Interest Rate Risk: An Evaluation of Duration Matching as a Risk-Minimizing Strategy for Property/Casualty Insurers

CAS Valuation, Finance, and Investments Committee

INTEREST RATE RISK: AN EVALUATION OF DURATION MATCHING AS A RISK-MINIMIZING STRATEGY FOR PROPERTY/CASUALTY INSURERS

Casualty Actuarial Society

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Executive Summary

In this analysis, the CAS Valuation, Finance and Investments Committee used Dynamic Financial Analysis to test the hypothesis that duration-matching of assets to a company's liability duration will yield an improved risk profile (e.g., reduced risk with essentially the same return) compared to longer or shorter investment strategies. Although the results varied by scenario tested, the overall conclusion was that duration matching does not appear to be the sole optimal strategy for most property casualty insurers. In many cases, a duration-matched strategy yields a result that belongs to a family of optimal strategies, from which the decisionmaker must choose based on desire for return and appetite for risk; i.e., the strategy lies on the efficient frontier, but is not inherently "better" than other strategies.

In several situations the matched strategy and longer strategies lay on the efficient frontier, with longer strategies yielding higher return at higher risk; but the shorter strategies were sub-optimal. This helps to explain the relatively long-duration investment posture assumed by the average property casualty insurer.

The Committee also noted that the results of the analysis were strongly influenced by the accounting convention used. Statutory results showed greatly reduced asset risk because of the amortized cost accounting method. As a result, in many cases longer investment strategies yielded higher return, and equal or lower risk, when viewed on a statutory basis.

Furthermore, neither statutory nor GAAP displayed the full measure of overall interest rate risk, because of the absence of discounting for the liabilities. Such effects tend to make the results highly specific to the accounting method under consideration. VFIC is considering undertaking a future research project in which "economic value" will be used as the accounting convention; in such a matching of asset and liability risk lies the final test of whether duration matching holds any benefit for property casualty insurers.

Introduction

The relationship between the portfolio of assets and the portfolio of liabilities of a property and casualty (P&C) insurance company is of interest to many audiences. People who influence this relationship include the insurer's management, board, actuaries and investment staff; as well as regulators and rating agencies. Other parties – such as

policyholders, investors, investment bankers, and investment analysts – are also concerned with this relationship.

Insurers can choose one of many strategies for managing this relationship. Cash flow matching, or (more generally) duration matching of the asset and liability portfolios has been advocated by many as the preferred strategy. Duration measures the average time to maturity, using discounted cash flows as the weights, associated with a particular investment instrument or portfolio, usually a bond or group of bonds. It can be shown that duration so defined also approximately equals the units of change in the market value of a portfolio of assets and liabilities that would arise from a unit parallel shift in the market yield curve.[1] The unit of duration under this second definition is value per interest rate, but as interest rate is value per time, duration is also expressed as units of time.

Duration matching uses asset allocation to hedge the portfolio against parallel shifts in the yield curve; that is, interest rate (or reinvestment rate) risk. Specifically, if liabilities are discounted by current interest rates, then, if all else is equal, the value of the liabilities will decrease as interest rates increase. The bond market values also will decrease. Thus, surplus is potentially insulated. Managing the duration of the assets in this way immunizes the portfolio of assets and liabilities against this form of interest rate risk.

However, the adoption of a duration-matched strategy often leads to a reduction of the insurer's investment returns and thus of its potential increases in policyholder's surplus. These reductions reflect a combination of the relatively short duration of the liabilities of most P&C insurers, and the typically upward slope of the yield curve for available investments. Thus using duration matching to hedge against parallel shifts is not a costless strategy. Both income and long-term surplus growth can be adversely impacted.

Analysts who have looked at the actual behavior of P&C insurers find that most companies invest in portfolios of assets with durations longer than those of their liabilities. This suggests that most companies have either implicitly or explicitly concluded that the value of the duration hedge is not worth its cost. A contributing factor to this conclusion may be the fact that the effectiveness of the hedge varies depending on the accounting convention being used.

For instance, under GAAP accounting for P&C companies, liability values do not respond to changes in the yield curve. This prevents P&C companies from immunizing GAAP results through asset/liability management. The impact on GAAP equity of a change in interest rates would be the same as the impact on assets.

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[1] Panjer, Harry H. (ed.), Financial Economics, The Actuarial Foundation, Schaumburg, Illinois, 1998, p. 100. The two values differ by a factor, close to unity, which is described in the text.

Statutory accounting measures liabilities similarly, and in addition uses amortized value for bonds. Statutory surplus is thus automatically immunized against changes in interest rates. The only exception is if bonds have to be sold to pay losses. Then their value goes immediately from amortized to market. In this case the statutory surplus behaves somewhat like the GAAP surplus, in that some assets have been impacted by changes in interest rates while liabilities have not.

Life insurers have often used a matching strategy as a benchmark, but the typical life insurer's portfolio of liabilities is much longer in duration than that of a P&C insurer, which greatly reduces the cost of the duration hedge. These insurers also discount many of their liabilities, bringing them closer to an economic presentation than is the case for P&C insurers. Finally, because most life contracts provide a fixed amount of benefits, the only risk (other than mortality) is interest rate. As such, in the case of life contracts, duration matched assets are more likely to provide an optimal risk profile. Nevertheless, some regulators and other analysts schooled in the asset and liability matching strategies developed for life insurers have assumed that this strategy should apply to P&C insurers as well. Accordingly, regulators considering insurance investment laws and risk-based capital charges have at times developed proposals that would have the effect of penalizing P&C insurers that do not apply a matching strategy to their investment decisions.

In this paper, the Valuation, Finance and Investments Committee (VFIC) of the Casualty Actuarial Society (CAS) presents an analysis designed to shed light on the question of the appropriateness of an asset and liability matching strategy for P&C insurers under GAAP and statutory accounting conventions. VFIC is building upon work done by predecessor committees that have addressed this question. These previous studies were limited by the fact that their committees did not have access to the increasingly usable tools designed to support dynamic financial analyses. In particular, the former Financial Analysis Committee of the CAS did pioneering work on this subject that was presented in summary form but never published in detail, due to the difficulty of obtaining a validation of results using an independently developed model.[2]

Goals

For this analysis, we perform a simulation study of risk vs. return for a variety of investment strategies, and two company types (a monoline workers' compensation writer, and a monoline homeowners writer).

[2] Financial Analysis Committee, "A Study of the Effects of Asset/Liability Mismatch on P&C Insurers," Valuation Issues: Special Issues Seminar, Casualty Actuarial Society, 1989.

