GOAL PROGRAMMING APPROACH FOR HEDGING A PORTFOLIO WITH FINANCIAL FUTURES: AN EMPIRICAL TEST

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GOAL PROGRAMMING APPROACH FOR HEDGING A PORTFOLIO

WITH FINANCIAL FUTURES: AN EMPIRICAL TEST

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Purpose of Study:

The primary purpose of this study is to test the Sharda and Musser goal programming hedging model in a portfolio environment employing real world data. The model is modified to accommodate a portfolio of securities, refined to include priorities and previous week's hedging information, and is also condensed to exclude constraints pertinent to past week's hedging activities. Results of the model are compared to those obtained from implementing the static hedge ratio models, the original GP model, the GP-naive model as well as to the best case scenario using perfect forecasts. Performance evaluation is based on four criteria; ending portfolio value, riskiness of the strategy, risk-return tradeoffs, and the number of positive quarters.

Findings and Conclusion:

Findings from the study reinforce conclusions from the earlier works which employed the goal programming approach. The condensed GP model was far superior than the original GP model and the GP-naive model in providing consistent net values. It also outperformed all the other ratio-related strategies in almost all of the criteria concerned. When actual, historical data were used, the model's performance improved substantially. Forecasting inaccuracies remain the major factor in impeding the model's potential performance. Putting it aside, the goal programming approach to hedging appears to perform remarkably well even in a portfolio environment.

ADVISOR'S SIGNATURE Ramesh Sharda

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1. INTRODUCTION

1.1 PROBLEM DEFINITION

Interest rate futures emerged in the mid 1970's [2] to fulfil a growing need in the economic function of our financial system. Since their inception, interest rate futures have proved to be a viable risk management tool. Increasingly, institutions are seeking efficient and economical means to reduce their financial risks through forward contracting. This is especially visible from 1970 onwards when interest rates began to fluctuate considerably. Involvement in the futures market, therefore, raises the question of the optimal hedge ratio for a given level of cash investment.

Various theories have been proposed in the hedging literature to calculate the optimal hedge ratio. However, most of these theories do not allow for dynamic decision making throughout the hedging period. Sharda and Musser [19] developed a multiobjective, goal programming model which attempts to account for this inflexibility. This study extends on their approach.

The goal programming model allows the hedger to simultaneously achieve the conflicting goals of transaction and margin opportunity costs, cash flow regulation, and risk minimization [19]. Furthermore, it is a dynamic model. The hedger can revise his futures position on a regular basis upon receiving the most recent price and interest rate information from the market. Instead of assuming a single asset as was in the original study, a portfolio of treasury notes with varying maturities and coupon structures is employed here. Application-wise it adapts the shorter, refined model with priorities proposed by Sharda and Wingender [20]. The model was developed and tested for a real investor holding a portfolio of securities.

1.2 ELEMENTS OF THE FUTURES MARKETS

Futures contracts are essentially a highly institutionalized form of forward contracting [13]. By definition, in buying or selling a futures contract, a trader agrees to receive or deliver a given commodity at a specified time in the future for a price that is determined in the present [18]. Among the vast array of futures contracts which are available, interest rate futures exhibit the most variety. Since the characteristics of these contracts are tailored to the attributes of their underlying securities, futures trading on interest-bearing assets are therefore contingent upon interest rate movements. The direction of these movements determines whether a trader should initiate a short or a long futures position.

1.2.1 Market Structure

The majority of interest rate futures trading take place in two exchanges, the Chicago Board of Trade (CBOT) and the International Monetary Market (IMM) of the Chicago Mercantile Exchange (CME) [13]. The CBOT specializes in contracts of longer maturities while the IMM offers contracts which are mostly in the shorter end of the maturity spectrum [13].

Although forward contracting occurs in both the forward and futures markets, the principal components which characterize the futures markets are: (1) the organized exchange, (2) the contract terms, (3) the clearinghouse, and (4) margin requirement and daily resettlement.

(1) The Organized Exchange: The Organized Exchange is a physical, central location where futures contracts are traded by open outcry to all traders present. Membership is required to trade on the Exchange. The open outcry system provides automatic adjustment of prices in response to the most recent market information. This automatic adjustment ensures attainment of competitive prices in the market. The oldest and largest futures exchange in the United States is the CBOT.

(2) Contract Terms: Unlike forward contracts which are tailored to the desires of the trader, futures contracts are highly

uniform and well specified. Standardized contracts help to promote trading by providing liquidity. This is because traders know what is being offered and the terms of the transactions. This highly developed framework also eliminates exhaustive negotiations and high transaction costs inherent in forward contracts.

(3) <u>The Clearinghouse</u>: The clearinghouse serves all trading parties by interposing itself between buyers and sellers in every transaction. Its purpose is basically to guarantee performance to all participants in the market by helping to reduce risk of default on the part of the participants. In essence, the existence of the clearinghouse transfers trust from individual trading parties to that of the clearinghouse which has little risk of default.

(4) <u>Margin Requirements and Daily Resettlement</u>: At the time of a transaction, every trader in the futures market is required to post a specified amount of money with the broker for each contract transacted. This deposit or margin requirement must be maintained throughout the hedging period. Replenishment funds must be made into the margin account to bring the margin back to the maintenance level. This requirement protects against unexpected value changes and contributes to the stability of the futures market.

Daily resettlement is also another safeguard built into the system whereby losses are realized on the day they occur. These losses are deducted from the trader's margin deposited with the broker. Likewise, profits are credited to the account on a daily basis and may be withdrawn immediately by the trader.

These characteristics of the futures market are enacted to aid in stabilizing the market against unforeseen events such as adverse price changes or any inefficiencies that may arise. To date, interest rate futures have flourished dramatically. Although some contracts have failed to take off, such as commercial paper and Certificate Delivery GNMA contracts, interest rate futures currently represent about one-third of all trading activities in the futures market [13]. This has been a phenomenal growth since 1978. Then, more than ninety percent of CBOT futures activities came mainly from agricultural and metallurgical futures [13] but the picture is changing. Further growth in interest rate futures activities is expected to continue in the years to come.

1.2.2 Participants in The Market

Principal players in the futures market are speculators and hedgers. Speculators enter the market in the hope of making a profit. This occurs if and only if there is a favorable movement in the price of the futures contract. Needless to say, speculating in the futures market entails a considerable amount of risk. The other group of participants, the hedgers, trade in the market to decrease a pre-existing risk. To offset the risk they face in the cash market, hedgers will have to be either long or short in the futures market. A long trader has a commitment to buy at current futures price while a short trader has a commitment to sell at current futures price. When trading involves interest-sensitive instruments, falling interest rates would be ideal for the long trader. Conversely, a short trader would benefit in the event of rising interest rates.

Conceptually, the futures market provides a place for hedgers to transfer unwanted risk to the speculators. In return, the hedger pays the speculator for bearing this risk. The payment to the speculator is derived from the difference between the futures price and expected future spot price. However, the profit is earned only when the expected future spot price materializes.

Although speculating activities do abound in the futures market, the prime social rationale for futures trading is to hedge against unwanted risk. In this way, the futures market actually helps in enhancing economic activity by allowing risk averse individuals to profit from these events via risk transfer to third parties [13].

1.3 LITERATURE REVIEW

1.3.1 Hedging As a Risk Reduction Tool

Contrary to the general misconception that getting involved in futures trading is a risky venture, a thorough understanding of how futures market works can actually aid in managing corporate financial risks. Although hedging activities do not always seek to eliminate all risks, they allow the investor the option to specify his level of risk. Conducive to the nature of risk return trade-off, hedge ratios that carry higher risks will also lead to higher returns. On the other hand, reducing risk also lowers expected returns above and beyond the risk minimizing level [4].

For most financial institutions that hold large portfolios of fixed income securities, the prime concern is to hedge against fluctuations in interest rates. Interest rate futures such as treasury bonds, treasury bills, and treasury notes are ideal for such hedges. Figlewski, John, and Merrick [4] identified two approaches to hedging interest rate exposures. One is micro hedging and the other is macro hedging. Micro hedging treats each asset separately in the hedging program while macro hedging focuses on the entire asset holdings of the investor. Micro hedging entails higher transactions cost since it ignores offsetting positions that are naturally taken care of in macro hedging. Moreover, interest rate exposures exist only if the characteristics of assets and liabilities do not match in the macro hedging environment [4].

The important decision to be made prior to any hedging activity is the risk exposure that the investor is prepared to assume on his hedged position before undertaking the hedge. The risk exposure that a futures hedge can aid in reducing is the risk that a cash position is exposed to due to price fluctuations. Residual risks, primarily basis risk, cannot be eliminated by a futures hedge [4].

1.3.2 Theories of Hedging

The hedging literature has seen a lot of research in the area, most of which are aimed at deriving the optimal hedge ratio for a given level of cash investment. The most well known theories that have surfaced are the traditional hedging theory, Working's hypothesis and the portfolio hedging theory. As mentioned by Musser [18], all these theories succeed only in developing a theoretical base for hedging activities. Little was accomplished in terms of achieving practical uses of the theories by the real world investor.

The traditional hedging theory recommends a "one-to-one" hedge or more commonly known as the naive hedge. Here, the investor will establish a hedge ratio of one. This approach assumes concurrent as well as equivalent movements in spot and futures prices. A perfect hedge results if the difference between futures and spot prices (basis) is zero. As such, the underlying assumption of this theory is a zero or near-zero basis. This rather simplistic approach to hedging is subject to criticisms. Foremost of all, spot and futures prices do not necessarily move together and even if they do, the movements may not be proportional. In addition, given the highly uniform futures contracts and the variety of cash instruments available, coupon rates and maturity of the hedged instruments may play a role in hedging activities [7]. Unfortunately, the naive approach does not take such structure into consideration. To account for this discrepancy, the conversion factor approach was proposed. This approach utilizes the appropriate CBOT conversion factor to adjust for the number of futures contracts recommended by the naive approach [18]. Although the conversion factor approach does improve performance, it is still bounded by some of the problems that affect the naive strategy.

