
Martin L. Leibowitz

A New Perspective on Asset Allocation

The Research Foundation of
The Institute of Chartered Financial Analysts

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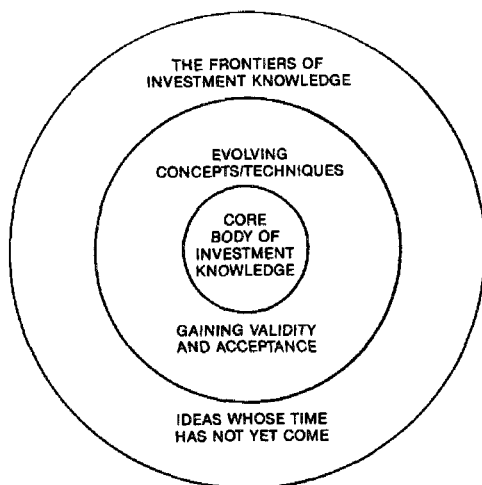
ISBN 10-digit: 0-943205-00-X ISBN 13-digit: 978-0-943205-00-7

Printed in the United States of America

Mission

The mission of the Research Foundation is to identify, fund, and publish research material that:

- expands the body of relevant and useful knowledge available to practitioners;
- assists practitioners in understanding and applying this knowledge, and;
- enhances the investment management community's effectiveness in serving clients.



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Foreword

James R. Vertin, CFA

The effective development and well-being of any professional endeavor depends upon knowledge expansion and enhancement. Nowhere is this more apparent than in the investment management profession, where mushrooming complexity in recent years has threatened to overtake the ability of practitioners to keep themselves fully informed. At the same time, the availability of high-quality, practitioner-oriented investment research has declined, in part because many of the most able researchers have moved to other areas of the profession and are no longer involved in the exploration of the knowledge frontier or the public dissemination of research results. A gap is developing between the realities of the investment professional's world and the availability of the requisite knowledge with which to address these realities successfully.

The Research Foundation of the ICFA is committed to the task of closing this gap. The Foundation, extensively reorganized in the recent past, intends to spark nothing less than a research renaissance by providing funding for research that addresses areas of fundamental importance, as well as neglected and as-yet-unexplored issues of concern to the investment management community and its clients.

The mission of the Research Foundation is clearly stated: to identify, fund, and publish high-quality research material that expands the body of useful and relevant knowledge available to practitioners; assists practitioners in understanding and applying this knowledge; and contributes to the investment management community's effectiveness in serving clients.

Given the nature of its mission, it is particularly fit-

ting that the Research Foundation's first publication is a monograph written by Martin Leibowitz, an eminent practitioner and respected researcher, on a topic of great moment and practical importance. In his Preface, Leibowitz brings us face-to-face with the immediacy of the issue defined and addressed in this paper. Subsequently, with patience, skill, and clear-cut explanations, he leads us to understand what it means when he says that "When the future liabilities of a fund are taken into account, a dimension of risk quite different from the risk of fluctuation in the market value of assets becomes prominent." He points out that practitioners lack standard conceptual guideposts against which to check their bearings (and make useful judgments), and provides us with a good foundation for filling this void. From beginning to end, he is precise and pragmatic in his exposition.

Leibowitz's insightful findings and effective presentation are representative of the knowledge that the Foundation seeks to provide to the investment management community: relevant, high-quality research that affords investment professionals the opportunity to expand and enhance their knowledge, skills, and understanding. We are grateful to Dr. Leibowitz for sharing his work so generously.

James R. Vertin, CFA
President
Research Foundation of the Institute
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December 1987

Preface

The allocation of portfolio assets has seldom seemed so critical to the growth of the pension fund, so fraught with economic peril, or so lacking in standard conceptual guideposts against which the investment manager can check his bearings. Investors shaken by the terrifying spectacle of the equity markets in October 1987 must now confront a world in which the familiar relations between risk and expected return may no longer be taken for granted. Yet even before the October debacle, pension fund managers had begun to realize that many comfortable assumptions about those relations would have to be reviewed. When the future liabilities of a fund are taken into account, a dimension of risk quite different from the risk of fluctuation in the market value of assets becomes prominent. That risk is the fluctuation of interest rates and its impact on the fund's liabilities.

In the study that follows, we examine the effect of historical interest-rate movements on the present value of the liabilities of a typical pension fund. We then compare the performance of these liability values with the performance of several different mixtures of asset classes. In this way, we can trace the variations in what we call the surplus function—the excess of the market value of the fund's assets over the present value of its liabilities.

The most surprising result of this analysis is the volatility of the surplus function and its sensitivity to interest rates. This sensitivity is particularly high for asset allocations that are heavily concentrated in equities. Adopting an idea from the fixed-income markets, we show how the concept of "duration" may be used as a measure of the interest-rate sensitivity of

assets, liabilities, and the surplus function itself. This unifying measure points the way for incorporating interest-rate sensitivity into decisions about asset allocation. In particular, the traditional asset allocation approach of focusing only on asset class percentages is shown to be an inadequate procedure for the control of overall portfolio risk or surplus-function risk.

The author would like to express his appreciation to Peter G. Brown for his assistance in preparing this manuscript.

Introduction

By any performance standard, the bond and stock markets have provided extraordinary returns during the 1980s. Professional investment managers may have mixed feelings as they compare their own performance with broad market return indexes. Few managers of real-life portfolios with real-life clients have found themselves totally free of the return-dampening influences of portfolio cash, calls, refundings, prepayments, or the cautionary impulses that naturally follow a rally which thunders forward for one record-setting week after another. Money managers may have mixed feelings, but their sponsor clients are elated. In particular, pension fund sponsors—virtually regardless of their pattern of asset allocation—have seen their assets surge to astonishing levels. With such superb absolute performance, it may seem petty to fault their managers' relative performance when it falls somewhat short of the broad market indexes.

The general euphoria among sponsors may be shortsighted. Assets are not the only component of the pension fund structure that have grown apace during the past several years. Quietly and without the fanfare of broadly-cited performance numbers, the cost of pension liabilities also has exploded. This extraordinary growth

in liability costs—this high level of “liability returns”—has been fueled by the same dramatic decline in interest rates that has driven the historic rally in bonds and stocks.

The net impact of these two forces varies greatly from one fund to another. In many cases, however, the liability return has far outdistanced the fund’s asset growth. The liability portfolio, after all, is relatively free of the return-dampening factors that restrain the asset portfolio—for example, calls, refundings, prepayments, and cautionary or frictional cash components. The growing realization of the importance of liability returns has led to a renewed focus on the linkage between a pension fund’s asset returns and its liability framework. The most direct method for quantifying this linkage is through a surplus function: the amount by which the market value of a fund’s assets exceeds the present value of its liabilities. A fund with an ample surplus is deemed comfortably situated, while a fund with a negative surplus (that is, a deficit) must address the need for catch-up funding.

The vulnerability of the surplus value may be quite surprising. The volatility of stocks, bonds, and other asset classes used in modern asset allocation is well recognized. The volatility in the value of liabilities, however, has not received comparable attention, perhaps because more traditional approaches to liability have dominated actuarial practice. With the new initiatives of Financial Accounting Standards Board (FASB) Statement No. 87 (FAS 87) and the removal of the traditional smoothing techniques, interest-rate movement is the central factor linking assets and liabilities. Because rate-driven changes in liability value may represent a greater threat to a plan’s surplus than any other potential variation in portfolio value, this

oversight clearly may lead to inappropriate asset allocations. Indeed, this danger looms particularly large in light of the interest-rate volatility in recent markets.

The analysis that follows is based on three articles published in 1986: "Total Portfolio Duration" (February 1986), "Liability Returns" (May 1986), and "Surplus Management" (September 1986). Chapter 2 of this monograph describes a measure of total portfolio duration. One is in a much better position to assess the impact of various allocations on the vulnerability of the surplus value when the duration measure encompasses both the fixed-income component and all asset classes in the fund. In fact, a total duration measure may be computed for equity portfolios, and this measure may be integrated into a total duration measure for portfolios consisting of fixed-income and equity components. The method used in constructing this measure may, in theory, be extended to cover other types of assets as well. Moreover, this method does not depend on any specific valuation model, such as dividend discount models or growth models, for stock market behavior; rather, it relies only on the statistical measures currently used in virtually all asset allocation procedures.