Under GAAP, we would expect the higher risk strategy (longer asset duration, higher interest rate risk) to generally have the higher return, with no strategy being clearly optimal. This risk-return relationship is what is seen in an "efficient frontier," wherein the risk bears a positive relationship with return and a higher return cannot be obtained without taking on more risk. In such cases the selection of strategy depends upon the entity's appetite for risk, because taking more risk will, on average, yield a greater return. For purposes of simplicity, we will assume that this traditional relationship, when observed in this analysis, describes the efficient frontier for the specific scenario under consideration.

The anticipated outcome for statutory results is that, unless assets have to be sold to pay losses, there is no risk from interest rate fluctuations. Since neither assets nor liabilities respond to interest rate shifts, the highest yielding investment portfolio would generally seem the optimal strategy, with equal or even *lower* risk than the lower-yielding portfolios. One reason that the risk could be lower, is that the higher investment income provides a cushion against loss experience.

In no case would there be any reason to expect that duration management would immunize the combined portfolio, or even lower its risk unless liabilities are discounted – this is expected to be the subject of a future VFIC paper related to the effect of interest rate risk on economic surplus.

The foregoing discussion primarily relates to traditional risk measures such as standard deviation. These describe risk purely in terms of variability. This is the case in this study for each of the two-sided risk measures. Other tests measure risk relative to some threshold; i.e., an adverse outcome larger than some value X. All of the down-side tests in this study are of this type. A key element of this type of test is that it is not independent of income, or return. A scenario with higher expected return has lower risk, all else being equal, because the higher return reduces the chance of the adverse outcome. In many respects this leads to a more meaningful and useful measure of risk.

On tests of this latter sort, such as Value at Risk (VaR) (an X% VaR calculation measures the Xth percentile of the projected annual change in capital), the risk measure itself is often inversely correlated with return. This powerfully contributes to turning many scenarios "upside down," causing their risk to decrease as their reward increases, in contradiction of traditional assumptions. We anticipate that this effect would often continue to exhibit itself if the scenarios were run on an "economic surplus" basis, as well.

This paper first discusses the design of the analysis, including:

- The standards used to compare the effect of various investment strategies on the modeled insurers, both with regard to risk and reward.

- The selection of representative types of insurers to model in order to develop conclusions of some generality with respect to P&C insurers.

- The description of the various investment strategies.

Next, this paper presents the findings for each selected modeled company. It then summarizes VFIC's conclusions, outlines some suggested directions for further research and then presents the limitations of this analysis.

The appendices to this paper present information regarding the following:

- Appendix A: A summary of the key assumptions used to parameterize each of the sample companies.

- Appendix B: The interest rate scenarios used in this analysis. (Note, we have assumed yields similar to historical averages, with randomness, but with no expected change in the mean interest rate over time.)

- Appendix C: Some sample graphs of the outcomes that resulted from this study.

We hope that this paper will generate discussion and further contributions on this very interesting subject.

Brief Description of Approach

To test the appropriateness of an asset and liability matching strategy for P&C insurers, we used random simulation to compare the selected measures of reward against various measures of risk for a range of investment strategies for eight sample insurance companies over a five year period.

Reward and Risk Measures

We chose two different bases for measuring reward to reflect the different accounting structures underlying statutory and GAAP financial statements. Although we could have selected others, we concluded that the results would be unlikely to change fundamentally. The return measures we chose are:

- Average annual statutory net income over the projected five-year period, as a percent of statutory policyholder surplus.

- Average annual GAAP net income over the projected five-year period (adjusted to remove the deferred taxes on the unrealized capital gains/losses), expressed as a percent of adjusted GAAP equity.

The important distinctions between the statutory and adjusted GAAP financial statements are displayed in Table 1.

Table 1

Value	Statutory Accounting	Adjusted GAAP/Total Return Accounting
Loss reserves	Undiscounted	Undiscounted
Unearned premium reserves	Pro rata *	Pro rata, with premium deficiency reserve
Bonds	Amortized cost	Market value
Deferred acquisition costs	Ignored	Recognized
Unrealized capital G/L	Ignored	Recognized
Deferred taxes	Ignored*	Recognized

* This analysis was done on the basis of pre-Codification Statutory Accounting Principles.

The risk measures were selected to consider both down-side risk and two-sided risk. Some companies or stakeholders may target consistency of results over time, whereas others will be more focused on threats to their ability to continue operations. Companies such as stock insurers, that are focused on consistency of results, might be interested in two-sided risk. We therefore selected as a measure of two-sided risk the standard deviation of income (on both a statutory and adjusted GAAP basis), as a percentage of surplus or equity.

We consider two-sided risk measures elegant, but less likely to be relevant to a company's actual performance and long-term success. Therefore, we focused more on income-sensitive measures of down-side risk. The following risk measures were selected to evaluate this risk, on a GAAP and statutory basis separately.

- Probability of a drop in surplus of more than 25% in any one year.
- Probability of ruin (where surplus or equity drops below zero, causing insolvency).
- The 5-year 5% surplus (or equity) VaR.
- The 5th projected year 5% surplus (or equity) VaR.

The VaR measures reflect the expected loss at the 5% level, as a percent of surplus. For example, a 5% surplus VaR of 15% implies that, 5% of the time, the company results will entail a financial loss of 15% or more of the company's surplus. The 5-year measure calculates this factor for all five projected calendar years; the 5th-year measure calculates it only for the final year of the projection period.

We also tested a newer risk measure called "Tail Value at Risk", or Tail VaR. We found that the results would not lead us toward significantly different conclusions than did the measures shown above. Furthermore, Tail VaR shares with standard deviation the weakness of being heavily affected by extreme outliers. For these reasons we did not include the Tail VaR measure among the results displayed in this report.

Sample Companies

The sample companies were selected to represent a relatively wide range of P&C insurers. The companies can be generally characterized (in approximate order of worsening results) as follows (specific assumptions are shown on Appendix A):

(1) Growing premiums at 5% per annum with a "typical" loss ratio.

(2) Declining premiums at 5% per annum with a "typical" loss ratio.

(3) Declining premiums at 5% per annum with a worse-than-"typical" loss ratio.

(4) Growing premiums at 5% per annum with a worse-than-"typical" loss ratio.

Each of these four sets of characteristics were applied to a hypothetical monoline workers' compensation writer, and a monoline homeowners writer, separately. This generated eight company scenarios.

Our intent is to capture a range of company conditions typical of the insurance industry. For example, the workers' compensation writer is intended to be representative of companies which, either due to their size or mix of business, have relatively stable cash flows and long-duration liabilities from year to year. We expect that this type of company will not have many cash calls and therefore will not be subject to significant interest rate risk when being viewed from a statutory accounting perspective.

In contrast, the homeowners writer is intended to be representative of companies which have erratic cash flows and short-duration liabilities. The average cash flows for these companies are expected to be positive, but for some years, such as those in which large

catastrophes occur, or in scenarios where loss ratios are unusually high, cash flows can be negative and assets might be liquidated. This type of company will, at times, feel the effects of changes in the market value of bonds even on a statutory basis.

