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Bank Funding Risks, Risk Aversion, and the Choice of Futures Hedging Instrument

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ABSTRACT

Currently, theories of financial futures hedging are based on either a portfolio-choice approach or a duration approach. This article presents an alternative: a firm-theoretic model of bank behavior with financial futures. Assuming the bank is uncertain about cash CD interest rates and the quantity of CDs it needs in the future, expressions for the optimal futures hedge are derived under constant absolute risk aversion and constant relative risk aversion. The performance of these two strategies is estimated from 1981–1983 using either the recently developed CD futures contract or the T-Bill futures contract. These results are also compared with the performance of a portfolio-choice strategy and a routine hedging strategy. The analysis indicates that the CD futures market can serve a hedging purpose that is not served by the previously established T-Bill futures market.

THE EMERGENCE AND RAPID growth of interest rate futures markets suggest that they satisfy a previously neglected economic function in our financial system. Recently, certificate of deposit (CD) and eurodollar futures contracts were developed to complement successful contracts in three different U.S. Treasury securities and Government National Mortgage Association certificates. This product proliferation raises the question of how many different interest rate futures contracts can be traded in sufficient volume to be viable (see Houthakker [10]). A viable interest rate futures contract is one whose correlation with a group of securities is such that trading volume provides a minimum of liquidity, thereby reducing the transactions cost of participants. As of yet, the viability of a particular futures contract cannot be predicted. However, it does seem likely that a sufficient condition for long-run contract viability is widespread acceptance by hedgers; the contract must represent a distinct risk-shifting vehicle not found elsewhere. Given the importance of the instruments underlying the CD and eurodollar futures contracts as bank liabilities, the long-run viability of these futures contracts would then seem to depend on their usefulness as anticipatory hedging instruments for bank funding risks.[1]

The purpose of this paper is threefold. First, an anticipatory hedging strategy is developed based on a theory of the banking firm that incorporates interest rate

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[1] Throughout this paper, the terms "bank," "financial firm," and "financial intermediary" are used synonymously.

and quantity risks in funding bank operations, different risk-bearing preferences, and expectations about the outcome of future events. This is warranted because the existing theory of financial futures hedging, anticipatory or otherwise, has not been formally modeled in the specific context of a banking firm. The second purpose is to compare the performance of the firm-theoretic hedging strategies with two less complex strategies present in the financial futures literature: a pure portfolio-choice hedging strategy and a routine hedging strategy. Any performance difference between strategies then requires balancing the greater information requirements of the firm-theoretic strategies against the simpler, although possibly suboptimal, portfolio-choice and routine hedging strategies. Finally, to assess the potential economic benefit of the CD futures contract innovation, hedging strategy performance is compared using either the CD or the Treasury bill (T-Bill) futures contracts. Since the latter is also a money market futures instrument and was established prior to the CD futures contract, the purpose is to investigate whether or not the CD futures contract represents a sufficiently distinct risk-shifting vehicle to maintain long-run viability.

In the literature on financial futures hedging, two different theoretical approaches have been used. Ederington [4] pioneered the use of mean-variance portfolio theory in determining financial futures hedges that minimize the variability of returns (see also Ciccehetti et al. [2] and Franckle [6] for methodological revisions). The alternative is the duration approach (see Bierwag et al. [1], Gay et al. [8], and Kolb and Chiang [12]). The duration approach to financial futures hedging adjusts for differences in the price sensitivity of hedged and hedging instruments due to mismatches in maturities, coupons, and term structures, as well as risks. The major limitations of both approaches are that neither treat risk-bearing preferences or stochastic quantities satisfactorily.

In contrast, a firm-theoretic approach to banking is used here to develop an anticipatory hedging strategy specific to bank funding risks. A position in a financial futures market is used to hedge the interest rate risk on funds purchased in the CD market and the quantity risk associated with fixed-rate deposits, simultaneously. Traditionally, depository financial intermediaries agree to accept whatever quantity of deposits is forthcoming at a predetermined deposit rate. As long as the bank has access to a perfectly competitive funds market, such as the CD market, its balance sheet constraint can always be satisfied, although at an uncertain cost. Thus, the bank's funding risk involves an interest rate and a quantity risk in the CD market; the bank does not know the cost or the amount of purchased funds until the level of deposits is revealed. This paper contributes to the literature on the anticipatory hedging of bank liabilities (see Franckle and Senchack [7], Ho and Saunders [9], Parker and Daigler [13], and Speakes [17]) because it explicitly considers deposit quantity risk in the anticipatory hedging strategy.

Section I presents the firm-theoretic model with futures trading. In Section II, two different explicit solutions for the optimal financial futures position are derived assuming joint normally distributed random variables and either constant absolute or constant relative risk aversion on the part of bank management. In Section III, the performance of the firm-theoretic models of anticipatory hedging is compared with the performance of the portfolio-choice and routine hedging strategies using bank data compiled by the Federal Reserve. This section also compares the hedging performance of the CD and T-Bill futures markets for two-week and four-week hedging periods from 1981–1983. Overall, the analysis indicates that the CD futures market can serve a hedging purpose that is not served by the previously established T-Bill futures market. Section IV concludes the paper by examining the critical assumptions used in the analysis and by commenting on the results.

