1-1-1980

Hedging effectiveness and market efficiency of financial futures.

Shantaram P. Hegde
University of Massachusetts Amherst

HEDGING EFFECTIVENESS AND MARKET EFFICIENCY OF FINANCIAL FUTURES

A Dissertation Presented

By

SHANTARAM P. HEGDE

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

February 1980

Business Administration

HEDGING EFFECTIVENESS AND MARKET EFFICIENCY
OF FINANCIAL FUTURES

A Dissertation Presented

By

Shantaram P. Hegde

Approved as to style and content by:

Joseph E. Finnerty, Chairman

Ben Branch, Member

Alan Gleit, Member

Thomas Schneeweis, Member

Donald G. Frederick
Director of the Doctoral Program
School of Business Administration

ACKNOWLEDGEMENTS

I have received valuable help from many sources in successfully completing this dissertation. The rigorous training during the first two years of the doctoral program provided me with the necessary background to undertake this project. The teaching associateship offered by the Director of Doctoral Studies was particularly useful in meeting the financial obligations underlying this research effort.

The active and supportive role played by the Dissertation Committee deserves special mention. Their periodic review and constructive feedback have contributed immeasurably to the quality of this work. The Chairman, Joe Finnerty, has been particularly helpful in tying together the various parts and improving the presentation of the material. Without his continual prodding and prompt feedback, it would have taken probably another semester to complete this project.

I am highly indebted to Ben Branch for the long hours he spent with me discussing the various aspects of financial futures markets. These discussions and the critical reviews he offered on the several drafts of the thesis have been highly instructive and inspiring. I have drawn heavily from his expertise in writing up the empirical analysis on market efficiency of financial futures. The guidance he provided has added immeasurably to the form and substance of the dissertation.

Alan Gleit has contributed considerably to the statistical awareness and sophistication exhibited in this study. The statistical analysis employed herein benefited significantly from his expertise. Tom

Schneeweis has helped me with various issues relating to spot markets in debt securities. I am thankful to Ram Mukund for his friendly programming assistance.

ABSTRACT

Hedging Effectiveness and Market Efficiency of
Financial Futures

(February 1980)

Shantaram P. Hegde, B.Com., Karnatak University, India
M.Com., Karnatak University, India, Ph.D., University of Massachusetts

Directed by: Professor Joseph E. Finnerty

Since the late 1960s interest rates in the United States have been generally rising and growing in volatility. Such a behavior of interest rates exposes the borrowers and lenders in the money and capital markets to increasingly uncertain costs and returns. Hedging is a traditional mechanism of dealing with the risk stemming from uncertain price movements. To provide hedging facilities to borrowers and lenders in the mortgage market, the GNMA futures market was first established in late 1975. This was followed by the addition of futures contracts in short-, intermediate-, and long-term Treasury securities and 90-day commercial paper.

The phenomenal growth registered by the financial futures markets raises several interesting issues. In particular, one wonders about their hedging effectiveness, hedging costs, market efficiency, impact on spot market prices, etc. The basic objectives of this investigation are to examine the following issues concerning the functioning of futures markets in 3-month T bills (of the Chicago Board of Trade), 15-year government bonds, and 8 percent GNMAs (both of the Chicago Board of Trade) during the period from January 1976 to April 1979:

1. Hedging effectiveness. How effective are the financial futures instruments in reducing the interest rate risk associated with a wide spectrum of spot market securities?

2. Hedge ratio. How many futures contracts should an investor intending to minimize the interest rate risk sell relative to a given investment in spot securities?

3. Market efficiency. Is it possible for an investor maintaining a continuously adjusted portfolio of short and long positions in futures and spot instruments to earn a rate of return that is consistently higher than the riskless rate?

To examine the first proposition a hedging model has been developed. The model reveals that hedging effectiveness is a function of the interest rate elasticities of securities and the level and volatility of yields in the spot and futures markets. Based on these premises seven hypotheses embracing the following dimensions have been formulated: term to maturity of spot securities; level of default-risk; coupon effect; delivery period; form of cash security; individual securities vs. portfolios; and bond futures vs. GNMA futures. The basic theme underlying these hypotheses is that hedging effectiveness of financial futures varies directly with the interest rate elasticities of spot and futures instruments and the comovement of yield changes in the two markets.

The second proposition on the hedge ratio has been analyzed by extending the hedging model to examine the relative volatility of spot and futures prices. The model indicates that the futures prices are more volatile than the spot prices given the credit risk, coupon, term, and yield to maturity. This suggests that the risk-minimizing hedge ratio is generally less than unity.

To evaluate the hypotheses mentioned above the simple regression of cash price changes against futures price changes has been employed.

Further, the proposition on market efficiency has been examined by comparing the weekly holding period returns on the hedged portfolios of futures instruments and their underlying spot securities with the riskless rate.

The empirical results strongly support the hypothesis that hedging effectiveness varies directly with the interest rate elasticities of spot and futures instruments and the comovement of yield changes in the two markets. The hypothesis that the risk-minimizing hedge ratio is generally less than unity is also well supported. The empirical results seem to reject the hypothesis that the T bill futures and the bond futures markets were efficient during the study period. While the evidence on the efficiency of the GNMA futures market is mixed, it appears that the level of mispricing obtaining during the period covered by the investigation was large enough to allow one to construct different trading strategies that would have produced returns consistently in excess of the accompanying market risk.

The theoretical model and the empirical findings of this research effort are believed to be of use to the investors in making informed and effective hedging decisions. Moreover, they offer potentially useful guidance to the managements of futures exchanges and the regulators of futures industry in determining the optimal terms to maturity of futures instruments, number and spacing of delivery periods, coupon rates, and variety of instruments.

TABLE OF CONTENTS

LIST OF TABLES

Table

CHAPTER I

INTRODUCTION

Interest Rate Risk

Until the late 1960s interest rates were relatively low and stable, but since then have been generally rising and increasing in volatility. The relatively higher level and volatility of interest rates confronts borrowers and lenders in the credit and capital markets with costs and returns of varying degrees of uncertainty.

An investor's interest rate exposure depends upon the type of financial instrument he or she holds. In the simple case of a zero-coupon bond the price falls with rising interest rates, and appreciates when rates decline. Such a capital loss or gain on a zero-coupon bond due to interest rate fluctuations is commonly called "price risk."

In addition to price risk the holder of a coupon-bond is also exposed to "reinvestment rate risk." When interest rates go up the price of a coupon bond falls as before, but now the investor has an opportunity to reinvest the coupon receipts at higher rates. Conversely, with a decline in interest rates, the price of a coupon-bond appreciates in value but the investor is faced with lower rates for the reinvestment of coupon payments. The overall effect of price risk and reinvestment rate risk associated with a coupon-bond is commonly known as "interest rate risk" or "basis risk."[1] Both common and preferred stocks are also exposed to interest risk as are quite a number of other securities such as mutual fund shares, unit investment trusts, annuities and mortgages.

The interest rate risk of financial instruments is determined by a number of factors, such as the level of default risk, term to maturity, coupon, call provisions, dividend policy, and growth of earnings. A common measure of the interest rate risk exposure of a security is its duration. Briefly stated, duration is the weighted average maturity of a financial instrument, with the present value of cash flows used as weights.

Coping with Interest Rate Risk

The investor may adopt several strategies to reduce his (her) exposure to interest rate risk. First, he (she) may hold a coupon bond with a term to maturity identical to his (her) planned holding period. This strategy is rather naive because it still exposes the investor to reinvestment rate risk. Moreover, it is impractical for those who have difficulty forecasting their likely holding period. Second, the investor may diversify his (her) investment to include both short- and long-term securities. This strategy provides only partial relief from basis risk as the long-term component is still quite sensitive to interest rate moves. Third, the investor may hold a security or a portfolio whose duration is identical to his (her) planned holding period horizon. This immunizes the investment from interest rate risk under certain conditions and is therefore considered the optimal strategy.[2]

Yet another way of coping with the basis risk is to use the futures market to hedge the spot position. The spot (cash) market is the market for immediate (spot) delivery where the terms of a transaction regarding quality and quantity of the commodity, time of delivery, time and mode of payment, etc. are commonly decided on a case by case basis by the market participants themselves. The futures market, on the other hand, is the market for future (forward) delivery where excepting the price and the number of contracts traded, other terms such as the quality and quantity of the commodity in the contract, the time and place of delivery, and the mode of payment are standardized by the commodity exchange. This market is designed, among other things, to facilitate the shifting of risk due to uncertain spot price movements to speculators. Only a small proportion of transactions in this market is closed out by actual delivery of the commodity. The vast majority are closed out prior to delivery through the use of offsetting transactions.

In a conventional hedge, the investor assumes a position in the futures market of equal quantity but on the opposite side of the market to his (her) spot market position. Since the spot and futures prices typically are positively correlated, the investor's price gain (loss) on the cash position tends to offset the price loss (gain) on the futures position, thus minimizing the basis risk associated with his (her) investment.[3]

Emergence of Financial Futures

Until very recently such hedging could be practiced only in the traditional commodity and currency futures markets. But with the generally increasing level and volatility of interest rates witnessed in the last several years, it became obvious to some market participants the the conventionsl strategies of coping with the basis risk were not adequa te. A futures market in financial instruments was an obvious solution. Specifically, the mortgage industry was the foremost to feel that shocks of volatile interest rate behavior. Accordingly, in October 1975 futures trading was first instituted in the GNMA securities by Chicago Board of Trade (CBT) in order to provide mortgage market participants with a new mechanism to deal with the growing interest rate risk. This institutional innovation was generally well received by the financial community and was soon followed by the addition of the three month T bill futures at the Chicago Mercantile Exchange (CMT) in January 1976. As interest rates continued their upward trend the new futures markets witnessed phenomenal growth. In the latter part of 1977, the CBT began trading contracts in the fifteen-year or longer government bond and the ninety-day commercial paper.

Encouraged by the impressive record of new commodities, the CBT and the CMT respectively added one year T bills and certificate delivery GNMAs to the futures list in 1978, while the Amex Commodities Exchange (ACE) joined the futures network with trading in GNMAs. Recently, the CBT, the CMT, and the ACE expanded the futures trading to 4-6 year T note, 4-year T note, and 90-day T bills respectively. Several other exchanges are reported to have active plans to enter the futures arena soon with various securities possibly including common stocks.

Research Objectives

The rapid growth of trading in interest rate futures raises several interesting issues. In particular, one wonders about the hedging performance, hedging costs, market efficiency, and impact on spot market prices of financial futures. Accordingly this investigation deals with the following issues relevant to the functioning of futures markets in 3-month T bills (CMT), government bonds, and GNMAs (CBT):

1. Hedging performance. How effective are the financial futures in reducing price risk associated with a wide spectrum of securities?

2. Hedge ratio. How many contracts should an investor intending to minimize price risk sell in the futures markets for each unit of his (her) cash position?

3. Market efficiency. Is it usually possible for an investor maintaining a continuously adjusted portfolio of short and long positions in futures and spot instruments to earn a rate of return which differs systematically from the riskless rate?

The basic motivation for pursuing the above stated objectives stems from the belief that the financial futures markets are to a large extent hedging markets intended to provide insurance coverage against interest rate exposure.[4] The rationale for the first objective is not only to assess their risk reduction potential but also to identify factors promoting the hedging effectiveness of financial futures.

The amount of price protection that the investor obtains from financial futures obviously depends on the quality of his (her) hedging decision. An important aspect of the hedging decision relates to the number of futures contracts that the investor should buy or sell relative to his (her) spot position. The second objective therefore involves an examination of the optimal hedge ratio.

The final question of interest in this study is the efficiency of financial futures markets. Market efficiency implies that the reward is proportional to the risk undertaken. Moreover, an efficient market should also be a more effective market for hedging,[5] and thus is in the larger interests of the society. This market effectiveness/efficiency issue is particularly important in the case of futures markets because of the strong apprehension voiced about them in some quarters of the economy.[6]

The Theoretical Model

Given the assumption that offering protection against interest rate risk is a primary purpose of the financial futures markets, it is legitimate to assume further that the market participant's basic motive in hedging is to minimize the price risk to which his (her) spot investment is exposed. A hedging model developed on this premise reveals that the hedging effectiveness of futures instruments depends upon the degree of positive correlation between cash and futures price changes.

The focus of the model is then shifted to the determinants of correlation between cash and futures price changes. In the existing literature it is commonly assumed that price correlation is primarily a function of the term to maturity. That is, the price of a short-term security has a higher degree of correlation with another of similar maturity than the price of a long term security. Recall that until the 1930s the term to maturity was also thought to be an accurate measure of the riskiness of a security.[7] The model brings out, however, that the interest rate elasticity (i.e., the duration) is a more meaningful barometer of price correlation than is the term to maturity considered in isolation. It indicates that within the broad categories of short-term, intermediate-term and long-term maturities, securities with high durations tend to have a high degree of price correlation. Accordingly it is hypothesized that the hedging performance of financial futures is primarily an increasing function of the interest rate elasticities of spot and futures instruments.

Expanding on this nexus between interest rate elasticity and hedging effectiveness, the next step involves identifying the variables that determine the interest rate sensitivity of cash and futures instruments and showing how they relate to hedging performance. Accordingly, several subhypotheses suggesting the relationship between the following dimensions of interest rate elasticity and hedging performance were drawn up: the maturity of spot securities, the level of default risk, the coupon effect, the distance to delivery of contracts, the form of spot security--debt or equity, the type of spot security--individual issue or portfolio, and the type of hedging instrument--the bond futures[8] or the GNMA futures.

The model is then applied to determine what constitutes the optimal hedge ratio for the risk-minimizing investor. It is shown that the optimal hedge ratio is a ratio of cash price changes to futures price changes and that it is a function, among other things, of the relative volatility of spot and futures yields. The question then arises: Which is more volatile, the spot or the futures rate? It is argued that, for a given maturity, coupon, and default-risk, the futures yield is systematically much more volatile than the spot. It follows then that the optimal hedge ratio would be less than unity. Further, it is shown that the hedge ratio is largely an increasing function of hedging effectiveness.

To examine the issue of market efficiency the Black-Scholes (BS) option pricing principle is employed [9]. The BS model is built on the assumption that in an efficient market it should not be possible to earn a consistently higher return than the riskless rate on a correctly hedged portfolio of long and short positions in the spot and futures instruments. Clearly, a hedged rate of return close to the riskless rate signifies that the futures markets are efficient. But if the former deviates systematically from the riskless rate, the markets may be inefficient.

Methodology and Sample

To investigate both the hedging performance of financial futures and the optimal hedge ratio, one needs to estimate the correlation coefficient and the slope coefficient between cash and futures price changes respectively. The estimates are obtained by regressing cash price changes against futures price changes. Then the hedging effecitveness and the hedge ratio are compared across the various dimensions of interest rate elasticity and their statistical significance examined by employing correlation tests.

The evaluation of market efficiency essentially involves estimating optimal hedge ratios in the first place and then comparing the returns on optimal hedges with the riskless rate. Employing the simple regression described earlier, the hedge ratios are estimated on a weekly basis. Based on these hedge ratios, risk-minimizing hedges are constructed and their weekly returns measured both before and after taking transaction costs into account. These returns are then compared with a rate of interest bereft of interest rate risk and the differences between them are subjected to a paired t test.

The comparison of hedging performance and hedge ratio across the various dimensions of interest rate elasticity requires a wide spectrum of spot and futures instruments. Accordingly, the sample used herein covers short-term, intermediate-term, and long-term spots, risky and risk-free issues, discount and non-discount coupon bonds, debt, equity, and hybrid securities, individual securities, fund portfolios, and security indices, and the near-term and distant contracts of short-term and long-term futures instruments. The futures markets covered in the study are the 90-day T bill futures (CMT), the bond futures (CBT), and the GNMA futures (CBT). While this study is generally based on an analysis of data from the period between January 1976 and April 1979, the length of the periods varies somewhat with each futures instrument.

Implications

It is hoped that this investigation provides several useful insights into the design and functioning of financial futures markets. First, it demonstrates the extent of potential interest rate risk reduction that the holder of various types of spot instruments can hope to obtain from the three financial futures markets. Second, it is designed to guide the hedger in the choice of more effective long-term hedging instruments. Third, it should help the hedger choose a more effective contract within each instrument. Fourth, it should provide guidance in determining the optimal hedge ratio. Thus the study is expected to provide useful insights that would promote the quality of hedging decisions.

In addition, this investigation is intended to provide guidance to the futures exchanges in designing and maintaining effective hedging markets. The management of futures exchanges have to determine (1) the term to maturity of the spot security to which the futures instrument is to be tied; (2) the coupon on the underlying spot security, (3) the optimal number of delivery periods, (4) the optimal spacing of delivery periods, and (5) the optimal number of futures instruments within each broad category of term structure. The hedging model and the empirical results of this study are expected to be of potential help in deciding the above mentioned operational issues.

Finally, the regulators, charged as they are with the responsibility of ensuring that the futures markets effectively cater to the needs of the financial community, are interested in the hedging performance and efficiency of futures markets. It is believed that the theoretical model and the empirical findings of this study are useful to the overseeing authorities in exercising healthy regulation over the futures industry.

Outline of the Study

The next chapter reviews the literature on hedging, interest rate risk, and market efficiency. Chapter III presents the hedgingmodel and the various hypotheses of this investigation. The research design, methodology, and the sample are described in Chapter IV. Following this is the chapter containing empirical results. Finally the summary and conclusions of the study are presented in Chapter VI.

CHAPTER II

LITERATURE REVIEW

The traditional base of futures markets is in agricultural commodities. Accordingly the literature on hedging in commodity futures is surveyed at the outset. Then the existing studies on the measurement of interest rate risk and risk reduction strategies are reviewed. Finally, the literature on the efficiency of stock, bond, commodity futures, and financial futures markets is discussed.

Hedging in Futures Markets

The available literature on hedging in financial futures is, due to their brief history, relatively limited. There is, however, a vast literature on hedging in the commodity futures markets. As there are many similarities in the functioning of these two markets, it is desirable to review the relevant aspects of the literature on commodity futures.[1]

Theories of hedging. The concept of hedging has undergone substantial transformations over the years. Until the 1950s the primary motive of hedging was thought to be risk-avoidance, i.e., minimizing the variance of spot price movements. The hedger was assumed to hold positions in futures markets that were equal in magnitude and opposite to their cash market positions. For instance, Roy [81] described hedging behavior in terms of the the "safety first principle" which assumed that entrepreneurs sought to minimize the probability of disaster by means of hedging. Keynes [53] referred to futures markets as an insurance mechanism whereby the hedger transferred price risk to speculators through the process of normal backwardation.

The theory of hedging was, however, soon reformulated by Working [102] following the advent of the Markowitz mean-variance approach to portfolio selection. Working described the hedger as an arbitrager seeking to maximize the expected return and minimize risk of his (her) overall portfolio. He wrote:

> The role of risk avoidance in most commercial hedging has been greatly overemphasized in economic discussions. Most hedging is done largely and may be done wholly, because the information on which the merchant or processor acts leads logically to hedging. He buys the spot commodity because the spot price is low relative to the futures price and he has reason to expect the spot premium to advance; therefore he buys the spot and sells the future [p. 325].

Johnson elaborated the "hedger is an arbitrager" concept of Working. He asserted:

> There is no distinction between the hedger and the 'ordinary' speculator insofar as both are motivated by a desire to obtain a for them optimum combination of E(R) and V(R) as determined by their respective utility functions. The only essential distinction between them is that the hedger has a primary market, which in this model gives rise to a merchandising profit [52; p. 150].

He developed a hedging model in the mean-variance framework. It accounted for the observed behavior of the hedger to take cognizance of not only the relative price movements but also absolute price movements, leading him (her) to hold very often a mix of hedged and speculative positions.

Effectiveness of hedging. Following these different interpretations, several approaches have been adopted to analyze the effectiveness of hedging. Of these, the following are noteworthy.

Stability of the basis. Some researchers have suggested the measurement of the basis to determine hedging effectiveness. Basis is the difference between the contemporaneous cash and future prices. A stable basis is regarded as indicative of an effective hedge since the price changes in cash and futures markets tend to offset each other when the basis is stable. The effectiveness of a hedge is measured by comparing the variability of cash price with that of the basis. This criterion has been criticized because it assumes that the hedger is not an arbitrager seeking to profit from the relative price movements but only a risk-minimizer [27; p. 77]. Another shortcoming of the basis analysis is that it is based on the unrealistic assumption that the hedger always holds a unit-to-unit hedge [52].

Comovement of cash and futures prices. The higher the positive correlation between cash and futures prices the more effective is the hedge, and with perfect positive correlation it is possible to eliminate completely the price risk of a hedged position. Johnson [53] developed the coefficient of determination based on cash and future price changes as a measure of hedging effectiveness. The factors that limit the parallel movement of cash and futures prices limit the effectiveness of hedging.[2] Working [102], however, criticized the use of comovement of cash and futures prices to measure hedging effectiveness on the grounds that the hedger is not just a risk averter but an arbitrager as well.

> . . . the basic idea that complete effectiveness of hedging depends on parallelism of movement of spot and futures prices is false, and an improper standard by which to test the effectiveness of hedging. The effectiveness of hedging intelligently used with commodity storage depends on inequalities between the movements of spot and futures prices and on reasonable predictability of such inequalities [pp. 547-49].

Costs of hedging. Gray [35] discussed the structural characteristics of futures markets for hedging rather than the measures of effectiveness of hedging using hedging costs as a criterion of market effectiveness for hedging. Estimating profits on a consistently long position over a number of years in several futures markets, he concluded that hedging costs were low in balanced liquid markets and high in imbalanced markets.

Revenue stability. This approach is based on the premise that the hedger considers both expected return and risk in deciding how much of the cash position to cover by selling futures contracts. Under this approach a hedge is regarded as effective if it stabilizes revenues accruing to the hedger. Tomek and Gray [95] empirically tested a producer-hedging strategy that required that the production decisions be hedged by selling futures constracts (maturing after the harvest) prior to starting the production process and lifting the hedge after the harvest. They observed:

> . . . given a viable futures market, a necessary condition for a routine hedging program to stabilize a producer's revenue is that the hedge be initiated at prices that are more stable year to year than the subsequent cash prices at which the commodity is sold. If the futures price is essentially as variable as the cash price, the hedge does not stabilize revenue.
>
> The empirical evidence suggests that cash and futures prices are almost equally variable for commodities with continuous inventories. Hence, routine hedging by producers in such markets is unlikely to stabilize their revenues. For commodities such as potatoes, which lack continuous inventories, prices of distant futures are less variable than cash prices and hence producer hedging in such markets tends to stabilize revenue [p. 378].

Peck [71] took exception to the use of the traditional variance of cash and futures prices in evaluating income stabilizing effects of hedging routines. Employing instead the forecast variance (as measured by the mean squared error), she found that both optimal and total hedging routines yielded considerable gains in stabilizing revenues.

Interest Rate Risk

Over the last decade interest rates have generally been rising and increasing in volatility. In particular, during the 1976-79 period covered in this study interest rates registered pronounced variations in level as well as volatility.[3] While the yield curve was upward sloping with roughly 5 percent yield in 13 week T bills and 7 percent yield in 15 year government bonds at the beginning of the period, it was slightly downward sloping at the end with a little over 9 percent short rate and a little lower than 9 percent long rate [97].

The above figures point out an important historical characteristic of interest rate movements. That is, the short-term rate is far more volatile than the long-term rate. Because of the discounting process involved in the price formation of debt instruments, however, the long-term price is much more volatile than the short-term price [45]. Accordingly, the growing volatility of interest rates exposes borrowers and lenders, particularly those in the long end of the market, to increasing basis risk. Haugen and others observed "as a consequence of increased volatility in the level of rates, interest rate risk has assumed greater significance as a determinant of the systematic risk associated with common stock" [42; p. 707].

Measures of interest rate risk. The subject of interest rate risk has long been studied. Surveying the existing literature, it is possible to identify three measures of interest rate risk: (1) interest rate elasticity, (2) duration, and (3) systematic interest rate risk coefficient.

Interest rate elasticity. The traditional measure of the responsiveness of a security's price to interest rate fluctuations is its interest rate elasticity. For continuous compounding, the elasticity, D_1, of the price of a security to small shifts in interest rates is given by

$$D_1 = \frac{dP}{P}\frac{1}{di} \quad (2\text{-}1)$$

where dP = the change in price of a security
P = the price of a security
di = the change in interest rates

For discrete compounding, the corresponding formulation is

$$D_2 = \frac{dP}{P}\frac{i+1}{di} \quad (2\text{-}2)$$

where D_2 = the interest rate elasticity based on discrete compounding
i = the level of interest rates

In both of these formulations, dP and di are inversely related, and consequently D_1 and D_2 are negative in sign. Note that D_1 and D_2 are pure numbers as they are ratios of percentage changes in price and interest rates.

Duration.[4] The concept of duration was first developed by Macaulay in 1938 to measure the average term to maturity of a stream of cashflows [62]. He defined duration, D_3', as

$$D_3' = \frac{\sum_{t=1}^{n} A(t) \cdot t(1+I)^{-t}}{\sum_{t=1}^{n} A(t) \cdot (1+I)^{-t}} \tag{2-3}$$

where A(t) = the cash flows over time

I = the yield to maturity

n = the term to maturity

A year later in 1939, Hicks defined duration as the average length of time for which the various payments are deferred from the present when the times of payment are weighted by the discounted values of payments [43; p. 186]. Further, he showed that for small changes in interest rates the interest rate elasticity of a bond is identical to its duration. Thus Macaulay and Hicks independently introduced the concept of duration as a measure of the true length of a bond. Recently, Bierwag and Kaufman described duration as "the time period at which the directions of change in the price risk and coupon reinvestment risk are equal and opposite in sign" (5; p. 367]. From eq. (2-3) it is clear that the duration of a fixed coupon bond, D_3, is given by (for discrete compounding)

$$D_3 = \frac{\sum_{t=1}^{n} \frac{C \cdot t}{(1+I)^t} + \frac{M \cdot n}{(1+I)^n}}{\sum_{t=1}^{n} \frac{C}{(1+I)^t} + \frac{M}{(1+I)^n}} \tag{2-4}$$

where C = the fixed coupon receipt

M = the face value of the bond

I = the yield to maturity

Thus duration is the weighted maturity of a stream of receipts or payments over time. It is the summation of the present value of individual cash flows multiplied by their time-points of occurrence relative to the current price of a security or an asset. It takes into account not only the length of time over which the cash flows occur but also the magnitudes of cash flows at each point in calendar time.

It is important to note the following with reference to eqs. (2-3) and (2-4):

1. In both the equations the term structure of interest rates is represented by the nominal yield to maturity rather than the spot and forward rates

2. The equations are based on the assumption that the yield curve is flat

3. There is only a single change in the yield curve and this change takes the shape of a parallel shift

Evidently these assumptions are quite restrictive and limit the value of the Macaulay-Hicks duration as a measure of interest rate sensitivity of a security. Since the early 1970s the increasing volatility of interest rates has led to a renewed interest in the theoretical properties and empirical potentials of duration in measuring the basis risk. Several new measures of duration have been proposed to assess the impact of the real world behavior of interest rates on security prices and returns. Fisher and Weil [34], for instance, suggested the following measure of duration to reflect the changing term-structure of interest rates.

$$D_4 = \frac{\sum_{t=1}^{n} \frac{C \cdot t}{\prod_{j=1}^{t} (1+i_j)} + \frac{M \cdot n}{\prod_{j=1}^{t} (1+i_j)}}{\sum_{t=1}^{n} \frac{C}{\prod_{j=1}^{t} (1+i_j)} + \frac{M}{\prod_{j=1}^{t} (1+i_j)}} \qquad (2\text{-}5)$$

where i_j = the forward rate in each period.

Note that when the yield curve is horizontal the forward rates are all equal and thus $D_4 = D_3$ [5].

Cooper [22] criticized the Macaulay-Hicks duration concept because of its reliance on the assumption of a flat term structure of interest rates. He showed that the concept of duration defined in eq. (2-4) is valid for only parallel shifts in the yield curve. Pointing out that the short-end of the term structure is rarely flat but rather is either rising or falling, he argued that the Macaulay-Hicks duration is not an adequate measure of interest rate risk for securities with maturities up to seven years.

In a recent study, Ingersoll et al. [50] observed that the use of the yield to maturity rather than the forward rate as the appropriate discount rate in the present value function renders the traditional duration measure unsuitable as a general proxy for basis risk. They further pointed out that the Macaulay-Hicks duration is an appropriate measure of basis risk only if the yield curve is flat and assumes shifts that are constant, additive, and infinitesimal.

Bierwag [6] asserted that "the measure of duration that achieved immunization varies with the nature of the assumed stochastic changes in future interest rates" [p. 726]. He derived several theoretical measures of duration that were appropriate for different stochastic changes in interest rates. Bierwag and Kaufman [5], however, showed that the values of different measures of duration do not vary greatly except at high coupons and long maturities and concluded that the Macaulay-Hicks duration is a reasonably good approximation to more complex measures of duration.

In view of the important role of the concept of duration in this thesis, it is desirable to discuss the various properties of the Macaulay-Hicks duration. First note that duration, unlike most other measures of risk in finance, is not a measure of dispersion but rather of the (weighted) average maturity of cash flows over time. With regard to the pattern of cash flows over time, the duration of a zero-coupon instrument, such as the T bill, is identical to its term to maturity, while the duration of a coupon-bond is less than its term to maturity. For a given coupon, default-risk, and yield to maturity, the duration of a coupon-bond selling at par or above increases at a decreasing rate, while that of a discount coupon bond increases and then falls with term to maturity [50].

Further, the duration of a bond varies inversely with its coupon-level. In other words, a high coupon bond has a shorter duration than another with a low coupon, given identical term to maturity, yield to maturity, and default-risk. Joehnk et al. [51] examined the price elasticity of 239 Aa rated discount bonds during several periods of falling interest rates between 1957 and 1974. Their findings on the interest rate sensitivity of bonds at varying levels of discount were, however, mixed and they attributed their results to market imperfections.

The duration of all instruments generally varies inversely with the level of interest rates. Further, a change in the level of interest rates alters the relative structure of interest rate elasticities of various securities [42]. With regard to the level of default risk, the duration of a risk-free bond is more than that of a risky bond. Haugen and Wichern observed:

> . . . the interest elasticity of a risky, coupon bearing bond is less than a risk free issue of identical maturity and nominal yield. This is because we are working under the assumption that the certainty equivalents decay for the risky issues . . .
>
> Risky issues are less sensitive to interest rate changes because they are securities of shorter duration. Their duration is shorter even if their maturity is of equal length, because the relative magnitudes of the contributions made by distant payments to the total present value are small relative to a risk free issue. The certainty equivalents for the risk free issue are the promised payments; these do not decay with increasing term [40; p. 123].

