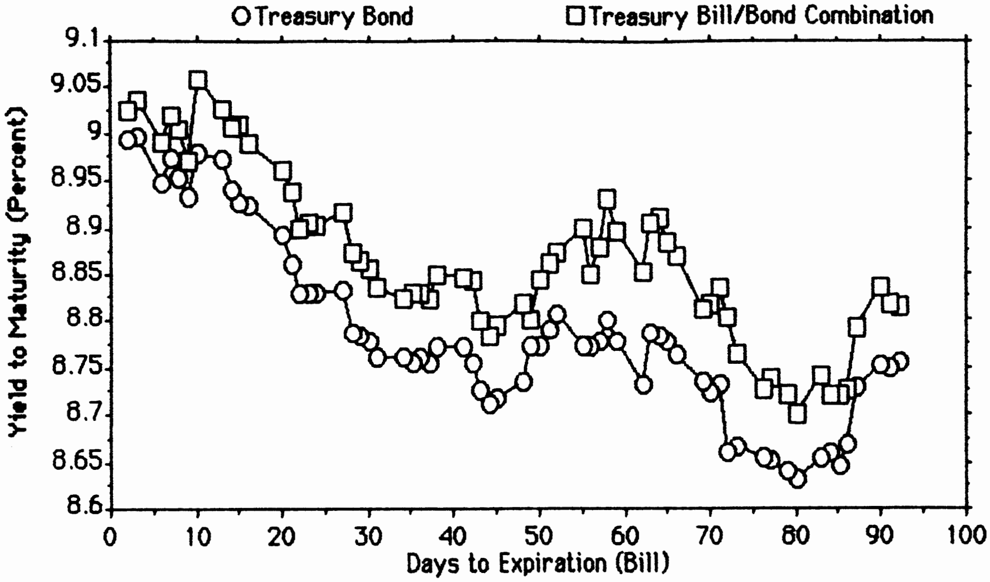

Treasury Bond vs Artificial Bond: September 1978 Contract
Treasury Bond
Treasury Bill/Bond Combination
Yield to Maturity (Percent)
8.7
8.65
8.6
8.55
8.5
8.45
8.4
8.35
8.3
8.25
0
10
20
30
40
50
60
70
80
90
Days to Expiration (Bill)


Treasury Bond vs Artificial Bond: December 1978 Contract
Treasury Bond
Treasury Bill/Bond Combination
Yield to Maturity (Percent)
8.9
8.85
8.8
8.75
8.7
8.65
8.6
8.55
8.5
8.45
8.4
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)

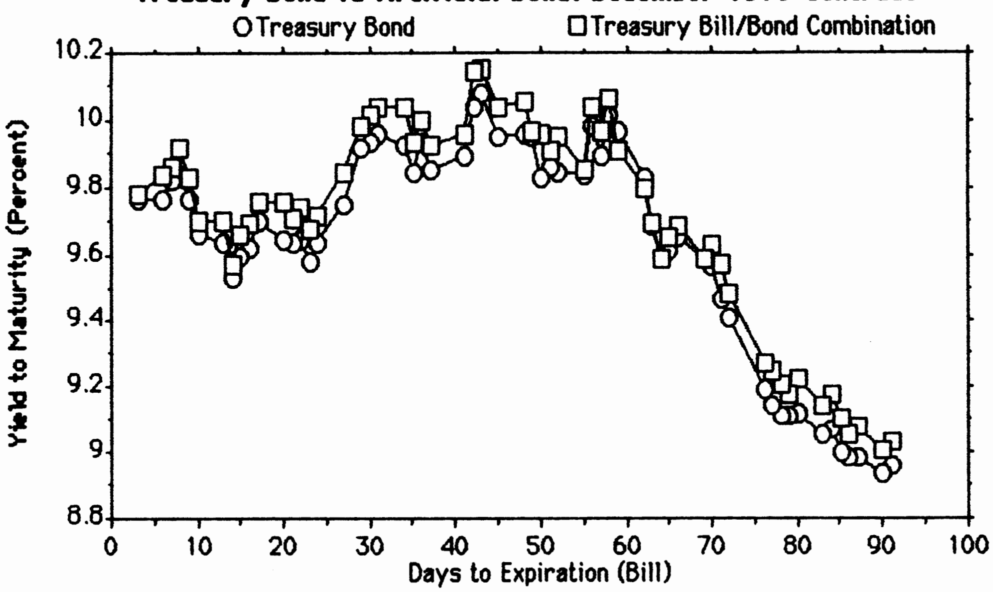

Treasury Bond vs Artificial Bond: March 1979 Contract
Treasury Bond
Treasury Bill/Bond Combination
Yield to Maturity (Percent)
9
8.95
8.9
8.85
8.8
8.75
8.7
8.65
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)

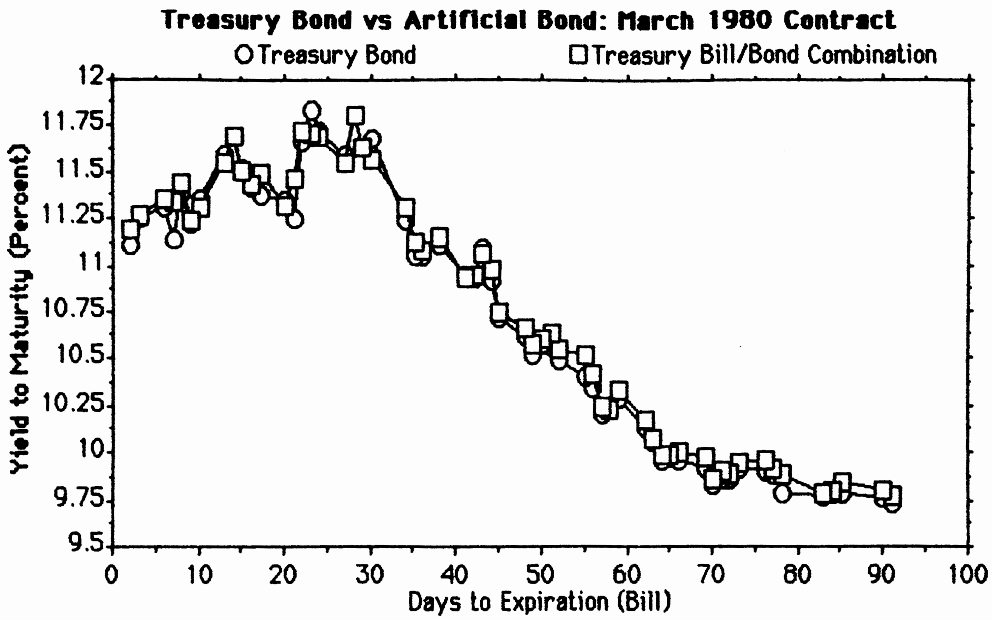

Treasury Bond vs Artificial Bond: June 1979 Contract
Treasury Bond
Treasury Bill/Bond Combination
Yield to Maturity (Percent)
9.15
9.1
9.05
9
8.95
8.9
8.85
8.8
8.75
8.7
8.65
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)

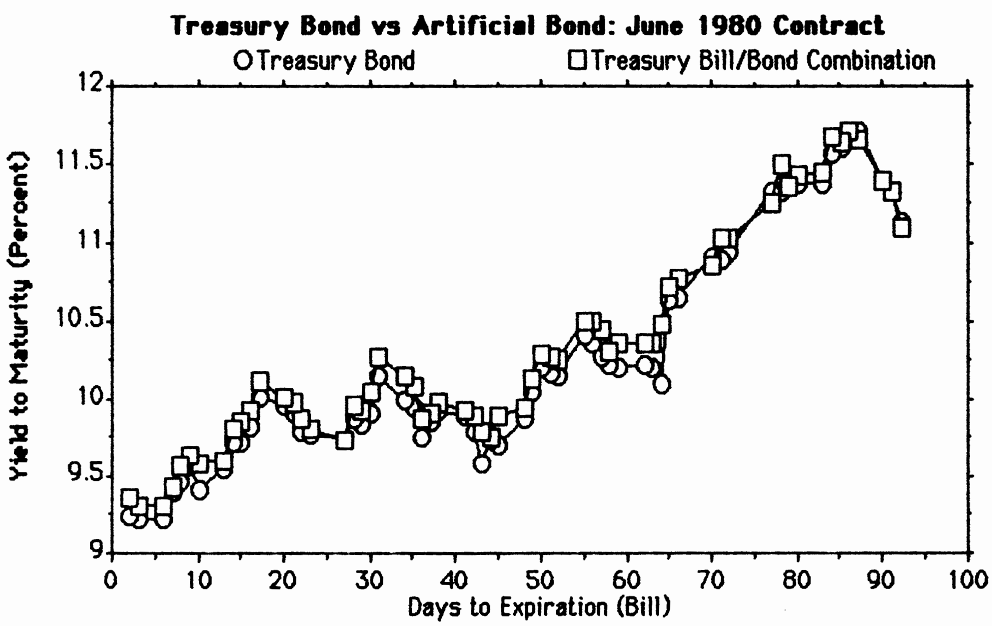
Treasury Bond vs Artificial Bond: September 1979 Contract

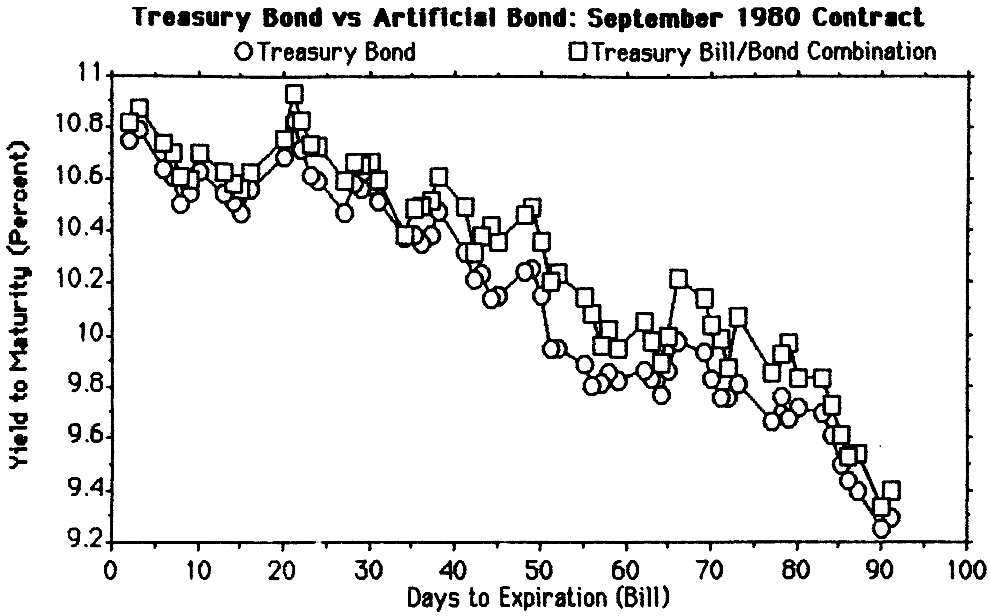


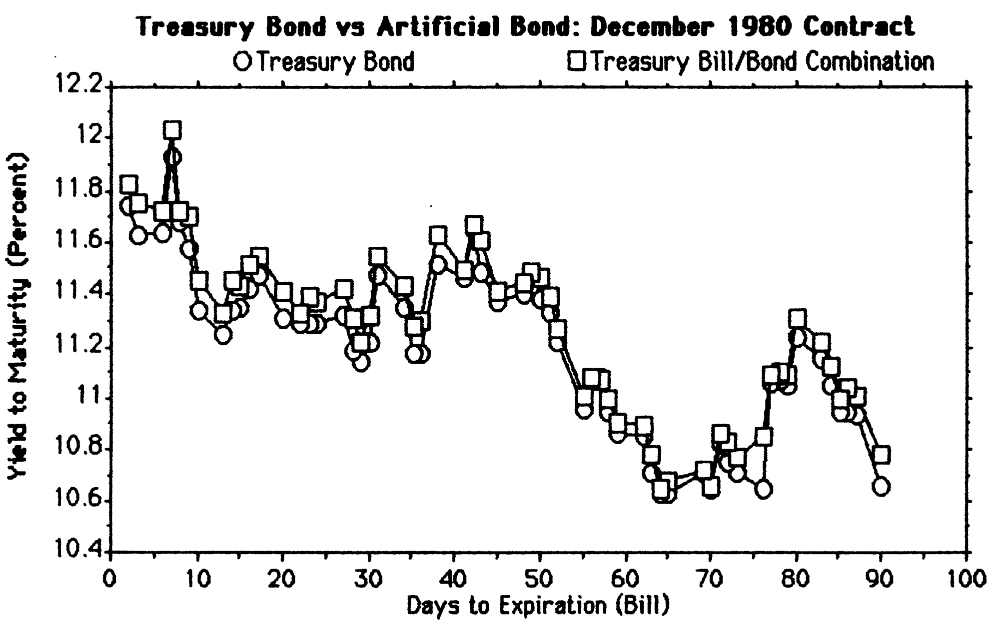
Treasury Bond vs Artificial Bond: December 1979 Contract

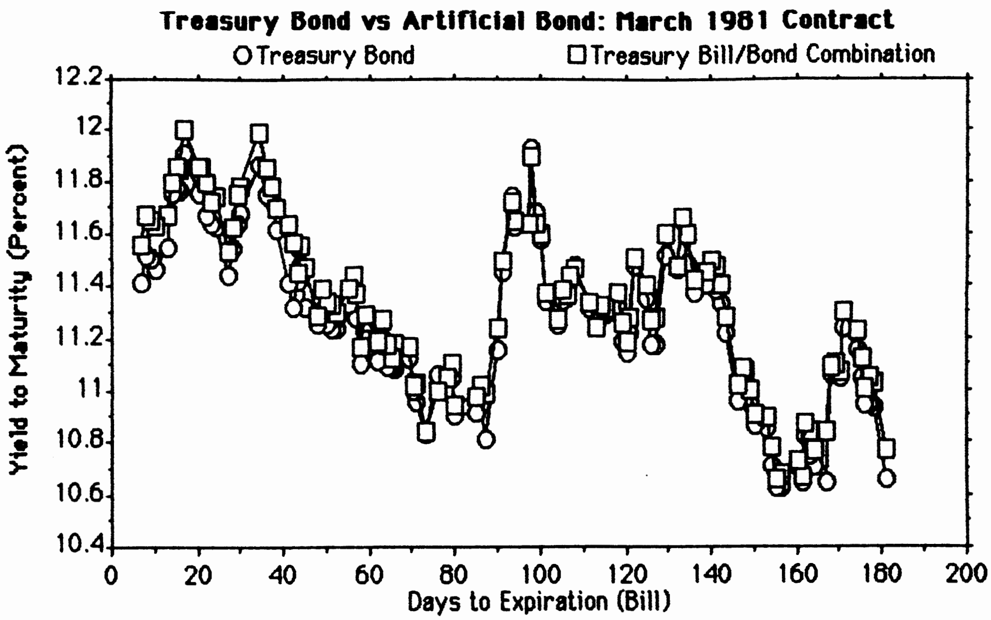


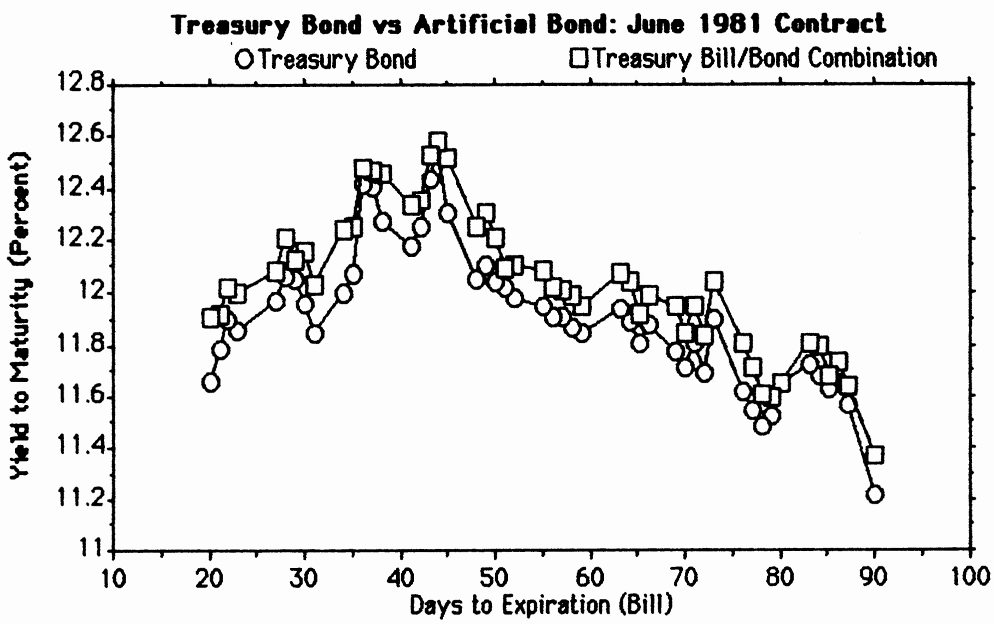

Treasury Bond vs Artificial Bond: March 1980 Contract
Treasury Bond
Treasury Bill/Bond Combination
Yield to Maturity (Percent)
12
11.75
11.5
11.25
11
10.75
10.5
10.25
10
9.75
9.5
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)


Treasury Bond vs Artificial Bond: June 1980 Contract
Treasury Bond
Treasury Bill/Bond Combination
Yield to Maturity (Percent)
12
11.5
11
10.5
10
9.5
9
0
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)


Treasury Bond vs Artificial Bond: September 1980 Contract
O Treasury Bond
□ Treasury Bill/Bond Combination
Yield to Maturity (Percent)
Days to Expiration (Bill)
11
10.8
10.6
10.4
10.2
10
9.8
9.6
9.4
9.2
0
10
20
30
40
50
60
70
80
90
100


Treasury Bond vs Artificial Bond: December 1980 Contract
O Treasury Bond
□ Treasury Bill/Bond Combination
Yield to Maturity (Percent)
Days to Expiration (Bill)
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
0
10
20
30
40
50
60
70
80
90
100


Treasury Bond vs Artificial Bond: March 1981 Contract
O Treasury Bond
□ Treasury Bill/Bond Combination
Yield to Maturity (Percent)
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
0
20
40
60
80
100
120
140
160
180
200
Days to Expiration (Bill)


Treasury Bond vs Artificial Bond: June 1981 Contract
O Treasury Bond
□ Treasury Bill/Bond Combination
Yield to Maturity (Percent)
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10
20
30
40
50
60
70
80
90
100
Days to Expiration (Bill)

APPENDIX D

BOX CHARTS: YIELDS FROM STRATEGIES I AND IA

SETTLED EARLY: TREASURY BILL, NOTE

AND BOND CONTRACTS.

Actual yield, with settlement occurring after 21-day holding periods, from outright purchase of a Treasury bill (Bill Rate) versus purchase of a Treasury Instrument and short Treasury instrument contract position (Treasury Note Position and Bond Rate).

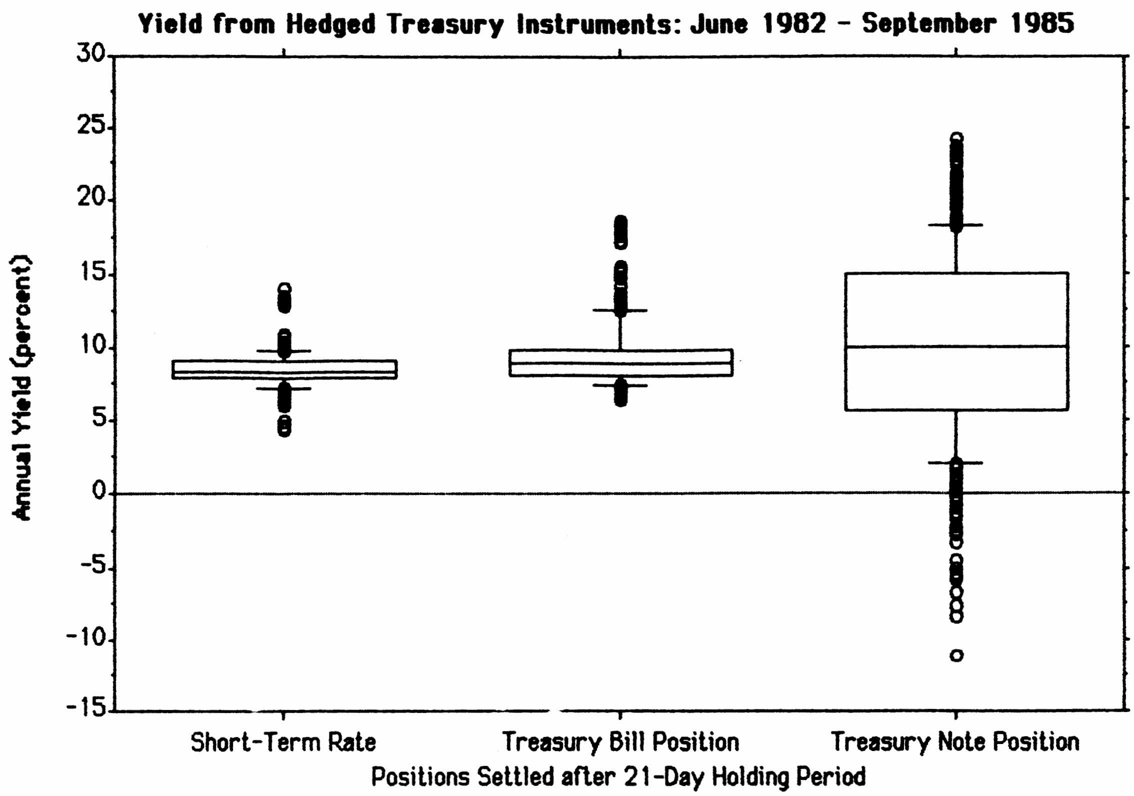
Sample Interval: Daily.

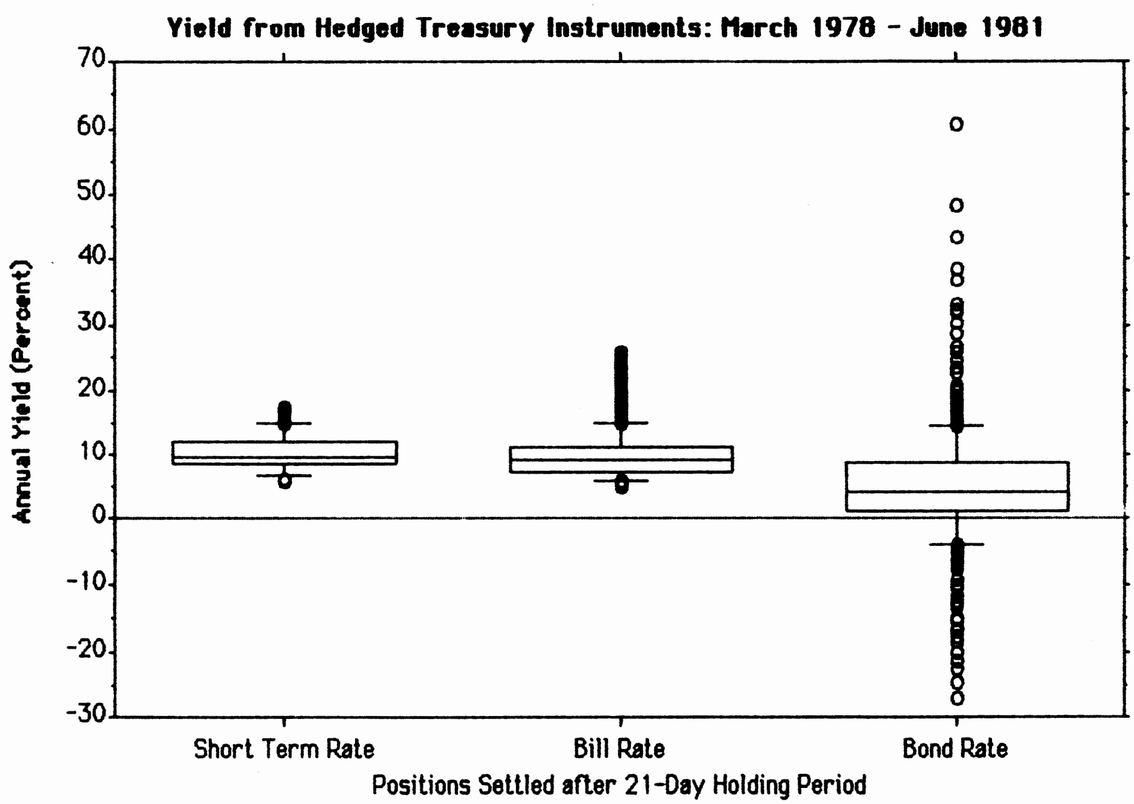
Sample Duration: June, 1982 contract through September, 1985 contract (note).
March, 1978 contract through June, 1981 contract (bond).

Source of Data: Futures Contracts: Chicago Board of Trade and Wall Street Journal.
Treasury Bill: Wall Street Journal.
Treasury Note: Wall Street Journal
Treasury Bond: Compuserve Information Services.

Description: The upper chart in this appendix shows summary data for actual annualized yield from two investment strategies: purchase of a deliverable Treasury bill and bill futures contract sale (Treasury Bill Position), and the simultaneous purchase of a Treasury note and sale of a matching futures contract (Treasury Note Position). The lower chart shows summary data from hedged purchase of a Treasury bill (Bill Rate), and the simultaneous purchase of a Treasury bond and sale of a matching futures contract (Bond Rate). The positions are assumed to be settled after holding periods of 21 days. In both charts, the current Treasury bill yield is also presented (Short Term Rate). Yields are calculated by dividing the actual dollar profit by the actual dollar cost, and annualizing by multiplying by the ratio of the number of days per year (365) to the number of days in the holding period. The holding period is 21 business days - approximately one calendar month. Costs include payment of commission ($60) and margin ($1,500) while the contract is in force. Margin is returned at settlement. The two yields are equivalent to the yields from Strategy I and Strategy IA, assuming early settlement (see Section II, Tables 1-3 in the text). The Treasury bond that is assumed to be purchased and held until settlement is the August, 1996-2001 8% bond. The Treasury note purchased is the February, 1992 14 5/8% note. Both instruments met the delivery requirements during the test periods. Neither instrument was cheapest-to-deliver. The Treasury bill purchased, however, was the unique instrument to be delivered in contract fulfillment.

In these box and whisker charts, the horizontal line in the center of the box represents the median, or 50th percentile. The top and bottom of the box represent the 75th and 25th percentile, so that 1/2 of all yields are within the box. The horizontal marks above and below the box - the whiskers - represent the 90th and 10th percentiles.