The various premium and loss ratio characteristics further stress test the results of these companies to evaluate our conclusions under a wider range of scenarios.

Investment Strategies

To focus the analysis on the issue of the duration of the invested assets and to keep the analyses relatively simple, we assumed that the insurers invested only in US government bonds and cash. For each of the eight companies, we tested strategies with the approximate durations shown in Table 2.

Table 2

Investment Strategy	Line of Business	Duration of Invested Assets and Cash	Duration of Claims Liabilities
Short	Workers' Compensation	1.0	3.8
	Homeowners	1.0	2.2
Matched	Workers' Compensation	3.8	3.8
	Homeowners	2.2	2.2
Long	Workers' Compensation	7.5	3.8
	Homeowners	7.5	2.2

In the above strategies, 1% of assets is held in cash and the rest in government bonds, so that the combined duration of bonds and cash is equal to the amounts shown above.

The insurer is assumed to hold bonds to maturity, unless available cash is insufficient to meet obligations, in which case bonds are sold in proportion to the mix owned on the balance sheet date. At that time, the mix of assets between cash and bonds is re-balanced. If bonds are purchased, they are purchased to maintain the target average duration of liabilities (which is assumed to be approximately constant throughout the projection period).

The durations are calculated relative to liabilities and assets carried as of each financial evaluation date. There is no consideration in this analysis of the duration of future cash flows (relating, for example, to losses to be incurred and premiums to be written in the

future), as we considered this to somewhat depart from the classical concept of asset-liability duration matching as it is commonly understood.[3]

Economic Projections

We used randomly varying macroeconomic variables (such as short and long-term interest rates) and random variations in payment patterns to simulate a wide variety of future outcomes. Parameters for the variables we used for interest rate are shown on Appendix B. We projected these future outcomes five years from the statement date of the company being modeled.

We assumed no upward or downward movement on average for future interest rates (although there was substantial variation in the actual interest rates from year to year and iteration to iteration). We used the same assumption for the other modeled economic variables. The model used is mean-reverting, meaning that any deviation from the average in a modeled year results in an increased probability that the following year's observation will be closer to the mean rather than farther from it.

To check the sensitivity of the model to these assumptions, we tested models with increasing and decreasing average interest rates over time. We found that the results for such environments, which generally pertained for relatively short intervals, yielded quite different optimal investment strategies for that interval than our base model. However, these results did not have a major effect upon the companies' long-term investment strategies for either statutory or GAAP accounting. This is because the changing interest rate environment will tend to level off at some point in time.

Note further that, because the level interest rate scenarios we used include a wide variety of random economic deviates, a spread of alternative interest rate environments is already reflected in this analysis. Specifics regarding the interest rate model we did use are found in Appendix B.

Findings of Each Modeled Company

Tables 3 through 10 show the analytical results for each of the eight hypothetical insurers under the three investment strategies.

[3] Panjer, p. 100 ff. We used the Macaulay duration in our analysis, which in general terms is the weighted average time to maturity, with present-valued cash flows used as weights. See the text for a precise definition, and a discussion of some other measures of duration.

Workers' Compensation Insurer – Growing premiums at 5% per annum with a "typical" loss ratio (80%)

Table 3

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	6.3%	8.8%	9.6%
Avg. Adj. GAAP Net Income	7.2%	10.7%	12.2%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	0.0%	0.0%	0.0%
P{Stat. Surplus<0}	0.0%	0.0%	0.0%
5-Year 5% VaR (Stat.)	2.0%	-6.4%	-7.7%
5th Year 5% VaR (Stat.)	5.1%	-5.4%	-6.9%
P{ΔGAAP Equity<-25%}	0.0%	0.0%	1.2%
P{GAAP Equity<0}	0.0%	0.0%	0.0%
5-Year 5% VaR (GAAP)	1.1%	4.0%	15.7%
5th Year 5% VaR (GAAP)	4.3%	6.0%	16.9%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	4.7%	1.5%	1.1%
Standard Deviation of Net Income (Adjusted GAAP)	4.9%	9.9%	18.7%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

For this company, both measures of net income are maximized when the long strategy is selected. This finding reflects the impact of the usually positively sloping yield curve. That is, the insurer benefits from the additional yield gained by investing in long maturities. Because the company, as modeled, rarely experiences negative cash flows, its income measures appear to be only modestly affected by losses from the sale of bonds.

Under statutory accounting, all of the measures of risk are minimized when the long strategy is selected. The longer duration investment strategies benefit from the amortized accounting convention and the lack of bond liquidations. As a result of these characteristics, there is little risk to surplus arising from the effect of changing interest rates on assets. Statutory risk measures are optimized under the long strategy because, under statutory accounting, the investors in long bonds lock in an interest rate and thus

shield themselves from interest rate fluctuations for a longer period of time. An example of the risk-return curve resulting from a two-sided risk measure is found on Appendix C, Sheet 1. See Sheet 2 for a sample down-side measure.

However, under GAAP accounting, all measures of risk are maximized when the long strategy is selected, and therefore the increased reward is coupled with increased risk. Sheets 3 and 4 of Appendix C provide examples of these risk-return analyses.

In no case, however, does duration matching appear objectively to be a superior approach. It is either inferior to longer investments (in the case of statutory accounting), or is arguably an equally viable pick to the longer term investments due to the classic risk-return tradeoff (in the case of GAAP), where greater risk yields greater return.

Workers' Compensation Insurer – Declining premiums at 5% per annum with a "typical" loss ratio (80%)

Table 4

Strategy	**Short**	**Matched**	**Long**
Reward Measures			
Avg. Stat. Net Income	8.9%	10.9%	11.7%
Avg. Adj. GAAP Net Income	8.8%	11.8%	13.3%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	0.0%	0.0%	0.0%
P{Stat. Surplus<0}	0.0%	0.0%	0.0%
5-Year 5% VaR (Stat.)	-2.0%	-8.9%	-9.9%
5th Year 5% VaR (Stat.)	0.0%	-8.1%	-9.1%
P{ΔGAAP Equity<-25%}	0.0%	0.0%	0.4%
P{GAAP Equity<0}	0.0%	0.0%	0.0%
5-Year 5% VaR (GAAP)	-1.4%	1.9%	12.6%
5th Year 5% VaR (GAAP)	0.7%	2.6%	11.7%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	4.0%	1.2%	1.0%
Standard Deviation of Net Income (Adjusted GAAP)	4.3%	9.1%	17.2%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

The results in Table 4 are similar to the results seen in Table 3, that is, under statutory accounting, risk decreases with duration and in contrast, risk increases with duration under GAAP accounting. For example, because of the relatively low loss ratio and the long tail of the business, the declining premium does not frequently cause liquidation of bonds to be necessary under this scenario (even though, with payment pattern fluctuations, such a cash call could occasionally occur).