In contrast to the traditional theory which views hedgers as risk avoidance participants in the futures market, Working's [22,23,18] hypothesis says that hedgers seek to maximize profit rather than to minimize risk. With this objective in mind, hedgers holding a long position would enter the futures market to hedge if they anticipate a fall in the basis and would not hedge otherwise. The decision is either to assume a zero or one hedge ratio [18]. By assuming that investors are profit maximizers rather than risk minimizers, this theory suffers almost the same criticism as the traditional approach. Both theories require extreme behaviors on the part of the investor.

The third most cited theory in the hedging literature is the portfolio hedging theory. This theory integrates the naive concept with Working's hypothesis in an attempt to arrive at an optimal hedge ratio to account for both risk avoidance and profit maximization [12].

Originally developed by Johnson and Stein [12,18,21], this theory argues for hedging activities to involve only portions of the investor's cash position in accordance to his risk-return preferences. The question raised here is not whether to hedge or not as in Working's hypothesis, but how much of the cash position that requires hedging.

1.3.3 Hedging Models

The three theories of hedging invited considerable research. The naive approach was found to work relatively well under conditions of mild fluctuations in interest rates but less well under volatile conditions [11]. Increasing volatility in interest rates in the 70's have prompted more studies in this area. One of the early studies was Ederington's [3] risk minimizing hedge ratio which was based on Johnson and Stein's portfolio theory. According to Ederington, a relationship exists between futures contracts and security holdings as defined by this ratio:

$$b_{min} = \frac{-Cov(s,f)}{V(f)}$$

where:

$Cov(s,f)$ = Covariance of price changes between spot (s) and futures (f) contracts
$V(f)$ = Variance of futures price (f) changes.

Ederington found his hedge ratio worked for hedges on GNMA's, T-bills, wheat and corn [3,11]. Franckle [6] modified Ederington's work by adjusting Ederington's hedge ratio to reflect decreasing maturity of the financial instrument over the life of the hedge [11,18]. Although the Ederington-Franckle approach was found to be effective by Cichetti, Dale and Vignola [1,18] with respect to hedging T-bills, Gay, Kolb and Chiang [8,11] had several criticisms. The authors argue that Franckle's adjustment to the Ederington's hedge ratio requires time series data on the spot and futures instruments which are often not available. Improving on the Ederington-Franckle approach, Kolb and Chiang [14] arrived at five key factors pertinent to an effective hedge. The five factors are:

(1) the maturity of the hedged and hedging instrument,

(2) the coupon structure of the hedged and hedging instruments,

(3) the varying risk structure of interest rates,

(4) the changes in the term structure of interest rates, and

(5) the length of the hedging period.

According to the authors, the uncertainty of the third and fourth factors has been the major problem in determining the perfect hedge in hedging interest rate risk. With this finding, Kolb and Chiang argue that hedging strategies which do not take these factors into consideration will fail to perform. In a latter study, Gay, Kolb and Chiang [8] propose a new hedging strategy known as the price sensitivity model (PS). By incorporating all the key factors in their model, they hope to avoid the Ederington-Franckle criticisms mentioned earlier. This duration based approach builds on the Ederington-

Franckle's b_{min} by combining Macaulay's [17,13] duration definition to arrive at the following hedge ratio:

$$N = \frac{R_j P_i D_i}{R_i FP_j D_j}$$

Where:

R_i = 1 + the expected yield to maturity on asset i
R_j = 1 + the rate expected to obtain on the asset underlying futures contract j
FP_j = the price agreed upon in the futures contract for title to the asset underlying j
P_i = the price of asset i expected to prevail on the planned termination date of the hedge
D_j = the duration of the asset underlying futures contract j expected to prevail on the planned termination date of the hedge

Unlike the minimum variance hedge ratio which minimizes the variability of returns, the PS hedge ratio focuses on the price sensitivities of the futures and spot rates so as to adjust for the mismatched maturities, coupons, term as well as the risk structures of the hedged and hedging instruments [3,11,14].

In a subsequent study, Howard and D'Antonio [10] developed yet another optimal hedge ratio (HD) as a by-product of their work on deriving a risk-return measure of hedging effectiveness (HE). This strategy calls for derivation of HE before initiating a futures hedge. If HE > 1, benefits accrue from a futures hedge. On the other hand, if HE = 1, the investor's net value remains unchanged and no hedge is recommended. The key factors behind this approach are the risk return relative ( ) and the spot-future correlation coefficient (p). Whereas Ederington's [3] risk minimizing ratio focuses only on risk reduction, this approach incorporates expected returns considerations as well. HE and HD are defined as follows:

$$HE = \sqrt{\frac{1 - 2\lambda p + \lambda^2}{1 - p^2}}$$

$$HD = \frac{(\lambda - p)}{y \cdot n \cdot (1 - \lambda p)}$$

where

λ = the risk return relative,
p = the spot-futures correlation coefficient,
y = ratio of futures price to spot price (P_f/P_s), and
n = ratio of standard deviations of futures price to spot price (σ_f/σ_s)

On applying their strategy in a later study [11], the authors discovered that T-bill futures did not yield hedging benefits on a risk-return basis. Instead, the traditional one-to-one hedge outperformed their more sophisticated HD hedge ratio model. The disappointing results appeared to have accrued from having to use historical data in projecting for the future. Potential benefits were ascertained from the outcomes of the perfect foresight model.

Koppenhaver [15] utilized the Ederington-Franckle's portfolio and the duration approach in a comparison study with a firm theoretic model of bank behavior with financial futures. CD futures contracts were employed to assess its potential effectiveness in a hedging environment. Optimal ratio of futures contracts to risk exposure is derived under constant absolute risk aversion and constant relative risk aversion [15]. However, uncertainty with respect to future CD requirement and cash CD interest rates remains a factor. Lack of data on futures hedging activities by banks also prevented a comprehensive test of the model [15]. The comparative study revealed that for some degrees of constant absolute and constant relative risk aversion, the simple portfolio-choice and routine hedging strategies performed better. Results on the CD futures were more positive. The analysis indicates that CD futures contract outperforms T-bill futures contract if banks hedge to minimize the variability of CD cost.

Departing from the more conventional hedging models, Sharda and Musser [19] proposed a multiobjective approach to hedging via goal programming (GP). The GP model has the following objectives in mind:

(1) to allow the hedger to simultaneously achieve the conflicting goals of transactions and margin opportunity cost minimization, cash flow regulation, and risk minimization, and

(2) to permit an ongoing revision of the futures position throughout the cash holding period in response to the most recent market information.

The study yielded very promising results. The GP model outperformed the naive approach as well as a no hedge position. However, as in the Howard and D'Antonio [11] study, the results were contingent upon the superiority of the forecasting method used. Better forecasts led to better performance as was justified by the perfect foresight model which returned the most promising results. In a following study, Sharda and Wingender [20] adapted the model in hedging foreign exchange risks. The model was reformulated to include priorities and was also refined into a condensed version which incorporated previous week's hedging information. The GP strategy led to higher value of the portfolio on a risk-adjusted basis.

1.4 PURPOSE OF THE STUDY

This paper is an extension of the Sharda-Musser [19] and Sharda-Wingender [20] studies. The latter, refined version of the model is adapted here. The model was formulated for hedging a portfolio of U.S. Treasury Notes with varying maturities and coupon rates. In contrast to the previous studies which assumed holding of a single asset, this paper seeks to address the hedging effectiveness of the model when applied to a portfolio environment. The size of the portfolio is also varied over time.

Specific objectives of this study are to:

(1) Test the revised GP model in a portfolio environment using real world data,

(2) Compare the performance of the original model in this environment to the performance of the condensed, priority model,

(3) Compare the performance of the forecast model to that of the "perfect foresight" model,

(4) Implement a dual strategy approach which combines the GP priority model with the naive hedging strategy, and

(5) Compare the performance of the forecast model to no hedge, various hedge ratio approaches, and the dual GP-naive strategy.

2.METHODOLOGY

2.1 DATA DESCRIPTION

Data for this study were obtained from a portfolio holding of a well established Oklahoma bank. The bank's holdings include various cash instruments ranging from short term investment funds to miscellaneous government and agency obligations. The holdings of U.S. Treasury Notes are chosen for this study since they represent the largest proportion of the entire cash portfolio holding of the bank. The size of the portfolio changes every quarter. The bank adjusts the portfolio whenever it is necessary, liquidating some securities and allocating the funds to another area, or adding new treasury notes. Table 1 gives a summary of the total value of the treasury notes portfolio at the beginning of each quarter. As can be seen from the table, the portfolio value ranges from a high of $11,143,436 in March 1986 to a low of $2,968,595 in September 1987. Securities which mature within the quarter have been excluded instead of reinvested for the duration of the hedge for simplication purposes.

The characteristics of the Treasury Notes vary from an 8% 5-month to maturity Note to a 9.3% Note with 9 years to maturity. Twelve different maturities can be found in the sample. The different maturities represent varying degrees of price risk. The samples employed in this analysis are purposely selected to correspond directly to the quarters in which treasury notes futures contracts are traded.

Table 1: Beginning Portfolio Values for all Quarters

Quarter	No.of Different Securities	Beg. Value	End. Value No Hedge	Percent Change
Mar 86	11	$11,143,436	$11,096,436	-0.4218%
Jun 86	10	$7,415,031	$7,423,594	0.1155%
Sep 86	9	$6,918,593	$6,986,562	0.9824%
Dec 86	8	$6,486,405	$6,422,561	-0.9843%
Mar 87	7	$4,752,093	$4,550,562	-4.2409%
Jun 87	6	$4,050,562	$3,891,281	-3.9323%
Sep 87	7	$2,968,595	$3,021,720	1.7896%

Specifically, beginning market values of the treasury note portfolios were collected for the months of March, June, September, and December. Altogether 7 quarters were analyzed commencing March 1986 to September 1987.

A 13-week hedging period was assumed. Futures prices, spot prices, and prime rates were collected for each of the 13 week over the time period January 1986 to December 1987. Plot of the futures and spot prices over this time horizon reveals some fairly stable and some volatile interest rates (Figure 1). Prices went up in one quarter, down five quarters and stayed almost flat in one. The unpredictable nature of the sample made forecasting future prices much more difficult. This is undeniably a tough sample over which to test hedging performance.

