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ON THE SELECTIVE HEDGING OF BANK ASSETS WITH TREASURY BILL FUTURES CONTRACTS

Introduction

Recent economic conditions have stimulated a search for quick and inexpensive methods to reduce the interest rate risk borne by banks and other financial intermediaries. Typically, banks borrow short-term and lend long-term funds. This balance sheet structure exposes the bank to the risk that interest rates will rise unpredictably, narrowing the spread between asset and liability interest rates. Increased interest rate volatility creates planning problems for bank management. These factors, along with a heightened competitive environment in the banking industry, work to erode interest rate spreads and create a need for new risk management tools.

In response to these recent conditions, banks have sought a match of interest rate-sensitive assets with interest rate-sensitive liabilities. One method of doing this is to substitute variable rate loans for those with fixed rates. Another alternative is to restructure the balance sheet by either shortening the maturity of bank assets or lengthening the maturity of bank liabilities. Both alternatives involve either waiting until bank portfolios turn over or selling long-term loans and investments to fund short-term loans and investments. Capital market imperfections usually prevent a quick sale of loans without risk of loss due to different market evaluations of loan assets. It is also difficult to lengthen the term to maturity of bank liabilities without a significant increase in the cost of bank funds. All of these methods of responding to current market conditions represent relatively long-term solutions to the problem.

This article focuses on a short-term solution to the problems of matching interest rate-sensitive assets and liabilities. Financial futures contracts can be used to hedge the gap between rate-insensitive assets and rate-sensitive liabilities, effectively protecting the value of assets. To hedge the risk of an increase in interest rates, the bank sells a T-bill futures contract[1] calling for the future delivery of securities in an amount sufficient to lock in the value of bank assets relative to liabilities.

Use of financial futures markets allow banks to respond quickly to changes in the economic environment and to continue making long-term, fixed rate loans. However, there is evidence that the precentage of banks currently using financial futures is quite small.[2] Explanations for the lack of futures trading by banks include current bank regulations, the use of cash market alternatives to futures trading as discussed above, or the lack of research on the specific practice and usefulness of futures hedging. Since financial futures markets are relatively new, increased bank participation in these markets may result from a greater understanding of the optimal bank use and resulting effectiveness of financial futures.

Several authors have contributed to our present understanding of financial futures as hedging instruments. Ederington was the first to apply mean-variance portfolio theory to financial futures trading. Subsequently, articles by Franckle, and Cicchetti, Dale and Vignola extended Ederington's work by correcting for misspecification in the portfolio model. For the Treasury Bill and Government National Mortgage

Association Certificate futures contracts, these authors estimate that 60-70 percent of the variance of the hedged asset's return can be eliminated for two-week hedges and 70-80 percent for four-week hedges. As a result, financial futures could serve as an excellent mechanism for hedging interest rate risk.

The portfolio model used in these articles is not directly applicable to the typical situation faced by financial intermediaries, however. Futhermore, optimal financial futures positions in these articles are found by minimizing the variance of the hedged asset's return without regard to alternative risky assets, interest rate expectations, or the investment required to trade futures. Much of the same criticism applies to a variation on the basic portfolio model developed by Franckle and Senchak. A study by Parker and Daigler, however, directly addresses the effectiveness of T-bill futures in hedging the gap between rate-insensitive assets and rate-sensitive liabilities in a bank's balance sheet. Unfortunately, the hedging strategy they employ is not based on a theory of bank behavior.

To correct the shortcomings of the existing literature, this research addresses the following questions. How should a bank trade 90-day T-bill futures in an asset management strategy that includes T-bill investments and illiquid, uncertain loans? To what extent can bank profits be stabilized by trading T-bill futures and is the stabilization potential similar across banks of various sizes? What is the effect of different interest rate forecasts and risk bearing preferences on the optimal hedging strategy? Lastly, to what extent are bank futures trading decisions constrained by the regulatory requirement that futures positions represent bona fide hedges of interest rate exposure?

Beginning with a theory of optimal futures trading by a risk averse banking firm, this paper calculates T-bill futures positions as a function of T-bill investments, loans, and expectations about interest rates. The optimal use of the hedging strategy over the period 1976 to 1981 for banks of various asset sizes in the Eleventh Federal Reserve District is then simulated. Depending upon bank size, risk aversion, and interest rate expectations, different results from the hedging strategy are calculated and summarized. The simulation results show that partial hedging of interest rate risk is usually optimal, especially for banks with assets between $.5 and $1 billion, and that current bank regulations on futures trading have a limited benefit for only the smallest banks in the sample.

A Simple Model of a Bank

To answer the questions posed above and guide a simulation of Treasury bill futures trading by banks, a model of bank decisionmaking is needed. Articles by Pyle and by Baltensperger suggest several possible approaches. One approach is to assume that total bank liabilities are exogenous and the problem for the banking firm centers on optimal asset choice, where asset returns are uncertain. Another approach is to focus on the liability side of the balance sheet, assuming the asset side is exogenously determined. In this situation, the banking firm can decide on either deposit quantities with interest rates given (perhaps by Regulation Q or market forces) or deposit rates with random deposit flows. Finally, the most complete approach goes beyond the partial models of asset or liability choice to consider the interaction of asset and liability decisions.

The approach used in this paper is a complete model of the banking firm, but with simplifications to facilitate a simulation of Treasury bill futures trading. The model used here is closely related to the model developed by Sealey. Similar to Sealey's model, deposit flows and the return to bank loans are uncertain. However, in the model below, Treasury securities are a risky alternative to risky loans. Loans are assumed illiquid and predetermined, rather than a choice variable. A T-bill futures decision is included as a liability on the bank's balance sheet with a return related to the random T-bill return. Finally, unlike Sealey, the model assumes that bank management does not set demand and savings deposit interest rates and they are given by Regulation Q restrictions.

