Optimal Futures Positions for Life Insurance Companies

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INTRODUCTION

The development of futures and options markets has given an impetus to the search for hedging strategies that would most effectively reduce the risk of business operations. The historical progression of these strategies has been from hedging individual transactions to composite models. These latter include the mean variance based models of Ederington (1979) and Franckle (1980) where financial futures hedges are determined by minimizing the variability of returns and the duration approach based on the models of Bierwag et al. (1983) and Gay et al. (1983), which construct the hedge based on differential price sensitivity arising from different maturities, coupons, and term structure. The third generation of hedging models by Koppenhaver (1985), Morgan and Smith (1988), and Morgan et al. (1988) adopt a firm theoretic approach in developing anticipatory hedges specific to the firm. The portfolio choice and duration based models are less complex and less information intensive but their major limitation is that neither treats risk bearing preferences or stochastic quantities satisfactorily. This may lead to suboptimal portfolio choice and hedging strategies [see Koppenhaver (1985)]. The existing state of the art establishes the theoretical superiority of the firm theoretic model.

To some extent, these approaches are reflected in the hedging models developed for life insurance companies. The concept of immunization, first invented by Redington (1952) for application to life insurance companies has formed the basis of several hedging models, e.g., Fogler (1984), Keintz and Stickney (1980), Tilley (1980), and Vanderhoof (1972). A number of writers use the Markowitz-Tobin portfolio approach to select assets and liabilities which have an offsetting impact on firm value as a result of changes in exogenous variables, e.g., Krinsky (1985), Haugen and Kroncke (1970), and Kahane (1977b). With the advent of financial futures markets, attention has shifted to hedging risk by taking an off balance sheet position in futures, e.g., Edmonds et al. (1983), Gottlieb (1985), Szala (1986), and Schwarz et al. (1986). However, most of these studies do not extend beyond micro

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The Journal of Futures Markets, Vol. 12, No. 1, 105–115 (1992)
 CCC 0270-7314/92/010105-11$04.00

hedging of specific asset or liability transactions. Forbes (1987) describes the whole field of dealing with interest rate exposure in life insurance companies as being "in its infancy."

A number of firm theoretic hedging models have been developed for banking firms, e.g., Koppenhaver (1985) and Morgan et al. (1988). The bank hedging models are not directly applicable to insurance firms because of the different nature of their operations, assets, and liabilities. The major objective of life insurance companies is to provide protection from pure risk—an aspect which has no comparable counterpart in banks. The operations of life insurance companies are designed around this objective and this imparts maturity gap and stochastic characteristics to life insurance companies which are quite distinct from banks. The liabilities of life insurance companies are driven by both pure and speculative risk. For banks, the relevant risk is only speculative. Pure risk differs from speculative risk in being more amenable to the law of large numbers [Williams and Heins (1989)]. Both banks and life insurance companies have investment operations, but the nature of these operations, which must be constrained by the nature of their liabilities, is quite different. Banks take in deposits which are usually short term and lend them long in the form of loans. For life insurance companies, the liabilities are usually long while the asset maturities are shorter. This difference in the nature of the asset–liability maturity gap results in different interest exposures. Banks experience adverse effects in a rising interest rate environment from price risk. The gap adversely effects life insurance companies through the reinvestment risk when interest rates fall. In banks, there is no equivalent of underwriting profits and the operational results from assets and liabilities are not conceived separately. Life insurance companies, on the other hand, expect a favorable claim experience to generate an underwriting profit. The markets in which the two financial institutions operate, both on the liability and asset side, are different. This leads to differences in the stochastic character of variables that enter into their respective profit functions. Insurance firms, therefore, require consideration specific to their business in terms of optimal hedging policies. This article develops a theoretic model specifically for a life insurance firm.

THEORETICAL MODEL OF OPTIMAL HEDGING POSITION

The framework used here is similar to the model developed by Morgan et al. (1988) for banking firms. The life insurance company faces uncertainty from several sources. Following Morgan et al. (1988) the timing of events in this study's model is shown in Table I. The period of commitment may vary from several months in the case of forward loans to a few hours or even minutes in the case of investment of new premiums. Quantity uncertainty arises because the extent of drawdown of forward loans is uncertain. This in turn affects the amount available for reinvestment in stocks and bonds. The amount of new premiums forthcoming for investments is also random because the number of new policies written and lapses on existing policies is uncertain. Rate uncertainty arises because the rates available on reinvestment and investments in bonds and equities are those prevailing at time 2 and are unknown at time 1. The life insurance company can hedge some of the quantity and rate risk by taking a position in futures.