2.2 MODEL SCENARIO

The scenario is that of a bank which has to hold a portfolio of treasury notes for a 13-week period. The bank cannot liquidate its holdings during this time. If interest rates at the end of the 13 weeks are higher than that at the initiation of the cash position, the bank's portfolio will decline in value. Conversely, if interest rates have fallen instead, the portfolio will increase in value.

Ideally, the bank can hedge its exposure to interest rate risks by initiating a short position in treasury note futures contracts. Treasury note futures are most suitable in this scenario since the underlying cash instruments are treasury note holdings. However, the highly standardized nature of the futures contracts means there does

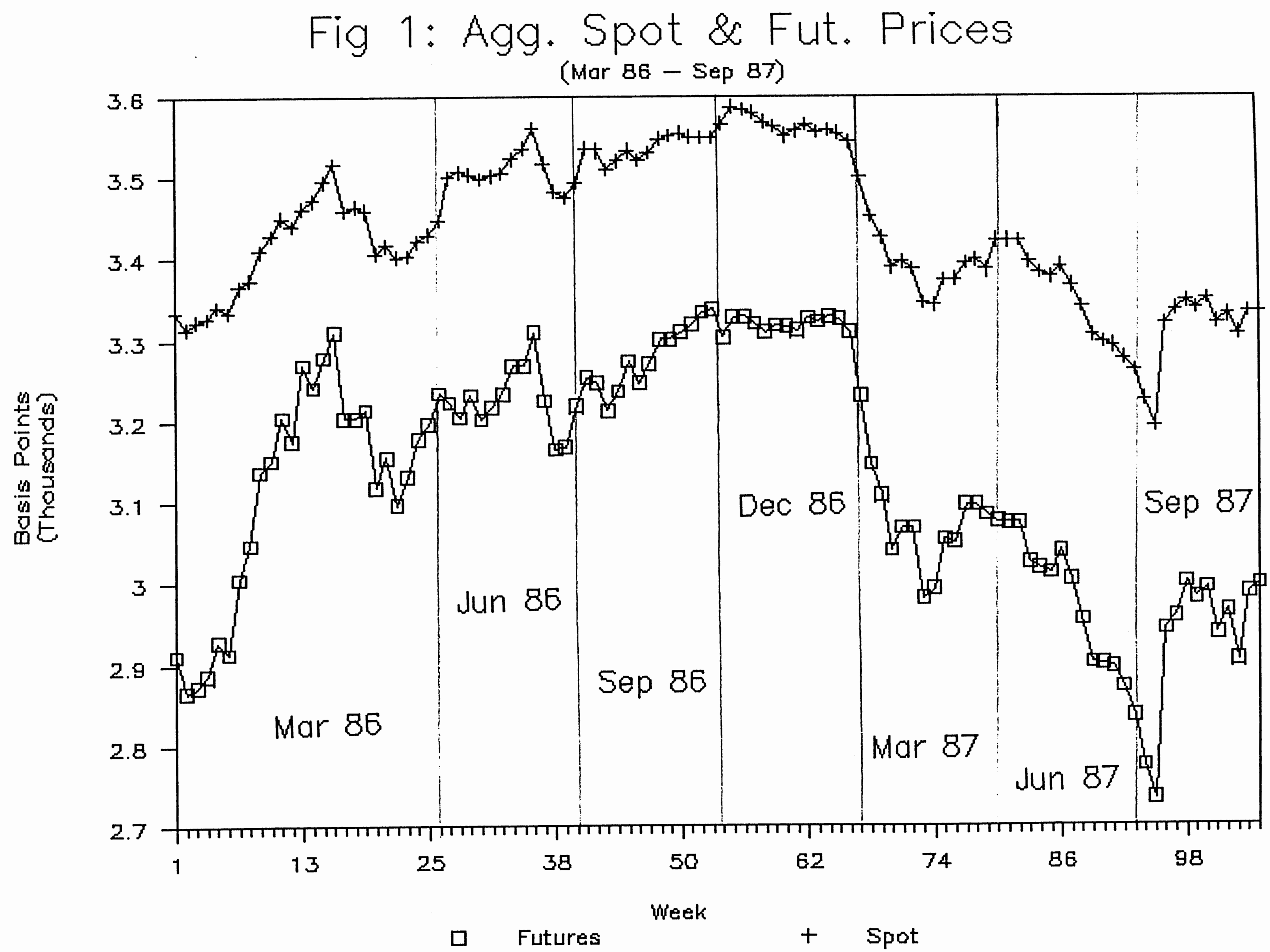


Fig 1: Agg. Spot & Fut. Prices
(Mar 86 — Sep 87)
Basis Points
(Thousands)
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
Mar 86
Jun 86
Sep 86
Dec 86
Mar 87
Jun 87
Sep 87
1
13
25
38
50
62
74
86
98
Week
Futures
Spot

not exist a perfect match for all hedged and hedging instruments. To account for this discrepancy, all the cash prices are standardized using the appropriate CBT conversion factors. Since the model handles only a single spot price, a weighted average of all the cash prices is computed for this application.

In order to truly represent a hedging activity in real life, certain cost and cash flow considerations have been included in the development of the model [see 18]. These are briefly summarized below:

Element	Structure
Brokerage Fees	$60 per round trip contract for each contract sold short. Offsetting contracts are not affected.
Margin Requirements	$2000 for each contract acquired. $1500 minimum balance for each contract held throughout the hedging period.
Margin Opportunity Cost	Investment income foregone on funds deposited in the margin accounts. The prime rate is used to reflect the return on investment.

Unlike the hedge ratio approaches which focus only on the cash and futures value relationships, the GP model provides a more realistic picture of the real costs involved in making a hedging decision.

2.3 MODEL DEVELOPMENT

The GP model used in this study is adapted from the shorter, refined, priority version implemented by Sharda and Wingender [20] in their foreign exchange futures hedging paper. Modifications are made to the model to customize it to a portfolio hedging environment. The priority scheme developed by Sharda and Wingender [20] is implemented here as well. These priorities add an invaluable feature to the model by allowing the hedger to exercise his desires over the goals preferred. As in the earlier studies (see [19] [20]) the model is kept to a weekly basis to facilitate processing. The hedger can revise his futures position at the end of each week as recommended by the model. Inclusion of previous week's hedging decision increases the informational content of the model when solving for this week's decision.

2.3.1 Decision Variables

(a) Cash/Futures Position Variables

x_{1t} = number of futures contracts held at the end of week t

x_{2t} = number of futures contracts acquired at the end of week t

x_{3t} = number of futures contracts offset at the end of week t

(b) Margin Accounts Variables

$BMarg_t$ = Beginning margin account balance at the end of week t

$EMarg_t$ = Ending margin account balance at the end of week t

$ReqM_t$ = Required margin balance at the end of week t

(c) Deviational Variables

SLACi = underachievement of the ith goal constraint

SURPi = overachievement of the ith goal constraint

for i = C (cash/futures position), O (opportunity cost) M (margin requirements), and TR (transaction cost)

(d) Other Variables

a_t = forecasted change (in basis points) in the cash price from week t-1 to week t, t = 1,..N

b_t = forecasted change (in basis points) in the futures price from week t-1 to week t, t = 1,..N

P_t = prime rate in week t

N = number of weeks in the planning horizon

V = value of one basis point = $31.25

Q = equivalent number of cash holdings per futures contracts (market value of portfolio/$100,000)

M = a big number

j = week numbers at which the model is being implemented, j = 1,..N

2.3.2 Constraints Development

The constraints in this formulation are developed with several objectives in mind. These objectives are of a typical investor who seeks to balance the costs and benefits accrued from participation in the futures market. Foremost of all, he seeks to minimize (i) his exposure to price fluctuations via short selling, (ii) total transactions costs, (iii) margin opportunity cost, and (iv) required margin deposits [19]. These objectives are accomplished by minimizing the appropriate slack and surplus variables in the objective function.

The structure of the initial GP model depends on the size of N. The larger the value of N, the larger the size of the initial model. For each consecutive week that follows, the model is condensed to exclude the constraints which relate to previous week's decision. Only constraints that are relevant to the remaining (N-j) weeks are retained. However, only current week's recommended decision is implemented. The rest of the decisions serve as guidelines for long range planning implementations. Besides condensing the model, the (N-1) models have also been refined to incorporate (i) previous week's hedging decision, i.e. number of contracts held last week, and (ii) previous week's ending margin balance.

The constraints as adapted from Sharda and Musser [19] are:

Objective Function

$$\text{Minimize} \quad Z = \sum_{t=j}^{N} SLACC_t + \sum_{t=j}^{N} SURPC_t + \sum_{t=j}^{N} SURPO_t + \sum_{t=j}^{N} SLACM_t + SURPTR$$

subject to

(a) System Constraints

(i) Continuity Constraint

$$X_{1t} = X_{1,t-1} + X_{2t} - X_{3t}, \qquad t = j,..,N$$

This relates the number of contracts held in week t-1 to the number held, acquired, and offset in week t.

(ii) Simultaneous Buy/Sell Prevention Constraints

$$X_{2t} < MY_t, \qquad t = j,..,N$$
$$X_{3t} < M(1 - Y_t), \qquad t = j,..,N$$

These constraints are introduced to prevent simultaneous buying and selling of contracts in the same week (see [19]). Y_t is a binary variable defined as follows:

$$Y_t = \begin{cases} 1 & \text{if contracts are acquired in week t} \\ 0 & \text{otherwise,} \quad t = j,..,N \end{cases}$$

(iii) Beginning Margin Balance Constraint

$$BMarg_t = EMarg_{t-1} - b_t \cdot V \cdot X_{1t}, \qquad t = j,..,N$$

This equation ties the beginning margin balance to previous end-of-week margin balance adjusted for any futures market gains or losses. The latter is a function of the number of contracts held and weekly price change per futures contract.