Workers' Compensation Insurer – Declining premiums at 5% per annum with a worse-than-"typical" loss ratio (110%)

Table 5

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	-78.1%	-22.3%	-17.4%
Avg. Adj. GAAP Net Income	-21.9%	-11.4%	-8.2%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	57.3%	22.4%	7.8%
P{Stat. Surplus<0}	37.2%	0.1%	0.0%
5-Year 5% VaR (Stat.)	128.8%	38.9%	27.8%
5th Year 5% VaR (Stat.)	648.8%	58.6%	37.4%
P{ΔGAAP Equity<-25%}	22.3%	13.1%	23.9%
P{GAAP Equity<0}	5.1%	0.0%	1.0%
5-Year 5% VaR (GAAP)	50.4%	30.8%	46.6%
5th Year 5% VaR (GAAP)	101.1%	39.4%	60.6%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	1038.4%	9.0%	6.1%
Standard Deviation of Net Income (Adjusted GAAP)	19.8%	13.6%	29.4%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

This is a particularly adverse scenario, in which the company is subject to negative underwriting results which prevent the new premium from adequately shielding the company from its looming cash flow problems. Thus, its risk profile differs somewhat from the previous examples studied.

Under the statutory environment, the relationship between investment strategies in Table 5 is similar to the relationships evident in Tables 3 and 4. Specifically, the risk to this insurer decreases, and the net loss is reduced, the longer the asset duration is relative to the duration of the claim liabilities.

For the GAAP risk measures in this scenario, the poor overall results drive the risk upward for the short (low investment income) approach relative to the matched (higher investment income) strategy – that is, investing short yields higher risk and lower reward in this case. As a result, the matched strategy is superior to the shorter options in this case, because it yields higher return with lower risk. The choice between the matched and longer strategies, however, is a tradeoff conditioned upon the insurer's appetite for risk.

Workers' Compensation Insurer – Growing premiums at 5% per annum with a worse-than-"typical" loss ratio (110%)

Table 6

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	-261.6%	-506.7%	-180.7%
Avg. Adj. GAAP Net Income	-123.2%	-41.2%	-36.9%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	99.7%	77.3%	78.5%
P{Stat. Surplus<0}	99.0%	99.1%	97.3%
5-Year 5% VaR (Stat.)	582.2%	439.0%	595.8%
5th Year 5% VaR (Stat.)	6452.0%	5716.7%	2616.1%
P{ΔGAAP Equity<-25%}	79.7%	54.9%	49.9%
P{GAAP Equity<0}	71.3%	35.0%	36.2%
5-Year 5% VaR (GAAP)	246.2%	119.3%	127.0%
5th Year 5% VaR (GAAP)	1281.9%	263.5%	327.3%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	2520.6%	12663.3%	1306.2%
Standard Deviation of Net Income (Adjusted GAAP)	1639.2%	83.5%	273.2%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

This is the most adverse scenario, because the company is writing progressively greater amounts of unprofitable business.

Although this is a highly adverse scenario under both the statutory and the GAAP environments, the long strategy still minimizes the loss (i.e., maximizes the income measure).

Because of the high frequency of insolvency, the risk measures are substantially distorted by missing values (observations which are removed from the analysis because the starting surplus is negative), and by outlier values caused by very small starting surplus (and correspondingly very large risk percentages). As a result, two of the statutory risk measures are minimized by a duration-matched strategy, while two of them are maximized. It is therefore difficult to draw any strong conclusions from statutory results in this scenario.

The GAAP risk pattern continues to be broadly similar to that observed under the previous scenario.

Homeowners Insurer – Growing premiums at 5% per annum with a "typical" loss ratio (72.5%)

Table 7

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	4.8%	5.2%	8.3%
Avg. Adj. GAAP Net Income	4.6%	5.1%	6.4%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	5.8%	5.8%	5.8%
P{Stat. Surplus<0}	2.7%	2.8%	1.8%
5-Year 5% VaR (Stat.)	46.8%	46.2%	42.3%
5th Year 5% VaR (Stat.)	38.9%	40.5%	39.0%
P{ΔGAAP Equity<-25%}	5.7%	5.7%	4.8%
P{GAAP Equity<0}	0.5%	0.6%	0.4%
5-Year 5% VaR (GAAP)	28.1%	27.4%	24.1%
5th Year 5% VaR (GAAP)	42.6%	44.2%	35.0%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	17.9%	17.6%	145.8%
Standard Deviation of Net Income (Adjusted GAAP)	13.1%	12.9%	14.3%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

For homeowners the matched strategy uses a duration of 2.2 years, in contrast to the 3.8 years for workers' compensation, and so it is closer to the short strategy (the duration of which is one year).

As with the workers' compensation companies, the homeowners companies (Tables 7 though 10) also produce measures of net income that are maximized when the long strategy is selected.

Under statutory accounting, generally speaking, return increases and risk decreases as the duration of assets increases. However, at least three of the five statutory risk measures indicate that short has no greater risk than the matched strategy. This pattern might be attributable to the fact that the shorter asset duration creates smaller asset value

fluctuations in a line where liquidation of assets is unavoidable due to catastrophes; this effect works to offset the slightly lower investment income of the short strategy. For the long strategy, on the other hand, the additional stability arising from the locked-in investments causes the risk to be reduced relative to a matched strategy.

For the statutory standard deviation risk measure, note that the seeming riskiness of the long strategy arises from a single extreme outlier in the model. Without that observation (which is one of a thousand in this run), the risk for the long strategy is lower than for the matched. This is an indicator of how a measure like standard deviation, which is more heavily affected by observations that are further from the mean, can be greatly influenced by a very few or even a single outlier. The VaR measure is more robust in this regard. However, Tail VaR suffers from the same limitations as standard deviation, though to a lesser degree.

Under GAAP accounting, the results are generally similar to statutory results, for the down-side tests. That is, the longer duration strategy has the highest return and lowest risk relative to the other strategies, because the extra income of the longer strategy provides risk reduction. This is a significant result, because it represents a situation in which the income sensitivity of the selected down-side risk measures has inverted the risk-return relationship when compared to a pure variability measure. The two-sided GAAP standard deviation of net income, is highest for the long strategy, as asset value fluctuation is greatest there. However, we believe the down-side results are more meaningful, because they put the variability into the context of the average income being generated by the scenario.

Note that the result is different than for the corresponding workers' compensation scenario in this regard. The reason is that in homeowners, with its catastrophe exposure, the higher yield of the investments from the long scenario is able to shield the company from adverse underwriting results, which are relatively large in comparison to the extra investment risk that the longer scenario entails.