The conventional policy of life insurers is to generate a profit both on their underwriting activity (mortality savings) and their investment activity (excess interest)

Table I
TIMING OF COMMITMENTS

Time	Commitments Made
1	Forward loans Reinvestment in stocks and bonds Investment of new premiums Futures contract
2	Accept premium on new and existing policies Disburse on forward loan commitments Make policy loans Make investments Liquidate futures position Pay claims

as stated by a number of authors, e.g., Doherty (1980), Mehr (1970), and Lovelace (1961). The profit function may be stated as:

Total Profit = Underwriting Profit + Investment Profit[1]

$$\pi = (P - \Delta L - C) + I(R_I - r_A) + er_A + f(R_f - r_f) \tag{1}$$

where

P = Premium paid.
$\Delta L = L_2 - L_1$ = Change in legal reserves.
C = Claims paid during the period.
I = Dollar value of investments made.
r_A = Assumed rate at which the reserves are calculated.
R_I = Rate earned on investments.
f = Quantity of forward contracts that the insurance firm enters ($f > 0$ corresponds to a short position and $f < 0$ corresponds to a long position).
R_f = Rate on futures contract at the time of liquidation.
r_f = Known futures rate when the contract is made.
e = Equity

The uppercase letters indicate random variables. Equation (1) can be written as

$$\pi = PR_{UP} + I(R_I - r_A) + er_A + f(R_f - r_f) \tag{2}$$

where R_{UP} = Underwriting profit rate. The balance sheet constraint is:

$$I = L + e$$

[1]There is nothing in the theoretical derivation of the model which restricts the meaning of underwriting and investment profits to statutory accounting profits. Economic profits will include realized and unrealized capital gains, interest, and dividends. Economic underwriting profits would then be changes in firm value over the period minus investment profits. However, because of data limitations, in the empirical portion of this article, statutory underwriting and investment profits are used. In regulated firms like insurance companies, where the purpose of regulation is to set solvency standards based on accounting measures of earning [Kahane (1977a)], management may be concerned with hedging accounting profits as well. Other evidence also indicates the accounting profit motivation of life insurance managers in decision making, e.g., Hadley (1977).

where L is legal reserves. Substituting I from the balance sheet constraint into the profit function [eq. (2)]:

$$\pi = PR_{UP} + L(R_I - r_A) + eR_I + f(R_f - r_f)$$

The insurance company is presumed to maximize expected utility of profits[2] where the utility function $U(\pi)$ exhibits constant absolute risk aversion.[3]

Assuming that the joint distribution of π and R_f can be closely approximated by a joint normal distribution, it can be shown that the first order conditions can be solved for f^*, the optimal volume of forward contracting, as

$$\begin{aligned} f^* = [-E\{R_f - r_f\}/a \operatorname{var}\{R_f\}] - [\operatorname{cov}\{PR_{UP}, R_f\}/\operatorname{var}\{R_f\}] \\ - [\operatorname{cov}\{L(R_I - R_A), R_f\}/\operatorname{var}\{R_f\}] - [e \operatorname{cov}\{R_I, R_f\}/\operatorname{var}\{R_f\}] \end{aligned} \quad (3)$$

where a is the measure of absolute risk aversion $-U''(\pi)/U'(\pi)$, which is assumed to be a constant.

Since the theory of adaptive expectation implies that futures prices reflect market expectation [Anderson and Danthine (1983); Ederington (1979)], the first term in eq. (3) is zero and drops out.

The above ratios may be considered as regression coefficients:

$$f^* = -\beta_{UP,f} - \beta_{IP,f} - e\beta_{RI,f} \quad (4)$$

where f is variable R_f and UP, IP, and RI are underwriting profit, investment profit on legal reserves, and rate on investment, respectively.