(iv) Required Margin Balance Constraint

$$ReqM_t = 2000X_{2t} + 1500(X_{1,t-1} - X_{3t}), \qquad t = j,..,N$$

This constraint posits the relationship between the required, initial, and maintenance margins. For each new contract acquired during the week, the investor must deposit $2000 to the margin account. Furthermore, a minimum of $1500 must be maintained for each existing contract held.

(b) Goal Constraints

(i) Cash/Futures Position Constraint

$$b_t \cdot V \cdot X_{1t} + SLACC_t - SURPC_t = a_t \cdot V \cdot Q, \quad t = j, .., N$$

The above constraint seeks to establish the number of contracts to hold at the end of the week. The right hand side of the relationship gives the total expected change in the value of the cash position during the week while the left hand side gives the change in value per futures contract. The goal is to offset the total change in value of the cash position during that week. The slack and surplus variables capture the under and over achievement of this goal. For example, the slack variable represents the excess of futures gain over cash loss or excess of cash gain over futures loss. The surplus variable represents the net loss between these two variables.

(ii) Transaction Cost Constraint

$$60 \sum_{t=j}^{N} X_{2t} + SLACTR - SURPTR = 0, \quad t = j, .., N$$

This defines the total transaction cost for the week which is $60 for each new contract acquired during that time frame. This cost is captured by the surplus variable SURPTR.

(iii) Margin Opportunity Cost Constraint

$$P_t \bullet (7/360) \bullet EMarg_t + SLACO_t - SURPO_t = 0, \quad t = j,..,N$$

Opportunity cost exists in terms of income foregone on the margin funds deposited with the broker. This is estimated using that week's prevailing prime rate.

(iv) Regulation of Margin Deposit Constraints

$$BMarg_t + SLACM_t - SURPM_t = ReqM_t, \quad t = j,..,N$$

The required margin balance at the end of the week must equal that of the beginning margin prior to any withdrawals/deposits plus actual withdrawals or deposits made during that week. This requirement is described in the relationship above whereby the slack variable represents deposits to the account and the surplus variable withdrawals from the account. Since the required margin balance at the end of the week is essentially the ending margin balance for that week, we have

$$BMarg_t + SLACM_t - SURPM_t = EMarg_t, \quad t = j,..,N$$

(v) Absolute Constraints

$X_{1,j-1}$ and $EMarg_{j-1}$ are known

Two additional constraints are required for week 2 to week N. These are absolute values obtained from previous week's hedging decision and its corresponding ending margin balance.

2.3.3 Allocation of Priorities

In all respects, it is not unrealistic to assume that most investors want to minimize losses but welcome profits. The original objective function [19] which assumed a risk averse investor gave equal weights to all the goals. Assuming that the investor is indifferent to an increase in value, the rationale is to prioritize the goals. As such, minimizing excess of futures (cash) loss over cash (futures) gain is the major concern. The scheme used here is adapted from Sharda and Wingender [20]. Priorities are assigned in the following order; min $SURPC_t$, min $SURPTR_t$, min $SURPO_t$, min $SLACM_t$.

The resulting objective function with priorities becomes

$$\text{Minimize } Z = P_1 \sum_{t=j}^{N} SURPC_t + P_2 SURPTR + P_3 \sum_{t=j}^{N} SURPO_t + P_4 \sum_{t=j}^{N} SLACM_t$$

2.4 Implementation of the Model

Model implementation was facilitated using XA, a linear programming (LP) package developed by Sunset Software, 1987 [24]. XA reads LP formulations from Lotus 1-2-3 spreadsheet, solves the problem and stores the results back into designated areas in the same spreadsheet.

The GP model is defined by two sections; a data section and a constraints section. The data section occupies the top part of the spreadsheet from cell A1 to AQ36 for the March 86 quarter. The actual width of this section depends on the number of security-types in the portfolio holding. Therefore it varies with each quarter. Calculation of conversion factors for the different types of securities given their coupon rates, months and years to maturity is formulated at the top of this section. Below this resides the database which begins with the historical data for the futures price, prime rate, and adjusted spot price. These are followed by forecasts of the respective entities, which are developed using the corresponding historical data. The coefficients of the model, generated from the forecasts, are placed next. The rightmost side of the data section houses the spot prices. These are the actual prices in basis points before adjustment by the appropriate CBT conversion factors.

The constraints section for the week #1 model consumes the space defined by cell A38 to FQ161. The size of this space decreases for each consecutive week. Cell B38 to FP38 defines the solution space where XA stores back the results. B39 to FO39 defines the variables, B40 to FO40 the objective function, and A46 to FQ161 the constraints.

Spreadsheet #14 is an exact replica of the model for week #1 except actual data are used in place of the forecasts. Solution to this model yields the perfect foresight recommendations. A special section has also been included in this spreadsheet to evaluate the performance of the model as well as that of the naive. This can be found next to the data section and it begins with the number of contracts held during each week, rounded up to whole numbers.

Calculations of the various costs and cash flows at the end of each quarter are facilitated using spreadsheet #15. This spreadsheet comprises of two sections; a data section as defined in the home area of the spreadsheet and a computation section which occupies the area defined by cell FS1 to GI68 (varies with size of portfolio). The decisions recommended each week are entered into the cells designated (FV14 to FV27) while the computations of transaction costs, margin opportunity costs, margin deposit required, margin withdrawals available, futures value change, and cash value change can be found in the area defined by cell FS54 to FY67. A copy of these spreadsheets is enclosed in appendix 3.

2.5 Application of the Model

Application of the model in a sequential decision making process involves three steps. First, forecasts must be generated for the cash prices, futures prices and prime rates. The investor may choose a number of forecasting methods in this process. If decisions are to be implemented in period j, forecasts have to be generated for period j through N. For the cash prices, forecasts are obtained individually before the aggregation. The model is then solved. Solution of the model gives recommended strategies for period j through N but only that of period j will be implemented. In the following week, new prices and prime rate are available for the previous week. These data are entered to update the historical database. As such, new forecasts for weeks (j+1) through N are generated based on the latest cash and futures price information and interest rate developments. A new model is set up for weeks (j+1) through N from which decisions for week (j+1) will be implemented. This process is repeated each week. This permits the investor to change the hedging position weekly in response to latest price movements.

2.6 Testing of the Model

A comprehensive assessment of the model requires a comparison of the model's results to other hedging strategies as well as the best case scenario and a no hedge scenario. For comparison purposes, the naive hedge, the minimum variance hedge, the PS hedge, the HD hedge, the original GP, and the dual strategy (original plus naive) were utilized as comparison tools.

The naive hedge, which is easily implemented, makes it a standard for comparison. Its ease of application has widened its use by investors therefore it serves well as a comparison tool. Ederington's [3] risk-minimizing hedge ratio, the PS ratio, and Howard and D'Antonio's [10] risk-return ratio were computed for all quarters. These ratios were maintained throughout the hedging period and their results observed.

The original GP model [19] with its full planning horizon formulations was modified to accommodate for portfolio hedging and solved in a batch mode. This was possible because updating of previous week's hedging information was not required. In reality, this would not be done since the model will be solved weekly only after new information on the futures price, spot price, and prime rate have been included in the model.

The dual GP-naive model uses the following rules; if the original GP model recommends a nonzero hedge, that decision will be implemented. If it results in a no hedge decision, the naive hedge will be pursued instead. Essentially, this strategy leads to an "always hedge" position. Integration of these two approaches was suggested by Sharda and Wingender [20]. The authors' runs on the GP condensed priority model resulted in a number of "no hedge" quarters even during an increasing interest rates trend. In these quarters, the simple naive hedge performed remarkably well in comparison.

A fourteenth run is necessary to evaluate the potential benefits of the goal programming approach in the absence of forecasting inaccuracies. Actual observed price data was used. The perfect foresight model serves as the "best case scenario" and provides a ceiling on the model's potential performance.

As described in section 2.2, this model simulates the scenario of a bank which is holding a portfolio of treasury notes for a 13-week duration in 7 different quarters. A 13-week moving average was selected for forecasting futures prices and prime rate. In selecting an appropriate forecasting method, effort was directed toward choosing a technique that has performed well in the past and which is also frequently used. Moving average and exponential smoothing approaches represent more common approaches to price forecasting. Since both [19] and [20] reported higher performance with the moving average method its use has been continued here. This paper does not attempt to study the effectiveness of various forecasting techniques. As such, only one forecasting method has been tested in conjunction with the model.

3.ANALYSIS OF RESULTS

3.1 Measurement of Performance

At the end of each quarter, actual observed data were used to calculate the performance of the model upon implementation of the weekly recommended decisions. Each week's recommendations were recorded while progressing through the 13-week period. Besides reporting the net value changes for each quarter, transaction costs, margin opportunity cost, margin deposits required, and margin withdrawals available were key variables observed.

Various criteria may be used in judging hedging performance. Oftentimes, performance evaluation is individual specific and depends on the goals and objectives of the investor. Among many others, some of the major criteria are:

(1) highest average returns,

(2) fewest negative quarters,

(3) lowest overall cost, and

(4) highest return on a risk-adjusted basis.

Standard deviation serves to measure the overall riskiness of the strategy over the entire 7 quarters whereas the coefficient of variation provides similar assessment but on a risk-adjusted basis.

3.2 Comparison of Results

3.2.1 Comparison of Average Net Returns

A comparison of net value changes and their averages for all quarters using the various hedging strategies are reported in Table 2. With the exception of the perfect foresight model, all the strategies reported negative values. The dual strategy had the worst performance, resulting in an average net loss of $96,655. The GP condensed model had an average $6,757 net loss but was superior to the other strategies in the presence of forecast inaccuracies. Not hedging over the 7 quarters would have resulted in an average net loss of $48,857 per quarter. Clearly, the GP condensed model outperformed all the other strategies. When provided with perfect forecasts, the GP model would have yielded $160,137 in average net gain, which was certainly a considerable improvement over using forecast data.