Homeowners Insurer – Declining premiums at 5% per annum with a "typical" loss ratio (72.5%)

Table 8

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	6.1%	6.2%	7.6%
Avg. Adj. GAAP Net Income	5.0%	5.5%	6.7%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	5.4%	5.3%	4.7%
P{Stat. Surplus<0}	0.6%	0.6%	0.7%
5-Year 5% VaR (Stat.)	27.5%	26.5%	22.4%
5th Year 5% VaR (Stat.)	18.5%	19.4%	19.2%
P{ΔGAAP Equity<-25%}	2.6%	2.5%	2.3%
P{GAAP Equity<0}	0.0%	0.0%	0.0%
5-Year 5% VaR (GAAP)	17.2%	16.2%	14.7%
5th Year 5% VaR (GAAP)	20.3%	21.6%	14.2%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	35.7%	19.9%	59.4%
Standard Deviation of Net Income (Adjusted GAAP)	9.2%	9.2%	11.1%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

Most of the statutory and GAAP risk measures indicate the common theme of higher return and lower risk as asset durations increase. This is explained as previously discussed. In two cases, the matched scenario actually has the *greatest* risk.

However, the GAAP two-sided risk measure indicates the opposite result; that is, return and risk have a positive relationship. The two-sided risk measures both the up-side and the down-side fluctuations in annual income, with no mitigation of risk when return increases. Therefore, it continues to display the classical risk-reward relationship.

The statutory two-sided risk measure shows the duration-matched scenario to have the minimum risk. However, as in Table 7, this is due to a single outlier driving the value for

the long scenario upward. Without this outlier, the long scenario would be the least risky of the three investment strategies.

Homeowners Insurer – Declining premiums at 5% per annum with a worse-than-"typical" loss ratio (87.5%)

Table 9

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	0.9%	1.4%	2.5%
Avg. Adj. GAAP Net Income	1.1%	1.6%	2.9%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	5.8%	5.8%	5.8%
P{Stat. Surplus<0}	1.9%	1.9%	1.6%
5-Year 5% VaR (Stat.)	40.2%	38.8%	34.4%
5th Year 5% VaR (Stat.)	30.0%	31.6%	30.9%
P{ΔGAAP Equity<-25%}	4.6%	4.3%	4.1%
P{GAAP Equity<0}	0.0%	0.0%	0.0%
5-Year 5% VaR (GAAP)	23.4%	22.6%	20.5%
5th Year 5% VaR (GAAP)	28.5%	30.2%	22.8%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	15.9%	15.7%	15.1%
Standard Deviation of Net Income (Adjusted GAAP)	10.1%	10.1%	11.8%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

Under both statutory and GAAP accounting, we see from the above table that, in general, the risk and the return have an inverse relationship as the duration increases.

However, we again see that the GAAP two-sided risk measure indicates a positive relationship between risk and return as the asset duration increases. We would expect this relationship since the adjusted GAAP risk measure considers the additional volatility due to the inclusion of unrealized capital gains and/or losses, which are substantially higher for the long-duration strategy.

Homeowners Insurer – Growing premiums at 5% per annum with a worse-than-"typical" loss ratio (87.5%)

Table 10

Strategy	Short	Matched	Long
Reward Measures			
Avg. Stat. Net Income	-1.4%	-0.8%	0.5%
Avg. Adj. GAAP Net Income	-0.9%	-0.6%	0.9%
Down-Side Risk Measures			
P{ΔStat. Surplus<-25%}	5.8%	5.8%	5.8%
P{Stat. Surplus<0}	2.8%	2.8%	2.8%
5-Year 5% VaR (Stat.)	65.0%	64.5%	59.7%
5th Year 5% VaR (Stat.)	58.1%	60.4%	58.0%
P{ΔGAAP Equity<-25%}	6.2%	6.1%	6.2%
P{GAAP Equity<0}	1.8%	1.7%	1.6%
5-Year 5% VaR (GAAP)	37.0%	36.4%	33.2%
5th Year 5% VaR (GAAP)	62.2%	64.5%	52.6%
Two-Sided Risk Measures			
Standard Deviation of Net Income (Stat.)	23.2%	22.5%	21.1%
Standard Deviation of Net Income (Adjusted GAAP)	26.1%	16.6%	17.7%

Notes: 1. Net income is net of taxes.
2. Stat. is statutory.
3. Δ is "percentage change in."
4. VaR is value at risk. A negative value represents a gain.
5. All values as % of starting surplus/equity for the modeled iteration/year.
6. GAAP has been adjusted to reflect the deferred taxes on unrealized capital gains/losses.

The results on this table appear generally consistent with Table 9. The two-sided GAAP risk measure, however, shows a result more like Table 7.

Conclusions

Under statutory accounting, the majority of the eight modeled companies have an inverse risk-return relationship (including the two-sided risk measures) as the asset duration increases. Variability in income arises primarily from changes in bond yields; since these occur more slowly with a long-investment strategy in an amortized cost environment, longer strategies yield lower risk.

When the risk and return have an inverse relationship, purely statutory decision-making will result in a preference for longer investments, since additional income can be had for less risk. But when underwriting losses force liquidation of assets, a direct relationship can take hold between risk and reward, with the trade-off that that entails among equally viable alternative strategies. We observed this last pattern infrequently in this analysis.

Under GAAP accounting, for workers' compensation writers, the majority of our results indicate a positive correlation between risk and return (including the two-sided risk measures). This is generally what we would expect under GAAP since the higher the duration, the higher the fluctuations in the market value of assets.

However, under GAAP accounting for the homeowners writer, most of our modeled results indicate a generally inverse relationship between return and down-side risk. This we consider to be due to the higher underwriting risk (due to catastrophe exposure). The increased income due to longer investment offsets more of this risk, but the increase in investment variability is modest in comparison. Since our selected down-side risk measures are income sensitive, this results in a reduction in risk under longer strategies.

Regardless of the accounting convention, line of business, or the company's underwriting experience, the surplus (or equity) at the end of the projected period (i.e., year 5) had, on average, a positive relationship with the length of the asset duration. That is, long duration strategies performed better than matched duration strategies, on average. Using traditional risk-return analysis, then, a matched portfolio is not inherently superior to a longer one. Although it may be less risky, it is also less profitable.

Note that some of the strength of our conclusions arises from our reliance on income-sensitive down-side risk measures such as VaR, which have the characteristic of being favorably influenced by increased return. This widens the range of scenarios under which increased return will yield lower risk, because for these measures an increase in return can actually *cause* a decrease in risk.