More formally, the model is given as follows. Suppose bank management has a three-month planning horizon. At the beginning of the planning horizon before deposit flows is revealed, management must decide on the investment in Treasury bills, and the size of the T-bill futures position, given a fixed level of loans. Once these decisions are made, the size of deposit inflows or outflows is revealed. Funds are purchased or sold for the 90-day planning period to insure that the balance sheet balances. No other decisions are made until the beginning of the next planning period.

Besides uncertainty associated with deposit flows, it is assumed that the term to maturity of all bank loans and T-bill investments extend beyond the planning horizon. This implies that at the beginning of the decision period bank management does not know the return to holding loans and T-bill investments over the planning period.[3] For simplicity assume all bank assets have a six-month term to maturity so that at the end of the period bank assets have 13 weeks to maturity. The uncertain return to holding Treasury bills over the planning period is related to the uncertainty associated with initiating a T-bill futures position three months prior to contract maturity, provided both interest rates converge at maturity. The model assumes convergence of cash and futures T-bill rates or the absence of basis risk.[4] The simulation described in the next section does not. In sum, bank liabilities are more interest rate-sensitive than assets, exposing the bank to the risk that profits will fall if interest rates rise over the planning period.

To initiate a futures trade, margin money must be deposited with a commodity broker. This margin is not applied against the value of the futures contract as in a stock purchase but is held by the brokerage house as a performance bond.[5] To exit the futures market, the trader need only take an equal and opposite position at a later date to offset the initial position. After performing this contract offset, all margin deposited with the broker is returned, less a fixed commission.[6] This margin deposit is required to initiate either a buy or a sell position.

Define $I(X)$ as a binary function that depends on the type of futures position taken. Let $I(X) = +1$ if X is positive (a buy position) and let $I(X) = -1$ if X is negative (a sell position). If h is the per dollar margin requirement, then $I(X)h(1 - R_X)X$ is the margin deposit for a futures position of value $(1 - R_X)X$. Note that by construction $I(X)h(1 - R_X)X$ is positive regardless of whether the trader buys or sells futures contracts.

The bank's balance sheet can now be expressed as:

$$L + T + I(X)h(1 - R_X)X = B + D \qquad (1)$$

where, L = predetermined loans maturing in 26 weeks, ≥ 0,

T = a 26-week T-bill investment, a decision variable ≥ 0,

X = a T-bill futures position with X>0 representing an asset (buy) position and X<0 representing a liability (sell) position, a decision variable,

B = purchase (B>0) or sale (B<0) of funds over a 90-day period, a decision variable, and

D = demand and savings deposits.

Bank management must choose T and X before the random level of deposits, D, is realized. The variable B then adjusts to balance the bank's balance sheet.

Currently, a joint policy statement issued by the Federal Reserve System, Federal Deposit Insurance Corporation, and the Comptroller of the Currency sets the guidelines for bank use of financial futures contracts.[7] These regulations are quite general in allowing individual banks to apply their own futures trading strategy to specific bank conditions. Regulatory guidelines do require that financial futures trading strategies be bona fide hedges of the interest rate exposure of the overall balance sheet, leaving the specifics of the hedging program up to individual banks.

In the model, this governmental restriction can be captured by limiting the position in the T-bill futures market to be no greater than the absolute value of the interest rate exposure of the bank, (L + T). This is called macro hedging and does not preclude the possibility that the T-bill futures position is a partial hedge (less than 100 percent) of the bank's interest rate exposure. Alternatively, a micro hedge is a futures market position that hedges a specific asset or liability in the bank's balance sheet rather than some measure of the gap between rate-insensitive assets and rate-sensitive liabilities. That is, a micro hedging program in this model restricts the futures decision to a liability position in the T-bill futures market no greater, in absolute value, than the bank's T-bill investment. Since a macro hedging strategy would obviously be more effective in reducing the variability of bank wealth in this model, micro hedging is not investigated in the simulation below.[8]

Bank profits are given by the revenues from loans, T-bill investments, T-bill futures trading and the sale of funds minus the costs of purchasing funds, Regulation Q deposits, and factor services. For simplicity, assume the loans are made on a discount basis. Therefore, bank profits at the end of the planning horizon are given by:

$$\pi = [(1 - \tilde{R}_L) - (1 - R_L)]L + [(1 - \tilde{R}_T) - (1 - R_T)]T + [(1 - \tilde{R}_T) - (1 - R_X) - h(1 - R_X)]X - R_B B - R_D \tilde{D} - f_L - f_T \qquad (2)$$

where, $\tilde{R}_L$ = the interest rate on loans with 90 days to maturity,

R_L = the interest rate on loans with 180 days to maturity,

$\tilde{R}_T$ = the interest rate on T-bills with 90 days to maturity,

R_T = the interest rate on T-bills with 180 days to maturity,

R_X = the interest rate on a 13-week T-bill futures contract 90 days before maturity,

R_B = the rate of return on purchased or sold funds for 90 days,

R_D = the rate of return payable on demand and savings deposits, set by Regulation Q,

$f_L(L)$ = the real resource costs of servicing loan accounts, $f'>0$, $f_L''>0$, and

$f(T)$ = the real resource costs of making T-bill investments, $f'>0$, $f''>0$.

Note in equation (2) that the return to loans, T-bill investments, and T-bill futures trading is the price change in these discount instruments over the planning period.[9] It is also assumed that the real resource cost of operating the bank can be measured on the uses of funds side of the balance sheet.