Judging from the results, it is observed that the hedge ratio strategies, original GP and the condensed GP models were closely related in performance. The original model was marginally better than the naive while the condensed GP was about 10% better than the former. However, close observation of each quarter revealed that the original GP model actually performed a lot better than the GP condensed model in 5 of the 7 quarters. The remarkable performance of the original model was offset by a terrible performance in the September 87 quarter (see Table 2). Naive reported the best result among all the hedge ratio models, reporting an average net loss of $11,181 whereas the PS model

Table 2

Hedging With T-Note Futures
A Comparison of net value changes between cash
& futures position using various strategies

Quarter	Spot (No Hedge)	Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	13 Wk MA Prioritie	Perfect Forecast
Mar 86	-47000	75100	68500	-800	-1900	2500	199200	-203090	138080	317900
June 86	8563	-7716	-6618	-1998	863	-3098	459693	332413	91353	299823
Sept 86	67969	-185951	-171231	-79231	-49791	-93951	-45591	-103551	-7871	104369
Dec 86	-63844	-59944	-60244	-62884	-62104	-62704	-54124	-104823	-69664	-49984
Mar 87	-201531	107659	82419	50869	-56401	76109	-81001	-136681	-201531	68339
June 87	-159281	80159	62639	10079	-36641	27599	-48491	-11591	-86471	279179
Sept 87	53125	-87575	-78195	-31295	39055	-50055	-518565	-449265	88805	101335
Net Tot	-341999	-78268	-102730	-115260	-166919	-103600	-88879	-676588	-47299	1120961
Mean	-48857	-11181	-14676	-16466	-23846	-14800	-12697	-96655	-6757	160137
High	67969	107659	82419	50869	39055	76109	459693	332413	138080	317900
Low	-201531	-185951	-171231	-79231	-62104	-93951	-518565	-449265	-201531	-49984
Std Dev	94926	99053	87021	41417	34660	53853	275862	216701	112113	129680
C.V.	-1.94	-8.86	-5.93	-2.52	-1.45	-3.64	-21.73	-2.24	-16.59	0.81
+ve Qtr	3	3	3	2	2	3	2	1	3	6
-ve Qtr	4	4	4	5	5	4	5	6	4	1
	Percent Improvement from No Hedge									
Mar 86	0.00%	259.8%	245.7%	98.3%	96.0%	105.3%	523.8%	-332.1%	393.8%	776.4%
June 86	0.00%	-190.1%	-177.3%	-123.3%	-89.9%	-136.2%	5268.4%	3782.0%	966.8%	3401.4%
Sept 86	0.00%	-373.6%	-351.9%	-216.6%	-173.3%	-238.2%	-167.1%	-252.4%	-111.6%	53.6%
Dec 86	0.00%	6.1%	5.6%	1.5%	2.7%	1.8%	15.2%	-64.2%	-9.1%	21.7%
Mar 87	0.00%	153.4%	140.9%	125.2%	72.0%	137.8%	59.8%	32.2%	0.0%	133.9%
June 87	0.00%	150.3%	139.3%	106.3%	77.0%	117.3%	69.6%	92.7%	45.7%	275.3%
Sept 87	0.00%	-264.8%	-247.2%	-158.9%	-26.5%	-194.2%	-1076.1%	-945.7%	67.2%	90.7%
Net Tot	0.00%	77.1%	70.0%	66.3%	51.2%	69.7%	74.0%	-97.8%	86.2%	427.8%
Mean	0.00%	77.1%	70.0%	66.3%	51.2%	69.7%	74.0%	-97.8%	86.2%	427.8%
High	0.00%	58.4%	21.3%	-25.2%	-42.5%	12.0%	576.3%	389.1%	103.2%	367.7%
Low	0.00%	7.7%	15.0%	60.7%	69.2%	53.4%	-157.3%	-122.9%	0.0%	75.2%
Std Dev	0.00%	4.3%	-8.3%	-56.4%	-63.5%	-43.3%	190.6%	128.3%	18.1%	36.6%
+ve Qtr		4	4	4	4	4	5	3	5	7
-ve Qtr		3	3	3	3	3	2	4	2	0

which had the worst performance reported a loss of $23,846. Overall, the GP models did better than the hedge ratios. The dual strategy model was the only strategy that did worse than not hedging. Following this strategy would have resulted in a 98% more loss over not hedging whereas the GP condensed model would have reported a hefty 86% improvement. The poor performance of the dual strategy approach can be explained. Firstly, as described in section 2.1, this sample, notably the December 86 and March 87 quarters, were especially demanding quarters to forecast. From Figure 1, we can see that prices for March 87 tended to even out in the first 13 weeks but saw a sharp decline from week 14 onwards. A simple 13-week moving average employing the first 13 weeks of historical data would have given a biased upward or flat price trend instead of portraying the sharp plunge in prices. This bias affected performance of all strategies that relied on forecasts data.

Secondly, the dual GP-naive approach always recommends hedging even when the perfect foresight model recommends no or moderate hedges. Table 3 shows the number of contracts recommended by all strategies for the March 86 quarter. The additional naive hedge in the "no hedge" weeks was largely responsible for the resulting net loss for that quarter. Spot prices were increasing in the latter part of the quarter, meaning the portfolio was increasing in value, which merits not hedging at all.

Statistics on percent improvement over not engaging in hedging activities for all quarters show marked improvements in several quarters (see Table 2). The perfect foresight improved in all quarters.

Table 3: No. Contracts Held for March 1986 Quarter

Week	Hedge Ratio Approaches: Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Goal Programming Models: Original	Original & Naive	Condensed	Perfect Foresight
1	111	105	42	41	45	35	35	35	0
2	111	105	42	41	45	45	45	88	0
3	111	105	42	41	45	49	49	64	0
4	111	105	42	41	45	53	53	53	55
5	111	105	42	41	45	55	55	55	0
6	111	105	42	41	45	72	72	72	0
7	111	105	42	41	45	55	55	55	56
8	111	105	42	41	45	0	111	0	25
9	111	105	42	41	45	0	111	0	25
10	111	105	42	41	45	0	111	0	0
11	111	105	42	41	45	2	111	0	0
12	111	105	42	41	45	0	111	0	0
13	111	105	42	41	45	0	111	0	0
Trans.Cost	6660	6300	2520	2460	2460	4440	7680	6420	6660
Opp.Cost	3723	3522	1409	1375	1509	990	2681	1166	491
Deposit	942390	891450	356580	348090	382050	207140	918340	289100	0
Withdrawal	897990	849450	339780	331690	364050	453340	595750	474180	364900
Fut.Chg.	122100	115500	46200	45100	49500	246200	-156090	185080	364900
Cash Chg.	-47000	-47000	-47000	-47000	-47000	-47000	-47000	-47000	-47000
Gain/Loss	75100	68500	-800	-1900	2500	199200	-203090	138080	317900

The GP condensed model did better in 4 quarters, worse in 2 and stayed even in one. All the hedge ratio strategies performed better in 4 quarters but suffered in 3. The dual GP-naive model was alone in reporting more negative improvements than positive. Overall, the magnitude change was much higher in the GP models than in the hedge ratio models which also explains their higher total net returns.

3.2.2 Positive/Negative Quarters Comparison

In terms of minimizing the number of negative quarters, again, the perfect foresight model outperformed others with only 1 negative quarter (see Table 2). As noted previously, the nature of the data (see Figure 1) contributed to a negative bottom line in the December 86 quarter for all the strategies. Price trends remain fairly flat throughout the quarter. A few sharp drops in prices explain why no hedging led to a negative quarter but too much hedging as in the GP-naive case also brought about negative results. There were only moderate gains from the futures market for the December 86 quarter; $3,900 for the naive (best scenario), $3,600 for the conversion factor approach, $960 for the minimum variance hedge, $1,740 for the PS model and $1,140 for the HD model (see Appendix 2c). The GP-naive and GP condensed models suffered losses from the futures market. Nevertheless, the perfect foresight model still managed to improve the portfolio's value by 22%. A conservative manager who is concerned with the portfolio's value on a quarter per quarter basis would want a strategy that results in positive quarters all the times. Most of the hedge ratio and GP condensed strategies reported 3 positive quarters. Under such circumstances, the investor would benefit most by looking at the net average return as well. The dual strategy performed the worst, reporting only 1 positive quarter.

3.2.4 Comparison of Overall Hedging Costs

Transaction costs as reported in Table 4 were higher for all the GP models, especially for the GP-naive hedge. The minimum variance hedge had the lowest average transactions cost ($2,020) while GP-naive topped the list with $10,003. However, the GP models entailed lower margin opportunity costs. When compared to the hedge ratio models, the GP condensed model reported a neglible $691 on average whereas the naive approach reported $1,972. Although the margin opportunity cost was not a substantial sum to be concerned about, it did affect the bottom line results. The GP condensed model which also had the best return reported the lowest margin deposit requirements. These figures (see Table 4) were fairly substantial amounts and would impact on the investor's capital outlay. Lower deposit requirements leave the firm with more capital to invest elsewhere rather than having them tied up with the broker. Margin withdrawals (Table 4) were fairly substantial too, ranging from an average of $196,424 for the GP condensed model to a high of $399,969 for the GP-naive model. The naive model did fairly well, with close to $0.4 million in available withdrawals. On a dollar cost adjusted basis, the GP condensed model still outperformed the

Table 4

Hedging With T-Note Futures
A Comparison of Average Cost and Cash Flows
(Standard Deviation)

Quarter	Naive	Con. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	13 Wk MA Priorities	Perfect Forecast
Trans. Costs	$3,856	$3,600	$2,020	$1,619	$2,247	$7,383	$10,003	$4,143	$6,297
	(1501)	(1428)	(660)	(703)	(675)	(6420)	(5185)	(2352)	(3761)
Margin Opp.Costs	$1,972	$1,842	$1,047	$819	$1,164	$881	$1,586	$691	$813
	(813)	(777)	(357)	(364)	(366)	(570)	(613)	(500)	(505)
Margin Dep.Req.	$441,394	$413,327	$230,243	$171,400	$265,000	$299,890	$526,481	$159,467	$25,953
	(262401)	(249168)	(129990)	(112351)	(131958)	(365119)	(366402)	(107579)	(23763)
Margin With.Avail.	$384,999	$359,651	$219,849	$156,983	$243,557	$330,907	$399,969	$196,424	$220,233
	(247657)	(234201)	(124662)	(103962)	(134081)	(244051)	(21232)	(156876)	(160761)
Futures Val.Chg.	$37,676	$34,181	$32,391	$25,011	$34,057	$36,160	($47,799)	$42,100	$208,994
	(186108)	(17309)	(128778)	(82709)	(143099)	(297994)	(245753)	(76590)	(160869)

naive hedge and no hedge. In analyzing the percent change in portfolio (see Table 5), the GP condensed model reported an average -0.0265% change while the naive saw -0.0389% and a no hedge would have resulted in an average of -0.1117% change. Whilst the GP condensed model was almost 2 times better than naive before the cost adjustment, it has now dropped to only about 1.5 times (see Table 6).