Having specified a measure of the interest-rate sensitivity of a total portfolio, the monograph then discusses the rate sensitivity of a representative liability structure and shows how liability returns compare with market performance in recent months and over longer historical periods. This discussion has major implications for the structure of the asset allocation process for pension funds. One clear finding is that for many pension funds interest-rate volatility is a key, if not overriding, risk factor affecting surplus status. Because a fund's total portfolio duration provides a

measure of control for this risk, asset allocations should be determined with at least some consideration of the resulting total duration value. More specifically, the process of asset allocation should be expressed not in stock-to-bond ratios, as is the current general practice, but in terms of equity weightings and total portfolio duration.

The third section of this monograph combines the approaches of the first two to explore how interest-rate movements would have affected a hypothetical surplus position over the past several years. Interest-rate sensitivity is an important consideration in determining the growth or erosion of the surplus level based on the results of this analysis. Traditional asset allocations of stocks and bonds are shown to lead to highly vulnerable surplus functions. Indeed, it appears that throughout most of the 1980s there would have been considerable erosion in the surplus posture of a typical fund. This result is quite striking in light of the extraordinary positive market returns achieved during this period.

Total Portfolio Duration

A liability framework of a given pension fund may be quite complex and may have many dimensions. One can assume, however, that at least one clear-cut liability value may be defined that responds in a prescribed fashion to movements in interest rates. Thus, for a corporate pension fund concerned with the potential for reversion at some point, the surplus function becomes the cost of the insurance company annuity package needed to cover these liabilities.

The liability framework is illustrated in Figure 1. The present value of the liabilities and the market value of the assets are depicted on the vertical axis; the horizontal axis corresponds to changes in the interest rate. When the liabilities are defined in terms of a fixed stream of nominal dollar payments, the present value pattern exhibits the convex response curve shown in Figure 1.

The risk-free posture is illustrated in Figure 2. If the portfolio is invested totally in cash instruments, so that there is no change in market value with instantaneous market movements, then the asset values trace out on the horizontal line. This represents the conventional zero-variability definition of a risk-free asset.

The Surplus Function

Risk-Free Postures

Variance in market value may mask significant movement in the value of the surplus function. Thus, as interest rates move lower, the present value of the liabilities rises, and the surplus shrinks against a fixed

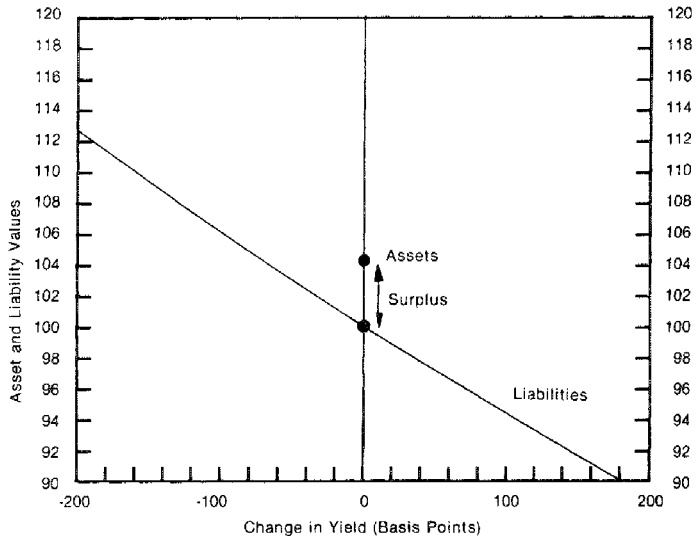


Figure 1. The Liability Framework

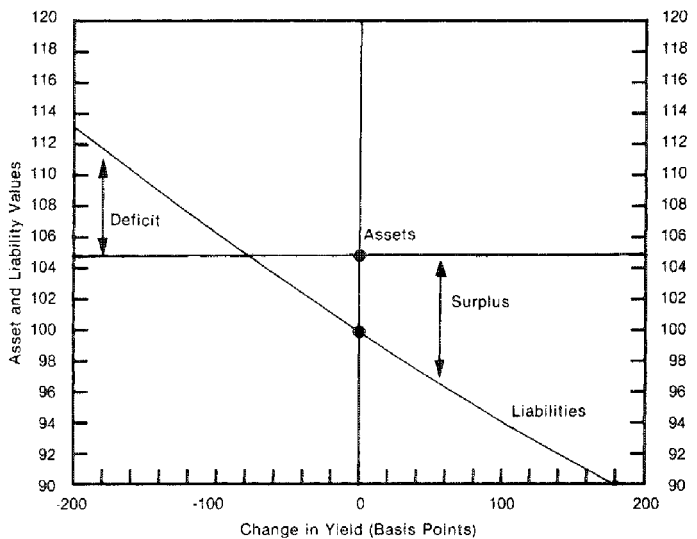


Figure 2. The Cash Portfolio

market value for the risk-free asset. To be risk free in terms of the surplus function, the assets would have to preserve their altitude above the changing liability values, as shown in Figure 3. This concept is called

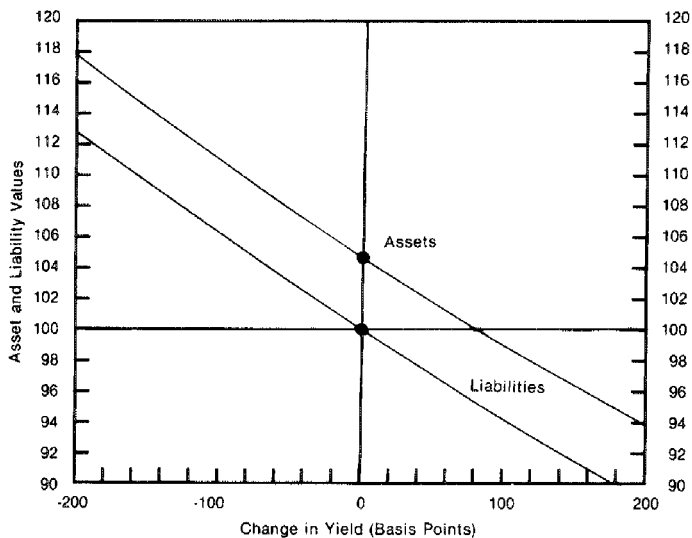


Figure 3. The Surplus—Risk-Neutral Portfolio

surplus invariance, and it may be based on maintaining either the dollar value or the percentage value of the assets to the liabilities.

In the fixed-income area, the concept of duration has proven a valuable tool for gauging the sensitivity of present values to movements in interest rates [Kopprasch (1985)]. This tool also may be applied to liabilities when they are defined as a stream of nominal dollar payments. When dealing with a 100 percent fixed-income portfolio, one may create a risk-neutral position by balancing the duration of the assets against that of the liabilities to achieve the posture depicted in Figure 3. In fact, this approach forms the basis for the immunization/dedication procedures that emerged with such force early in this decade.

It would be highly desirable to extend this approach to portfolios with both fixed-income and equity components. To do this, a technique for estimating the interest-rate sensitivity of an equity portfolio is needed.

The Co-Movement of Stocks With Bonds

Virtually all asset allocation procedures use estimates of variance and correlation among different asset classes. These estimates are often extracted from historical periods and may be derived either directly or through building block premia approaches [Ibbotson and Sinquefeld (1982)]. Historical values may be adjusted to reflect anticipated changes in market dynamics. For example, suppose a fund sponsor believes that all earnings and economic trends are fully impounded in market prices, with little prospect for surprises. Then, one might conclude that the stock market's behavior in the coming period will be determined largely by changes in interest rates. With such assumptions, a historically large value may be selected for the positive correlation between the stock and bond markets.