The objective of the banking firm is to choose the ex ante controls T and X and the ex post control B to maximize the expected utility of profit, denoted $U(\pi)$, subject to the balance sheet constraint in equation (1) and the expectations about the future. Since the balance sheet constraint can be solved for the ex post control B, in terms of the ex ante controls, T and X, the relevant maximization problem can be stated as:

$$\underset{T\geq 0,\ 0\geq X\geq -(L+T)}{\text{Maximize}} \quad EU[(R_L - \tilde{R}_L - R_B)L + (R_T - \tilde{R}_T - R_B)T$$
$$+ (R_X - \tilde{R}_T - h(1 - R_X)(1 - R_B))X$$
$$+ (R_B - R_D)\tilde{D} - f_L - f_T], \qquad (3)$$

where E = the expectations operator, and it is assumed the regulatory constraint $0\geq X\geq -(L+T)$ applies. Bank management is assumed to be risk averse so that $U'(\pi)>0$ and $U''(\pi)<0$. Recall the random variables in this problem are $\tilde{R}_L$, $\tilde{R}_T$, and $\tilde{D}$. Bank management is assumed to possess a subjective, joint probability distribution on these random variables, denoted $F(\tilde{R}_L, \tilde{R}_T, \tilde{D})$. Furthermore it is assumed this joint distribution does not change over the planning horizon.

The first order optimality conditions for this problem are given by:[10]

$$EU'(\pi)(\widetilde{R}_T - R_T - R_B - f_T') = 0 \qquad (4)$$

$$EU'(\pi)[\widetilde{R}_X - R_T - h(1 - R_X)(1 - R_B)] = 0 \qquad (5)$$

By subtracting condition (5) from condition (4), the optimal T-bill investment decision is the solution of:

$$R_T - R_X - R_B + h(1 - R_X)(1 - R_B) - f_T' = 0 \qquad (6)$$

Since no random elements appear in condition (6) and this condition is independent of the other decisions, it uniquely determines the optimal T-bill investment, T*. Optimal T-bill investments depend only on the T-bill spot and futures market interest rates at the beginning of the planning period, the known interest rate on funds purchased or sold, the per dollar margin requirement, and the marginal resource cost of making T-bill instruments. Expectations about the future and aversion to risk play no part in the decision.

Focusing on the optimality condition in (5), note that it can be rewritten as:

$$EU'(\pi)E(\widetilde{R}_X - R_T - h(1 - R_X)(1 - R_B)) + Cov(U'(\pi), - \widetilde{R}_T) = 0 \qquad (7)$$

where Cov(a,b) is the covariance between random variables a and b. When the random variables are joint normally distributed, Rubinstein has shown in general that equation (7) can be expressed as:

$$EU'(\pi)E(\widetilde{R}_X - R_T - h(1 - R_X)(1 - R_B) + EU''(\pi)Cov(\pi, - \widetilde{R}_T) = 0 \qquad (8)$$

Further, if bank management is constant absolute risk averse then the fixed index of risk aversion c equals $-U''(\pi)/U'(\pi)$.[11] This implies $cEU'(\pi) = -EU''(\pi)$. Since $Cov(\pi, -\widetilde{R}_T) = LCov(\widetilde{R}_L, \widetilde{R}_T) + (T+X)Var(\widetilde{R}_T) - (R_B - R_D)Cov(\widetilde{D}, \widetilde{R}_T)$, condition (8) can be solved for the optimal T-bill futures position, X*.

$$X^* = \frac{-T^* + R_X - ER_T + h(1 - R_X)\ (1 - R_B)}{c\ \mathrm{Var}\ (R_T)}$$

$$- \quad \frac{L\mathrm{Cov}(\widetilde{R}_L, \widetilde{R}_T) - (R_B - R_D)\mathrm{Cov}(\widetilde{D}, \widetilde{R}_T).}{\mathrm{Var}(R_T)} \qquad (9)$$

In the right hand side of equation (9), it seems plausible that: (i) the covariance between the interest rates on loans and T-bills ($\mathrm{Cov}(\widetilde{R}_L, \widetilde{R}_T)$) is positive, (ii) the difference between the interest rates on purchased funds and deposits (R_B - R_D) is positive, and (iii) the covariance between T-bill interest rates and the level of deposits ($\mathrm{Cov}(\widetilde{D}, \widetilde{R}_T)$) is negative. The latter effect is due to disintermediation and the presence of interest rate ceilings. If so, then expectations of lower T-bill interest rates and an expected increase in T-bill prices, decreases the liability position in the futures marekt. Less will be hedged in the futures market, since the bank expects it's interest rate exposure to be smaller. In fact, the bank might even desire to speculate in interest rate futures ($X^* > 0$), if interest rates are expected to fall sufficiently far, and regulators allowed such behavior. Conversely, the greater the expected T-bill rate at the end of the period or the greater the expected decline in T-bill prices, the greater the futures market hedge.

Also note that the greater the sensitivity of deposit flows to T-bill rates, the greater the futures market hedge. The more sensitive deposit outflows are to higher T-bill interest rates, the greater the outflow of funds at T-bill rates rise. Relatively high cost funds must be purchased to balance the balance sheet. To protect against this squeez on profits, the bank is pushed toward a short liability rather than long asset futures position to lock in the known interest rate on assets. A short position is then used to protect against the higher cost of purchased funds when disintermediation is a problem.

The Hedging Simulation

To simulate the T-bill hedging strategy suggested by the model of the banking firm, observations for each of the elements on the right hand side of equation (9) must be collected. The purpose here is not to perform a complete simulation of all bank decisions in the model, but to calculate the optional futures position assuming the T-bill investment decision is optimal. In the last section, equation (6) shows the T-bill investment decision can be separated from the other portfolio decisions. This allows the calculation of an optimal T-bill futures position based on existing data for bank loans and investments.