The duration of variable income securities, such as a common stock and other forms of wealth, is a direct function of the expected rate of growth of their cash flows and the length of their growth horizon [40]. This suggests that a growth stock is more interest rate volatile than a non-growth stock. Further, the duration of equity is a weighted average of the interest rate elasticities of assets and liabilities of the firm. Specifically, the duration of equity, D_e, is given by [41]

$$D_e = D_a \frac{V_a}{V_d} - D_d \frac{V_d}{V_a} \qquad (2\text{-}6)$$

where D_a = the duration of assets
D_d = the duration of liabilities
V_a = the value of assets
V_d = the value of liabilities

Clearly, the interest rate elasticity of equity depends on the capital structure of the firm as well as the cash flows associated with its assets and liabilities.

It is clear from the above discussion that the interest rate elasticity of a coupon-bond depends on its term to maturity, default-risk, coupon, and yield to maturity. Table 2-1 shows durations (in years) of bonds with different coupons, terms, and yields to maturity. A few observations regarding the relative importance of coupon, yield, and term to maturity are worth noting:

1. Given the yield and coupon at 8 percent (a par value bond), the duration of a one year bond is 0.981 years while that of a 20 year bond is 10.292 years and that of a perpetual bond is 13.0 years

2. Given the yield at 8 percent but coupon at 4 percent (a deep discount bond), the duration of a one year bond is 0.990 years while that of a 20 year bond is 11.986 years. Clearly, in general the effect of coupon on duration is marginal

3. Given the coupon at 8 percent, the duration of a one year bond at yields of 4 percent and 8 percent is virtually identical; the duration of a 20 year bond at 4 percent yield is 12.181 years while it declines to 10.292 years at 8 percent yield

It is evident that within the normal ranges of coupons, default-risk, and nominal yields, the term to maturity is the preponderant determinant of duration of a coupon-bond. Note, however, that the term to maturity is not a substitute for duration, especially for long-term bonds and higher coupon levels. At the long end of the market, bonds with widely varying maturities are quite comparable in terms of their durations given yield, coupon, and credit risk. In other words, the durations of a 10 year bond and a 20 year bond are far closer than their terms to maturity. Evidently, at normal ranges of coupon, yield and default-risk, long-term bonds are not all that different in terms of the

TABLE 2-1. Duration of selected bonds[5]

Years to Maturity	Promised Yield to Maturity											
	4 Percent				6 Percent				8 Percent			
	Coupon Rate				Coupon Rate				Coupon Rate			
	2%	4%	6%	8%	2%	4%	6%	8%	2%	4%	6%	8%
1	0.995	0.990	0.986	0.981	0.995	0.990	0.985	0.981	0.995	0.990	0.985	0.981
5	4.770	4.581	4.423	4.290	4.756	4.558	4.193	4.254	4.742	5.533	4.361	4.218
10	9.007	8.339	7.859	7.497	8.891	8.169	7.662	7.286	8.762	7.986	7.454	7.067
20	15.837	13.951	12.876	12.181	14.981	12.980	11.904	11.232	14.026	11.966	10.922	10.292
50	25.379	21.980	20.629	19.903	19.452	17.129	16.273	15.829	14.832	13.466	12.987	12.473
100	26.416	25.014	24.535	24.293	17.567	17.232	17.120	17.061	13.097	13.029	13.006	12.995
∞	25.500	25.500	25.500	25.500	17.167	17.167	17.167	17.167	13.000	13.000	13.000	13.000

Source: Fisher and Weil [34; p. 418]

time value profiles of their cash flows as their terms to maturities seem to indicate.[6]

In the case of a zero-coupon bond, such as T bills, the duration is identical to the term to maturity. This implies that the level of interest rates has little effect on the interest rate risk of money market instruments. This is apparent from the Table 2-1, although it does not include zero-coupon issues per se. At the low coupon of 2 percent, the duration of a one year bond is virtually identical (0.995 years) at 4 percent as well as 8 percent yields to maturity.

In the light of these properties of duration of debt instruments, what could one speculate about the duration of a typical common stock? Recall that common stock is a variable income security having no fixed maturity. That is, it is similar to a perpetual instrument with a variable stream of cash flows over time. Relative to a long-term bond, it commonly has a higher rate of earnings and dividends and a much longer term to maturity. In light of the earlier observations on the relative importance of coupon, term, and yield to maturity in determining the duration of a long-term bond, it is obvious that common stock typically has a much longer duration than a long-term coupon bond. It should, however, be noted that beyond fifty years the incremental effect of term to maturity on duration is negligible.

Some empirical estimates of interest elasticities of common stocks and bonds were reported by Haugen and others [42]. Using a sample of ninety-eight regulated electric utility firms, they estimated the mean duration of equity at twenty years with a cross-sectional standard deviation of eight years and that of debt at three years during the two-month period from December 1970 to January 1971. They further observed that the regulation of electric utilities increased the sensitivity of their common stock to interest rate movements in comparison to that of non-regulated firms. Recently, Lanstein and Sharpe [57] reported that their sample of 220 stocks had a mean duration of 32.6 years with a standard deviation of 13.8 years.

Dual index model. In the existing literautre, one also comes across a decomposition of interest rate risk into systmeatic and unsystematic risks. Stone wrote:

> When holdings are concentrated in a narrow maturity range, both gains and losses are possible from 'pure twists' in the term structure where a pure twist is defined as a change in term structure with the average level of interest rates constant, e.g., falling short-term rates and rising long-term rates. In contrast, by holding a suitably weighted average of all maturities, an investor can essentially eliminate the effect of pure twists so that he bears only the risk of level change. In analogy to the market index model, the risk from pure twists is nonsystematic since it can be eliminated by diversifying over maturity ranges but risk due to level changes cannot be diversified away if only long positions are held [92; p. 711].

The Sharpe-Lintner Capital Asset Pricing Model [59,85] suggests that the systematic interest rate risk of a security can be estimated by regressing its rate of return against the return from a debt market portfolio.[7] Stone [92] proposed a dual index model consisting of debt and equity indexes as an alternative to the Sharpe-Lintner single index market model and described the coefficient of the debt index as a measure of the systematic interest rate risk of a security. Stone's dual index model was empirically tested in two recent studies. Investigating the sources of extra-market covariation in stock returns in public utilities and financial institutions, Martin and Keown [64] found the existence of a common group factor related to interest rate sensitivity. Lloyd and

Shick [60] performed a more direct test of the dual index model. Using quarterly data on a sample of sixty commercial bank stocks over a four year period, they reported that the addition of the bond index improved the explanatory power of the model, although its omission did not bias equity beta estimates.

Another recent empirical work based on multiple indexes is that by Haugen et al. [42] which employed a three-factor model consisting of debt, equity, and industry factors. Using monthly data from 1967 to 1975 on 78 electric utility stocks and stocks of 163 non-regulated firms in 10 industries, they reported that the stocks of regulated firms exhibited significantly higher interest rate sensitivity than those of non-regulated firms.

Duration and conventional measures of risk. There is evidence to show that duration and the slope coefficient in the regression of security returns against an index of general level of interest rates are highly correlated. Comparing the slope coefficient from regressing monthly portfolio bond returns against the holding period return on a government bond index and the duration during 1947-73, Bildersee [8] found that the two measures had a rank correlation of 0.984.

Further, there exists a direct relationship between the duration and systematic risk (beta coefficient) of a common stock. Boquist et al. [11] showed that:

$$\text{Beta}_i = \frac{D_i[\text{cov}(dG_i, R_m) - \text{Cov}(dK_i, R_m)]}{V(R_m)} \tag{2-7}$$

where D_i = the duration

G_i = the constant growth rate

R_m = the return on the market portfolio

$V(R_m)$ = the variance of R_m

K_i = the cost of equity capital

Eq. (2-7) reveals that the systematic risk of a common stock arises from two sources: (1) the risk due to changes in the term-structure of interest rates (D_i), and (2) the risk due to changes in the expected cash flows of a stock relative to that of the market portfolio.

Eddy [27] reformulated the capital asset pricing model in the multi-period context in terms of price forecasting errors. He wrote, "interest rate risk can be regarded as systematic risk in returns due to price forecasting errors," and that "beta coefficient is a (non-linear) measure of interest rate risk in the determination of expected returns on default free bonds" [p. 629].

It has also been shown that the duration of a bond is related to its price volatility. Hopewell and Kaufman showed that:

$$\frac{dP}{P} = -D\ dI \tag{2-8}$$

They observed: "for a given basis point change in market yield percentage changes in bond prices vary proportionately with duration and are greater, the greater the duration of the bond" [46; p. 749]. Elaborating on this relationship, Bierwag et al. indicated that "for a given basis point change in interest rates, the relative change in bond price will be greater: (a) the lower the coupon rate, (b) the lower the market yield, and (c) the longer the maturity" [7; p. 673].

Risk reduction strategies. There are primarily four approaches to coping with interest rate risk: diversification, concentration, immunization, and hedging. As discussed earlier, diversification involves spreading one's investments across the maturity range. While this strategy is effective in dealing with unsystematic interest rate risk, it is of little help in combating the risk which stems from level changes. The second strategy, concentration, involves moving out of term instruments and into money market securities when the volatility of interest rates is expected to increase. It has been pointed out earlier that although the short yields are more volatile than their long-term counterparts, their effect on duration of short-term issues is marginal. Note, however, that these two strategies only mitigate the adverse impact of interest rate changes, but do not eliminate it.

The third approach to coping with interest rate risk is known as the duration strategy (or the immunization rule).[9] Originally propounded by Hicks and Samuelson, the duration theorem posits that it is possible to immunize the investor's net worth against small changes in interest rates by equating the weighted duration of liability streams with that of the asset streams [38,39,43,78,82]. As applied to coupon-bearing debt instruments, this strategy requires that investors choose the coupon rate and term to maturity in such a way that the duration of the bond is equal to their planned holding period [34]. Bierwag [6] showed that for complicated stochastic changes in the term structure of interest rates, duration strategy requires the diversification of a single bond investment into a multi-bond portfolio. The strategy also suggests that holders of zero-coupon instruments can protect themselves against price risk by matching their expected holding periods with the term to maturity of these securities.

Recently, Lanstein and Sharpe [57] pointed out that the duration strategy provides complete immunization only if the bond returns are perfectly correlated. Examining the monthly returns on bond portfolios of varying maturities, they observed "the substantial departures from perfect correlation show that simple duration calculations will not suffice to completely immunize a bond portfolio" [p. 661]. They further noted that the traditional notion of immunization assumes that the extra-market covariances[10] associated with bonds are negligible. While the extra-market covariances are small for default-free bonds, they are substantial for common stocks.

As observed earlier, the possibility of hedging against interest rate risk has only recently become possible. The use of financial futures in hedging interest rate risk associated with 3-month T bills and GNMA issues was recently examined by Ederington [28]. Using bi-weekly and 4-weekly data over January 1976 to December 1977, he employed the coefficient of determination based on cash and futures price changes to evaluate the hedging performance of the T-bill futures and GNMA futures markets and reported that:

1. The hedging performance of GNMA futures was superior to that of T-bill futures; the coefficient of determination for GNMA hedges varied between .661 and .817 as compared to .140 and .741 for T-bill hedges. The hedging performance of GNMA futures was comparable to that of corn futures but inferior to that of wheat futures

2. The long term (4-weekly) hedges were more effective than the short term (2-weekly) hedges

3. The cash prices for both T-bill and GNMAs consistently exceeded futures prices during the period, thus resulting in a positive change in the basis. This would improve returns on long hedges and reduce returns on short hedges

4. Contrary to the traditional theory, the risk minimizing hedge ratio, (i.e., the ratio of futures to cash positions) was generally less than unity

Market Efficiency

Stock markets. The capital markets are deemed to be efficient when security prices quickly and effectively reflect all available information and thus are equal to their underlying intrinsic values [31,83]. In the empirical literature on stock markets, three different degrees of market efficiency have been examined: the weak, semi-strong, and strong forms of the efficient market hypothesis [31].

The weak form of the efficient market hypothesis posits that it is not possible for the investor to earn a consistently higher rate of return than that of a naive buy-and-hold strategy using information from historical price and volume data. The available evidence demonstrates that stock markets in the United States for the most part have attained this level of efficiency [31].

The semi-strong form of the hypothesis claims further that security prices also quickly and accurately reflect all publicly availalbe information. The existing evidence on whether the United States stock markets have attained this level of efficiency is mixed [61; pp. 101-279].

The strong form of the hypothesis asserts that no investor, not even the specialist or the insider, can consistently earn a rate of return higher than that on a naive buy-and-hold strategy. Finnerty [33] tested the strong form of the efficient market hypothesis by examining if the insiders could earn better than average profits. He concluded, "Insiders are able to outperform the market. Insiders can and do identify profitable as well as unprofitable situations within their corporations. This finding tends to refute the strong form of the efficient market hypothesis" [p. 1148].

Bond markets. The efficiency of bond markets has also been examined by some researchers. Roll [80] noticed significant deviations from efficiency in the T bills market. In a later study, however, Fama [32] reported that the T bills market was efficient: ". . . during 1953-1971 the bond market seems to be efficient in the sense that in setting one to six-month nominal rate of interest, the market correctly uses all the information about future rates of change in purchasing power that is in the time series of past rates of change" [p. 282]. The efficiency of the long-term debt markets has not yet been well explored.

Commodity futures markets. One implication of market efficiency is that short-run price movements are characterized by the martingale process which is loosely called a random walk. The question of market efficiency of commodity futures has been examined through the analysis of the stochastic nature of futures prices. The two major theories describing the price formation of commodity futures are the unbiased expectations hypothesis and the normal backwardation hypothesis.

Under the unbiased expectations hypothesis futures prices are regarded as unbiased estimates of expected spot prices at the expiration of the relevant contracts. Samuelson [83] showed recently that this hypothesis implies that futures prices follow a martingale. The normal backwardation hypothesis, on the other hand, argues that futures prices contain a downward bias in order to compensate speculators for bearing the risk of unexpected price fluctuations. A number of studies have tested these hypotheses empirically [23,24,37,79,93,94], and the general conclusion is that backwardation is not a normal feature of futures prices. While futures prices in underused, imbalanced markets (i.e., markets characterized by a lack of speculation) sometimes seem to exhibit a downward or upward bias, in balanced markets the unbiased expectations hypothesis largely holds.

There are several studies that have examined the random behavior of futures price-changes. In his theory of anticipatory market prices [103] Working described changes in futures prices as approximately a random walk. Larson [58], in examining daily price-changes of Chicago corn futures during 1922 to 1931, and 1949 to 1958, observed both positive and negative serial dependence, but concluded that price changes closely approached random walk behavior. While Cootner [25] found stock prices to be negatively correlated over short time intervals and positively correlated over long term periods, he noted that commodity futures prices approached a random walk more closely than stock prices.

On the other hand, quite a few studies have reported that futures prices do not follow a random walk. Employing filter rules, Houthakker [47,48] concluded that futures prices moved in trends. Smidt [88] used trading rules on the Chicago soybean daily price data over the 1952 to

1961 period to discover statistically significant negative serial dependence. In an empirical study covering the period from 1957 to 1968, Stevenson and Bear [91] concluded:

> The various tests applied to July corn and July soyabeans suggest that the random walk hypothesis does not offer a satisfactory explanation of the movement of those speculative price series. Specifically, a tendency for negative dependence in short periods of time and positive dependence over long periods was evident . . . Serial correlation and an analysis of runs substantiated the short-run, one- and two-day, tendency toward reversal. The success of large filters verifies the existence of long term trends. While the existence of long term trends does not in itself contradict the random walk hypothesis, the profitability which was found in this analysis of playing long term movements on both the long and short sides over a buy and hold policy, does cast considerable doubt on the applicability of this hypothesis to the market for commodity futures [p. 80].

Financial futures markets. The existing literature on the market efficiency of financial futures has focused on the testing of the unbiased expectations hypothesis of the term structure of interest rates. This hypothesis implies that in an efficient market yields on financial futures should be equal to implied forward rates. That is, the forward and futures yields should be equal for identical maturities. Examining the 3-month T-bill futures Poole [75] found that the nearest maturity T-bill futures yields were indeed approximately equal to spot T-bill yields, thus leaving hardly any profitable arbitrage opportunities between the two markets.

Branch provides by far the most extensive studies on financial futures. Using monthly data on 3-month T-bill futures from June 1976 to July 1978, he found little support for the unbiased expectations hypothesis and reported that his results were favorable to the segmented market hypothesis [13]. He observed that while the cash and nearest maturity long futures yields were closely related, the gap between them widened in favor of futures as their term to expiration lengthened. He noticed several profitable arbitraging opportunities associated with distant maturity futures which were not just temporary but consistent and persistent over time. He wrote

> An efficient market should drive the two sets of rates together. That this has not thus far happened and that there appears to be little or no progress in that direction is rather clear evidence of both a segmentation of the two markets (cash governments and futures governments), and an inefficiency in the linkage between the two markets [p. 63].

Branch [14] further explored the exploitation of inefficiencies in financial futures markets for improving portfolio returns. He compared returns on cash securities with that on portfolios of cash and futures in 3-month T-bills, T-bonds and GNMAs of equivalent maturities. He found that portfolios involving long positions in distant futures provided higher returns relative to spot security returns and that the portfolio returns generally increased with the distance to expiration of futures contracts.

Lang and Rosche [56] examined 3-month T-bill futures data from March 1976 to March 1978 and reported results similar to Branch [13]. Examining the daily data on T-bill futures Puglisi [76], and Vignola and Dale [96] discovered persistent arbitrage opportunities and concluded that the T-bill futures market was inefficient.

Several explanations for the systematic differences have been put forward, such as, transaction costs, default risk premium, rising futures yield curve, etc. While the transaction costs associated with futures are small, they are positive in spot markets. This has the effect of raising forward rates relative to the associated futures rates and explains why near-delivery futures rates are below spot rates [56]. For distant delivery futures, however, default risk premium becomes increasingly important.

> . . . a futures contract is not guaranteed by the U.S. government, but is rather guaranteed by the exchange on which it is traded. Although the futures contract involves delivery of T-bills that are default free, the contract itself is not default free. Consequently, the future rate may contain a risk premium associated with default risk.
>
> This default risk factor would be more important for the future contracts that are further from delivery . . . [56; p. 25].

Due to the existence of transaction costs and default risk premium,

> future rates do not necessarily reflect the expected level of future interest rates. However, these results do not conflict with the proposition that changes in market expectations of future interest rates can be inferred from changes in futures rates [56; p. 30].

A third explanation is the general expectation in the market during the last 2-3 years that long term interest rates are likely to rise. This has resulted in an upward yield structure in futures markets with the result that while the near-delivery futures yields are close to cash markets yields, yields on distant delivery futures are considerably above their cash market counterparts [13,14]. Other explanations are the lack of information regarding trading opportunities in futures, institutional constraints on futures trading, and thin volume of trading in distant deliveries.

CHAPTER III

HYPOTHESES

Propositions

The basic propostions discussed in this chapter are:

Proposition 1. How effective are the financial futures in coping with the price risk faced by a wide spectrum of cash securities?

Proposition 2. How many futures contracts should a risk minimizing investor sell for each unit of his (her) long cash position?

Proposition 3. Are the financial futures markets efficient? That is, is it possible to earn a consistently higher than riskless rate of return by maintaining a continuously adjusted portfolio of short and long positions in the financial futures and spot securities?

The chapter begins with the development of a hedging model. In formulating the model it is assumed that the primary rationale underlying most hedge trading in financial futures is to minimize the basis risk associated with spot positions. The model indicates that the coefficient of determination between cash and futures price changes can be employed to measure the effectiveness of hedging and cross-hedging strategies. It reveals further that hedging performance is primarily a function of the relative interest rate elasticities of spot and futures securities.

Following this the hypothesis regarding the hedging performance of thirteen week T bill futures (CMT), bond futures (CBT), and 8 percent GNMA futures (CBT) are presented in relation to: spot securities of varying maturities; securities of different default-risk levels; individual issues vs. portfolios; discount vs. non-discount issues; form of security-stocks and bonds; distance to expiration of futures contracts; and comparison between bond futures and GNMA futures. Finally, the hypotheses on the risk minimizing hedge ratio and the efficiency of financial futures markets are discussed.

The Hedging Model

The impact of fluctuations in interest rates varies with the type of financial instruments. While the shifts in interest rates lead to a gain or loss in the price of a zero-coupon bond, they expose a coupon bond or a stock not only to price appreciation or decline but also to uncertain returns on the reinvestment of periodic cash flows. One way to cope with the basic risk exposure of a financial instrument is to hedge the spot market investment in the futures market.

Consider for instance the case of a zero coupon bond investor. The expected return in dollars, $E(AR_{ct})$, from holding X_c units of a zero coupon bond is given by

$$E(AR_{ct}) = X_{ct}E(P_{t+1} - P_t) \tag{3-1}$$

where $E(P_{t+1} - P_t)$ = the expected price change associated with an unhedged cash position

The price risk,[1] $V(AR_{ct})$, of the unhedged spot position is

$$V(AR_{ct}) = X_{ct}^2 V(CP_t) \tag{3-2}$$

where CP_t = the change in spot prices.

The expected dollar returns, $E(AR_{ft})$, on long holdings of X_f units of futures contracts (net of transaction costs, $T(X_f)$), can be estimated by

$$E(AR_{ft}) = X_{ft}E(F_{t+1} - F_t) - T(X_{ft}) \tag{3-3}$$

where $E(F_{t+1} - F_t)$ = the expected futures price change

X_f = the number of futures contracts

The X_f is positive for a long position and negative for a short position

If the investor constructs a portfolio of long X_c units of a zero coupon bond and short X_f units of the related futures contract, the expected dollar return, $E(AR_{ht})$, and the price risk, $V(AR_{ht})$, of the hedged portfolio are given by

$$E(AR_{ht}) = X_{ct}E(CP_t) + X_{ft}E(CF_t) - T(X_{ft}) \quad (3\text{-}4)$$

$$V(AR_{ht}) = X_{ct}^2 V(CP_t) + X_{ft}^2 V(CF_t) + 2X_{ct}X_{ft}r_{cft}(CP_t,CF_t) S(CP_t)S(CF_t) \quad (3\text{-}5)$$

where CF_t = the change in futures prices

$r_{cft}(CP_t,CF_t)$ = the correlation coefficient between price changes

$S(CF_t)$ = the standard deviation of futures price changes

$S(CP_t)$ = the standard deviation of spot price changes

Since $r_{cft}(CP_t,CF_t)$ can be normally expected to be positive, the last term in eq. (3-5) will have a negative sign in a short hedge. Therefore, the closer $r_{cft}(CP_t,CF_t)$ is to one the smaller the $V(AR_{ht})$.

Assume now that the objective of the investor in constructing the hedged portfolio is to minimize the price risk relative to his (her) spot position. The number of futures contracts that (s)he has to sell short to minimize the price risk can be derived by differentiating eq. (3-5) with respect to X_f and solving for its value:

$$\frac{dV(AR_{ht})}{dX_{ft}} = 2X_{ft}V(CF_t) + 2X_{ct}\ Cov(CP_t,CP_t) = 0$$

$$-X^*_{ft} = \frac{X_{ct}Cov(CP_t,CF_t)}{V(CF_t)} \qquad (3\text{-}6)$$

Substituting the value of X^*_f in eq. (3-5) yields the price risk, $V(AR_{nt})*$, associated with the risk minimizing portfolio:

$$V(AR_{ht})* = X^2_{ct}V(CP_t) - \frac{X^2_{ct}Cov^2(CP_t,CF_t)}{V(CF_t)} \qquad (3\text{-}7)$$

The extent of price risk reduction, Ø, resulting from the hedging strategy, can be seen by comparing the price risk of the unhedged cash position, $X^2_{ct}V(CP_t)$, with that of the hedged portfolio, $V(AR_{ht})*$:

$$\emptyset = X^2_{ct}V(CP_t) - X^2_{ct}V(CP_t) + \frac{X^2_{ct}Cov^2(CP_t,CF_t)}{V(CF_t)} \qquad (3\text{-}8)$$

Dividing throughout by $X^2_{ct}V(CP_t)$ indicates the percentage risk reduction obtained through hedging:

$$e = \frac{\emptyset}{X^2_{ct}V(CP_t)} = 1 - 1 + \frac{Cov^2(CP_t,CF_t)}{V(CP_t)V(CF_t)} = r^2_{cft} \qquad (3\text{-}9)$$

where e is a measure of the effectiveness of hedging.

Eq. (3-9) reveals the coefficient of determination between cash and futures price changes estimates the degree of price protection that can be obtained by hedging in financial futures markets. That is, the risk reduction potential of a hedge is determined by the degree of correlation between cash and futures price changes. The investor can immunize his (her) hedged portfolio against basis risk if the cash and futures price changes are perfectly positively correlated. The lower the degree of price correlation, the smaller is the amount of protection from interest rate risk offered by the hedge.

Interest Rate Elasticity and Hedging Effectiveness

Since price changes of cash and futures instruments are a function of their interest rate elasticities, it is critically important to establish the link between the correlation coefficient of cash and futures price changes, r_{cft}, and their interest rate elasticities. It has been shown that the duration of a financial security measures its interest rate elasticity [43]. Further, the price volatility of a debt security to small changes in interest rates has been shown to be related to its duration[2] as under [46]:

$$\frac{dP_{it}}{P_{it}} = -D_{it} dI_{it} \tag{3-10}$$

where dP_{it} = the change in price of security i

P_{it} = the price of security i

D_{it} = the duration - the constant of proportionality between percentage changes in the price of security i and changes in its yield to maturity

dI_{it} = the change in yield to maturity of security i over a short interval of time

For small changes in interest rates it follows from eq. (3-10) that

$$\begin{aligned} CP_t &= -D_{ct} dI_{ct} P_t \\ CF_t &= -D_{ft} dI_{ft} F_t \end{aligned} \tag{3-11}$$

where D_{ct} = the duration of the cash security

D_{ft} = the duration[3] of the futures contract

dI_{ct} = the change in yield to maturity of the cash security

dI_{ft} = the change in yield to maturity of the futures contract

The correlation coefficient between cash and futures price changes, r_{cft}, is given by

$$r_{cft} = \frac{Cov(CP_t, CF_t)}{S(CP_t)S(CF_t)} \qquad (3\text{-}12)$$

Substituting eq. (3-11) in the numerator of eq. (3-12)

$$\begin{aligned} r_{cft} &= \frac{Cov(-D_{ct}dI_{ct}P_t,\ -D_{ft}dI_{ft}F_t)}{S(CP_t)S(CF_t)} \\ &= \frac{D_{ct}D_{ft}\ Cov(dI_{ct}P_t,\ dI_{ft}F_t)}{S(CP_t)S(CF_t)} \end{aligned} \qquad (3\text{-}13)$$

In eq. (3-13), the covariance term in the numerator is normally positive due to the tendency of yield changes, dI_{ct} and dI_{ft}, to move in the same direction. The equation brings out that the correlation between cash and futures price changes is a function of three variables:

1. The durations of cash and futures instruments
2. The levels of cash and futures yields, I_{ct} and I_{ft}, which are reflected in the cash and futures prices, P_t and F_t
3. The change in the levels of cash and futures yields, dI_{ct} and dI_{ft}; that is, the volatility of yields

Assume now a common flat yield curve for both the markets and that the yield changes are equal. That is, $F_t = P_t$, and $dI_{ft} = dI_{ct}$. It follows that $D_{ct} = D_{ft}$. Clearly, then $r_{cft} = 1$. This signifies perfect positive correlation between price changes which results in an immunizing hedge. More realistically, however, $F_t \neq P_t$ and $dI_{ft} \neq dI_{ct}$. When the yield curve is upward sloping, $F_t < P_t$, and when it is downward sloping, $F_t > P_t$. Further, as argued later, dI_{ft} is commonly higher than dI_{ct} under all scenarios of the term structure of interest rates. Under realistic conditions, therefore, the durations of cash and futures instruments will not be equal to each other for a given level of default risk and coupon, and the r_{cft} will be generally less than one.

It is thus clear from eq. (3-13) that given the level and volatility of yields, the degree of price correlation is primarily a function of the durations of cash and futures instruments. Generalizing this result to spot securities, it emerges that what determines the degree of price correlation between two spot issues is not the identity or proximity between their terms to maturity but the extent of correspondence between the present value profiles of their cash flows. In other words, two coupon-bonds with identical durations will exhibit a higher degree of price correlation than another set of two coupon-issues with identical maturity but varying durations.

From the standpoint of a hedging strategy, several implications of eq. (3-13) are noteworthy. First, matching durations of cash and futures instruments does not yield immunization because of the difference in the level and volatility of interest rates in the two markets. Second, within the three broad classes of term-structure—the short-term, the intermediate-term, and the long-term--it is reasonable to expect that the covariance and variance between yield changes as reflected in $Cov(dI_{ct}P_t, dI_{ft}F_t)$ and $S(dI_{ct}P_t) \cdot S(dI_{ft}F_t)$ respectively will be similar. It follows then that, within each class of the term-structure, for a given D_{ft}, the higher the D_{ct} the higher is r_{cft}. That is, futures instruments provide greater price protection to more interest rate sensitive spot securities than to those less exposed to basis risk. It further implies that within each class of the term structure, hedging with lower interest rate sensitive future instruments will be less effective than hedging with more interest rate elastic instruments.

Determinants of Hedging Effectiveness

From eq. (3-9) it is obvious that the hedging performance of financial futures depends on the degree of correlation between cash and futures price changes. The hedge will completely eliminate the price risk if the price changes are perfectly positively correlated (see eq. (3-7)). A perfect positive price correlation implies

$$CP_t = B'CF_t \qquad (3\text{-}14)$$

where B' = the number of futures contracts in a risk minimizing hedge against each unit of long cash position

When eq. (3-14) holds, the price gain (loss) on the cash position will be offset by the price loss (gain) on a short futures position, leaving the equity of the investor intact. On the other hand, a less than perfectly positive correlation between cash and futures price changes will result in the risk minimizing short hedge being only partially successful in coping with the price risk. The imperfect positive price correlation can be formulated as

$$CP_t = A + BCF_t + E_t \qquad (3\text{-}15)$$

where A = the intercept

B = the slope parameter indicating the number of futures contracts in a risk minimizing hedge for each unit of cash position

E = the stochastic disturbance

From the intercept, A, and the disturbance term E_t in eq. (3-15) it is apparent that with imperfect price correlation the risk minimizing hedge containing B futures contracts for each cash bond will fail to equate the cash price gain (loss) with the futures price loss (gain). Consequently, the variance of the risk-minimizing hedged portfolio in eq. (3-7) will be greater than zero.

The degree of correlation between cash and futures price changes is govered by a number of factors. The unbiased expectations hypothesis posits that in an efficient market

$$F_t = E(P_{t+n}) \tag{3-16}$$

where $E(P_{t+n})$ = the expected price of the underlying spot security at the expiration of the futures contract

Any systematic deviation from this equilibrium relationship generates profitable arbitraging opportunities between cash and futures markets. Consequently, the profit seeking moves by market participants can be expected to drive the prices back to their equilibrium relationship.