At other times, the user of an asset allocation model may feel that economic events will dominate—in one direction or another—the impact of any changes in interest rates. This reasoning leads to a low correlation value by historical standards. Indeed, under some circumstances, a negative correlation value may be chosen to reflect the classical view of the antithetical movement between stocks and bonds. The impact of unexpected inflation also may be used to modify historical correlation values, assuming that agreement exists on a model for this intricate relationship.

In any case, variance and correlation values of some sort are currently utilized in the normal course of conventional asset allocation procedures. Such estimates

are not alien or highly-modeled numbers that are hard to determine outside the normal decision-making process. In the more traditional procedures, variance estimates are used to evaluate the short-term variability for portfolios consisting of various asset mixes. A trade off analysis is then performed by comparing the expected return for each asset mix with these short-term variance measures. The decision maker will then select an optimal asset mix that provides the best possible return, given certain constraints on short-term variability.

In a liability framework with a well-defined surplus function, short-term variability is not a comprehensive risk measure. For example, consider an immunization situation in which the total portfolio consists of fixed-income securities that match the duration of the liabilities. Sizable fluctuations in the portfolio's value will be fully compensated for by the changing liability valuation, and the surplus value will remain largely intact. Clearly, extending this immunization principle to a portfolio containing both stocks and bonds would be helpful to asset allocation in a liability framework. Such an extension would be beneficial even if it were only statistical, rather than the primarily deterministic result found for bonds. Any estimate of the stock-bond correlation may be used to develop a duration value for stocks. This equity duration component is then used to create a total duration measure for portfolios with both stock and bond components.

The duration of individual stocks and of the entire stock market has been addressed by several authors (see *References*). This research, however, has generally assumed a context of dividend/earnings discount models. Dividend discount models transform a stock

The Stock-Market
Duration

investment into a stream of future estimated payments. Once this is done, as with any payment stream, it becomes a simple matter to calculate the duration value.

The problem with this approach is that the models used to project the payment streams are not universally accepted. Many market participants have difficulty developing credible estimates for near-term payouts, much less for distant flows of dividends or earnings. Such use of discount models is further complicated by the effect that significant interest-rate changes have on the estimated payment streams. For this reason, stock duration values have not been broadly accepted outside the discount-model community, which computes them in their own fashion and uses them for their own rather specialized purposes. Certain studies have addressed the empirical elasticity of stock returns to interest-rate movements [Haugen, Stroyny and Wichern (1978), Haugen and Wichern (1974) and Lanstein and Sharpe (1978)]. These papers, however, focus primarily on interest rates as one of several factors affecting the behavior of various classes of common stock.

A more productive approach to estimating stock market duration is to draw upon the variance parameters routinely used and accepted in conventional asset allocation studies. Once one has accepted—by whatever means—estimated *ex ante* values for the variance of stock market returns, the variance of bond returns, and the correlation between the two asset classes, a duration-like measure is readily derived for the stock market, as well as for specific stock portfolios. (The mathematics underlying this derivation are provided in the Appendix.) The estimated duration (D_e) for the equity market is given in the following equation,

$$D_E = \left(\frac{\sigma_E}{\sigma_B} \right) \rho(E, B) D_B$$

where D_B is the duration of a broad-based measure of the bond market, such as the new Salomon Brothers Broad Investment-Grade (BIG) Bond IndexTM; σ_B is the standard deviation of bond market index returns; σ_E is the standard deviation of stock market returns; and $\rho(E, B)$ is the correlation of returns between the two markets.

This stock market duration value is, admittedly, a statistically-derived concept and consequently subject to uncertainty in its own right. It relates the stock market returns (R_E) to movements in long-term interest rates through the following equation,

$$R_E = A - D_E \tilde{\delta} + \tilde{e}$$

where A is the intercept, δ is the movement in long-term rates, and \tilde{e} is the stock market movement attributable to all other market forces. This concept of stock market duration may be extended to provide durations for stock portfolios with different beta values.

The calculation of stock market durations using variance parameters based on historical experience is illustrated in the following example. Consider the history of monthly returns from January 1980 to November 1985. The S&P 500 Composite Index is a proxy for the broad stock market; the New Salomon Brothers BIG Index is taken as a bellwether for the bond market [Leibowitz (1985)].

Historical Example

The cumulative return series for the two asset classes over this period is shown in Figure 4. The trailing 12-month standard deviations of these monthly returns are plotted in Figure 5. The average volatility

over this period was 14.2 percent for the S&P 500 and 9.5 percent for the Salomon Brothers BIG Index. Over time, stock market volatility has varied over a wide range, from a standard deviation of 7 percent to one as

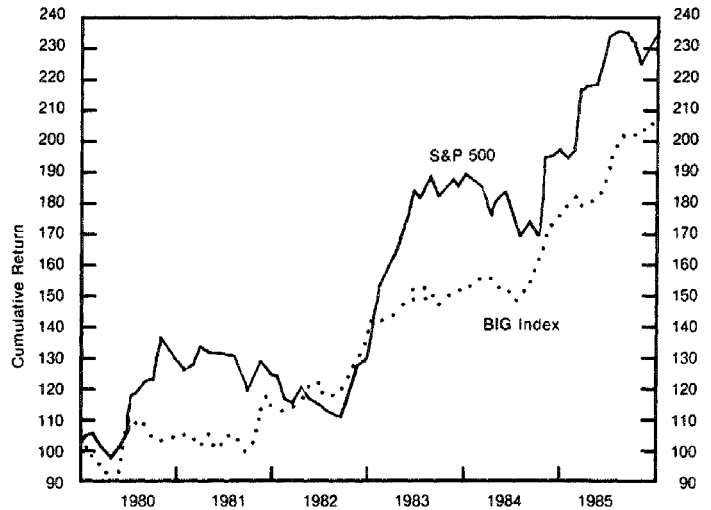


Figure 4. Cumulative Returns: Fixed-Income and Equity Markets, 1980-1985

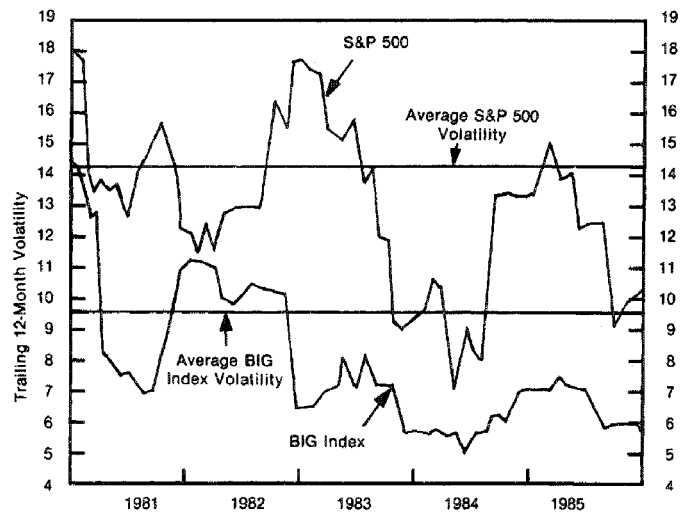


Figure 5. Rolling One-Year Volatility: Fixed-Income and Equity Markets, 1981-1985

high as 18 percent at the beginning of 1983. Over this same period, the bond market's volatility generally declined.