Since the term containing the measure of absolute risk aversion drops out, the result derived from the theoretical model is independent of the degree of risk aversion of the insurance firm. It is, therefore, of general applicability for calculating the optimal hedging position for all insurance firms.

EMPIRICAL SPECIFICATIONS

The empirical portion of this study consists of calculating the optimal futures position for insurance firms in the sample and conducting tests of statistical significance.

Equation (4) forms the basis for calculating the optimal futures position. The optimal futures position is the summation of values from three regression coefficients. These coefficients are calculated simultaneously using Seemingly Unrelated Regression (SUR) technique. SUR is superior to OLS where the error terms are not independent. The following three time series regressions are run as a SUR model:

$$\Delta\ (\text{Premium} * \text{Underwriting Profit Rate}) = a + \beta_1(\Delta\ \text{Futures Rate}) + \Omega_1 \quad (5)$$

$$\Delta\ (\text{Liability} * \text{Investment Rate Spread}) = b + \beta_2(\Delta\ \text{Futures Rate}) + \Omega_2 \quad (6)$$

$$\Delta\ (\text{Investment Profit Rate}) = c + \beta_3(\Delta\ \text{Futures Rate}) + \Omega_3 \quad (7)$$

[2]Santomero (1984) states that a financial intermediary may be an expected value-maximizer or a risk averse investor. Both choices are made in the literature. When marginal rate of substitution between risk and return is the focus, utility function concavity is assumed and where this is not of specific concern, risk neutral wealth maximization is assumed. Utility theory is extensively used in modeling the insurance firm, e.g., Freifelder (1976), Krinsky (1985), and Haugen and Kroncke (1970).

[3]Arrow (1970) shows that constant absolute risk aversion implies that the individuals's demand for the risky asset is invariant with respect to his initial wealth. Grossman and Stiglitz (1980) use an exponential utility function assuming constant absolute risk aversion. They argue that their results are not affected by letting investors have different coefficients of absolute risk aversion.

where Δ signifies the change from time t to time $t - 1$. The change in futures rate is the deviation of the futures rate from its expectation. This uses the assumption that the current futures rate is an unbiased estimate of the futures rate for the next period. The Δ futures rate is then calculated by subtracting the one period lagged value from the futures rate. To control bias in this assumption, the rate on the futures contract used in the empirical analysis is for three month T-bills. For such short term contracts the bias is nonexistent or imperceptibly small. The change in the futures rate is the variable specified in the theoretical model and the βs in the SUR equations are the coefficients based on eq. (4). The first difference of premium times underwriting profit rate, liabilities times investment rate spread, and investment profit rate are used on the assumption that the rates over the period of a year will experience a change.

The optimal futures positions are determined by substituting in eq. (4) values obtained from the SUR equations and equity values. These are the dollar forward positions that the insurance companies should take. The dollar positions are divided by net assets of the firm to determine standardized hedge ratios, R^*. This definition of hedge ratios is the same as employed by Morgan et al. (1988) for banking firms.

The balance sheet and income statement data for the insurance firms in this study is taken from Best Insurance Reports and the components of the time series SUR regression are constructed from it. For eq. (5), the variable premium is reported in the financial statements while the variable underwriting profit rate is obtained by dividing the underwriting profit by net premiums. The underwriting profit is calculated by subtracting from the net operating gain the investment income in excess of that on the basis of the assumed rate. For eq. (6), the variable liability is reported in the balance sheet while the variable investment rate spread is calculated by dividing the investment income in excess of that on the basis of the assumed rate by net assets. For eq. (7), the investment profit rate is calculated by dividing investment income by net assets. The data are available only on an annual basis. The time period for the empirical work of this study is from 1965 to 1987. Since this period extends beyond the start of financial futures markets, the futures rates are forecasted using ARIMA for the period 1965–1975.[4] The assumption in doing this is that if financial futures markets had existed, the T-bills futures rates would have been closely approximated by the forecast rates. Forecasts (one step ahead) are obtained using ARIMA. The model used for forecasting T-bills rates is ARIMA (1, 0, 0). The t-statistics for AR coefficients are very significant for all estimates. Future rates from 1976–1987 are taken from the Wall Street Journal.

The sample for empirical work consists of 12 large to medium size stock insurance companies.