The common determinant of price generation in cash and futures markets is the expected level and volatility of interest rates. Evidently the higher the level of expected interest rates the lower are the cash and futures prices. Similarly, the more volatile the expected interest rates the more unstable are the price movements in both the markets.

Eq. (3-13) indicates that hedging effectiveness should increase with the interest rate elasticities of cash and futures instruments given the covariance between yield levels and changes. Interest rate sensitivity of spot securities is a function of several variables such as term to maturity, level of default-risk, level of coupon, level of interest rates, growth or non-growth stock, etc.

The interest rate elasticity of futures instruments is primarily related to their underlying spot securities. In general, futures contracts are highly sensitive to interest rate expectations. Among the futures instruments the T bill futures are by far the least interest rate sensitive because they are tied to a short-term zero-coupon instrument. Of the long-term futures, the GNMA futures can be expected to be less interest rate sensitive than the bond futures. This is because the former is coupled with a cash security of twelve years to maturity while the latter is tied to government bonds of fifteen years or longer to maturity. Moreover, there tends to exist a direct relationship between interest rate elasticity and variance of price changes for both spot and futures instruments. That is, the higher the degree of interest rate elasticity the larger is the variance of price changes.

What emerges from the above discussion is that the degree of correlation between cash and futures price changes depends on those variables which determine their interest rate elasticities. Specifically, the determinants of their interest rate elasticities and hedging effectiveness are:

1. The term to maturity of spot securities
2. The level of default risk
3. The distance to delivery of futures contracts
4. The coupon effect
5. The form of cash security--debt or equity
6. The type of cash security--individual security vs. portfolios
7. The type of long-term hedging instrument--bond futures vs. GNMA futures

Hypothesis 1--Hedging Performance of Financial Futures

Equation (3-9) shows the relation between the hedging effectiveness of financial futures and the degree of positive correlation between cash and futures price changes. Price changes in both the markets are, however, primarily a function of their interest rate elasticities as shown in eq. (3-11). It follows then that the positive correlation between cash and futures price changes increases with their interest rate elasticities (see eq. (3-13)). That is, the higher the interest rate elasticities of cash and futures, the higher is the positive correlation between price changes.

Hypothesis 1: The degree of price protection offered by futures instruments is largely a direct function of the interest rate elasticities of spot securities and futures contracts.

Based on the determinants of interest rate elasticity outlined earlier, the following hypotheses regarding hedging performance can be formulated.[4]

Hypothesis 1A--Term to maturity of spot securities. The interest rate elasticity (duration) of a short-term zero-coupon security is identical to its term to maturity. For coupon-bearing bonds interest rate elasticity increases at a decreasing rate with their term to maturity, It follows then that the interest rate elasticity of most bonds exceeds that of the money market issues.

The interest rate elasticity of futures instruments is related to that of their underlying spot securities. This implies that the T bill futures are less interest rate sensitive than the long-term futures, and between the latter the bond futures are more responsive to interest rate movements than are the GNMA futures. Whether the interest rate elasticities of financial futures and their underlying spot securities are identical or not depends on the relative levels of interest rates prevailing in the spot and futures markets.

Given the above relationship between maturity and interest rate elasticity, it is clear from eq. (3-13) that futures prices will have a higher degree of correlation with spot securities of relatively long-term to maturity than those with short-term to maturity.

Hypothesis 1A: Futures instruments offer superior price protection to long-term spot securities relative to those with short-term to maturity.

It is worthwhile to note the following implications of this hypothesis:

1. Across spot maturities, the hypothesis suggests that a 1 week T bill will receive lower price protection from the T bill futures hedge than does a hedged 26 week T bill. Similarly, a short-term bond will receive lower protection against price risk from a hedge with the long-term futures than would a similar combination with a long-term bond.

2. Across hedging instruments, the hypothesis implies that the T bill futures will offer relatively lower price protection to money market issues than do the long-term futures to coupon-bonds. This is because both the T bill futures and money market instruments are less sensitive to interest rate variations in comparison to the long-term futures and bonds. Eq. (3-13) shows that the degree of correlation between price changes of the former is lower than that of the latter given the behavior of yields.

<u>Hypothesis 1B--Level of default risk</u>. For a given maturity and nominal yield, the risky coupon bonds (which have a higher coupon and thus a lower duration) are known to be less sensitive to interest rate changes

than those with little default risk [40]. Among the spot securities, treasuries, goverments, and agencies are viewed as being virtually free from default-risk while the level of risk varies among corporates, municipals, commercial paper, and mutual fund shares. The performance of futures contracts terms is guaranteed by the participant's brokers and sponsoring Exchanges. Moreover, the delivery instruments underlying the futures contracts are the related governments and agencies or documents backed up by these securities. Consequently, the amount of perceived default risk associated with futures contracts is negligible, and their price changes basically reflect interest rate expectations.

It follows that futures instruments will have a higher degree of price correlation with default-free spot securities than with risky issues.

Hypothesis 1B: The price risk reduction offered by futures instruments varies inversely with the level of default-risk. That is, the lower the level of default risk, the higher is the risk reduction potential available in futures markets.

Hypothesis 1C--Delivery period. By mid 1979 there were eight separate delivery periods of T bill futures contracts and eleven each of bond futures and GNMA futures contracts being traded at any one time. All the three futures instruments call for delivery at quarterly intervals; the first contract to mature may be up to three months into the future, the second six months from the start and so on with the result that it is possible to trade T bill futures calling for delivery twenty-four months into the future and to trade bond futures and GNMA futures with delivery thirty-three months ahead.

According to the unbiased expectation theory, the current futures price is equal to the expected spot price of the underlying spot security on expiration of the futures contract (eq. (3-16)). During a regime of generally rising interest rate expectations, it follows that lower prices and conversely higher yields will be associated with the more distant contracts, and higher prices and lower yields with the near-term contracts. For the nearest-term contracts, the yield may be only a few basis points away from its cash market counterpart due to the activities of profit-seeking arbitragers.

Moreover, the existing evidence indicates that the long futures yield generally exceeds the corresponding implied forward rate, and that the difference between them increases as the delivery period extends into the future [13,14]. Thus the long futures yield related to distant deliveries is even higher than what is implied by the unbiased expectation theory.

The interest rate elasticity of all debt securities is a negative function of the level of interest rates [40]. This suggests that the near-term deliveries with relatively lower futures yields are more interest rate elastic than the distant contracts offering higher yields. From eq. (3-13) it follows that the near-term contracts will correlate better with a given spot price than will the distant deliveries.

Hypothesis 1C: The near-term contracts will offer superior price protection to a given spot security in comparison to the distant deliveries.

<u>Hypothesis 1D--Coupon effect</u>. In general interest rate elasticity varies inversely with the coupon level of bonds [40]. That is, for a given term

and yield to maturity, a bond with a higher coupon is less sensitive to movements in interest rates than another with a lower coupon. For any given level of interest rates, a relatively low-coupon bond trades at a discount while a high coupon bond carries a premium. Thus, a discount bond is more interest rate elastic than another trading at a premium.

The bond futures prices are tied to the fifteen year maturity government bonds carrying an 8 percent coupon, and the GNMA futures prices are related to the 8 percent GNMAs with an effective maturity of 12 years. The expected levels of long-term interest rates during the 1976-79 period, however, were generally higher than 8 percent with the result that both futures instruments were selling for the most part at a discount. The only time when the first two near-delivery GNMA futures contracts sold slightly above par was for about five weeks beginning in December of 1976. And the bond futures sold marginally above par only during the first three months from their inception. During 1976-77 the GNMA futures prices ranged between 92 and 101 percent of face value and from 1978 through mid 1979 they varied between 86 and 95 percent. The bond futures steadily fell from par in January 1978 to 89 percent of their face value in April 1979. For both the contracts the distant maturities sold at larger discounts than the near-term maturities, reflecting the rising expectations on long-term rates.

From eq. (3-13) it is clear that the long-term futures instruments will have a higher degree of price correlation with a discount spot bond than another selling at par or premium.

Hypothesis 1D: A discount spot bond enjoys a higher risk reduction potential in the long-term futures market than another selling at par or premium.

It could not, however, be construed from this hypothesis that the distant contracts with fatter discounts would offer more price protection than the near-term contracts with yields close to spot yields. This is so because the relationship between the coupon and interest rate elasticity is known in the available literature for only a given yield and term to maturity. The near-term and distant contracts do, however, have varying yields to maturity.

Hypothesis 1E--Form of cash security. Another interesting issue is whether the long-term financial futures, which are tied to debt instruments, offer significant price protection to equity-type securities and hybrid securities. Since interest rates are the common denominator in the price generation process of all types of securities, the price changes of all of them reflect interest rate movements. Of course, the degree of interest rate sensitivity varies across the non-debt type securities. Hybrid securities such as preferred stocks are more responsive to interest rate changes than straight equities such as common stock. Within the common stock category growth stocks are known to be more interest rate elastic than non-growth stocks [40]. This implies that of the non-debt type issues the price changes of hybrid securities would have the highest degree of correlation with those of the long-term futures.[5] The next in rank in terms of degree of price correlation would be the growth stocks, and the last would be the non-growth stocks.

Hypothesis 1E: Of the non-debt type securities, the long-term futures will provide the highest degree of price protection to hybrid issues, the next highest degree to growth stocks and the least to non-growth stocks.

Hypothesis 1F--Individual securities vs. portfolios. A further classification of basis risk due to interest rate movements is: (1) risk caused by changes in the level of interest rates, and (2) risk due to interest rate fluctuations around a given level. Stone [92] termed the basis risk due to level changes as systematic interest rate risk and that due to fluctuations around a fixed average level as unsystematic interest rate risk. An alternative to hedging in dealing with unsystematic interest rate risk is to diversify a portfolio across maturity ranges of debt securities.

Evidently portfolios that are diversified across the maturity range are less prone to interest rate risk than are individual securities. This suggests that the price changes of individual securities would tend to have a higher degree of correlation with hedging instruments than that of the diversified portfolios.

Hypothesis 1F: Financial futures instruments offer superior price protection to individual securities than to portfolios diversified across the maturity dimension.

Hypothesis 1G--Bond futures vs. GNMA futures. The question of interest here is: Of the two long-term futures, which one would offer superior price protection for spot securities? The two relevant considerations are: (1) the kind of interest rates these futures represent, and (2) the maturity of their underlying spot securities. While the bond futures reflect the general level of long-term interest rate expectations in the economy, the GNMA futures mirror interest rate movements in the mortgage industry; the first is an economy-wide indicator while the second is an industry indicator of interest rate fluctuations. Also, the bond futures yield is lower than the GNMA futures yield. Further, the bond futures are tied to a spot bond of 15 years or longer to maturity while the GNMA 8 percent with which the GNMA futures are coupled have an expected effective maturity of 12 years. Since interest rate elasticity varies roughly monotonically with term to maturity and inversely with the level of interest rates, it follows that the bond futures are more sensitive to interest rate movements than the GNMA futures. Note further that there are other important differences in the underlying instruments regarding tax treatments, uncertainty of timing of payments, etc.

It can be inferred from these characteristics that the bond futures would generally have a higher degree of price correlation with bonds and stocks from various industries than would the GNMA futures.

Hypothesis 1G: The bond futures market is generally superior to the GNMA futures market in providing protection against interest rate risk. This superiority is, however, expected to be marginal when the hedged security is related to the mortgage industry.[6]

Hypothesis 2--The Hedge Ratio

An important issue that the hedger has to contend with in the process of constructing a short hedge is the number of futures contracts to be sold short against each unit of cash position. That is, the risk-minimizing investor needs to select a hedge ratio that will hopefully equate the price gain (loss) on the cash position with price loss (gain) on the futures position. Assume for instance the investor executes the following hypothetical hedge in T bills.

Table 3-1. A Hypothetical Hedge

Date	Cash Market		Futures Market	
June 1	Bought 1 unit of T bills	$98.00	Sold 1 contract of T bill futures	$97.50
August 31	Sold T bills	96.00	Bought back the futures	96.50
	Price loss on cash position	$ 2.00	Price gain on futures position	$ 1.00

Given these price changes, a unity hedge (i.e., a hedge involving one futures contract for each unit of cash position) would have been only partially successful in minimizing the price risk; ignoring transaction costs, the investor would have incurred a net loss of $1.00. If, on the contrary, the investor had sold short two futures contracts, the price loss on the cash position would have been completely offset by the price gain on the futures (ignoring, again, the trading costs), and the equity in the position would have remained intact.

It is apparent from the above illustration that the price-risk minimizing hedge ratio is the ratio of cash price changes to futures price changes. That is

$$h_t = \frac{CP_t}{CF_t} \tag{3-17}$$

where h_t = the hedge ratio.

Again, h_t indicates the number of futures contracts the investor has to sell short against each unit of the long cash position in order to minimize the price risk. A least square estimate of h can be obtained by regressing the cash price changes against the futures price changes as shown in eq. (3-15) which is reproduced below:

$$CP_t = A + BCF_t + E_t \tag{3-15}$$

The estimator of the slope coefficient in eq. (3-15) is

$$b = \frac{Cov(CP_t, CF_t)}{V(CF_t)} \tag{3-18}$$

That b = h = a risk-minimizing hedge ratio can also be seen by dividing eq. (3-6) by the number of bonds in the cash position, X_{ct}:

$$\frac{X_{ft}^*}{X_{ct}} = \frac{X_{ct}Cov(CP_t, CF_t)}{X_{ct}V(CF_t)} = b = h \tag{3-19}$$

Thus in the simple regression of cash price changes against futures price changes shown in eq. (3-15), the coefficient of determination, r_{cft}^2, is a measure of the hedging performance of financial futures markets while the slope coefficient gives an estimate of the risk minimizing hedge ratio.

Since the cash and futures prices generally move in the same direction, h will normally be positive. It can take negative values only when the P_t and F_t move in opposite directions, and consequently the $Cov(CP_t, CF_t)$ is negative. A positive h implies that the investor should take opposite positions in cash and futures (since these prices are positively correlated), and a negative hedge ratio suggests that the investor should maintain the same position, long or short, in both markets.

Traditionally, it is believed that a hedge ratio of unity is optimal [28,52]. But it is obvious from eqs. (3-17) and (3-19) that h = 1 only when $CP_t = CF_t$. There is, however, no reason to believe that cash and futures price changes will move in identical fashion. Thus h will equal 1 only by happenstance.

It is clear from eq. (3-17) that h is a function of relative cash and futures price changes. For securities of nominal default risk, price changes are largely determined by interest rate fluctuations.[7] Specifically, reproducing eq. (3-11)

$$
\begin{aligned}
CP_t &= -D_{ct} dI_{ct} P_t \\
CF_t &= -D_{ft} dI_{ft} F_t
\end{aligned} \tag{3-11}
$$

Evidently then

$$
h = \frac{CP_t}{CF_t} = \frac{D_{ct} dI_{ct} P_t}{D_{ft} dI_{ft} F_t} \tag{3-20}
$$

From the unbiased expectations theory, it is known that in a regime of rising interest rate expectations $P_t > P_{t+n}$, and therefore, $P_t > F_t$ (see eq. (3-16)). It then follows that for a given maturity, default risk, and coupon $D_{ct} > D_{ft}$. But what could be said about the relative magnitudes of dI_{ct} and dI_{ft}? That is, which market is more interest rate volatile, spot or futures? In the context of commodity futures Blau [10] observed:

> . . . the futures market is more sensitive to minor changes in supply and demand conditions. The formulation of prices in the cash and futures markets has been compared to the recording of temperature by two accurate thermometers, one graduated in degrees and the other in tenths of a degree [p. 8].

In view of the intrinsic nature of spot and futures markets in financial instruments it is intuitive to suggest that the futures markets are characterized by a much higher degree of interest rate volatility than the spot markets. That is, $dI_{ft} > dI_{ct}$ across all maturities.

In recent years, the behavior of interest rates has been more volatile relative to their historical record. The degree of volatility, however, has been far greater in the futures market than in the spot market. It is therefore argued here that dI_{ft} is, in general, so large that $D_{ft}dI_{ft}F_t > D_{ct}dI_{ct}P_t$. In other words, for a given maturity, default risk, and coupon, $CF_t > CP_t$. It follows from these arguments that cash price changes have been generally lower than futures price changes in recent years.

Hypothesis 2: The risk minimizing hedge ratio is generally less than unity.

That $h < 1$ if $CP_t < CF_t$ can also be seen from eq. (3-19). Define $CP_t = CF_t - G_t$ where G_t is the difference between futures and cash price changes. Then from eq. (3-19)

$$h = b = \frac{Cov(CF_t - G_t, CF_t)}{V(CF_t)}$$

$$= \frac{V(CF_t) - Cov(G_t, CF_t)}{V(CF_t)} < 1. \qquad (3\text{-}21)$$

How does the hedge ratio behave across the several determinants of the degree of price correlation such as the term to maturity of spot security, the level of default risk, the delivery period of futures contracts, the coupon effect, debt vs. equity securities, individual securities vs. portfolios, and the type of long-term futures contract? Eq. (3-19) implies that for a given variance of futures price changes, h is a direct function of the covariance between cash and futures price changes. This suggests that, in general, h will be the larger the higher the interest rate elasticities of cash and futures prices, and hence, the higher the degree of price correlation.[3]

<u>Hedge ratio and hedging effectiveness</u>. Further insights into the relationship between the hedge ratio and the degree of hedging effectiveness can be gained by comparing the coefficient of correlation between cash and futures price changes with eq. (3-19).

$$\gamma_{cft} = \frac{Cov(CP_t, CF_t)}{S(CP_t)S(CF_t)} \qquad h = \frac{Cov(CP_t, CF_t)}{S(CF_t)S(CF_t)}$$

Clearly when $S(CP_t) = S(CF_t)$, $\gamma_{cft} = h$. But as has been argued before generally $S(CP_t) < S(CF_t)$ for low default-risk securities. This implies that given $Cov(CP_t, CF_t)$, h is generally smaller than γ_{cft}. Also, when $\gamma_{cft} = 0$, $h = 0$. Since $\gamma^2_{cft} < \gamma_{cft}$, h is generally larger than γ^2_{cft} for lower ranges of γ_{cft}, however.

<u>Hypothesis 3--Efficiency of Financial Futures Markets</u>

The existing studies have adopted two methodologies to examine the efficiency of financial futures markets. The first involves the comparison of futures yields and their associated implied forward rates [13,56, 76,96]. A second approach compares yields on a spot security and a combination of futures and its underlying spot security for equivalent maturities [14]. Both the approaches report that markets for T-bill futures, bond futures, and GNMA futures are inefficient. In this investigation, it is proposed to employ a different methodology based on the Black-Scholes (BS) option pricing principle to examine the market efficiency of financial futures [9]. In essence, the methodology involves the construction of riskless hedges of futures and their underlying cash market securities, and comparing the returns on hedged portfolios with the riskless rate of return.

In their seminal work on option pricing, BS observed that "if options are correctly priced in the market, it should not be possible to make sure profits by creating portfolios of long and short positions in options and their underlying stocks" [p. 637].[9] Based on this principle, BS derived an option pricing formula and observed that the principle could be applied to the valuation of many other types of capital assets.

The evaluation of market efficiency in terms of the BS principle requires the construction of riskless hedges of interest rate futures and their underlying cash market counterparts. Suppose the investor buys a zero-coupon cash bond, estimates the risk minimizing hedge ratio, and sets up a short hedge. The rate of return on the short hedge, R^{w}_{t+1} is, ignoring trading costs, measured by

$$R^{w}_{t+1} = \frac{(P_{t+1} - P_t) + h_t(F_t - F_{t+1})}{P_t} \qquad (3\text{-}22)$$

If the investor continuously adjusts the hedge ratio, the hedge in effect will be risk free. The price gain (loss) on the cash position will be virtually offset by the price loss (gain) on the futures position leaving the equity position of the investor intact. In an efficient market, the investor maintaining such a continuously adjusted riskless hedge could expect to earn only the riskless rate of return.

Hypothesis 3: The expected return on a continuously adjusted portfolio of short and long positions in the financial futures and spot securities should not be consistently higher than the riskless rate.

The financial futures markets are efficient if the return on the hedged portfolio does not systematically exceed the riskless rate. If, on the other hand, the portfolio return is significantly different from the riskless rate, that will provide additional evidence that the interest rate futures markets are inefficient.

CHAPTER IV

METHODOLOGY

This chapter begins with an outline of the design of the study. Then the sample of securities and portfolios is described. Following this is a discussion of the measurement of different variables. Finally, the statistical analysis and tests employed to investigate the hypotheses are presented.

Research Design

The testing of the hypotheses calls for basically two types of design and methodology. Hypotheses 1 and 2 require the regression of cash price changes against futures price changes to estimate the coefficient of determination and the hedge ratio. Hypothesis 3 involves the construction of riskless portfolios of cash and futures and comparing the rates of return on these hedges with the riskless rate.

Hypotheses 1 and 2. These hypotheses deal with several dimensions of spot and futures instruments. Specifically, they involve the comparison of hedging performance and the hedge ratio across:

1. Different maturities of spot securities
2. Different levels of default risk
3. Various delivery periods of futures instruments
4. Discount and nondiscount spot issues
5. Debt, hybrid, and equity securities
6. Individual securities and portfolios
7. Bond futures and GNMA futures

A rigorous design for testing Hypotheses 1 and 2 requires that when the hedging effectiveness and the hedge ratio are being examined along one of the above dimensions the other dimensions are held constant. For example, if the hedging performance of bond futures is being studied across the maturity spectrum of individual bonds, then it is necessary to insure that bonds of various maturities are all of the same default risk, coupon effect, and security-type. Likewise, if the hedging performance is being compared across the coupon effect dimension--discount, premium, par--then it is necessary to ensure that the spot issues in the hedge are of the same level of default risk, maturity, security-form, and security-type but vary only in terms of their market price relative to their par value. In essence, in examining the hypothesis along one dimension, the securities are to be matched along other dimensions.

This implies that what one needs is a matched sample--matched along at least four dimensions. Clearly, it is very difficult to construct a sample matched on that many dimensions. Useful insights into the functioning of financial futures could still be obtained even by employing a design that lacks the above rigor. For the most part securities included in this study fulfill the above design requirements reasonably well.[1]

Hypothesis 3. This hypothesis assumes a continuous adjustment of the hedge ratio. It supposes that the investor estimates a risk minimizing hedge ratio based on his (her) current expectations regarding cash and futures price changes and constructs a hedge. Further, (s)he is assumed to revise the hedge whenever his (her) expectations change. A rigorous testing of the market efficiency hypothesis should, therefore, provide for a continuous adjustment of the hedge.

It follows then that for a superior empirical evaluation of the market efficiency hypothesis one should work with continuous price data, using the daily price changes. Since collecting and analyzing daily data would have involved a voluminous amount of work, the current research effort has been restricted to the investigation of weekly data.

Three additional questions need to be discussed regarding the market efficiency hypothesis. The first concerns the choice of a spot security to be coupled with each of the three financial futures in constructing riskless hedges. While the hypothesis does not require that any specific security be employed, the empirical considerations make it desirable to choose the cash market counterparts of each futures instrument. The underlying spot securities tend to have substantial price correlation with the futures and in addition, their price changes are likely to be more stable over time relative to futures price changes. Such a stable relationship between cash and futures price changes minimizes the error in the estimation of the hedge ratio due to the noncontinuous adjustment of the hedge. Thus the 13 week T bill, the 15 year government bond, and the 8 percent GNMA are employed in constructing hedges with the T bill futures, bond futures, and 8 percent GNMA futures respectively.

The second question pertains to the choice of the riskless rate of return against which the hedged portfolio return is to be compared. It is common to represent the riskless rate by the three month T bill rate. That choice is, however, inappropriate in the context of this study because the three month T bill rate is itself subject to interest rate risk. What is needed indeed is a rate with not only no default risk but also having as little exposure to interest rate movements as possible.

Thus a rate for lending and borrowing over a short period of time--essentially a continuously variable rate--is what is needed.

Several choices come to mind: the federal funds rate, the one week T bill rate, the call money rate, the one month rate on certificates of deposit (CD), and the thirty day commercial paper rate. The federal funds rate is for overnight lending and is often erratic due to sudden surges in demand and supply. The one week T bill rate has a wide bid-ask spread due to thin trading, and thus the results may depend on whether the bid or the ask yield is employed. The call money rate, although based on the stock market collateral, is not an attractive choice because it seems to contain some premium for default risk. The one month commercial paper rate was not conveniently accessible for some time at the beginning of the study. While the one month CD rate has a longer term than is desirable, it is believed to represent money market conditions fairly well and thus is employed as a proxy for the riskless rate.

Finally, the initial statement of hypothesis 3 assumes the absence of trading costs in the spot and futures markets. While this assumption is of some theoretical interest in gauging the level of market efficiency, it detracts from the real financial world where transaction costs are significant. From a practical viewpoint, it is more appealing to test whether one could have consistently made money, net of trading costs, in excess of the riskless rate by maintaining an approximately riskless hedge in cash and futures. Accordingly, the market efficiency hypothesis is examined at two levels: (1) ignoring transaction costs, and (2) adjusting for trading costs in computing the hedged returns.

Controls for Extraneous Variables

Spot prices. The key variables in this study are cash and futures prices, hedge ratio, return on the hedged portfolio, riskless rate, and trading costs. Of these, the price variable is common to all hypotheses. While the futures price changes are caused predominantly by interest rate expectations, the cash price changes of debt securities are a function of a number of factors other than interest rate movements. Of particular importance are the term to maturity, the default risk level, and the coupon effect. The price of a bond approaches its face value as it moves toward maturity. An increase in the level of default risk causes its price to decline. Besides, if the bond carries a coupon that is at variance with the current level of interest rate germane to its maturity and risk level, that will cause the bond to sell at a premium or discount. These three factors compound the effect of interest rate changes on the prices of debt securities.

The financial futures instruments are designed primarily to provide protection against the interest rate exposure of spot securities. As such, it is unreasonable to expect them to alleviate the price risk due to changes in the term to maturity, default risk, and coupon of spot securities. To make a fair and rigorous evaluation of their hedging performance it is therefore necessary to control for the price effects of maturity, default risk, and coupon.

Clearly then it would be desirable to have a set of spot securities and portfolios of constant maturity, constant level of default risk, and constant coupon effect during the entire period of investigation. Such an ideal set is, however, rarely possible to create in an empirical analysis. The best one could do in an empirical work is to minimize the noise created by the extraneous variables.

Note that in the ideal case the control of these extraneous variables requires that they be kept at a constant level during the study period. That is, any change in the term to maturity, in the level of credit risk, and in the level of discount or premium needs to be avoided. For instance, if a hedge is constructed with a thirteen week T bill, the control of maturity effect requires that the term of the bill be maintained at thirteen weeks from the beginning to the end of the study period. Similarly, if one starts with a discount bond, the control of the coupon effect calls for maintaining the same level of discount until the end of the study.

Of the three extraneous factors, by far the most difficult to control in this empirical work is the coupon effect. As the interest rates generally rose during the study period, the level of discount or premium also varied. An attempt has been made to minimize the resultant compounding effect on security prices by periodically replacing the individual issues with those that sold as close to par value as could be found. The maturity effect on individual securities is kept to a minimum by replacing

1. Each week the thirteen week T bill, the twenty-six week T bill, and the ninety day commercial paper with new securities of identical maturities

2. Each quarter the five year T note with a new note of approximately identical maturity

3. Each half year or year bonds of t years to maturity with new ones of approximately identical maturity

Due to the non-availability of suitable issues it has not been possible to adhere strictly to these procedures in a few instances involving government bonds, corporates, and municipals.

The default risk effect is minimized by choosing issues whose credit ratings as determined by the Moody's and the Standard and Poor's Financial Services did not undergo any change during the study period. Note that in trying to mitigate the distorting price effects these procedures inevitably add some further noise to the data base owing to the limitations on the availability of suitable issues. It is believed, however, that the net result is a reduction in the overall noise level. These controls are probably most effective in the case of T bills since only their maturity needs to be held constant. The controls are less successful in the case of corporates and municipals rated lower than A due to the non-availability of an adequate number of reported issues during the study period. It has not been possible to apply such controls to mutual fund portfolios because of the lack of information regarding the detailed terms of issue of individual securities included in the portfolios.

Futures prices. In addition to controlling the price effects of maturity, coupon, and credit risk on spot securities, it is also necessary to hold constant the distance to delivery of futures contracts. It was noted earlier that during the period of this study there were no more than eight T bill futures contracts, and eleven each of bond futures and GNMA futures contracts trading simultaneously. The first contract is due for delivery three months from its inception, the second six months later and so on through the eleventh contract falling due thirty-three months into the future. The delivery months fixed by the Exchanges are: March, June, September, and December. Presumably the prices of futures contracts reflect interest rates expected to prevail at the time of their expiration. Usually interest rate expectations vary over time. For instance, interest rate forecasts for three months will generally differ from those for six months into the future. It is thus clear that the time dimension of expectations is critically important in understanding the behavior of futures yields and prices.

With the passage of time the term to delivery of a futures contract diminishes, and a distant contract gradually turns into a near-term contract. Thus over its life-span the prices of a futures contract indicate interest rate expectations over varying lengths of time.

As posited in hypothesis 1C, the term to expiration of a futures contract has an important bearing on its hedging performance. For reasons advanced earlier, the prices of a near-term contract move more in tandem with spot prices than do those of a distant contract. It is therefore apparent that the term to delivery of a futures contract needs to be controlled in order to provide a sound explanation for the hedging effectiveness of financial futures.

In this investigation the distance to delivery of futures contracts is controlled at quarterly intervals. That is, contracts due for delivery in three months are designated as the first (the nearest term) contract; contracts due for delivery from three to six months into the future are named as the second contract. Thus the eleventh contract covers all those contracts due between thirty to thirty-three months into the future. Obviously, this results in only a partial control of the term to delivery, but it is believed that the procedure is reasonably adequate for the intended purpose.

In order to test hypothesis 1C it is further necessary to designate one of the futures contracts as the near-term contract and another as the distant contract. The first contract is perhaps too near to delievery, and, as such, may not be a suitable hedging instrument despite the fact that it is expected to have by far the highest degree of price correlation with spot issues. Moreover, it may be influenced to a sizeable extent by the delivery requirements and consequently may not aptly mirror the interest rate expectations of market participants. Additionally, the volume of open contracts may be too thin to fairly reflect futures prices.

In a similar vein, it is desirable to exclude a couple of contracts at the far end due to the modest number of contracts typically traded. An added reason justifying their exclusion is the small sample size associated with them. With these considerations in mind, the third contract containing all contracts due for delivery from six to nine months into the future is chosen to represent the near-term contract for all futures instruments. The sixth contract for T bill futures and the eighth contract for long term futures are designated as the distant contract. The eighth is preferable to the ninth contract in the case of long-term futures because of its considerably larger sample size. These choices are not believed to preclude the generalization of findings to contracts in their neighborhood because of the high degree of price correlation within the two categories of contracts.