The data

The hedging simulation covers the time period from June 1976 to December 1981. Trading in T-bill futures contracts began in January 1976, at the International Monetary Market of the Chicago Mercantile Exchange. Currently, T-bill contracts mature in the following four months: March, June, September, and December. Since the bank model above assumes a three month planning horizon and futures contract maturity at the end of the planning period, T-bill futures market interest rates were collected on the first day of contract maturity and on the first day of the month 90 days prior to maturity. This procedure avoids the duration problems with the underlying T-bill investment discussed by Franckle and Ciccehetti, Dale, and Vignola. The latter quotes are used for establishing the interest rates at which futures trading is initiated, R_X in equation (9), and the former are used for computing actual trading returns when the position is closed out. The time period contains 23 non-overlapping opportunities for hedging as a result.

The interest rate used to compute the variance of T-bill interest rates in the denominator of equation (9) is the monthly average of 13-week T-bill auction rates. To capture the effects of changing interest rate volatility, the variance of cash T-bill rates was recalculated for each new hedging period. This procedure creates a time series measuring interest rate volatility over the simulation period. The covariance between loan and T-bill interest rates was computed and updated in a similar manner using the monthly average prime rate for short-term business loans and the monthly average auction rate for 13-week T-bills. The rate at which banks were assumed to sell or purchase funds was taken to be the monthly average rate in the secondary market for three month certificates of deposit. The covariance between the 13-week T-bill rate and deposits was calculated in a manner similar to the method in the last paragraph. The cost of deposits, R_D, was taken to be the average interest rate on savings and demand deposits established by Regulation Q, weighted by the size of each deposit category. Margin requirements were set at .25 percent of position face value, approximately the exchange minimum.

The dollar value of T-bill investments, loans, and deposits over the period for banks in the Eleventh Federal Reserve District was taken from the Report of Condition data gathered by the Federal Reserve Bank of Dallas. All member banks in the District were sorted into three asset size categories: (i) more than $1 billion, (ii) $500 million to $1 billion, and (iii) $100 million to $500 million. The category limits were determined arbitrarily and not set to equalize the numbers of banks in each subset. Banks with assets less than \$100 million were omitted from this investigation since there is some evidence that they neither use or benefit from futures trading to the same extent as larger banks.12/ The number of banks in each subset varied over the simulation due to both asset growth and changes in reporting procedures.

Bank averages for these variables were then computed at each of the 23 simulation points to capture representative aspects of firms in each subset. From the Report of Condition, average T-bill investments were measured by total average Treasury securities maturing in one year or less, loans by total average gross loans, Regulation Q deposits by the sum of total average demand and savings deposits.

Risk aversion and expectations

Two elements of equation (9) remain to be specified. The first is the index of constant absolute risk aversion, c. This parameter influences the size and type (asset or liability) of futures position calculated at each decision point. For the entire simulation period and for each category of bank size, the index of constant absolute risk aversion was arbitrarily assumed to range between $1x10^{-5}$ and $1x10^{-8}$. Parameter values of $1x10^{-6}$ and $1x10^{-8}$ are reported below to indicate the change in the hedging strategies when risk aversion changes.

The last variable to be specified is ER_T, the three month forecast of the 13-week T-bill rate. Four alternative forecasts are studied. Initially it was assumed that bank decision-makers make no interest rate forecast other than the interest rate expected by the T-bill futures market. That is, at the initiation of the trading program, the interest rate in the current T-bill futures quote is taken to be the current expected rate. Banks without economic research or forecasting units may be able to use the T-bill futures market as an expectations generating mechanism; therefore, T-bill futures interest rates merit consideration as forecasts in a futures hedging strategy.

The second type of forecast used was the forward rate imbedded in the short-term segment of the yield curve.13/ The forward rate is the interest rate on an investment over a given period beginning at some time in the future. Since the purpose here is to forecast one period T-bill rates one period in the future, the forward interest rate can be calculated as:

$$R^f_{T,1} = (R_{T,2})^2/R_{T,1} \qquad (10)$$

where

$R^f_{T,1}$ = one plus the forward interest rate on a one period T-bill investment beginning one period in the future,

$R_{T,2}$ = one plus the current interest rate on a two period T-bill investment, and

$R_{T,1}$ = one plus the current interest rate on a one period T-bill investment.

From the pure expectations theory of the term structure of interest rates, the implied forward rate in the yield curve is an unbiased expectation of the actual future interest rate when markets are in equilibrium. Since the hedging simulation assumes the bank has a three-month planning horizon, a forecast of the three-month T-bill rate three months in the futures can be found by squaring the current six-month T-bill rate and dividing by the current three-month T-bill rate.

The third type of forecast used in the hedging simulation was an ex post prediction from a single equation regression model. The model is estimated to explain movements in the three-month T-bill interest rate, $R_{T,t}$ as a function of real aggregate disposable income, YD_t, and a three month moving average of changes in the current M1 money supply, MAM_t. Monthly data used in estmation started in March of 1970 and ended in December of 1981. Starting in June 1976 the model was reestimated every quarter with new data to keep the unconditional forecasts as accurate as possible. A slope dummy variable was also incorporated to account for the effects of the October 6, 1979, policy change by the Federal Reserve System.14/ On this date, the Fed announced a switch in policy, from targeting market interest rates to targeting the supply of money.