I. A Model

The framework used here is related to the model developed by Sealey [16]. Similar to Sealey's model, deposit flows are uncertain either because depositors' tastes and preferences for holding money balances fluctuate randomly or because the actions of the Federal Reserve are unpredictable. In the model below, however, the volume of bank lending is assumed predetermined prior to the start of the planning period rather than a choice variable. The interest rate earned on bank loans is known with certainty because all loans are held to maturity. It is assumed that the bank has access to two different deposit markets: a Regulation Q deposit market and a perfectly competitive certificate of deposit market. Regulation Q rates are assumed binding and, therefore, known, and are less than the interest rates payable in the CD market.[2] CD interest rates and Regulation Q deposits at the end of the period are unknown. In sum, random changes in deposits force the bank to enter the CD market at an unknown cost of funds in order to fill out the bank's balance sheet.

A futures market decision is the only choice variable available to the bank at the beginning of the planning period. The futures decision has an uncertain return depending on the price of the futures contract at the end of the period. Initial and variation margin required to enter and maintain the futures position are ignored for simplicity. If deposit flows and market interest rates are inversely related, as might be expected with binding Regulation Q ceilings, the bank can hedge deposit withdrawals by taking a short (sell) position in the futures market. A fall in Regulation Q deposits can be augmented with futures trading profits if interest rates rise. In addition, the cost of obtaining a given amount of funds in the CD market can also be hedged by the sale of futures contracts. A hedge of the deposit quantity risk and a hedge of the CD interest rate risk reinforce each other in the presence of disintermediation problems.[3]

The sequence of decision-making is assumed to be as follows. At the beginning of a one-period planning horizon before deposit flows are revealed, bank management must decide on the size and type of the futures position given a predetermined level of loans. At the end of the period, the size of deposit inflows

[2] It is not essential that one of the bank's liability markets be a Regulation Q deposit market. It is assumed here only to facilitate the exposition in later sections of the paper. It is essential that rates in this deposit market be set ex ante and lower than the CD interest rates. This may be done by the bank or by market forces without loss of generality.

[3] If deposit flows and market interest rates are directly related, a hedge of deposit quantities and a hedge of CD interest rates imply positions on opposite sides of the futures market. The net position depends on the market's relative effectiveness in hedging each funding risk.

or outflows is revealed with the CD interest rate. Funds are purchased or sold in the CD market to equate assets and liabilities. The futures position is also offset at this time, returning any futures trading profits or losses. The process repeats itself at the beginning of the next planning period. It is assumed that the term to maturity of bank loans extends beyond the end of the period. Since loans are held to maturity, this sequence of decision-making implies that the bank's CD liabilities reprice more quickly than its assets; the bank has a negative gap in its balance sheet. Given a negative gap and the presence of disintermediation problems, the bank is exposed to the risk that a rise in interest rates will lead to deposit withdrawals and force it to purchase funds in the relatively expensive CD market.[4]

The principle relationships in the model are expressed as follows. The bank's ex ante balance sheet is[5]

$$L = B + D \tag{1}$$

where

L = predetermined loans, $L > 0$,
B = certificates of deposit sold (purchased), $B > 0$ (< 0), and
D = demand and savings deposits.

Bank profits at the end of the planning period are the sum of revenues from the loan and futures position minus the cost of purchased funds in the CD and Regulation Q deposit markets. Bank profits, Π, are given by (a tilde indicates a random variable and future value)[6]

$$\tilde{\Pi} = R_L L + [(1 - \tilde{R}_X) - (1 - R_X)]X - \tilde{R}_B B - R_D \tilde{D} \tag{2}$$

where

R_L = the interest rate earned on loans,
$\tilde{R}_X$ = the futures contract interest rate at the end of the period,
R_X = the futures contract interest rate at the beginning of the period
X = the size of the futures position, a choice variable,
$\tilde{R}_B$ = the CD interest rate at the end of the period, and
R_D = the binding interest rate on Regulation Q deposits.

The bank's objective is to choose X and B to maximize the expected utility of profit, $EU(\tilde{\Pi})$, subject to the balance sheet constraint in Equation (1) and its subjective expectations about the future.[7] Let these expectations be described by

[4] Given a negative gap and the absence of disintermediation problems, the bank's risk is that a rise in interest rates will lead to deposit inflows that are insufficient to offset the higher cost of funds in the CD market.

[5] The balance sheet constraint in Equation (1) does not treat futures trading profits (losses) as a source (use) of funds. In reality, a bank's futures position is treated as an off-balance sheet item with trading profits and losses appearing in the income statement.

[6] This model ignores the quantity risk associated with bank loans such as default and prepayment risk. Note the price of a futures contract is $(1 - R_X)$. The model here also treats the two cash market sources of funds, B and D, as discount instruments. If interest is not paid on bank liabilities when the level of deposits is revealed, the model would have to be recast in a two-period framework, complicating the analysis.

[7] For justification of expected utility maximization by banks, see Edwards [5] and Ratti [14].

the joint cumulative density $F(\tilde{R}_X, \tilde{R}_B, \tilde{D})$. It is assumed that this joint distribution does not change over the planning period. The maximization can be stated as

$$\underset{X}{\text{maximize}}\ E[\max_{B}\ U(\tilde{\Pi}) \mid F(\tilde{R}_X, \tilde{R}_B, \tilde{D})] \tag{3}$$

subject to Equation (1), where E is the expectations operator and $\tilde{\Pi}$ is given in Equation (2). The model is closed by assuming that bank management is risk averse, such that $U'(\tilde{\Pi}) > 0$ and $U''(\tilde{\Pi}) < 0$ (a prime indicates derivation).