Sample

The general criteria for sample selection have already been discussed in the last two sections. They suggest that the sample should contain both securities and portfolios of debt, equity and hybrid forms, varying across the maturity, default risk, and the coupon dimensions. Table 4-1 describes the securities and portfolios included in the sample. Each of the individual securities shown in Table 4-1 in fact contains a series of issues which were changed periodically to control for the maturity and coupon effects. Appendix A presents the specific individual issues, their coupons, maturity, rating, interest payment dates, and date of inclusion in the study. The maturities shown against the individual securities are representative and not exact. The study covers the following overlapping periods:

1. For analysis involving GNMA futures--January 1976 to April 1979
2. For analysis involving the T bill futures--March 1976 to April 1979
3. For analysis involving the bond futures--October 1976 to April 1979

The futures contracts began trading earlier than the beginning months listed above. Data for the first few weeks were not used in the study in order to allow the market conditions to stabilize.

The data on individual securities and fund portfolios have been collected from The Wall Street Journal [97]. The security index data are those published in the Standard and Poor's Security Price Index Record [90]. All the data are the Wednesday closing quotes. The corporate bond quotes are the closing quotes, the prices of government notes, bonds,

Table 4-1. Description of sample securities and portfolios

Individual Securities	Fund Portfolios	Security Indices	Futures Instruments
1. AT&T bonds rated Aaa--25 years	A. Money market funds	A. Common stock index	1. 90-day T bill futures contracts--CME (TBIF1 to TBIF8)
2. Georgia Power Corp. and Alabama Power Corp. bonds rated Baa--25 years (GPAP)	1. Dreyfus Liquid Assets--predominantly in CDs (DLA)	1. S&P 500 common stock index	2. 15-year T bond futures--CTB (TBOF1 to TBOF11)
3. Municipal Assistance Corp. of New York and Ohio Turnpike issues rated Baa or better--15 years (Muni 2)	2. Scudder Managed Reserves--predominantly in CP and short US governments (SMR)	B. Bond indices	3. 8 percent GNMA futures--CBT (GNMAF1 to GNMAF11)
4. T notes--5 years	3. Mutual of Omaha America--predominantly in US governments and repos (MOA)	1. S&P high grade corporate bond index--20 years, 4 percent coupon (S&P CORP)	
5. T bonds--9 years	B. Bond funds	2. S&P long term government bond index--15 years, 3 percent (S&P LT GOVT)	
6. T bonds--15 years	1. Fund for U.S. government securities--predominantly longterm governments (FUSG)	3. S&P intermediate term government bond index--7.5 years, 3 percent (S&P IT GOVT)	
7. T bonds--24 years	2. Keystone B-1--high grade bonds	4. S&P short term government bond index--3.5 years, 3 percent (S&P ST GOVT)	
8. 1 week T bills (T bill 1)	3. Keystone B-2--straight bonds	5. S&P municipal bond index--20 years, 4 percent (S&P MUNI)	
9. 13 week T bills (T bill 13)	4. Keystone B-4--discount bonds		
10. 26 week T bills (T bill 26)	C. Municipal bond funds		
11. 90 day commercial paper (CP)	1. Dreyfus Tax-exempt Bond fund (DTEB)		
12. FNMA issues--7 years	2. Kemper Municipal Bond fund (KMBF)		
13. GNMA 8 percent issues	D. Stock fund		
	1. American Investors fund--98 percent in common stock--maximum capital gain (AmInv)		
	E. Balanced funds		
	1. AmCap fund--predominantly common stock--growth fund		
	2. American Balanced fund (AmBal)		

T bills, FNMA bonds, GNMA bonds, and municipal bonds are ask quotes, and the fund quotes are the net asset values without the sales charge. The study assumes that the investor generally holds a long cash position, and so the ask quotes are appropriate.

Measurement of Variables

For the money market securities and the T bill futures the published data are in terms of yields and thus need to be converted to prices. To generate the corresponding price data the following procedures are employed:

$$
\begin{aligned}
&1.\quad \text{1 week T bill price} = 100 - \frac{7}{360} \times \text{Ask Yield} \\
&2.\quad \text{13 week T bill price} = 100 - \frac{91}{360} \times \text{Ask Yield} \\
&3.\quad \text{26 week T bill price} = 100 - \frac{182}{360} \times \text{Ask Yield} \qquad (4\text{-}1) \\
&4.\quad \text{T bill futures price} = 100 - \frac{90}{360} \times \text{Futures Yield} \\
&5.\quad \text{90 day commercial paper price} = 100 - \frac{90}{360} \times \text{Yield}
\end{aligned}
$$

The published note and bond prices do not represent prices at which investors could have traded securities since they do not include accrued interest. For such issues the interest payment dates have been identified,[2] and the weekly accrued interest is added to published prices on a cumulative basis. In the case of bond indices semi-annual coupon payments on January 1 and July 1 are assumed.

Under hypothesis 3, the investor is assumed to have estimated the first hedge ratio, h_t, by utilizing the first fourteen weeks of price data in the simple regression shown in eq. (3-15). The successive hedge ratios for the t+1 week onwards are estimated by using all the previous weekly price changes. The h_t is employed in constructing the hedge for the t+1th week and computing the portfolio return, R^W_{t+1}.

For the no-trading costs case, the weekly R^W_{t+1} is measured as shown in eq. (3-22). This is subsequently converted into the annualized compound return, R_{t+1}, as under:

$$R_{t+1} = [(1+R^W_{t+1})^{52} - 1] \times 100 \tag{4-2}$$

The weekly portfolio returns net of transaction costs, R'^W_{t+1}, are arrived at by

$$R'^W_{t+1} = \frac{(P_{t+1} - P_t - T1) + h_t(F_t - F_{t+1} - T2)}{P_t + h_t M} \tag{4-3}$$

where T1 = the spot commission cost

T2 = the futures commission cost

M = the futures margin

The annualized compound returns, R'_{t+1}, is computed as follows:

$$R'_{t+1} = [(1 + R'^W_{t+1})^{52} - 1] \times 100 \tag{4-4}$$

Based on the information supplied by a few brokerage houses[3] T1 is set at \$0.25 for all the three spot securities. This amounts to a commission cost of \$2.50 per \$1000 face value and represents the typical commission charged on transactions involving 50 or more bonds. The reported representative round-trip commissions during the study period are: \$70 per contract for T bill futures (\$0.007 per \$100 face value) and \$65 per contract for the long-term futures (\$.065 per \$100 face value). Accordingly T2 is set at \$0.007 for T bill futures and \$0.065 for long-term futures. The reported initial margins are: \$1500 per contract for T bill and bond futures and \$1200 per contract for GNMA futures. So M is assigned a value of \$0.15 for T bill futures, \$1.50 for bond futures and \$1.20 for GNMA futures. Evidently, the above costs and margins represent only part of the total trading costs as they ignore other incidental expenses and subsequent margins that the investor has to post as prices fluctuate during the course of the hedge.

Statistical Analysis

As discussed earlier the basic statistical technique upon which this investigation is founded is the simple regression of weekly cash price changes, CP_t, against the corresponding futures price changes, CF_t, as reproduced below:

$$CP_t = A + BCF_t + E_t \qquad (3\text{-}15)$$

The measure of hedging effectiveness, r^2_{cft}, of hypothesis 1, the hedge ratio, h, of hypothesis 2, and the weekly hedge ratio, h_t, which is an input into hypothesis 3, are all derived from this statistical tool.

In fact, for hypothesis 1 the stochastic relationship between cash and futures price changes described in eq. (3-15) can be analyzed either in terms of a bivariate correlation model, or equivalently, in terms of the simple regression model. Hypotheses 2 and 3 are based on the latter model, however. So the simple regression model is employed in evaluating all the hypotheses.

The regression model is based on a number of assumptions. Of particular importance are those relating to the distributions of E_t, CP_t, CF_t, and B. It assumes that the E_t are serially independent and are normally distributed with a zero mean and constant variance. Further, the

CP_t are supposed to be independent with a homoscedastic conditional normal distribution given the CF_t. The parameter B is assumed to be constant over time, and the regression relationship between CP_t and CF_t is taken to be linear.

There is very little evidence regarding the conditional distribution of CP_t given CF_t. A few studies do, however, offer evidence on rates of return in stock and bond markets. Fama found that the stock market returns have a fat-tailed distribution [29,30]. Westerfield [99] examined the distributions of dividend adjusted daily return relatives for 315 common stocks listed on the New York Exchange during the period 1968-69 and found them to be slightly assymetric, highly leptokurtic, and non-stationary in calendar time.[4] On the distribution of bond market returns, Roll [80] reported that the T bill price changes are non-normal while Fama [32] in a later study concluded that the first differences in one month T bill returns are nearly normal. Garbade and Silber [35] examined the daily bid and ask price dispersions of forty-eight treasury coupon issues in 1975 and found them to be negatively skewed, fat-tailed and non-stationary.

Schneeweis and Schweser [84] investigated the one month holding period portfolio returns of corporate industrial, public utility, and municipal bonds of varying ratings based on the Moody's yield series during the 1952-75 period. They reported that the monthly bond portfolio returns are significantly positively skewed and leptokurtic. Investigating further the monthly holding period returns on government bonds across a wide range of maturities during 1961-73, they found that the distributions deviate from normality with slightly positive skewness and kurtosis. In addition, the commodity futures price changes are known to deviate from normality [88,91].

This evidence suggests the likelihood of non-normal distributions of cash and futures price changes. Even if the conditional distribution of CP_t given CF_t is not normal, it is not improper to employ simple regression to estimate r^2_{cft} and h so long as the price changes are uncorrelated over time. According to Neter and Wasserman, "No matter what may be the functional form of the distribution on e_i (and hence of Y_i), the least square method provides unbiased point estimators of β_0 and β_1 which have minimum variance among all unbiased linear estimators" [69; p. 47].

In a similar vein, Kmenta wrote:

> If the assumption that the disturbance is normally distributed is dropped, the least squares estimators of the regression coefficients are still BLUE, since this property is independent of the form of the form of the parent population. This means that even without the assumption of normality the least squares estimators are unbiased and have the smallest variance among all linear unbiased estimators. However, they can no longer be claimed to be efficient . . . [55; pp. 247-8].

Likewise, Malinvaud observed, "When the hypothesis of normality no longer holds exactly, the estimators of the coefficients are still efficient in the class of linear estimators, but not generally in the class of all regular estimators" [68; p. 30].

With regard to the serial correlation between price changes, economic theory does imply that the price changes are non-autoregressive since the information underlying them is thought to be generated in a random fashion. In "A Theory of Anticipatory Prices," Working observed that "the actions of traders seeking to evaluate a nearly continuous flow of new information bearing upon price would create conditions of nearly continuous price change, changes which would be nearly random since the occurrence of new information itself is random" [73; p. 253]. Further, Samuelson [83] demonstrated that in an efficient market futures prices behave according to a martingale.

The available empirical evidence on the autoregressive character of price changes is mixed. While Fama [29, 32] reported that the stock and T bill returns are uncorrelated over time, Smidt [88] and Stevenson and Bear [91] found low order serial dependence in the distribution of commodity futures price changes. In view of this evidence on normality and autoregression, it seems fair to conclude that the employment of simple regression to estimate r^2_{cft} and h is appropriate.

Hypothesis Testing

If the location, scale, and shape parameters of the distributions of price changes deviate considerably from those of a normal distribution, there are five possible ways to deal with the situation. The first is to see if the data can be converted to normality through some kind of mathematical transformation [12]. The second is to trim off extreme observations before employing the regression technique [44]. The third is to use robust estimators[5] that are not greatly influenced by outliers [49].

The need for adopting the second or the third approach has received a lot of attention in recent years. Andrews et al. [3] demonstrated the inefficiency of least squares relative to more robust estimates of location for a wide variety of distributions. Ramsay [77] compared the performance of least square estimators of regression coefficients with those of maximum likelihood type estimators across different levels of contamination of normal populations and reported that up to 25 percent rate of contamination the latter are more efficient than the former. In a similar vein, Hogg [44] and Andrews [4] recommended the use of robust regression[6] rather than least squares when the distributions are non-Gaussian.

The fourth approach to deal with non-Gaussian distributions is to use non-parametric estimates and tests.[7] Finally, one may go ahead with the traditional tests as if the distributions were normal but exercise extreme care in interpreting the results.

The last alternative is adopted in this study, leaving any statistical refinements for future research. Although this is a suboptimal choice, it is justified on two grounds. First, the t tests to be used here are known to be fairly reliable in the face of moderate departures from normality [69; p. 48]. According to Malinvaud,

> The significance level of the tests . . . is not very sensitive to deviations from normality, when the tests are applied to the comparison of <u>means of independent samples</u>. The F test and the two-tailed t-test have a significance level near that given by the tables [63; p. 298].

Reviewing the works of Cochran [20] and Srivastava [89] on the power of the analysis of variance tests, Banks [4] observed

> When the analysis of variance procedures are applied to measurements of quantitative data arising from continuous distributions . . . failure of the data to follow the symmetrical bell-shaped normal distribution introduces no serious errors into the significance levels of the F test . . .
>
> From a series of investigations in which F tests were applied to data derived from deliberately created non-normal distributions, Cochran . . . estimated that the true probability corresponding to the

> tabulated 5 percent significance level of the F distribution might be somewhere between 4 and 7 percent: for the 1 percent level, the true probability limits might be taken as 1/2 and 2 percent [pp. 72-3].

Second, the adverse effects of non-normality vary inversely with the sample size. According to Winkler and Hays

> When the sample size is fairly large and when the parent distribution is roughly unimodal and symmetric, the T distribution apparently still gives an adequate approximation to the exact (and often unknown) probabilities of intervals for T under these circumstances. . . . In effect, if the sample size is large enough so that the normal probabilities are good approximations to the T probabilities anyway, then the form of the parent distribution is more or less irrelevant [101; p. 367].

In this study the sample size is fairly large. For tests involving near-term T bill and GNMA futures contracts. The number of observations are commonly in the region of 160, while for the near-term bond futures contract it is around 70. For the distant contracts, the sample sizes are small and vary from about 40 to 120.[8]

Correlation test. It is perhaps helpful to recapitulate briefly the various operational subhypotheses on hedging performance before proceeding with a discussion of the relevant statistical tests. An overview of the subhypotheses is presented in Table 4-2.

A general pattern of tests for the above hypothesis can be formulated as:

$$H_0: \; r_{21}^2 = r_{31}^2 \qquad H_A: \; r_{21}^2 > r_{31}^2 \tag{4-5}$$

Or, equivalently, if the r's are all positive

$$H_0: \; r_{21} = r_{31} \qquad H_A: \; r_{21} > r_{31} \tag{4-6}$$

where r_{21} stands for the first part of each of the subhypotheses for which a higher r^2 is posited.

r_{31} indicates the second part of each subhypothesis with a supposedly lower r^2.

Table 4-2. An overview of hedging effectiveness hypotheses

Hypothesis 1A.	The long-term coupon bonds will receive more price protection than the short-term zero-coupon securities.
Hypothesis 1B.	The futures instrument will offer more effective price protection to default-free securities than to risky issues.
Hypothesis 1C.	The near-term futures onctracts will perform more successfully than the distant contracts.
Hypothesis 1D.	The hedges involving discount spot issues will be more successful than those coupled with non-dsicount securities.
Hypothesis 1E.	The hybrid securities will receive favorable price protection relative to the straight common stocks.
Hypothesis 1F.	The futures instruments will provide more price protection to individual securities than portfolios diversified across terms to maturity.
Hypothesis 1G.	In general, the bond futures will outperform the GNMA futures in cross-heding.

Note that r_{21} and r_{31} may themselves be correlated, rather substantially at times. The appropriate statistic for testing the difference between two correlated rs is described in [65], and involves the following t test:

$$t = \frac{(r_{21}-r_{31})\sqrt{(N-3)(1+r_{23})}}{\sqrt{2(1-r_{21}^2-r_{31}^2-r_{23}^2+2r_{21}r_{31}r_{23}}} \qquad (4-7)$$

where N = the sample size

r_{23} = the correlation between r_{21} and r_{23}

The test requires that the two sets of observations being compared be of equal sample size. The t statistic in (4-7) is known to be reliable[9] even when the observed distribution deviates considerably from normality [65]. It is interpretable with the help of the standard normal distribution table for N exceeding 50. Note, however, the reliance that one can place on the test results depends on how seriously the observed distributions deviate from the various underlying statistical assumptions.

Hypothesis 2 claims that the hedge ratio h would be generally less than unity. That is, from eq. (3-15)

$$H_0: \quad B = 1$$
$$H_A: \quad B < 1 \tag{4-8}$$

This calls for the following t test:

$$t = \frac{b - B}{S(b)} \tag{4-9}$$

where S(b) = the standard error of b

Hypothesis 2 further claims that the B_1 associated with the r_{21} of each of the subhypotheses outlined in Table 4-2 1A to 1G will be greater than B_2 related to r_{31} (see eq. (4-6)). This requires testing for the difference between two slope coefficients. To do so would involve the standardized regression coefficients, BETAs:

$$BETA = b\frac{S(CF_t)}{S(CP_t)} \tag{4-10}$$

But

$$b\frac{S(CF_t)}{S(CP_t)} = r \tag{4-11}$$

Essentially then the test for the difference between the slope coefficients of the simple regression is identical to the test for the difference between correlation coefficients. Thus the test described in eq. (4-6) is equally valid here.

Paired t test. Hypothesis 3 posits that the return on hedged portfolio, R_{t+1}, would not consistently exceed the riskless rate, RR_{t+1}, in an efficient market. To test this hypothesis, define the excess return, ER_{t+1}, as

$$ER_{t+1} = R_{t+1} - RR_{t+1} \tag{4-12}$$

Then,

$$\begin{aligned} H_0&: \quad ER_{t+1} = 0 \\ H_A&: \quad ER_{t+1} > 0 \end{aligned} \tag{4-13}$$

The null hypothesis implies that the futures markets are efficient while the alternative indicates market inefficiency in the sense that positive excess returns occur not by chance but systematically.

The appropriate test statistic for eq. (4-13) is described by Winkler and Hays [101]:

$$t = \frac{MER_{t+1}}{S(ER_{t+1})} \tag{4-14}$$

The paired t test shown in eq. (4-14) is based on the assumption that the population distributions of R_{t+1} and RR_{t+1} are normally distributed with homogeneous variances. While there is little evidence on the distributional properties of RR_{t+1}, Fama's [32] results indicate that the first differences in one month T bill returns are nearly normal. Regarding variances, it is safe to assume that the hedged returns are considerably more disperse than the riskless rate.[10]

How serious is the effect of violations of the above mentioned assumptions on the testing procedure described in eq. (4-14)? In the context of testing for the difference between two means, Winkler and Hays observed:

> The first assumption, that of a normal distribution in the populations, is apparently less important of the two. As long as the sample size is even moderate for each group, quite severe departures from normality seem to make little practical difference in the conclusions reached . . . On the other hand, the assumption of homogeneity of variances is more important. For samples of equal size, relatively big differences in the population variances seem to have relatively small consequences for the conclusions derived from a T statistic [101; pp. 371-72].

Clearly, the use of a fairly large sample size in this study mitigates the problems inherent in the data with respect to employing the paired t test. How much faith could one place on this testing procedure in gauging market efficiency is, however, an empirical question and depends on the seriousness of the observed departures from normality and homogeneity of variances.

CHAPTER V

RESULTS

A careful evaluation of empirical results requires an understanding of the underlying statistical distributions of relevant random variables. Accordingly the chapter begins with an examination of the distribution of cash and futures price changes. This is followed by a discussion of the empirical results relating to the hedging performance, the hedge ratio, and the market efficiency of financial futures.

Distribution of Price Changes

Cash price changes. Table 5-1 presents the distribution of price changes of selected cash and futures instruments; a more comprehensive tabular presentation is included in Appendix B. A few points need to be borne in mind in interpreting these statistics. First, the quality of published financial statistics on debt securities is much less accurate than those on stocks. The published price and yield quotes not only do not represent the prices at which actual transactions take place in the market but are also subject to more measurement errors and imprecision as they ignore small price changes. While the minimum price changes of coupon-bearing governments, agencies, and futures contracts are quoted in 32nds of one percent, those of exchange-listed corporates are reported in eighths of a percent, and of municipals in increments of one-half of one percent. Moreover, the price quotes of exchange-listed corporates, which are employed in this study, are not representative quotes in that most of their volume takes place in the over-the-counter market.[1]

TABLE 5-1. Distribution of weekly price changes--selected issues 1976-79[a]

(1) Security	(2) N	(3) Mean	(4) SD	(5) SR	(6) K-SZ
I. Individual issues					
1. T bills--13 weeks	164	-.006	.052	11.36	1.70n
2. Commercial paper--90 days	164	-.005	.044	11.07	3.29n
3. T notes--5 years	161	.103	.444	7.67	1.26
4. T bonds--15 years	167	.104	.709	7.75	1.18
5. GNMA 8 percent	172	.102	.531	7.11	1.19
6. AT&T bonds	169	.081	.898	9.59	1.46n
7. GPAP bonds	169	.144	.967	6.51	1.31
II. Fund portfolios					
1. MOA	164	-.002	.072	5.97	2.82n
2. FUSG	172	-.004	.063	10.79	1.83n
3. KMBF	99	-.005	.036	5.56	0.86
4. AmInv	172	.016	.160	5.75	1.26
III. Security indices					
1. S&P CORP	172	.048	.449	7.57	0.86
2. S&P LT GOVT	172	.037	.453	6.51	1.01
3. S&P 500	172	.050	1.733	5.41	0.48
IV. Futures instruments					
A. T bill futures					
1. Nearterm contract	164	-.004	.053	5.51	1.05
2. Distant contract	149	-.001	.063	9.48	1.24
B. GNMA futures					
1. Nearterm contract	172	-.051	.569	6.52	.88
2. Distant contract	134	-.045	.672	9.12	1.25n
C. Bond futures					
1. Nearterm contract	81	-.155	.744	5.26	0.62
2. Distant contract	59	-.104	.776	5.04	0.71

n = does not fit the specified normal distribution based on the observed mean and variance at .05 level

[a]The coverage of the time period varies across the instruments. For details see the secton on sample in Chapter IV.

Second, the interest rates were generally increasing during the study period and were near their peak towards the end of the period. Consequently, the expected value of price-changes is negative. This is clearly reflected in the price changes of futures contracts and of money market issues which are consistently negative with few exceptions. The bond futures have a higher absolute mean price-change and standard deviation since they belong to the recent more volatile interest rate period. Third, the reported mean price-change of coupon issues is generally positive. This is due to the addition of accured interest to the prices quoted in the financial press in order to arrive at prices that investors have to pay on purchase of coupon bonds. Assuming a coupon of 8 percent per annum, the accrued simple interest on a weekly basis is roughly $0.15, and for a 4 percent annual coupon it is close to $0.08. Thus the reported weekly mean price changes for coupon issues include accrued interest of approximately these magnitudes and are hence generally positive.

It was asserted earlier that for a given maturity, coupon, and default risk futures yields are normally more volatile than spot interest rates and as a result futures price changes and standard deviations are expected to be higher than those of spot issues. A comparison of mean price changes of the 13 week T bills and 90 day commercial paper with that of the T bill futures reveals that the former are slightly greater than the latter. In the case of the GNMAs, the spot price change is about twice that of the futures price change. For government bonds, in contrast, the futures price changes exceed the spot both before and after adjusting for the sample size. Thus the evidence on the hypothesized higher volatility of futures rates seems to be mixed.

Some caution is, however, called for in making inferences based on the mean price changes. While a normal distribution is fully described by the first two moments about the mean, it is not necessarily true of a non-normal distribution. In the latter case, the mean may be less reliable as a measure of central tendency. The findings presented later indicate that the futures price changes are as a class more nearly normally distributed than are the spot price changes. It follows that any inference on the relative volatility of cash and futures price changes based on their means could be misleading.

In the case of long-term instruments, the spot prices include the weekly accrued interest while the futures contract prices do not reflect any accrued interest. If the accrued interest is eliminated from spot prices, the futures do seem to have a slight edge over the former. The published commercial paper quotes are meant to be a general indicator of money market conditions, and are believed to contain more measurement errors relative to the T bill futures.

Note further that the futures prices are settlement prices while the spot T bill prices are asked and the spot long-terms are closing prices. Finally, the futures markets are regulated by the exchanges while the spot securities are not generally traded on exchanges and thus are largely traded in an unregulated market. The normal daily price limits for long term futures are 75 basis points above or below the previous day's settlement price while for the T bill futures it is 50 basis points [17,19].

Notwithstanding these problems with the comparison of mean price changes between cash and futures instruments, it still seems legitimate to go ahead with a review of their standard deviations. Clearly the latter are not affected by the addition of an approximately constant weekly accrued interest to price changes. A comparison of standard deviations suggests that futures price changes are more volatile than those of spot issues. In quite a few instances, even the spot issues with sizably longer maturities than that of futures contracts tend to have lower standard deviations (see Appendix B). Overall the findings, although mixed, seem to favor the proposition that the futures price changes are generally greater than their spot counterparts.

From the standpoint of hypothesis testing the critically important question is: How closely do the spot and futures price changes approach normal distributions? Or rather, how serious is the departure of the distributions of price changes from normality? To this end the studentized ranges, SR, are reported in column 5. In addition skewness and kurtosis are also reported in Appendix B. The studentized range is a statistic which indicates the range of observations in the sample in terms of the maximum price change minus the minimum price change divided by the standard deviation. Clearly it is very sensitive to extreme values and is widely used as a reliable statistic in assessing the distributional properties of stock market data.[2]

In interpreting the reported studentized ranges it is useful to note a few of their typical values for sample sizes comparable to the ones used in this study. In samples of 60, 150, and 200 cases from a normal distribution the probability that the studentized ranges will be equal to or less than 5.93, 6.64, and 6.85 respectively is .99 [26].

It is apparent from Table 5-1 that quite a few distributions of spot price changes of debt securities deviate from normality. Of the debt securities the money market issues appear to be more non-normal than the coupon-bearing issues. A further look at skewness and kurtosis presented in Appendix B reveals that with a few exceptions the distributions of spot price changes are negatively skewed and they are consistently leptokurtic relative to normal distribution. While the degree of negative skewness is marginal, the extent of leptokurtosis is often marked. Across maturities, money market issues tend to be characterized by higher degrees of leptokurtosis than coupon issues.

What can be inferred from these distributional properties? First, the higher values of SR suggest that the distributions of price changes of debt securities are generally fat-tailed. That is, the samples come from distributions where the probabilities of observations far from the mean are higher than if the distributions were normal. Relative to the normal, these distributions contain more extreme positive and negative price changes. Second, the negative skewness denotes that while the extreme values lie left of the mean, the cases cluster on the right side of the mean. That is, of the extreme values, the negative price changes far exceed the positive price changes. Third, the sizable degrees of leptokurtosis reveal that the central portion of these distributions contains more price changes than does the normal distribution.

<u>Futures price changes</u>. The distribution of futures price changes, on the other hand, presents some interesting contrasts (see Appendix B for more

details). Both the bond futures and the GNMA futures price changes are nearly normally distributed while those of T bill futures price changes are more non-normal. The bond futures price changes are generally thin-tailed reflecting relatively smaller probabilities of extreme values. Unlike the spot and the other two futures, the bond futures have a slight amount of positive skewness denoting a tendency for extreme values to lie to the right of the mean. With a few exceptions the futures price changes are marked by a slight degree of leptokurtosis.

Across the delivery periods, the distributional properties tend to be largely stable. The nearest term contract in all futures instruments is, however, associated with the distributions that are relatively more skewed to the left and more peaked. Note also that of the contracts chosen to represent the near term and distant delivery periods, the T bill futures and GNMA futures distant contracts fail to represent accurately the distributional properties of the contracts around them. Recall, however, that they were chosen to represent other contracts because of the larger number of observations associated with them.

How do the distributions of price changes of debt and futures contracts compare with those of stock price changes? The distributions can be compared only at the portfolio level since the sample does not include any individual stocks. From Table 5-1 it is apparent that the changes in the S&P 500 Common Stock Price Index are characterized by a nearly normal, thin-tailed platykurtic distribution. The distributions of price changes of two stock funds--AmCap and AmInv--are also nearly normal, but leptokurtic. The distributions of long-term futures compare very favorably with the distributions of stock price changes.

The Kolmogorov-Smirnov goodness of fit test. Given the mixed signals on the distributions of price changes it is perhaps desirable to go further and do a nonparametric distribution test. Column 6 in Table 5-1 lists the Kolmogorov-Smirnov Z statistic. In essence, this test computes the maximum absolute difference between the hypothesized normal distribution and the observed sample distribution. Multiplying this difference by the square root of the sample size gives the Z statistic. The smaller the values of Z, the closer is the approximation between the observed distribution and the theoretical distribution. At a significance level of 0.05 the null hypothesis that the price change distributions of T bill (13 weeks), commercial paper, AT&T bonds, Fund for U.S. Government Securities (FUSG), Mutual of Omaha America (MOA), and GNMA distant futures contract are normally distributed was rejected. In the remaining cases, the null hypothesis could not be rejected.

It emerges from the foregoing analysis that sizable departures from normality occur in the case of money market issues and funds. In all other cases it seems safe to assume that the distributions of price changes are nearly normal.

Correlation between futures price changes. Another question relevant to the correlation tests to be done later is whether the price changes of different futures contracts are uncorrelated. As interest rate changes across industries as well as maturities are highly correlated so will be the price changes generated by them. The correlation matrix presented in Table 5-2 shows that the correlations among futures price changes--both across contracts and across instruments--are substantial.

TABLE 5-2. Correlation matrix of futures price changes[a] 1976-1979[b]

	T Bill Futures		Bond Futures		GNMA Futures	
	Nearterm	Distant	Nearterm	Distant	Nearterm	Distant
T Bill Futures						
1. Nearterm	1.00					
2. Distant	.72	1.00				
Bond Futures						
1. Nearterm	.63	.78	1.00			
2. Distant	.49	.66	.97	1.00		
GNMA Futures						
1. Nearterm	.69	.62	.92	.90	1.00	
2. Distant	.49	.45	.88	.91	.95	1.00

[a]The sample sizes are identical to those reported in Table 5-1

[b]The coverage of the time period varies across the instruments. For details see the sample section of Chapter IV.

The statistical implication is that in comparing the hedging performance of futures instruments across spot issues, delivery contracts, and between instruments themselves, the test employed should provide for the fact that the correlation coefficients are themselves substantially correlated.

Hedging Effectiveness

The principal thesis of this investigation is that hedging performance is largely a function of the interest rate elasticities of cash securities and futures instruments.[3] Interest rate elasticity has several dimensions and those considered in this study are: maturity, level of default risk, coupon effect, delivery period, form of cash security, type of cash security, and type of futures contracts. Based on these dimensions, many subhypotheses regarding hedging performance have been formulated.