For the entire data period, March 1970 to December 1981, the model was estimated as (standard errors in parentheses):

$$R_{T,t} = \underset{(.692)}{.945} + \underset{(.105)}{1.052}\ YD_t + \underset{(.068)}{.329}(D_t)(YD_t)$$

$$- \underset{(.082)}{.443}\ MAM_t + \underset{(.186)}{.615}(D_t)(MAM_t) \qquad (11)$$

$$R^2 = .971 \qquad SER = .796 \qquad DW = 2.033$$

where, SER = the standard error of the regression, and

DW = the Durbin-Watson test statistic for first order serial correlation.

All variables are significant at the 1% level except the intercept term. As expected, decreases in the three month moving average of the money supply and increases in real disposable income increase T-bill rates, but only for the period prior to October 1979.

The fourth type of forecast used was the actual T-bill interest rate existing at the end of the planning period. This forecast assumes that bank management can predict T-bill interest rates perfectly. The hedging simulation results using a perfect interest rate forecast will serve as a performance standard for evaluating the other three alternative forecasts. Furthermore, using a perfect forecast in the simulation serves as a proxy for all other possible regression and time series models capable of predicting three-month T-bill interest rates.

Simulation Results

Table 1 shows the simulation results for the macro hedging strategy when the risk aversion index equals 1×10^{-6}. Sample means and standard deviations are calculated over the 23 futures positions taken from June 1976 to December 1981 depending upon bank size and type of T-bill forecast used. The hedging ratio in column two is defined as X/(T+L) and indicates the percent of interest risk exposure hedged in the T-bill futures market. In the third column, hedging effectiveness is calculated as:

$$1 - \frac{Var(\pi)}{Var(\pi_u)} = \frac{-(X^2+2XT)Var(\tilde{R}_T) - 2LXCov(\tilde{R}_L,\tilde{R}_T) + 2X(R_B-R_D)Cov(\tilde{D},\tilde{R}_T)}{Var(\pi_u)} \qquad (12)$$

where, $Var(\pi_u)$ = the variance of bank profits without futures hedging.15/ Hedging effectiveness is therefore the percent reduction in the variance of unhedged profits due to T-bill futures hedging. It takes a value of zero if no futures trading occurs ($X^* = 0$). Negative hedging effectiveness

Table 1. Hedging Simulation Results for $c = 1\times10^{-6}$, $0 \geq X \geq -L - T$

Bank Assets (in millions) and T-bill Forecasts	Hedging Ratio	Hedging Effectiveness	Futures Return (in millions)	Initial Margin (in millions)
1. More than $1000				
a. Futures Forecast	.998[a]	.808	3.652	3.756
	(.007)	(.054)	(36.655)	(.536)
b. Forward Forecast	-.998	.808	3.566	3.757
	(.007)	(.054)	(36.494)	(.534)
c. Regression Forecast	-1.000	.808	3.666	3.765
	(.000)	(.054)	(36.659)	(.537)
d. Perfect Forecast	-.999	.808	3.664	3.759
	(.005)	(.054)	(36.659)	(.537)
2. $500 to $1000				
a. Futures Forecast	-.849*	.746	.136	.790
	(.155)	(.104)	(6.359)	(.144)
b. Forward Forecast	-.879*	.719	.528	.797
	(.153)	(.141)	(5.922)	(.142)
c. Regression Forecast	-.965*	.687	.678	.876
	(.083)	(.189)	(6.973)	(.084)
d. Perfect Forecast	-.873*	.729	.915	.791
	(.135)	(.115)	(5.767)	(.124)
3. $100 to $500				
a. Futures Forecast	-.977*	.826	.241	.287
	(.040)	(.059)	(2.401)	(.015)
b. Forward Forecast	-.903*	.788	.391	.266
	(.176)	(.096)	(1.806)	(.054)
c. Regression Forecast	-.996	.822	.325	.293
	(.014)	(.058)	(2.481)	(.013)
d. Perfect Forecast	-.910*	.768	.743	.268
	(.212)	(.163)	(1.725)	(.064)

[a]Sample mean with sample standard deviation in parentheses.
*Significantly less than -1 at the 5% level.

indicates financial futures hedging increases the variability of bank profits relative to non-hedging. By equation (12) negative hedging effectiveness is most likely to occur when the bank speculates long in the T-bill futures market (X*>0) and deposit flows are negatively correlated with T-bill interest rates. Column four computes the gross, annualized T-bill futures market return to each of the strategies excluding the repayment of initial margin at the end of the decision period.

Table 1 suggests the following relationships. Looking at the column of hedging ratios, note that for banks with assets less than $1 billion virtually all ratios are significantly different from -1 at the 5 percent level. This implies that these banks seek a partial hedge of their interest rate exposure, preferring to bear part of the interest rate risk themselves. This risk is borne because their mix of loan and T-bill investments is more heavily weighted toward T-bills relative to the largest banks and their flows are less sensitive to T-bill interest rates.16/ The extent to which this causes different partial hedges across bank sizes also depends on the total interest rate exposure facing the bank relative to the risk aversion index assumed to apply to all sized banks. These factors have the greatest influence on banks with assets between $.5 and $1 billion since their hedging ratios and hedging effectiveness are lower than either larger or smaller sized banks.17/

Turning to the results within each bank size category, note that using a futures market forecast in the hedging strategy yields the greatest hedging effectiveness relative to the other forecasts. Hedging with either forward or regression forecasts yields more selective position-taking which is usually more costly to initiate and reduces the variance of profits less. It also appears that using either of these forecasts results in greater, although insignificant, futures returns especially for the two smallest bank size categories. It is not surprising that the greatest futures returns for all bank sizes result when using perfect forecasts.