II. Optimal Strategies

Since Equation (1) can be solved for B in terms of L and D, the maximization problem in Expression (3) can be rewritten as

$$\underset{X}{\text{maximize}}\ EU[(R_L - \tilde{R}_B)L + (R_X - \tilde{R}_X)X + (\tilde{R}_B - R_D)\tilde{D}]. \tag{4}$$

Differentiating Expression (4) with respect to X gives[8]

$$EU'(\tilde{\Pi})(R_X - \tilde{R}_X) = 0,$$

or

$$EU'(\tilde{\Pi})E(R_X - \tilde{R}_X) + \text{Cov}[U'(\tilde{\Pi}), (R_X - \tilde{R}_X)] = 0 \tag{5}$$

where Cov represents covariance. Next, assume the random variables are joint normally distributed. Using Rubinstein's [15] result, Equation (5) can be rewritten as

$$EU'(\tilde{\Pi})E(R_X - \tilde{R}_X) + EU''(\tilde{\Pi})\text{Cov}[\tilde{\Pi}, (R_X - \tilde{R}_X)] = 0,$$

or

$$\begin{aligned} &EU'(\tilde{\Pi})E(R_X - \tilde{R}_X) + EU''(\tilde{\Pi})\{L\ \text{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)] \\ &\quad + X\ \text{Var}[(R_X - \tilde{R}_X)] + \text{Cov}[(\tilde{R}_B - R_D)\tilde{D}, (R_X - \tilde{R}_X)]\} = 0 \end{aligned} \tag{6}$$

where Var represents variance. Further, assume $\tilde{D} = D(\tilde{\theta}) = D + \tilde{\theta}$ and interpret $\tilde{\theta}$ as the random change in deposits at the end of the period. Using Rubinstein's result again, Equation (6) becomes

$$\begin{aligned} &EU'(\tilde{\Pi})E(R_X - \tilde{R}_X) + EU''(\tilde{\Pi})\{L\ \text{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)] \\ &\quad + X\ \text{Var}[(R_X - \tilde{R}_X)] + E(\tilde{R}_B - R_D)\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)] \\ &\quad - E\tilde{D}\ \text{Cov}[(R_D - \tilde{R}_B), (R_X - \tilde{R}_X)]\} = 0. \end{aligned} \tag{7}$$

At this point, two assumptions about bank risk aversion can be made to derive two different hedging strategies. If bank management exhibits constant absolute risk aversion, the index of risk aversion, γ, equals $-EU''(\tilde{\Pi})/EU'(\tilde{\Pi}) > 0$. Constant absolute risk aversion implies that the decision-maker requires unchanging, yet favorable, odds to accept a risk of given absolute size as profits

[8] A sufficient condition for a maximum in Expression (4) is that the utility function demonstrate risk aversion.

vary. Under constant absolute risk aversion, the optimal futures position, X_A^*, is found by rearranging Equation (7).

$$X_A^* = \{E(R_X - \tilde{R}_X)/\gamma + M + N\}/\mathrm{Var}[(R_X - \tilde{R}_X)] \tag{8}$$

where

$$M = -L\ \mathrm{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)] + E\tilde{D}\ \mathrm{Cov}[(R_D - \tilde{R}_B), (R_X - \tilde{R}_X)], \quad \text{and}$$

$$N = -E(\tilde{R}_B - R_D)\mathrm{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)].$$

Alternatively, bank management may exhibit constant relative risk aversion; let the index of risk aversion, λ, equal $E(\tilde{\Pi})\gamma > 0$. Constant relative risk aversion implies that the decision-maker requires unchanging, yet favorable, odds to accept a risk of given relative size as profits vary. After substituting the balance sheet constraint, Equation (1), into the profit equation (2), expected profits with futures trading can be written as

$$E\tilde{\Pi} = E(R_L - \tilde{R}_B)L + E(R_X - \tilde{R}_X)X + E(\tilde{R}_B - R_D)E\tilde{D} + \mathrm{Cov}[(\tilde{R}_B - R_D), \tilde{\theta}]. \tag{9}$$

Under constant relative risk aversion, the optimal futures position, X_R^*, is found by rearranging Equations (7) and (9).

$$X_R^* = \{E(R_X - \tilde{R}_X)E\tilde{\Pi}_u + \lambda M + \lambda N\}/\{\lambda\ \mathrm{Var}[(R_X - \tilde{R}_X)] - [E(R_X - \tilde{R}_X)]^2\} \tag{10}$$

where M and N are defined as in Equation (8) and $E\tilde{\Pi}_u$ is expected bank profits without hedging ($X = 0$).