Yield from Hedged Treasury Instruments: June 1982 - September 1985
Annual Yield (percent)
30
25
20
15
10
5
0
-5
-10
-15
Short-Term Rate
Treasury Bill Position
Treasury Note Position
Positions Settled after 21-Day Holding Period


Yield from Hedged Treasury Instruments: March 1978 - June 1981
Annual Yield (Percent)
70
60
50
40
30
20
10
0
-10
-20
-30
Short Term Rate
Bill Rate
Bond Rate
Positions Settled after 21-Day Holding Period

APPENDIX E

YIELDS FROM STRATEGIES I AND IA

SETTLED EARLY: TREASURY

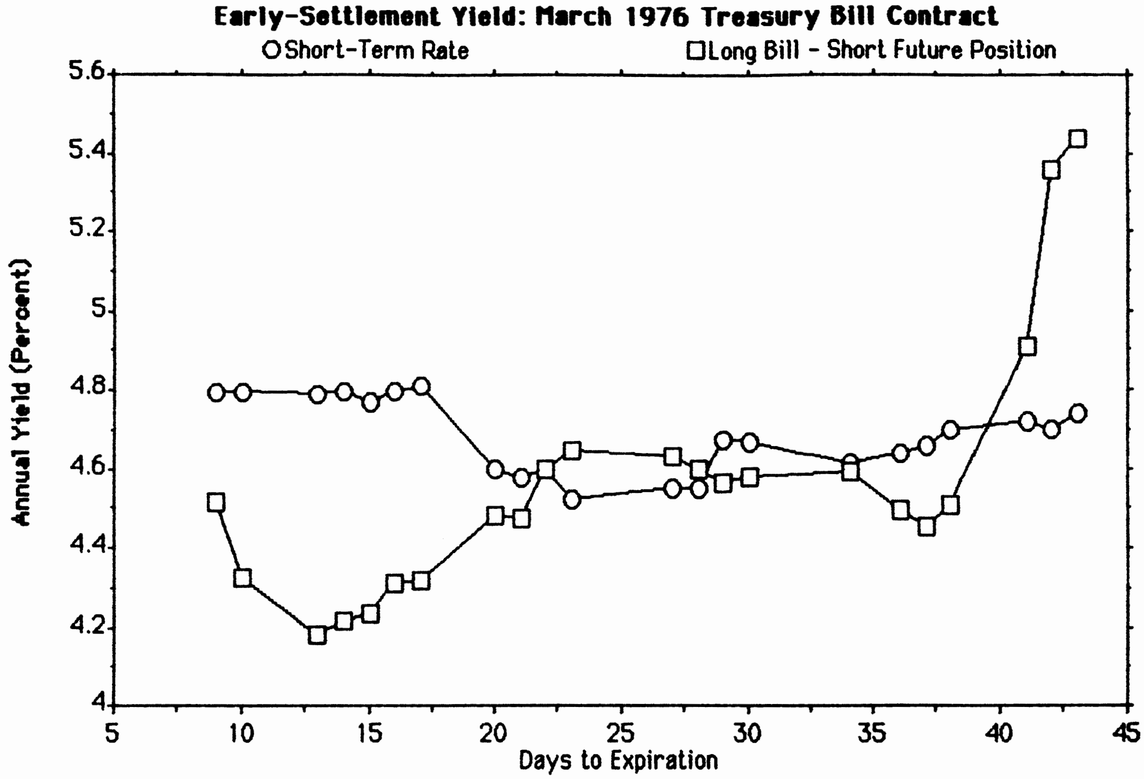
BILL CONTRACTS

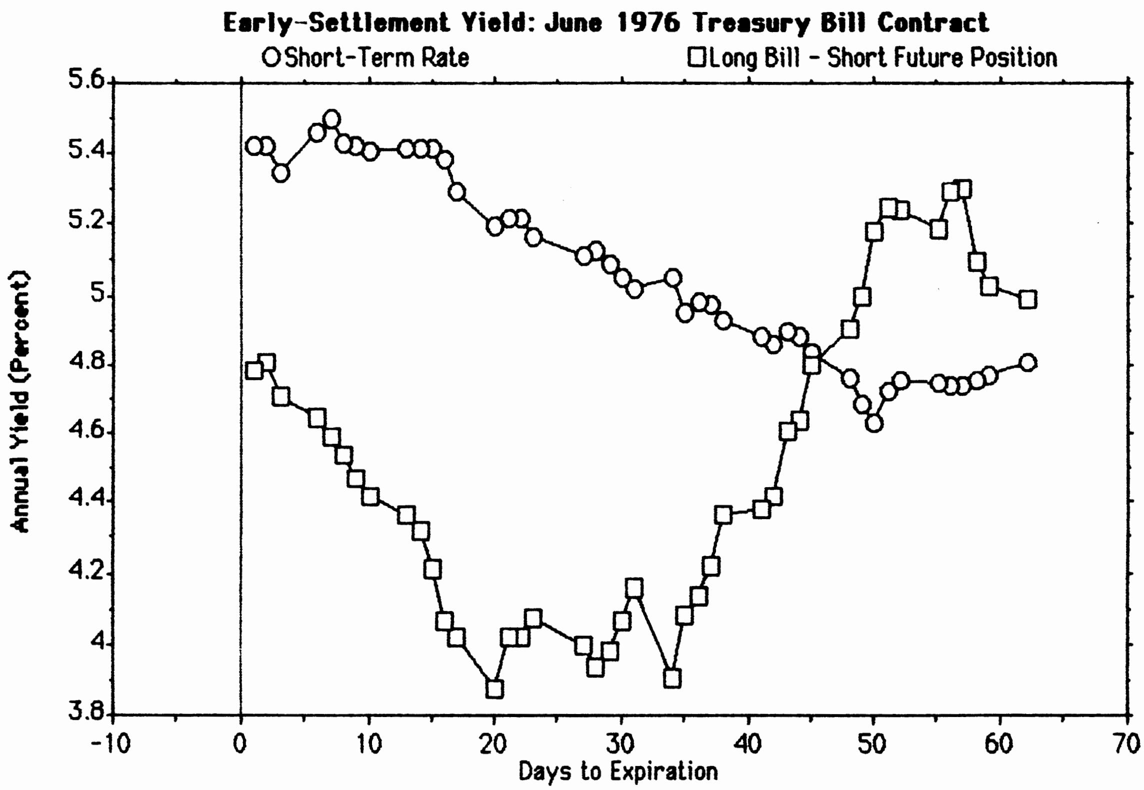
Prospective annual yield from outright purchase of a short term Treasury bill (Short-Term Rate), versus actual annual yield, with settlement occurring after 21-day holding periods, from purchase of a longer term Treasury bill and short Treasury bill contract position (Long Bill - Short Future Position).

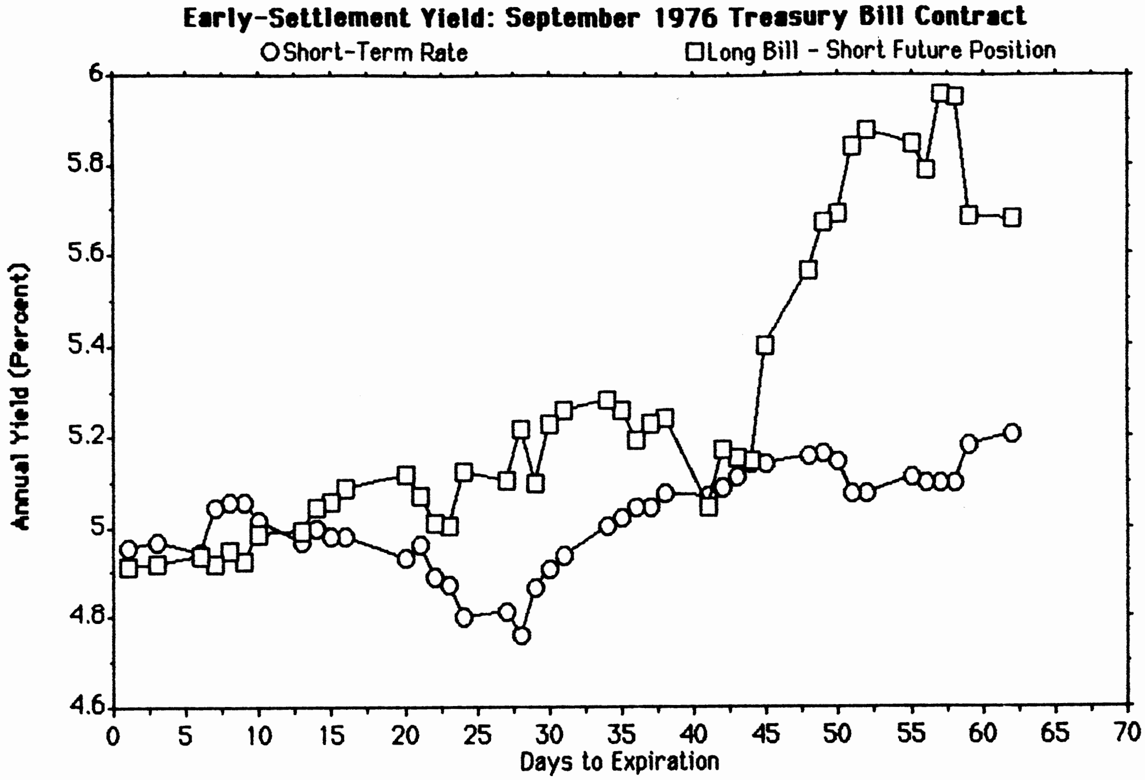
<u>Sample Interval</u>:	Daily.
<u>Sample Duration</u>:	March, 1976 contract through December, 1985 contract
<u>Source of Data</u>:	Futures Contracts: Wall Street Journal. Treasury Bill: Wall Street Journal.

<u>Description</u>: This appendix shows the annualized yield from two investment strategies: outright purchase and maturation of a Treasury bill (Short-Term Rate), and the simultaneous purchase of a deliverable Treasury bill and sale of a matching futures contract, settled after a holding period of 21 business days (Long Bill - Short Future Position). Yields are calculated by dividing the actual dollar profit by the actual dollar cost, and annualized by multiplying by the ratio of the number of days per year (365) to the number of days in the holding period. The holding period is 21 business days - approximately one calendar month. Costs include payment of commission ($60) and margin ($1,500) while the contract is in force. Margin is returned at settlement. The two yields are equivalent to the yields from Strategy I and Strategy IA, assuming early settlement of the futures position (see Section II, Tables 1-3 in the text). The Treasury bill

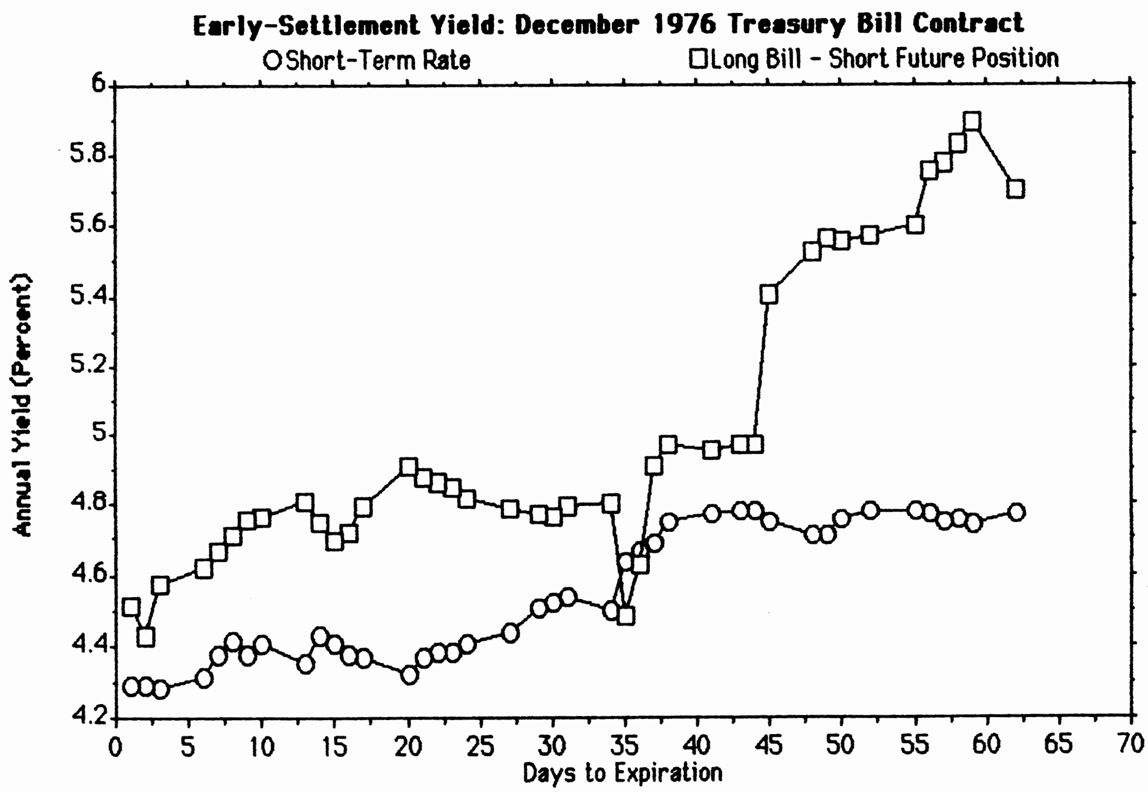
that is assumed to be purchased and held until settlement is the bill that is deliverable at contract expiration.


Early-Settlement Yield: March 1976 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
5
10
15
20
25
30
35
40
45

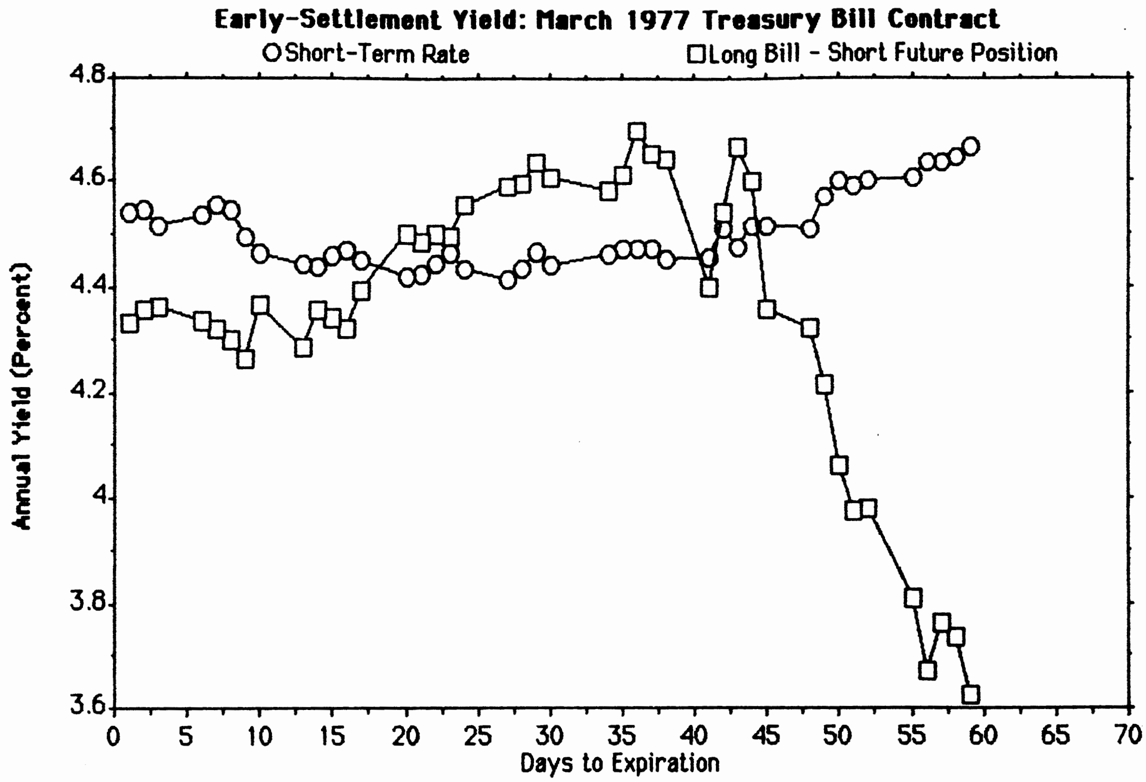

Early-Settlement Yield: June 1976 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
-10
0
10
20
30
40
50
60
70

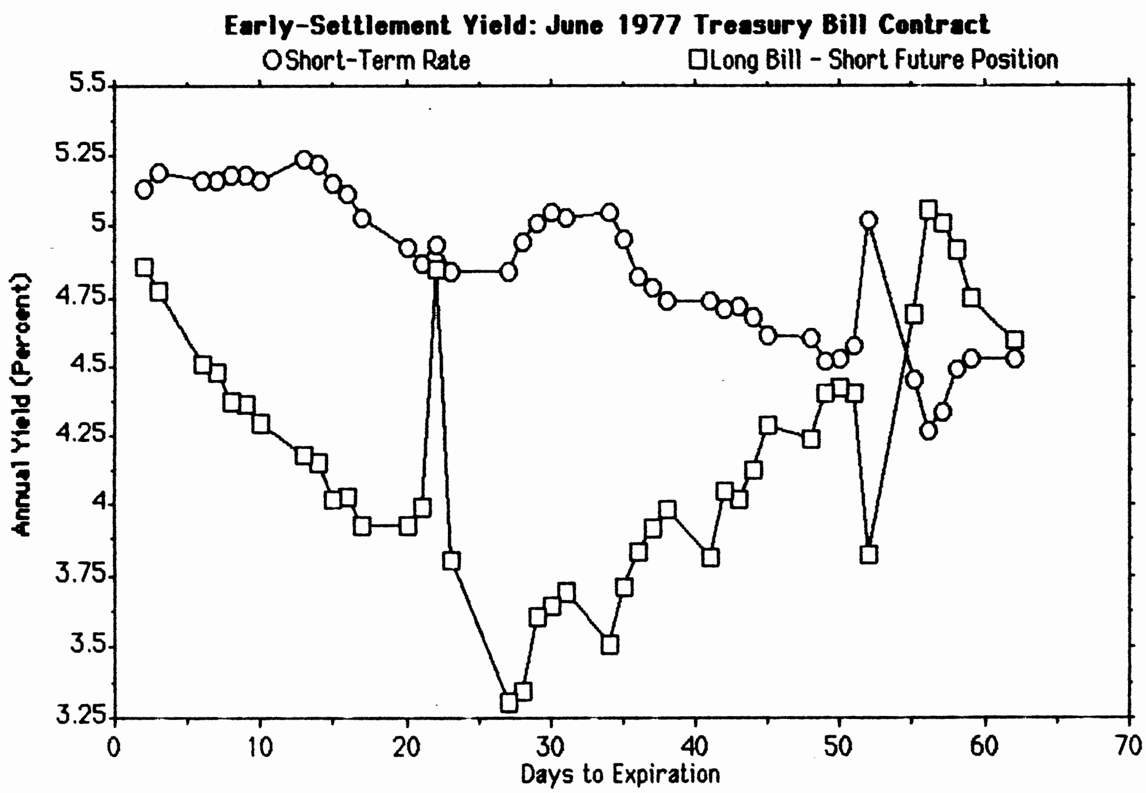


Early-Settlement Yield: September 1976 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

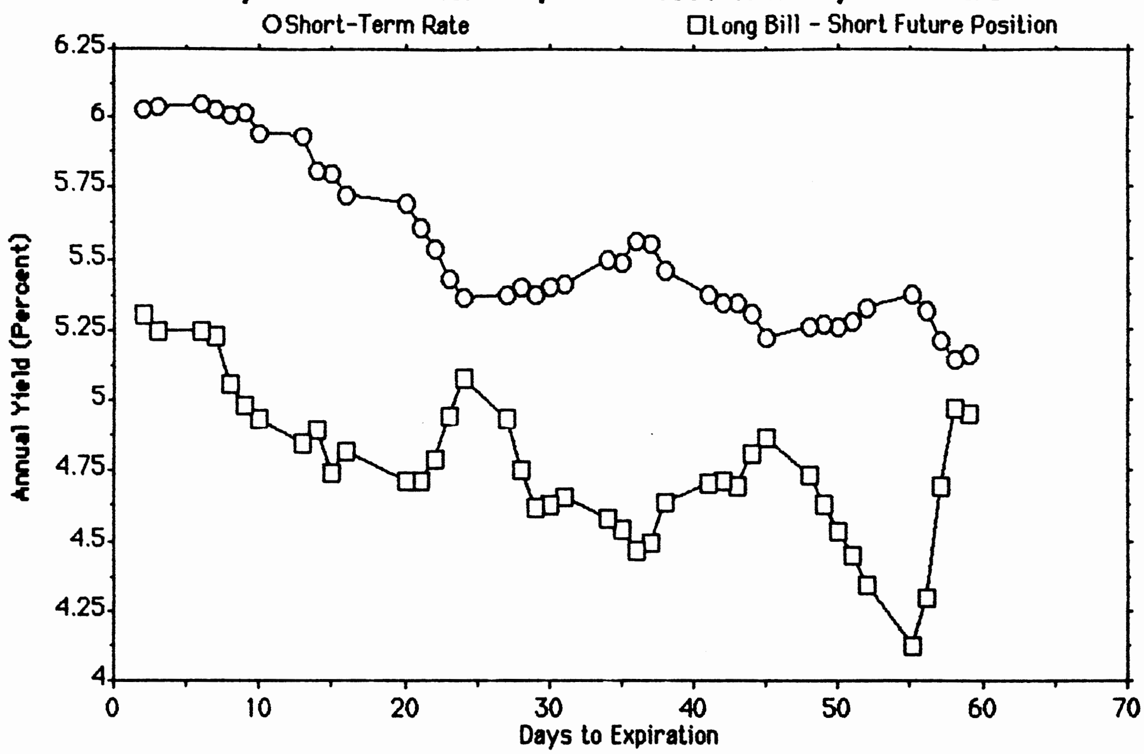


Early-Settlement Yield: December 1976 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

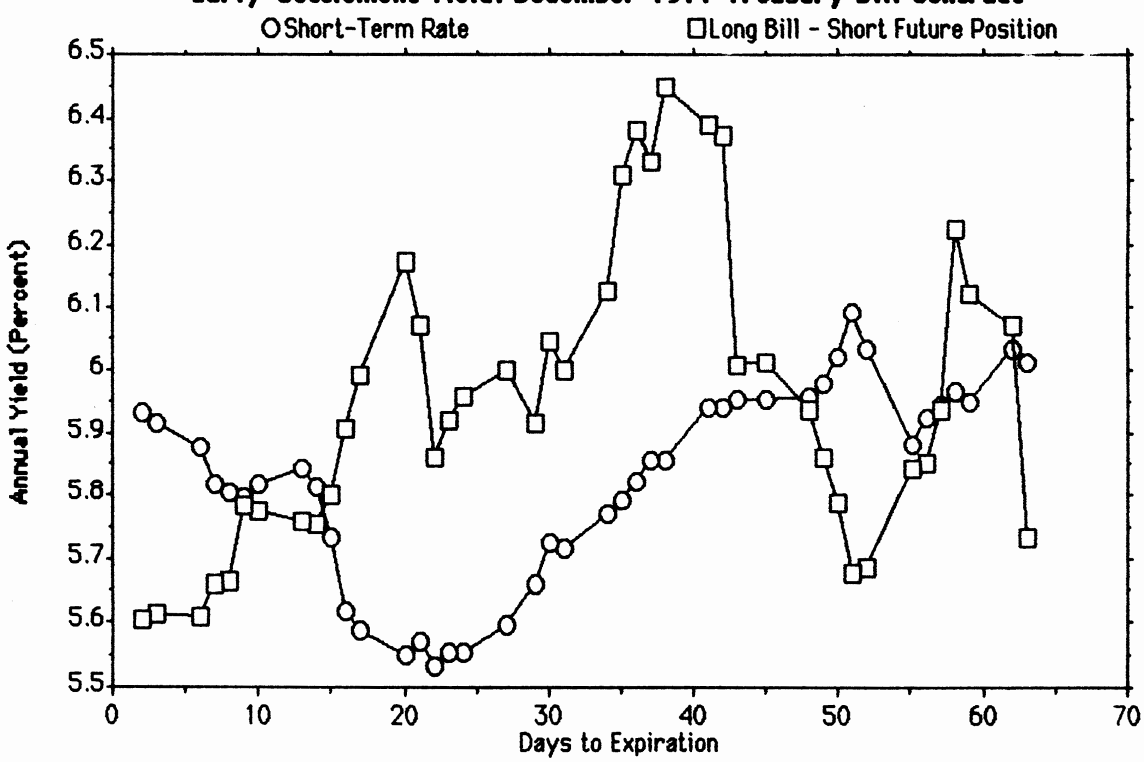

Early-Settlement Yield: March 1977 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

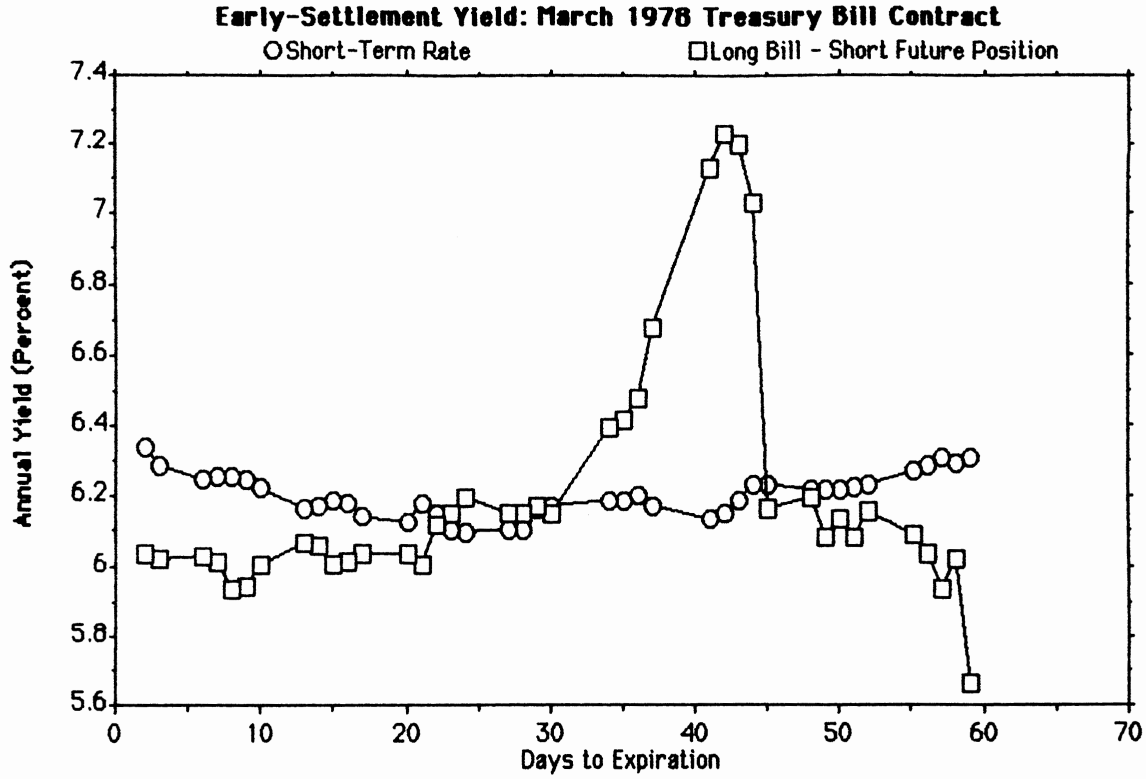

Early-Settlement Yield: June 1977 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

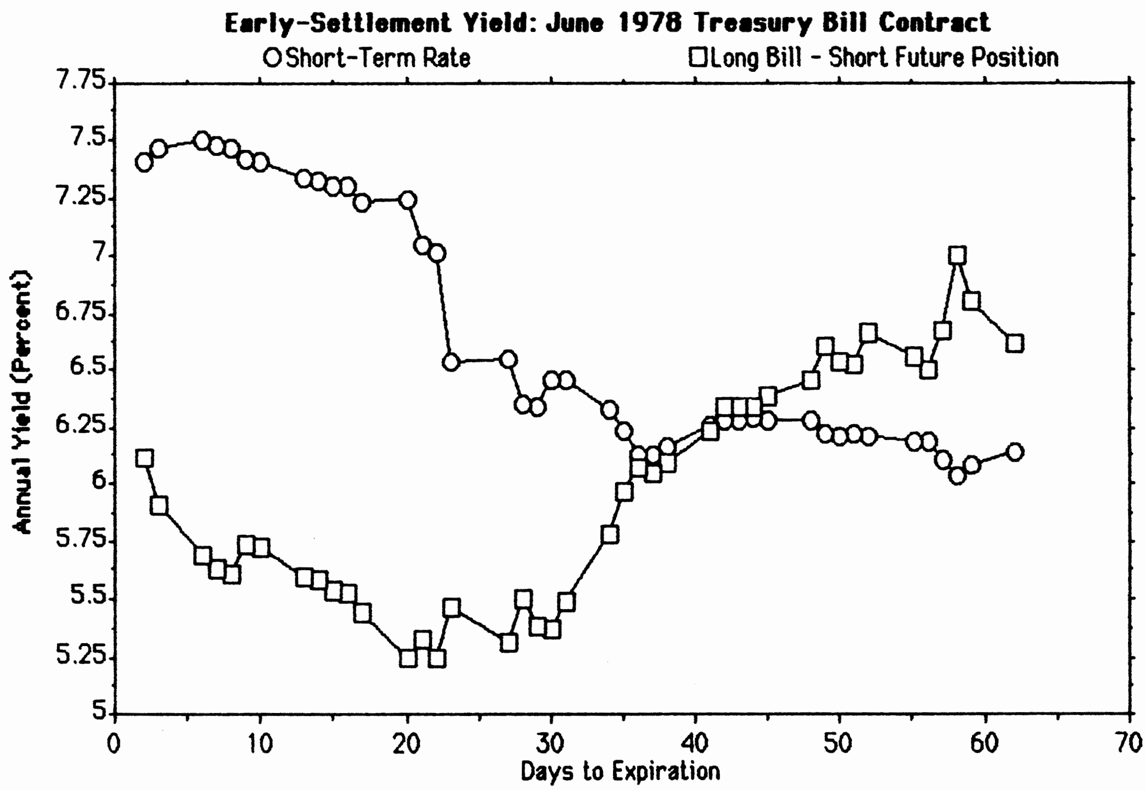
Early-Settlement Yield: September 1977 Treasury Bill Contract