Finally, note that for the largest banks the hedging ratio and hedging effectiveness measures are virtually independent of the type of forecast used, while for smaller banks the results are more sensitive to the quality of the forecast. The explanation for this lies in the assumption of equal risk aversion across all bank sizes. For the largest banks, interest rate exposure T*+L* is too large to be affected by different forecasts given a risk aversion index of 1×10^{-6}. This does not imply that the hedging results would be independent of the type of forecast used for smaller values of the risk aversion index. The less the bank's aversion to interest rate risk, the more important the quality of the forecast becomes. Conversely, the interest rate exposure of the smaller banks is small enough relative to the constant absolute risk aversion parameter to yield widely varying results depending on the forecast used. Conceptionally, modeling differential aversion to risk, such that small banks are more risk averse and large banks are less risk averse, would help equalize hedging effectiveness across bank sizes given an interest rate forecast. Overall, the hedging effectiveness results are similar to the findings of Ederington and Franckle, while optimal hedging ratios reported here are much higher.

To illustrate the sensitivity of the hedging simulation results to the specification of the risk aversion parameters, Table 2 shows the

Table 2. Hedging Simulation Results for c = 1x10-8, 0>X>-L - T

Bank Assets (in millions) and T-bill Forecasts	Hedging Ratio	Hedging Effectiveness	Futures Return (in millions)	Initial Margin (in millions)
1. More than $1000				
a. Futures Forecast	-1.000[a] (.000)	.808 (.054)	3.666 (36.659)	3.765 (.537)
b. Forward Forecast	-.738* (.381)	.608 (.289)	8.068** (17.799)	2.768 (1.451)
c. Regression Forecast	-.956 (.162)	.773 (.142)	4.539 (36.279)	3.625 (.841)
d. Perfect Forecast	-.770* (.368)	.626 (.295)	13.745** (19.959)	2.888 (1.472)
2. $500 to $1000				
a. Futures Forecast	-1.000 (.000)	.654 (.232)	.889 (7.882)	.908 (.047)
b. Forward Forecast	-.667* (.434)	.430 (.310)	1.882** (3.625)	.601 (.393)
c. Regression Forecast	-.930 (.198)	.608 (.243)	1.769 (6.266)	.842 (.183)
d. Perfect Forecast	-.739* (.403)	.439 (.310)	3.141** (4.337)	.667 (.365)
3. $100 to $500				
a. Futures Forecast	-1.000 (.000)	.823 (.057)	.314 (2.499)	.294 (.011)
b. Forward Forecast	-.652* (.449)	.524 (.364)	.598** (1.179)	.194 (.134)
c. Regression Forecast	-.913 (.249)	.749 (.212)	.706 (1.888)	.269 (.075)
d. Perfect Forecast	-.739* (.403)	.604 (.333)	1.017** (1.411)	.218 (.120)

[a] Sample mean with sample standard deviation in parentheses.
* Significantly different than -1 at the 5% level.
**Significantly different than zero at the 5% level.

hedging results for banks less risk averse than in Table 1. The risk aversion index, c, is here assumed to be $1x10^{-8}$.

In this situation, a 100% hedge of interest rate exposure is optimal for all sized banks when the T-bill forecast is taken from either the T-bill futures market or the regression model. Although these strategies do not generate significant profits, the reduction in the variability of bank profits is greater than any of the other strategies. This conclusion about hedging effectiveness is similar to the results in Table 1, indicating its generality across different aversions to risk. It is also interesting that banks less averse to interest rate risk should optimally hedge more of their exposure rather than less. Yet this is the case for the two smallest size categories of banks, upon a comparison of Tables 1 and 2, lines 2a and 3a. The explanation for this lies in the regulatory constraint, $0 \geq X \geq -L-T$. Banks desire to speculate on the short side of the market by selling T-bill contracts with greater value than their interest rate exposure, but the regulatory constraint prohibits them from doing so. Hence, a 100% hedge is the best that can be done.

As banks became less risk averse, one would expect that optimal hedging becomes more selective, except when using a T-bill futures market forecast as argued in the last paragraph. Therefore, the effectiveness of a hedging strategy at lower risk aversion levels should also be less. Indeed, these expectations are borne out, since the percent reduction in the variability of bank profits is smaller in Table 2 for all size categories and forecasts than in Table 1. This is true even for hedging with either a T-bill futures market or the regression forecast, indicating that a 100% hedge of interest rate exposure does not necessarily lead to the greatest hedging effectiveness especially for banks in the two smallest size categories studied. The tendency for banks with assets between $.5 and $1 billion to experience lower hedging effectiveness than either larger or smaller banks is preserved when banks are less risk averse. As for the significance of futures returns, significant positive returns are generated from the hedging simulation at low levels of risk aversion using either a T-bill forecast from the forward market or a perfect forecast. Also note that with either of these forecasts, the optimal hedging ratios are partial hedges.

To assess the impact of current regulations regarding futures trading by banks, the hedging simulation was also conducted without constraining the T-bill futures position to be a bona fide hedge of interest rate exposure. That is, the optimal futures position was calculated with requring $0 \geq X \geq -L-T$. The question is, what is the effect of regulating bank participation in interest rate futures markets and is this burden shared equally by all sized banks? Table 3 contains the simulation results when the T-bill futures position can assume any value on the real time and the risk aversion index is $1x10^{-6}$.