These findings are also consistent with the conclusions reached in the following CAS work on asset/liability matching:

- The 1989 Financial Analysis Committee article[4] identified the risk-return tradeoff (matching is less risky, and also less rewarding, but not necessarily better or worse than longer investments). Special cases of

[4] Financial Analysis Committee, "A Study of the Effects of Asset/Liability Mismatch on P&C Insurers."

expected value outcomes were examined under a limited set of scenarios such as rising and declining interest rates.

- In 1992, preliminary research[5] indicated that income-adjusted down-side risk measures might decrease as insurers invest in assets with longer duration. This result obtained under a variety of surplus assumptions, including market (i.e., economic) surplus, and is similar to those we observed under some of our scenarios.

Further Research

Our modeled results do not consider economic surplus, which would include discounting of the claim liabilities. Further research is needed to assess the impact on duration analysis of using economic assumptions across both assets and liabilities. Such an analysis is the subject of an anticipated followup to this paper.

Limitations on Analysis

A major source of uncertainty surrounding these findings is the appropriateness of the models used to derive the findings. Two components of model risk are (1) errors in the model and (2) appropriateness of the model as an approximation of the situation being modeled. We have addressed the first of these components by performing these analyses using two independent dynamic financial analysis models: the proprietary model developed and used by Milliman USA; and a proprietary model developed by Guy Carpenter. The results presented herein were derived from the Milliman model. The findings of the Carpenter model, which were used for verification and validation of the results shown, were generally consistent with those presented in this paper.

Many simplifications and approximations remain. Therefore, care must be taken to consider the scope of this analysis when seeking to draw conclusions from its findings.

[5] Grannan, Patrick J., Transcript of presentation at Asset/Liability Matching Session, at the 1992 Casualty Actuarial Society's Valuation Issues Seminar (unpublished). Copies available from Casualty Actuarial Society upon request.

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INTEREST RATE RISK: DURATION ANALYSIS

Line: Workers' Compensation

	Historical Base Period	Projected Period				
	0	1	2	3	4	5
Selected Loss and ALAE Ratio by Accident Year:						
Typical:	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
Adverse:	80.0%	110.0%	110.0%	110.0%	110.0%	110.0%
Underwriting Expense Ratio by Acc. Year:	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Unearned Premium:	4,762					
Tax Payment Pattern:	Used the most recent IRS WC pattern by accident year.					
Written Premium: (+5%)	9,524	10,000	10,500	11,025	11,576	12,155
Written Premium: (-5%)	9,524	9,048	8,595	8,165	7,757	7,369
Balance Sheet						
Cash	337					
Bonds	33,375					
Income Taxes Payable:	50					
Surplus	7,714					
Income Statement (Statutory values = GAAP values)						
Earned Premium	9,297					
Investment Income	1,500					
Incurred Losses	7,438					
Underwriting Expenses	2,857					
Income Taxes Incurred	200					
Cash Flow Statement						
Premium Collected	9,524					
Interest Dividends Received	1,500					
Losses Paid	6,558					
Underwriting expenses paid	2,857					
Income taxes paid	200					
Tax Discount Rate by Accident Year		0.063	0.063	0.063	0.063	0.063

Note: Dollars are in thousands.

INTEREST RATE RISK: DURATION ANALYSIS

Line: Workers' Compensation

Historical Period	Selected Loss & ALAE Reserves at End of Historical Period	Age	Expected Incremental Payment Pattern (*)
-19	$0	0	24.0%
-18	31	1	28.0%
-17	65	2	13.0%
-16	102	3	7.0%
-15	143	4	4.0%
-14	188	5	3.0%
-13	236	6	2.0%
-12	290	7	2.0%
-11	391	8	2.0%
-10	502	9	2.0%
-9	623	10	2.0%
-8	755	11	2.0%
-7	899	12	2.0%
-6	1,055	13	1.0%
-5	1,224	14	1.0%
-4	1,469	15	1.0%
-3	1,799	16	1.0%
-2	2,361	17	1.0%
-1	3,400	18	1.0%
0	5,653	19	1.0%
Total	$21,186	Total	100.0%

Note

(*) Variability was added to the payment pattern at each incremental payment date based on lognormal draws. The variability of the draws was set such that the coefficient of variation of the claims liabilities duration as of the statement date is approximately 25%.

INTEREST RATE RISK: DURATION ANALYSIS

Line: Homeowners

	Historical Base Period	Projected Period				
	0	1	2	3	4	5
Selected Loss and ALAE Ratio by Accident Year: (excluding CAT loss ratio)						
Typical:	62.5%	62.5%	62.5%	62.5%	62.5%	62.5%
Adverse:	62.5%	77.5%	77.5%	77.5%	77.5%	77.5%
Underwriting Expense Ratio by Acc Year:	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
CAT Expected Loss Ratio	10.0%	10.0%				
Unearned Premium:	4,762					
Tax Payment Pattern:	Used the most recent IRS Homeowners pattern by accident year.					
Written Premium: (+5%)	9,524	10,000	10,500	11,025	11,576	12,155
Written Premium: (-5%)	9,524	9,048	8,595	8,165	7,757	7,369
Balance Sheet						
Cash	337					
Bonds	33,375					
Income Taxes Payable:	50					
Surplus	21,741					
Income Statement (Statutory values = GAAP values)						
Earned Premium	9,297					
Investment Income	1,500					
Incurred Losses	6,740					
Underwriting Expenses	2,857					
Income Taxes Incurred	200					
Cash Flow Statement						
Premium Collected	9,524					
Interest Dividends Received	1,500					
Losses Paid	6,400					
Underwriting expenses paid	2,857					
Income taxes paid	200					
Tax Discount Rate by Accident Year		0.063	0.063	0.063	0.063	0.063

Note: Dollars are in thousands

INTEREST RATE RISK: DURATION ANALYSIS

Line: Homeowners

Historical Period	Selected Loss & ALAE Reserves at end of Historical Period	Age	Expected Incremental Payment Pattern (*)
-19	$0	0	56.0%
-18	0	1	21.9%
-17	0	2	6.1%
-16	0	3	7.3%
-15	0	4	0.8%
-14	0	5	2.2%
-13	0	6	2.1%
-12	15	7	0.9%
-11	31	8	0.6%
-10	49	9	0.4%
-9	69	10	0.4%
-8	91	11	0.4%
-7	126	12	0.4%
-6	176	13	0.4%
-5	297	14	0.0%
-4	434	15	0.0%
-3	505	16	0.0%
-2	978	17	0.0%
-1	1,419	18	0.0%
0	2,969	19	0.0%
Total	$7,159		100.0%

Note

(*) Variability was added to the payment pattern at each incremental payment date based on lognormal draws. The variability of the draws was set such that the coefficient of variation of the claims liabilities duration as of the statement date is approximately 25%.