The solutions for X_A^* and X_R^* in Equations (8) and (10) show that the optimal futures positions can be decomposed into futures profit, CD market, and deposit flow terms. The first term in the numerator of each respective solution, the futures profit term, captures the influence of expected futures trading profits on the optimal decision. In Equation (8), X_A^* increases with lower expected futures interest rates or with higher current futures interest rates. In either situation, a long position is more profitable than a short position; X_A^* increases accordingly. In Equation (10), more restrictive conditions must be present before similar results can be derived for X_R^*. If $\lambda > [E(R_X - \tilde{R}_X)]^2/\mathrm{Var}[(R_X - \tilde{R}_X)]$, then $X_R^* > 0$ increases with lower expected futures interest rates or with higher current futures interest rates. But it is argued above that a bona fide hedge of interest rate and deposit risks is likely to involve a short futures position. With the same restriction on λ and $X_R^* < 0$, lower expected rates or higher current futures rates may increase or decrease X_R^*. The reason for this lies in the type of risk aversion exhibited by the bank. Higher expected futures profits from a long position lower $E\tilde{\Pi}$ when $X_R^* < 0$, raising the relative risk exposure of the bank. To keep the relative risk exposure constant, the bank can either decrease futures market participation or hedge more of its cash market risk. In sum, expectations of higher futures rates decrease the optimal hedge under constant absolute risk aversion but may increase or decrease the optimal hedge under constant relative risk aversion.

The second term in the numerator of Equations (8) and (10), the CD market term M, illustrates the effect of CD interest rate risk on the optimal futures positions. It in turn is the sum of two components because the bank's interest rate risk exposure, $L - E\tilde{D}$, depends on the relationship between loans and expected deposits. It is plausible to assume $\mathrm{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)] > 0$ and $\mathrm{Cov}[(R_D - \tilde{R}_B), (R_X - \tilde{R}_X)] > 0$. If a sale of CDs is anticipated, $(L - E\tilde{D}) > 0$, the CD market term implies a short futures position to hedge the CD interest rate risk under both types of risk aversion. Given a constant correlation between $\tilde{R}_B$ and $\tilde{R}_X$ and a constant $\mathrm{Var}[(R_X - \tilde{R}_X)]$, an increase in the variability of $\tilde{R}_B$ increases both $\mathrm{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)]$ and $\mathrm{Cov}[(R_D - \tilde{R}_B), (R_X - \tilde{R}_X)]$. In this case, it can be shown that X_A^* and X_R^* decrease, provided $\lambda > [E(R_X - \tilde{R}_X)]^2/\mathrm{Var}[(R_X - \tilde{R}_X)]$. That is, as the bank's CD cost becomes more uncertain, regardless of withdrawal risk, more risk exposure is hedged in the futures market. Similarly, with a constant correlation between $\tilde{R}_B$ and $\tilde{R}_X$, an increase in the variability of $(R_X - \tilde{R}_X)$ increases the covariance terms, and X_A^* and X_R^* again change to reflect a greater hedge of exposure. If a purchase of CDs is anticipated, $(L - E\tilde{D}) < 0$, the CD market term implies a long futures position and the same comparative static results apply.

Note in passing that if the model had ignored the quantity risk of uncertain deposit flows, then the deposit flow term in Equations (8) and (10) would vanish. If, in addition, the futures market is martingale-efficient, such that the expected futures interest rate equals the current futures rate, X_A^* and X_R^*, become

$$X_A^* = X_R^* = \{-L\,\mathrm{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)] + E\tilde{D}\,\mathrm{Cov}[(R_D - \tilde{R}_B), (R_X - \tilde{R}_X)]\}/\mathrm{Var}[(R_X - \tilde{R}_X)]. \quad (11)$$

The optimal firm-theoretic futures hedge in Equation (11) can be interpreted as a combination of solutions from the portfolio-choice model analyzed by Ederington [4]. To see this, rewrite Equation (11) as

$$X_A^*/(-L + E\tilde{D}) = X_R^*/(-L + E\tilde{D}) = \xi\beta_1 + (1 - \xi)\beta_2 \quad (11')$$

where

$\xi = -L/(-L + E\tilde{D})$,

$\beta_1 =$ the coefficient from the regression $(R_L - \tilde{R}_B) = \alpha_1 + \beta_1(R_X - \tilde{R}_X) + \varepsilon_1$, and

$\beta_2 =$ the coefficient from the regression $(R_D - \tilde{R}_B) = \alpha_2 + \beta_2(R_X - \tilde{R}_X) + \varepsilon_2$.

That is, the optimal ratio of futures contracts to risk exposure is a weighted average of two different cross-hedges that are each solutions to portfolio-choice problems.

The usual application of the portfolio-choice model, however, considers the hedged object to be a single cash market instrument rather than a spread between instruments as implied by β_1 and β_2. When applied to hedging CD interest rate risk, the usual solution for the portfolio-choice approach is

$$X_E^*/(-L + E\tilde{D}) = \mathrm{Cov}[(R_B - \tilde{R}_B), (R_X - \tilde{R}_X)]/\mathrm{Var}[(R_X - \tilde{R}_X)]. \quad (12)$$

The solutions in Equations (11′) and (12) are equal only if $\text{Cov}[(R_L - \tilde{R}_B), (R_X - \tilde{R}_X)] = \text{Cov}[(R_D - \tilde{R}_B), (R_X - \tilde{R}_X)] = \text{Cov}[(R_B - \tilde{R}_B), (R_X - \tilde{R}_X)]$, which seems unlikely. This exercise illustrates the advantage of the firm-theoretic model over the portfolio-choice approach when applying financial futures hedging to bank behavior. The firm-theoretic approach can explicitly incorporate different expectations and risk preferences, quantity risks, and interest rate spreads in a theory of bank hedging; the portfolio-choice model is not as flexible.