Upon comparing Table 3 with Table 1, note that in the absence of the regulatory constraint banks with assets of more than $1 billion and with assets between $100 and $500 million would optimally hedge more than 100% of their interest rate exposure. For the largest sized banks this involves average short speculation of 12% of their interest rate exposure, over the four alternative forecasts. For the smallest sized banks, short speculation averages 33% of their exposure over the four forecasts. The intermediate sized banks optimally hedge either less than, greater than, or

Table 3. Hedging Simulation Results for $c = 1x10^{-6}$, - <X<+

Bank Assets (in millions) and T-bill Forecasts	Hedging Ratio	Hedging Effectiveness	Futures Return (in millions)	Initial Margin (in millions)
1. More than $1000				
a. Futures Forecast	-1.101[a] * (.064)	.817 (.056)	3.117 (40.443)	4.136 (.612)
b. Forward Forecast	-1.120* (.065)	.815 (.057)	3.615 (39.964)	4.207 (.600)
c. Regression Forecast	-1.162* (.058)	.812 (.059)	3.877 (41.236)	4.361 (.598)
d. Perfect Forecast	-1.102* (.056)	.816 (.056)	3.992 (39.821)	4.144 (.611)
2. $500 to $1000				
a. Futures Forecast	-.911 (.217)	.749 (.106)	.065 (6.408)	.826 (.197)
b. Forward Forecast	-.991 (.256)	.706 (.146)	.563 (6.001)	.897 (.227)
c. Regression Forecast	-1.162* (.231)	.624 (.241)	.824 (7.228)	1.051 (.198)
d. Perfect Forecast	-.920* (.184)	.730 (.117)	.940 (5.772)	.834 (.166)
3. $100 to $500				
a. Futures Forecast	-1.082* (.131)	.827 (.059)	.204 (2.459)	.317 (.032)
b. Forward Forecast	-1.317* (.512)	.538 (.344)	.702 (2.194)	.388 (.154)
c. Regression Forecast	-1.842* (.507)	.033** (.796)	.934 (3.384)	.543 (.156)
d. Perfect Forecast	-1.105 (.320)	.698 (.194)	1.080*** (2.256)	.325 (.096)

[a] Same mean with sample standard deviation in parentheses.
* Significantly different than -1 at the 5% level.
** Not significantly different than zero at the 5% level.
***Significantly different than zero at the 5% level.

equal to 100% of this exposure depending on the forecast. All hedging ratios are higher on average without the regulatory constraint than with it.

Probably more indicative of the impact of bank regulations, are the hedging effectiveness measures. If, by requiring futures positions to be bona fide hedges, bank regulations reduce the effectiveness of a hedging strategy then risk shifting opportunities are lost in the futures market and must be sought elsewhere. This problem does not appear in the results in Table 3. In fact the mean differences between hedging effectiveness in Tables 1 and 2 is statistically insignificant for all hedging strategies for the two largest size categories of banks. For the smallest banks, hedging strategies that use either the forward market forecast or the regression forecast result in significantly different measures of hedging effectiveness.18/ Using these forecasts hedging effectiveness is greater when the regulatory constraint is in effect than without it. By prohibiting speculative activity on the long and short sides of the T-bill futures market, the regulations on futures trading make little difference to the average reduction in the variance of bank profits obtainable through hedging. The cost of these regulations is an insignificant reduction in the average futures return, as well as a reduction in initial margin investment.

Conclusions

The practical applicability of these results depends on the assumptions of the underlying model, as well as several assumptions specific to the simulation itself. Bank assets certainly include loans and government securities other than 26-week loans and T-bills. To assume so creates an opportunity for futures trading in T-notes, T-bonds, and GNMAs, along with T-bills. These alternative investments were not modeled into the bank's decision problem, however, for simplicity. Considering such a diverse asset structure would lead to an integrated micro hedging strategy with possibly differing results. Also, to the extent that bank loans may have terms to maturity of less than three months, carry variable interest rates or are liquid, then using the sum of T-bill investments and loans as a measure of interest rate exposure overstates the true gap requiring management. As a result, hedging ratios and hedging effectiveness in the simulation would be biased upward. Finally, this investigation could have focused at futures hedging to lock in interest rates on the liability side of the balance sheet, instead of hedging to insure against a loss of asset value.

As for the simulation itself, one objectionable assumption concerns equal risk aversion indices across all three size categories of banks. It is likely that smaller banks are more risk averse than larger ones, but it is a question best answered by empirical analysis. The degree of risk aversion does influence the results and there is no a priori justification for the parameter values assumed above. Assuming equal risk aversion across bank sizes when it is not true tends to understate the results for smaller banks or overstate the results for larger banks. It also remains to be seen whether the characteristics of banks in the Eleventh Federal Reserve District are representative of banks across the entire U.S. Since the southwest has experienced relatively greater economic growth than other regions of the U.S., one would also expect its banking institutions to be different in asset composition and in the sensitivity of deposit flows to T-bill rates. If so, the hedging simulation results are not generally applicable.

In conclusion, the bank hedging strategy developed above is a macro hedging strategy that considers the interest rate risks associated with illiquid loans, T-bills, and random deposit flows. The modeled bank faces the risk that interest rates will rise, decreasing the value of its assets and forcing it to seek relatively costly sources of funds. Selling contracts in the T-bill futures market is a tool for the short term management of all these risks. In this sense, the model of bank decision-making extends the prevalent literature on the theory of hedging with interest rate futures. The solution of the model for the optimal futures position under constant absolute risk aversion reveals the importance of interest rate expectations and risk aversion in the hedging strategy. Both these parameters help determine the type of position taken and its size.

The simulation of the hedging strategy for stylized banks of different sizes with different mechanisms for generating expectations, different aversions to risk, and different regulatory constraints illustrates the generality applicability of the futures trading decision rules. Overall, optimal hedging with the T-bills futures contract does not imply a 100% hedge of a bank's interest rate exposure in virtually all simulations. This result is heavily dependent on bank size, T-bill rate expectations and the bank's degree of risk aversion, however. It does not appear that Eleventh District banks with assets between $.5 and $1 billion can reduce the variability of profits through hedging to the extent that either larger or smaller banks can. The reason for this is that (i) their assets contain a greater percentage of T-bills over loans and (ii) their Regulation Q deposits are relatively less sensitive to T-bill interest rates.