As shown in Figure 6, the correlations averaged

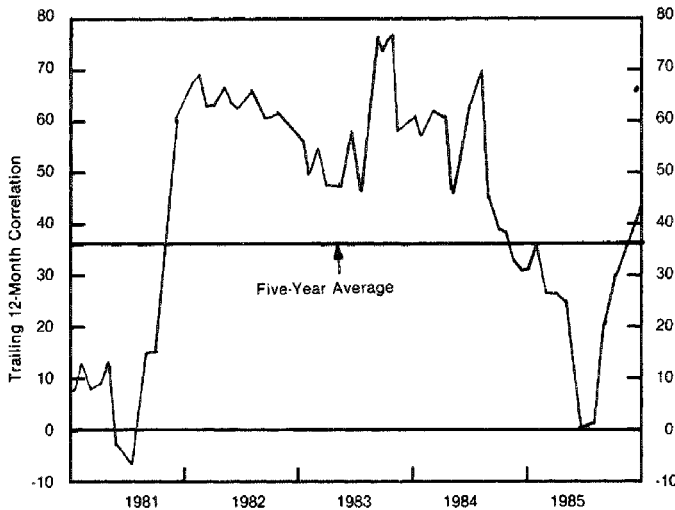


Figure 6. Rolling One-Year Correlations: Fixed-Income and Equity Markets, 1981-1985

0.34, but ranged from slightly negative to almost 0.8. The correlation hovered between 0.4 and 0.8 for the two-and-a-half years from January 1982 to mid-1984. Thus, while there are wide variations in historical volatility, there are also long periods when the volatilities and the correlations remain stable. These results may justify using either *ex ante* correlations that correspond with these locally stable historical values, and therefore depart from the long-term average, or choosing quite different modified estimates based on anticipated changes in the character of the markets.

The first step in computing total portfolio duration is to use the average variability values over this five-year period to estimate the correlation of S&P returns with bond market returns. The regression is illustrated in

Figure 7. Clearly the correlation is not strong, although the scattergram and the correlation of 0.34 suggest that the relationship is significant. (One would expect to find much stronger correlations and tighter

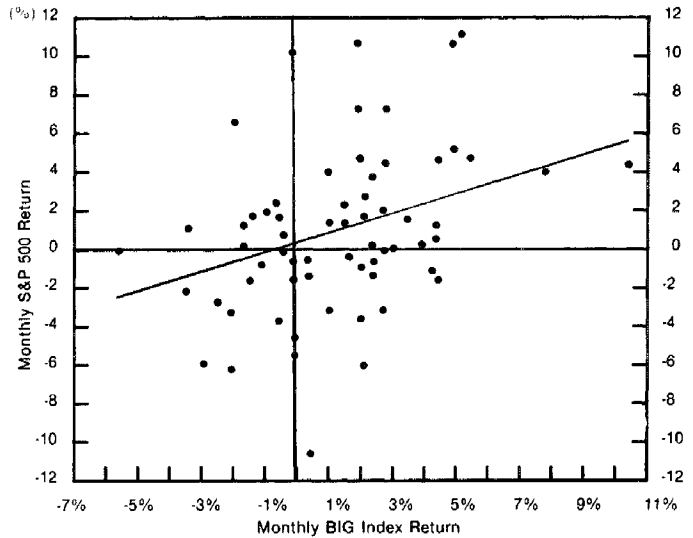


Figure 7. S&P 500 Return Versus BIG Index Return, January 1980-November 1985

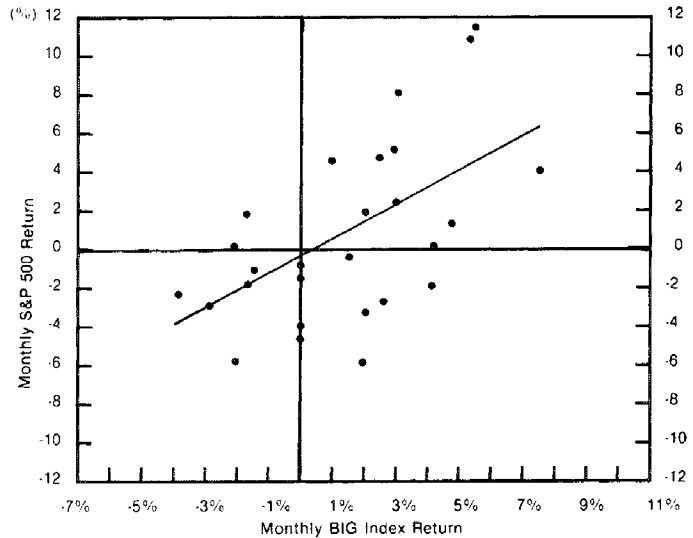


Figure 8. S&P 500 Return Versus the BIG Index Return, January 1981-July 1983

scattergrams by restricting oneself to specific periods such as the one depicted in Figure 8, which covers the period from 1981 to mid-1983. To maintain a more conservative posture in this example, however, the full five-year-period values represented in Figure 7 are used.)

The next step is to show the behavior of bond market returns to changes in a benchmark yield. Figure 9 illustrates the Salomon Brothers BIG Index

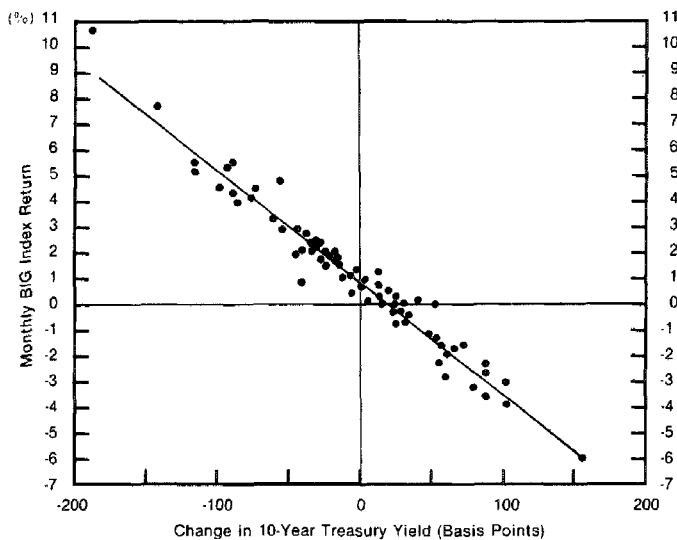


Figure 9. BIG Index Return Versus Change in 10-Year Treasury Yield, January 1980-November 1985

returns plotted against changes in 10-year Treasury yields. As expected, the scattergram is very tight, with a correlation of -0.98. From this diagram, one can determine an effective duration value for the bond market relative to 10-year Treasury yields. This value is 4.27, which is close to the 4.51 *pro forma* duration calculated mathematically for the BIG Index.

Figure 10 combines the two preceding results and plots the S&P returns against the changes in 10-year Treasury yields. The correlation is -0.34, and the implied stock market duration is 2.190. This value com-

compares favorably with the mathematically derived value of 2.186, based on the preceding equation. A total duration for a portfolio of both stocks and bonds may be computed using these historical values.

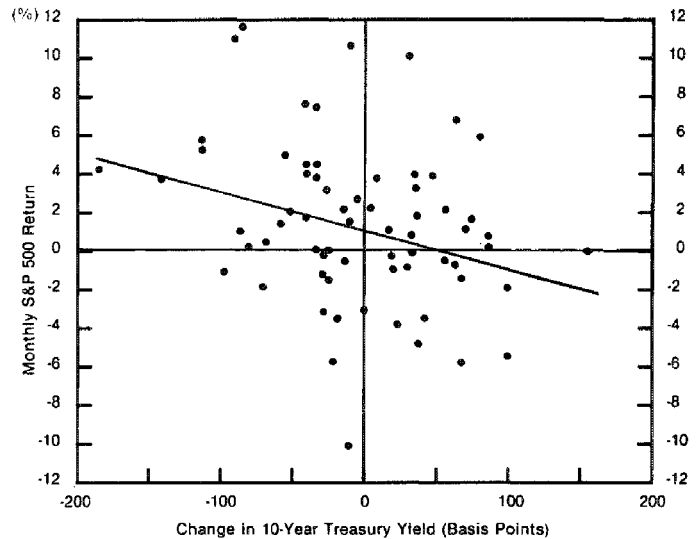


Figure 10. S&P 500 Return Versus Change in 10-Year Treasury Yield, January 1980-November 1985

Total Portfolio Duration

Total portfolio duration (D_{TP}) is given by the following formula,

$$D_{TP} = W_{BP}D_{BP} + W_{EP} \beta_{EP}D_E$$

where W_{BP} and W_{EP} are the fractional allocations to bonds and stocks; D_{BP} is the duration of the bond component; D_E is the duration of the stock component; and β_{EP} is the beta value of the equity portfolio. In this model, as derived in the Appendix, the beta characteristics of a stock portfolio are interpreted as magnifying *all* components of return on a pro-rata basis.