3.2.5 <u>Comparison of Outcomes on a Risk-Adjusted Basis</u>

The "risk" factor represents a third dimension to measuring performance. Based on standard deviations, the study found that the GP models carried more risks than either no hedge or the ratio related strategies (see Table 2). The GP condensed model reported deviation of $109,511 while not hedging saw only a $94,926 deviation. Except for the original, the GP-naive, the minimum variance, and HD models, the standard deviations for the other strategies were essentially compatible to each other. The minimum variance approach was least risky. It reported only a $41,017 standard deviation. All these reflect the greater sensitivities of the GP models in response to price changes. These subsequently led to frequent changes in the number of futures contracts held each week. As such, the difference was also larger between the high and low values in the GP models.

On a quarter per quarter basis, the ratio-related models appear to do better since there were no substantial losses. The largest loss came from the dual GP-naive hedge which reported a huge $449,225 loss while the minimum variance hedge only had a $79,231 largest loss. The GP

Table 5

Hedging With T-Note Futures
A Comparison of Percent Return on Portfolio
(adjusted for transactions costs and margin opportunity costs)

Quarter	Spot (No Hedge)	Naive	Con. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	13 Wk MA Priorities	Perfect Forecast
Mar 86	-0.4218%	0.5808%	0.5266%	-0.0424%	-0.0515%	-0.0153%	1.7389%	-1.9155%	1.1710%	2.7886%
June 86	0.1155%	-0.1945%	-0.1735%	-0.0856%	-0.0311%	-0.1065%	5.9397%	4.2188%	1.1274%	3.9137%
Sept 86	0.9824%	-2.7766%	-2.5587%	-1.1967%	-0.7609%	-1.4147%	-0.7196%	-1.6082%	-0.2025%	1.4533%
Dec 86	-0.9843%	-1.0235%	-1.0205%	-0.9939%	-1.0018%	-0.9967%	-0.8712%	-1.7685%	-1.0983%	-0.8472%
Mar 87	-4.2409%	2.1714%	1.6479%	0.9936%	-1.2311%	1.5171%	-1.7840%	-3.0569%	-4.2409%	1.3754%
June 87	-3.9323%	1.8852%	1.4595%	0.1825%	-0.9526%	0.6082%	-1.2901%	-0.4067%	-2.2387%	6.4934%
Sept 87	1.7896%	-3.0455%	-2.7232%	-1.1115%	1.3061%	-1.7562%	-18.1094%	-15.8110%	2.7702%	3.2427%
Net Tot	-0.7820%	-0.2722%	-0.3220%	-0.3126%	-0.4207%	-0.2916%	-0.3355%	-1.7325%	-0.1855%	2.4493%
Mean	-0.1117%	-0.0389%	-0.0460%	-0.0447%	-0.0601%	-0.0417%	-0.0479%	-0.2475%	-0.0265%	0.3499%
High	1.7896%	2.1714%	1.6479%	0.9936%	1.3061%	1.5171%	5.9397%	4.2188%	2.7702%	6.4934%
Low	-4.2409%	-3.0455%	-2.7232%	-1.1967%	-1.2311%	-1.7562%	-18.1094%	-15.8110%	-4.2409%	-0.8472%
+ve Qtr	3	3	3	2	1	2	2	1	3	6
-ve Qtr	4	4	4	5	6	5	5	6	4	1

Table 6

Hedging With T-Note Futures
A Comparison of net value changes adjusted for
transactions costs and margin opportunity costs

Quarter	Spot (No Hedge)	Naive	Con. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	13 Wk MA Priorities	Perfect Forecast
Mar 86	-47000	64717	58678	-4729	-5735	-1709	193770	-213451	130494	310749
June 86	8563	-14420	-12867	-6345	-2307	-7898	440427	312823	83595	290200
Sept 86	67969	-192104	-177027	-82798	-52644	-97874	-49783	-111264	-14007	100551
Dec 86	-63844	-66390	-66194	-64471	-64980	-64588	-56509	-114712	-71238	-54955
Mar 87	-201531	103185	78310	47217	-58501	72092	-84779	-145268	-201531	65360
June 87	-159281	76360	59118	7392	-38587	24634	-52257	-16473	-90681	263020
Sept 87	53125	-90409	-80840	-32995	38772	-52133	-537596	-469366	82235	96264
Net Tot	-341999	-119061	-140822	-136729	-183982	-127476	-146727	-757711	-81133	1071189
Mean	-48857	-17009	-20117	-19533	-26283	-18211	-20961	-108244	-11590	153027
High	67969	103185	78310	47217	38772	72092	440427	312823	130494	310749
Low	-201531	-192104	-177027	-82798	-64980	-97874	-537596	-469366	-201531	-54955
Std Dev	94926	98803	86733	41017	35073	53475	275952	216669	109511	126891
C.V.	-1.94	-5.81	-4.31	-2.10	-1.33	-2.94	-13.17	-2.00	-9.45	0.83
+ve Qtr	3	3	3	2	1	2	2	1	3	6
-ve Qtr	4	4	4	5	6	5	5	6	4	1

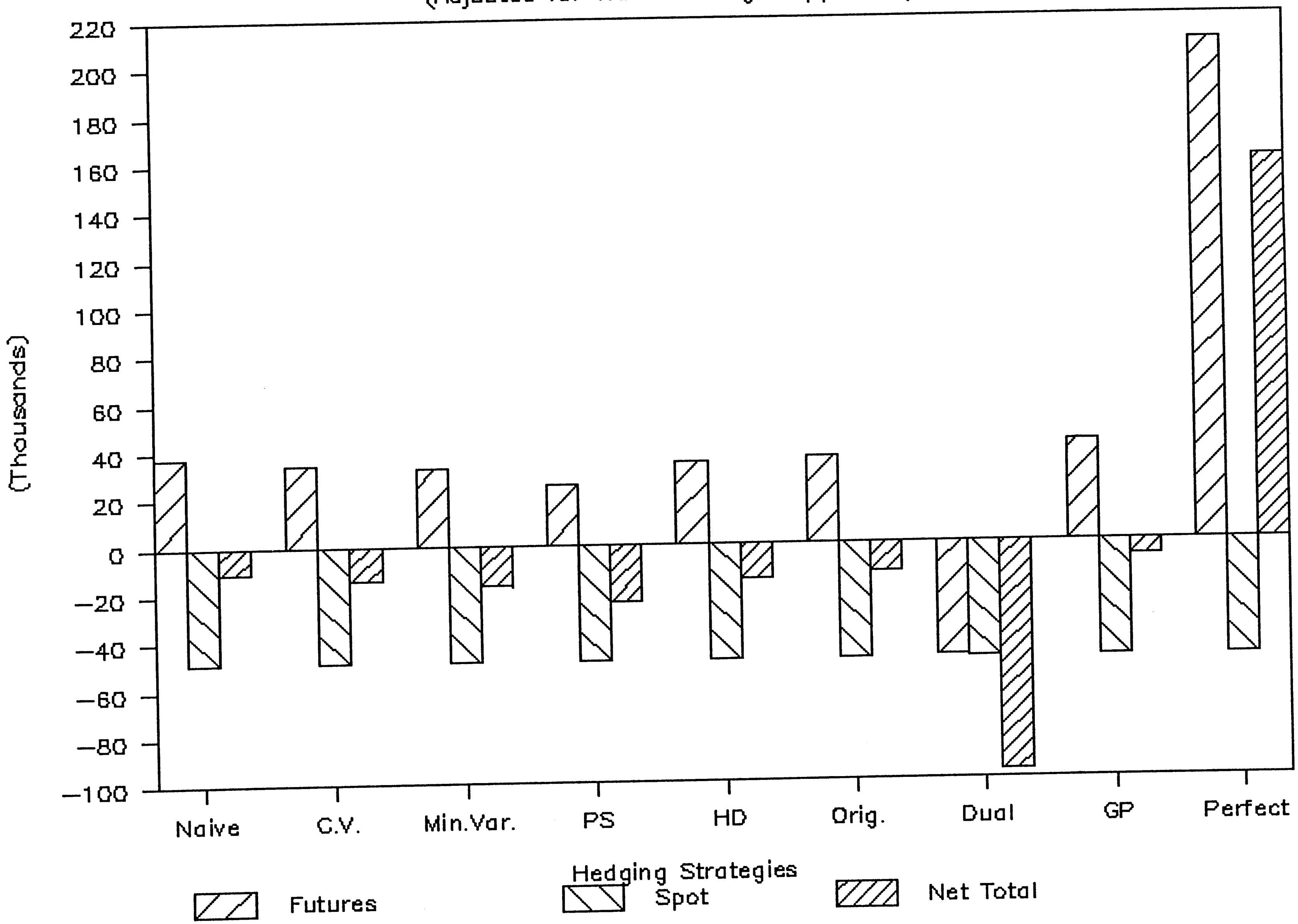
condensed model did not hedge at all in the March 1987 quarter therefore its largest loss was $201,531 which accrued from a decline in the cash value in that quarter. On the other hand, the GP models also had much higher gains than the hedge ratio models even after adjusting for transaction and margin opportunity costs (see Table 6). Average futures market gains for the GP condensed model was $42,100 which was about $5,000 more than naive, the best of the hedge ratio models (see Figure 2).