EMPIRICAL RESULTS

The values obtained from the SUR model and the hedge ratios obtained by standardizing the dollar hedging positions by net assets are given in Table II. The hedge ratios vary from 0.30 to −0.259. Eight of the 12 firms in the sample have negative hedge ratios, implying that these firms should take a short position in futures. Four firms have positive ratios, implying that these firms should take a long position in futures.

[4]Term structure can be used to construct proxy future rates but recent evidence indicates the superiority of time series forecast over interest rate forecasts [see Hafer and Hein (1990)].

Table II

COEFFICIENTS AND OPTIMAL HEDGE RATIOS FOR LIFE INSURANCE COMPANIES IN THE SAMPLE

Life Insurance Co.	$\beta_{UP,f}$	$\beta_{IP,f}$	$\beta_{RI,f}$	h^*
Aetna Life Insurance Co. (Connecticut)	−43679	820357	0.14	−0.028[a] (0.003)
Allstate Insurance Co. (Illinois)	−2101568	263388	0.15	0.300[a] (0.011)
American National Insurance Co. (Texas)	289950	387036	0.18	−0.259[a] (0.008)
California Western States Life Insurance Co. (California)	−45629	81511	0.18	−0.053[a] (0.012)
Connecticut General Life Insurance Co. (Connecticut)	−184489	1044679	0.06	−0.049[a] (0.005)
Continental Assurance Co. (Illinois)	19327	198484	0.14	−0.104[a] (0.014)

Au: Footnote reference correct?

Equitable Life Insurance Co. of Iowa (Iowa)	60133	138427	0.17	−0.152[a] (0.004)
The Franklin Life Insurance Co. (Illinois)	−61668	568275	0.15	−0.165[a] (0.007)
Hartford Life Insurance Co. (Connecticut)	−447215	303534	0.19	0.051[a] (0.003)
Lincoln Life Insurance Co. (Indiana)	−2366473	1795059	−0.01	0.058[a] (0.011)
Sun Life Insurance Co. of America (Maryland)	−281981	138378	0.18	0.072[a] (0.011)
The Travellers Insurance Co. (Connecticut)	−381593	3906614	0.21	−0.014[a] (0.003)

Standard deviations are in parentheses.
[a]Significantly different from zero and one at the 1% level using a two-tailed test.

Two-tailed tests performed on the hedge ratios show that all the ratios are significantly different from zero and one at the 1% level. This implies that the model prescribes hedging strategies different from the naive strategies of no hedging and hedging all transactions.

The results in Table II show that there is a positive relationship between investment rate and change in futures rate. When interest rates rise, the investment income, which for life insurance companies is mostly composed of interest income, also increases. Only in one case, that of Lincoln National Life Insurance Co., is the relationship observed to be marginally negative. This may reflect some firm specific investment decisions made by the company.

There is also a positive relationship between investment profits and change in futures rates. Since the assumed rate which is used to calculate the policy reserves is generally much smaller than the investment rate and also since the assumed rate is constant for long periods of time, the positive relationship between investment profits and change in futures rates only mirrors the first relationship discussed above.

The relationship between a change in futures rates and underwriting profit is much more variable. In nine out of the 12 firms, this relationship is found to be negative. The dominant negative relationship may reflect the well-documented phenomenon that when interest rates rise, life insurance becomes a less attractive investment because of the constant interest rate built into the benefits. This causes investors to cash in their life insurance and move their money into higher yield investments. This has an adverse effect on underwriting profits.

The optimal hedging position for a firm is the summation of the estimates of the three terms in eq. (4). All three terms enter the equation with negative signs so that the signs of the estimated values change during the summation to produce the hedging position for the firm. The first and second terms, i.e., $\beta_{UP,f}$ and $\beta_{IP,f}$ are regression coefficients estimated by eqs. (5) and (6), respectively. The estimates for $\beta_{UP,f}$ are negative for nine firms and positive for three. The regression coefficient $\beta_{IP,f}$ is positive in all cases. The third term of eq. (4) is the product of regression coefficient $\beta_{RI,f}$ times equity. $\beta_{RI,f}$ is estimated by eq. (7) and is found to be positive for 11 of the 12 firms in the sample. The sign for the hedge ratio of the firm is determined by the sign and size of $\beta_{UP,f}$ in relation to the other two terms. In the three cases when it is positive and of the same sign as the other two terms, the hedge ratios for the firms are negative. Of the nine cases when $\beta_{UP,f}$ is negative, it is large enough in only four cases to dominate the positive values of the other terms and result in positive hedge ratios for the firms. In the remaining five cases, the negative sign of $\beta_{UP,f}$ reduces the size of the ratios but leaves the signs unchanged. For the sample as a whole, the model prescribes negative hedging ratios for eight and positive ratios for four firms.