INTEREST RATE RISK: DURATION ANALYSIS

Line: Homeowners

Annual Probability of a CAT event	CAT Severity Under +5% Premium Growth Scenario					CAT Severity under -5% Premium Decline Scenario				
	Projected Year					Projected Year				
	1	2	3	4	5	1	2	3	4	5
6.25%	$15,619.20	$16,400.16	$17,220.17	$18,081.18	$18,985.24	$14,857.30	$14,114.44	$13,408.71	$12,738.28	$12,101.36

Appendix B

INTEREST RATE RISK: DURATION ANALYSIS

Approximate Interest Rate Scenario
Used In Model

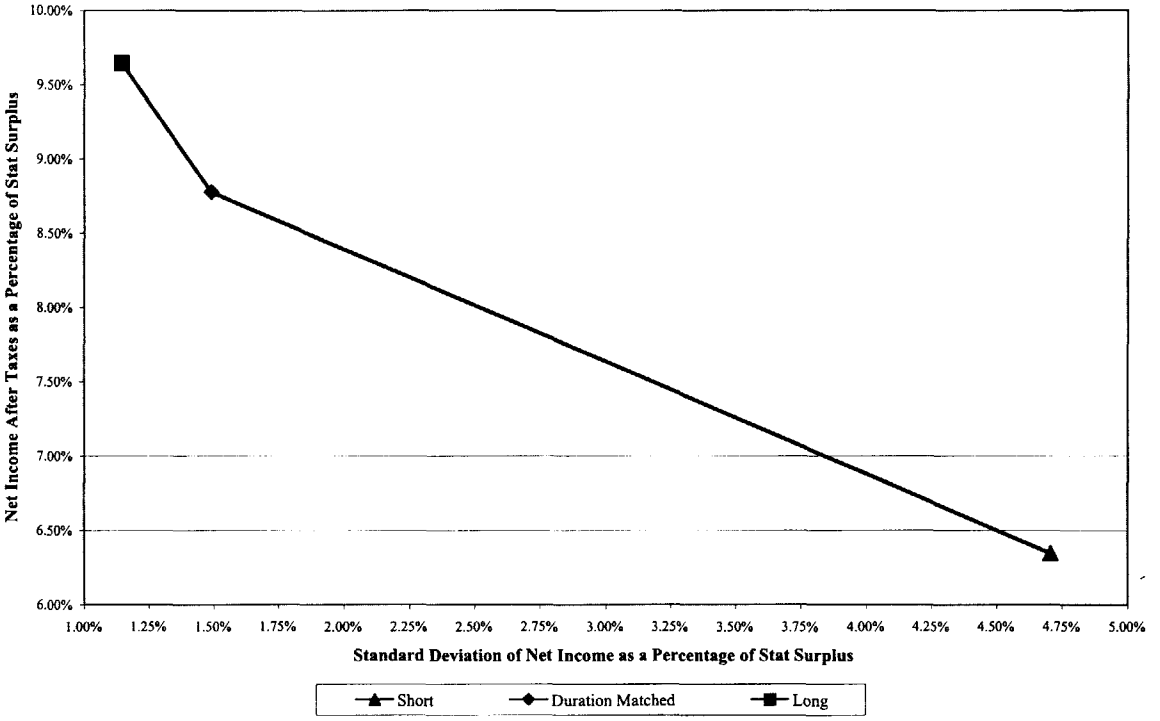
	Projected Year				
Year	1	2	3	4	5
Short Term Rate					
Mean	5.5%	5.5%	5.5%	5.5%	5.5%
Std. Dev.	1.2%	1.6%	1.8%	1.9%	2.0%
Min.	2.0%	1.0%	1.0%	1.1%	1.0%
Max.	9.5%	11.9%	11.7%	12.2%	12.1%
CV	21.1%	29.5%	32.3%	34.6%	36.0%
Long Term Rate					
Mean	7.0%	7.0%	7.0%	7.0%	7.0%
Std. Dev.	0.9%	1.2%	1.4%	1.4%	1.5%
Min.	4.2%	3.1%	2.8%	2.9%	2.8%
Max.	9.7%	11.2%	11.6%	12.0%	11.8%
CV	12.1%	17.3%	19.4%	20.6%	21.2%

Rates other than short and long term reflect selected yield curve.

WORKERS COMPENSATION COMPANY

Normal Loss Ratio (80%), Increasing Premium (5% per year)

Statutory (excludes bond unrealized capital gains/losses)

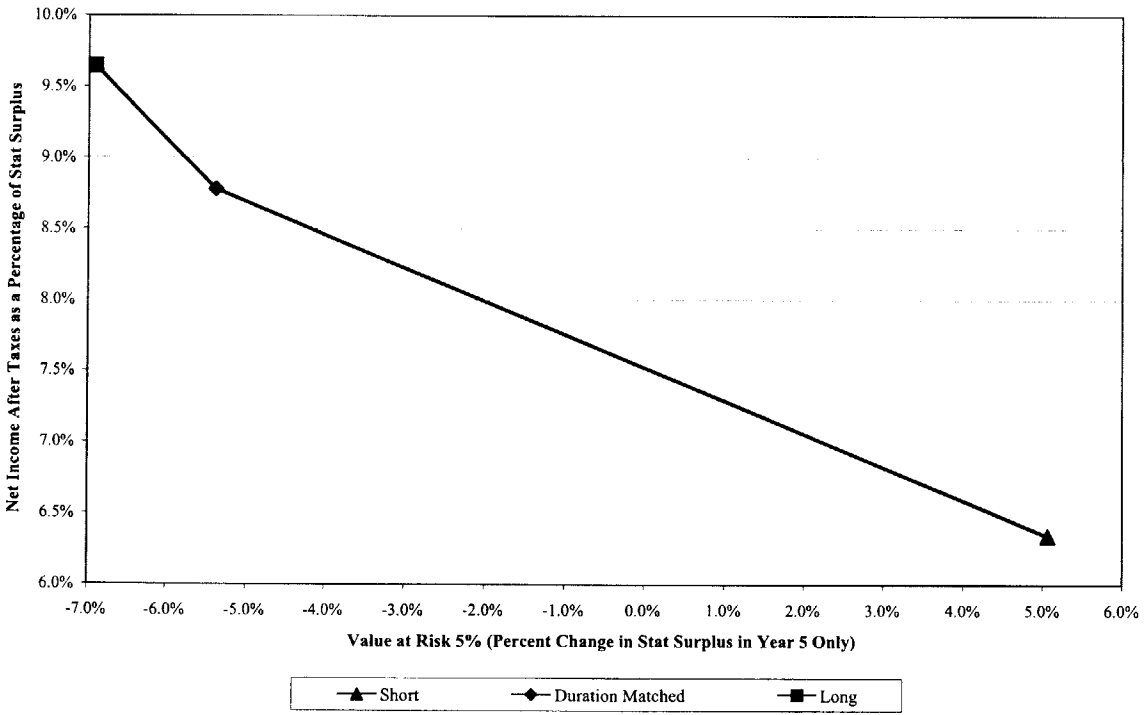


Note: Lines between plotted points do not represent tested scenarios, but only approximate the shape of the actual curve.