Continuing with the historical values used in the preceding example, consider a portfolio comprising 40 percent bonds with a duration (D_{BP}) of 4.27 and the re-

maining 60 percent in stocks with a beta (β_{EP}) of 1.
 From the above formula, the total portfolio duration is:

$$D_{TP} = 0.40 \times 4.27 + 0.60 \times 1 \times 2.19$$

$$= 3.02$$

With this, one can plot the sensitivity of a given portfolio in the surplus framework. The interest-rate sensitivity of the total portfolio and of the liabilities are shown in Figure 11.

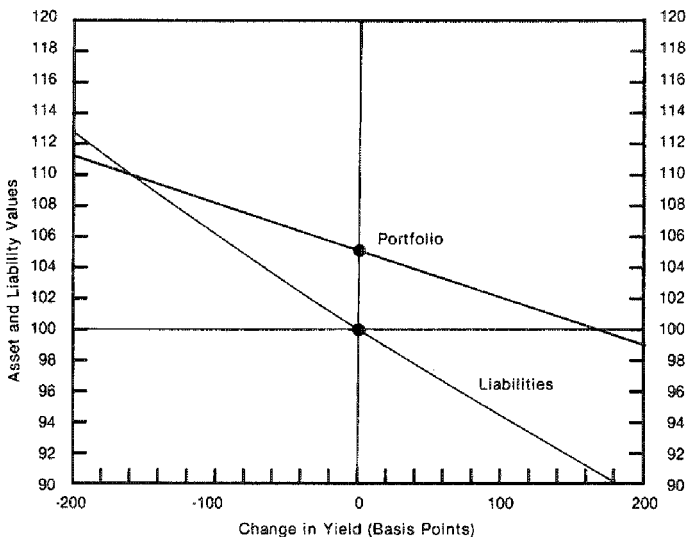


Figure 11. Total Portfolio Duration

The total duration concept is illustrated by plotting the value of the surplus—that is, the market value of the assets less the liability value—as a function of interest rates. For simplicity, the surplus function behavior is illustrated in Figure 12, assuming that a change in interest rates is the only factor affecting the market value of assets. Given this simplifying assumption, the initial slope of the surplus function is determined by the difference between the total portfolio duration and the liability duration (after adjustment for

the initial surplus value). For a given asset allocation, the shape of the surplus function depends on the assumed correlation. This dependence is more critical for portfolios with high equity percentages.

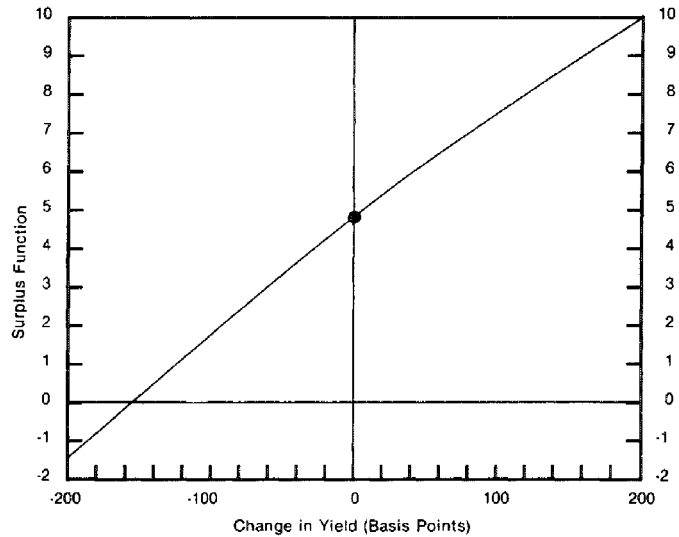


Figure 12. The Surplus Function

Using the example of a 60 percent/40 percent allocation, Figure 13 illustrates how different correlation assumptions cause the surplus function to rotate. Thus, the correlation assumption can play a key role in constructing asset allocations that satisfy specified risk constraints. Going one step further, this analysis suggests a concept of total portfolio immunization, whereby the surplus value is preserved across interest-rate movements.

The validity of any total portfolio immunization strategy is, of course, limited by the simplifying assumptions underlying Figures 12 and 13. Additional variability from market factors may move the surplus value up or down independently of any changes in interest rates. In addition, the total duration value is an

estimate and is therefore subject to error and to statistical variability. Thus, the total portfolio response might vary with the outcome of various statistical factors, adding another element of uncertainty to the

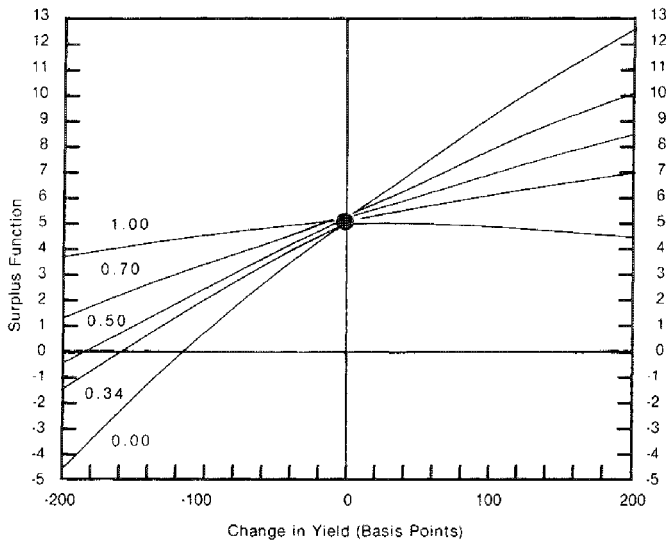


Figure 13. Surplus Function Under Different Correlation Assumptions

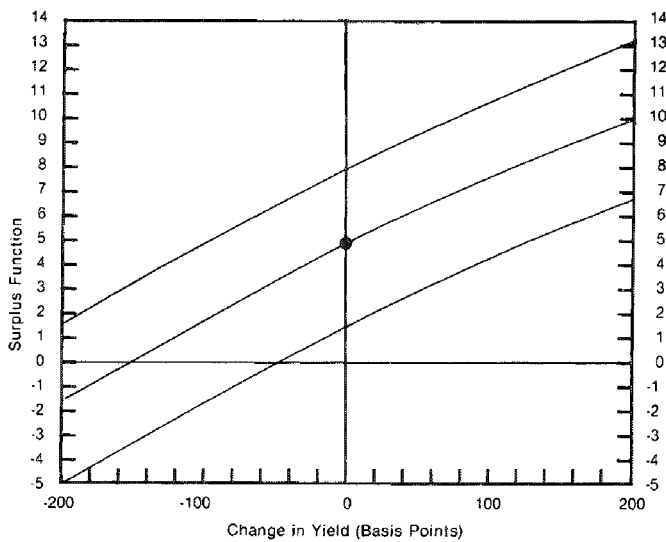


Figure 14. 80 Percent Confidence Bands on Surplus Function

surplus values, as illustrated schematically in Figure 14.

Total portfolio duration is a valuable measure of the sensitivity of the surplus function to interest rates, but it is only one of several risk factors. In some circumstances it may be the primary factor, depending on the allocation percentage, the degree of correlation, and the magnitude of interest-rate movements. Total portfolio duration should account for a significant part of the surplus movement when there are large changes in interest rates, which is precisely when the concept is most valuable. In other words, the total duration measure may be most reliable in periods when it is most needed.