The final term to discuss in Equations (8) and (10) is the deposit flow term, N. It indicates the influence of deposit withdrawal risk on the optimal futures decision. Since $E(\tilde{R}_B - R_D) > 0$, the sign of this term depends on the sign of $\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)]$. Binding Regulation Q ceilings on deposit interest rates could yield $\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)] > 0$ through disintermediation effects. As market interest rates rise, deposit withdrawals cause the bank to borrow more expensive funds in the CD market. To cover this quantity risk, a short futures hedge should be increased to reflect the bank's greater combined interest rate and deposit quantity risk exposure.[9]

Of course, the magnitude of the deposit flow term depends on the spread between CD and Regulation Q deposit interest rates. As R_D increases with the deregulation of deposit markets, the deposit flow terms in Equations (8) and (10) become less important in determining the optimal futures position. The bank's funding risks are reduced as R_D approaches $E\tilde{R}_B$ because the mix of liabilities become less important for bank decision-making, even with uncertain deposit flows.

III. An Evaluation of Markets and Strategies

Unfortunately, an empirical test of the model is extremely difficult given the lack of data on actual futures hedging by banks. Indeed, several surveys of bank futures trading indicate that perhaps 10% of all banks currently participate in financial futures markets (see Drabenstott and McDonley [3], Koch et al. [11], and Veit and Reiff [18]). An alternative empirical application of the hedging strategies is to use them to test the effectiveness of a financial futures market in reducing the funding risks discussed above. Such an application becomes a joint test of the futures market and the firm-theoretic model itself.

To address the second purpose of this paper, this section compares the performance of the hedging strategies under constant absolute and constant relative risk aversion, Equations (8) and (10), with the performance of the portfolio-choice hedging strategy, Equation (12), and a routine hedging strategy. All four hedging strategies are in turn compared with a nonhedging strategy. The portfolio-choice and routine hedging positions are much less complex than

[9] On the other hand, $\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)] < 0$ implies that market interest rates and deposit flows move together; this relationship should appear with unregulated, competitive deposit markets. In this case, a hedge of deposit withdrawals causes the net futures hedge to be smaller for a hedge of interest rate risk alone or a hedge of interest rate risk and deposit withdrawals with disintermediation. The interest rate sensitivity of deposit flows counteracts the CD interest rate risk, making the bank's net exposure smaller, and requiring a smaller futures position to hedge the reduced risk.

Equations (8) and (10), computationally and conceptually. To address the third purpose of this paper, the hedging effectiveness of the recently developed CD futures contract is compared with the more established T-Bill futures contract. Both contracts have money market instruments as underlying securities and their relative performance should give an indication of the potential economic benefit resulting from the development of the CD futures contract. If no performance difference is observed, the CD futures contract may be criticized as serving a bank hedging purpose that is already served by the previously established T-Bill futures contract.

To evaluate the different futures markets and strategies, observations for each of the elements in the right-hand side of Equations (8), (10), and (12) must be collected. This requires firm-specific data for L, $E\tilde{D}$, $\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)]$, and $\text{Cov}[(\tilde{R}_B - R_D), \tilde{\theta}]$. It is unlikely that any existing financial intermediary faces a situation exactly satisfying the assumptions of the model, but Equations (8) and (10) can be simulated using Report of Condition data compiled by the Federal Reserve. Commercial banks with domestic assets greater than \$750 million report their assets and liabilities on a mid-weekly basis (170 banks total).[10] L was calculated as the average reporting bank's gross loans excluding federal funds sold. Since the model in Section I assumes a single homogeneous source of Regulation Q deposits, the average bank's sum of demand and savings deposits was used to determine $\tilde{\theta} = D - \tilde{D}$, $\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)]$, and $\text{Cov}[(\tilde{R}_B - R_D), \tilde{\theta}]$.[11] R_B was taken to be the three-month rate on certificates of deposit and R_D was set at 5.25%. R_L was taken to be the weekly average prime rate on business loans. To capture the effects of changing interest rate and deposit volatility, all variances and covariances were recalculated after adding new data for each new hedging period in the simulation.

The simulation period begins in September 1981 and ends in May 1983.[12] Wednesday settlement prices for the nearby CD and T-Bill contracts were collected from the *Wall Street Journal* to calculate $(R_X - \tilde{R}_X)$. The bank's planning period was assumed to be either two weeks or four weeks to facilitate a comparison with empirical results on hedging interest rate risk reported by Ederington [4] and Franckle [6]. For two-week and four-week planning periods, the simulation period contains 43 and 21 nonoverlapping opportunities, respectively, for hedging. Ex post values were used for expected cash and futures interest rates and expected deposits. The simulation results using perfect forecasts serve as a performance standard for evaluating other ex ante forecasts.

[10] These data were obtained from the *Federal Reserve Bulletin*, volumes 67–69.