WORKERS COMPENSATION COMPANY

Normal Loss Ratio (80%), Increasing Premium (5% per year)

Statutory (excludes bond unrealized capital gains/losses)

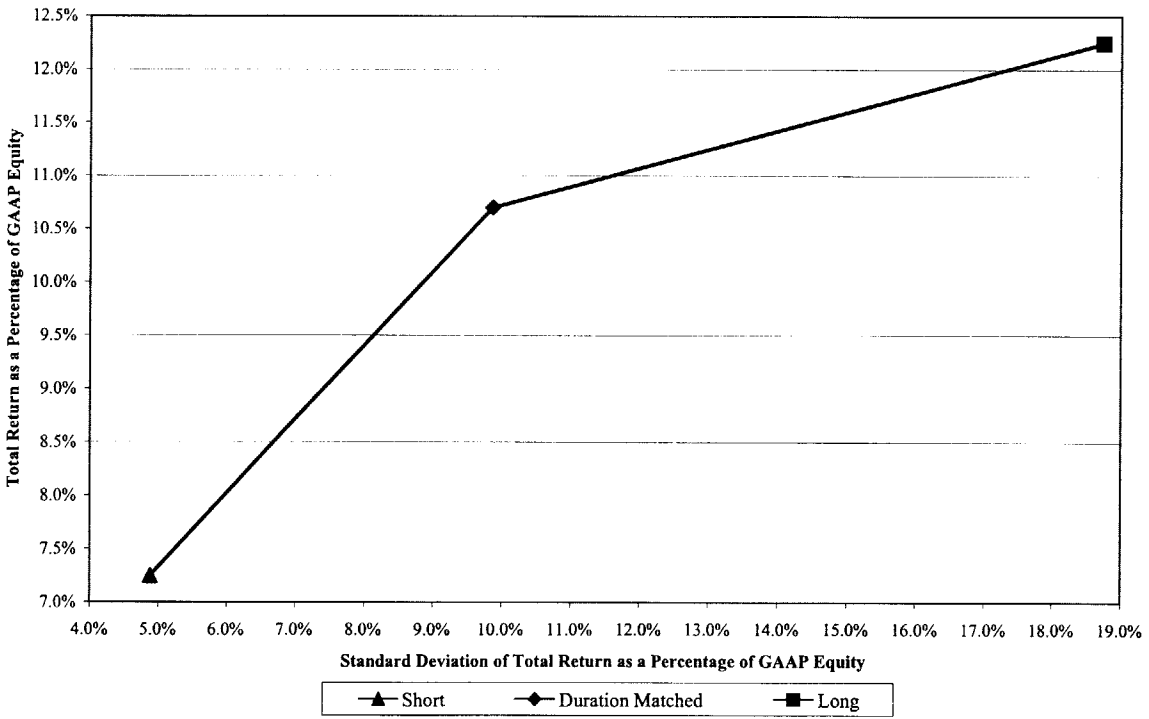


Note: Lines between plotted points do not represent tested scenarios, but only approximate the shape of the actual curve.

WORKERS COMPENSATION COMPANY

Normal Loss Ratio (80%), Increasing Premium (5% per year)

Adjusted GAAP (includes tax-adjusted bond unrealized capital gains/losses)

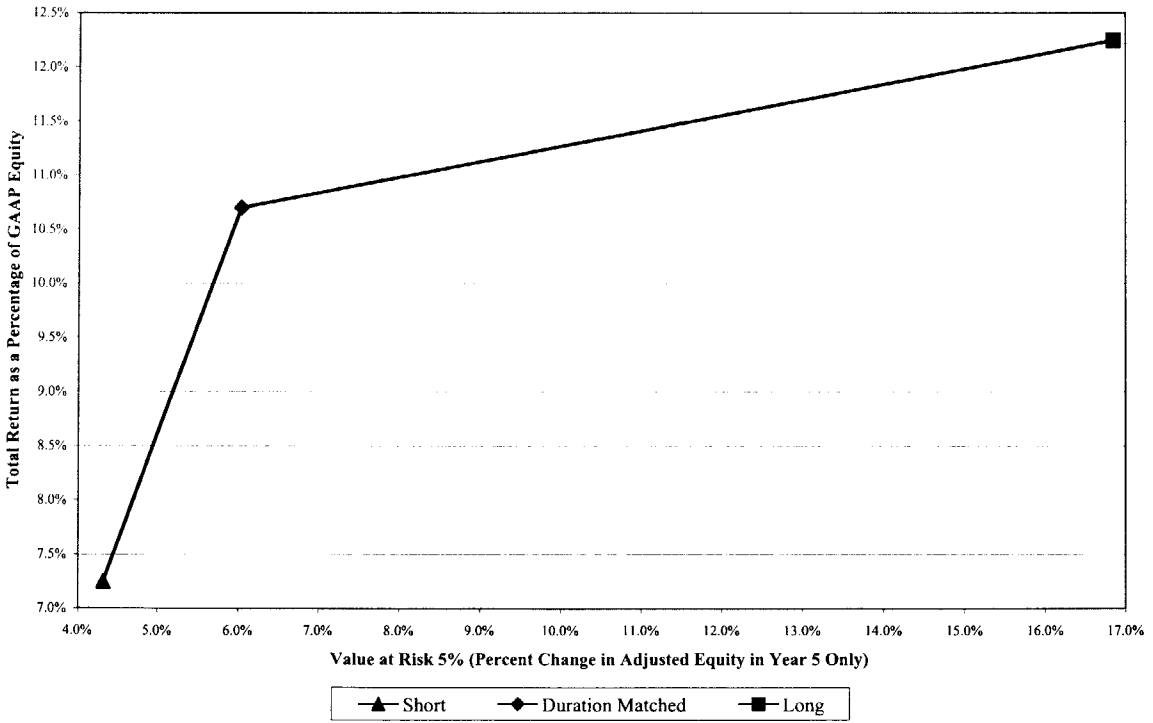


Note: Lines between plotted points do not represent tested scenarios, but only approximate the shape of the actual curve.

WORKERS COMPENSATION COMPANY

Normal Loss Ratio (80%), Increasing Premium (5% per year)

Adjusted GAAP (includes tax-adjusted bond unrealized capital gains/losses)



Note: Lines between plotted points do not represent tested scenarios, but only approximate the shape of the actual curve.