The policy implications of the simulation are that current bank regulations which limit bank participation in interest rate futures markets prevent the stylized banks from speculating on the short side of the market. However, the loss in expected utility associated with the regulatory constraint is not realized in significantly reduced hedging effectiveness but in insignificantly smaller futures trading returns and smaller initial margins. Since hedging effectiveness is the same with as without the regulatory constraint when banks use the T-bill hedging strategy, the current usefulness of these regulations might be questioned. If banks behave as modeled here, they do not willingly speculate in interest rate futures without reference to the maximization of the expected utility of profits, which includes both expectations and risk-bearing preferences. Only for the smallest category of banks could a limited case be made for the benefits of current futures trading regulations. For these banks and for two of the four forecasting methods, the presence of the regulatory constraint significantly increases hedging effectiveness. Yet on average, none of the above uses of the hedging strategy result in an increase in the variability of bank profits, even assuming the lack of regulation. As banks become more aware of the benefits of financial futures, it seems likely that current bank regulations on futures trading will be found to be inconsistent with the desire for a more competitive banking industry.

FOOTNOTES

1. The T-bill futures contract traded at the International Monetary Market of the Chicago Mercantile Exchange calls for delivery of T-bills with 90 days to maturity. Contract size is $1 million in T-bill face value. Interest rates on the T-bill futures contract are quoted on a discount basis.

2. Drabenstott and McDonley report that of 330 agricultural banks responding to a nationwide financial futures survey, 7 percent were using futures to hedge interest rate risk as of January 1982. Koch, Steinhauser, and Whigham report that of 230 financial institutions responding to a survey in the Sixth Federal Reserve District, 10 percent were using financial futures as of May 1982.

3. This model abstracts from the problems caused by default risk on bank loans. All loans are assumed default risk free.

4. Using regression techniques, one can not reject the hypothesis that 13-week T-bill spot interest rates and T-bill futures market interest rates on the first day of contract maturity are equal from June 1976 to December 1981.

5. Any excess margin monies beyond maintenance margin is usually invested in a money market mutual fund by the brokerage house. T-bill securities are also accepted as initial margin in many cases. These aspects of futures trading are not modeled here and hence the estimated costs of futures trading in the simulation tend to be biased upward.

6. Fixed commissions are ignored. Currently (10/1/82) these commissions amount to be approximately 100 dollars per contract per roundturn transaction.

7. For regulations relating to national banks see Banking Circular No. 79, issued by the Comptroller of the Currency, revised March 1980. For excellent discussions of these regulations, see the articles by Drabenstott and McDonley and by Koch, Steinhauser, and Whigham.

8. Although not reported in the simulation results below, the author has estimated that futures positions be micro hedges. These results are available upon request.

9. Bank loans are not usually made on a discount basis, as is assumed in equation (2). This assumption is made for simplicity and since loan decisions are not the focus of analysis, no loss of generality results.

10. A sufficient condition for a maximum requires that the utility function demonstrate risk aversion.

11. The only known function exhibiting the CARA property is the negative exponential, $-\exp[-c\pi]$, where c is the index of constant absolute risk aversion and π is the bank's profit.

12. See Drabenstott and McDonley and see Koch, Steinhauser, and Whigham. Simulation results for banks with less than $100 million in deposits are available upon request to the author.

13. For further discussion on a comparison between forward and futures interest rates as expectations see Lang and Rasche, and Poole.

14. A Chow test was performed to test the hypothesis of a structural change in the model in October 1979. The null hypothesis of equal regression coefficients before and after the Fed policy change was tested using an F-test with 5 and 34 degrees of freedom. The computed F was 3.43 which exceeds the critical value of the F distribution at the 5% significance level.

15. The variance of unhedged profits is given by:

$$\begin{aligned}\mathrm{Var}(\pi_n) = {} & L^2\,\mathrm{Var}(\tilde{R}_L) + T^2\,\mathrm{Var}(\tilde{R}_T) + (R_B - R_D)^2\mathrm{Var}(\tilde{D}) \\ & + 2LT\mathrm{Cov}(\tilde{R}_L,\tilde{R}_T) - 2L(R_B - R_D)\mathrm{Cov}(\tilde{R}_L,\tilde{D}) \\ & - 2T(R_B - R_D)\mathrm{Cov}(\tilde{R}_T,\tilde{D}).\end{aligned}$$

16. The distinguishing characteristics between the different size categories of banks are as follows (means over the simulation period with standard deviations in parentheses).

	Bank Asset Size (in millions)		
	More than \$1000	\$500 - \$1000	\$100 - \$500
T/(T + L)*	.038 (.024)	.064 (.024)	.059 (.013)
SD/(SD + DD)**	.107 (.027)	.176 (.044)	.206 (.033)
$\mathrm{Cov}(D,R_T)$***	-1,499,000 (472,000)	-1,018,000 (354,000)	-237,000 (75,000)

* The percent of stylized bank assets held as T-bills
** The percent of Regulation Q deposits that are savings deposits.
***The covariance between deposits and T-bill interest rates.

As can be seen, T-bills are more important and deposits are more expensive for the two smallest size categories of banks than for the largest. While the $\mathrm{Cov}(\tilde{D},\tilde{R}_T)$ is also smaller for these banks, the relative cost of this source of funds is also higher. Hence, profits are less sensitive to Regulation Q deposit flows.

17. See footnote 16, above.

18. Statistical significance henceforth implies the 5% level.

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