Total portfolio duration is a function of the allocation to the bond market and of the correlation assumption. Figure 15 provides an illustration of these relationships

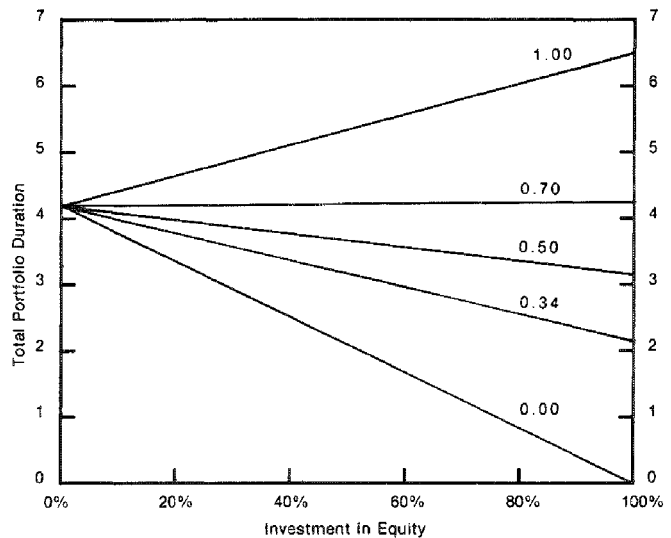


Figure 15. Total Portfolio Duration for Different Allocations and Correlations

using the data from the earlier numerical example. With a correlation of zero—that is, when the two asset

classes are independent—the total duration declines from the duration of the bond market for a 100 percent bond portfolio to zero for a portfolio without bonds. At a correlation of 0.34, the total duration is 4.27 for an all-bond portfolio and declines to 2.19 for an all-stock portfolio. With positive correlations of 0.70 or higher, the duration of the portfolio rises as the stock market component increases.

This analysis suggests that the traditional framework for characterizing the allocation of asset classes may be inappropriate in a surplus function framework. The total portfolio duration for an asset allocation of 40 percent bonds/60 percent stocks depends on the correlation assumption. As shown in Figure 15, a 40 percent allocation to bonds when there is a 0.34 correlation between stock and bond returns provides a total duration of 3.02. This is the same total portfolio duration value that would be achieved under a 70 percent allocation to bonds in an environment in which bonds were uncorrelated with the stock market. Thus, the effective allocation to interest-rate sensitive assets may be far greater than the literal allocation to bonds.

The key variable is how one defines the benchmark for measuring the impact of any given asset allocation. If the benchmark is defined in terms of achieving bond market index returns apart from any stock market co-movements, then the above procedure is correct and provides a useful effective allocation value. If the actual bond component has a duration greater than the bond market duration or if a positive stock-bond correlation is assumed, then the effective allocation to interest-rate sensitive assets may be markedly higher than the literal bond allocation. At other times, it might be more useful to use the duration of the

The Effective Asset
Allocation

liabilities as the interest-rate sensitivity benchmark. When the total portfolio duration matches the liability duration, the surplus function is immunized with respect to interest-rate movements. Higher or lower total portfolio durations would entail different risk exposures to interest-rate changes.

Portfolio Optimization

The surplus function approach may be used to develop expected values of return as well as measures of both interest-rate and market variability. With this quantification, the asset allocation problem may be formulated as an optimization problem, aimed at achieving the desired balance between return and risk as measured through the fund's surplus values. In this context, the difference between total portfolio duration and liability duration represents one risk measure. The effect of non-interest-rate factors constitutes a second dimension of risk. In this surplus/liability framework, asset allocations may be developed through a portfolio optimization process that is similar to existing procedures. The resulting allocations, however, would be more consistent with the fund's liability framework and, hence, more directed toward the sponsor's objectives.

Liability Returns

In the preceding chapter, a procedure was developed for computing a total duration value for a portfolio that included both stocks and bonds. This duration value is related to the interest-rate sensitivity of the liabilities. The emphasis was on gauging the net interest-rate risk for a given asset allocation. The duration of the stock market was estimated using the volatility and correlation characteristics of the S&P 500 relative to the Salomon Brothers BIG Index. The resulting S&P duration value, surprisingly, is far lower than the generally accepted equity duration values derived using dividend discount models.

This section examines the return dimension. The “returns” from representative pension liabilities, that is, the changes in the present value of future benefits, are compared with returns from the S&P 500 and the Salomon Brothers BIG Index. Again there are some surprising results. While the asset returns of both classes have performed well over the six-and-one-quarter-year period January 1, 1980 to March 31, 1986, the return on the liabilities also has been extremely high. In fact, the liability returns from the long-duration active-lives liability schedule far exceed the stellar performance of both the stock and bond

markets. More concretely, the true economic surplus for many pension funds has actually shrunk, even though asset performance has forged ahead at a historic pace.

Market Returns and Asset Durations

As a first step, it might be worthwhile to review the historical returns on the Salomon Brothers BIG Index. Figure 16 depicts monthly returns by fixed-income

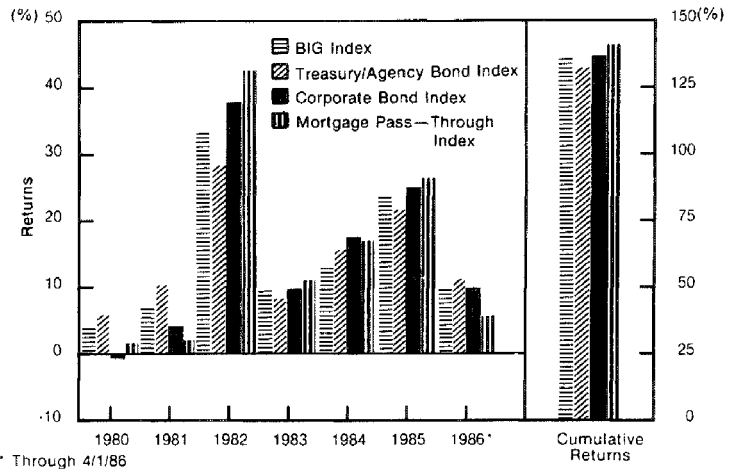


Figure 16. BIG Index Return By Fixed-Income Component, 1980-1986

components from January 1, 1980 through April 1, 1986. The total return figures for both the BIG Index and the S&P 500 are presented in Figure 17. Figure 18 updates the rolling volatilities over trailing one-year periods for these two markets. The average volatilities over the entire span dropped slightly to 9.40 percent for the BIG Index and rose to 14.34 percent for the S&P 500.

The rolling one-year correlations tell a different story. As shown in Figure 19, the correlation for the 12 months from April 1985 to March 1986 surged to a

high value of 0.78. This was virtually as high a correlation as for any 12-month period over the preceding six-and-one-quarter years. This high level was consistent with the intuition of many market participants

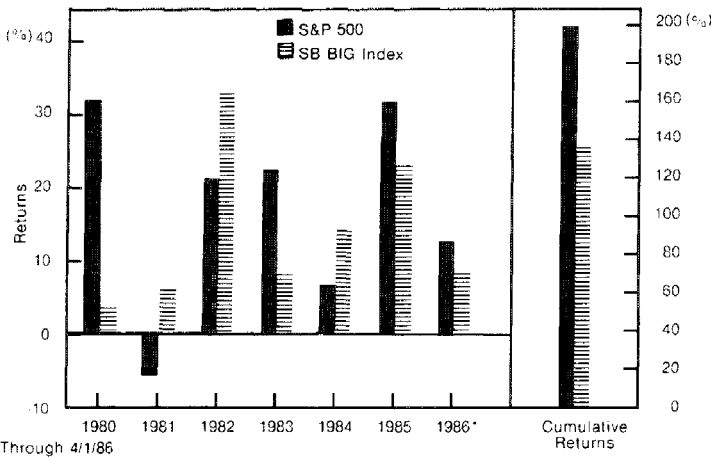


Figure 17. Equity and Fixed-Income Returns, 1980-1986

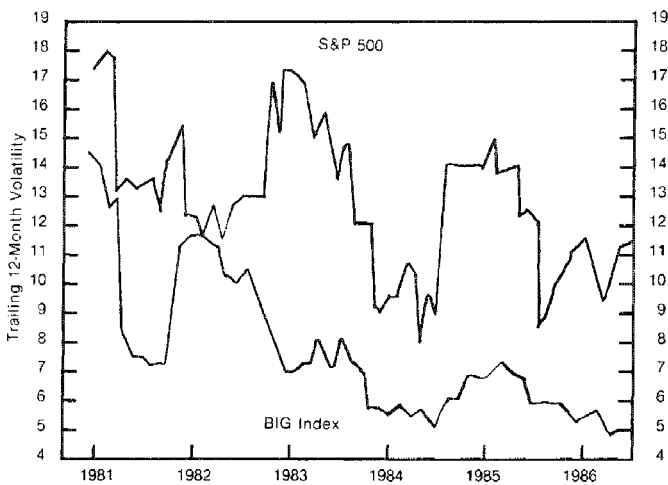


Figure 18. Rolling One-Year Volatility: Fixed-Income and Equity Markets, 1981-1986

that lower interest rates had been a particularly direct driving force behind the stock market rally at that time.