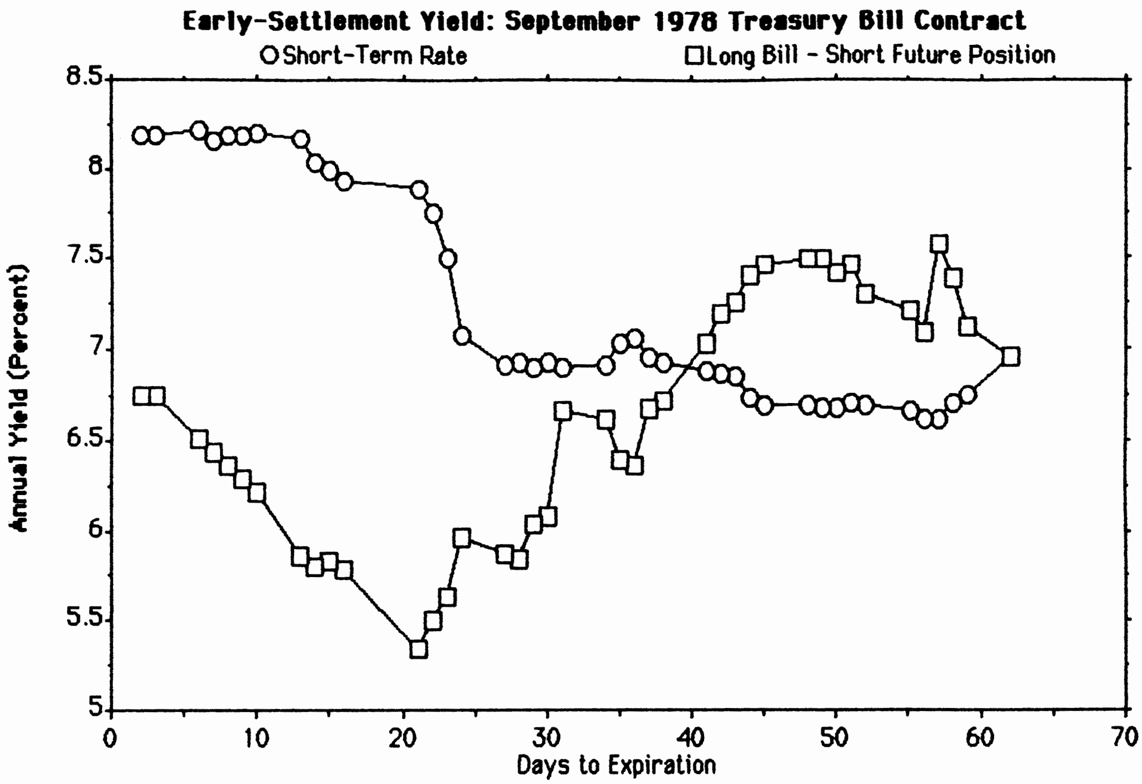


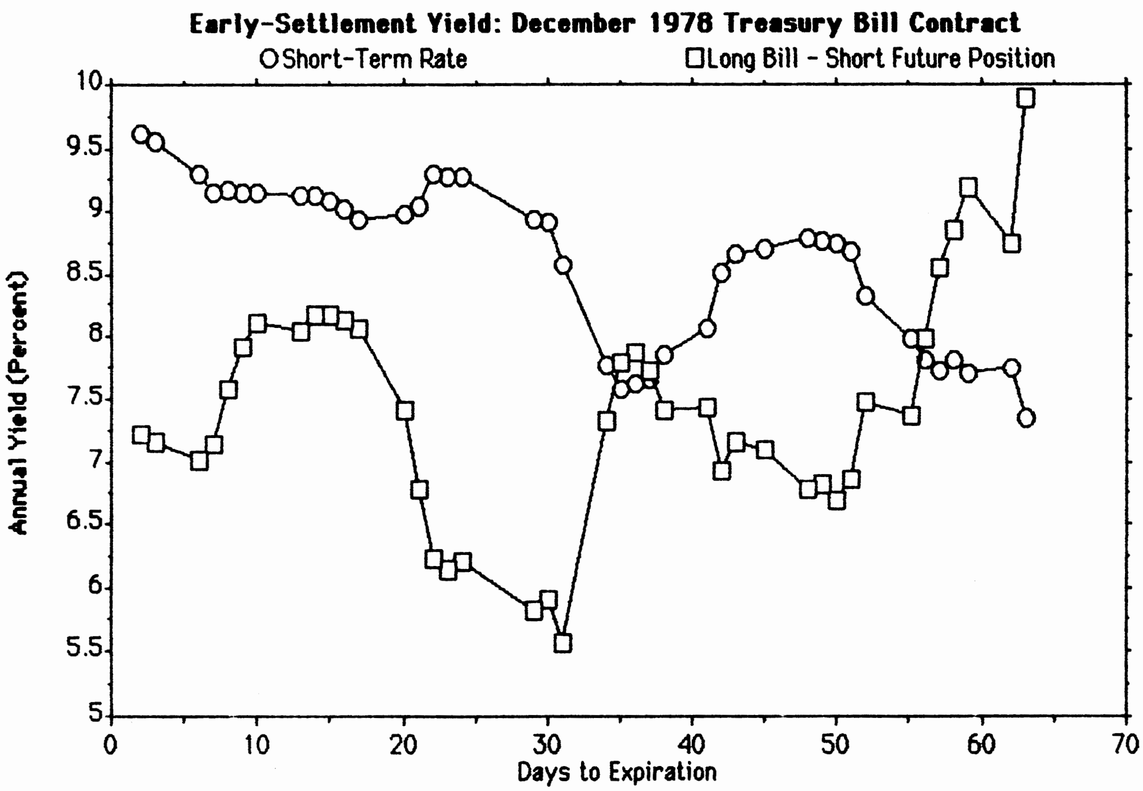
Early-Settlement Yield: December 1977 Treasury Bill Contract

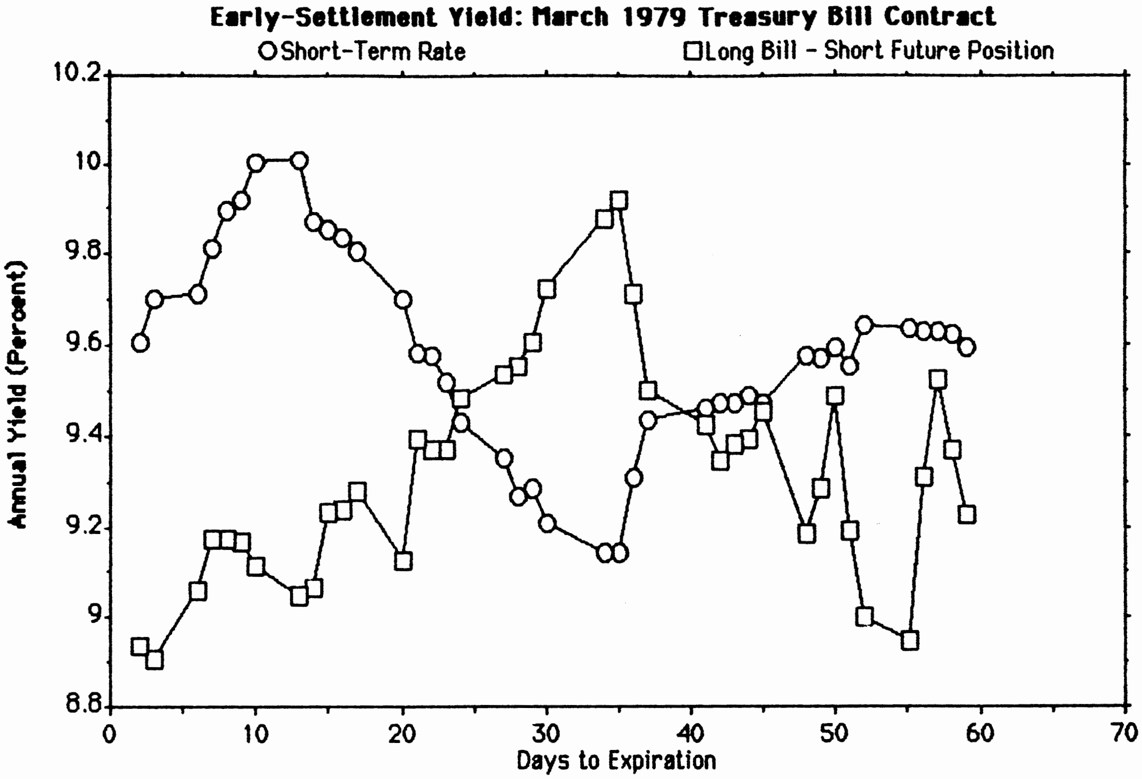


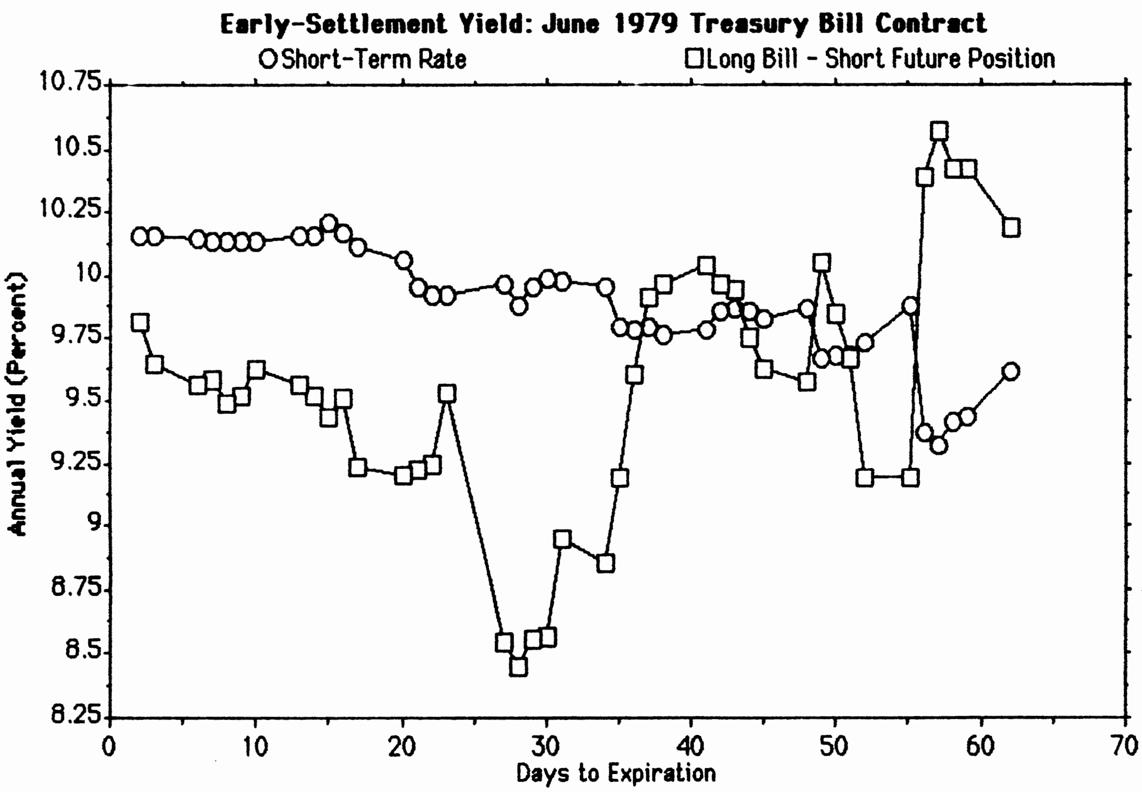

Early-Settlement Yield: March 1978 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
0
10
20
30
40
50
60
70
Days to Expiration

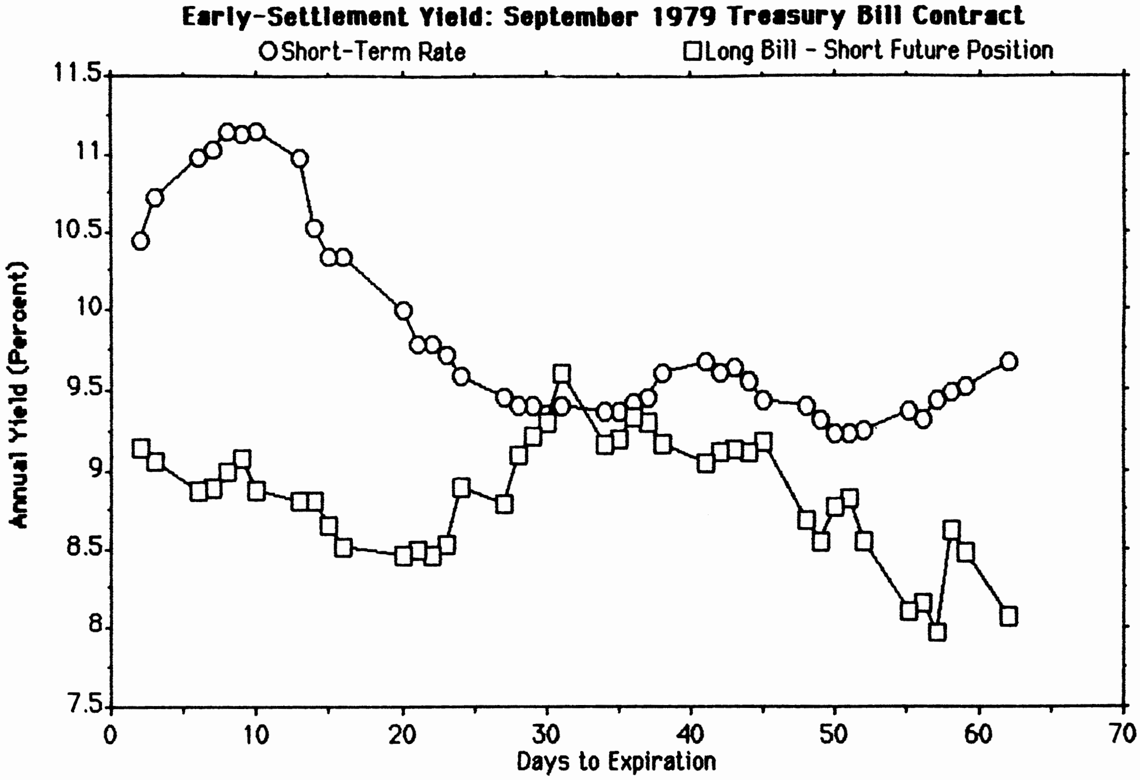

Early-Settlement Yield: June 1978 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
7.75
7.5
7.25
7
6.75
6.5
6.25
6
5.75
5.5
5.25
5
0
10
20
30
40
50
60
70
Days to Expiration

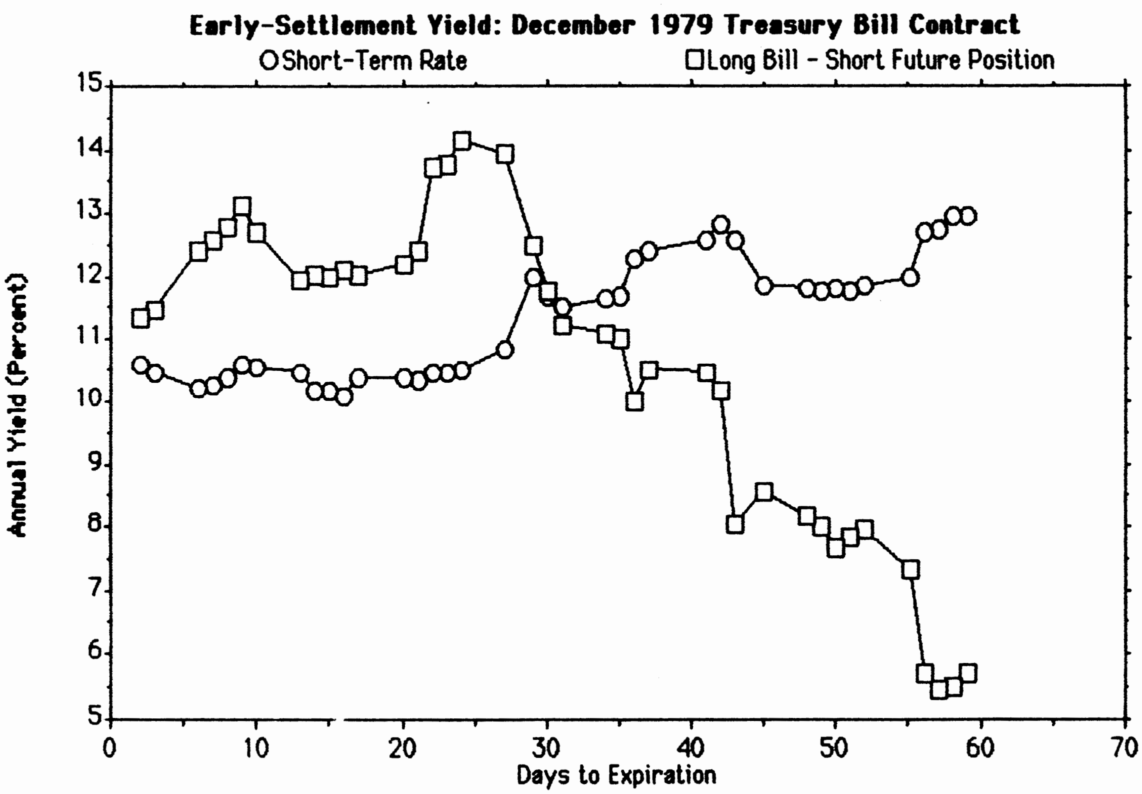

Early-Settlement Yield: September 1978 Treasury Bill Contract
O Short-Term Rate
□ Long Bill - Short Future Position
Annual Yield (Percent)
8.5
8
7.5
7
6.5
6
5.5
5
0
10
20
30
40
50
60
70
Days to Expiration

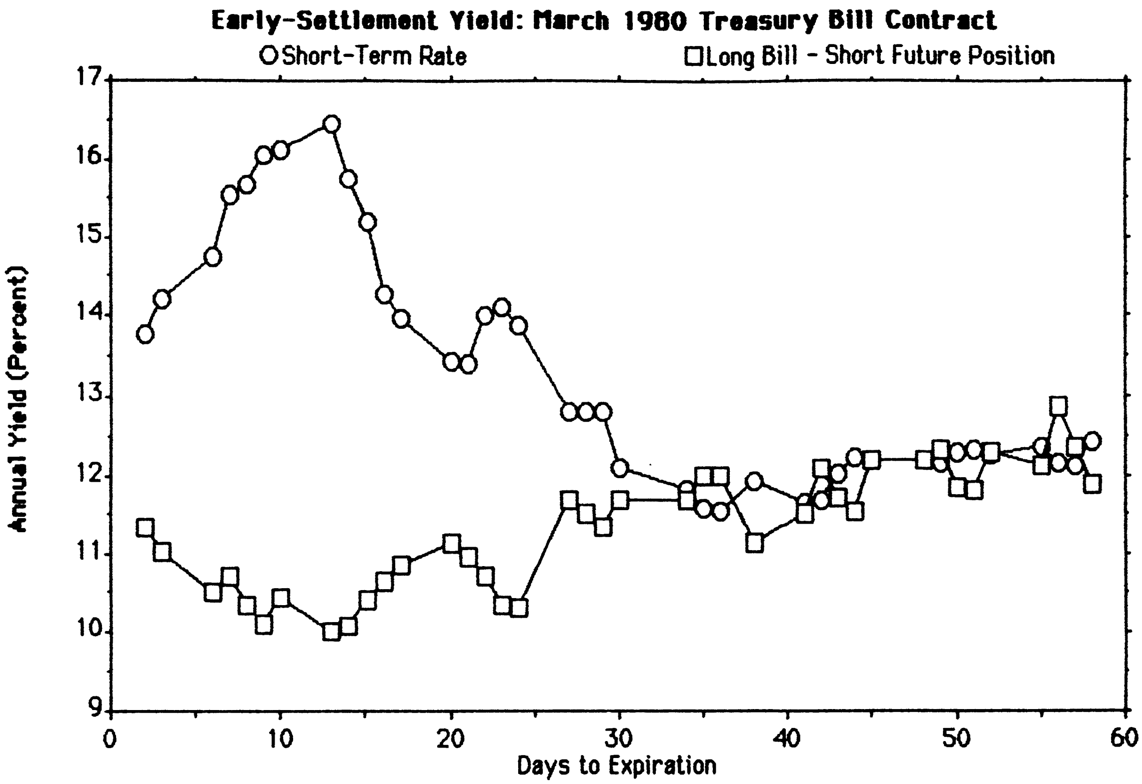

Early-Settlement Yield: December 1978 Treasury Bill Contract
O Short-Term Rate
□ Long Bill - Short Future Position
Annual Yield (Percent)
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
0
10
20
30
40
50
60
70
Days to Expiration

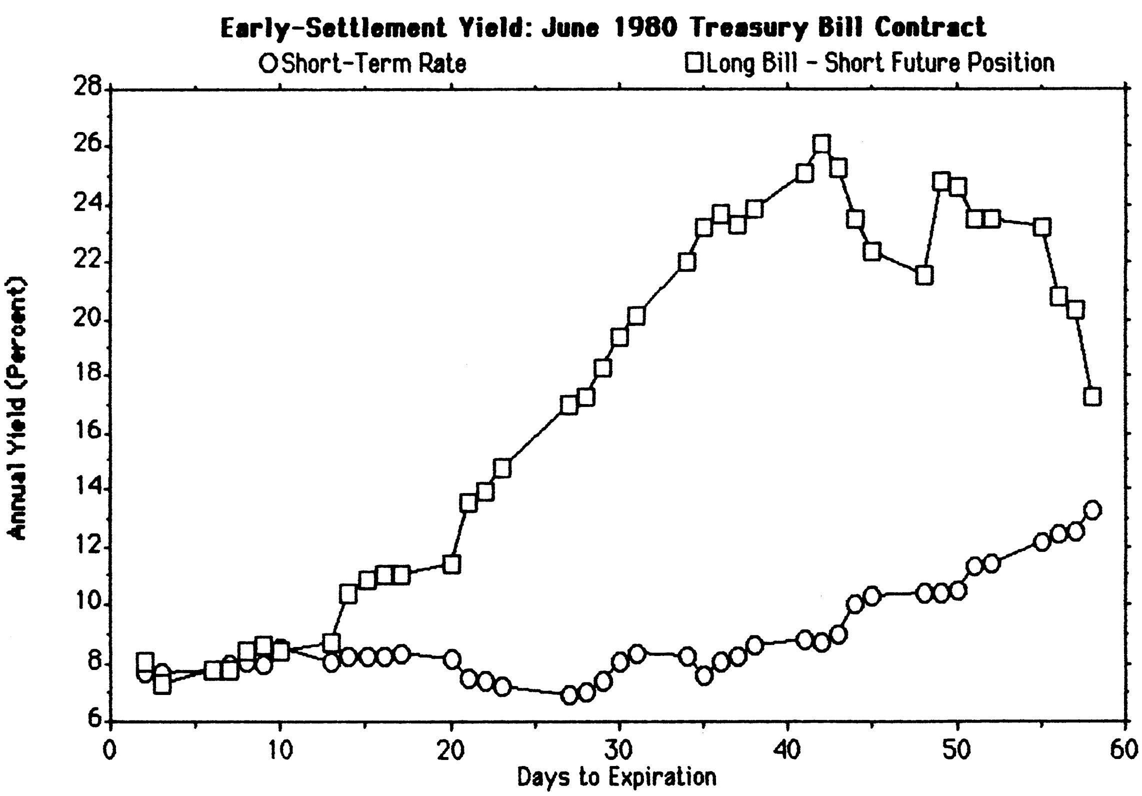

Early-Settlement Yield: March 1979 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
10.2
10
9.8
9.6
9.4
9.2
9
8.8
0
10
20
30
40
50
60
70
Days to Expiration

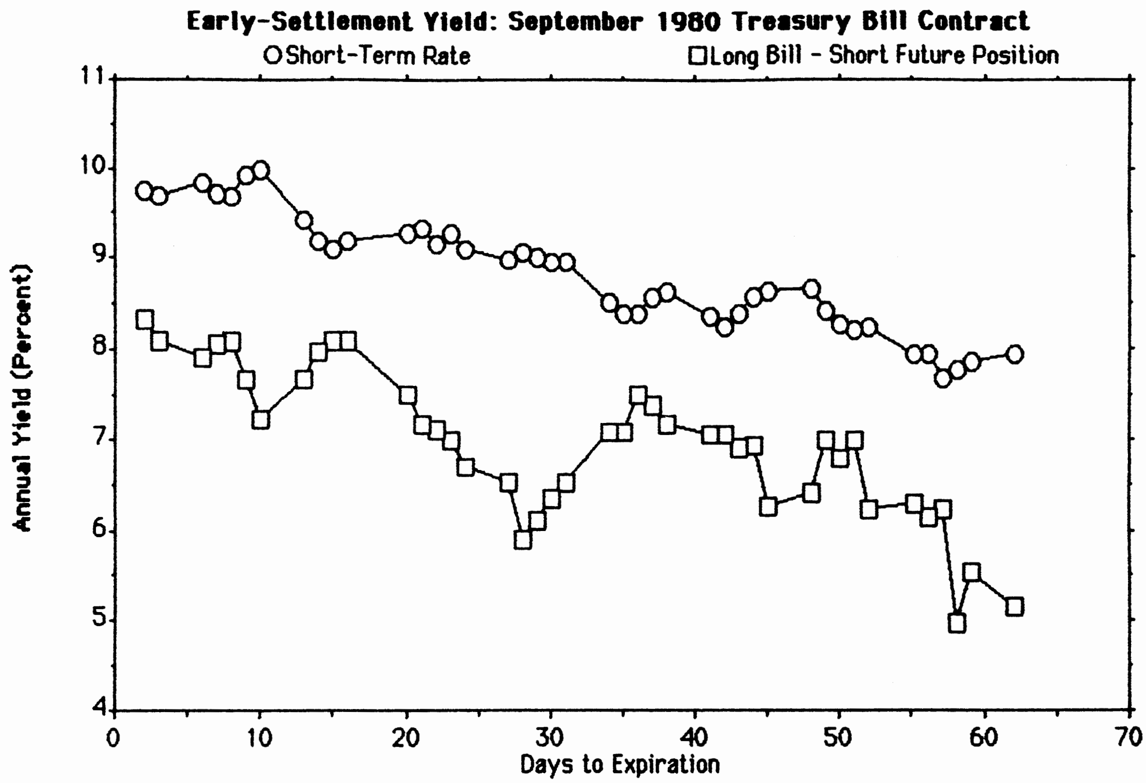

Early-Settlement Yield: June 1979 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
10.75
10.5
10.25
10
9.75
9.5
9.25
9
8.75
8.5
8.25
0
10
20
30
40
50
60
70
Days to Expiration

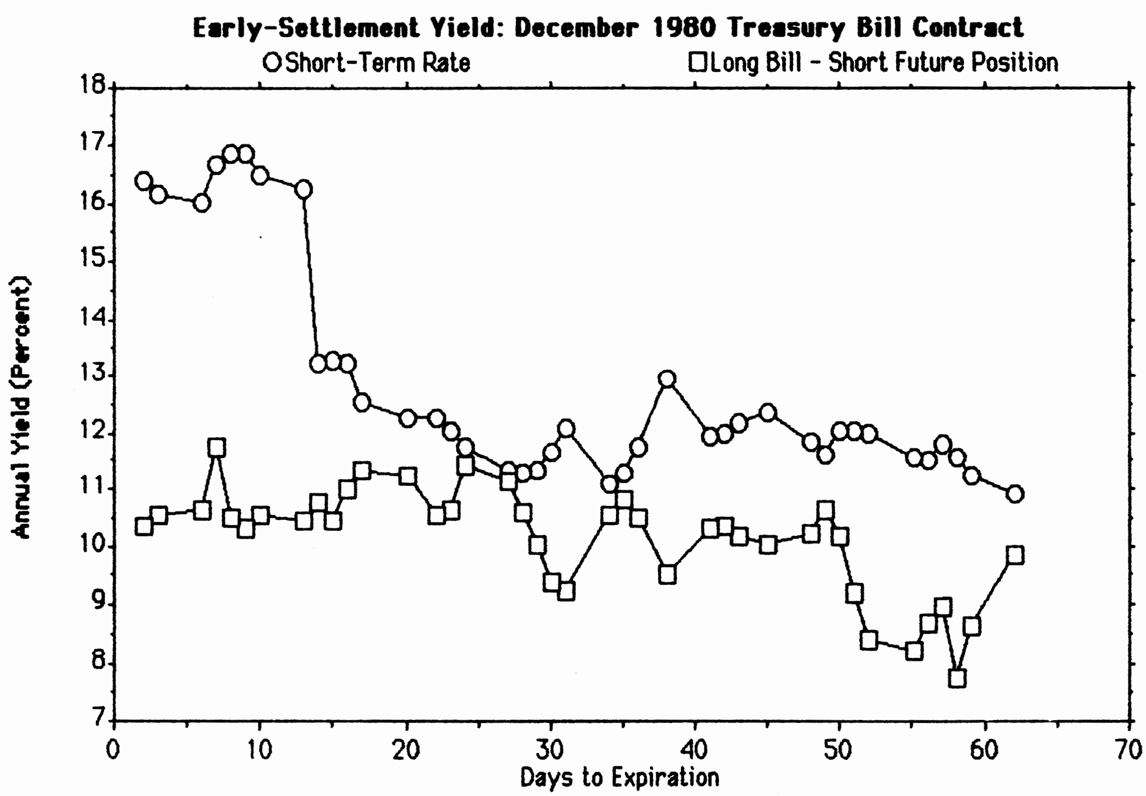

Early-Settlement Yield: September 1979 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
11.5
11
10.5
10
9.5
9
8.5
8
7.5
0
10
20
30
40
50
60
70
Days to Expiration