[11] A few of the bank-specific items used in the simulation are as follows (means over the simulation period with standard error in parentheses):

L (in millions)	D (in millions)	$\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)]$ (*two-week hedges*)	$\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)]$ (*four-week hedges*)
\$2,828	\$1,605	−57,097	−456,777
(15)	(32)	(10,240)	(75,139)

[12] CD futures contracts began trading in the International Money Market of the Chicago Mercantile Exchange in July 1981; T-Bill futures contracts began trading in the same exchange in January 1976.

Two elements in Equations (8) and (11) remain to be specified, the indices of constant absolute and constant relative risk aversion. Little if any empirical research has been done on the appropriateness of a particular value of either index in the banking industry. Rather than make an ad hoc assumption about particular index values, the simulation was run with a variety of values for each index. The constant absolute risk aversion index, γ, ranged from $1 \times 10^{-5.8}$ to $1 \times 10^{-7.4}$; the constant relative risk aversion index, λ, ranged from 7.0 to 2.2. Five values for each are reported below so that the reader may gain a feeling for the changes in the hedging strategies as risk-bearing preference change. The bank exhibits greater preference for bearing risk as each index becomes smaller.

The simulated futures positions were also constrained to be bona fide hedges of the bank's risk exposure in conformance with current bank regulations on financial futures trading. The regulations, set out in a joint policy statement issued by the Federal Reserve, Federal Deposit Insurance Corporation, and Comptroller of the Currency in November 1979 and revised in March 1980, require that financial futures positions be nonspeculative, leaving the specifics of the hedging program up to the individual bank. To capture this regulatory constraint in the simulation, the size of the bank's short position in the futures market was limited to a position greater than or equal to the bank's expected purchase of funds in the CD cash market. A routine hedge was taken to be $-EB$. From the theory developed in the last section, it is also possible that the optimal futures hedge is a long position, provided the deposit flow terms in Equations (8) and (11) are positive ($-\text{Cov}[\tilde{\theta}, (R_X - \tilde{R}_X)] > 0$) and it dominates the other two terms. If so, the size of the bank's long position in the futures market was limited to a position less than or equal to the bank's expected change in deposits. Neither constraint on the long or short side of the market precludes the possibility of a partial hedge of the bank's exposure, however.

Table I presents the simulation results for two-week hedges of the bank's funding risks. Columns (1) and (4) show the average hedge ratio of the futures market position to expected borrowings in the CD market. Columns (2) and (5) indicate the percentage change in the variability of unhedged profits realized by hedging with a particular model and contract. This is the measure of hedging effectiveness used by Ederington [4] but applied here to banking firm profits rather than portfolio returns. To provide a rough estimate of the costs of implementing a particular strategy, Columns (3) and (6) show the percentage change in the level of unhedged profits realized by hedging the bank's funding risks. Other important costs that would require consideration in a more complete analysis of hedging costs are: initial margin, variation margin from daily marking-to-market, and roundturn brokerage commissions.

Several conclusions can be drawn from the results in Table I. Looking at the performance of the CD futures market, Columns (1)–(3), the optimal hedge ratio, X/B, is significantly less than -1 for the constant absolute risk aversion, constant relative risk aversion, and portfolio-choice strategies. Given these three strategies, the size of the futures trading positions are the largest using the portfolio-choice program and the smallest using the constant absolute risk aversion program. The greater selectivity of the two strategies incorporating risk aversion is reflected in

Table I

Simulation Results for Two-Week Hedges by Strategy and by Contract October 1981–May 1983

	CD Futures Contract			T-Bill Futures Contract		
	(1) X/B	(2) $\%\Delta\,\mathrm{Var}[\Pi_u]$	(3) $\%\Delta\Pi_u$	(4) X/B	(5) $\%\Delta\,\mathrm{Var}[\Pi_u]$	(6) $\%\Delta\Pi_u$
A. Constant Absolute Risk Aversion Strategy						
1. $\gamma = 1 \times 10^{-5.8}$	−42.22%[a]	−26.74%	0.20%*	−39.20%	−18.64%	0.46%*
	(4.12)	(2.56)	(0.39)	(4.65)	(2.40)	(0.35)
2. $\gamma = 1 \times 10^{-6.2}$	−41.97	−25.46	0.49*	−39.44	−17.81	0.74
	(4.45)	(2.63)	(0.37)	(4.92)	(2.43)	(0.34)
3. $\gamma = 1 \times 10^{-6.6}$	−42.27	−22.34	0.96	−40.98	−15.35	1.27
	(5.27)	(2.66)	(0.38)	(5.74)	(2.35)	(0.37)
4. $\gamma = 1 \times 10^{-7.0}$	−42.62	−17.52	1.48	−44.71	−12.13	1.76
	(6.33)	(2.84)	(0.37)	(6.75)	(2.34)	(0.41)
5. $\gamma = 1 \times 10^{-7.4}$	−46.93	−14.13	1.73	−48.88	−8.90	2.00
	(7.26)	(2.89)	(0.37)	(7.70)	(2.30)	(0.42)
B. Constant Relative Risk Aversion Strategy						
1. $\lambda = 7.0$	−46.47%	−14.71%	1.71%	−51.05%	−9.89%	1.51%
	(7.11)	(2.89)	(0.37)	(7.64)	(2.36)	(0.67)
2. $\lambda = 5.8$	−50.09	−15.78	1.42	−53.73	−11.67	1.26*
	(7.34)	(3.10)	(0.52)	(7.66)	(2.77)	(0.72)
3. $\lambda = 4.6$	−53.54	−16.04	0.96*	−56.28	−12.80	1.08*
	(7.48)	(3.09)	(0.72)	(7.63)	(2.84)	(0.75)
4. $\lambda = 3.4$	−59.75	−18.02	0.29*	−58.56	−13.53	0.78*
	(7.46)	(3.10)	(0.90)	(7.63)	(2.89)	(0.82)
5. $\lambda = 2.2$	−62.74	−18.78	−0.03*	−53.64	−12.50	0.26*
	(7.41)	(3.08)	(0.95)	(7.79)	(2.93)	(0.74)
C. Portfolio-Choice Strategy						
	−67.03%	−39.51%	−0.85%*	−68.05%	−30.17%	−0.67%*
	(0.61)	(1.79)	(0.67)	(0.78)	(1.87)	(0.68)
D. Routine Hedging Strategy						
	−100.00%	−27.11%	−1.24%*	−100.00%	−21.08%	−0.84%*
	(—)	(1.74)	(1.00)	(—)	(2.30)	(0.97)