A conservative manager who has to revalue his portfolio on a quarterly basis may prefer the small gains and small losses from the hedge ratio strategies rather than opting for huge potential gains but possible large losses as well in the GP models.

On a risk-adjusted basis, the GP original model was less risky for the level of average returns than the alternatives. (The lower the coefficient of variation the better the results). Surprisingly, all GP models had better coefficient of variations than the hedge ratios and no hedge (see Table 2). Even the worst performing dual strategy model had a better coefficient than no hedge. However, using coefficient of variation when the mean is negative is somewhat questionable.

Fig.2: Avg Fut, Spot & Net Value Change

(Adjusted for Trans.& Margin Opp.Costs)



3.3 Summary of Results

The findings of this analysis reinforce as well as support the earlier conclusions put forth by Sharda and Musser [19], and Sharda and Windgender [20]. Even in a portfolio hedging environment the GP model has consistently outperformed the hedge ratio and no hedge strategies. Introduction of forecast data plays a major factor in the overall potential effectiveness of the model. Bad forecasts impair performance and undermine potential outcomes.

The GP condensed model produced the most favorable overall results although its performance tends to swing from large gains in some quarters to large losses in others. It also had the highest overall net gain adjusted for transaction and margin opportunity costs. It also did well on a risk-adjusted basis and was comparable to the conservative approaches in the number of positive quarters achieved. Moreover, it also required the least margin deposit thereby freeing up vital capital for other purposes. Out of all the criteria mentioned in section 3.1, the GP condensed model was superior in almost all of them. Nevertheless, it is noted that naive has performed surprisingly well. Its performance rivals that of the GP condensed model and is actually better in terms of producing consistent results. Its simplication of implementation makes it a likely candidate for hedging strategy.

If we look at the quarterly results in retrospect, we can see that the hedge ratio models performed badly in March, June, and September 1986. In these same quarters, the GP condensed model did superbly well. Coincidentally, these are also the only quarters it reported net gains instead of net losses. On the other hand, the opposite results are observed for the March and June 1987 quarters. Two causes remain to be explained.

First, the ratio models did not call for forecasting data throughout the quarter. The ratio established at the beginning of the hedging period held throughout the entire quarter. From Figure 1, the sharp plunge in prices in the latter part of the March 87 quarter was not immediately reflected in the forecasts. The earlier increases in prices had led to moderate hedging recommendations for the GP models whereas in the hedge ratio models, the actions recommended in the beginning was held throughout which helped dramatically when prices started to fall. Conversely, March 86 did not recommend hedging actions for the latter part of the quarter when prices trend upwards. Hence, selling contracts short as recommended by the hedge ratios in those weeks were costly.

4. CONCLUSION

This study is directed toward a test of the Sharda and Musser goal programming hedging model in a portfolio environment using actual data provided by an Oklahoma bank. Although the model was initially developed by Sharda and Musser [19], actual adaptation of the model is based on the shorter, refined version with priorities proposed by Sharda and Wingender [20].

Hedging results over the 7 quarters using the goal programming approach were mostly positive, implying significant benefits for portfolio hedging. Mediocre performance occurred only because forecast data were used. Thirteen-week moving average was used to forecast futures prices, cash market prices, and prime rates. As presented by the perfect foresight model, significant improvement in performance is possible.

Overall, further research in the area is needed. Aggregating the spot data in both the models and in calculating various hedge ratios may introduce bias into the results obtained. Better forecasting methods are clearly needed in order to improve performance substantially. Future research in the area may be extended to incorporate a variety of cash instruments in a truly macro hedging environment.

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6.APPENDIX

Appendix 1 - Beginning and Ending Portfolio Values

Appendix 2 - Number of Contracts Held for Various Hedging Strategies

Appendix 3 - Copy of Spreadsheets #1, 14, & 15 for March 1986

Appendix 1a: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: March 1986

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE (3/31/86)	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO (3/31/86)
10	8%	08/15/86	1004062	1001875	-2187
10	10%	12/31/86	1021562	1017187	-4375
10	9.5%	11/15/95	1116875	1125000	8125
10	10.5%	06/30/87	1040312	1036562	-3750
20	10.5%	11/15/92	2300625	2283750	-16875
4	10.75%	11/15/89	441500	438625	-2875
10	9.125%	02/15/91	1068750	1063125	-5625
10	9.125%	05/31/87	1022500	1021562	-938
10	10.875%	02/15/93	1171875	1164062	-7813
4	12.375%	01/15/88	434750	431250	-3500
5	13.875%	11/15/86	520625	513438	-7187
	No Hedge		$11,143,436	$11,096,436	($47,000)
	Naive			$11,208,153	$64,717
	Conversion Factor			$11,202,114	$58,678
	Minimum Variance			$11,138,707	($4,729)
	PS Model			$11,137,701	($5,735)
	HD Model			$11,141,727	($1,709)
	Original GP			$11,337,206	$193,770
	GP-Naive			$10,929,985	($213,451)
	Condensed GP			$11,273,930	$130,494
	Perfect Forecasts			$11,454,185	$310,749

Appendix 1b: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: June 1986

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO
5	10%	12/31/86	508594	505469	-3125
10	9.5%	11/15/95	1125000	1123750	-1250
5	10.5%	06/30/87	518281	516875	-1406
10	10.5%	11/15/92	1141875	1149062	7187
4	10.75%	11/15/89	438625	442625	4000
10	9.125%	02/15/91	1063125	1071250	8125
5	9.125%	05/31/87	510781	510625	-156
10	10.875%	02/15/93	1164062	1167812	3750
4	12.375%	01/15/88	431250	431125	-125
5	13.875%	11/15/86	513438	505000	-8438
	No Hedge		$7,415,031	$7,423,593	$8,562
	Naive			$7,400,611	($14,420)
	Conversion Factor			$7,402,164	($12,867)
	Minimum Variance			$7,408,686	($6,345)
	PS Model			$7,412,724	($2,307)
	HD Model			$7,407,133	($7,898)
	Original GP			$7,855,458	$440,427
	GP-Naive			$7,727,854	$312,823
	Condensed GP			$7,498,626	$83,595
	Perfect Forecasts			$7,705,231	$290,200

Appendix 1c: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: September 1986

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO
5	10%	12/31/86	505469	500156	-5313
10	9.5%	11/15/95	1123750	1152812	29062
5	10.5%	06/30/87	516875	511250	-5625
10	10.5%	11/15/92	1149062	1170625	21563
4	10.75%	11/15/89	442625	443375	750
10	9.125%	02/15/91	1071250	1085000	13750
5	9.125%	05/31/87	510625	506406	-4219
10	10.875%	02/15/93	1167812	1191562	23750
2	12.375%	01/15/88	431125	425375	-5750
	No Hedge		$6,918,593	$6,986,561	$67,968
	Naive			$6,726,489	($192,104)
	Conversion Factor			$6,741,566	($177,027)
	Minimum Variance			$6,835,795	($82,798)
	PS Model			$6,865,949	($52,644)
	HD Model			$6,820,719	($97,874)
	Original GP			$6,868,810	($49,783)
	GP-Naive			$6,807,329	($111,264)
	Condensed GP			$6,904,586	($14,007)
	Perfect Forecasts			$7,019,144	$100,551

Appendix 1d: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: December 1986

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO
10	9.5%	11/15/95	1152812	1144687	-8125
5	10.5%	06/30/87	511250	505469	-5781
10	10.5%	11/15/92	1170625	1158125	-12500
4	10.75%	11/15/89	443375	439000	-4375
10	9.125%	02/15/91	1085000	1075937	-9063
5	9.125%	05/31/87	506406	502344	-4062
10	10.875%	02/15/93	1191562	1178125	-13437
4	12.375%	01/15/88	425375	418875	-6500
	No Hedge		$6,486,405	$6,422,562	($63,843)
	Naive			$6,420,015	($66,390)
	Conversion Factor			$6,420,211	($66,194)
	Minimum Variance			$6,421,934	($64,471)
	PS Model			$6,421,425	($64,980)
	HD Model			$6,421,817	($64,588)
	Original GP			$6,429,896	($56,509)
	GP-Naive			$6,371,693	($114,712)
	Condensed GP			$6,415,167	($71,238)
	Perfect Forecasts			$6,431,450	($54,955)

Appendix 1e: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: March 1987

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO
10	9.5%	11/15/95	1144687	1065312	-79375
5	10.5%	06/30/87	505468	500000	-5468
5	10.5%	11/15/92	579063	550313	-28750
4	10.75%	11/15/89	439000	426750	-12250
10	9.125%	02/15/91	1075937	1035937	-40000
5	9.125%	05/31/87	589063	560000	-29063
4	10.875%	02/15/93	418875	412250	-6625
	No Hedge		$4,752,093	$4,550,562	($201,531)
	Naive			$4,550,562	$103,185
	Conversion Factor			$4,855,278	$78,310
	Minimum Variance			$4,830,403	$47,217
	PS Model			$4,799,310	($58,501)
	HD Model			$4,693,592	$72,092
	Original GP			$4,824,185	($84,779)
	GP-Naive			$4,667,314	($145,268)
	Condensed GP			$4,606,825	($201,531)
	Perfect Forecasts			$4,550,562	$65,360

Appendix 1f: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: June 1987

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO
10	9.5%	11/15/95	1065312	999375	-65937
5	10.5%	11/15/92	550313	528438	-21875
4	10.75%	11/15/89	426750	416375	-10375
10	9.125%	02/15/91	1035937	1005937	-30000
5	10.875%	02/15/93	560000	535156	-24844
4	12.375%	01/15/88	412250	406000	-6250
	No Hedge		$4,050,562	$3,891,281	($159,281)
	Naive			$4,126,922	$76,360
	Conversion Factor			$4,109,680	$59,118
	Minimum Variance			$4,057,954	$7,392
	PS Model			$4,011,975	($38,587)
	HD Model			$4,075,196	$24,634
	Original GP			$3,998,305	($52,257)
	GP-Naive			$4,034,089	($16,473)
	Condensed GP			$3,959,881	($90,681)
	Perfect Forecasts			$4,313,582	$263,020