This high correlation level had several implications. For example, Figure 20 shows the scatter pattern for

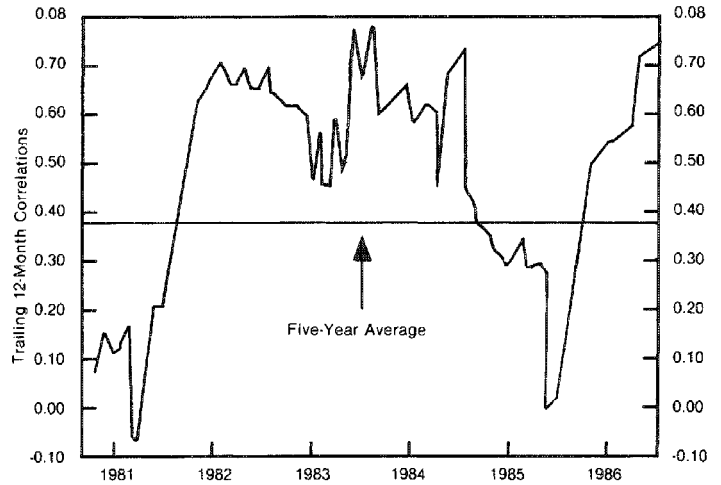


Figure 19. Rolling One-Year Correlations: Fixed-Income and Equity Markets, 1981-1986

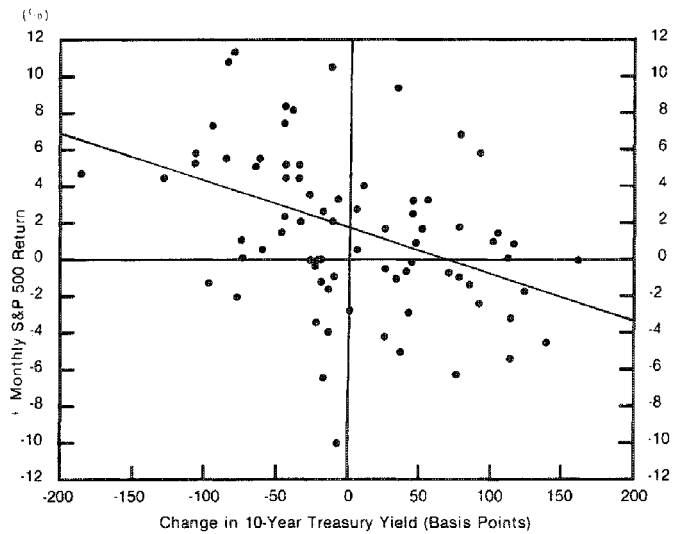


Figure 20. The S&P 500 Return Versus Change in 10-Year Treasury Yield, January 1980-March 1986

S&P 500 returns versus changes in the 10-year Treasury rates against a regression line for the entire period. Because of the high weight assigned to the earlier period, this regression reflects an empirical duration of 2.17, which is close to the 2.19 value found earlier using the January 1980 to November 1985 data. The overall correlation of -0.38 differs only marginally from the earlier value of -0.34.

Figure 21 shows the scattergram for the trailing 12

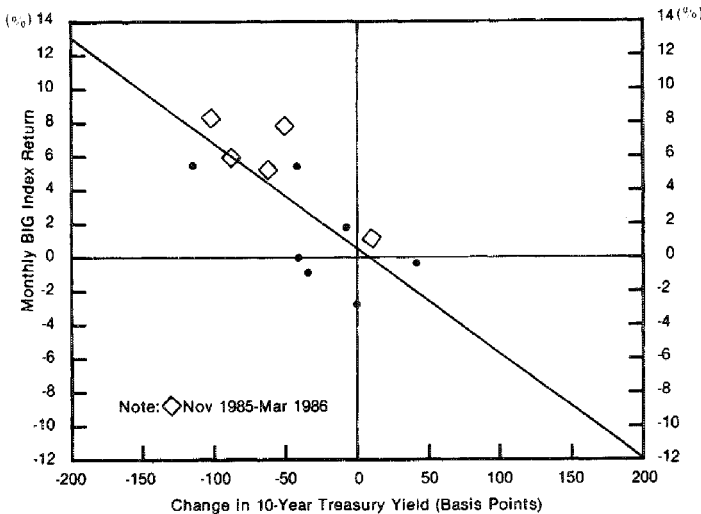


Figure 21. The S&P 500 Return Versus Change in 10-Year Treasury Yield, April 1985-March 1986

months ending April 1, 1986. Although statistical reliability is compromised by such a small number of data points, the results are nonetheless startling. The correlation of 0.78 corresponds to the last point plotted on Figure 19, and the duration of 6.18 is more than twice as great as the duration estimated over the entire preceding six-and-one-quarter-year period. Moreover, the last five months of data reflect an even stronger enhancement of this trend.

There is no reason to believe that stock market dura-

tion should be stable over time; in fact, intuition suggests that the duration could be significantly greater during some market periods than in others. The period ending in March 1986 appears to be one of them.

Liability Structures for Pension Plans

A pension plan has two basic types of liabilities, active lives and retired lives, each with quite different characteristics. Retired lives represent retired employees who currently receive benefits, and terminated pensioners who will receive deferred benefits. Figure 22 shows the general pattern of benefit

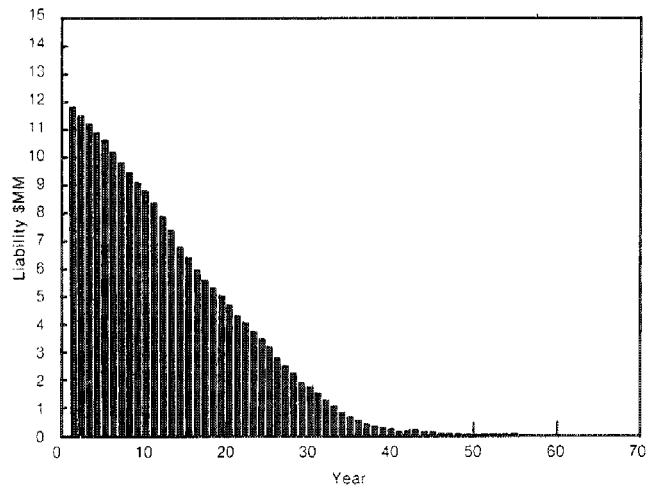


Figure 22. Retired-Lives Liability Schedule

payments to a fixed pool of such retirees. Given a fixed pool, this pattern is typically frontloaded, with benefits declining exponentially in accordance with mortality tables.

Active lives represent current employees who have vested (or accrued but unvested) interests in future benefits. For members of this class, the receipt of payments is deferred until some actuarially specified

retirement time. Projected benefit payments for active lives begin to increase with those who are about to retire, then grow to a peak that represents the bulk of future retirement benefits. This pattern is backloaded and includes some very long-term flows, as shown in Figure 23.