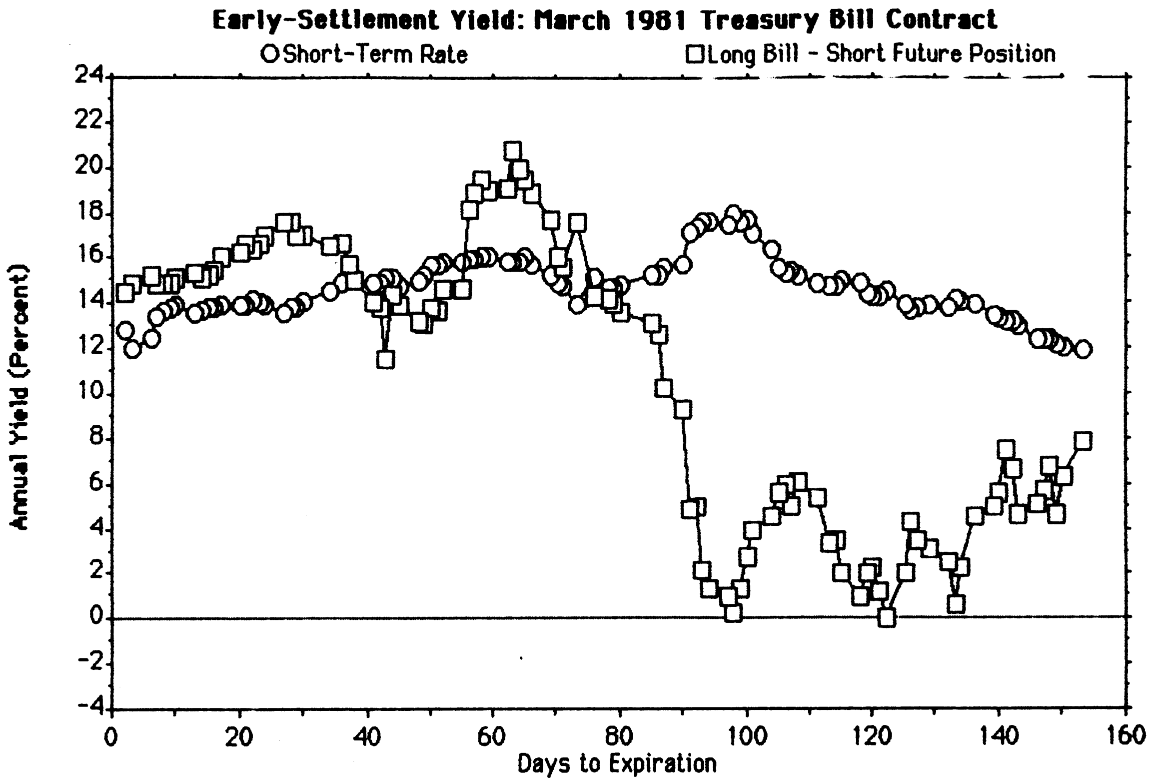

Early-Settlement Yield: December 1979 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
15
14
13
12
11
10
9
8
7
6
5
0
10
20
30
40
50
60
70
Days to Expiration

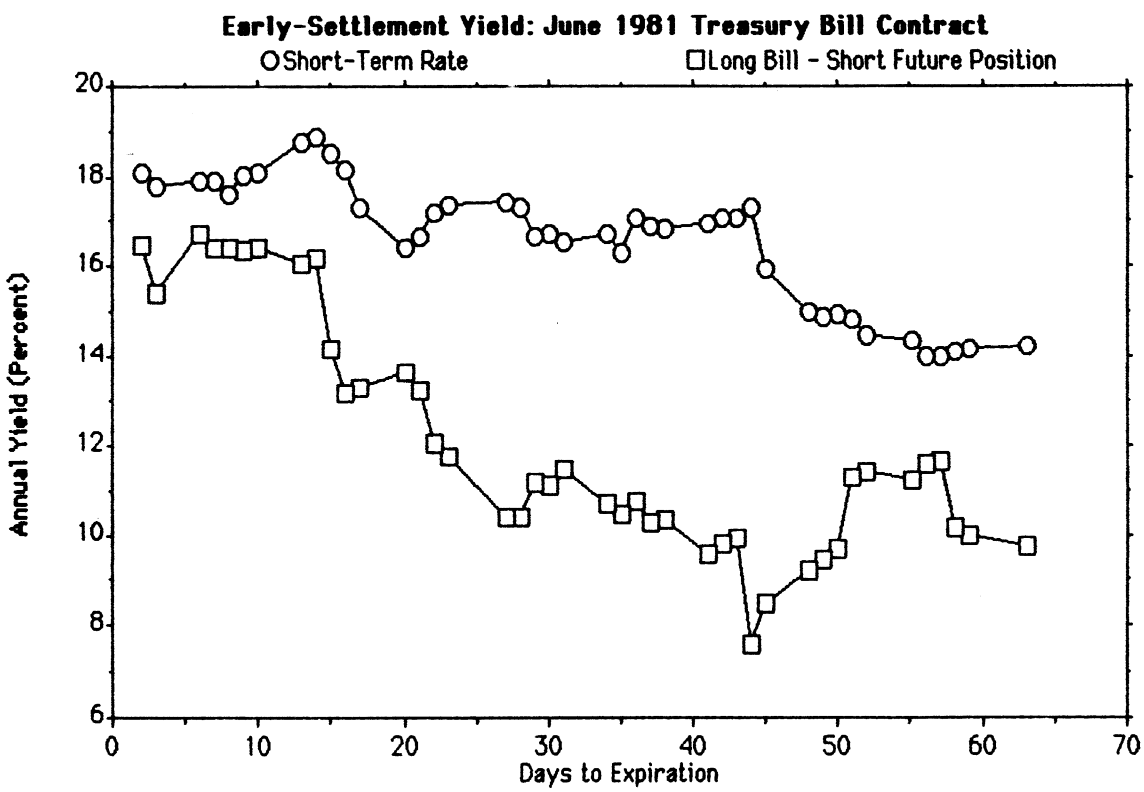

Early-Settlement Yield: March 1980 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
17
16
15
14
13
12
11
10
9
0
10
20
30
40
50
60

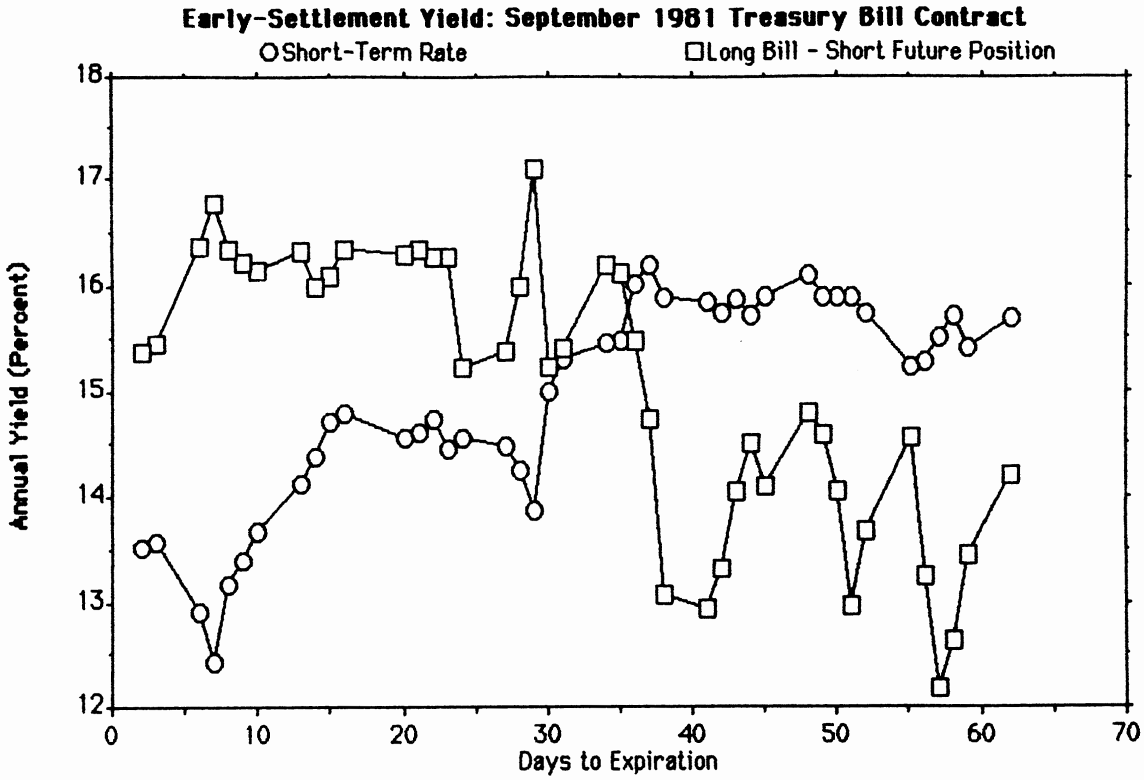

Early-Settlement Yield: June 1980 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
28
26
24
22
20
18
16
14
12
10
8
6
0
10
20
30
40
50
60

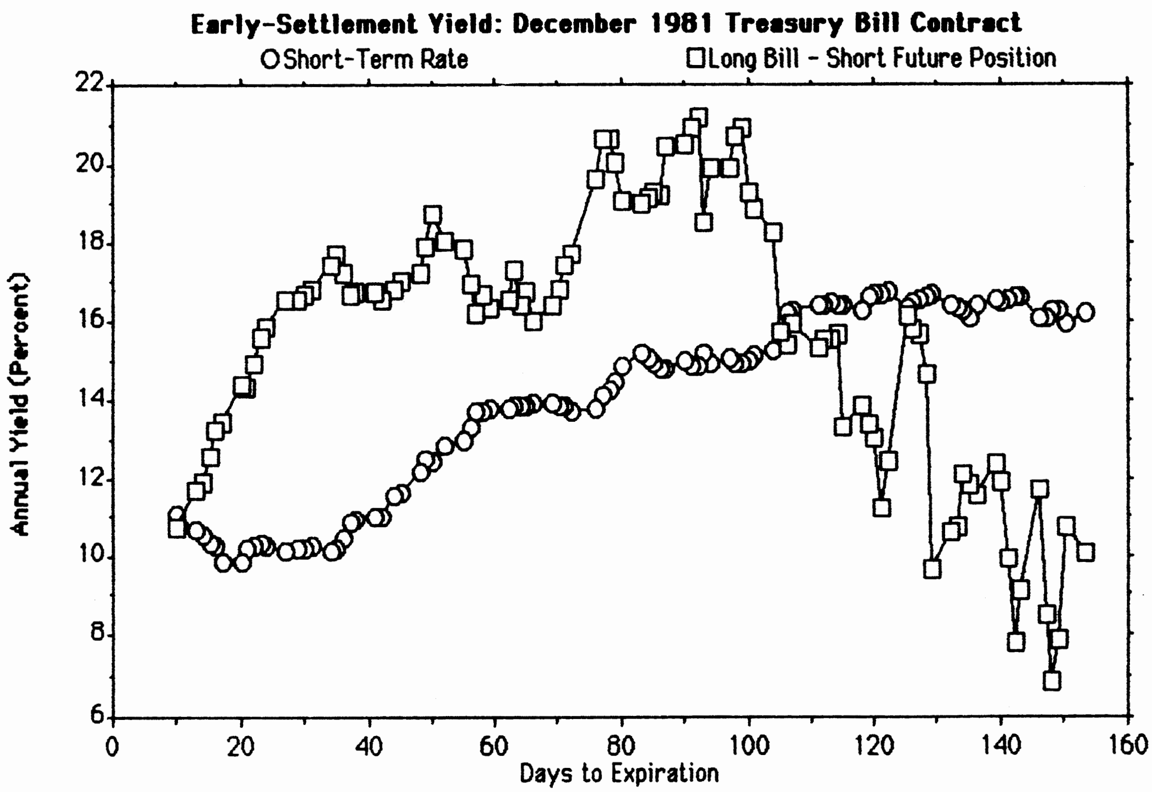

Early-Settlement Yield: September 1980 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
4
5
6
7
8
9
10
11
0
10
20
30
40
50
60
70

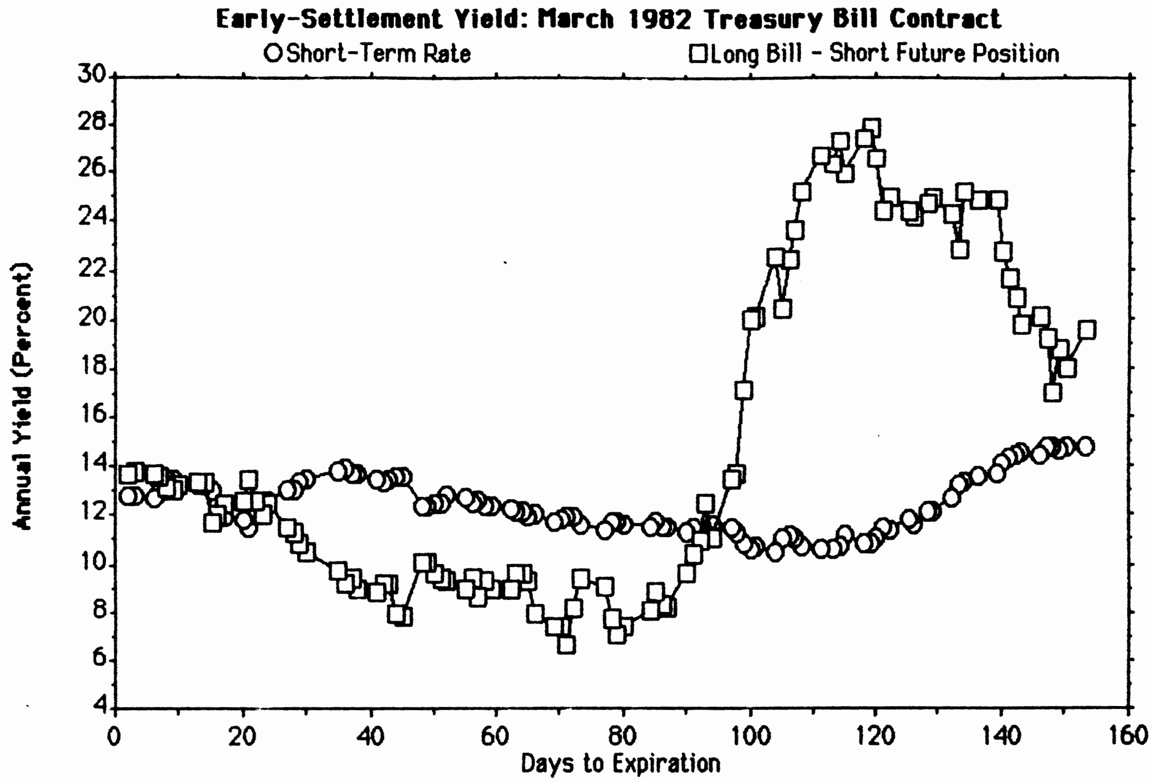

Early-Settlement Yield: December 1980 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
7
8
9
10
11
12
13
14
15
16
17
18
0
10
20
30
40
50
60
70

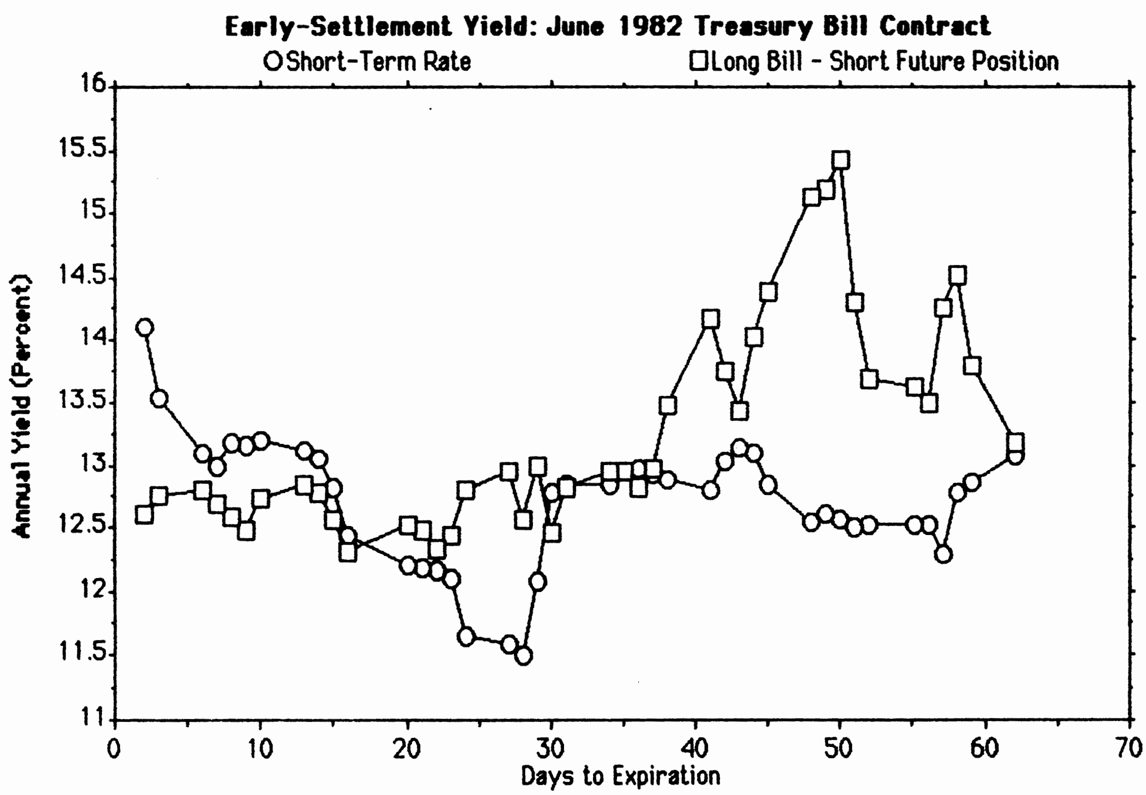

Early-Settlement Yield: March 1981 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

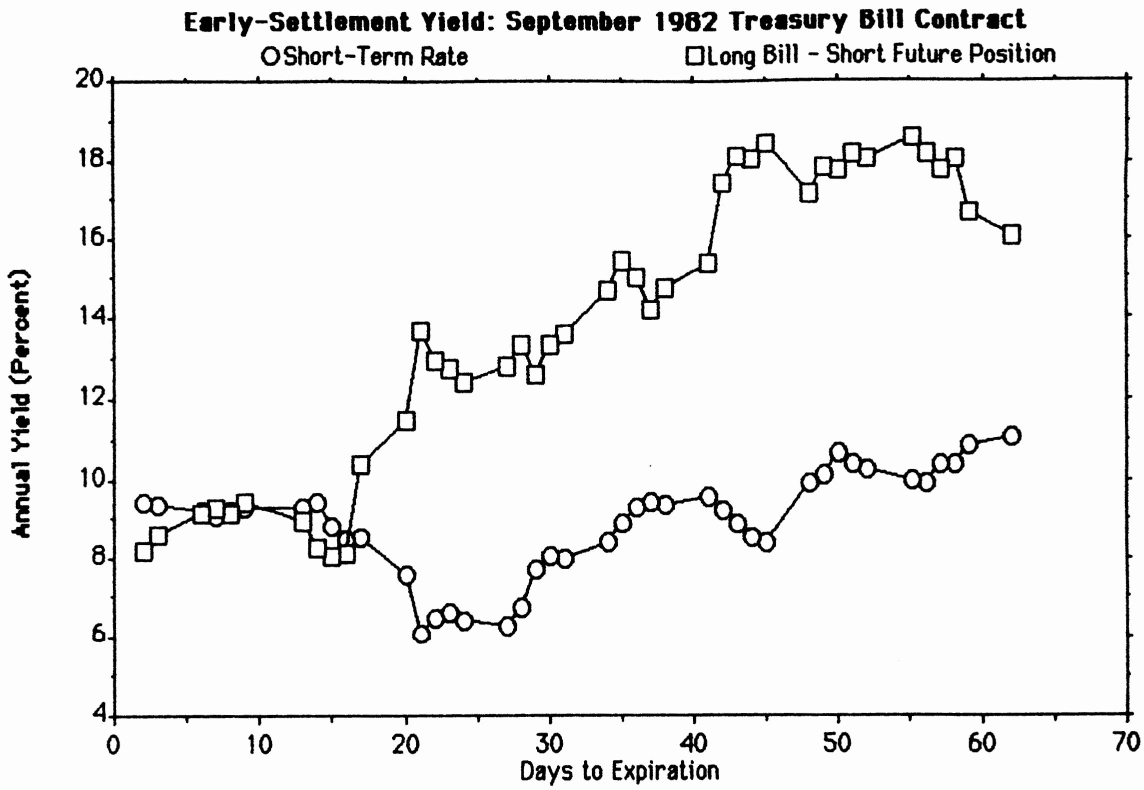

Early-Settlement Yield: June 1981 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

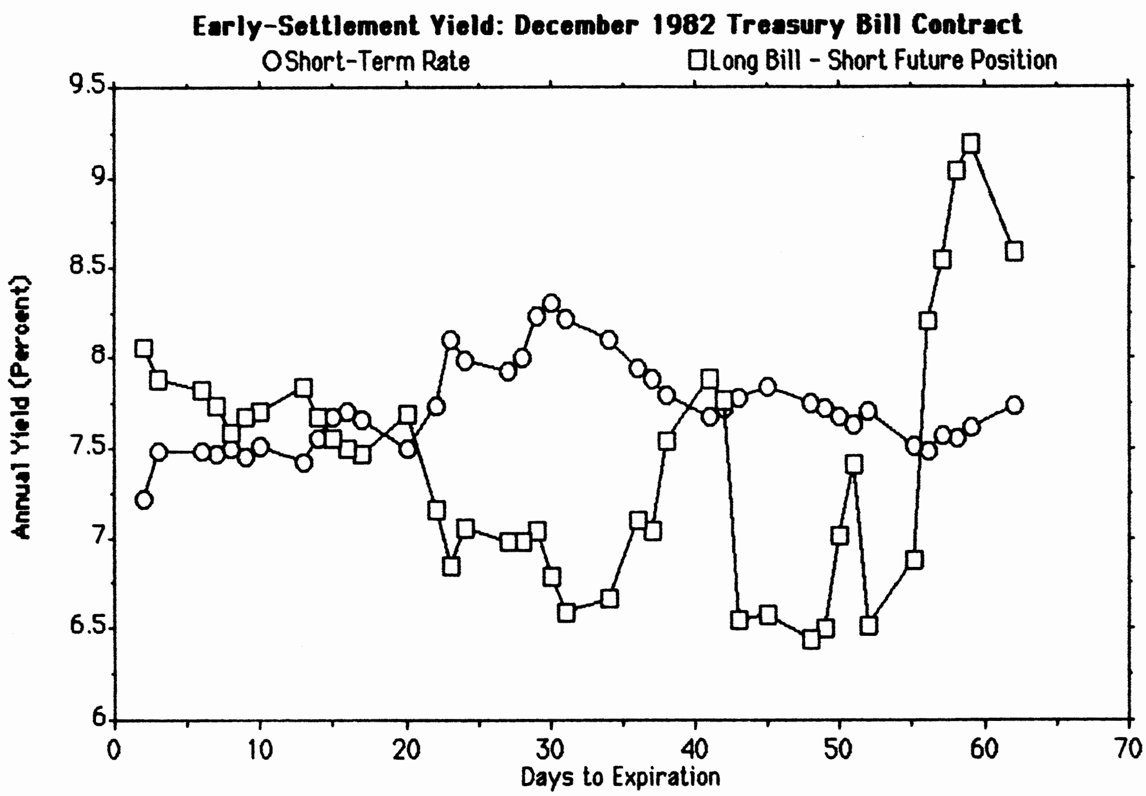

Early-Settlement Yield: September 1981 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
12
13
14
15
16
17
18
0
10
20
30
40
50
60
70

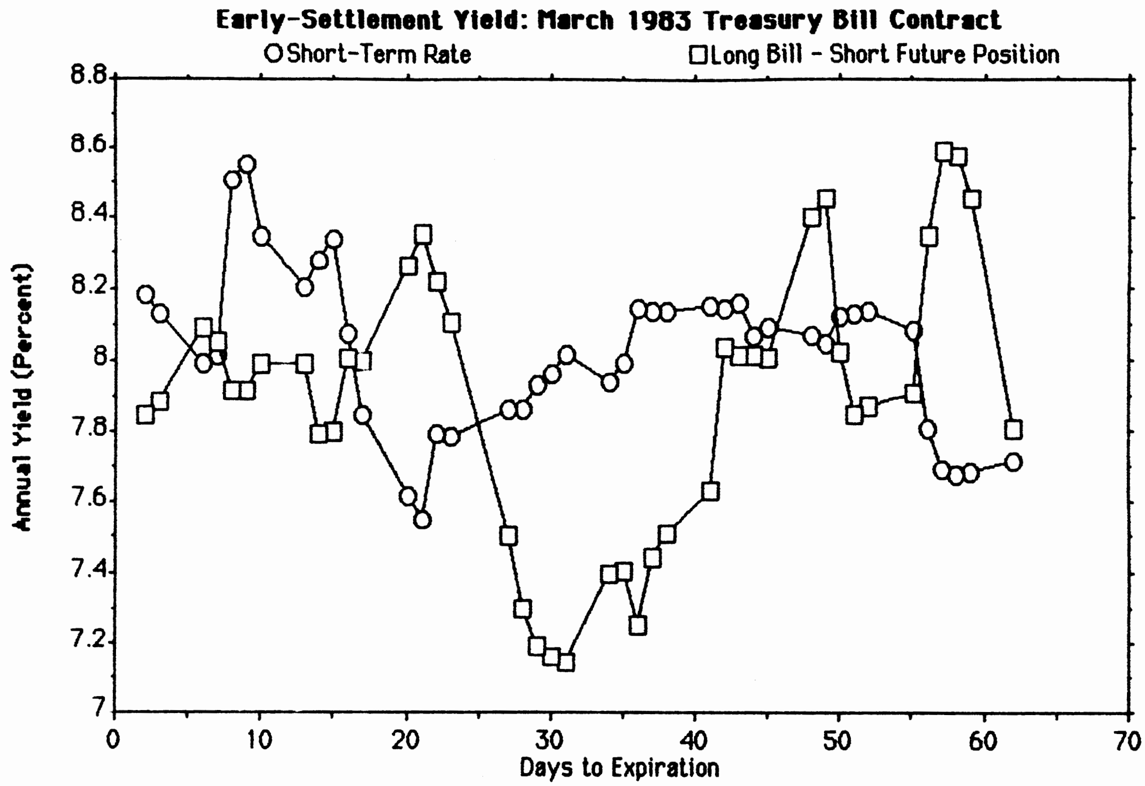

Early-Settlement Yield: December 1981 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
6
8
10
12
14
16
18
20
22
0
20
40
60
80
100
120
140
160


Early-Settlement Yield: March 1982 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
30
28
26
24
22
20
18
16
14
12
10
8
6
4
0
20
40
60
80
100
120
140
160

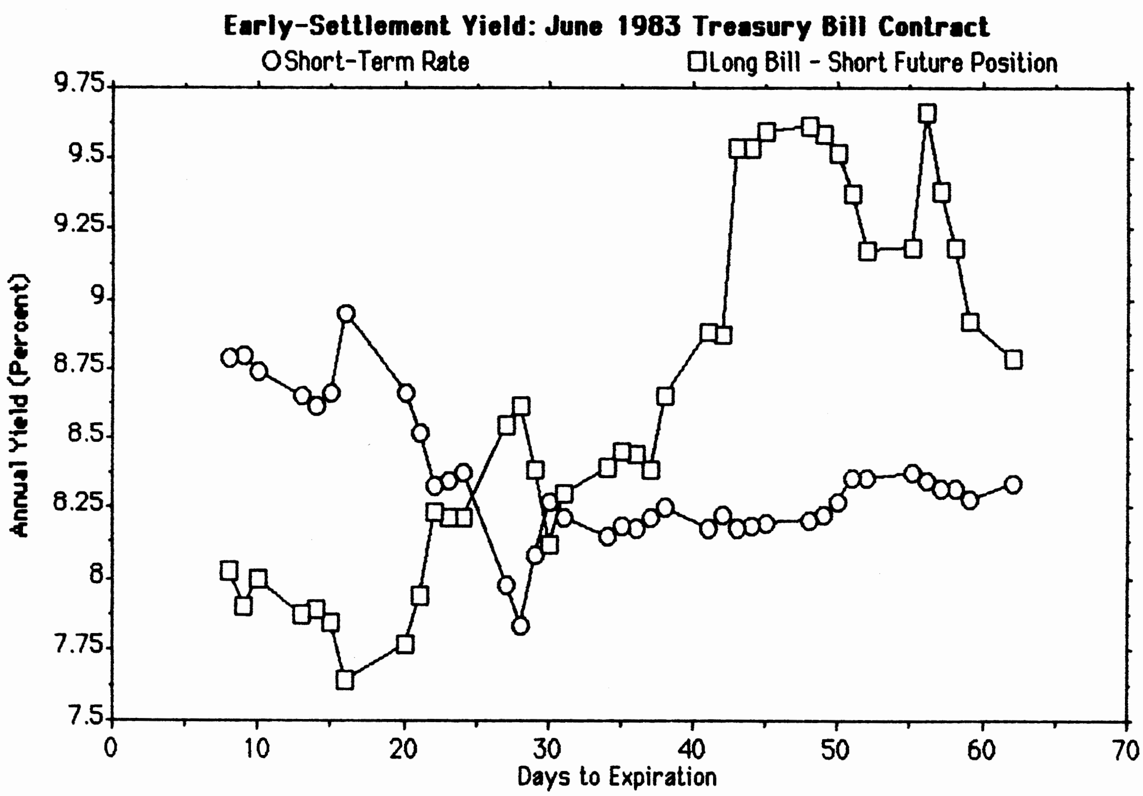

Early-Settlement Yield: June 1982 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
0
10
20
30
40
50
60
70


Early-Settlement Yield: September 1982 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
20
18
16
14
12
10
8
6
4
0
10
20
30
40
50
60
70
Days to Expiration