[a] Sample mean for 43 observations with standard error of the mean in parentheses.

* Not different from zero at the 5% significance level.

the greater variability of their hedging ratios relative to the variability of the portfolio-choice hedging ratio. The reduction in the variability of unhedged profits is greatest with the portfolio-choice strategy, followed by the routine hedging strategy and the two firm-theoretic strategies. This is intuitive since the portfolio-choice strategy is constructed by minimizing the variance of returns. It is somewhat surprising, however, that ignoring deposit quantity risk, as implied by both the portfolio-choice and routine hedging strategies, results in the greatest reduction in the variability of unhedged bank profits.

Over the range of index values reported for the constant absolute risk aversion strategy, less aversion to funding risks results in significantly smaller reductions in the variability of unhedged profits. In contrast, over the range of index values reported for the constant relative risk aversion strategy, less aversion to funding risk does not significantly change the reductions in the variability of unhedged profits. The reason for this difference is that altering futures participation has a larger effect on altering the bank's absolute risk exposure than on altering the relative elements of its risk exposure. As Columns (2) and (3) show, there is an inverse relationship between the percentage change in the variability of unhedged profits and the percentage change in the level of unhedged profits as risk aversion changes. The percentage change in unhedged profits across all strategies illustrates the potential benefits of the more selective, firm-theoretic strategies. They are significantly positive only for low levels of constant absolute risk aversion and high levels of constant relative risk aversion. Insignificant losses are realized on average with the portfolio-choice and routine hedging strategies.

If one turns to the performance of the T-Bill futures market in hedging bank funding risks, virtually all of the above conclusions hold when comparing the different models. It is of interest to note that the optimal hedging ratios are not significantly different than the hedging ratios estimated for the CD futures market. The percentage reduction in the variability of unhedged profits is consistently smaller for the T-Bill futures market relative to the CD futures market, overall, and significantly lower for the two highest constant absolute risk aversion strategies, the portfolio-choice strategy and the routine hedging strategy. On the basis of this, it appears that the CD futures market serves a valuable economic function in hedging bank funding risks that is not served by cross-hedging in the T-Bill futures market. Greater hedging effectiveness can be achieved in the former by taking smaller positions. Differences in the percentage change of the level of unhedged profits are not consistent across the two markets and not statistically significant, in general.

Table II presents the simulation results for four-week hedges of the bank's funding risks. The data show the same relationships as discussed with respect to Table I. The primary difference between Tables I and II is in the absolute value of the estimates. Ederington [4, p. 165] argues that hedging effectiveness "will be greater for four-week than for two-week hedges because absolute changes in cash prices should generally be greater and futures prices would have more time to respond (if there is a lag) over the longer period." The results in Table II are consistent with this argument. Although the hedging ratios are not significantly different for four-week relative to two-week hedges, excluding the portfolio-choice strategy, the percentage reduction in the variability of unhedged profits is

Table II

Simulation Results for Four-Week Hedges by Strategy and by Contract October 1981–May 1983