It is necessary to construct a number of tests for each of the sub-hypotheses. As observed in the methodology chapter, the research design requires that when a test is being done across one dimension, all other dimensions must be held constant. This requirement is evidently a theoretical ideal and can only be approximately fulfilled in an empirical analysis owing to numerous limitations on data availability.

The maturity dimension. Hypothesis 1A posits that futures contracts will yield a superior hedging performance[4] with relatively long-term spot issues compared to those with short-terms to maturity. The relevant tests on this hypothesis are reported in Table 5-3.

The first column in Table 5-3 lists the two hedges being compared in each of the tests. The first hedge in each test is hypothesized to perform superior to the second hedge. r_{21} is the correlation coefficient associated with the supposedly "more effective" hedge. r_{31} is the correlation coefficient of the "less effective" hedge. r_{23} indicates the correlation between the two spot securities in each test. The subscript "1" refers to the hedging instrument, "2" to the spot issue in the "more effective" hedge, and "3" to the spot security in the "less effective" hedge. N denotes the sample size which is usually equal in both the hedges.[5] The entry in column 6 is the t statistic derived from eq. (4-6). The alternative hypothesis for each of the tests is that r_{21} is greater than r_{31}. That is, the first hedge is more effective than the second hedge as the spot maturities in the first hedge are longer than those in the second hedge.

TABLE 5-3. Hedging effectiveness and term to maturity of spot securities 1976-1979[d]

	(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{23}	(5) N	(6) t
1.	T bill 26[e]-TBIF3 vs. T bill 1-TBIF3	.64	.22	.46	164	6.714a
2.	T bill 26-TBIF3 vs. T bill 13-TBIF3	.64	.57	.82	164	1.937b
3.	T bond 24-TBOF3 vs. T note-TBOF3	.89	.60	.63	58	5.517a
4.	T bond 24-TBOF8 vs. T note TBOF8	.89	.57	.63	58	6.053a
5.	S&P CORP-TBOF8 vs. S&P ST GOVT-TBOF8	.79	.37	.45	59	4.889a
6.	S&P LT GOVT-TBOF8 vs. S&P ST GOVT-TBOF8	.76	.43	.43	59	3.615a
7.	SUSG-TBOF3 vs. MOA-TBOF3	.37	.43	.24	59	- .423
8.	T bond 15-TBOF8 vs. T bill 13-TBIF3	.81	.67	.22	58	2.800a
9.	GNMA 8%-GNMAF8 vs. T bill 13-TBIF3	.71	.59	.31	134	1.992b
10.	T bond 24-TBOF8 vs. T bill 1-TBIF3	.88	.27	.04	59	7.981a
11.	AT&T-TBOF8 vs. CP-TBIF3	.69	.37	-.05	59	2.755a
12.	FNMA-GNMAF8 vs. CP-TBIF3	.64	.08	.20	130	6.506a
13.	T bond 24-TBOF8 vs. T bond 9-TBOF8	.88	.86	.94	58	.921c
14.	FUSG-TBOF8 vs. MOA-TBOF3	.38	.43	.26	59	- .354
15.	S&P CORP-TBOF8 vs. S&P ST GOVT-TBOF3	.79	.43	.45	59	4.229a
16.	T bond 24-TBOF8 vs. T note-TBOF3	.88	.60	.63	57	5.122a

a = significant at .01 level [t*=2.06]
b = significant at .05 level [t*=1.28]
c = significant at .10 level [t*=0.84]

d. The coverage of the time period varies across securities. For details see the sample section of Chapter IV

e. The numbers associted with the spot securities listed in column (1) denote their terms to maturity. For example:

T bill 26 = 26 week T bill
TBIF3 = Nearterm T bill futures contract
TBIF6 = Distant T bill futures contract
TBOF3 = Nearterm bond futures contract
TBOF8 = Distant bond futures contract

For further details see the sample description provided in Table 4-1.

Given that the distributions of price changes underlying some of the above tests are non-normal, the primary thing of interest is whether the correlation coefficients are in hypothesized directions. Table 5-3 shows that of the seven tests all but one are consistent with the hypothesis. The one that runs contrary to the hypothesis involves two fund portfolios, the FUSG which is a longterm government bond fund and the MOA, a money market fund composed largely of short-term governments. Note that the price quotes used for fund portfolios are their published net asset values without the sales charge. The net asset values represent the market value of the portfolio of securities and cash balances after adjusting for the liabilities of mutual funds [100]. It is possible that the observed results might be due to the use of the net asset values rather than the market values of fund portfolios.[6]

The t values are reported in column 6. The examination of the second, third, and fourth moments about the mean and the non-parametric test results indicated earlier that the distributions of price changes of several securities deviate from normality, the departures being more serious in the case of money market issues. How serious are the effects of these departures on the confidence intervals and significance levels of the t test have not been examined in this investigation. Accordingly it is thought prudent to avoid any discussion of the significance of tests in the analysis of results. The observed t values and their significance levels are, however, reported in order to enable the reader to make his (her) own judgment regarding the reliability of the findings of this study.

Another interesting question in this context is the relative importance of different dimensions of interest rate elasticity in determining hedging effectiveness. Tests 8 through 16 in Table 5-3 are intended to evaluate the relative effects of the maturity and delivery period dimensions on hedging performance. In each of these tests, a relatively long-term spot is coupled with the distant contract and a short-term spot with the near-term contract. From hypothesis 1C it is obvious that these results are biased against the maturity hypothesis. Yet all but one of the results are in favor of hypothesis 1A. It is thus evident from these findings that the term to maturity is far more important than the delivery period of futures contracts in determining hedging performance. Furthermore, notice from tests 8 through 12 that of the three financial futures the long-term futures are considerably more effective than the T bill futures in affording price protection.

<u>The default-risk dimension</u>. The default-free securities are more interest rate sensitive than the risky securities since the former carry a lower coupon than the latter. Additionally they follow interest rate movements much more closely than do risky issues. Accordingly hypothesis 1B contends that futures instruments offer more price protection to default-free securities than to risky issues.

Table 4 presents the relevant empirical tests. The rationale underlying these tests is set out below:

Test 17. T bill 13 has a lower level of default risk than even the high grade commercial paper

Test 18. AT&T issues are rated Aaa while those of the GPAP Baa

Test 19. MUNI2 issues are rated Baa or better

TABLE 5-4. Hedging effectiveness and level of default-risk of spot securities 1976-1979

	(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{23}	(5) N	(6) 5
17.	T bill 13-TBIF3 vs. CP-TBIF3	.57	.10	.25	164	5.935a
18.	AT&T-TBOF8 vs. GPAP-TBOF8	.69	.23	.25	59	3.861a
19.	AT&T-TBOF8 vs. MUNI2-TBOF8	.69	.57	.43	59	1.279b
20.	MOA-TBIF3 vs. SMR-TBIF3	.35	.21	.27	164	1.582b
21.	FUSG-TBOF8 vs. KMBF-TBOF8	.38	.35	.33	59	.217
22.	AMBAL-TBOF8 vs. AMINV-TBOF8	.47	.28	.78	59	2.459a
23.	AMBAL-GNMAF8 vs. AMINV-GNMAF8	.40	.28	.79	34	2.317a
24.	S&P CORP-TBOF8 vs. S&P MUNI-TBOF8	.79	.59	.64	59	2.924a
25.	S&P LT GOVT-TBOF8 vs. S&P MUNI-TBOF8	.76	.59	.58	59	2.226a

a = significant at .01 level [t*=2.06]
b = significant at .05 level [t*=1.28]
c = significant at .10 level [t*=0.84]

Test 20. MOA is made up of mostly short-term governments while a large portion of SMR is invested in commercial papers

Test 21. FUSG is a government securities fund while KMBF is that of municipal bonds

Test 22. AMBAL is a balanced fund with over 30 percent in fixed income securities while AMINV is predominantly a stock fund. Fixed income securities are less prone to default risk than common stocks on account of their prior claim on earnings and assets of the issuing firm

Test 23. The intent here is to broadbase the tests across futures instruments

Test 24. Both the indices relate to high grade bonds but it is believed that investors tend to perceive that high grade corporates generally involve a lower level of default risk than high grade municipals especially since the financial debacle of New York City.

Test 25. Credit risk associated with government bonds is lower than that of municipal bonds.

A comparison of r_{21} with r_{31} reveals that the results are decisively in favor of the hypothesis. All of the nine tests reported in Table 5-4 are in favor of the hypothesis and in a large number of cases the difference between the correlation coefficients is substantial.

The delivery period dimension. The delivery requirement drives the futures prices towards their underlying spot security prices, and this delivery effect on price movements varies inversely with the futures contract's distance to expiration. Further, the near-term contract is more interest rate elastic than the distant contract. Accordingly, Hypothesis 1C posits that the near-term contract provides superior price protection in comparison to the distant contract.

The empirical results are presented in Table 5-5. Note that r_{23} in this context refers to the correlation between the near-term and distant contracts. It is apparent that the results are in favor of the hypothesis. It may however be noted that the support for the hypothesis varies across hedging instruments. While the near-term contracts in the T bill futures markets prove clearly superior to their distant counterparts, in the long-term futures markets their superiority seems only marginal. This is in fact reflected in the futures correlation matrix presented earlier in Table 5-2. It is evident from that matrix that the correlation between the near-term and distant contracts in the bond futures as well as GNMA futures is much higher than the corresponding correlation in the T bill futures.

TABLE 5-5. Hedging effectiveness and term to expiration of futures contracts 1976-1979

(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{23}	(5) N	(6) t
26. AT&T-TBOF3 vs. ATT-TBOF8	.73	.69	.97	59	1.799b
27. MUNI2-TBOF3 vs. MUNI2-TBOF8	.59	.57	.97	59	.757
28. T note-TBOF3 vs. T note-TBOF8	.60	.57	.97	56	1.117c
29. T note-GNMAF3 vs. T note-GNMAF8	.72	.67	.80	125	1.292b
30. T bond 24-TBOF3 vs. T bond 24-TBOF8	.89	.88	.97	59	.678
31. GNMA8%-GNMAF3 vs. GNMA8%-GNMAF8	.72	.71	.80	136	.275
32. T bill 13-TBIF3 vs. T bill 13-TBIF6	.59	.39	.72	134	3.796a
33. T bill 26-TBIF3 vs. T bill 26-TBIF6	.67	.47	.72	134	4.122a
34. DLA-TBIF3 vs. DLA-TBIF6	.27	.19	.72	134	1.271c
35. FNMA-GNMAF3 vs. FNMA-GNMAF8	.71	.64	.80	134	1.826b
36. T note-TBIF 3 vs. T note TBIF6	.70	.60	.72	125	2.107a
37. S&P CORP-TBOF3 vs. S&P CORP-TBOF8	.83	.79	.97	59	2.250a
38. FUSG-TBOF3 vs. FUSG-TBOF8	.37	.38	.97	59	- .330

a = significant at .01 level
b = significant at .05 level
c = significant at .10 level

The coupon effect dimension. Given the term and yield to maturity, a relatively low coupon bond is more sensitive to interest rate movements than another with a high coupon. In regimes of high interest rates, this implies that a coupon bond trading at a discount is more interest rate elastic than an otherwise similar non-discount bond. Based on this, hypothesis 1D claims that futures instruments accord superior price protection to discount coupon bonds relative to those selling at par or premium.

Table 5-6 exhibits the results bearing on this hypothesis. While tests 39, 40, 46, and 47 favor the hypothesis, the others run counter to

TABLE 5-6. Hedging effectiveness and the coupon effect of spot securities 1976-1979

(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{23}	(5) N	(6) t
39. GNMA8%-GNMAF8 vs. GNMA9%-GNMAF8	.71	.68	.73	134	.704
40. S&P CORP-TBOF3 vs. AT&T-TBOF3	.83	.73	.73	80	2.264a
41. S&P LT GOVT-TBOF3 vs. T bond 15-TBOF3	.81	.82	.81	79	- .274
42. S&P LT GOVT-TBOF3 vs. T bond 1-TBOF3	.65	.87	.65	78	-4.741a
43. S&P MUNI-TBOF3 vs. MUNI2-TBOF3	.52	.54	.53	81	- .229
44. S&P MUNI-GNMAF3 vs. MUNI2-GNMAF3	.24	.30	.53	171	- .740
45. S&P ST GOVT-TBOF3 vs. T note-TBOF3	.39	.66	.52	77	-3.164a
46. S&P LT GOVT-TBOF3 vs. FUSG-TBOF3	.81	.41	.45	81	5.766a
47. S&P MUNI-TBOF3 vs. KMBF-TBOF3	.56	.27	.45	81	2.948a

a = significant at .01 level
b = significant at .05 level
c = significant at .10 level

it. It is, however, necessary to keep in mind a few points in interpreting the results. First, tests 40 through 45 are biased against the hypothesis because they compare a portfolio against an individual security. The portfolio effect is not expected to be sizable, however, since these portfolios are not diversified across maturity ranges.

Despite this basis, test 40 clearly supports the hypothesis and tests 41, 43, and 44 deviate only marginally. Tests 46 and 47 are free from the portfolio bias in the sense that one portfolio is compared with another. Yet the results might have been biased in favor of the hypothesis because the fund portfolios are generally more diversified across maturity ranges than index portfolios.

Second, recall that the impact of the level of discount on interest rate elasticity is marginal (see Chapter III). So even though the index portfolios represent deep discount spot instruments, the price protection they receive is not expected to be much higher than that associated with non-discount issues. Overall, the tests do offer some support for and some against the coupon effect hypothesis and thus call for further investigation.

The security-form dimension. This hypothesis argues that hybrid securities will receive more price protection from hedging in financial futures markets than do common stocks. The following tests are set up to evaluate this hypothesis:

Test 48. AmBal-TBOF8 vs. AmCap-TBOF8. Both AmBal and AmCap are balanced funds, but the proportion of investment in fixed income securities was over 30 percent for AmBal and about 10 percent for AmCap during the study period. It is therefore expected that futures contracts will offer more price protection to AmBal than to AmCap.

Test 49. AmBal and AmInv hedged with TBOF8. AmInv is a stock fund with over 98 percent investment in common stock

Test 50. AmCap and AmInv hedged with TBOF8. Not only that AmCap is a balanced fund while AmInv is a stock fund, but also the former was classified as a growth fund while the latter as a maximum capital gain fund by Weisenberger Financial Services during the study period [100]. Growth stocks are known to be more sensitive to interest rate than non-growth stocks.

The test results are reported in Table 5-7. Clearly, all of the results are consistent with the hypothesis. Further, even the differences in results are in anticipated directions. The correlation coefficient associated with the balanced fund is more than that of the growth fund, and the latter exceeds the correlation coefficient pertaining to the stock fund.

TABLE 5-7. Hedging effectiveness and form of spot securities 1976-1979

(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{23}	(5) N	(6) t
48. AmBal-TBOF8 vs. AmCap-TBOF8	.47	.33	.88	59	2.472a
49. AmBal-TBOF8 vs. AmInv-TBOF8	.47	.28	.78	59	2.459a
50. AmCap-TBOF8 vs. AmInv-TOBF8	.33	.28	.89	59	.845c

a = significant at .01 level
b = significant at .05 level
c = significant at .10 level

The security-type dimension. Portfolios that are made up of securities of varying maturities are bereft of unsystematic interest rate risk while an individual security suffers from both systematic and unsystematic interest rate risk. Accordingly, hypothesis 1F states that hedging with financial futures provides more price protection to individual securities than to diversified portfolios.

Partial evidence in favor of this hypothesis was obtained in testing the coupon effect hypothesis. Additional tests which are not clouded by the coupon effect are shown in Table 5-8. It is fair to assume that the fund portfolios are reasonably well diversified since they contain debt securities of various maturities. The results unambiguously support the hypothesis.

The hedging instrument dimension. The final question examined here is whether a choice between the two long-term futures instruments matters. Based on their industry yield and maturity characteristics it was hypothesized that the bond futures generally provide superior price protection compared to the GNMA futures.

TABLE 5-8. Hedging effectiveness and type of spot securities 1976-1979

(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{32}	(5) N	(6) t
51. T bill 13-TBIF3 vs. MOA TBIF3	.57	.35	.24	164	2.860a
52. T bond 24-TBOF8 vs. FUSG-TBOF8	.88	.38	.47	59	7.676a
53. MUNI2-TBOF8 vs. KMBF-TBOF8	.59	.35	.39	59	2.041b

a = significnat at .01 level
b = significant at .05 level
c = significant at .10 level

The empirical results are exhibited in Table 5-9. While the results are generally in favor of the hypothesis, the difference in the performance of the two hedging instruments appears marginal. The high degree of correlation among different long-term interest rates and the small difference in the maturity of the futures contracts' underlying instruments seem to diminish the slight edge that the bond futures have over the GNMA futures.

TABLE 5-9. Comparison of hedging effectiveness of bond futures and GNMA futures 1976-1979

(1) Test	(2) r_{21}	(3) r_{31}	(4) r_{23}	(5) N	(6) t
54. AT&T-TBOF8 vs. AT&T-GUMAF8	.69	.68	.91	59	.247
55. MUNI2-TBOF8 vs. MUNI2-GNMAF8	.57	.51	.91	59	1.288b
56. FNMA-GNMAF3 vs. FNMA-TBOF3	.74	.72	.92	76	.642
57. AmInv-TBOF8 vs. AmInv-GNMAF8	.28	.27	.91	59	.186
58. S&P CORP-TBOF8 vs. S&P CORP-GNMAF8	.79	.74	.91	59	1.443b
59. S&P MUNI-TBOF8 vs. S&P MUNI-GNMAF8	.59	.60	.91	59	- .222
60. GPAP-TBOF8 vs. GPAP-GNMAF8	.23	.25	.91	58	-.361

b = signficant at .05 level

Hedge Ratio

That futures yields are systematically more volatile than spot rates implies that for a given maturity, coupon and defulat risk the magnitude of price changes of spot securities will normally be less than those of futures instruments. This will result in the covariance between cash and futures price changes being lower than the variance of the latter. Consequently, the risk-minimizing hedge ratio is generally expected to be less than unity.

Table 5-10 presents the hedge ratios for a selected number of issues across the three futures instruments. It is obvious that the empirical results are preponderantly consistent with the hypothesis and deviate from it only in a few cases. Given these results there is little need to carry out statistical tests to show that the hedge ratio is less than unity.

Further, the hypothesis implies that smaller hedge ratios will be associated with those issues which are less interest rate elastic relative to futures instruments, while larger hedge ratios will go with those spots with interest rate sensitivity exceeding that of futures contracts. Money-market issues, fund portfolios, and risky bonds belong to the first category, and long-term issues, and discount coupon bonds fall into the latter group. A closer look at the empirical results reveals that this indeed is the case. Notice, in particular, CP, MOA (both belong to the money market group), FUSG (a fund portfolio), AT&T, T bond 24 (long-term bonds), and S&P MUNI (a discount bond portfolio). It was also argued that hedge ratio and hedging performance are directly related to

Table 5-10. Selected hedge ratios[a]

(1) Securities	(2) T Bill Futures[b] TBIF3	(3) TBIF6	(4) Bond Futures TBOF3	(5) TBOF8	(6) GNMA Futures GNMAF3	(7) GNMAF8
1. T bill 13	.56 (.06)	.29 (.06)				
2. CP	.08 (.07)	.06 (.06)				
3. MOA	.47 (.10)	.44 (.09)				
4. T notes			.42 (.11)	.36 (.12)	.66 (.09)	.37 (.10)
5. T bond 15			.68 (.22)	.77 (.24)	.99 (.18)	.79 (.17)
6. T bond 24			1.03 (.14)	1.06 (.14)	1.08 (.14)	1.05 (.12)
7. FNMA			.70 (.14)	.57 (.16)	.60 (.16)	.20 (.16)
8. GNMA8%			.53 (.13)	.62 (.14)	.88 (.10)	.56 (.10)
9. AT&T			.94 (.33)	1.61 (.32)	1.05 (.24)	.68 (.24)
10. FUSG			.04 (.01)	.04 (.01)	.06 (.01)	.05 (.01)
11. DTEB			.04 (.01)	.04 (.01)	.06 (.01)	.07 (.01)
12. Keystone B-1			.02 (.05)	.02 (.05)	.06 (.03)	.04 (.03)
13. AmBal			.09 (.01)	.07 (.02)	.08 (.01)	.06 (.01)
14. AmInv			.11 (.03)	.07 (.03)	.09 (.02)	.07 (.02)
15. S&P CORP			.45 (.07)	.47 (.08)	.70 (.06)	.46 (.06)
16. S&P LT GOVT			.45 (.06)	.44 (.06)	.64 (.05)	.46 (.06)
17. S&P MUNI			.55 (.10)	.59 (.11)	.65 (.16)	.40 (.17)
18. S&P 500			1.26 (.25)	.94 (.30)	.84 (.39)	.44 (.38)

a = Hedge ratios for other securities in the sample are reported in Appendix D.

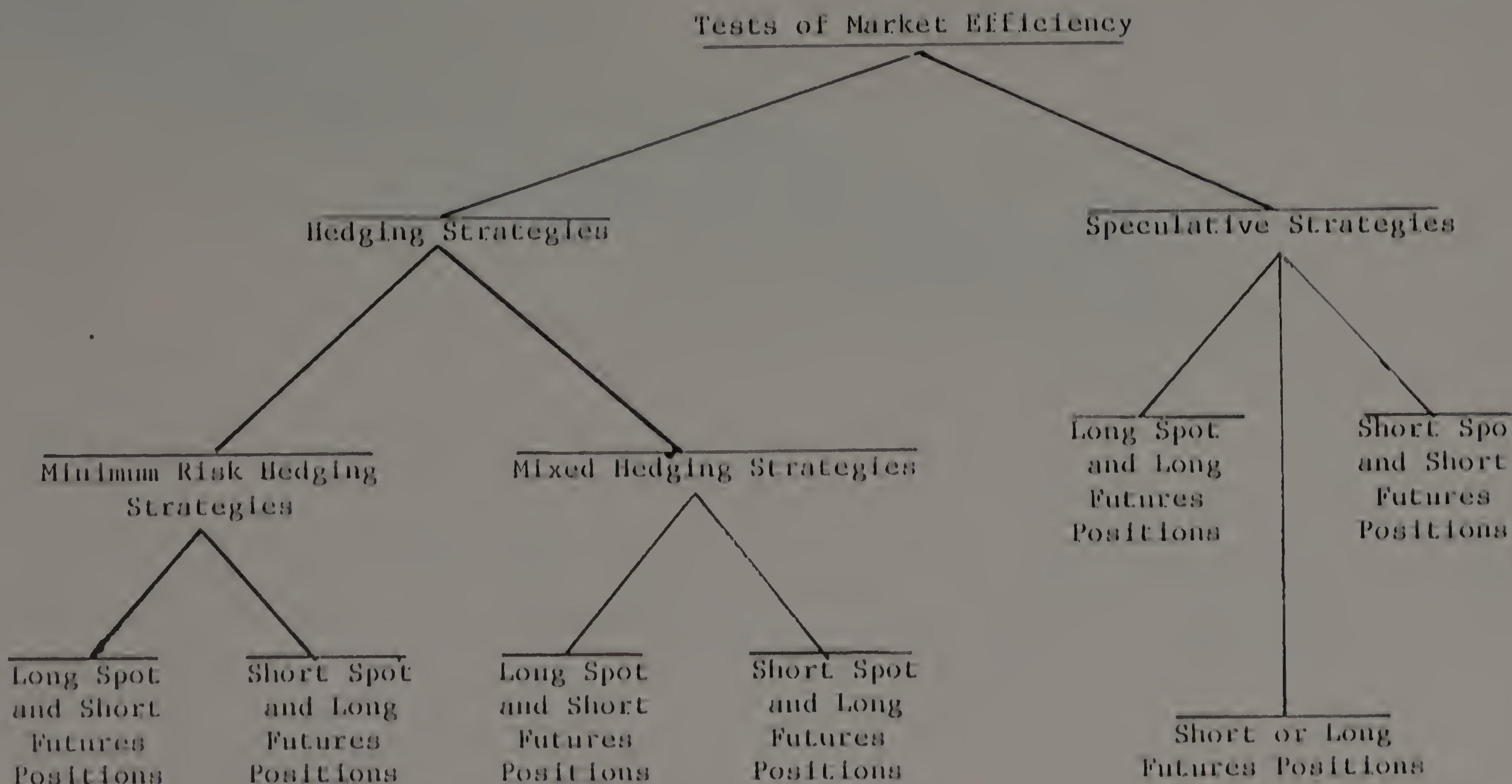
b = Figures in parentheses are the standard errors of hedge ratios each other. That is, higher hedge ratios go with superior hedging performance and lower hedge ratios are related to inferior hedging performance. As shown under the methodology chapter, the testing procedures for the hedge ratio-hedging performance relationship and hypothesis 1 are equivalent. Since the empirical results have been strongly in favor of hypothesis 1 along almost every dimension, it follows that the hedge ratio-hedging performance hypothesis is also supported to a similar extent.

Market Efficiency

A number of investment strategies could be used to test the market efficiency of financial futures. A broad outline of such tests is exhibited in Table 5-11.

Market efficiency implies that the expected return on a portfolio is proportional to (or at best no higher than that justified by) its market risk [9,59,85]. The minimum risk Black-Scholes hedging strategies involve constructing a portfolio of long spot and short futures positions such that the price gain (loss) on the spot position is completely offset by the price loss (gain) on the futures position. In the mixed hedging strategies the long spot and short futures positions are combined in proportions that are different from the risk-minimizing hedge ratio. Consequently the mixed hedging strategies are more risky than the Black-Scholes hedging strategies. By far the most risky are the speculative investment strategies since they involve no offsetting positions in the spot and futures markets. A trader following speculative strategies is

TABLE 5-11. A Paradigm of Market Efficiency Tests



primarily or exclusively either at the long end or at the short end of either or both the spot and futures markets.

The advantage of employing the BS hedging strategy to assess market efficiency is that one does not have to be concerned with the measurement of risk associated with hedged returns (since the accompanying risk is by definition at a minimum). All that one needs to show is that the excess returns of the hedged portfolio are not consistently positive. Using mixed hedging and speculative strategies requires, however, the measurement of both risk and returns on hedged portfolios and demonstrating that the returns are proportional to the risk involved.

This investigation confines itself to the minimum risk hedging strategy in examining the market efficiency of financial futures. Within the minimum risk strategy, the strategy involving long spot and short futures positions has been directly tested and the likely consequences of adopting the opposite strategy of short spot and long futures positions are analyzed without employing any testing procedures. The concept of market efficiency implies that the return on a risk-free security should not be consistently higher than the riskless rate. Accordingly a riskless portfolio created by continuously adjusting a hedge of long and short positions in spot and futures instruments should earn no more than the riskless rate. To test this hypothesis thirty hedges of long spot and short futures positions were constructed:

1. T bill 13 hedged with each of the T bill futures contracts
2. Government bond 15 hedged with each of the bond futures contracts
3. GNMA 8 percent hedged with each of the GNMA futures contracts

While the hypothesis does not require that the underlying spot issues be employed in constructing hedges, it does call for continuous adjustment of the hedged ratio in order to maintain a riskless hedge. In this investigation the hedges are revised on a weekly basis and this is likely to make them more risky than would have been the case if they had been continuously adjusted. The imperfections in the hedge stemming from discrete adjustment of the ratio could, however, be mitigated by choosing those spot issues which have a relatively stable time series correlation with futures prices. Clearly, the underlying spot instruments would be expected to have by far the most stable and predictable relationship with futures. Thus the returns on hedges involving the futures instruments and their spot market counterparts should not contain appreciable measurement errors as a result of the use of weekly rebalancing. The hedged returns are first computed ignoring spot and futures transaction costs. Later, the returns net of transaction costs are analyzed.

Hedged returns without transaction costs. The distributional properties of price changes of individual spot securities and futures instruments were discussed at the beginning of this chapter. The reader will recall, however, that while a linear combination of independent normal random variables is also normally distributed, the cash and futures price changes are not independent. Thus knowing their individual distributions does not help to determine the distribution of hedged returns. Accordingly, the distributional statistics pertaining to hedged returns are reported in Table 5-12.

TABLE 5-12. Returns before transaction costs on hedged portfolios of futures instruments and their underlying spot securities 1976-1979

	T Bill Futures Hedges			Bond Futures Hedges			GNMA Futures Hedges		
Contract	Mean (SD)	Skewness (Kurtosis)	SR (N)	Mean (SD)	Skewness (Kurtosis)	SR (N)	Mean (SD)	Skewness (Kurtosis)	SR (N)
1	-.37 (1.86)	-.42 (7.67)	9.18 (127)	10.38 (26.90)	1.53 (4.96)	6.04 (53)	9.01 (20.23)	.84 (3.38)	7.48 (130)
2	-.22 (2.34)	-.62 (11.04)	10.81 (151)	7.61 (28.49)	1.96 (8.43)	7.02 (62)	8.72 (24.83)	1.90 (11.18)	9.09 (153)
3	-.22 (2.30)	-.73 (11.73)	10.89 (151)	7.15 (20.97)	.90 (3.17)	6.31 (62)	8.07 (18.84)	.15 (2.13)	7.04 (153)
4	-.25 (2.40)	-.40 (12.66)	11.21 (151)	6.39 (21.13)	.92 (3.23)	6.18 (62)	7.92 (18.66)	-.14 (1.14)	5.95 (153)
5	-.27 (2.49)	-.29 (12.58)	11.21 (151)	6.53 (21.30)	.68 (3.96)	6.57 (62)	8.28 (21.32)	.37 (2.22)	6.97 (153)
6	-.34 (2.77)	-.30 (10.98)	10.63 (136)	6.79 (25.44)	1.04 (4.17)	6.55 (62)	7.37 (19.88)	.12 (1.30)	6.50 (144)
7	-.37 (3.18)	-.08 (7.91)	8.91 (88)	7.10 (26.60)	.66 (2.28)	5.45 (41)	8.02 (25.35)	2.20 (12.64)	8.86 (116)
8	-.39 (3.21)	-.08 (7.77)	8.89 (88)	6.81 (26.76)	.38 (1.95)	5.50 (41)	5.84 (18.72)	.22 (1.41)	6.32 (116)
9				6.64 (27.98)	.15 (1.46)	5.23 (41)	7.61 (18.37)	.16 (.11)	6.64 (66)
10				6.90 (28.37)	.44 (2.34)	5.65 (41)	7.54 (18.61)	.29 (.54)	4.68 (66)
11				7.57 (26.44)	.32 (1.76)	5.51 (41)	6.14 (21.14)	.10 (-.04)	4.44 (44)

SD = Standard deviation
N = Sample size

The sample sizes vary from about 40 to about 150 and at these levels the theoretical studentized ranges (SR) corresponding to .01 and .99 fractiles of a normal distribution vary from 3.46 and 6.64. In particular in samples of 40, 60, 80, 100, and 150 the probability that the studentized range will be equal to or less than 5.54, 5.93, 6.18, 6.36, and 6.64 respectively is .99 [26]. Comparing the observed SRs with the above theoretical values one could not reject the hypothesis that hedged returns in the bond futures and GNMA futures markets are nearly normally distributed while those in the T bill futures markets are relatively less normal. Note, however, that the studentized range provides a reliable test of normalities only when the alternative distribution is of the fat-tailed variety such as the stable.