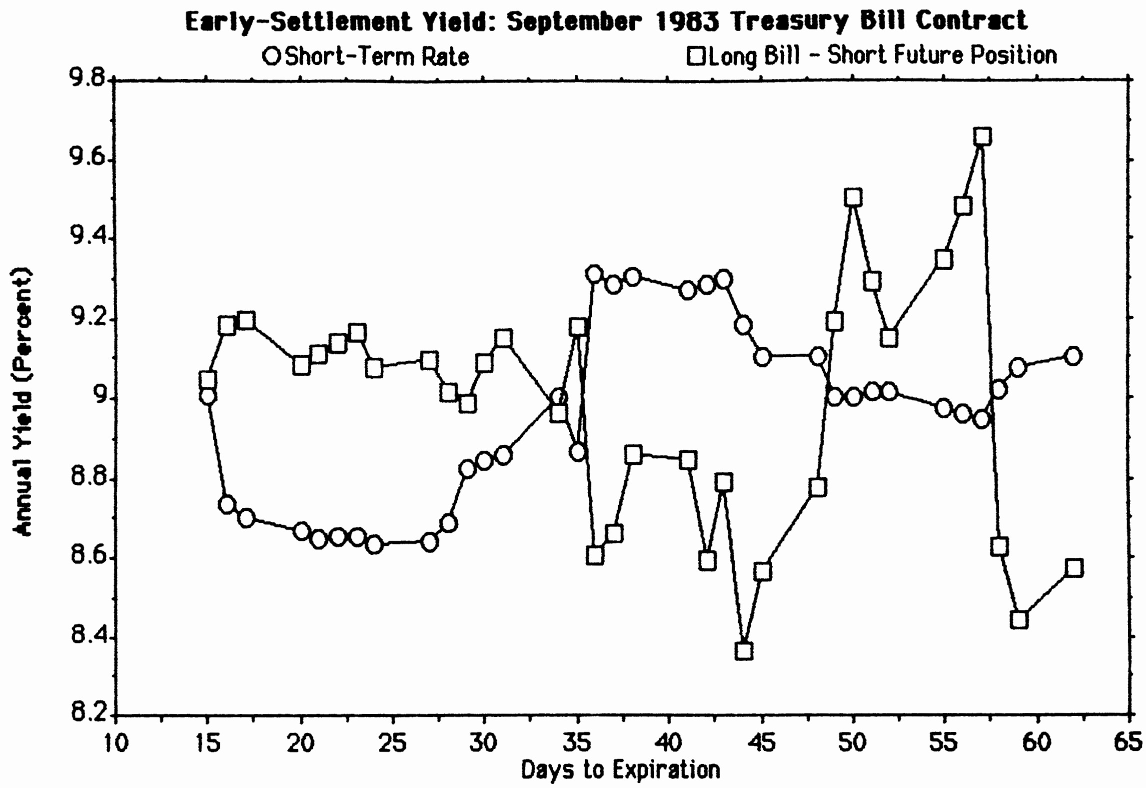

Early-Settlement Yield: December 1982 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
9.5
9
8.5
8
7.5
7
6.5
6
0
10
20
30
40
50
60
70
Days to Expiration

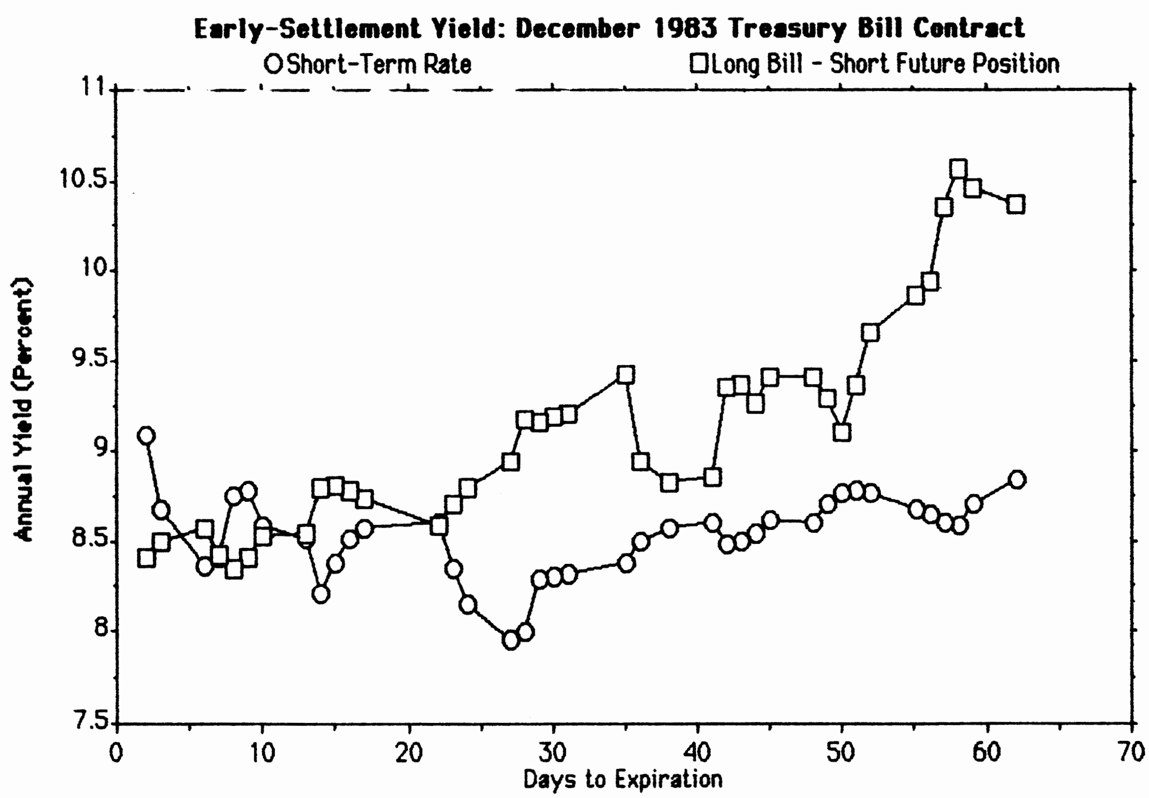


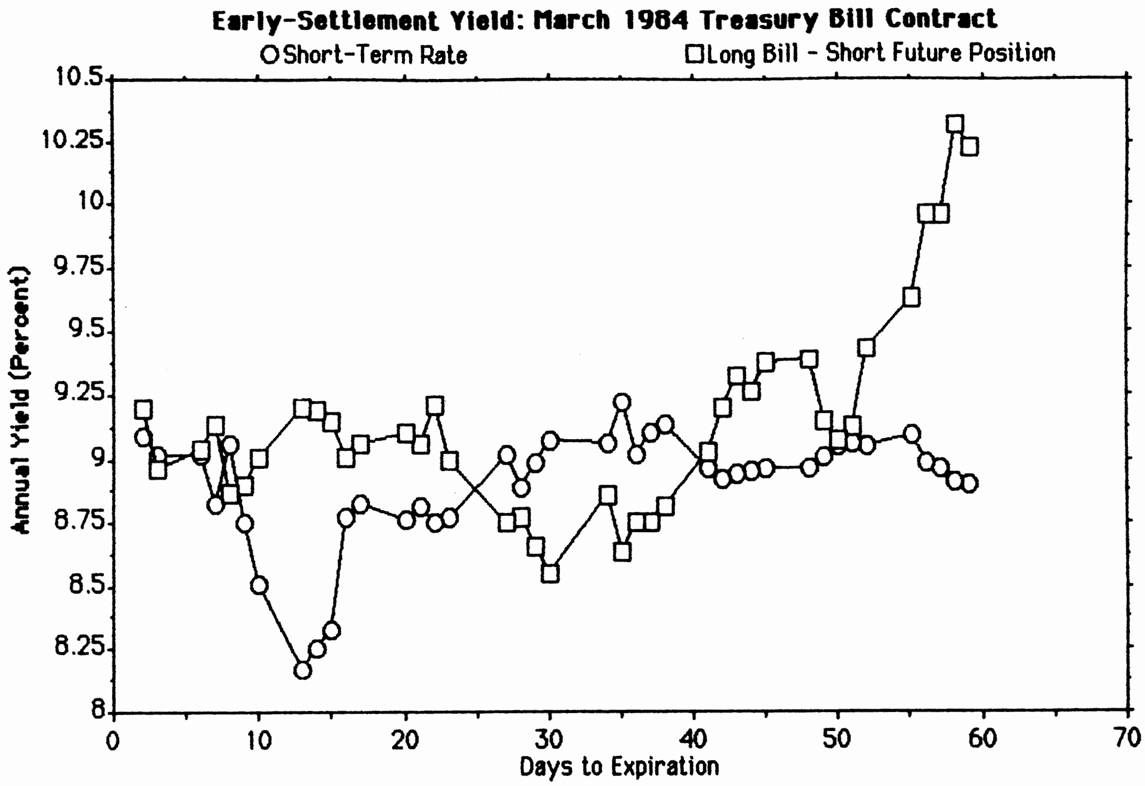
Early-Settlement Yield: March 1983 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
0
10
20
30
40
50
60
70
Days to Expiration



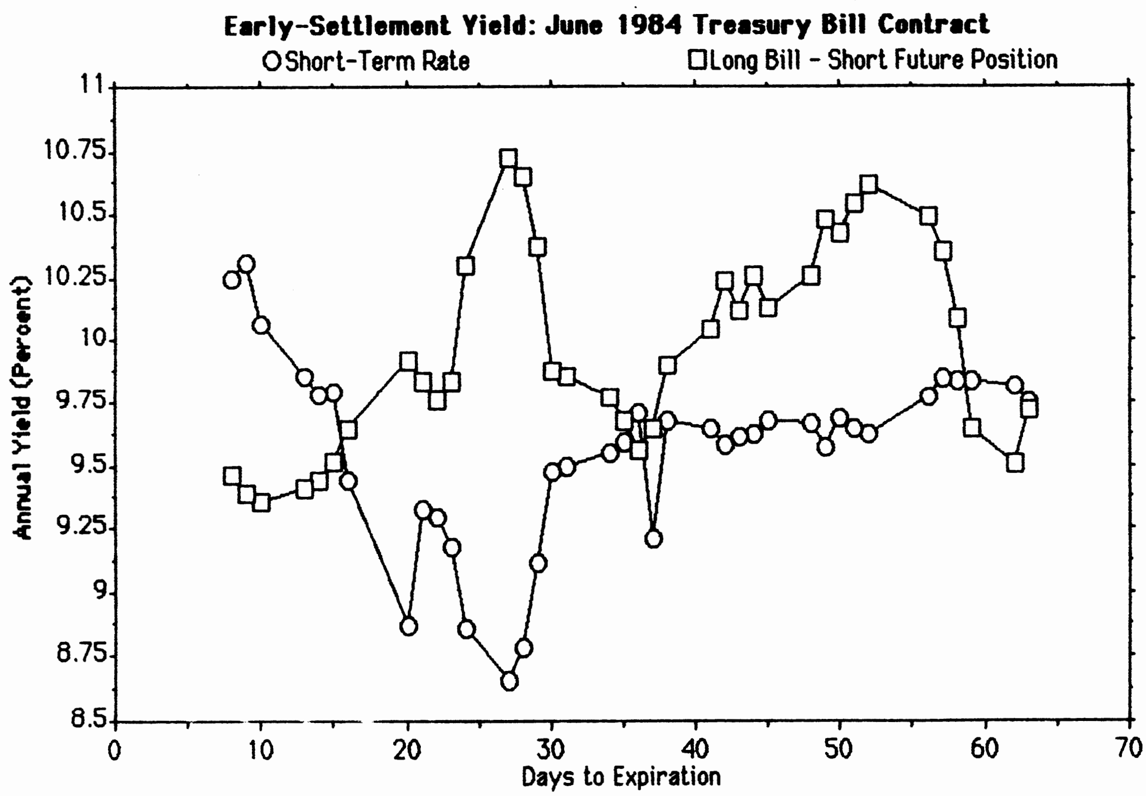
Early-Settlement Yield: June 1983 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
9.75
9.5
9.25
9
8.75
8.5
8.25
8
7.75
7.5
0
10
20
30
40
50
60
70
Days to Expiration


Early-Settlement Yield: September 1983 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
10
15
20
25
30
35
40
45
50
55
60
65

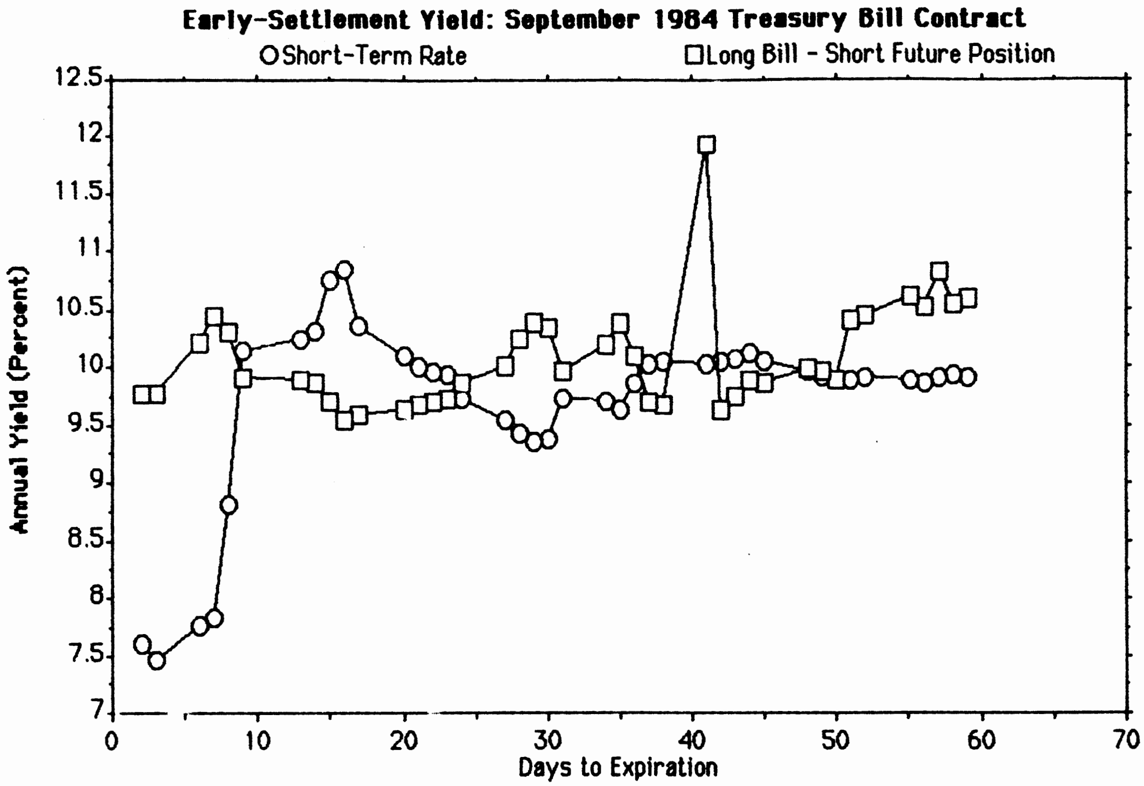

Early-Settlement Yield: December 1983 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
11
10.5
10
9.5
9
8.5
8
7.5
0
10
20
30
40
50
60
70

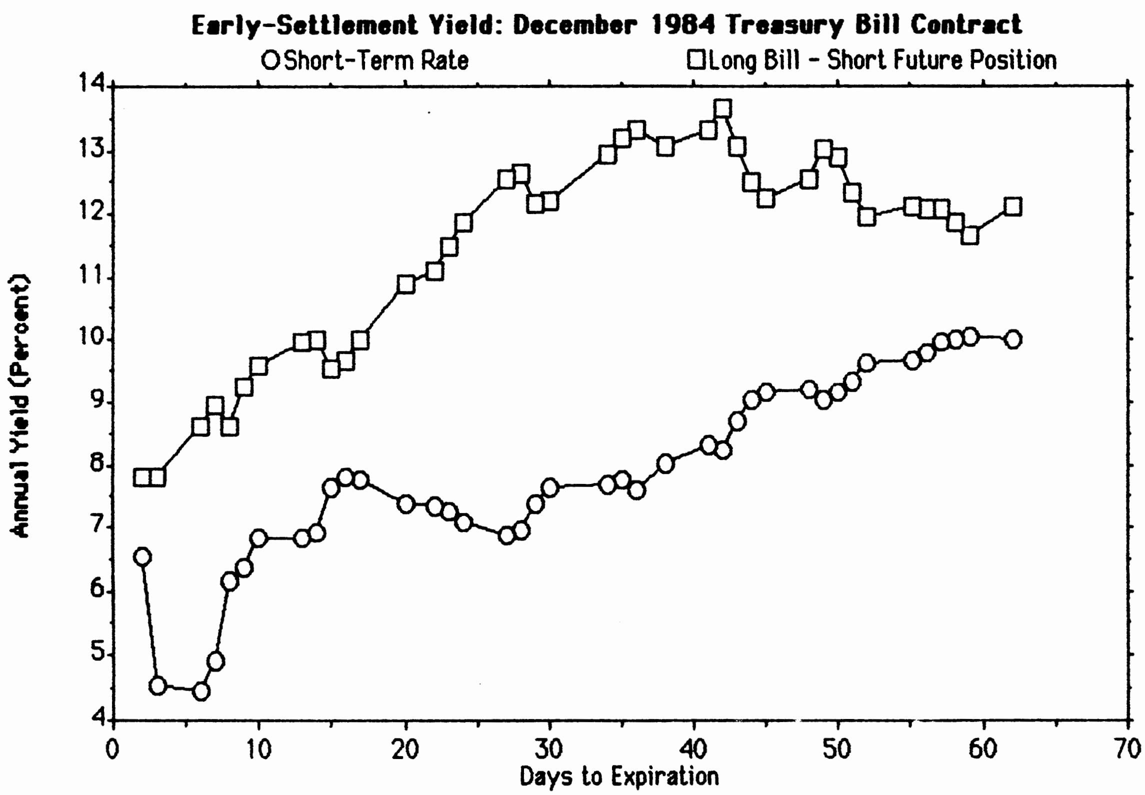


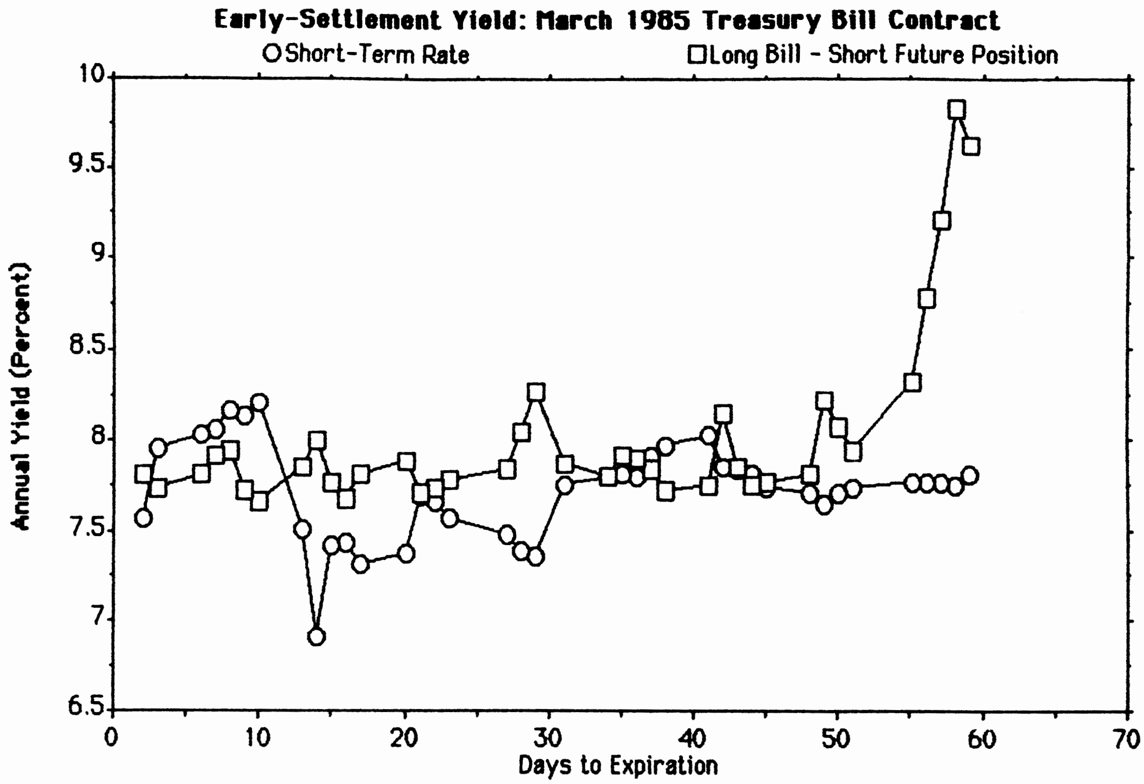
Early-Settlement Yield: March 1984 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration

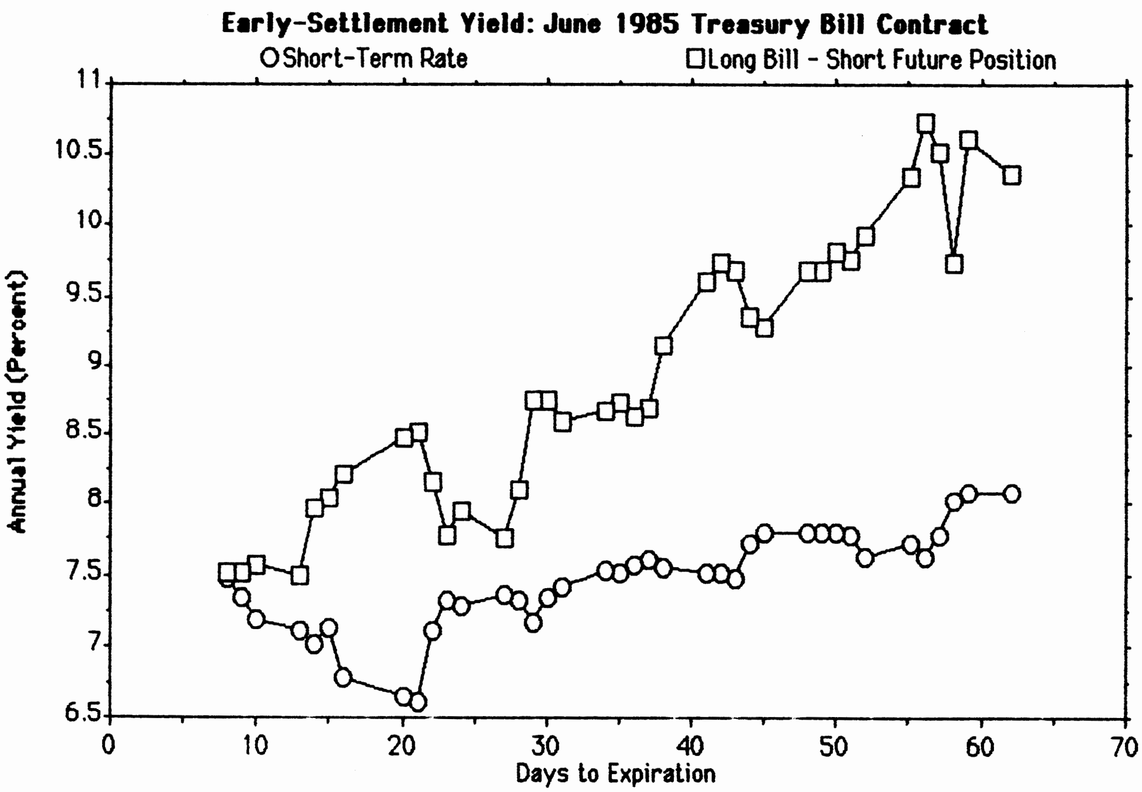


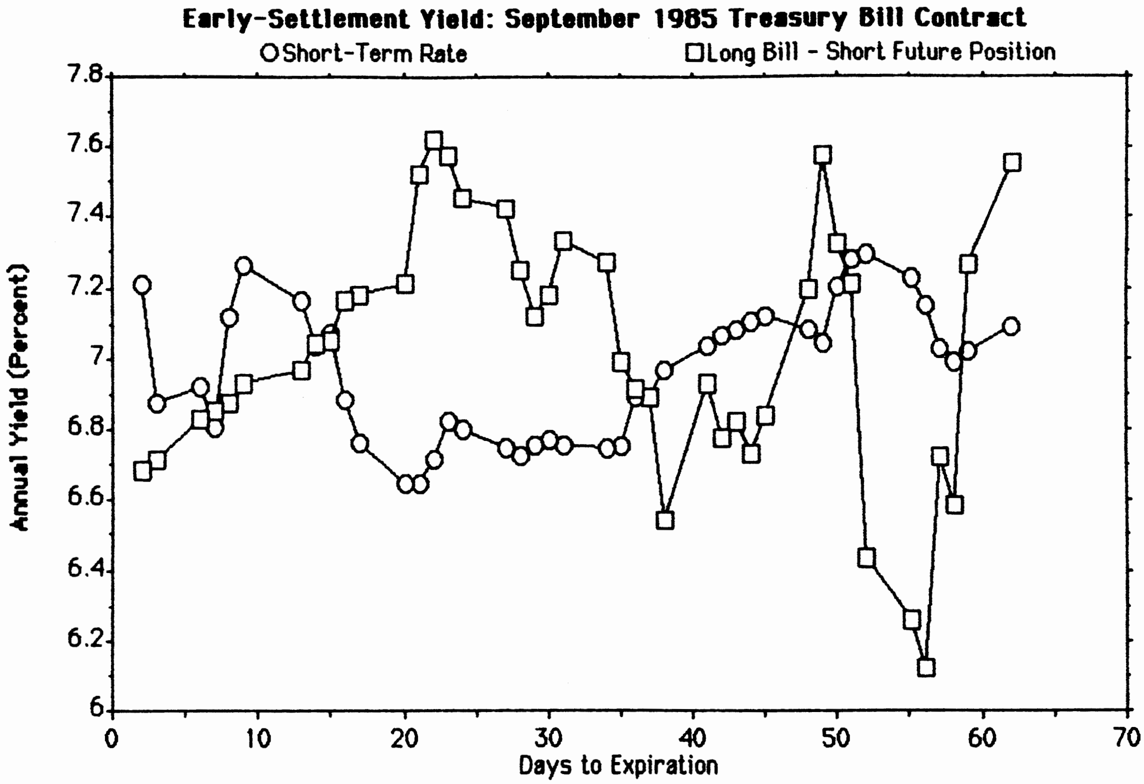
Early-Settlement Yield: June 1984 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration


Early-Settlement Yield: September 1984 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
0
10
20
30
40
50
60
70

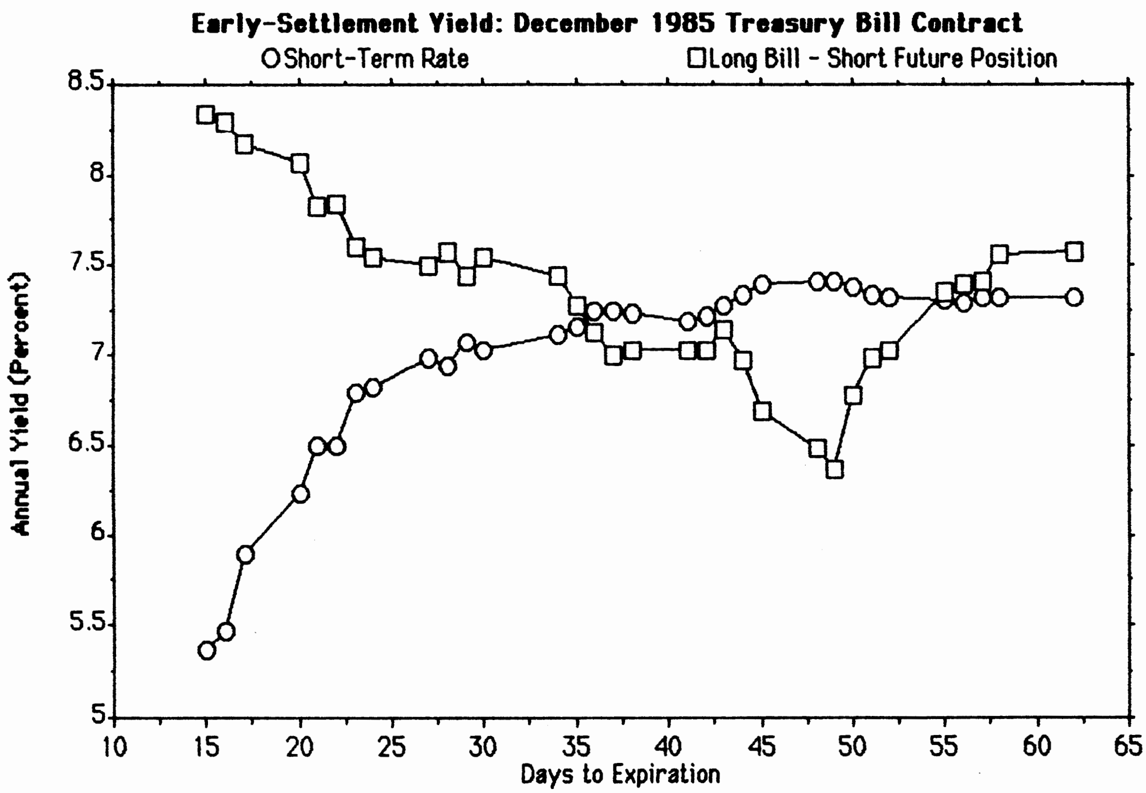

Early-Settlement Yield: December 1984 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
14
13
12
11
10
9
8
7
6
5
4
0
10
20
30
40
50
60
70


Early-Settlement Yield: March 1985 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
10
9.5
9
8.5
8
7.5
7
6.5
0
10
20
30
40
50
60
70


Early-Settlement Yield: June 1985 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
Days to Expiration
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
0
10
20
30
40
50
60
70



Early-Settlement Yield: September 1985 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
0
10
20
30
40
50
60
70
Days to Expiration



Early-Settlement Yield: December 1985 Treasury Bill Contract
Short-Term Rate
Long Bill - Short Future Position
Annual Yield (Percent)
8.5
8
7.5
7
6.5
6
5.5
5
10
15
20
25
30
35
40
45
50
55
60
65
Days to Expiration

APPENDIX F

YIELDS FROM STRATEGIES I AND IA SETTLED EARLY:

TREASURY BILL AND TREASURY

NOTE CONTRACTS.