The negative ratio implies that the life insurance company should take a long position in futures while a positive ratio implies a short position. The dominant prescription of long futures position for eight of the 12 firms in the sample is in line with the literature on gap management, which suggests that the positive maturity gap in life insurance companies would cause the firms to be harmed by a fall in interest rates [Rahman (1987)]. However, there is no simple relationship between the degree of reliance on underwriting profit versus investment income and the sign of h^*. Morgan et al. (1988), using principal component analysis of the variables in their optimal futures position equation, find that no one variable can be identified as the major source of the cross-sectional variation in hedge ratios. The results of this study for the insurance firms lead us to the same conclusion. This conclusion is not surprising because interest rate changes affect the profits of life insurance firms in many different ways and the relative impact on each firm would depend upon its specific policies with regard to its exposure to reinvestment risk, price risk, interest rate assumptions that are used in premium pricing, the proportion of whole versus term life insurance, and the options attached with life insurance assets and liabilities [Weinberger (1984)].

One of the premises of this study is that life insurance companies are sufficiently different from banks in terms of their operations, assets, and liabilities to warrant an industry-specific model. It is, therefore, instructive to compare the results of this study with that of Morgan et al. (1988) for banking firms. Morgan et al. work with a much larger sample of 83 firms, whereas the sample size of this study is only 12 life insurance firms. Morgan et al. report that, in their sample, 39 of the 83 hedge ratios are significantly different from zero at the 1% level. Of these, eight are significantly negative and 31 are significantly positive. In this study, all the insurance firms have hedge ratios significantly different from zero. Out of these, eight are significantly negative and four are significantly positive. In the Morgan et al. banking sample, the null hypothesis of a hedge ratio equal to one is not rejected for two cases out of 83 at the 0.5% level of confidence. In the insurance sample, the null hypothesis of a hedge ratio equal to one is rejected for all firms at the same significance.

This comparison reveals that the results of this study give even stronger evidence than given by Morgan et al. for banks that life insurance companies can employ futures beneficially. For banks, over half have hedge ratios that are not distinguishable from zero but for life insurance companies, the hedge ratios are significantly different from zero for all firms. The results also indicate the different response to interest rate exposure in banks and insurance companies. A predominantly short position in futures for most banks that can benefit from hedging is consistent with the negative gap between asset and liability maturities in banks. The Morgan et al. study suggests that approximately 80% of the banking firms that can benefit from hedging need to take a short position in futures. The positive gap between asset and liability maturities in life insurance companies suggests a long position in futures. The insurance model prescribes that 67% of the life insurance companies in the sample should take a long position.

CONCLUSION

This study develops a firm theoretic model of a life insurance company and tests the model on a sample of 12 stock companies. Hedge ratios are developed for these companies. The hedge ratios indicate that some life insurance companies (a majority in the sample) should take a long position in futures. This prescription is in line with the gap management literature, which suggests that the positive maturity gap in life insurance companies would harm the firm when interest rates fall and suggests a long position in futures. However, interest rate changes affect life insurance companies in several ways and the degree of impact is firm-specific. It is not, therefore, surprising to find that for some firms, the model prescribes a short position in futures.

All the hedge ratios are found to be significantly different from zero and one. Thus the model suggests hedge ratios which are significantly different from the naive hedging strategies of not hedging at all or hedging all transactions.

A comparison with the results of Morgan et al. (1988) for banks shows a much stronger beneficial impact of hedging for life insurance companies. The predominant prescription from the bank study is a short position in futures while the life insurance model prescribes a long position in most cases. The predominant positions prescribed are consistent with the nature of the maturity gap and the consequent interest rate exposure in the two institutions.

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