	CD Futures Contract			T-Bill Futures Contract		
	(1) X/B	(2) %Δ Var[Π_u]	(3) %ΔΠ_u	(4) X/B	(5) %Δ Var[Π_u]	(6) %ΔΠ_u
A. Constant Absolute Risk Aversion Strategy						
1. $\gamma = 1 \times 10^{-5.8}$	−47.63%[a]	−48.96%	0.05%*	−51.06%	−40.13%	0.42%*
	(4.62)	(4.09)	(0.93)	(5.47)	(4.04)	(0.88)
2. $\gamma = 1 \times 10^{-6.2}$	−47.13	−48.11	0.31*	−50.76	−39.26	0.76*
	(4.84)	(4.21)	(0.90)	(5.78)	(4.21)	(0.86)
3. $\gamma = 1 \times 10^{-6.6}$	−45.85	−45.10	0.98*	−50.60	−37.00	1.42*
	(5.70)	(4.80)	(0.87)	(6.69)	(4.64)	(0.88)
4. $\gamma = 1 \times 10^{-7.0}$	−44.65	−37.30	2.04	−51.17	−32.38	2.30
	(7.95)	(5.54)	(0.95)	(8.65)	(5.28)	(0.89)
5. $\gamma = 1 \times 10^{-7.4}$	−42.89	−26.90	2.83	−50.41	−28.65	2.74
	(10.53)	(6.90)	(0.92)	(9.96)	(6.28)	(0.87)
B. Constant Relative Risk Aversion Strategy						
1. $\lambda = 7.0$	−48.03%	−33.07%	1.62%*	−55.38%	−33.20%	1.78%*
	(10.36)	(7.45)	(1.56)	(9.76)	(6.62)	(1.34)
2. $\lambda = 5.8$	−47.82	−32.28	1.67*	−55.39	−32.90	1.82*
	(10.56)	(7.51)	(1.56)	(9.86)	(6.63)	(1.34)
3. $\lambda = 4.6$	−46.99	−31.28	1.68*	−60.21	−35.47	0.56*
	(10.71)	(7.62)	(1.56)	(9.91)	(6.63)	(1.94)
4. $\lambda = 3.4$	−50.48	−32.67	0.41*	−59.34	−34.02	0.62*
	(11.05)	(7.98)	(2.08)	(10.35)	(6.83)	(1.94)
5. $\lambda = 2.2$	−49.99	−31.48	−0.43*	−58.93	−32.60	0.67*
	(11.27)	(8.32)	(2.08)	(10.75)	(7.10)	(1.94)
C. Portfolio-Choice Strategy						
	−75.60%	−65.46%	−1.94%*	−81.95%	−55.46%	−1.63%*
	(1.35)	(2.71)	(1.65)	(1.56)	(3.48)	(1.83)
D. Routine Hedging Strategy						
	−100.00%	−61.56%	−2.56%*	−100.00%	−54.36%	−1.80%*
	(—)	(2.69)	(2.31)	(—)	(3.63)	(2.18)

[a] Sample mean for 21 observations with standard error of the mean in parentheses.
* Not different from zero at the 5% significance level.

significantly greater the longer the hedging period. This result holds regardless of the strategy or market. In comparison with Franckle [6], the optimal hedging ratios and concomitant hedging effectiveness calculations for the firm-theoretic strategies reported here are lower for both two-week and four-week hedges. This suggests that placing a financial futures hedging strategy in the context of a simple portfolio-choice problem overstates the potential hedging effectiveness that could be realized by a risk-averse banking firm.

IV. Concluding Comments

The purpose of this research has been to apply the concepts of hedging theory to the management of bank funding risks and to assess the long-run viability of the recently developed CD futures contract. The performance of two firm-theoretic hedging strategies was also compared with two simpler strategies, one based on the theory of portfolio-choice and one based on routine hedging. It has been shown that the portfolio-choice strategy can be viewed as a special case of the firm-theoretic strategies if deposit quantity risk and expected futures rate changes are ignored and if the bank's spread between interest rates approximates the change in cash CD interest rates. Since bank decision-making typically involves interest rate expectations, risk-bearing preferences, and quantity risk, the portfolio-choice hedging strategy may result in suboptimal futures positions from the bank's point of view. The firm-theoretic strategies developed here can be viewed as an ex ante liability management tool focused on the bank's total funding risk, a combined interest rate and quantity risk. The alternative portfolio-choice and duration approaches cannot treat the hedging of quantity risks and ignore explicit risk-bearing preferences. In the firm-theoretic approach used here, the risk-averse bank's futures position is an anticipatory hedge of an uncertain quantity of CDs purchased at an uncertain interest rate. To date, little theoretical or empirical work investigates this type of bank-specific, financial futures hedge.

The comparison of hedging performance across four different strategies illustrates the importance of bank objectives and risk attitudes in formulating a futures trading program. If bank management acts to maximize the expected utility of profits, as implied in the constant absolute and constant relative risk aversion strategies, financial futures participation is likely to be more selective and less costly on average than hedging based on the minimization of return variability. The expected utility maximization strategies trade the potential of reduced variability of unhedged profits for the potential of enhanced profitability. The estimated performance of the different hedging strategies illustrates that, for some degrees of constant absolute and constant relative risk aversion, this tradeoff reduces hedging effectiveness without significantly increasing profits. In these instances, the simple portfolio-choice and routine hedging strategies dominate the firm-theoretic strategies in hedging effectiveness and ease of implementation.

Finally, what are the prospects for the long-run viability of the CD futures contract? The answer seemingly depends upon the risk attitude of hedgers. If banks hedge to minimize the variability of a given CD cost or hedge routinely, the CD futures contract represents a positive hedging innovation over the T-Bill futures contract and is likely to maintain its viability in the long-run. The simulation results indicate that hedging effectiveness is significantly greater with the CD rather than the T-Bill futures contract. However, if banks hedge to maximize the expected utility of profits and are constant relative risk averse, hedging effectiveness is not significantly different using either the CD or the T-Bill futures contract. In this case, hedging ratios tend to be insignificantly less with the CD futures contract relative to the T-Bill contract; transactions costs in the form of initial and variation margin and brokerage fees are not significantly different. This result might lead one to question the viability of the CD futures contract as a distinct risk-shifting vehicle. A clear-cut answer rests with further empirical research into actual bank hedging behavior. Such research can be conducted in the future only after financial firms have made greater use of futures instruments.

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