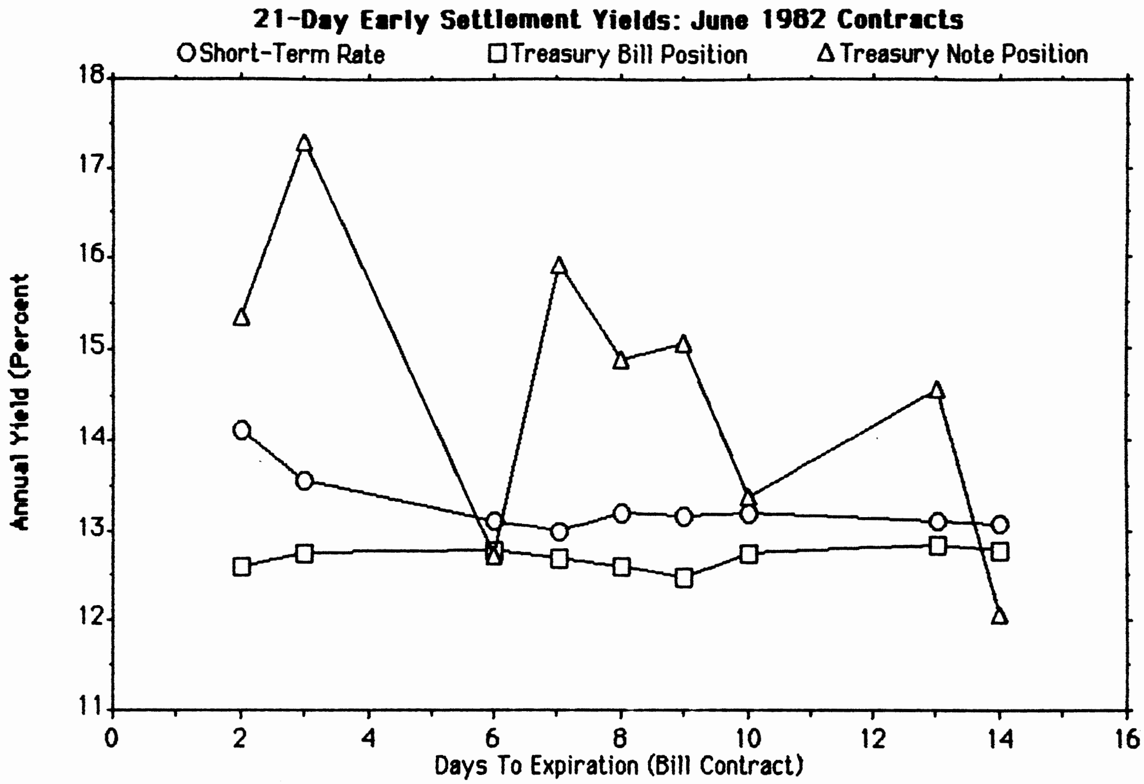
Prospective annual yield from outright purchase of a short term Treasury bill (Short-Term Rate), versus actual annual yield, with settlement occurring after 21-day holding periods, from purchase of a longer term Treasury bill and short Treasury bill contract position (Treasury Bill Position), and purchase of a Treasury note and short Treasury note contract position (Treasury Note Position).

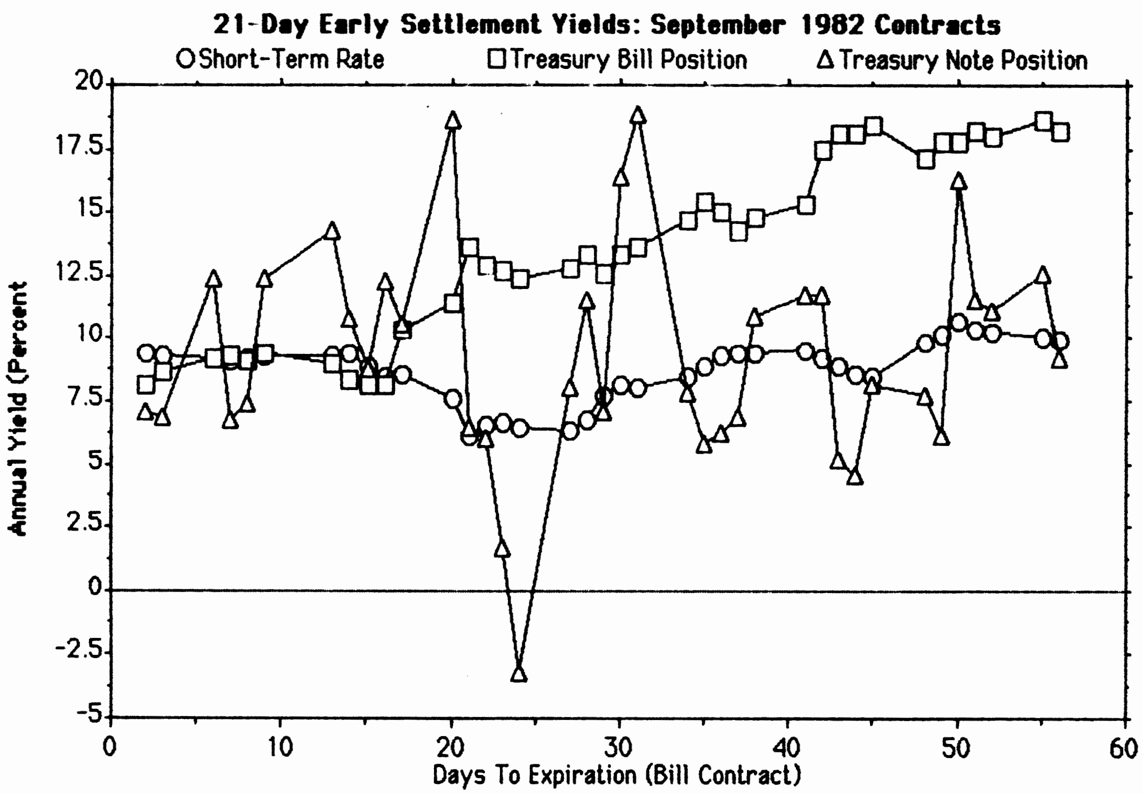
Sample Interval: Daily.

Sample Duration: June, 1982 contract through September, 1985 contract

Source of Data: Futures Contracts: Chicago Board of Trade and Wall Street Journal.
Treasury Bill: Wall Street Journal.
Treasury Note: Wall Street Journal

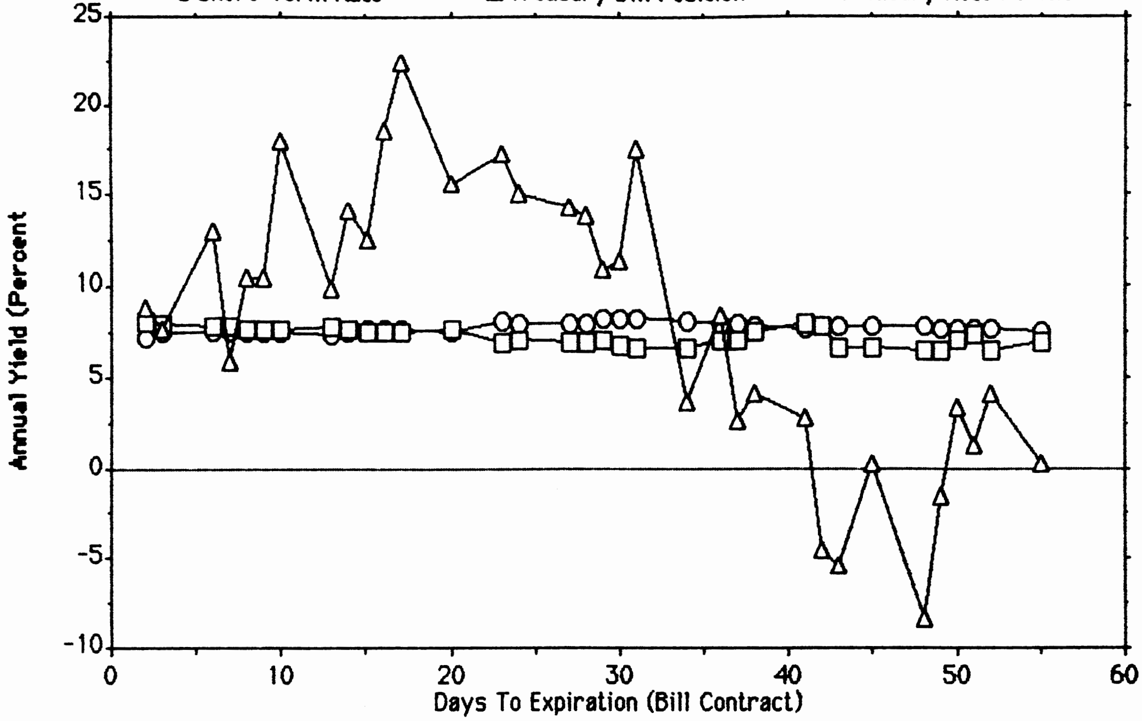
Description: This appendix shows the annualized yield from three investment strategies: outright purchase and maturation of a Treasury bill (Short-Term Rate), the simultaneous purchase of a deliverable Treasury bill and sale of a matching futures contract (Treasury Bill Position), and the simultaneous purchase of a deliverable Treasury note and sale of a matching futures contract (Treasury Note Position). Yields are calculated by dividing the actual dollar profit by the actual dollar cost, and annualizing by multiplying by the ratio of the number of days per year (365) to the number of days in the holding period. The holding period is 21 business days. Costs include payment of commission ($60) and margin ($1,500) while the contract is in force. Margin is returned at settlement. The two yields are equivalent to the yields from Strategy I and Strategy IA, assuming early settlement of the position (see Section II, Tables 1-3 in the text). The Treasury bill that is assumed to be purchased and held until settlement is the bill that is deliverable at contract expiration. The Treasury note is the February, 1992 14 5/8% note.


21-Day Early Settlement Yields: June 1982 Contracts
O Short-Term Rate
□ Treasury Bill Position
Δ Treasury Note Position
Annual Yield (Percent
18
17
16
15
14
13
12
11
0
2
4
6
8
10
12
14
16
Days To Expiration (Bill Contract)


21-Day Early Settlement Yields: September 1982 Contracts
O Short-Term Rate
□ Treasury Bill Position
Δ Treasury Note Position
Annual Yield (Percent
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
0
10
20
30
40
50
60
Days To Expiration (Bill Contract)

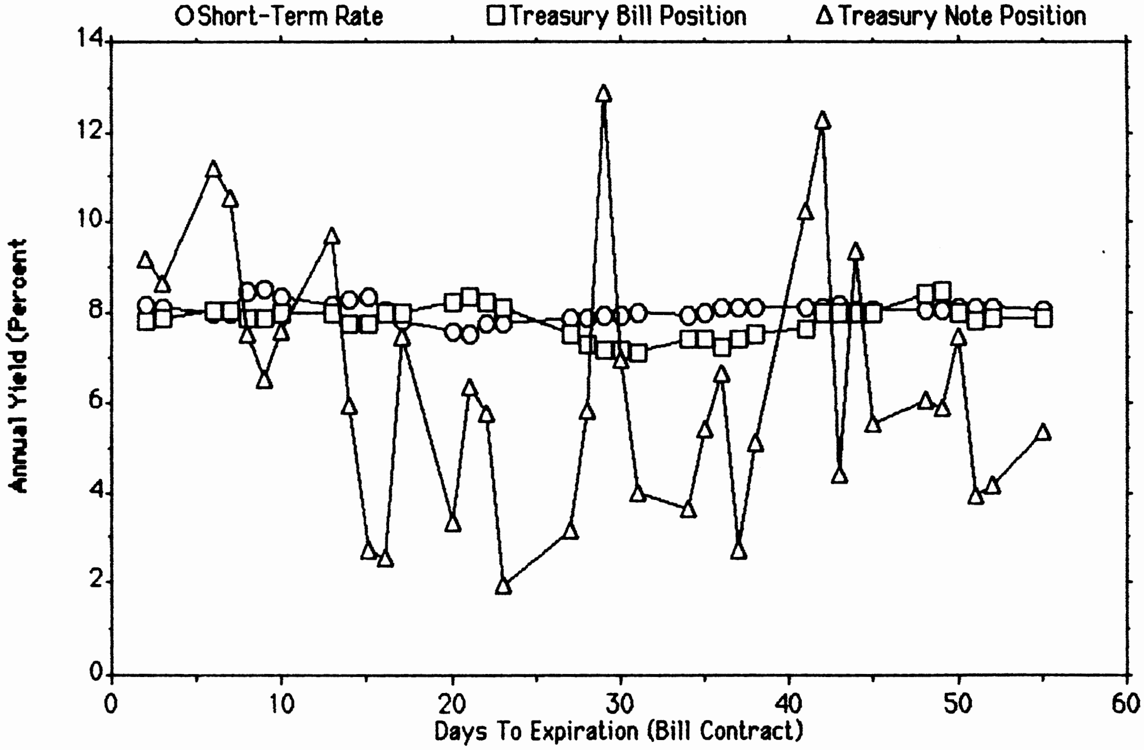
21-Day Early Settlement Yields: December 1982 Contracts

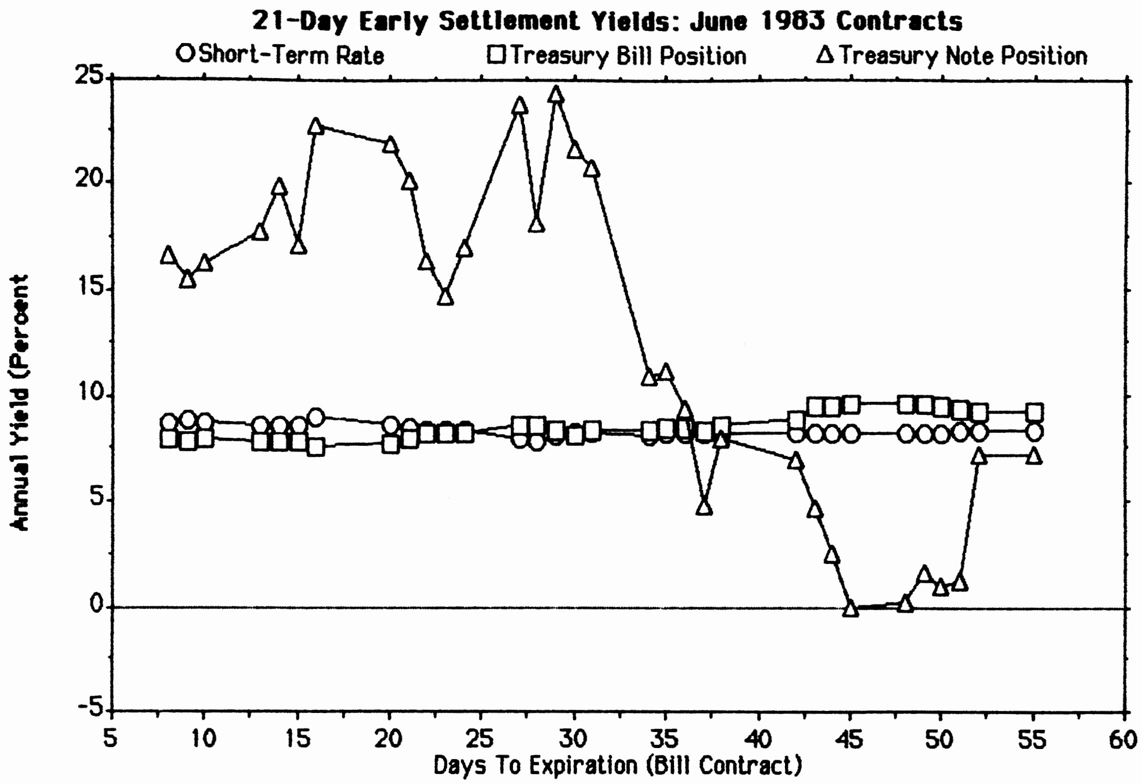
O Short-Term Rate □ Treasury Bill Position Δ Treasury Note Position

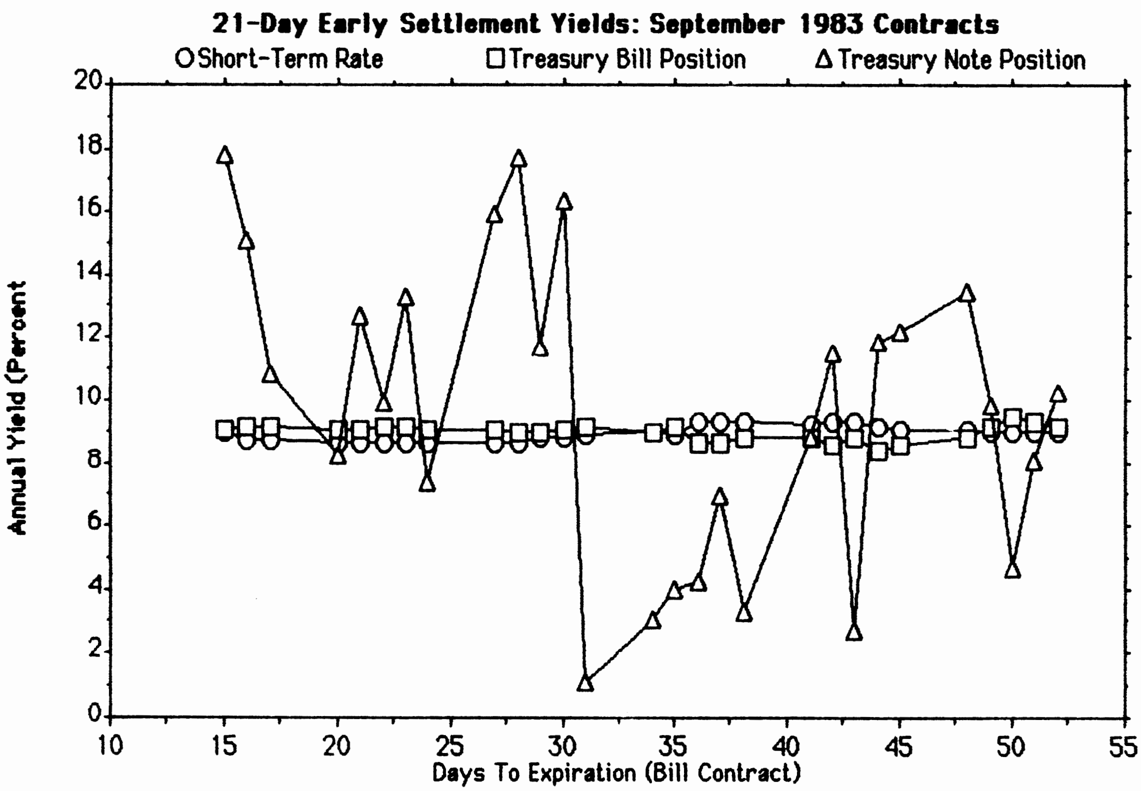


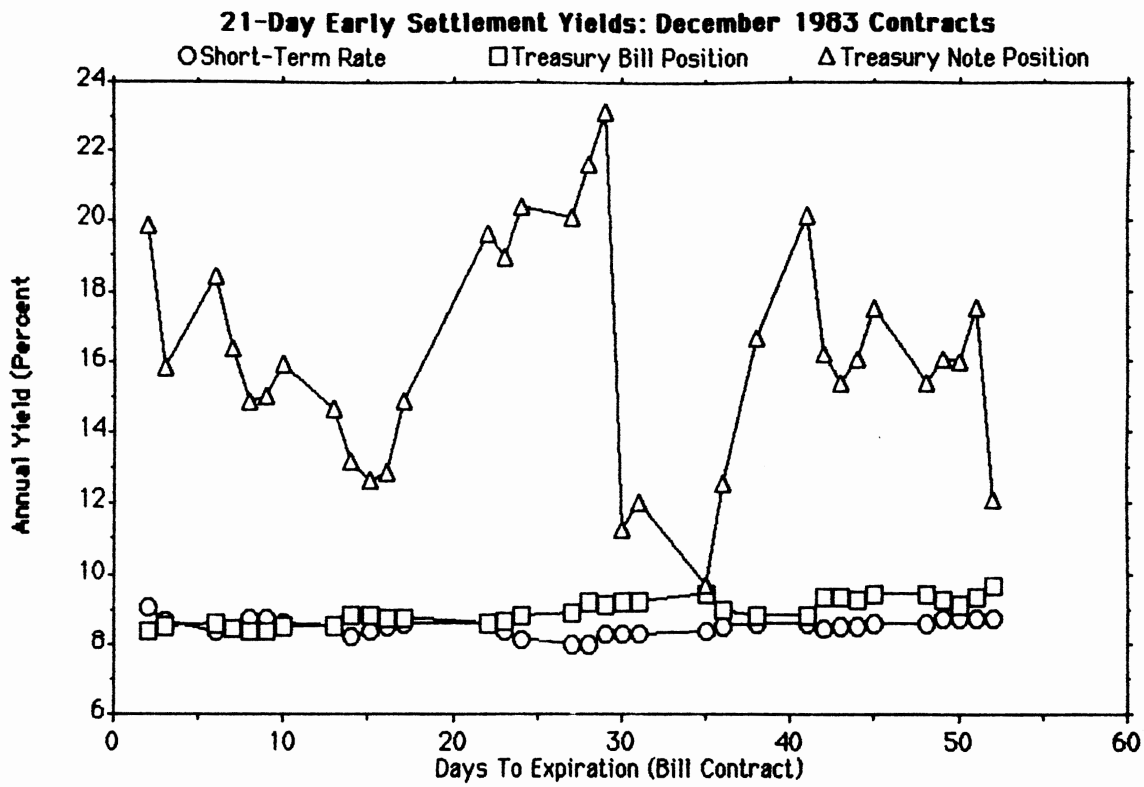
21-Day Early Settlement Yields: March 1983 Contracts

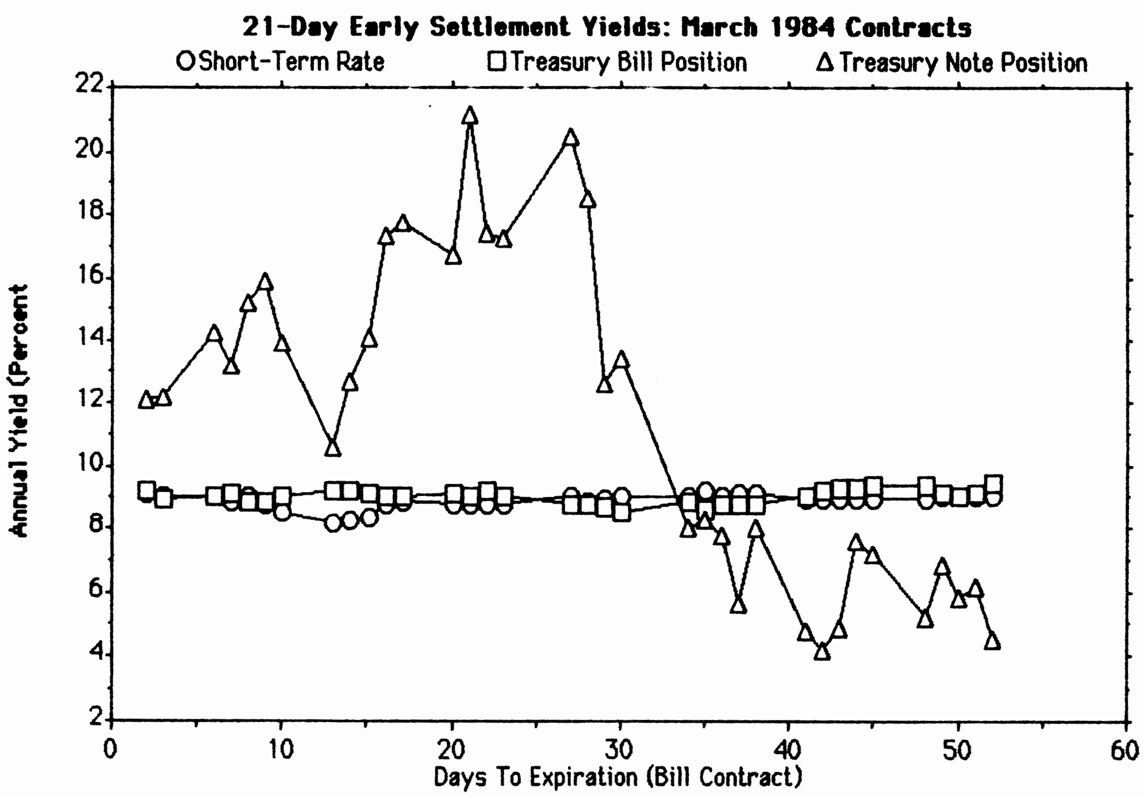
O Short-Term Rate □ Treasury Bill Position Δ Treasury Note Position



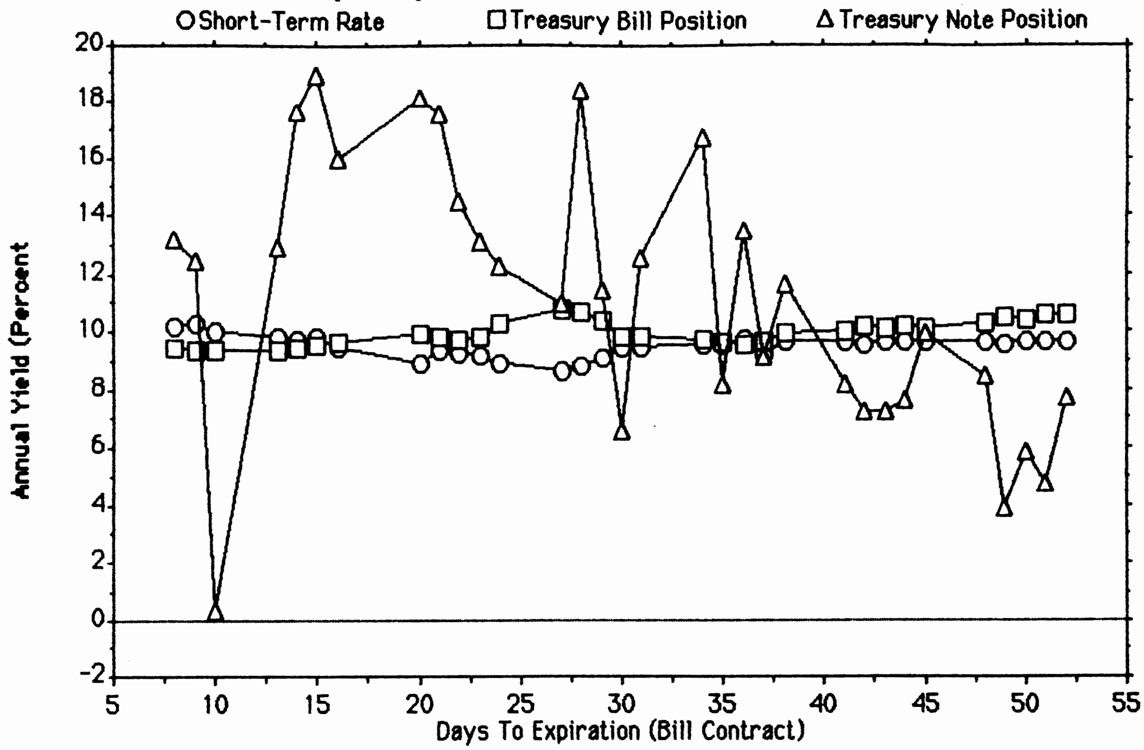

21-Day Early Settlement Yields: June 1983 Contracts
Short-Term Rate
Treasury Bill Position
Treasury Note Position
Annual Yield (Percent
Days To Expiration (Bill Contract)


21-Day Early Settlement Yields: September 1983 Contracts
Short-Term Rate
Treasury Bill Position
Treasury Note Position
Annual Yield (Percent
Days To Expiration (Bill Contract)