It is apparent that the return distributions are leptokurtic across all futures markets with the tails being substantially fatter in the T bill futures than in other markets. The degrees of skewness are generally small. While the distribution is negatively skewed in the T bill futures, the skewness is positive in all but one contract in the long-term futures markets.

In a regime of (unanticipated) generally rising interest rates a short hedge is expected to involve a price loss on the cash position and a price gain on the futures position. If the hedge is maintained riskless by continuously adjusting the positions, the difference between the futures price gain and the cash price loss in an efficient market should not systematically vary from the riskless rate.

From Table 5-12 it is obvious that the mean hedged returns in the T bill futures are close to zero with a consistently negative sign which implies that the cash price loss typically exceeds the futures price gain. Note, however, that the distributions across all T bill futures contracts are negatively skewed implying that the observations cluster to the right side of the negative mean return and that the extreme observations are mostly negative. Furthermore, the sharp degree of leptokurtosis suggests that the central portion of the distribution contains a relatively large proportion of observations and that the tails are fat relative to the normal distribution.

The mean hedged returns in the long-term futures markets are, in contrast, consistently positive. Recalling that the prices of long-term spot bonds include accrued interest, it should be noted that the mean hedged returns for both bonds and GNMA futures are not far from their coupons. It can be inferred then that the spot price loss excluding the weekly accrued interest is approximately equal to the futures price gain. Note further that the hedged returns in the long-term futures are highly volatile relative to those in the T bill futures market.

Excess hedged returns. In order to test for market efficiency it is necessary to compare the hedged returns obtained above with a rate of interest that is free from interest rate risk. That is, it needs to be shown that the excess of hedged returns over the riskless rate does not systematically exceed zero. For reasons advanced earlier, the one month certificate of deposit (CD) rate is employed as the proxy for the riskless rate.

Given that the annualized compound hedged returns in the T bill futures are consistently negative, it is clear that the excess hedged returns will be systematically negative with even larger magnitudes. Evidently any statistical testing is unnecessary. Thus a hedger in the T bill futures market would have, by maintaining a weekly hedge, on average lost a little more than the riskless rate instead of earning the riskless rate of return. How does this compare with the existing evidence on the efficiency of T bill futures? These studies show that the long T bill futures yield tends to exceed the corresponding implied forward rate. In other words, a combination of long spot and long futures has a higher yield than a long cash position of identical maturity. By implication the short futures yield is lower than the corresponding implied forward rate. As a result, a combination of long spot with short futures will have a lower yield than that on a long cash position of identical maturity. Since this study employs a short hedge, it appears that at least part of the observed negative return is due to the reported tendency of the short futures yield to lag behind the implied forward rate.

Furthermore, the available evidence indicates that the gap between the long futures yield and the implied forward rate tends to increase in favor of the former as the distance to expiration of futures contracts increases. From Table 5-12 it is apparent that the absolute mean return excluding that of the nearest contract also steadily increases as the delivery period stretches into the future. As the available evidence implies, distant contracts have higher negative returns than do the near-term contracts. Recall that the data for distant contracts are available for only the more recent study period while the near-term contract data come from the entire study period. Interest rates were generally rising from late 1977 until mid-1979,and thus these higher levels of interest rates cover most of the period for which the absolute mean returns across delivery periods were found to increase. Therefore the apparent increasing tendency may in some way be related to that particular time period. Also, note that the sample sizes for distant contracts are smaller than those of near-term contracts.

The mean excess returns on the T bill futures hedges varied from -.22 to -.39 percent with the standard deviations ranging from 1.86 to 3.21 percent during the study period. The one month CD rate which is used here as a proxy for the riskless rate had a mean of 6.5 percent and a standard deviation of 1.7 percent during the same period. Thus the short hedger in the T bill futures market would have on average lost (including opportunity costs) about 7 percent per annum. The existing evidence suggests that a little less than two percentage points of this loss could be explained by the tendency of the long futures yield to exceed the corresponding implied forward rate [13,14]. Conceivably part of the remaining difference is due to the weekly rather than the daily rebalancing of the hedge ratio. There does not seem to be any reasonable explanation for the remainder of the difference.

What are the implications of these findings for an opposite hedging strategy involving a short spot position and a long futures position? In terms of financial theory, the investor going short borrows the spot security from a security lender, usually a broker who in turn gets it from those who buy on margin. The security is then sold and the proceeds are assumed to be invested in risk-free short-term securities whose term to maturity is approximately equal to the term of the short-sale. The short-seller is assumed to deposit these short-term securities with the lender as a collateral for the borrowed security. When the market price of the borrowed security rises, the short-seller is required to make further deposits with the security lender and if the price falls the excess deposits are made available to the short-seller. Note, however, the lender may be expected to be satisfied with relatively smaller deposits because of the hedged protection enjoyed by the short-seller. Furthermore, if the borrowed security is a coupon-bearing instrument the short-seller is obliged to pay to the lender an amount equal to the interest payments that would otherwise have been received during the term of the short sale. When the short sale is closed out the borrower returns the security to the lender in exchange for the collateral security (assuming no transaction costs).

Thus in theory the short sale generates cash for the borrower of the security. Part of this cash goes to meet the margin requirements on the long futures position and the rest can be used for investing in other short-term securities. Where a coupon-bearing security is borrowed the interest income from the short-term investment can be applied to satisfy the accrued coupon on the borrowed security. It follows then that the short sale in theory would generate capital for the short seller. Since the hedge is by definition riskless and the strategy involves no capital investment, the expected return should not systematically vary from zero in an efficient market.

In order to analyze the short spot and long futures hedging strategy define the weekly holding period dollar return, AR_{t+1}, on the hedged portfolio as:

$$AR_{t+1} = P_{t+1} - P_t + h_t(F_{t+1} - F_t) \tag{5-1}$$

During a regime of rising interest rate expectations, the hedge involving a short spot and a long futures position is expected to yield a price gain in the spot market, $P_t - P_{t+1} > 0$, and a price loss on the futures position, $F_{t+1} - F_t < 0$. Further, as the prices are generally expected to fall in such a period, one might also assume that the short seller would be required to make few additional deposits.

The earlier findings indicate that the hedger with a long spot and a short futures position in T bills would have earned a consistently negative return during the study period. This implies that the hedger following an opposite strategy of short spot and long futures positions would have earned a consistently positive return during the same period.[7] In light of this it is difficult to accept the hypothesis that the T bill futures market was efficient during the study period.[8]

Mean excess hedged returns before transaction costs on the bond and GNMA futures are exhibited in Table 5-13. The mean returns vary from -2.27 percent to 2.26 percent for the bond futures, the ranges of standard deviations being 20.88 percent to 28.41 percent. If one examines the returns on the eleven bond futures hedged portfolios individually, each of them does not seem to be systematically different from zero. Note, however, that ten out of eleven mean portfolio returns are negative. Thus a joint consideration of all the mean portfolio returns seems to reject the hypothesis that the bond futures market was efficient during the study period.[9]

For the GNMA futures the mean excess returns range between -2.80 to 2.49 percent with the standard deviations being in the neighborhood of 20 percent. While the returns on the first seven portfolios are positive,

TABLE 5-13. Mean excessive returns before transaction costs on hedged portfolios of long-term futures and their underlying spot securities 1976-1979

Contract	Bond Futures Hedge MER (SD)	t (DF)	GNMA Futures Hedge MER (SD)	t (DF)
1	2.26 (26.80)	.61 (.53)	2.49 (20.10)	1.41 (130)
2	-.57 (28.41)	-.16 (62)	2.17 (20.75)	1.09 (153)
3	-1.03 (20.88)	-.39 (62)	1.53 (18.85)	1.00 (153)
4	-1.79 (21.11)	-.67 (62)	1.37 (18.72)	.91 (153)
5	-1.65 (21.27)	-.61 (62)	1.74 (21.38)	1.01 (153)
6	-1.38 (25.48)	-.43 (62)	1.34 (19.93)	.81 (144)
7	-1.81 (26.58)	-.44 (41)	1.00 (25.39)	.43 (166)
8	-2.11 (26.72)	-.50 (41)	-1.17 (18.71)	-.68 (116)
9	-2.27 (27.92)	-.52 (41)	-.60 (18.36)	-.27 (66)
10	-2.01 (28.32)	-.45 (41)	-.67 (18.59)	-.29 (66)
11	-1.34 (26.43)	-.33 (41)	-2.80 (20.97)	-.89 (44)

MER = mean excess return

SD = standard deviation

DF = degrees of freedom

t = observed t values. All the t's were found to be insignificant at .01 level.

those on the last four are negative. Thus on the basis of an individual as well as a joint examination of the eleven portfolio returns one cannot reject the hypothesis that the GNMA futures market was efficient during the study period. It may, however, be noted that the mean excess returns generally diminish across delivery periods (though erratically at times) in both the long-term futures markets. This behavior of returns is generally consistent with the existing evidence on the short futures yield to fall farther behind the implied forward rates as the distance to maturity of contracts rises. This diminishing trend in the GNMA portfolio returns runs counter to the concept of market efficiency. Thus the evidence obtained in this investigation on the efficiency of GNMA futures market is mixed.

Hedged returns net of transaction costs. The foregoing analysis is principally of theoretical interest as the trading costs in spot and futures markets were ignored in estimating hedged returns. The more important issue from a practical standpoint, however, is: Can a market participant make consistently higher returns, net of all trading costs, than the riskless rate by maintaining continuously adjusted long and short positions in spot and futures instruments?

Several types of trading costs are encountered in the spot and futures markets, and they vary from dealer to dealer as well as over time. Spot trades involve a commission cost plus a transaction fee for small orders. In futures markets a participant is confronted with commissions and margins that vary across the type of futures instrument. Day trade round trip commissions are lower usually by about a third than the regular commission rates. Futures margins are depository in nature, and are of two types, initial and maintenance. While initial dollar margins in a transaction are fixed, maintenance margins vary with price volatility with participants asked to post additional maintenance margin if prices move against them. Typically, maintenance margins (in percent) are three-fourths of initial margins. Brokerage firms may require house margins which exceed the exchange set minimum. Further, some Exchanges allow posting a portion of the margin sums in treasuries.

In this study only a few typical transaction costs are considered. For spot deals a commission cost of a quarter of a point ($0.25 per $100 face value) is subtracted from price changes of T bills 13, T bonds 15, and GNMA 8 percent. The round trip commission costs employed are $70 per contract for T bill futures and $65 per contract for both long term futures. The initial margins considered are $1500 per contract for both T bill and bond futures and $1200 per contract for GNMA futures. The initial margins are treated as part of initial investment in the short hedge. Inquiries with several brokers indicated that these rates are fairly typical across the industry and were relatively stable over time during the study period.[10] While these costs are not exhaustive, it is believed that they represent at a minimum a substantial part of actual trading costs.

The mean annualized compound hedged returns net of transaction costs are presented in Table 5-14. The most striking result is that both the bond futures and the GNMA futures have consistently negative returns. The positive returns with no trading costs in the long-term futures were in the neighborhood of 7 to 8 percent, but after accounting for

TABLE 5-14. Mean returns after transaction costs on hedged portfolios of futures instruments and their underlying spot securities 1976-1979

Contract	13 week T bill-TBIF Mean (SD)	13 week T bill-TBIF Skewness (Kurtosis)	15 year T bond-TBIF Mean (SD)	15 year T bond-TBIF Skewness (Kurtosis)	8% GNMA-GNMAF Mean (SD)	8% GNMA-GNMAF Skewness (Kurtosis)
1	-12.93 (1.63)	-.47 (7.61)	-6.41 (22.32)	1.44 (4.70)	-7.68 (17.12)	.93 (3.89)
2	-12.67 (2.05)	-.68 (.0.96)	-7.26 (24.40)	1.94 (8.40)	-7.37 (20.87)	1.82 (10.52)
3	-12.69 (2.02)	-.80 (11.62)	-7.82 (17.91)	.87 (3.08)	-7.86 (16.05)	.21 (2.17)
4	-12.71 (2.11)	-.48 (12.50)	-8.40 (18.11)	.91 (3.18)	-7.63 (16.02)	-.07 (1.13)
5	-12.73 (2.18)	-.35 (12.44)	-8.48 (18.19)	.66 (3.89)	-7.45 (18.21)	.38 (2.03)
6	-12.76 (2.43)	-.35 (10.85)	-7.69 (21.99)	1.07 (4.27)	-8.48 (16.66)	.12 (1.31)
7	-12.90 (2.78)	-.10 (7.85)	-8.27 (22.72)	.63 (2.22)	-8.53 (21.01)	2.04 (11.44)
8	-12.91 (2.81)	-.10 (7.70)	-8.63 (22.81)	.34 (1.87)	-8.80 (16.00)	.19 (1.22)
9			-8.77 (23.84)	.12 (1.42)	-8.59 (15.49)	.14 (.04)
10			-8.58 (24.13)	.39 (2.22)	-8.65 (15.68)	.26 (.42)
11			-7.95 (22.51)	.29 (1.69)	-10.37 (17.73)	.08 (.01)

transaction costs they turn out to be negative with similar magnitudes. This implies that the transaction costs considered are around 15 percent per annum.

Notice further that a trader maintaining a weekly hedge would have on average lost more money in the T bill futures market than in the long-term futures markets. The volatility of returns in the latter markets is far above that in the T bill futures market and is more disperse in the bond futures than in the GNMA futures. These differences in standard deviations across futures instruments are attributable to the fact that the long-term futures are far more interest elastic than the T bill futures. Moreover, the bond futures are more sensitive to interest rates than are the GNMA futures because the former are tied to a spot bond with fifteen years or more to maturity while the latter are related to GNMA bonds with an effective maturity of twelve years. In addition, there is a tendency for the mean loss to increase across delivery periods. As observed earlier this is due at least in part to the steady rise of interest rates during the latter part of the study period.

Thus instead of earning the riskless rate a market participant maintaining a weekly hedge would have lost money in all the futures markets, the losses varying from about 8 percent in the long-term futures markets to about 12 percent in the T bill futures market. That these are systematically different from the riskless rate is clear enough, and any further testing is probably not necessary.

Following the earlier approach it is perhaps worthwhile to analyze the consequences of adopting an opposite strategy of a short cash position and a long futures position. In a short sale the borrowed security usually comes from the broker's inventory, some of which may belong to those purchasing securities on margin.[11] The short seller commonly receives no interest on the deposits and is additionally required to maintain a certain amount of equity in his (her) account in times of adverse price changes. Thus a short sale in the spot market in reality usually requires not only a certain amount of capital investment, but even the transaction costs in terms of lost interest on deposits, payment of accrued coupon during the period the bond is on loan, commissions, premium payments, etc. are higher than those associated with a long spot position.

To examine the returns on a hedged portfolio of short spot and long futures positions, define the weekly holding period dollar returns net of transaction costs, AR^T_{t+1}, as

$$AR^T_{t+1} = (P_{t+1} - P_t - T_3) + h_t(F_{t+1} - F_t - T_2) \qquad (5\text{-}2)$$

where T_3 = the transaction costs on short sale in the spot market

In a period of rising interest rate expectations, the short spot sale is expected to yield a price gain, $P_t - P_{t+1} > 0$, and the long futures position a price loss, $F_{t+1} - F_t < 0$. From the earlier analysis, which ignored transaction costs, it is apparent that the sum of the spot and futures price changes for an opposite hedging strategy would be slightly positive (between 0.2 and 0.4 percent) in the case of T bill futures. It follows then that to make positive returns on the opposite strategy, the transaction costs would have to be very low. It thus seems that the "outsiders," that is the market participants other than the financial intermediaries, could not have earned consistently positive returns on the minimum risk portfolio of short spot and long futures positions in the T bills market.

Note, however, the "insiders," that is the brokers and dealers, with their easy access to securities held in the street name, enjoy low trading costs. These intermediaries could have sold short the margin based securities from their inventories and gone long on the futures to create a minimum risk hedge in T bills. This would have involved very little capital investment and insignificant trading costs. If one recognizes the return on the investment of short sale proceeds, such a strategy would have produced consistently positive returns for the insiders during the study period.

In the case of bond futures the earlier analysis ignoring transaction costs brought out that in ten out of eleven cases the returns on the long spot and short futures hedging strategy were generally a couple of percentage points lower than the riskless rate. In view of the high transaction costs associated with the opposite strategy, it seems that the outsiders combining short spot and long futures positions would have encountered a consistent loss of substantial magnitude. The insiders with their negligble trading costs would also have incurred a net price loss of a couple of percentage points less than the riskless rate but would have had the proceeds from the short sale available for further investment. It seems reasonable to assume that the insiders could have earned at least the riskless rate of return on the investment of short sale proceeds. Accordingly the insiders in the bond futures market would have earned consistently positive returns in excess of the net price loss in ten out of eleven cases reported in Table 5-13. Thus the analysis of the opposite strategy seems to support the earlier finding that the bond futures market was not efficient during the study period.

The outsiders in the GNMA futures market would have incurred consistent losses by adopting the short spot and long futures hedging strategy because of high transaction costs associated with the spot short sale. The results that the insiders would have obtained seem to vary with the distance to maturity of futures contracts. The findings reported in Table 5-13 suggest that the insiders using the last four contracts in the opposite strategy would have earned consistent profits in excess of the net price loss while those employing the first seven contracts would probably have incurred consistent losses. Thus the analysis of the opposite strategy does not seem to clarify the mixed evidence on the market efficiency of GNMA futures witnessed in the case of long spot and short futures hedging strategy.[13]

One could perhaps go further and speculate about the consequences of following the mixed hedging and speculative strategies in the futures market. The findings obtained in this investigation seem to suggest that both the outsiders and insiders would have found enough mispricings in the financial futures markets to earn returns systematically in excess of the accompanying market risk by following investment strategies other than the minimum risk hedging strategy tested in this investigation.

Hedging Effectiveness and Returns

It is of interest to examine the relationship between hedging performance and hedging returns. From eq. (3-22) the expected return on a risk minimizing short hedge, $E^*(R_{t+1})$, is given by

$$E^*(R_{t+1}) = \frac{E(CP_t) - r_{cft}(CP_t, CF_t)S(CP_t)}{P_t S(CF_t)} \qquad (5-3)$$

Clearly, a higher degree of positive correlation between cash and futures price changes, $r_{cft}(CP_t, CF_t)$, lowers the expected return on the risk minimizing portfolio. That is, a more effective hedge will have a lower expected return than a less effective hedge. This is because with a higher degree of correlation, the price gain (loss) on the spot position tends to be more nearly offset by the price loss (gain) on the futures position.

In Table 5-14 are assembled some data on hedging effectiveness and costs. Note that the negative returns net of transaction costs observed earlier are termed hedging costs in this context. Note further that the sample sizes for hedging costs associated with T bill futures and GNMA futures are far larger than those of bond futures. If a comparable sample size for the former two were chosen, the hedging costs for those markets would probably be even higher because of the rising interest rates during the latter part of the study period.

From the correlation coefficients between cash and futures price changes it is obvious that the T bill futures are the least effective. The performance of the two long-term futures is comparable although the GNMA futures have a slight edge over the bond futures. Recall however, that in cross-hedging bond futures are generally superior to GNMA futures.

As anticipated the T bill futures have the highest hedging costs of all. The costs in the long-term futures markets are comparable. That the distributions of hedging costs are far more disperse in the long-term

TABLE 5-15. Hedging effectiveness and costs

Hedge	Correlation Coefficient N = 170	N = 135	N = 80	N = 60	Cost (SD)	N
I. T bill futures						
1. T bill 13-TBIF3	.57	.59	.69	.67	12.69	151
2. T bill 13-TBIF6		.39	.44	.40	12.76	136
II. T bond futures						
3. T bond 15-TBOF3			.82	.84	7.82	62
4. T bond 15-TBOF8				.81	8.63	41
III. GNMA futures						
5. GNMA8-GNMAF3	.68	.72	.86	.88	7.86	153
6. GNMA8-GNMAF8		.72	.81	.85	8.80	116

futures market than the T bill futures market can be attributed to the higher degree of interest rate elasticity of the former. Thus it clearly emerges that the more effective long-term futures markets have a lower mean hedging cost (negative return) than the less effective T bill futures market.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The chapter first reviews the objectives underlying the current research effort and summarizes its findings. Then the insights gained into the functioning of financial futures markets and the implications for their management are discussed. Following that up is a note on the limitations of this study. Finally the areas for further research are outlined.

Review of Objectives and Results

The following problems were explored in this investigation:

1. How effective are the financial futures instruments in mitigating the price risk faced by an investor in spot securities?

2. How many futures contracts should an investor intending to minimize his (her) price risk exposure sell for each unit of cash security?

3. Is it possible for an investor maintaining a virtually risk-free hedge in the financial futures markets to earn a rate of return consistently higher than the riskless rate? That is, are the financial futures markets efficient?

To evaluate the first problem a hedging model was formulated which revealed that the effectiveness of hedging instruments is a function of the various facets of interest rate elasticity. The empirical results based on this model indicate that:

1. The futures instruments provide superior price protection to relatively long-term spot issues in comparison to those with a short term to maturity

2. Among the financial futures, the long-term futures are more effective hedging vehicles than the T bill futures

3. The futures instruments are more successful in hedging the interest rate exposure of default-free spot securities than that of risky issues

4. The discount coupon bonds enjoy a marginally superior price protection in the futures markets in comparison to those selling at par or a premium

5. Across the delivery periods, the near-term contracts perform better than the distant contracts as hedging instruments

6. The price protection provided by the long-term futures to hybrid spot securities is relatively greater than what they offer to common stocks. Within the common stock category, the growth stocks enjoy superior price protection relative to the non-growth stocks

7. Between individual securities and diversified portfolios, the financial futures exhibit a superior hedging performance with the former

8. Of the long-term futures, the bond futures have a slight edge over the GNMA futures in coping with interest rate risk

The problem concerning the optimal hedge ratio was analyzed employing the slope coefficient from a simple regression of cash price changes against futures price changes. The empirical findings confirm the hypothesis that the risk-minimizing hedge ratio is normally less than one and that it varies directly with the hedging effectiveness of futures instruments.

The market efficiency hypothesis was investigated by comparing the returns on weekly hedges of the three financial futures and their spot market counterparts with the one month CD rate as a proxy for the riskless rate. The results indicate that gross of trading costs an investor would have earned roughly the same as the one month CD rate in the long-term futures makrets; but lost marginally in the T bill futures market. Further, if the transaction costs are taken into account, the results show that the investor would have lost money in all the futures markets instead of earning the riskless rate, the magnitude of loss varying from about 12 percent in the T bill futures to about 8 percent in the long-term futures markets.

With these results in hand, the analysis was then extended to see if there existed a clear relationship between hedging effectiveness and hedged returns. The findings support the hypothesis that hedging costs (negative returns) are lower in the more effective long-term futures markets than those in the T bill futures market.

Insights and Implications

Why do the financial futures provide superior price protection to some spot securities relative to others? A general, rather naive, answer is that the correlation of futures price changes with those of spot issues varies from security to security. But that begs the question: What is it that makes future price changes correlate better with some spot price changes? As shown in the hedging model, the pivotal variable determining price correlation is the interest rate elasticity of cash and futures instruments.[1]

The term to maturity—a key consideration. The theoretical model shows, and the empirical results confirm, that each financial futures instrument offers more price protection to more interest rate elastic spot securities than those with a lower interest rate sensitivity. A key determinant of interest rate elasticity is the term to maturity. It then follows that a 26-week T bill enjoys greater price protection in the T bill futures market than a 13 week T bill. Likewise, a 25-year government bond can have more of its interest rate risk reduced in the bond futures market than a 15-year government bond. Conversely, a one-week T bill and a nine year government bond receive less price protection in their respective hedging markets relative to a thirteen-week T bill and a fifteen-year government bond. It is evident then that the term to maturity of spot securities is a very important factor to consider in hedging decisions. Moreover, note that the greater is the interest rate exposure of a spot security the higher the price protection available in the futures markets.

Prerequisites for an effective network of futures markets. The model further suggests that hedging effectiveness varies across the futures instruments as a function of their interest rate elasticities. That is, the futures instruments that are more interest rate sensitive provide superior price protection in relation to the less interest rate elastic instruments. Thus the protection provided by the T bill futures to the thirteen-week T bill is less than the protection provided by the GNMA futures to the 8 percent GNMAs, and that provided by the bond futures to the fifteen year government bonds is marginally lower than that offered by the GNMA futures to its underlying spot security.

What is the policy implication of this finding? Does it now suggest that to be more effective hedging vehicles the futures instruments should also be designed to be more interest rate elastic?

A. Optimal terms to maturity. There are several ways to augment the interest rate elasticity of futures instruments. By far the most important and practical of them is to tie the futures instruments to spot securities of long maturities within each of the maturity classes, namely the short-term, the intermediate-term, and the long-term.[2] An optimal set of futures instruments is outliend below:

1. A short-term futures instrument tied to a one year T bill
2. An intermediate-term futures instrument coupled with a T note of ten years to maturity
3. A long-term futures instrument related to a government bond of twenty-five years to maturity
4. An industry-based futures instrument for securities of each key industry in the economy

Compare the existing futures instruments with the optimal set. Of the three Treasury maturities recommended above, only the one year T bill futures was being traded in mid-1979. While it is true that the open interest in the one year T bill futures has been substantially smaller than that in the 90-day T bill futures, it should be borne in mind that the former has been in existence for about one and one-half years while the latter has been trading for about three and one half years. Further, the 15 year bond futures and the newly instituted 4 to 6 year Treasury note futures fall considerably short of the recommended terms to maturity.

Looking at the current maturities of futures instruments, one wonders whether they were chosen based on the volume of trading of their underlying spot securities. The theoretical model reveals, however, that the interest rate elasticities and the comovement of yield changes in the spot and futures markets, not the volume of business of underlying spot securities, are the key determinants of hedging effectiveness.

Some important considerations other than the term to maturity in constructing an optimal set of futures instruments are the importance of an industry in the national economy and its capacity to sustain a separate futures market. A case in point is the GNMA futures market. The empirical results obtained in this study show that the hedging performance of this market is marginally superior to that of the bond futures in offering price protection to the spot 8 percent GNMAs. Note that this is so despite the lower effective maturity and higher yield associated with the GNMA futures. Given the public policy objective of providing adequate financing for housing and the large volume of trading in the GNMAs, a separate futures market may be justified even though their hedging performance is not considerably superior to the cross-hedging potential available in the bond futures market.

B. Optimal number of delivery periods. How many delivery periods are optimal for each hedging instrument? The evidence obtained in this study indicates:

1. In all the futures markets, the near-term contracts are generally more effective hedging tools than the distant contracts. Across the futures instruments, the near-term contracts seem to be less effective in the T bills futures than in the long-term futures markets

2. In the T bill futures markets, the distant contracts are significantly less effective than their counterparts in the long-term futures makrets

3. In the long-term futures markets, the superior performance of the near-term contracts over their distant counterparts is less impressive than that in the T bill futures market

Note that these findings are highly time-specific. That is, they pertain to a regime of generally rising and highly volatile interest rates. It may further be noted that a partial explanation for observations 2 and 3 above lies in the behavior of short-term and long-term interest rates. It is well established in the existing interest rate literature that short-term rates are relatively more volatile than long-term rates.

An implication arising from this behavioral pattern is that the yield differential between the near-term and distant contracts in the T bill futures market exceeds that in the long-term futures. An examination of the actual data confirms it [97].

The above explanation is only partial, however. The available evidence on market inefficiency indicates that the long futures yield in all markets deviates farther from the corresponding implied forward rate as the terms to delivery of the contracts increase. The higher yields associated with the distant contracts reduce their interest rate elasticity and consequently render them less effective. One may speculate that the T bill futures market is relatively less efficient than the long-term futures markets and as such the difference in the effectiveness of distant and near-term contracts in the former market exceeds that obtaining in the long-term futures markets.

Although the empirical results of this study pertain to the rising interest rate period, the theoretical model is not grounded in any particular market situation. The model is versatile enough to draw viable inferences applicable to other types of interest rate periods as well. In a period of generally stable interest rates, the model suggests that the difference in hedging performance of the near-term and distant contracts would be minimal. On the contrary, a period of generally falling interest rates would tend to make the distant contracts superior to the near-term contracts. Again, the difference in hedging effectiveness across delivery periods would be much less pronounced for the long-term than the short-term futures market because of the generally higher volatility of short rates over long rates.

It is conceivable that regardelss of the expected behavior of interest rates, the nearest-term futures contract may have a high degree of price correlation with spot securities because of the "delivery effect." That is, the delivery requirement on futures contracts would tend to drive the two prices together in all market situations. Despite its high price correlation, the nearest-term contract is commonly not a useful hedging vehicle on account of its brief life span.

Yet another important consideration in determining the optimal number of delivery periods is the commitment requirements of market participants. In other words, the hedging facilities that the futures markets provide should be tailored to how far in advance the borrowers and lenders have to make commitments in the spot markets. The "commitment-time" usually varies from industry to industry. A builder may have to make commitments farther in advance than a bond-dealer, or a corporate treasurer, or an exporter. It is conceivable that the commitment-time consideration may call for contracts with long delivery periods, but the expected interest rate behavior might render them less effective. Yet it would be desirable to provide for such long delivery periods because partial price protection is better than none.

What emerges from the above discussion is that there are basically three important determinatns of the optimal number of delivery periods: the term-structure of futures contracts, the expected behavior of interest rates, and the commitment-time requirements of borrowers and lenders. Of the three criteria, the last is probably the most important for the simple reason that some price protection is commonly better than none. The importance of the second determinant is contingent upon the first due to the less volatile nature of long interest rates in relation to short rates. Accordingly, the expected interest behavior should be given more attention in determining the optimal number of futures contracts in the short-term futures market compared with the intermediate- or long-term futures markets. It follows then that the predominant consideration in deciding the optimal number of contracts in the long-term, and perhaps even the intermediate-term, futures markets is the commitment-time requirements of market participants.

In the short-term futures market, the desirable number of contracts varies with the expected behavior of interest rates given the commitment time needs of borrowers and lenders. While a lesser number of contracts would be optimal in a regime of rising and volatile interest rates, a larger number would be desirable when interest rates are generally expected to decline in level and volatility.

Further, the higher volatility of short-rates implies that spacing the short-term futures contracts closer than the long-term futures contracts might add to the hedging utility of the former. It may therefore be desirable to have monthly delivery periods in the short-term futures instead of quarterly delivery periods.