Appendix 1g: Hedging With T-Note Futures
Ending Portfolio Value
Quarter: September 1987

WEIGHT	COUPON	MATURITY	BEGINNING MARKET VALUE	ENDING MARKET VALUE	NET CHANGE IN PORTFOLIO
3	9.5%	11/15/95	299813	311625	11812
5	10.5%	11/15/92	528438	540000	11562
4	10.75%	11/15/89	416375	419500	3125
5	9.125%	02/15/91	502969	512344	9375
5	10.875%	02/15/93	535156	547656	12500
4	12.375%	01/15/88	406000	400625	-5375
3	8%	07/15/94	279844	289969	10125
	No Hedge		$2,968,595	$3,021,719	$53,124
	Naive			$2,878,186	($90,409)
	Conversion Factor			$2,887,755	($80,840)
	Minimum Variance			$2,935,600	($32,995)
	PS Model			$3,007,367	$38,772
	HD Model			$2,916,462	($52,133)
	Original GP			$2,430,999	($537,596)
	GP-Naive			$2,499,229	($469,366)
	Condensed GP			$3,050,830	$82,235
	Perfect Forecasts			$3,064,859	$96,264

Appendix 2a: No. Contracts Held for June 1986 Quarter

Week	Hedge Ratio Approaches: Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Goal Programming Models: Original	Original & Naive	Condensed	Perfect Foresight
1	74	69	48	35	53	30	30	30	0
2	74	69	48	35	53	37	37	63	45
3	74	69	48	35	53	58	58	67	38
4	74	69	48	35	53	79	79	94	74
5	74	69	48	35	53	80	80	94	65
6	74	69	48	35	53	65	65	87	49
7	74	69	48	35	53	34	34	37	28
8	74	69	48	35	53	34	34	34	28
9	74	69	48	35	53	46	46	46	15
10	74	69	48	35	53	46	46	46	74
11	74	69	48	35	53	243	243	47	74
12	74	69	48	35	53	0	74	0	0
13	74	69	48	35	53	0	74	0	0
Trans.Cost	4440	4140	2880	2100	3180	17340	17340	6240	8400
Opp.Cost	2263	2110	1468	1070	1621	1926	2250	1518	1223
Deposit	610500	569250	396000	288750	437250	282140	400540	275670	66080
Withdrawal	483220	450570	313440	228550	346090	733270	613390	358460	357340
Fut.Chg.	-16280	-15180	-10560	-7700	-11660	451130	323850	82790	291260
Cash Chg.	8563	8563	8563	8563	8563	8563	8563	8563	8563
Gain/Loss	-7717	-6617	-1997	863	-3097	459693	332413	91353	299823

Appendix 2b: No. Contracts Held for September 1986 Quarter

	Hedge Ratio Approaches					Goal Programming Models			
Week	Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	Condensed	Perfect Foresight
1	69	65	40	32	44	0	69	0	0
2	69	65	40	32	44	21	21	21	17
3	69	65	40	32	44	17	17	34	45
4	69	65	40	32	44	40	40	0	28
5	69	65	40	32	44	30	30	31	16
6	69	65	40	32	44	37	37	45	29
7	69	65	40	32	44	38	38	51	0
8	69	65	40	32	44	46	46	58	0
9	69	65	40	32	44	42	42	53	0
10	69	65	40	32	44	26	26	26	0
11	69	65	40	32	44	27	27	27	0
12	69	65	40	32	44	19	19	19	0
13	69	65	40	32	44	13	13	13	0
Trans.Cost	4140	3900	2400	1920	2640	3420	6600	5280	3480
Opp.Cost	2013	1896	1167	993	1283	772	1113	856	338
Deposit	538200	507000	312000	249600	343200	188650	392750	230550	32300
Withdrawal	180780	170300	104800	83840	115280	55590	201730	135210	68700
Fut.Chg.	-253920	-239200	-147200	-117760	-161920	-113560	-171520	-75840	36400
Cash Chg.	67969	67969	67969	67969	67969	67969	67969	67969	67969
Gain/Loss	-185951	-171231	-79231	-49791	-93951	-45591	-103551	-7871	104369

Appendix 2c: No. Contracts Held for December 1986 Quarter

	Hedge Ratio Approaches					Goal Programming Models			
Week	Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	Condensed	Perfect Foresight
1	65	60	16	29	20	13	13	13	29
2	65	60	16	29	20	0	65	20	25
3	65	60	16	29	20	22	22	20	25
4	65	60	16	29	20	12	12	12	29
5	65	60	16	29	20	0	65	0	36
6	65	60	16	29	20	0	65	0	32
7	65	60	16	29	20	73	73	0	33
8	65	60	16	29	20	0	65	0	36
9	65	60	16	29	20	0	65	0	28
10	65	60	16	29	20	0	65	0	30
11	65	60	16	29	20	0	65	0	27
12	65	60	16	29	20	0	65	0	28
13	65	60	16	29	20	0	65	0	39
Trans.Cost	4550	4200	1120	2030	1330	2240	8400	1400	4060
Opp.Cost	1896	1750	467	846	554	145	1488	174	911
Deposit	195000	180000	48000	87000	57000	61320	342050	45850	53270
Withdrawal	101400	93600	24960	45240	29640	71040	203570	40030	3130
Fut.Chg.	3900	3600	960	1740	1140	9720	-40980	-5820	13860
Cash Chg.	-63844	-63844	-63844	-63844	-63844	-63844	-63844	-63844	-63844
Gain/Loss	-59944	-60244	-62884	-62104	-62704	-54124	-104824	-69664	-49984

Appendix 2d: No. Contracts Held for March 1987 Quarter

Week	Hedge Ratio Approaches: Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Goal Programming Models: Original	Original & Naive	Condensed	Perfect Foresight
1	48	45	40	23	43	0	48	0	29
2	48	45	40	23	43	19	19	0	29
3	48	45	40	23	43	29	29	0	31
4	48	45	40	23	43	29	29	0	24
5	48	45	40	23	43	28	28	0	11
6	48	45	40	23	43	0	48	0	11
7	48	45	40	23	43	3	3	0	21
8	48	45	40	23	43	28	28	0	0
9	48	45	40	23	43	0	48	0	0
10	48	45	40	23	43	0	48	0	0
11	48	45	40	23	43	0	48	0	0
12	48	45	40	23	43	0	48	0	0
13	48	45	40	23	43	0	48	0	0
Trans.Cost	2940	2700	2400	1380	2640	3420	7380	0	2580
Opp.Cost	1534	1409	1252	720	1377	358	1207	0	399
Deposit	240590	220952	196400	112930	216040	81160	327280	0	9300
Withdrawal	476280	437400	388800	223560	427680	201690	320130	0	279170
Fut.Chg.	309190	283950	252400	145130	277640	120530	64850	0	269870
Cash Chg.	-201531	-201531	-201531	-201531	-201531	-201531	-201531	-201531	-201531
Gain/Loss	107659	82419	50869	-56401	76109	-81001	-136681	-201531	68339

Appendix 2e: No. Contracts Held for June 1987 Quarter

Week	Hedge Ratio Approaches					Goal Programming Models			
	Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	Condensed	Perfect Foresight
1	41	38	29	21	32	16	16	16	0
2	41	38	29	21	32	13	13	32	8
3	41	38	29	21	32	16	16	37	11
4	41	38	29	21	32	18	18	26	45
5	41	38	29	21	32	20	20	20	61
6	41	38	29	21	32	0	41	0	44
7	41	38	29	21	32	19	19	0	17
8	41	38	29	21	32	17	17	15	24
9	41	38	29	21	32	24	24	0	26
10	41	38	29	21	32	25	25	11	158
11	41	38	29	21	32	25	25	0	195
12	41	38	29	21	32	28	28	0	33
13	41	38	29	21	32	0	41	0	26
Trans.Cost	2460	2280	1740	1260	1920	3180	4080	3780	14340
Opp.Cost	1339	1241	947	686	1045	586	802	430	1819
Deposit	138580	128440	48020	70980	108160	102480	83370	81190	18070
Withdrawal	316520	293360	223880	162120	247040	213270	163060	154000	417530
Fut.Chg.	239440	221920	169360	122640	186880	110790	147690	72810	438460
Cash Chg.	-159281	-159281	-159281	-159281	-159281	-159281	-159281	-159281	-159281
Gain/Loss	80159	62639	10079	-36641	27599	-48491	-11591	-86471	279179

Appendix 2f: No. Contracts Held for September 1987 Quarter

	Hedge Ratio Approaches					Goal Programming Models			
Week	Naive	Conv. Factor	Min. Variance	PS Model	HD Model	Original	Original & Naive	Condensed	Perfect Foresight
1	30	28	18	3	22	0	30	0	1
2	30	28	18	3	22	0	30	0	19
3	30	28	18	3	22	15	15	0	65
4	30	28	18	3	22	18	18	0	15
5	30	28	18	3	22	15	15	14	11
6	30	28	18	3	22	18	18	21	6
7	30	28	18	3	22	92	92	96	9
8	30	28	18	3	22	18	18	26	7
9	30	28	18	3	22	23	23	28	14
10	30	28	18	3	22	15	15	15	10
11	30	28	18	3	22	13	13	13	11
12	30	28	18	3	22	207	207	13	0
13	30	28	18	3	22	11	11	11	0
Trans.Cost	1800	1680	1080	180	1320	17640	18540	5880	4560
Opp.Cost	1034	965	620	103	758	1391	1561	690	511
Deposit	424500	396200	254700	42450	311300	1176340	1221040	193910	2650
Withdrawal	238800	222880	143280	23880	175120	588150	702150	213090	50860
Fut.Chg.	-140700	-131320	-84420	-14070	-103180	-571690	-502390	35680	48210
Cash Chg.	53125	53125	53125	53125	53125	53125	53125	53125	53125
Gain/Loss	-87575	-78195	-31295	39055	-50055	-518565	-449265	88805	101335

VITA

SZE-WAN GAN

Candidate for the Degree of

Master of Business Administration

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