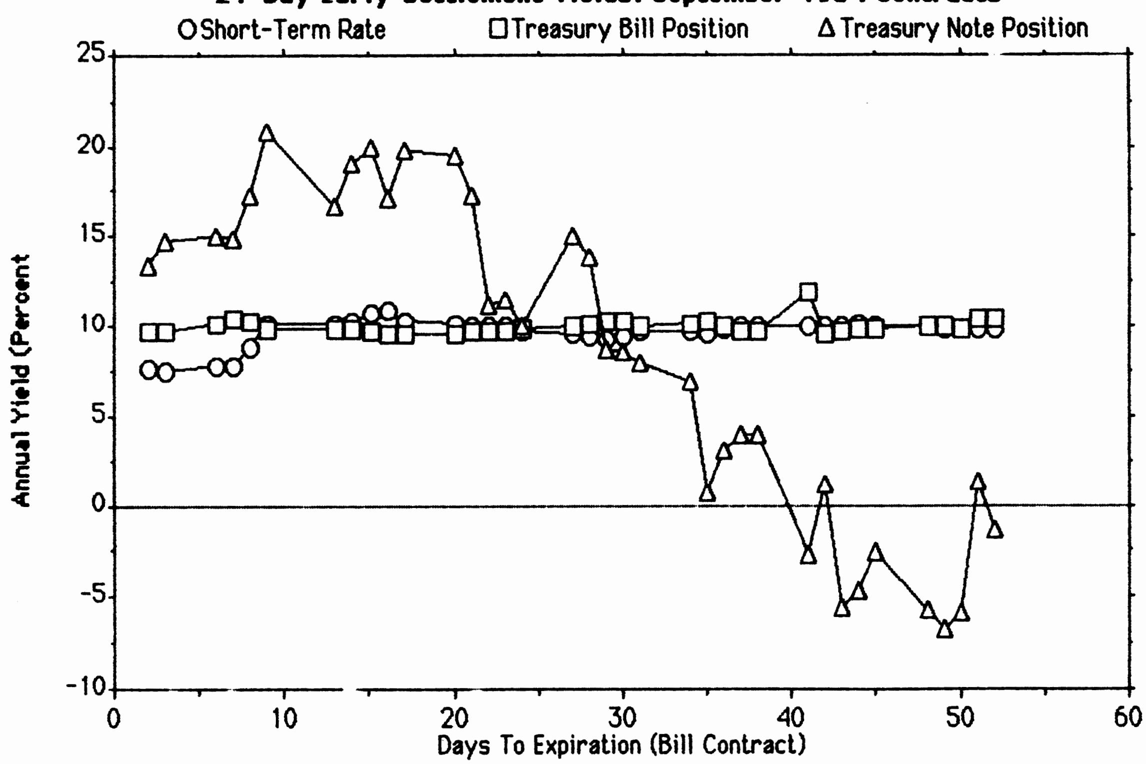

21-Day Early Settlement Yields: December 1983 Contracts
O Short-Term Rate
□ Treasury Bill Position
Δ Treasury Note Position
Annual Yield (Percent
24
22
20
18
16
14
12
10
8
6
0
10
20
30
40
50
60
Days To Expiration (Bill Contract)

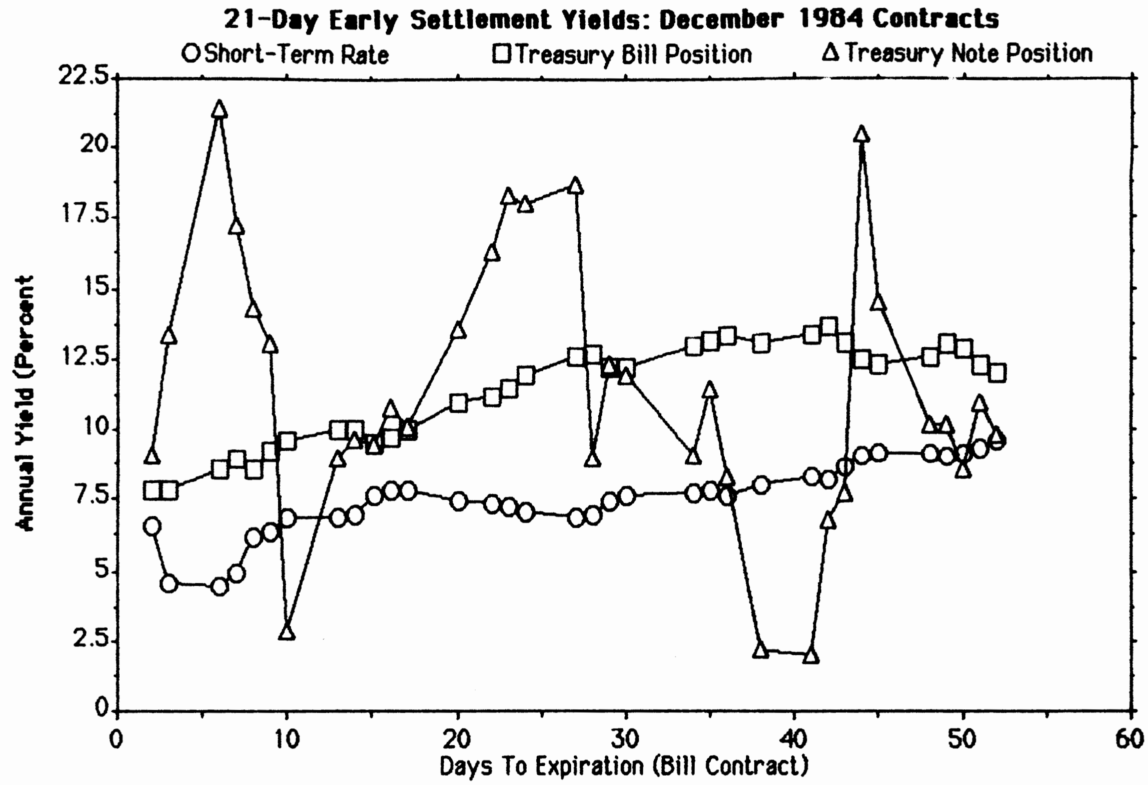

21-Day Early Settlement Yields: March 1984 Contracts
O Short-Term Rate
□ Treasury Bill Position
Δ Treasury Note Position
Annual Yield (Percent
22
20
18
16
14
12
10
8
6
4
2
0
10
20
30
40
50
60
Days To Expiration (Bill Contract)

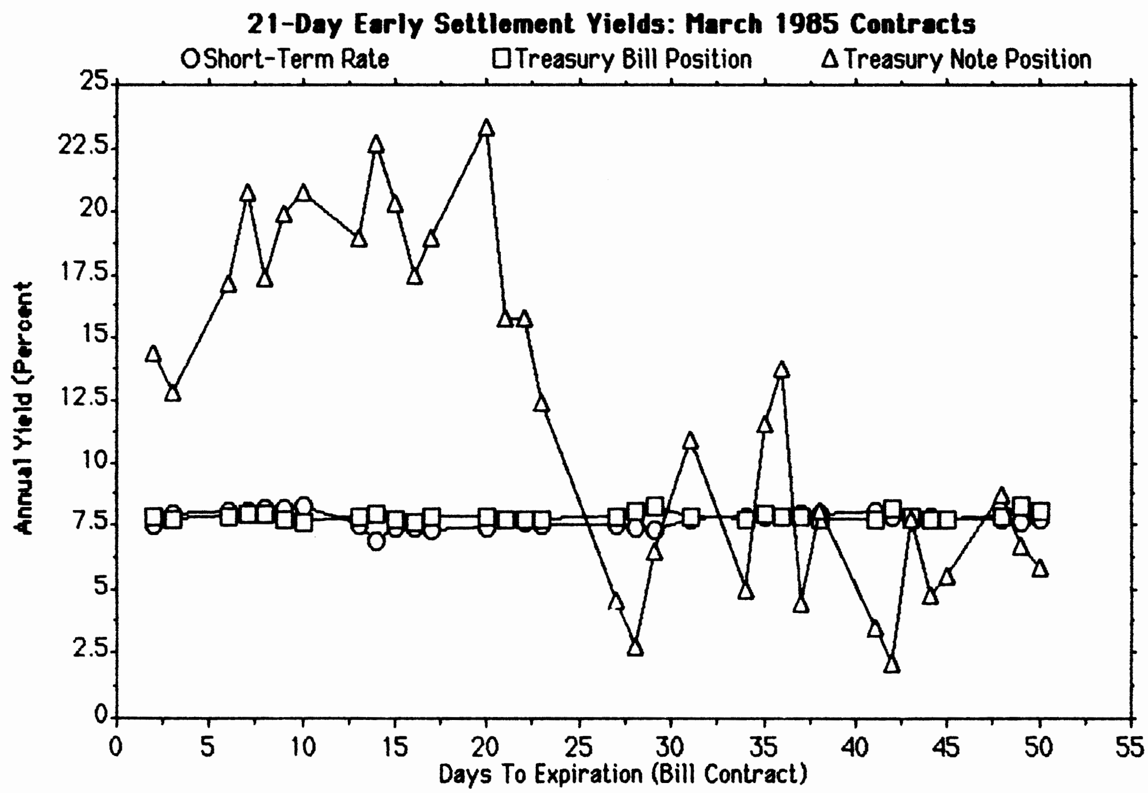
21-Day Early Settlement Yields: June 1984 Contracts

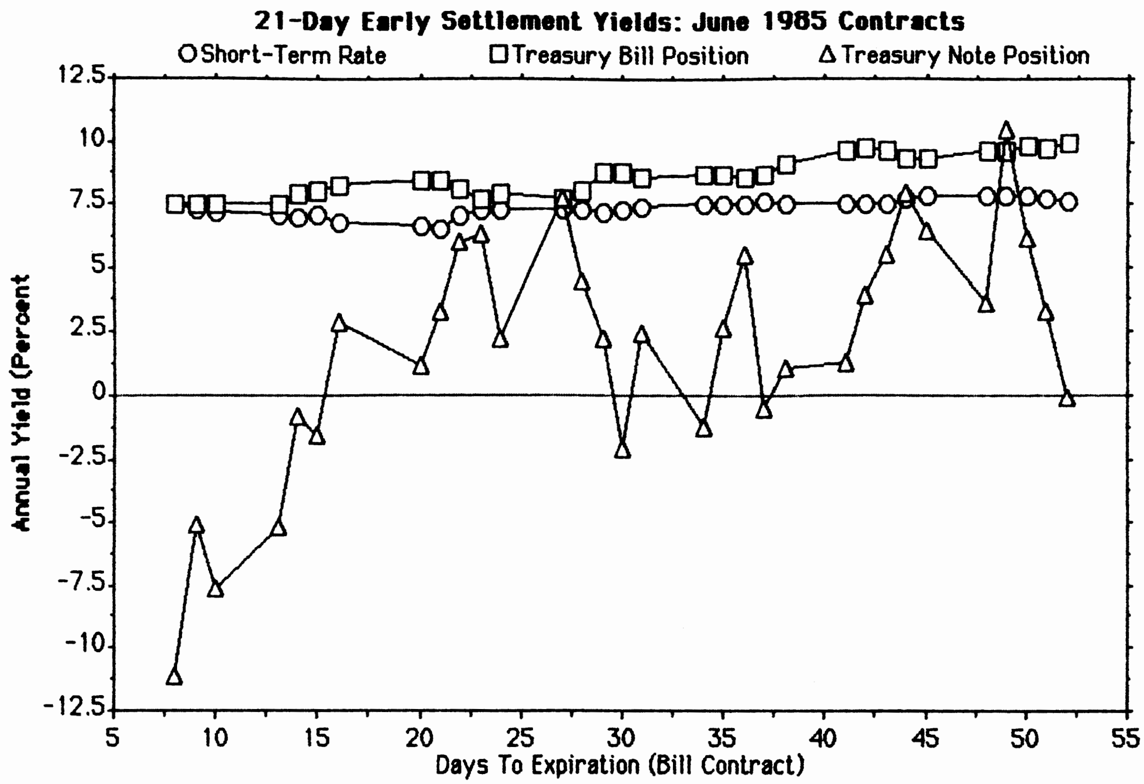


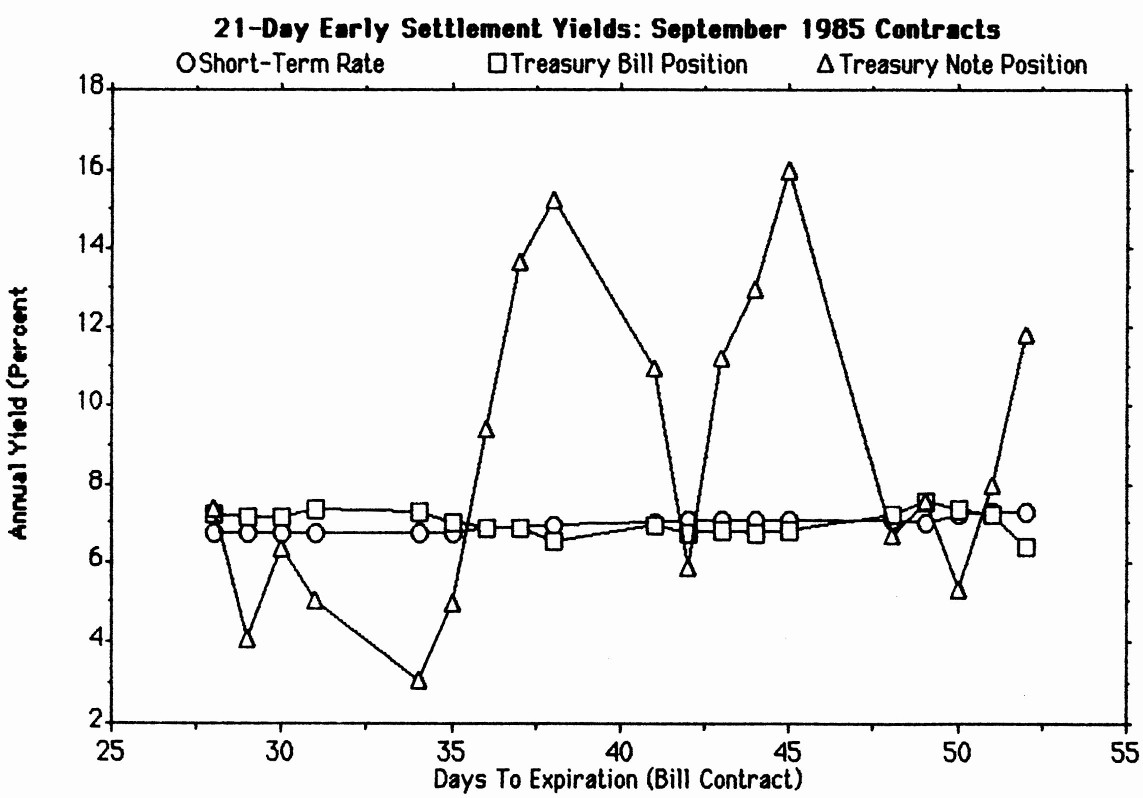
21-Day Early Settlement Yields: September 1984 Contracts




21-Day Early Settlement Yields: December 1984 Contracts
O Short-Term Rate
□ Treasury Bill Position
Δ Treasury Note Position
Annual Yield (Percent
Days To Expiration (Bill Contract)
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
0
10
20
30
40
50
60


21-Day Early Settlement Yields: March 1985 Contracts
O Short-Term Rate
□ Treasury Bill Position
Δ Treasury Note Position
Annual Yield (Percent
Days To Expiration (Bill Contract)
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
0
5
10
15
20
25
30
35
40
45
50
55


21-Day Early Settlement Yields: June 1985 Contracts
Short-Term Rate
Treasury Bill Position
Treasury Note Position
Annual Yield (Percent
Days To Expiration (Bill Contract)


21-Day Early Settlement Yields: September 1985 Contracts
Short-Term Rate
Treasury Bill Position
Treasury Note Position
Annual Yield (Percent
Days To Expiration (Bill Contract)

APPENDIX G

YIELDS FROM STRATEGIES I AND IA SETTLED EARLY:

TREASURY BILL AND TREASURY

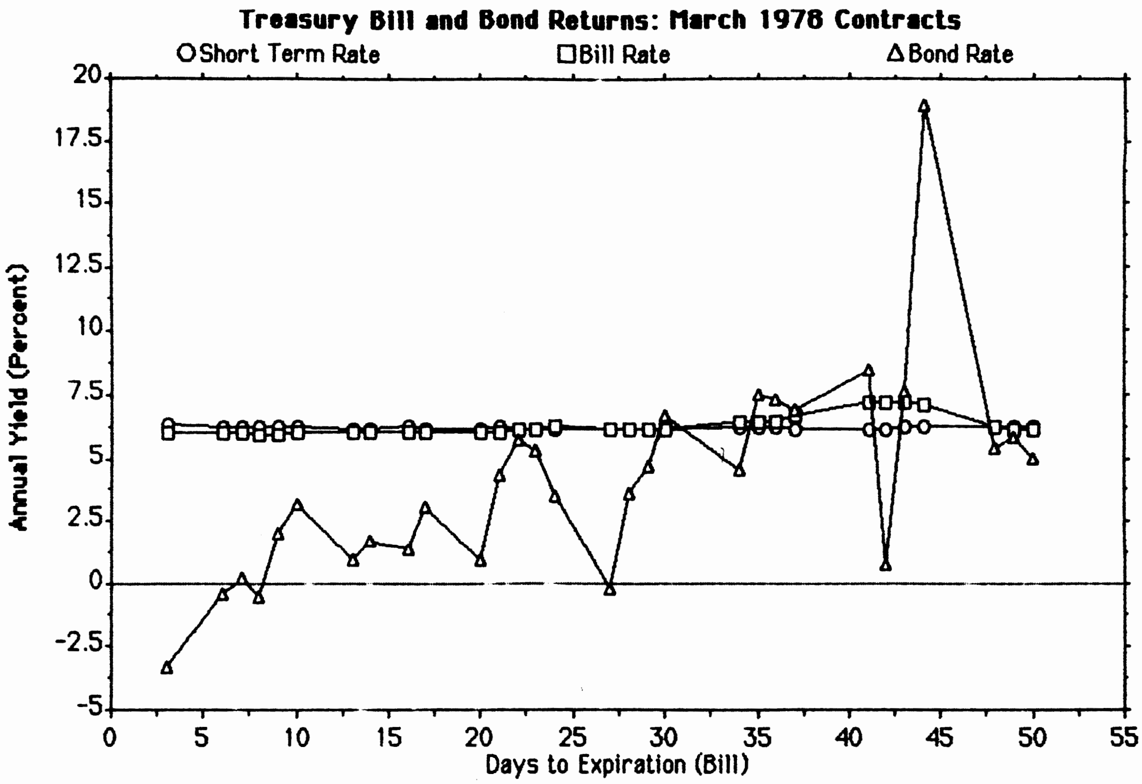
BOND CONTRACTS.

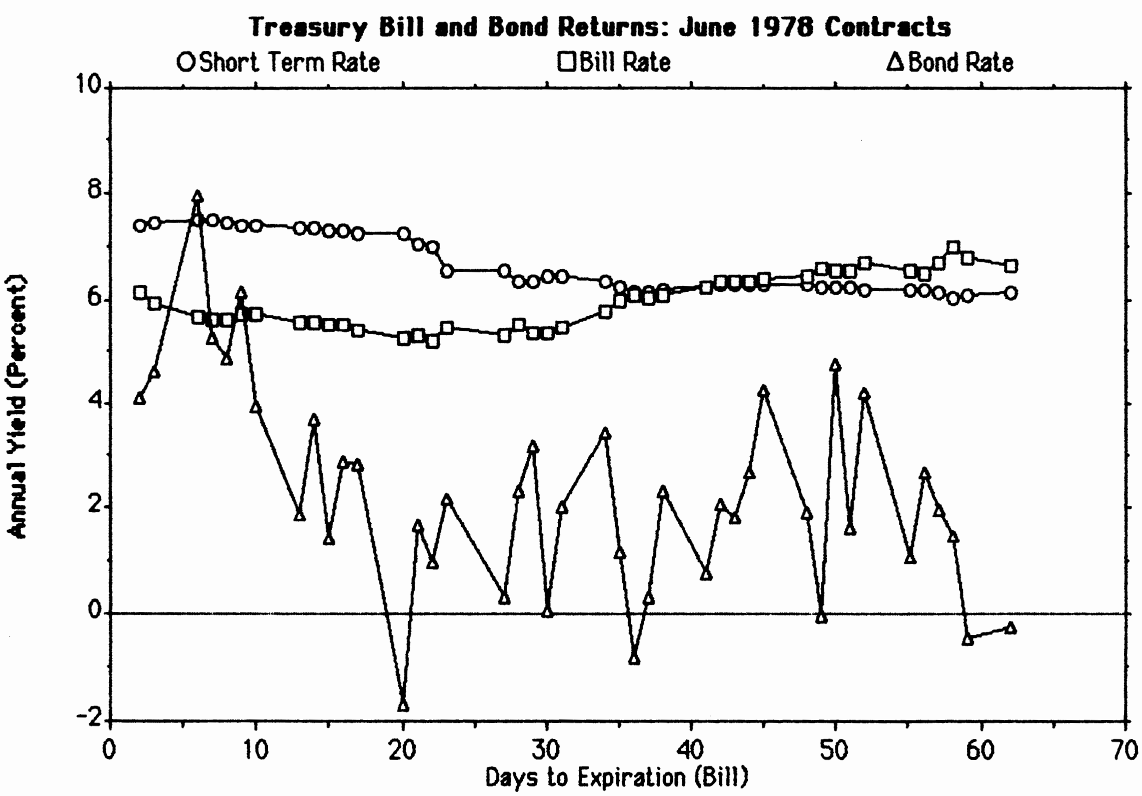
Prospective annual yield from outright purchase of a short term Treasury bill (Short Term Rate); actual annual yield from purchase of a Treasury bill and short Treasury bill contract position (Bill Rate); and actual annual yield from purchase of a Treasury bond and short Treasury bond contract position (Bond Rate).

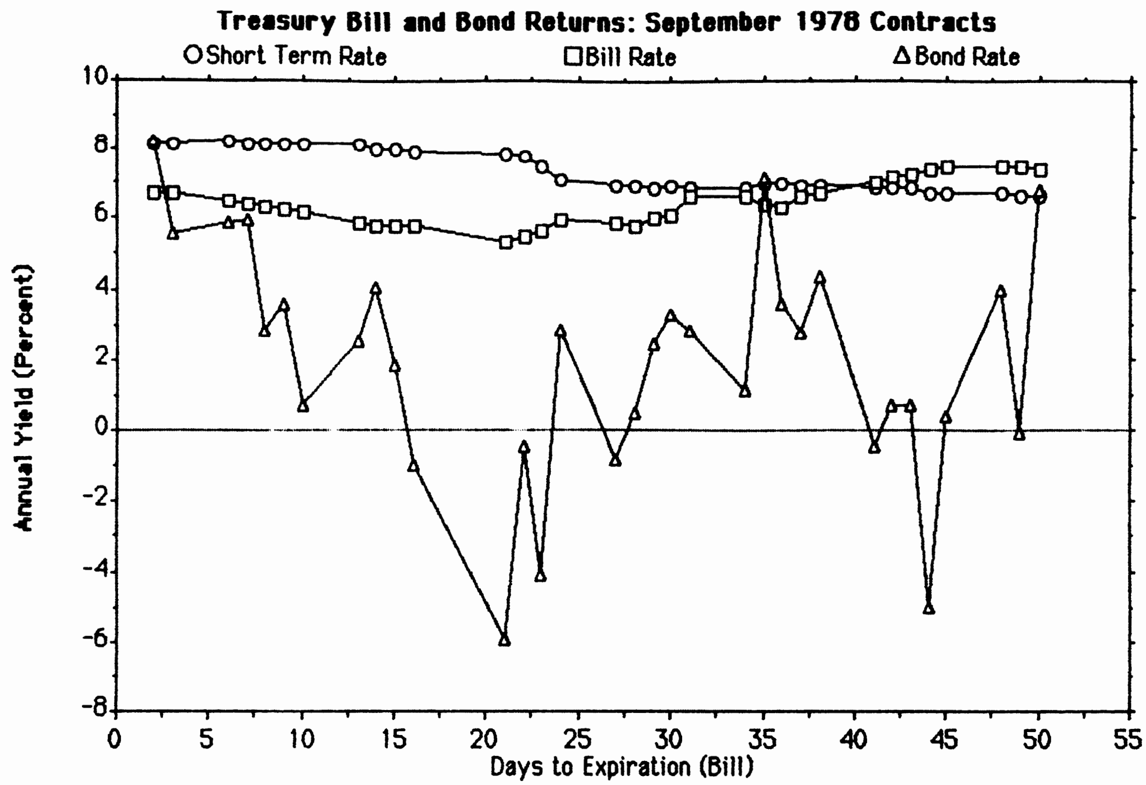
<u>Sample Interval</u>:	Daily.	
<u>Sample Duration</u>:	March, 1978 contract through June, 1981 contract.	
<u>Source of Data</u>:	Futures Contracts:	Chicago Board of Trade, and Wall Street Journal.
	Treasury Bill:	Wall Street Journal.
	Treasury Bond:	Compuserve Information Services

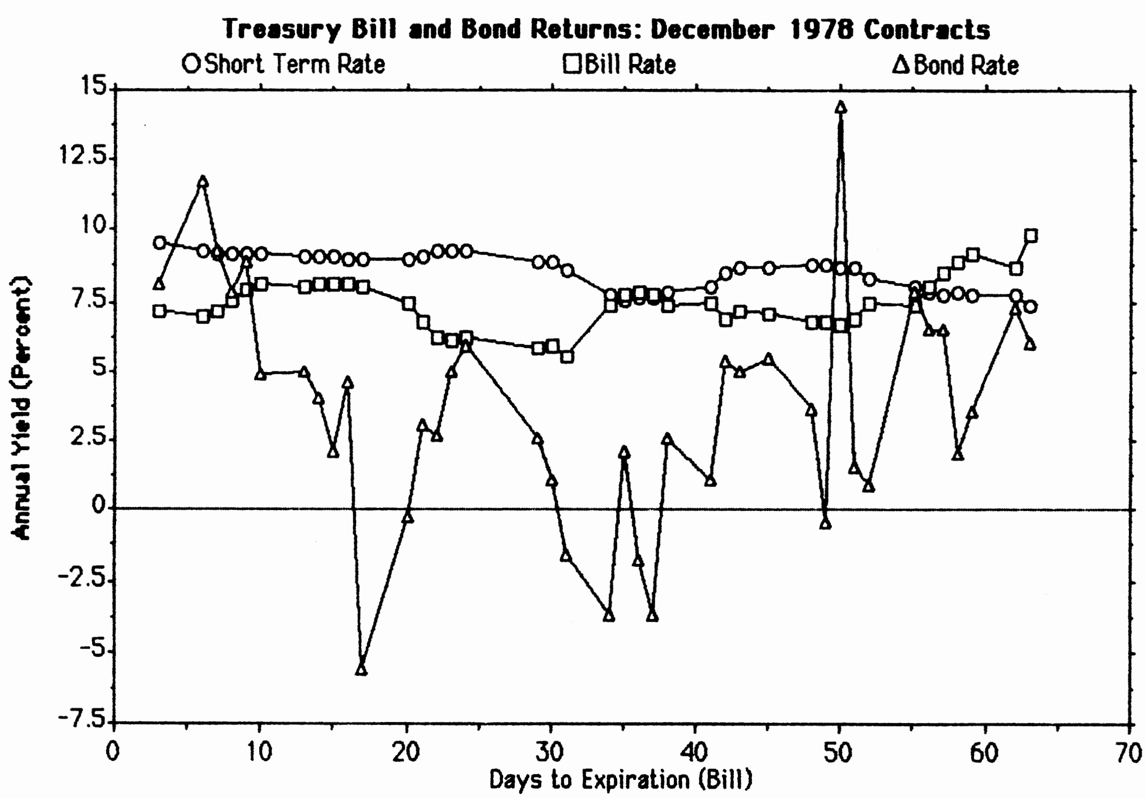
<u>Description</u>: This appendix shows the annualized yield from three investment strategies: outright purchase and maturation of a Treasury bill (Short Term Rate), the simultaneous purchase of a deliverable Treasury bill and sale of a matching futures contract (Bill Rate), and the simultaneous purchase of a deliverable Treasury bond and sale of a matching futures contract (Bond Rate). Yields are calculated by dividing the actual dollar profit by the actual dollar cost, and annualizing by multiplying by the ratio of the number of days per year (365) to the number of days in the holding period. The holding period is 21 business days. Costs include payment of commission ($60) and margin ($1,500) while the contract is in force. Margin is returned at settlement. The two yields are equivalent to the yields from Strategy I and Strategy IA, assuming early settlement of the

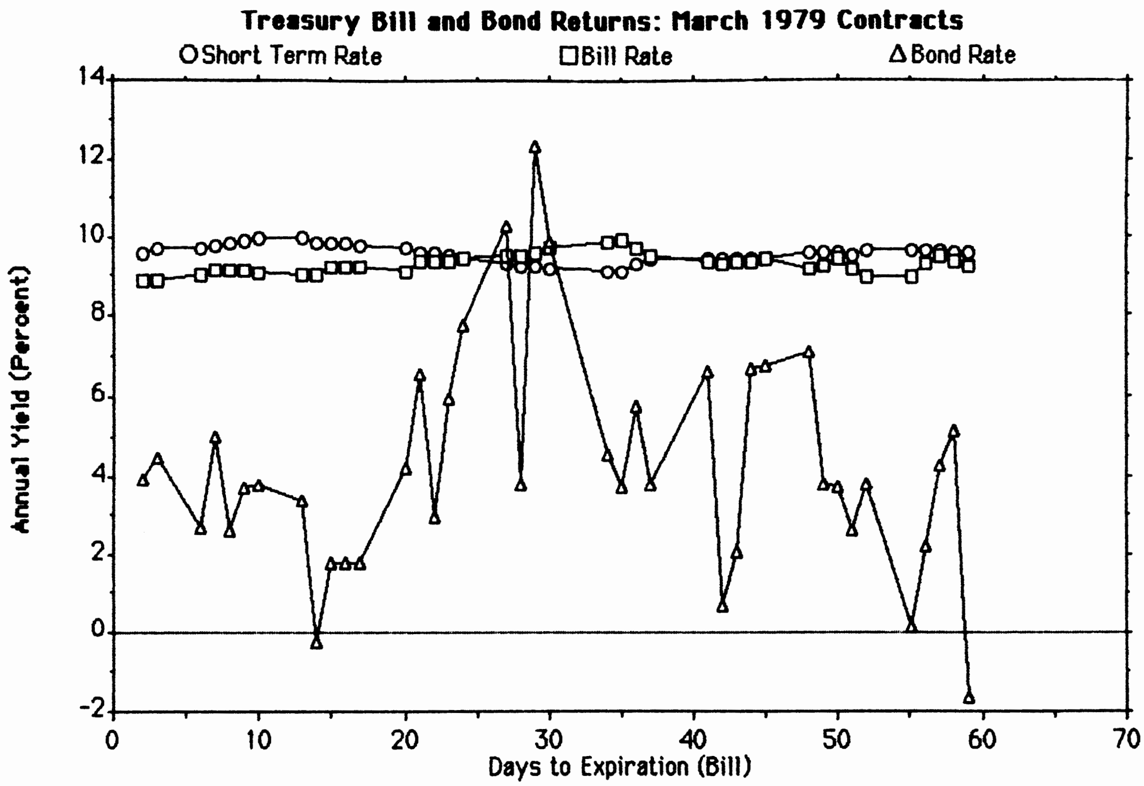
position (see Section II, Tables 1-3 in the text). The Treasury bill that is assumed to be purchased and held until settlement is the bill that is deliverable at contract expiration. The Treasury bond is the August, 1996-2001 8% bond. It is not the cheapest-to-deliver against the bond contract, but does fulfill the Chicago Board of Trade delivery conditions.