C. Optimal coupon rate. That a discount coupon bond is more interest rate elastic than another trading at par or premium implies that a discount term futures instrument would be a more effective hedging vehicle than another with no discount. Whether a bond with a given coupon trades at discount or not evidently depends on the current and expected level of interest rates. Thus the general guidance that the model provides is to keep the coupon on the spot security underlying the term futures instruments lower when the yield curve is downward sloping than when it is upward sloping.

It is apparent from the existing theory, however, that the effect of normal ranges of coupon on interest rate elasticity is small relative to that of term to maturity. Consequently, the differential gain in hedging effectiveness from two instruments with low and high coupons may be marginal in both rising and falling interest rate periods. Accordingly it is desirable to keep the coupon on spot securities attached to the term futures instruments at a conservative level across all interest rate horizons.

D. Optimal variety of instruments. A further policy question in designing an effective network of futures markets is: What is the optimal number of hedging instruments in the short-term, intermediate-term, and long-term futures markets? In other words, does there exist a real need for a separate futures instrument for commercial paper, certificates of deposit, repurchase agreements, etc. in addition to the one year T bill futures in the short-term futures market? Likewise, do separate instruments for municipal bonds, auto-industry related issues, etc., apart from the government note and bond futures, add significantly to the practical utility of term futures markets?

The answer largely depends on the behavior of interest rates and consequently that of interest rate elasticities, across the various segments of the economy. The Treasury issues are the foremost choice for establishing futures markets because they are by far the most representative barometers of interest rate movements all over the economy. There is a genuine need for financial security-based, or industry-based interest rate futures markets in addition to the Treasury based futures only if the level and movement of interest rates vary considerably across financial instruments and industries.[3]

The available evidence indicates that within the three term structures the interest rates are highly correlated across the various segments of financial markets, and that the level differences are commonly within 2-3 percentage points. Given the marginal impact of the coupon effect on interest rate elasticity and the empirical evidence on the general cross-hedging superiority of the bond futures over the GNMA futures obtained in this investigation, it seems safe to speculate that a plethora of futures instruments does not add significantly to the utility of the futures market network.

Finally the need for a futures market to deal with transnational interest rate risk can also be analyzed within the broad framework of the hedging model employed in this study. To the extent that level differences are not sizable across national boundaries and that interest rate volatilities are similar in different financial centers of the world, a separate futures market for hedging international commitments may not be of much use. The issue is, however, not simple, and needs to be examined in conjunction with the functioning of currency futures.

E. Futures market for common stocks. Assume that the philosophy of a futures market for stocks is to provide some insurance against their interest rate exposure. Do the theoretical model and empirical findings of this study suggest a need for, and provide some guidance on the design of, such a futures market? Clearly the answer largely lies in the interest rate elasticity of stocks and the level and volatility of spot and futures rates.

Duration is the common measure of interest rate elasticity across all financial instruments. The net interest rate exposure (that is, duration) of a common stock depends on a number of factors such as the depth of capital investment, the payback period of assets, the debt-equity structure of the firm, the dividend payout ratio, the expected rate of growth in earnings and dividends, and the extent of regulation of the industry [42].

Commonly the durationof stocks is substantially greater than that of debt securities; a difference of the order of about five times is not unusual. Given such a wide difference in the durations of stocks and debts, the hedging model implies that the price protection available for stocks in the futures markets for debt securities may be inadequate, or even scanty. So the guidance available from the theoretical model seems to underscore the need for a separate futures market for common stocks.[4] The empirical evidence obtained in this investigation vindicates this inference drawn from the model in that the price protection available for a stock fund and the S&P 500 Common Stock price index in the existing long-term futures market was found to be substantially lower than that available to debt securities.

Some guidelines the model offers for the design of a stock futures market can be laid down now. First, it is apparently desirable to establish an equity futures market using stocks with high duration. As observed in the context of debt futures the higher the interest rate elasticity of the hedging instrument the larger is its risk reduction potential. Second, tying the equity futures market to an individual growth stock rather than a portfolio of growth and non-growth stocks might promote its hedging effectiveness because of the tendency of the latter to have lower duration than the former.

Third, the optimal number of stock hedging instruments depends on the difference in duration of stocks and yield volatilities across industries. A variety of hedging instruments is called for only if such differences are considerable across industries. Fourth, noting the low volatility of long rates, the optimal number of delivery periods and their spacing appears to be predominantly a functionof the needs of holders of stocks. Finally, it is obvious that the chosen stocks must contain little default risk. Evidently, the above guidelines are broad and inexhaustive. The whole issue is a complex one, and calls for further investigation.

How many contracts to buy or sell? The model, along with the empirical results, suggests that the hedger should take into account primarily three factors in deciding this question: (1) the relative volatility of spot and futures yields, (2) the interest rate elasticity of the spot security being hedged, and (3) the term-structure of interest rates. Given the maturity, coupon, and default risk, an upward sloping yield curve implies that the spot price is less than the futures price, and that the spot duration is higher than the futures' interest rate elasticity. Given further the relative volatility of spot and futures yields, a rising yield curve would signal the risk-minimizing investor to hold a relatively large number of futures contracts. In light of this, the investor faced with a falling yield curve needs to hold relatively fewer futures contracts.

The model further suggests that for a given relative volatility of rates and yield curve, the number of futures contracts in a riskless hedge varies directly with the duration of the spot security. To see this, recall that the hedge ratio is an increasing function of hedging effectiveness, which, in turn, varies in step with spot duration. Finally, given the yield curve and spot duration, a hedger needs to sell relatively fewer contracts when the expected volatility of the futures rate is higher than that of the spot.

Limitations

In drawing inferences from the empirical findings, it is important to keep in mind the assumptions underlying the theoretical model and the limits of the methodology and the sample. First, the model assumes that the primary motive for hedging is risk-minimization. From a public policy standpoint, it is perhaps a legitimate assumption of hedging behavior. Even from the practical viewpoint, the assumption is believed to describe the hedging behavior of a substantial part of market participants.

Despite these justifications, the model is rather restrictive in portraying the market behavior of participants. The available literature on commodity futures and investments argues that a hedger is more of an arbitrager than a risk-minimizer. According to this theory, the basic motive of hedging is to profit from relative price movements between cash and futures markets. To the extent that such a pattern of hedging behavior is appropriate for the financial futures, the model needs to be modified. It is debatable, however, whether the models of hedging behavior in commodity and financial futures should be identical. The question involves implications for public policy and monetary policy and calls for further research.

The methodological weaknesses of the study are primarily in the choice of weekly data. It is believed that the use of daily data would improve the quality of empirical findings on market efficiency by reducing the error in the estimation of the hedge ratio. The conclusions reached here are not, however, expected to be altered by this inverval-ing effect. Moreover, as observed earlier, the attempt to control for maturity, coupon effect, and default risk has introduced some errors into the data base, but they are expected to be random and on balance inconsequential.

Finally, the sample employed lacks a suitable number of discount coupon bonds and individual stocks. This is partly an error in planning, rather than a limitation due to the non-availability of suitable issues. The inclusion of these two groups of securities would have enhanced the value of the study. Furthermore, the sample comes from a period of generally rising and volatile interest rates, and as such there is need for caution in generalizing the findings to other regimes of interest rate behavior.

Extensions

The study indicates quite a few directions for future research. In the first place, it is desirable to replicate the market efficiency analysis employing the daily data. Further, certain propositions regarding the interest rate elasticity of futures instruments and relative volatility of futures rates have not been directly tested in this study. Given their critical importance in determining hedging effectiveness and hedge ratio, they deserve further attention.

The relationship between hedging effectiveness and hedging costs seems to provide another fertile area for future research. In this work, the negative returns were called hedging costs. A more appropriate definition of hedging costs is the difference between unhedged and hedged returns. The model implies that hedging costs, thus defined, tend to increase with hedging effectiveness. It is worth investigating whether the empirical analysis would support this implication.

The unbiased expectations hypothesis of the term structure of interest rates implies that an efficient market is also an effective market for hedging since the spot and futures prices are linked by the implied forward rates. This linkage between market efficiency and hedging effectiveness has not been examined in detail in this investigation and deserves further research. Finally, an examination of the stability of the hedge ratio over time would be useful to a market participant in maintaining an effective hedge.

FOOTNOTES

Chapter I

[1]The term "basis" has two distinct connotations. In the financial literature, the term "basis point" refers to the one hundredth part of a percentage point of interest rate. Changes in interest rates are measured in terms of basis points, and their impact on the value of financial securities is called "basis risk." In the futures market literature, on the other hand, basis means the difference between spot and futures prices. In this study, the term "basis risk" is used in the former sense.

[2]According to Fisher and Weil, "a portfolio of investments in bonds is immunized for a holding period if its value at the end of the holding period, regardless of the course of interest rates during the holding period, must be at least as large as it would have been had the interest rate function been constant throughout the holding period.

If the realized return on an investment in bonds is sure to be at least as large as the appropriately computed yield to the horizon, then that investment is immunized" [34; p. 415]. The conditions under which the duration strategy immunizes an investment are discussed in Chapter III. Fisher and Weil empirically tested the duration strategy by comparing the realized terminal wealth for a given holding period with the promised terminal wealth and reported that this strategy performs better (in spite of its unrealistic assumptions) than the naive strategy of holding a coupon bond with term to maturity equal to one's planned holding period.

[3]For a detailed discussion of spot and futures markets in commodities see Blau [10] and Johnson [52].

[4]For a discussion of the basic premises of financial futures markets see [17,18,19].

[5]This is implied by the unbiased expectations theory of the term structure of interest rates according to which the linkage between spot and futures prices is provided by implied forward rates.

[6]Specifically the Treasury and the Federal Reserve Board have reportedly protested to the Commodities Futures Trading Commission that futures trading distorts the spot prices for government securities [15,68].

[7]This is apparent from Macaulay [62]. He wrote, "for a study of the relations between long and short term interest rates, it would seem highly desirable to have some adequate measure of 'longness.' Let us use the word 'duration' to signify the essence of the time element in a loan . . . It is clear that 'number of years to maturity' is a most inadequate measure of 'duration.'" [p. 74]

[8]Hereinafter the terms "bond futures" will be used to refer to the 15 year T bond futures instrument.

Chapter II

[1]The three publications of the CBT [16,72,73] provide an extensive reference on the commodity futures markets.

[2]For a discussion of factors limiting the effectiveness of a hedge see [10].

[3]In its ". . . Introduction to the Interest Rate Futures Markets," the Chicago Board of Trade (CBT) observed:

> Since the late 1960s, interest rates in the United States have risen and have fluctuated as in no other period in their history. Historically, both long- and short-term interest rates were less than 6 percent. But in recent years, borrowers and investors in the credit market have been exposed to increasingly higher interest rate risks [18; p. 2].

A survey of the Federal Reserve Bulletins points out the generally rising level and volatility of various interest rates during 1976-79. For an overview of the behavior of interest rates from 1967 see [19].

[4]In a strict sense, interest rate elasticity and duration are not measures of risk because risk by definition assumes a certain utility function. For a discussion on common misinterpretations of duration see Bierwag et al. [7].

[5]The coupon rates and yields in Table 2-1 are based on semi-annual compounding.

[6]Hopewell and Kaufman [46] even suggested that it might be more useful to derive the yield curves with respect to duration rather than term to maturity. Recently, Bierwag and Kaufman attributed the sub-optimal results of various bond portfolio strategies to the inadequate attention given to duration [50].

For a detailed discussion of the limitations of the traditional concept of duration as a general measure of basis risk, see Ingersoll et al. [50].

[7]On the use of single and multiple indices to describe the security return generating processes, see Alexander [1], Cohen and Pogue [21], King [54], and Sharpe [85,86].

[8]See Lanstein and Sharpe [57] for a detailed discussion on the relation between duration and systematic risk of a stock.

[9]According to Ingersoll et al. [50], "An asset is said to be immunized against a shift in interest rates if its postshift holding period return is at least as great as the holding period return would have been in the absence of the shift" [p. 634].

[10]Extra-market covariances are covariances among security returns due to factors other than the common market factor which includes changes in interest rates. The non-market factors include industry factors and factors unique to the firm. For a detailed discussion of extra-market covariances, see Cohen and Pogue [21], King [54], and Sharpe [86].

Chapter III

[1]Note that the model holds for coupon bonds as well as stocks. When applied to coupon bonds, the model assumes that the bond prices include accrued interest. This is appropriate because although the published prices of coupon issues do not include accrued interest, the buyers have to pay for it. Note further that the price quotations for stocks reflect expected dividend payments.

The price risk, $V(AR_{ct})$, represents the interest rate risk associated with a security only to the extent price changes are caused by interest rate movements. There are, however, a number of factors other than shifts in interest rates which contribute to price changes. To mention a few, changes in the term to maturity, coupon, level of default-risk, expected rate of growth in earnings and dividends, and capital structure of the firm. The price risk defined above reflects the interest rate exposure of a security to the extent that these other factors are held constant over time and as such do not contribute to price change.

In this investigation the research design employed minimizes the price effect of factors other than changes in interest rates. Therefore the price risk as defined in eq. (3-2) is believed to be a close approximation to the interest rate risk associated with a security, and the two terms are used interchangeably.

[2]There is no unique measure of duration. The specific measure of duration varies with different types of stochastic shifts in the term-structure of interest rates. In this dissertation, the Macaulay-Hicks duration is employed in spite of the fact that it is based on the unrealistic assumption of a flat term structure of interest rates and parallel shifts therein. This is because as Bierwag [6] indicated the differences between the simple traditional measure and the more sophisticated measures of duration are not critical within the normal ranges of coupon and yield. Further, the empirical work by Fisher and Weil [34] shows that the traditional duration is a useful measure despite all its unrealistic assumptions regarding the behavior of interest rates.

[3]The application of the concept of duration to a futures instrument poses some difficulties. The central theme of duration is the relative importance of the time value of interim and final cash flows associated with a security. Although the futures instrument is tied to a spot security of given coupon and maturity, the cash flows associated with it are quite different from those related to the underlying spot security. On purchase or sale of the contract, the investor pays the margin and commission costs. The interim cash flows associated with the contract are those related to the maintenance margin. When the contract expires, the holder of the instrument receives or pays the agreed price and gets back the margin money. Note, however, that only a small number of contracts are closed out by actual delivery. When the contract is terminated before delivery, the holder receives or pays the price difference after adjusting for the margin. It is thus clear that there are no coupon cash flows associated with the futures instrument.

Further, the term to expiration of the long-term futures contract is far shorter than the term to maturity of a long-term bond, while the opposite is commonly true for the short-term futures instrument. In view of these it is thought that the use of the phrase, "interest rate elasticity" rather than "duration" is more meaningful in the context of the futures instrument as the former is not laden with the notion of present value of cash flows.

[4]The discussion that follows refers primarily to debt instruments. While the implications of the discussion for common stocks are fairly apparent, a detailed treatment of the subject is left for future investigation.

[5]As observed earlier, the duration of a common stock is typically way above that of a long-term bond. Note, however, that when a common stock is hedged in the long-term futures market the covariance term in the numerator of eq. (3-13) is expected to be considerably lower, and the standard deviation of the spot price change in the denominator much larger, than those associated with a bond hedge or even a hybrid security hedge. Consequently, the correlation between cash and futures price changes will be relatively lower for a common stock hedge.

[6]This can be attributed to two reasons. First, the covariance term in eq. (3-13) will be higher for the GNMA futures hedge than the bond futures hedge. Second, the standard deviation of the GNMA futures price changes will be lower for the former than that for the bond futures hedge.

[7]This assumes that the term to maturity and coupon level are held constant.

[8]One implication of this relation is that h is likely to assume values equal to or greater than unity for relatively long-term spot issues.

[9]B-S derived the following option valuation formula

$$p_o = p_s c(d_i) - p_E e^{-rt} c(d_2)$$

where $$d_1 = \frac{\ell n(p_s/p_E) + (r+(1/2)s^2)t}{st^{1/2}}$$

$$d_2 = \frac{\ell n(p_s/p_E) + r - (1/2)s^2)t}{st^{1/2}}$$

p_o = option price

p_s = stock price

p_E = exercise price of option

r = the continuously compounded riskless interest rate

t = time remaining before expiration of option

s = standard deviation of the continuously compounded annual stock return

$c(d)$ = cumulative normal density function

ℓn = natural logarithm

e = 2.71828

They showed that the perfect hedge ratio is equal to the term $c(d_1)$ in the valuation formula. Employing the B-S principle it can be shown that $F_t = E(P_{i+n})$ which is the basic premise of the unbiased expectations hypothesis.

Chapter IV

[1]Note, however, that in a few instances it has not been possible to control the various dimensions as rigorously as demanded by the design. It is believed, however, that in spite of such inadequacies, the insights gained would still be useful in understanding the performance of financial futures.

[2]The credit ratings, maturity and interest payment dates of individual issues were identified from the two Moody's publications [66,67].

[3]The information on trading costs were obtained over telephone from the following sources:

(1) Bernard J. Doherty
Vice President-Retail Sales
Drexel Burnham Lambert, Inc.
1 Federal Street
Boston, Massachusetts
Telephone: (617)482-3600

(2) Richard P. Ziencina
Commodity Specialist
Shearson Hayden Stone, Inc.
Valley Bank Tower
1500 Main Street
Springfield, Massachusetts 01115
Telephone: (403)734-7311

[4]Two models have been proposed to explain the process of price-change generation in the stock market. The stable paretian hypothesis posits that price changes measured over calendar time follow the symmetric stable laws with a characteristic exponent θ which lies between 1 and 2. The subordinated stochastic processes theory, on the other hand, claims that price changes come from mixtures of normal distributions stemming from the accumulation of several small pieces of information during a particular period of time. Westerfield [99] examined these two hypotheses and reported that the common stock price changes were better described by the subordinated probability model.

[5]While there are several shades of meaning of the term "robust," a typical one is that given by Andrews [4]: "techniques of fitting are said to be robust of efficiency when their statistical efficiency remains high for conditions more realistic than the utopian cases of Gaussian distributions with errors of equal variance" [p. 523].

[6]Typically robust estimation of regression coefficients involves minimizing the sum of the pth power of the absolute values of residuals. Hogg, for example, recommends the following adaptive robust regression procedure:

1. Find some reasonable estimators of the regression coefficients that are not influenced too much by outliers . . .
2. Compute the residuals from that fitted expression and determine the length of tails . . .
3. Recompute estimates of the regression coefficients using a loss function consistent with the lengths of the tails [44; p. 917].

[7]For a review of adaptive distribution-free procedures see Hogg [44].

[8]On the question of sample size that leads to convergence of the T and the normal distribution, Winkler and Hays further observe, "How large is 'large enough' to permit the use of normal tables? If the population distribution is truly normal, a sample size of 30 or 40 permits a

quite accurate use of the normal tables. . . . For most purposes a ν of 30 or 40 should be large enough to permit the use of the normal tables" [101; p. 366].

[9] In the general context of testing for the significance of r, McNemar [65] observed, "There is evidence, as with the t test for means, that sizable violations of the assumptions are tolerable. . . ." [p. 138]. He states further that the test statistic described in (4-7) follows the T distribution with N-3 degrees of freedom when the null hypothesis of no difference between the two r's holds.

[10] Refer to the discussion on volatility of futures yields in Chapter III.

Chapter V

[1] For a discussion of other problems involved in the collection and analysis of bond price data, see [84].

[2] Fama and Roll [30] observed that the studentized range provides a fairly reliable test of normality when the alternative distribution is stable symmetric non-normal.

[3] Note from eq. (3-13) that the comovement of yield changes in spot and futures markets is another important determinant of hedging effectiveness. Yield changes are , however, not a decision variable in the sense that they are beyond the control of individual market participants in a perfect market. The interest rate elasticity or duration, on the other hand, is a strategic variable in that the investor can partially influence the price response to a given shift in interest rates by selecting the level of credit risk, coupon, and term to maturity appropriate to his (her) investment objectives. From the hedging strategy point of view, therefore, focusing the attention on the relationship between interest rate elasticity and hedging performance is important.

[4] In this study the terms "hedging effectiveness" and "hedging performance" are used synonymously. Further, the superior (inferior) hedging performance is defined in terms of a high (low) degree of correlation between cash and futures price changes. It is, however, conceivable that others might use different criteria such as costs and returns in gauging hedging performance of financial futures.

[5] The sample sizes underlying r_{21} and r_{31} varied slightly in some instances and the difference was around 5. In such cases the reported N in Table 5-3 is the average of the two samples.

[6] The hedging performance results associated with bond funds are particularly unimpressive. For hedging performance results associated with several other securities included in the sample, see Appendix D.

[7]Note that the net price changes in the range of 0.22 to 0.39 percent are approximately equal to the typical commission revenue of 0.25 percent obtained during the study period.

[8]It may be noted that these observations are to some extent speculative since the minimum risk hedging strategy involving short spot and long futures positions has not been rigorously examined in this study. While the spot and futures price changes are identical in the two types of minimum risk strategies outlined in Table 5-11, the strategies differ in terms of transaction costs and cash flows generated by the spot short sale. A detailed examination of the short spot and long futures minimum risk strategy is left for future research.

[9]The available evidence on the efficiency of long-term futures is scanty. Of the studies reviewed earlier, Branch [14] reported that long futures yields in the long-term futures markets were higher than their corresponding implied forward rates during the 1976-78 period.

[10]The brokerage houses from whom this information was obtained are listed in footnote 3 to Chapter IV.

[11]Securities purchased on margin are left in the custody of the brokerage house and are registered in its name. It is a common practice among brokerage firms to lend these margin-based securities to short sellers.

[12]In the case of long-term futures the opposite strategy of short spot and long futures positions would have resulted in a net negative price change before transaction costs during the study period. So the analysis of the opposite strategy is not of interest.

[13]The methodology employed above assumes the efficiency of the related spot markets and thus provides a joint test of the market efficiency of spots and futures instruments.

Chapter VI

[1]Note again from eq. (3-13) that the other two variables influencing price correlation are the level and volatility of spot and futures yields.

[2]The rationale for recommending a network of financial futures based on the three-tier term-structure can be deciphered from eq. (3-13). It is clear from that equation that yield volatility in spit and futures markets plays an important role in determining hedging effectiveness. Yield volatility is known to vary considerably across the maturity spectrum. Short-term yields are far more volatile than long-term yields, and the volatility of intermediate-term yields can be expected to fall in between those of the former two. In the light of this behavioral pattern

of yields, it appears that a separate market each for short-term instruments, intermediate-term instruments, and long-term instrumen s would be conducive to the evolutionof an effective network of futures markets.

[3]This statement is to be read in conjunction with the need for key-industry based futures instruments discussed earlier.

[4]While interest rate exposure is the major source of risk for most bonds, it is only one of several such sources for stocks. In the latter case, the uncertainty associated with the expected cash flows may be even more important than the basis risk [57].

SELECTED BIBLIOGRAPHY

1. Alexander, G. J. "Mixed Security Testing of Alternative Portfolio Selection Models." Journal of Financial and Quantitative Analysis (December 1977):817-32.

2. Andrews, D. F.; Bickel, P. J.; Hampel, F. R.; Huber, P. J.; Rogers, W. H.; and Tukey, J. W. Robust Estimates of Location. Princeton, New Jersey: Princeton University Press, 1972.

3. Andrews, D. F.; Bickel, P. J.; Hampel, F. R.; Huber, P. J.; Rogers, W. H.; and Tukey, J. W. "A Robust Method for Multiple Linear Regression." Technometrics (November 1964):523-31.

4. Banks, S. Experimentation in Marketing. New York: McGraw-Hill Book Company, 1964.

5. Bierwag, G. O., and Kaufman, G. G. "Coping with the Risk of Interest Rate Fluctuations: A Note." Journal of Business (July 1977):364-70.

6. Bierwag, G. O., and Kaufman, G. G. "Immunization, Duration and the Term Structure of Interest Rates." Journal of Financial and Quantitative Analysis (December 1977):725-42.

7. Bierwag, G. O.; Kaufman, G. G.; and Khang, C. "Duration and Bond Portfolio Analysis: An Overview." Journal of Financial and Quantitative Analysis (November 1978):671-81.

8. Bildersee, J. S. "The Use of Average Maturity as a Risk Proxy in Investment Portfolios: Discussion." Journal of Finance (May 1975):334-36.

9. Black, F., and Scholes, M. "The Pricing of Optins and Corporate Liabilities." Journal of Political Economy (May-June 1975):637-54.

10. Blau, G. "Some Aspects of the Theory of Futures Trading." Review of Economic Studies 12 (1944-45)1-30.

11. Boquist, J. A.; Racette, G. A.; and Schlarbaum, G. G. "Duration and Risk Assessment for Bonds and Common Stock." Journal of Finance (December 1975):1360-65.

12. Box, G. E. P. and Cox, D. R. "An Analysis of Transformations." Journal of the Royal Statistical Society (1964):211-52.

13. Branch, B. "Testing the Unbiased Expectation Theory of Interest Rates." Financial Review (Fall 1978):51-68.

14. ________. "The Use of Interest Futures in Portfolio Management." Unpublished working paper, University of Massachusetts, 1979.

15. "T Bill Futures Vexes the Treasury." Business Week, 22 August 1977, p. 17.

16. Chicago Board of Trade. Commodity Trading Manual. Chicago: Chicago Board of Trade, 1976.

17. ________. Making and Taking Delivery on Interest Rate Futures Contracts. Chicago: Chicago Board of Trade, 1977.

18. ________. An Introduction to the Interest Rate Futures Market. Chicago: Chicago Board of Trade, 1978.

19. Chicago Mercantile Exchange. Futures Trading in U.S. Treasury Bills. Chicago: Chicago Mercantile Exchange, 1976.

20. Cochran, W. G. "Some Consequences When the Assumptions for the Analysis of Variance are not Satisfied." Biometrics (March 1947): 22-38.

21. Cohen, K. J., and Pogue, G. A. "An Empirical Evaluation of Alternative Portfolio-Selection Models." Journal of Business (April 1967):166-93.

22. Cooper, I. A. "Asset Values, Interest Rate Changes, and Duration." Journal of Financial and Quantitative Analysis (December 1977):701-24.

23. Cootner, P. H. "Returns to Speculators: Telser versus Keynes." Journal of Political Economy (August 1960):396-404.

24. ________. "Rejoinder." Journal of Political Economy (August 1960).

25. ________, ed. The Random Character of Stock Market Prices. Cambridge, Massachusetts: MIT Press, 1964.

26. David, H. A.; Hartley, H. O.; and Pearson, E. S. "The Distribution of the Ratio in a Single Normal Sample of Range to Standard Deviation." Biometrika (1954):491.

27. Eddy, A. R. "Interest Rate Risk and Systematic Risk: An Interpretation." Journal of Finance (May 1978):626-30.

28. Ederington, L. H. "The Hedging Performance of the New Futures Markets." Journal of Finance (March 1979):157-70.

29. Fama, E. F. "The Behavior of Stock Market Prices." Journal of Business (January 1965):34-105.

30. Fama, E. F., and Roll, R. "Some Properties of Symmetric Stable Distributions." Journal of the American Statistical Association (September 1968):817-36.

31. Fama, E. F., and Roll R. "Efficient Capital Markets: A Review of Theory and Empirical Work." Journal of Finance (May 1970):383-417.

32. Fama, E. F., and Roll R. "Short-Term Interest Rates as Predictors of Inflation." American Economic Review (June 1975):269-82.

33. Finnerty, J. E. "Insiders and Market Efficiency." Journal of Finance (September 1976):1141-48.

34. Fisher, L., and Weil, R. L. "Coping with the Interest Rate Fluctuations: Returns to Bond Holders from Naive and Optimal Strategies." Journal of Business (October 1971):408-31.

35. Garbade, K. D., and Silber, W. L. "Price Dispersion in the Government Securities Market." Journal of Political Economy (August 1976):721-40.

36. Gray, R. W. "The Importance of Hedging in Futures Trading; and the Effectiveness of Futures Trading for Hedging." In Futures Trading Seminar, Vol. 1. Madison, Wisconsin: Mimir Publishers, 1960, pp. 61-82.

37. ________. The Characteristic Bias in Some Thin Futures Markets." In Readings in Futures Markets, Vol. 2; Selected Writings on Futures Markets. Edited by A. E. Peck. Chicago: Chicago Board of Trade, 1977, pp. 83-100.

38. Grove, M. A. A Model for the Maturity Profile of the Balance Sheet." Metroeconomica (April 1966):40-55.

39. ________. "On 'Duration' and the Optimal Maturity Structure of the Balance Sheet." Bell Journal of Economics and Management Science (Autumn 1974):696-709.

40. Haugen, R. A., and Wichern, D. W. "The Elasticity of Financial Assets." Journal of Finance (September 1974):1229-40.

41. Haugen, R. A., and Wichern, D. W. "The Intricate Relationship Between Financial Leverage and Stability of Stock Prices." Journal of Finance (December 1975):1283-92.

42. Haugen, R. A.; Stroyny, A. L.; and Wichern, D. W. "Rate Regulation, Capital Structure, and the Sharing of Interest Rate Risk in the Electric Utility Industry." Journal of Finance (June 1978): 707-22.

43. Hicks, J. R. "Value and Capital." London: Oxford University Press, 1939.

44. Hogg, R. V. "Adaptive Robust Procedures: A Partial Review and Some Suggestions for Future Applications and Theory." Journal of the American Statistical Association (December 1974):909-23.

45. Homer, S., and Leibowitz, M. Inside the Yield Book. Englewood Cliffs, New Jersey: Prentice Hall, 1972.

46. Hopewell, M. H. and Kaufman, G. G. "Bond Price Volatility and Term to Maturity: A Generalized Respecification." American Economic Review (September 1973):749-53.

47. Houthakker, H. S. "Can Speculators Forecast Prices?" Review of Economics and Statistics (May 1957):143-51.

48. ________. "Systematic and Random Elements in Short Term Price Movements." American Economic Review (May 1961):164-72.

49. Huber, P. J. "Robust Statistics: A Review." The Annals of Mathematical Statistics (1972):1041-67.

50. Ingersoll, J. E.; Skelton, J.; and Weil, R. L. "Duration Forty Years Later." Journal of Financial and Quantitative Analysis (November 1978):627-50.

51. Joehnk, M. D.; Fugler, H. R.; and Bradley, C. E. "The Price Elasticity of Discounted Bonds: Some Empirical Evidence." Journal of Financial and Quantitative Analysis (September 1978):559-66.

52. Johnson, L. L. "The Theory of Hedging and Speculation in Commodity Futures." Review of Economic Studies (1959-60):139-60.