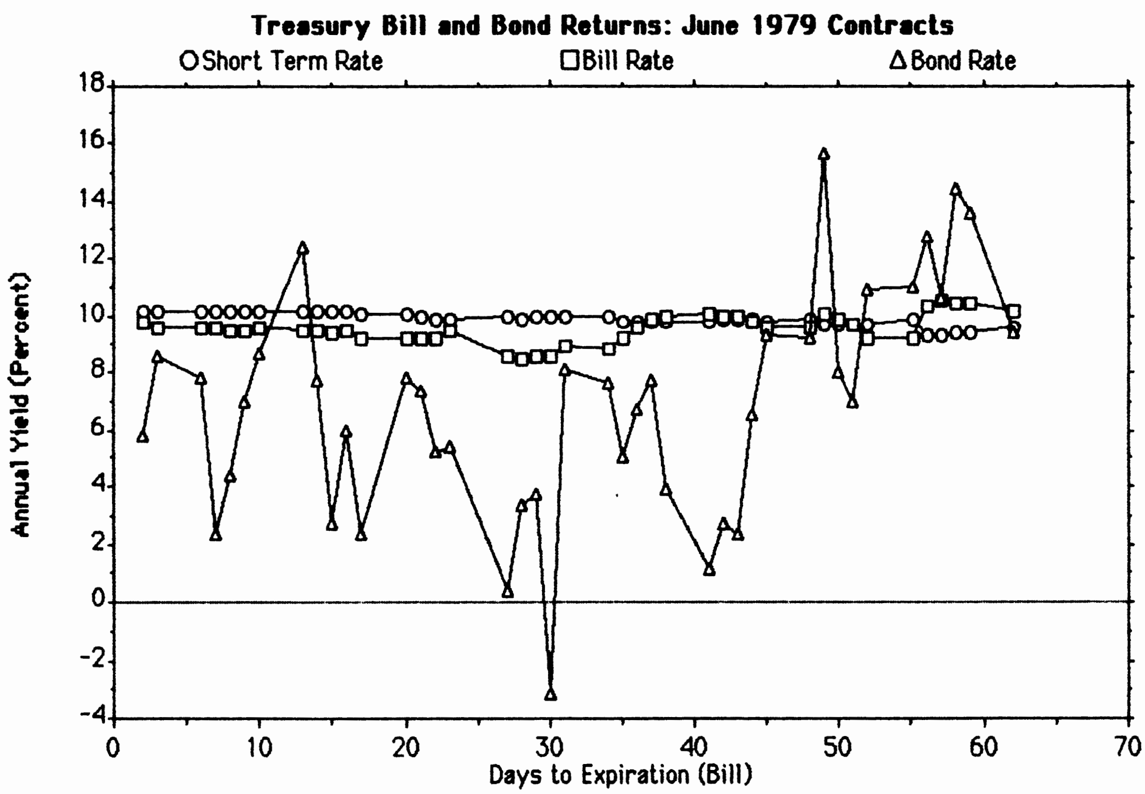

Treasury Bill and Bond Returns: March 1978 Contracts
Short Term Rate
Bill Rate
Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)
20
17.5
15
12.5
10
7.5
5
2.5
0
-2.5
-5
0
5
10
15
20
25
30
35
40
45
50
55

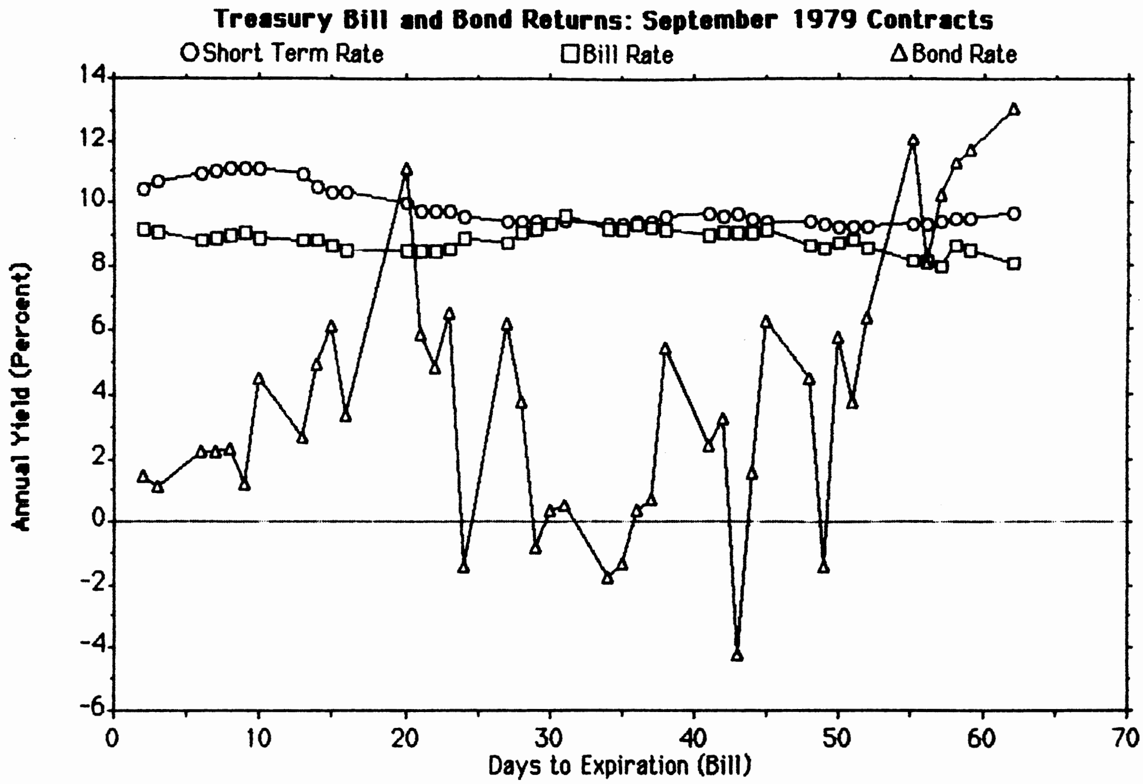

Treasury Bill and Bond Returns: June 1978 Contracts
Short Term Rate
Bill Rate
Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
70

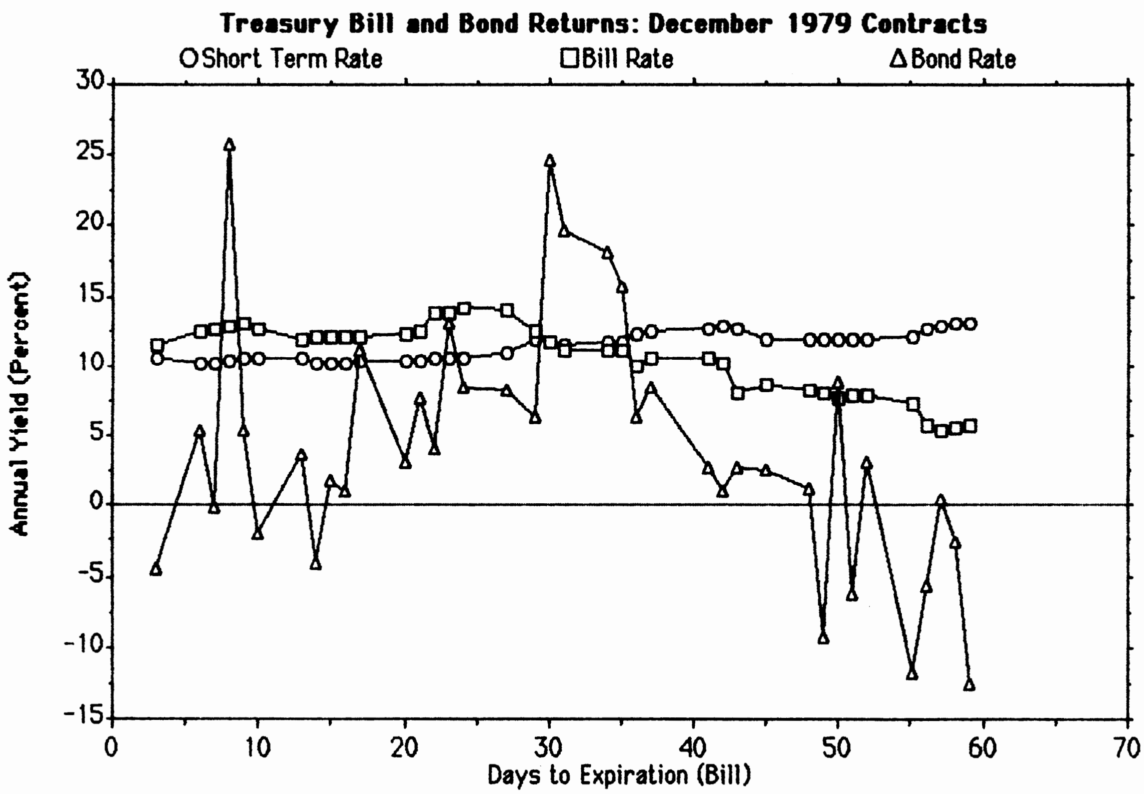

Treasury Bill and Bond Returns: September 1978 Contracts
Short Term Rate
Bill Rate
Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)

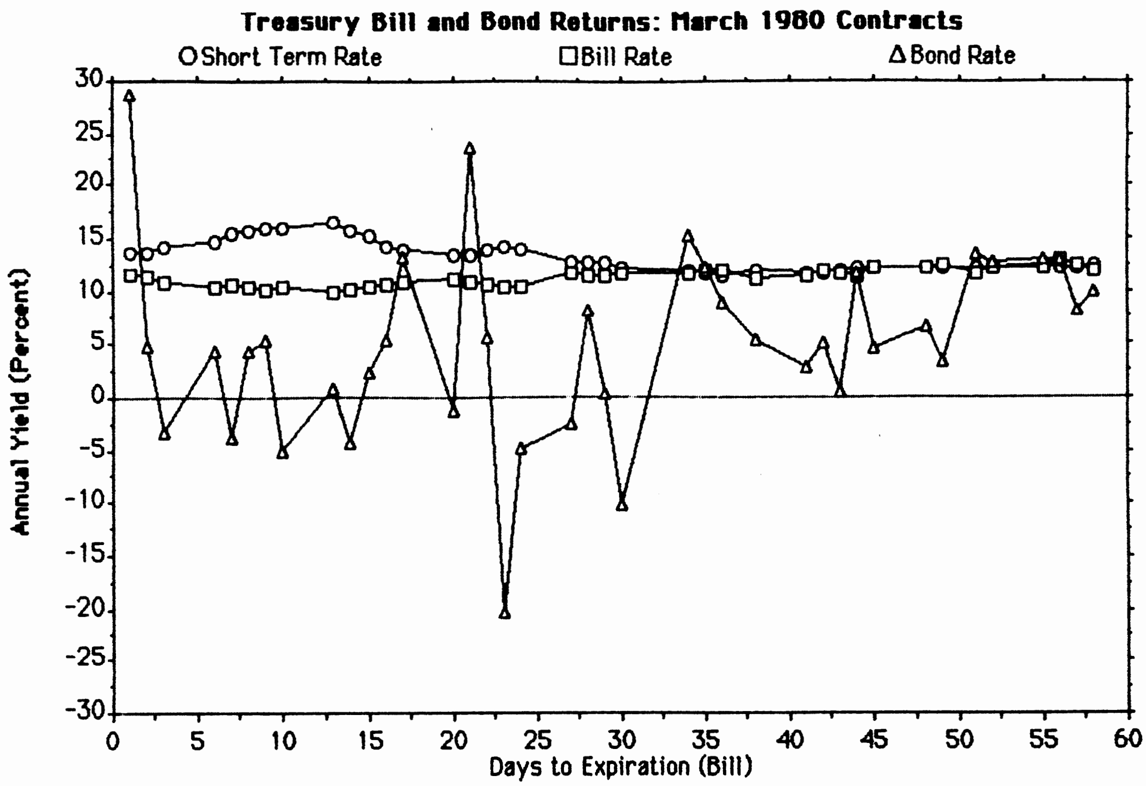

Treasury Bill and Bond Returns: December 1978 Contracts
Short Term Rate
Bill Rate
Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)

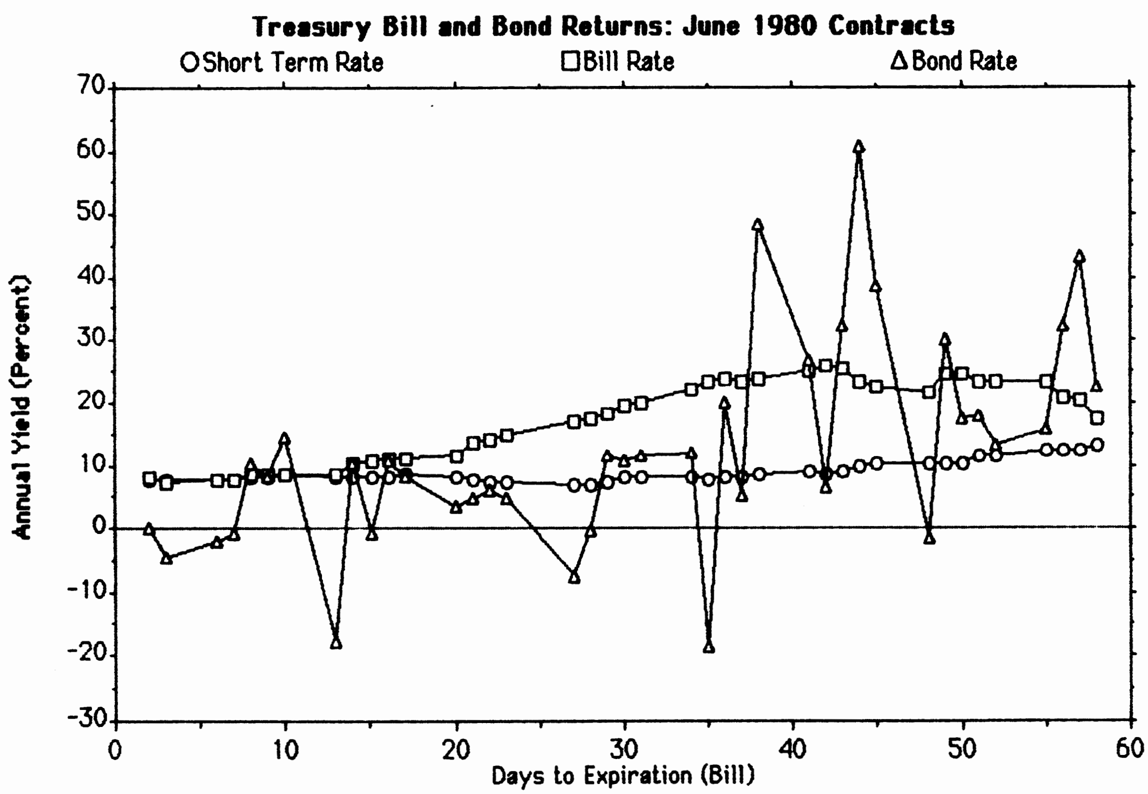

Treasury Bill and Bond Returns: March 1979 Contracts
○Short Term Rate
□Bill Rate
ΔBond Rate
Annual Yield (Percent)
Days to Expiration (Bill)
14
12
10
8
6
4
2
0
-2
0
10
20
30
40
50
60
70

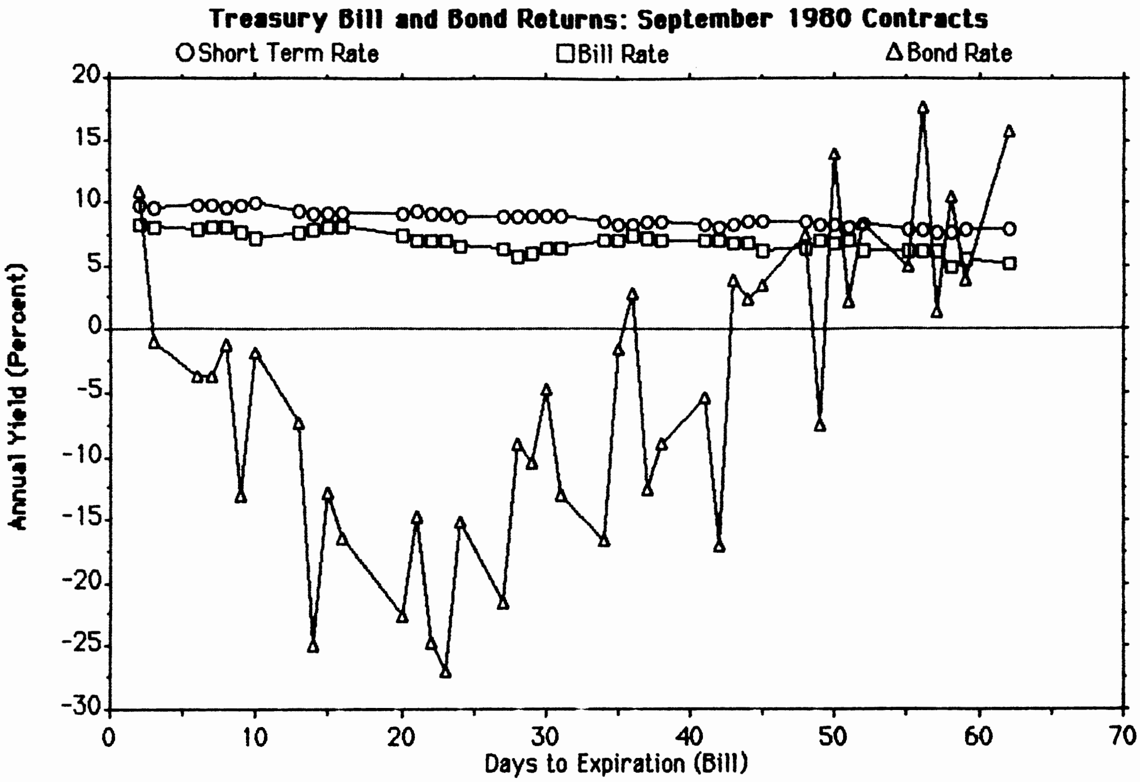

Treasury Bill and Bond Returns: June 1979 Contracts
○Short Term Rate
□Bill Rate
ΔBond Rate
Annual Yield (Percent)
Days to Expiration (Bill)
18
16
14
12
10
8
6
4
2
0
-2
-4
0
10
20
30
40
50
60
70

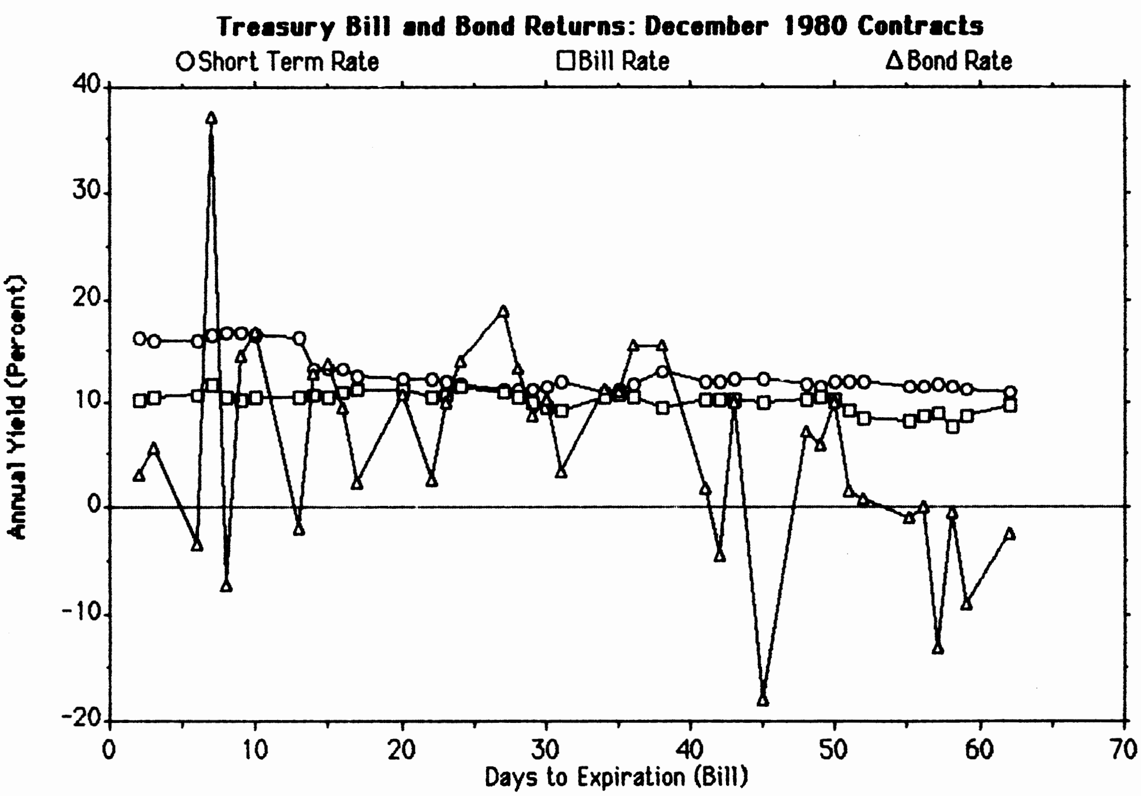

Treasury Bill and Bond Returns: September 1979 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
14
12
10
8
6
4
2
0
-2
-4
-6
0
10
20
30
40
50
60
70
Days to Expiration (Bill)

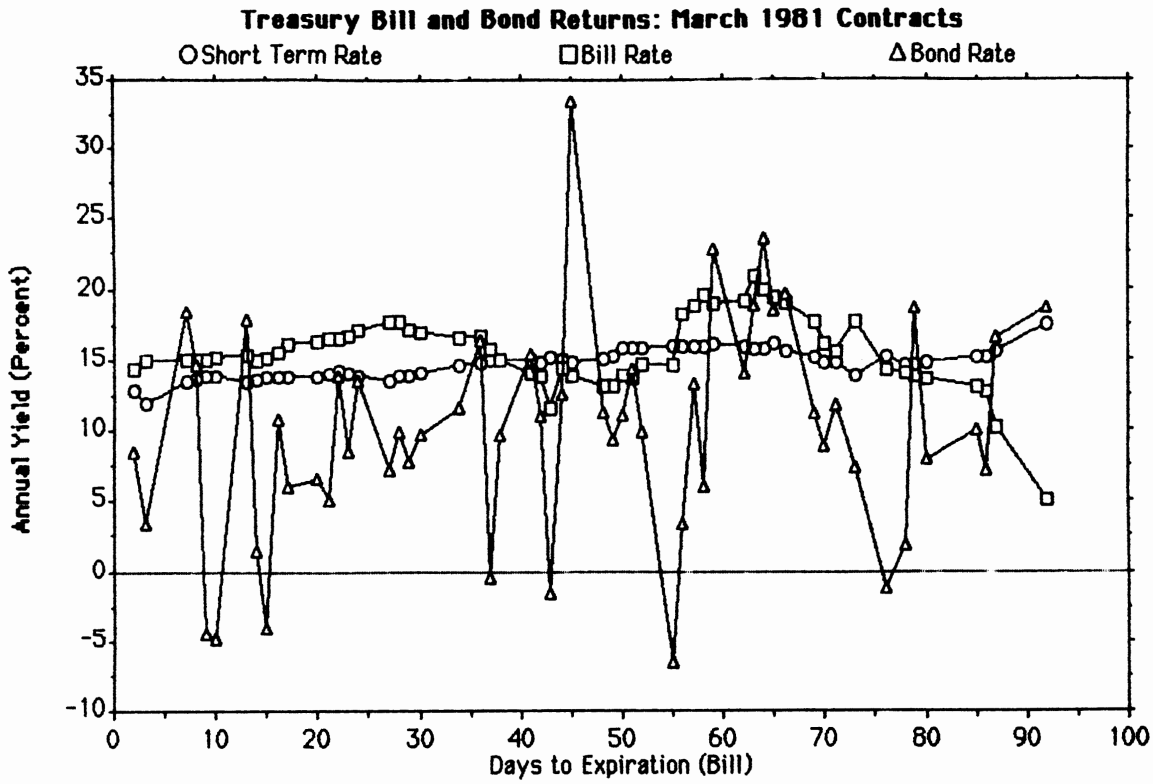

Treasury Bill and Bond Returns: December 1979 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
30
25
20
15
10
5
0
-5
-10
-15
0
10
20
30
40
50
60
70
Days to Expiration (Bill)


Treasury Bill and Bond Returns: March 1980 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)

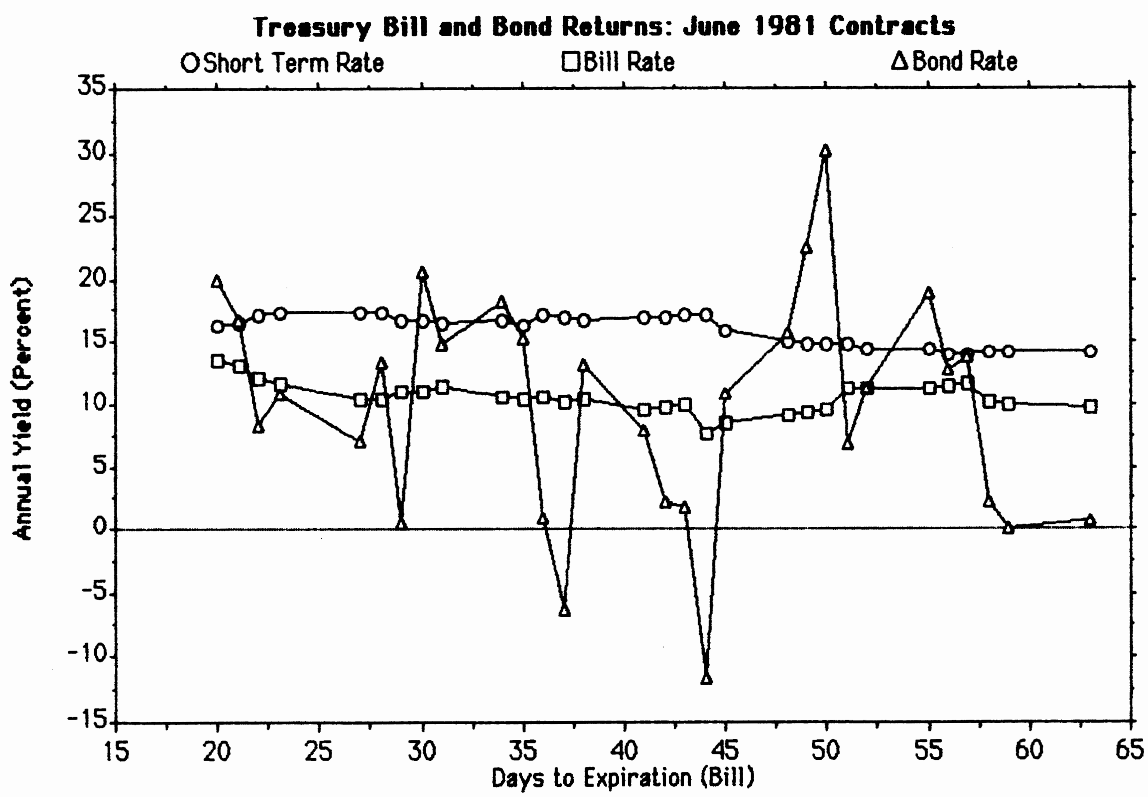

Treasury Bill and Bond Returns: June 1980 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)


Treasury Bill and Bond Returns: September 1980 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)
20
15
10
5
0
-5
-10
-15
-20
-25
-30
0
10
20
30
40
50
60
70


Treasury Bill and Bond Returns: December 1980 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70



Treasury Bill and Bond Returns: March 1981 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)



Treasury Bill and Bond Returns: June 1981 Contracts
O Short Term Rate
□ Bill Rate
Δ Bond Rate
Annual Yield (Percent)
Days to Expiration (Bill)

VITA

Ralph Clarence Gamble, Jr.

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Doctor of Philosophy

Dissertation: THE EFFICIENCY OF FINANCIAL FUTURES MARKETS

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