53. Keynes, J. M. A Treatise on Money. Vol. 2. London: MacMillan, 1930.

54. King, B. F. "Market and Industry Factors in Stock Price Behaviour." Journal of Business (January 1966):139-60.

55. Kmenta, J. Elements of Econometrics. New York: MacMillan Publishing Co., 1971.

56. Lang, R. W., and Rasche, R. H. "A Comparison of Yields on Futures Contracts and Implied Forward Rates." Federal Reserve Bank of St. Louis Review (December 1978):21-30.

57. Lanstein, R., and Sharpe, W. F. "Duration and Security Risks." Journal of Financial and Quantitative Analysis (November 1978):653-68.

58. Larson, A. B. "Measurement of a Random Process in Futures Prices." In Readings in Futures Markets. Vol. 2: Selected Writings on Futures Markets. Edited by A. E. Peck. Chicago: Chicago Board of Trade (1977):295-306.

59. Lintner, J. "Security Prices, Risk and Maximal Gains from Diversification." Journal of Finance (December 1965):587-615.

60. Lloyd, W. P., and Shick, R. A. "A Test of Stone's Two-Index Model of Returns." Journal of Financial and Quantitative Analysis (September 1977):363-76.

61. Lorie, J., and Brealey, R., ed. Modern Developments in Investment Management." New York: Praeger Publishers, 1976.

62. Macaulay, F. R. Some Theoretical Problems Suggested by the Movements of Interest Rates, Bond Yields, and Stock Prices in the U.S. Since 1856. New York: National Bureau of Economic Research, 1938.

63. Malinvaud, E. Statistical Methods of Econometrics, Second edition. New York: American Elsevier Publishing Company, Inc., 1970.

64. Martin, J. D., and Keown, A. J. "Interest Rate Sensitivity and Portfolio Risk." Journal of Financial and Quantitative Analysis (June 1977):181-90.

65. McNemar, Q. Psychological Statistics. Third Edition. New York: John Wiley and Sons, Inc., 1962.

66. Moody's Investors Service. Moody's Bond Record. New York: Moody's Investors Service, Inc., January 1979.

67. ________. Moody's Municipal and Government Manual. 2 vols. New York: Moody's Investors Service, Inc., 1979.

68. "Playing the Futures Game." Newsweek, 15 January 1979:63-4.

69. Neter, J., and Wasserman, W. Applied Linear Statistical Models. Homewood, Illinois: Richard D. Irwin, 1974.

70. Nie, N. H.; Hull, C. H.; Jenkins, J. G.; Steinbrenner, K.; and Bent, D. H. Statistical Package for the Social Sciences. Second edition. New York: McGraw-Hill Book Company, 1975.

71. Peck, A. E. "Hedging and Income Stability: Concepts, Implications, and an Example." In Readings in Futures Markets. Volume 2. Selected Writings on Futures Markets. Chicago: Chicago Board of Trade (1977):237-50.

72. ________, ed. Selected Writtings of Holbrook Working. Chicago: Chicago Board of Trade, 1977.

73. ________, ed. Readings in Futures Markets. Vol. 2: Selected Writings on Futures Markets. Chicago: Chicago Board of Trade 1977.

74. Plant, K. M. "Playing the Futures Market Game." Federal Home Loan Bank Board Journal (November 1975):16-21.

75. Poole, W. "Using T-Bill Futures to Gauge Interest Rate Expectations." Economic Review, Federal Reserve Bank of San Francisco (Spring 1978):7-19.

76. Puglisi, D. J. "Is the Futures Market for Treasury Bills Efficient?" Journal of Portfolio Management (Winter 1978):64-67.

77. Ramsay, J. O. "A Comparative Study of Several Robust Estimates of Slope, Intercept and Scale in Linear Regression." Journal of the American Statistical Association (September 1977):608-15.

78. Reddington, F. M. "A Review of the Principles of Life Office Valuations." Journal of the Institute of Actuaries (1952):286-340.

79. Rockwell, C. S. "Normal Backwardation, Forecasting and the Returns to Commodity Futures Traders." In Readings in Futures Markets. Vol. 2: Selected Writings in Futures Markets. Edited by A. E. Peck. Chicago: Chicago Board of Trade (1977):167-89.

80. Roll, R. "The Behaviour of Interest Rates: Application of the Efficient Market Model to the U.S. Treasury Bill Rates." New York: Basic Books Inc., 1970.

81. Roy, A. D. "Safety First and the Holdings of Assets." Econometrica (July 1952):431-49.

82. Samuelson, P. A. "The Effects of Interest Rate Increases on the Banking System." American Economic Review (March 1945):16-27.

83. ________. "Proof That Properly Discounted Present Values of Assets Vibrate Randomly." Bell Journal of Economics and Management Science (Autumn 1973):367-74.

84. Schneeweis, T., and Schweser, C. "An Investigation into the Distributions and Risk Characteristics of Bond Holding Period Returns." Unpublished working paper, University of Massachusetts, 1978.

85. Sharpe. M. F. "A Simplified Model for Portfolio Analysis." Management Science (January 1963):277-93.

86. ________. Portfolio Theory and Capital Markets. New York: McGraw Hill Book Co., 1970.

87. Siegel, S. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill, 1956.

88. Smidt, S. "A Test of the Serial Independence of Price Changes in Soyabean Futures." In Readings in Futures Markets. Vol. 2: Selected Writings on Futures Markets. Edited by A. E. Peck. Chicago: Chicago Board of Trade (1977):257-78.

89. Srivastava, A. B. L. "Effect of Non-normality on the Power of the Analysis of Variance Test." Biometrika (1959):114-22.

90. Standard and Poor's Statistical Service. Security Price Index Record. New York: Standard and Poor's Corporation, 1979.

91. Stevenson, R. A., and Bear, R. M. "Commodity Futures: Trends or Random Walks." Journal of Finance (March 1970):65-81.

92. Stone, B. K. "Systematic Interest-Rate Risk in a Two-Index Model of Returns." Journal of Financial and Quantitative Analysis (November 1974):709-21.

93. Teker, L. G. "Futures Trading and the Storage of Cotton and Wheat." Journal of Political Economy (June 1958):253-55.

94. ________. "Reply." Journal of Political Economy (August 1960): 404-15.

95. Tomek, W. G., and Gray, R. W. "Temporal Relationships Among Prices on Commodity Futures Markets: Their Allocative and Stabilizing Roles." American Journal of Agricultural Economics (August 1970):372-80.

96. Vignola, A. J., and Dale, C. J. "Is the Futures Market for Treasury Bills Efficient?" Journal of Portfolio Management (Winter 1979):78-81.

97. Wall Street Journal, Eastern Edition. Thursday issues from January 1976 through April 1979.

98. Weil, R. L. "Macaulay's Duration: An Appreciation." Journal of Business (October 1973):489-92.

99. Westerfield, R. "The Distribution of Common Stock Price Changes: An Application of Transactions Time and Subordinated Stochastic Models." Journal of Financial and Quantitative Analysis (December 1977):743-65.

100. Wiesenberger Investment Companies SErvice. Investment Companies 1976, 1977, and 1978, ed. New York: Wiesenberger Financial Services.

101. Winkler, R. L. and Hays, W. L. Statistics: Probability, Inference, and Decision. Second edition. New York: Holt, Rinehart and Winston, 1975.

102. Working, H. "Hedging Reconsidered." Journal of Farm Economics (November 1953):544-61.

103. ________. "A Theory of Anticipatory Prices." American Economic Review (May 1958):188-99.

APPENDIX A

TABLE A-1. Specific Issues of Individual Securities[1] 1976-79

Issue	Coupon	Maturity	Rating[2]	Interest[3] Payment Dates	Date of[4] Inclusion
1. General Motors Acceptance Corporation					
a. Notes	8.62	1985	A	MN15	1/07/76
b. Junior Subordinate Notes	8.125	1986	A	AO15	1/05/77
c. Notes	7.350	1987	Aaa	JJ15	1/04/78
d. Notes	8.200	1988	Aaa	FA15	7/05/78
2. American Telephone and Telegraph					
a. Debentures	8.700	2002	Aaa	JD1	1/07/76
b. Debentures	7.125	2003	Aaa	JD1	1/05/77
c. Debentures	8.800	2005	Aaa	MN15	1/04/78
d. Debentures	8.625	2007	Aaa	FA1	1/03/79
3. General Telephone and Telegraph					
a. Sinking Fund Debentures	9.750	1995	Baa	FA15	1/07/76
b. Sinking Fund Debentures	9.375	1999	Baa	MN15	1/04/78
4. Georgia Power and Alabama Power					
a. Debentures	11.625	2000	Baa	FA1	1/07/76
b. Debentures	8.875	2003	Baa	FA1	7/06/77
c. Debentures	9.750	2004	Baa	JD1	1/04/78
d. Debentures	10.875	2005	Baa	AO1	1/03/79
5. Municipal Assistance Corporation of New York					
a.	11.000	1983	Baa	FA1	1/07/76
b.	9.000	1985	Baa	FA1	1/05/77
c.	8.000	1986	Baa	JJ1	1/04/78
6. Ohio Turnpike and Municipal Assistance Corporation of New York					
a.	3.250	1992	Aa	JD1	1/07/76
b.	9.375	1992	Baa	JJ1	7/06/77

APPENDIX A (continued)

Issue	Coupon	Maturity	Rating[2]	Interest[3] Payment Dates	Date of[4] Inclusion
7. Treasury Notes					
a.	6.875	May 1980		MN15	1/07/76
b.	7.000	Feb.1981		FA15	4/07/76
c.	7.375	May 1981		MN15	7/07/76
d. Government bond	7.00	Aug.1981		FA15	10/06/76
e.	7.000	Nov.1981		MN15	7/06/77
f. Government bond	6.375	Feb.1982		FA15	4/06/77
g.	7.000	May 1982		MN15	7/06/77
h.	8.125	Aug.1982		FA15	10/05/77
i.	7.875	Nov.1982		MN15	1/04/78
j.	8.000	Feb.1983		FA15	5/03/78
k.	7.875	May 1983		MN15	7/05/78
l.	8.000	Feb.1985		FA15	11/01/78
8. Treasury Notes--9 years					
a. Government bond	6.375	1984		FA15	1/07/76
b.	7.875	1986		MN15	1/05/77
c.	8.000	1986		FA15	7/06/77
d.	7.625	1987		MN15	1/04/78
e.	8.125	1988		MN15	7/05/78
f.	8.750	1988		MN15	1/03/79
9. Government Bonds--15 years					
a.	8.250	1990		MN15	1/07/76
b.	7.250	1992		FA15	7/06/77
c.	7.875	1993		FA15	1/04/78
d.	8.625	1993		FA15	10/04/78
e.	9.000	1994		FA15	1/03/79
10. Government Bonds--24 years					
a.	7.875	1995-00		FA15	1/07/76
b.	8.375	1995-00		FA15	1/05/77
c.	8.000	1996-01		FA15	1/04/78
11. FNMA Issues					
a.	8.200	Jul.1984		JJ10	1/07/76
b.	7.950	Nov.1984		MS10	7/07/76
c.	6.900	Dec.1984		JD10	1/05/77
d.	7.650	Mar.1985		MS11	7/06/77
e.	7.250	Jul.1985		JJ10	10/05/77
f.	7.900	Oct.1985		AO10	1/04/78
g.	8.200	Mar.1986		MS10	4/05/78
h.	7.950	Jul.1986		JJ10	7/05/78
i.	9.200	Apr.1986		AO10	1/03/79

APPENDIX A (continued)

Issue	Coupon	Maturity	Rating[2]	Interest[3] Payment Dates	Date of[4] Inclusion
12. World Bank Issues					
a.	8.150	Jan.1985		JJ1	1/07/76
b.	8.600	Jul.1985		JJ15	1/05/77
c.	8.850	Dec.1985		JD15	7/06/77
d.	8.375	Jul.1986		JJ1	1/04/78

[1]The list includes intermediate-term and long-term issues only. The money-market issues included in the sample were changed every week and so are too many to be listed here.

[2]The ratings reported here are those assigned by the Moody's [66]. The government and agency issues were all rated Aaa during the study period.

[3]The interest payments were identified from [66,67]. The coupon is payable semi-annually in all cases. MN15 denotes May and November 15.

[4]Indicates the date when the specific issue was included in the study. Note that the successive dates in this column indicate when the previous issue was replaced.

APPENDIX B

TABLE B-1. Distribution of price changes--selected spot securities 1976-79

Security	Cases	Mean	SD[1]	Skewness	Kurtosis	SR[2]
Individual issues						
1. T bills 1 week	164	-.001	.005	- .175	6.203	9.00
2. T bills 13 weeks	164	-.006	.052	- .996	13.116	11.36
3. T bills 26 weeks	164	-.011	.086	.010	10.699	10.63
4. Government notes--5 years	161	.103	.444	- .917	4.276	7.67
5. Government bonds--9 years	167	.089	.565	- .977	7.618	9.30
6. Government bonds--15 years	167	.104	.709	-1.370	6.652	7.75
7. Government bonds--24 years	170	.088	.702	- .530	2.714	7.82
8. GNMA 8 percent	172	.102	.531	- .696	2.314	7.11
9. GNMA 9 percent	172	.115	.479	- .714	1.907	6.92
10. CP--90 days	164	-.005	.044	.109	13.701	11.07
11. AT&T bonds	169	.081	.898	-1.901	12.434	9.59
12. GPAP bonds	169	.144	.967	.055	1.681	6.51
13. Muni 2 bonds	171	.172	.687	.177	.989	5.82
14. FNMA bonds	163	.118	.498	.014	1.541	6.52
Fund portfolios						
1. DLA	164	-.000	.005	2.474	20.055	10.00
2. SMR	164	-.000	.005	- .044	.966	4.00
3. MOA	164	-.002	.072	-1.741	3.747	5.97
4. FUSG	172	-.004	.063	- .413	10.585	10.79
5. KMBF	99	-.005	.036	- .073	.25	5.56
6. AmBal	172	.007	.100	- .214	.181	5.5
7. AmCap	172	.026	.149	- .235	1.718	6.98
8. AmInv	172	.016	.160	- .988	2.141	5.75
Security indices						
1. S&P CORP	172	.048	.449	- .357	2.556	7.57
2. S&P LT GOVT	172	.037	.453	- .482	1.278	6.51
3. S&P IT GOVT	172	.015	.527	- .575	1.839	6.43
4. S&P ST GOVT	172	.022	.626	- .386	9.876	9.62
5. S&P MUNI	172	.124	.682	- .015	.494	5.66
6. S&P 500	172	.050	1.733	- .086	-4.900	5.41

[1]SD = the standard deviation of price changes

[2]SR = the studentized range

[3]K-S Z = the Kolmogorov-Smirnov Z

n denotes that the price changes do not fit the normal distribution based on the observed sample mean and the variance at 5 percent level

APPENDIX B (continued)

TABLE B-2. Distribution of price changes--futures instruments 1976-79

Contract	Cases	Mean	SD[1]	Skewness	Kurtosis	SR[2]	K-SZ[3]
I. T bill Futures							
1. Contract 1	137	.003	.052	-1.381	8.503	8.56	1.410n
2. Contract 2	164	-.005	.059	- .040	3.610	8.000	1.222
3. Contract 3	164	-.004	.053	- .383	.569	5.51	1.050
4. Contract 4	164	-.003	.055	- .126	.847	6.14	.997
5. Contract 5	164	-.002	.053	- .214	1.055	6.60	.936
6. Contract 6	149	-.001	.063	.644	7.589	9.48	1.242
7. Contract 7	101	-.004	.039	- .414	.546	5.13	.931
8. Contract 8	101	-.003	.040	- .200	.879	5.45	.814
II. T bond Futures							
1. Contract 1	67	-.088	.742	- .001	.442	4.96	.597
2. Contract 2	81	-.163	.930	- .300	4.621	7.76	.865
3. Contract 3	81	-.155	.744	.195	.384	5.26	.622
4. Contract 4	81	-.163	.769	.082	.540	5.24	.577
5. Contract 5	81	-.148	.728	.071	.286	5.25	.663
6. Contract 6	81	-.151	.888	.111	2.251	6.78	.720
7. Contract 7	59	-.105	.781	.225	.212	4.96	.622
8. Contract 8	59	-.104	.776	.317	.356	5.04	.714
9. Contract 9	59	-.103	.814	.323	.848	5.50	.691
10. Contract 10	59	-.101	.785	.340	.390	4.99	.642
11. Contarct 11	59	-.101	.727	.263	- .159	4.65	.548
III. GNMA Futures							
1. Contract 1	140	.005	.570	- .761	2.107	6.58	.806
2. Contract 2	172	-.054	.597	- .400	1.413	7.02	.774
3. Contract 3	172	-.051	.569	- .430	1.360	6.52	.879
4. Contract 4	172	-.050	.575	- .430	1.533	6.64	.834
5. Contract 5	172	-.048	.564	- .495	1.506	6.91	.959
6. Contract 6	163	-.041	.541	- .322	2.111	7.34	.866
7. Contract 7	134	-.048	.578	.344	1.976	6.96	.653
8. Contract 8	134	-.045	.672	-1.964	13.643	9.12	1.249n
9. Contract 9	81	-.111	.572	.191	.919	5.86	.772
10. Contract 10	81	-.111	.569	.230	1.04	5.98	.690
11. Contract 11	59	-.096	.638	.168	.755	5.53	.634

[1] SD = the standard deviation of price changes

[2] SR = the studentized range

[3] K-S Z = the Kolmogorov-Smirnov Z

n indicates that the price changes do not fit the normal distribution based on the observed sample mean and variance at the 5 percent level

APPENDIX C

TABLE C-1. Distribution of hedged returns--1976-79 transaction costs ignored

Contract	Cases	Mean	SD	Skewness	Kurtosis	SR
I. T bill 13 weeks						
T bill futures						
1. Contract 1	127	- .371	1.861	- .418	7.686	9.18
2. Contract 2	151	- .221	2.339	- .622	11.044	10.81
3. Contract 3	151	- .218	2.302	- .729	11.732	10.89
4. Contract 4	151	- .248	2.401	- .410	12.656	11.21
5. Contract 5	151	- .268	2.486	- .289	12.578	11.21
6. Contract 6	136	- .343	2.766	- .302	10.975	10.63
7. Contract 7	88	- .368	3.180	- .083	7.911	8.91
8. Contract 8	88	- .390	3.214	- .081	7.766	8.89
II. T bond 15 years						
T bond futures						
1. Contract 1	53	10.381	26.898	1.526	4.962	6.04
2. Contract 2	62	7.608	28.488	1.955	8.432	7.02
3. Contract 3	62	7.152	20.968	.896	3.174	6.31
4. Contract 4	62	6.392	21.132	.922	3.234	6.18
5. Contract 5	62	6.526	21.297	.685	3.959	6.57
6. Contract 6	62	6.794	25.442	1.045	4.170	6.55
7. Contract 7	41	7.101	26.599	.658	2.275	5.45
8. Contract 8	41	6.805	26.765	.378	1.946	5.50
9. Contract 9	41	6.636	27.978	.152	1.463	5.23
10. Contract 10	41	6.904	28.374	.442	2.336	5.66
11. Contract 11	41	7.569	26.437	.324	1.759	5.51
III. GNMA 8 percent						
GNMA futures						
1. Contract 1	130	9.012	20.227	.840	3.379	7.48
2. Contract 2	153	8.717	24.833	1.900	11.182	9.09
3. Contract 3	153	8.070	18.843	.146	2.133	7.05
4. Contract 4	153	7.917	18.665	- .143	1.137	5.95
5. Contract 5	153	8.283	21.332	.374	2.224	6.97
6. Contract 6	144	7.972	19.879	.122	1.297	6.50
7. Contract 7	116	8.020	25.352	2.195	12.645	8.86
8. Contract 8	116	5.843	18.721	.218	1.406	6.32
9. Contract 9	66	7.607	18.368	.159	.110	4.64
10. Contract 10	66	7.537	18.614	.294	.537	4.68
11. Contract 11	44	6.139	21.144	.098	- .041	4.44

APPENDIX C (continued)

TABLE C-2. Mean returns on hedged portfolios net of spot commission costs 1976-79

	13 week T bill-TBIF		15 year T bond-TBOF		8% GNMA--GNMAF	
Contract	Mean Return	Standard Deviation	Mean Return	Standard Deviation	Mean Return	Standard Deviation
1	-.63	1.86	6.41	25.19	5.25	19.47
2	-.33	2.33	5.57	27.64	5.62	23.81
3	-.35	2.30	4.93	20.31	5.06	18.25
4	-.36	2.40	4.27	20.55	5.35	18.21
5	-.39	2.48	4.17	20.63	5.54	20.72
6	-.42	2.76	5.10	25.01	4.36	18.94
7	-.56	3.17	4.35	25.75	4.40	23.84
8	-.57	3.20	3.92	25.85	4.19	18.29
9			3.76	27.01	4.80	17.72
10			3.98	27.34	4.72	17.95
11			4.71	25.51	2.90	20.31

APPENDIX D

TABLE D-1. Hedge ratio and hedging effectiveness, money market issues and T bill futures 1976-79

	1 week T bills		13 week T bills		26 week T bills	
Contracts	h	r^2	h	r^2	h	r^2
1	.04 (.01)	.20 (136)	.80 (.05)	.64	1.30 (.10)	.56
2	.02 (.01)	.05 (163)	.48 (.06)	.31	.90 (.09)	.36
3	.02 (.01)	.05 (163)	.56 (.06)	.32	1.06 (.10)	.39
4	.02 (.01)	.03 (163)	.48 (.06)	.26	.90 (.11)	.31
5	.02 (.01)	.02 (163)	.45 (.07)	.21	.82 (.12)	.24
6	.01 (.01)	.02 (148)	.29 (.06)	.12	.59 (.11)	.17
7	.01 (.01)	.01 (100)	.53 (.12)	.16	.87 (.21)	.15
8	.01 (.01)	.01 (100)	.48 (.12)	.14	.79 (.21)	.13

[1]h = the hedge ratio

r^2 = the coefficient of determination between ash and futures price changes

[2]Figures in parentheses in the h columns are the standard errors of h and those in the r^2 columns are the degrees of freedom.

TABLE D-1 (continued)

	CP		DLA		SMR		MOA	
Contracts	h	r^2	h	r^2	h	r^2	h	r^2
1	.15 (.07)	.03	.04 (.01)	.14	.03 (.01)	.07	.69 (.10)	.25
2	.12 (.06)	.03	.02 (.01)	.05	.02 (.01)	.04	.35 (.09)	.08
3	.08 (.07)	.01	.03 (.01)	.08	.02 (.01)	.04	.47 (.10)	.12
4	.06 (.06)	.01	.03 (.01)	.08	.03 (.01)	.09	.48 (.10)	.13
5	.05 (.06)	.0	.03 (.01)	.07	.03 (.01)	.08	.48 (.10)	.13
6	.06 (.06)	.01	.01 (.01)	.03	.01 (.01)	.03	.44 (.09)	.14
7	.04 (.11)	.0	.0 (.01)	.0	.04 (.01)	.12	.40 (.18)	.05
8	.03 (.11)	.0	.01 (.01)	.0	.05 (.01)	.14	.38 (.18)	.04

TABLE D-2. Hedge ratio and hedging effectiveness Government and municipal fund portfolios and longterm futures 1976-79

	FUSG[1]				DTEB				KMBF			
	TBOF		GNMAF		TBOF		GNMAF		TBOF		GNMAF	
Contract	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2
1	.04	.13	.05	.24	.03	.07	.05	.08	.01	.05	.02	.07
	(.01)	(66)	(.01)	(139)	.01	(66)	(.02)	(79)	(.01)		(.01)	
2	.03	.13	.05	.23	.02	.09	.05	.13	.01	.04	.02	.08
	(.01)	(80)	(.01)	(171)	(.01)	(80)	(.04)	(98)	(0)		(.01)	
3	.04	.17	.06	.27	.04	.14	.06	.16	.01	.07	.02	.14
	(.01)	(80)	(.01)	(171)	(.01)	(80)	(.01)	(98)	(.01)		(.01)	
4	.04	.16	.06	.28	.04	.13	.07	.17	.01	10	.03	.15
	(.01)	(80)	(.01)	(171)	(.01)	(80)	(.02)	(98)	(.01)		(.01)	
5	.04	.15	.06	.25	.04	.13	.07	.17	.01	.07	.02	.13
	(.01)	(80)	(.01)	(171)	(.01)	(80)	(.01)	(98)	(.01)		(.01)	
6	.03	.15	.06	.26	.04	.17	.07	.18	.02	.12	.02	.14
	(.01)	(80)	(.01)	(162)	(.01)	(80)	(.01)	(98)	(0)		(.01)	
7	.04	.15	.06	.26	.04	.17	.07	.18	.02	.12	.02	.14
	(.01)	(58)	(.01)	(133)	(.01)	(58)	(.01)	(98)	(.01)		(.01)	
8	.04	.14	.05	.28	.04	.18	.07	.18	.02	.13	.02	.13
	(.01)	(58)	(.01)	(133)	(.01)	(58)	(.01)	(98)	(.01)		(.01)	
9	.03	.14	.05	.19	.04	.17	.06	.16	.02	.11	.02	.12
	(.01)	(58)	(.01)	(80)	(.01)	(58)	(02)	(80)	(.01)		(.01)	
10	.03	.13	.05	.18	.04	.19	.06	.15	.02	.13	.02	.11
	(.01)	(58)	(.01)	(80)	(.01)	(58)	.02	(80)	(.01)		(.01)	
11	.03	.12	.04	.17	.05	.22	.06	.17	.02	.14	.02	.15
	(.01)	(58)	(.01)	(58)	(.01)	(58)	(.02)	(58)	(.01)		(.01)	

[1]Figures in parentheses in the h columns are the standard errors of h and those in the r^2 columns are the degrees of freedom. The degrees of freedom are identical for DTEB and KMBF.

TABLE D-3. Hedge ratio and hedging effectiveness--corporate bond funds and long-term futures 1976-79

	Keystone B-1				Keystone B-2				Keystone B-3			
	TBOF		GNMAF		TBOF		GNMAF		TBOF		GNMAF	
Contract	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2
1	.07	.03	.08	.04	.01	0	.05	.03	.0	.0	.01	.01
	(.05)	(66)	(.03)	(139)	(.03)		(.02)		(.01)		(.01)	
2	.01	.0	.05	.02	.03	.02	.09	.10	0	0	.01	.02
	(.04)	(80)	(.03)	(171)	(.02)		(.02)		(.01)		(.01)	
3	.02	0	.06	.02	.03	.01	.09	.09	0	0	.01	.02
	(.05)	(80)	(.03)	(171)	(.03)		(.02)		(.01)		(.01)	
4	.03	.01	.06	.03	(.03)	.02	.08	.06	0	0	.01	.01
	(.04)	(80)	(.03)	(171)	(.03)		(.02)		(.01)		(.01)	
5	.03	.01	.13	.03	.04	.02	.07	.05	.01	.01	.01	.01
	(.05)	(80)	(.03)	(171)	(.03)		(.02)		(.01)		(.01)	
6	.02	0	.05	.02	.02	.01	.06	.05	0	0	.01	.01
	(.04)	(80)	(.03)	(162)	(.02)		.02		(.01)		(.01)	
7	.11	.07	.06	.02	.02	.01	.06	.05	-0	0	.02	.02
	(.05)	(58)	(.03)	(133)	(.03)		(.02)		(.01)		(.01)	
8	.02	0	.04	.02	.03	.01	.03	.02	-0	0	.01	.01
	(.05)	(58)	(.03)	(133)	(.03)		(.02)		(.01)		(.01)	
9	.01	0	.04	.01	.02	.01	.07	.06	-0	0	.01	.03
	(.05)	(58)	(.04)	(80)	(.03)		(.03)		(.01)		(.01)	
10	.02	0	.05	.09	.02	.01	.07	.06	-0	0	.02	.02
	(.05)	(58)	(.04)	(80)	(.03)		(.03)		(.01)		(.01)	
11	.02	0	.05	0	.03	.01	.07	.07	-0	0	.01	.09
	(.06)	(58)	(.04)	(58)	(.03)		(.03)		(.01)		(.01)	

[1]Figures in parentheses in the h columns are standard errors of h and those in the r^2 column are the degrees of freedom which are identical for all funds

TABLE D-4. Hedge ratio and hedging effectiveness stock funds, S&P 500, and long-term futures 1976-79

	AMINV				AMCAP				AMBAL				S&P 500			
	TBOF		GNMAF		TBOF		GNMAF		TBOF		GNMAF				GNMAF	
Contract	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2	h	r^2
1	.11 (.06)	.16	.10 (.02)	.11	.12 (.03)	.21	.10 (.02)	.14	.09 (.02)	.31	.08d (.01)	.21	1.34 (.27)	.27	.84 (.43)	.03
2	.09 (.02)	.17	.08 (.02)	.10	.10 (.02)	.22	.08 (.02)	.10	.07 (.01)	.30	.06 (.01)	.15	1.06 (.20)	.27	.71 (.38)	.02
3	.11 (.03)	.16	.09 (.02)	.11	.11 (.02)	.19	.09 (.02)	.11	.09 (.01)	.31	.08 (.01)	.19	1.26 (.25)	.24	.84 (.39)	.03
4	.11 (.03)	.17	.08 (.02)	.08	.11 (.02)	.18	.08 (.02)	.09	.08 (.01)	.27	.07 (.01)	.16	1.18 (.24)	.22	.75 (.39)	.02
5	.10 (.03)	.12	.07 (.02)	.05	.10 (.03)	.15	.07 (.02)	.07	.08 (.02)	.22	.06 (.01)	.14	1.12 (.27)	.18	.63 (.40)	.01
6	.07 (.02)	.09	.07 (.02)	.07	.07 (.02)	.10	.07 (.02)	.09	.05 (.01)	.16	.06 (.01)	.14	.79 (.22)	.14	.74 (.42)	.02
7	.07 (.03)	.08	.07 (.02)	.08	.08 (.03)	.11	.08 (.02)	.09	.07 (.02)	.22	.07 (.01)	.15	.96 (.30)	.15	.71 (.44)	.02
8	.07 (.03)	.08	.07 (.02)	.08	.08 (.03)	.11	.06 (.02)	.08	.07 (.02)	.22	.06 (.01)	.16	.94 (.30)	.15	.44 (.38)	.01
9	.06 (.03)	.07	.10 (.03)	.12	.07 (.03)	.10	.10 (.03)	.16	.07 (.02)	.21	.08 (.02)	.22	.88 (.29)	.14	2.20 (.52)	.18
10	.06 (.03)	.06	.09 (.03)	.11	.07 (.03)	.09	.10 (.03)	.15	.07 (.02)	.21	.08 (.02)	.22	.88 (.30)	.13	2.17 (.53)	.18
11	.08 (.04)	.09	.08 (.03)	.09	.08 (.03)	.11	.08 (.03)	.12	(.08) (.02)	.23	.07 (.02)	.21	1.02 (.32)	.15	1.81 (.56)	.15

[1]Figures in parentheses are the standard errors of h. Degrees of freedom are identical to those reported in the previous table.