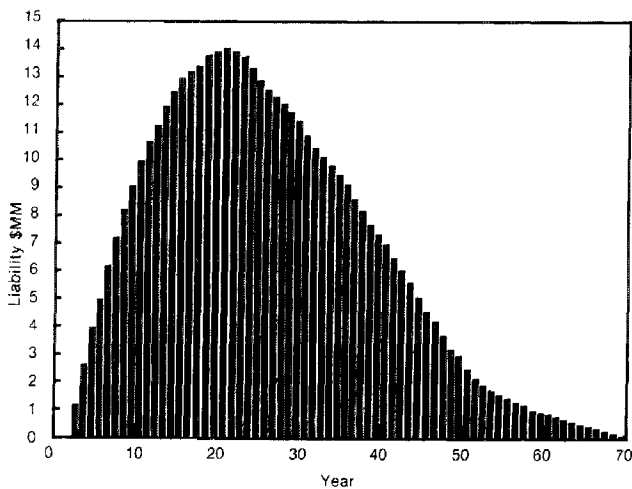


Figure 23. Active-Lives Liability Schedule

The actuarial procedure for determining these patterns is detailed and highly customized to the individual fund's circumstance, entailing many sources of complication. In particular, active-lives projections clearly depend on a host of assumptions regarding future benefit-payroll statistics. Different active-lives schedules may be used for the same payroll for different actuarial and reporting purposes. Moreover, interactions with the inflation rate must be taken into account in any more refined duration calculations. The flow of future contributions also may have a profound effect on interest-rate sensitivity. The fixed flow of nominal dollar payout, depicted in Figure 23, admittedly captures none of these important effects.

Liability Returns

The expression “return” has a dynamic connotation (certainly for any market participant), while the term “cost” tends to imply a well-defined and relatively unchanging value. Though it is common to speak of the return from assets and to contrast it with the cost of liabilities, this semantic distinction belies the structural similarity between assets and liabilities in the asset allocation equation. In particular, changes in the market environment are already recognized as leading to better or worse returns for different asset classes. This overemphasis on the asset-return side of the equation obscures recognition of concomitant changes in a more comprehensive measure of the fund’s status—the surplus function, that is, the difference between the market value of assets and the present value of liabilities. To correct this imbalance, the impact of market changes on the cost of liabilities should be investigated. Though this can be an intricate process, at least one facet of this impact may be explored readily: that of changing interest rates on the present value of a prescribed liability stream.

Changes in the cost of liabilities may be viewed as a kind of negative return. By defining this liability return properly, a measure may be obtained that is directly comparable with asset returns. Thus, for a given fund, to the extent that the asset return matches the liability return over a given period, the funding status would remain in balance, at least for the initial set of liabilities. The liability return may be defined as follows:

$$\begin{array}{r}
 \text{Discounted Present} \\
 \text{Value of Liability} \\
 \text{End of Period}
 \end{array}
 -
 \begin{array}{r}
 \text{Discounted Present} \\
 \text{Value of Liability} \\
 \text{Beginning of Period}
 \end{array}
 +
 \begin{array}{r}
 \text{Liabilities Discarded} \\
 \text{During the Period}
 \end{array}$$

$$\begin{array}{r}
 \text{Discounted Present} \\
 \text{Value of Liability} \\
 \text{Beginning of Period}
 \end{array}$$

This formula refers to liabilities existing at the beginning of the period and does not incorporate additional liabilities that may accrue during the period.

To illustrate this point, suppose the retired-lives liabilities depicted in Figure 22 were subject to a market discount rate of 8 percent at the beginning of the year, resulting in a present value of \$100 million. The first-year benefits of \$11.87 million are paid out during the year. At the end of the period, the remaining schedule is discounted at a new market rate of 7 percent, resulting in a year-end present value of \$102.86 million. The liability return in this case would be calculated as follows:

$$\frac{\$102.86 \text{ million} - \$100 \text{ million} + \$11.87 \text{ million}}{\$100 \text{ million}} = 14.73 \text{ percent}^a$$

^a Ignoring intraperiod compounding

In the past, actuarial smoothing and the highly lagged process for revision of actuarial valuation rates contributed to the perception that the present value of the liabilities had little immediate bearing on fund management. Accordingly, the liability-return calculation had limited appeal. In the new environment, however, rate-driven changes in the value of liabilities can be of great and immediate significance to the pension plan and the sponsor organization. The new FASB pension regulations (FAS 87) clearly favor the use of a market-sensitive discount rate to value the liabilities. In addition, with the increasingly routine consideration of potential annuity purchases, the fluctuating cost of these liabilities has an even more tangible impact. The concept of liability return, therefore, has become far more relevant today than it was in the past.

Liability Performance

This model for liability returns may be applied retrospectively to develop performance results for changing liabilities costs over various historical periods. This analysis must specify the structure of the flows for each evaluation point, together with a discounting mechanism. For example, for the retired-lives schedule in Figure 22 suppose that the discounting mechanism corresponded to a uniform interest rate approximated by the 10-year new A industrial rate. On January 1, 1980, this interest rate stood at 11.13 percent, yielding a present value of \$81.82 million and a modified duration of 5.87 years. During January 1980, approximately \$1 million would have been paid out to beneficiaries, and the remaining flow (aged one month) could be discounted at the 10-year new A industrial rate on February 1, 1980—12.00 percent. This results in a February 1, 1980 value of \$77.60 million. Under the simplified format, the return for this retired-lives liability amounts to -3.94 percent.

The BIG Index return for January 1980 is -3.03 percent. A large part of the difference between this and the retired-lives liability return is explained by the difference in the duration between the two flows—with its shorter duration, the BIG Index was less vulnerable to the increase in interest rates. Thus, for that month, an asset portfolio corresponding to the BIG Index would have gained some ground relative to this retired-lives liability.

Next, a liability stream beginning February 1, 1980, is required. This could be obtained in several ways; for example, the original stream could be aged from the preceding month's calculation. To keep the argument simple and to retain a consistent archetype over time, assume that the retired-lives liability of February 1, 1980, has the same (unaged) shape as depicted in

Figure 22. Given this assumption, the liability return for each succeeding month can be computed, and a comparison with the Salomon Brothers BIG Index return can be developed, as shown in Figure 24.

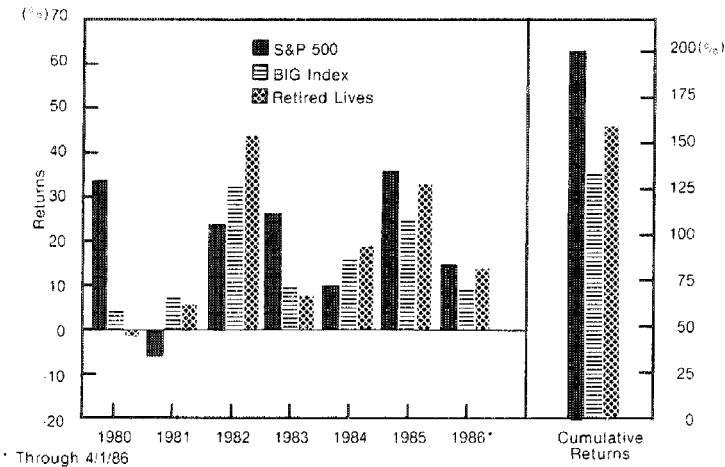


Figure 24. Retired-Lives Liability Returns, 1980-1986

In 1980 and 1981, the retired-lives component produced slightly lower returns than the BIG Index. In 1982, the BIG Index returns were an excellent 31 percent, but they were surpassed by the 41 percent liability return. The returns in 1983 were roughly comparable. In 1984, 1985, and the first three months of 1986, however, the liability returns pulled ahead of the BIG Index. Figure 24 also shows equity returns (S&P 500) over the same 75-month period, during which the cumulative liability return exceeded the growth in the BIG Index but fell short of the S&P growth. A \$100 million fund that was in perfect balance in January 1980 would have a surplus of \$36 million in 1986 had it been invested totally in stocks, but it would have incurred a \$26 million deficit had it been invested totally

in the BIG Index. This result, of course, is highly period-specific.

Moreover, the impact of asset and liability returns on the surplus clearly depends on the initial surplus condition. Thus, if a fund is in balance—that is, the market value of assets is equal to the present value of liabilities—market returns over a period may be offset directly against liability returns to determine the net surplus change. For a fund with a large starting surplus, however, the market returns will give rise to an asset base that is larger than the initial liability value, and appropriate adjustments must be made to determine surplus change.

The same approach may be applied to the active lives; performance results are shown in Figure 25. The

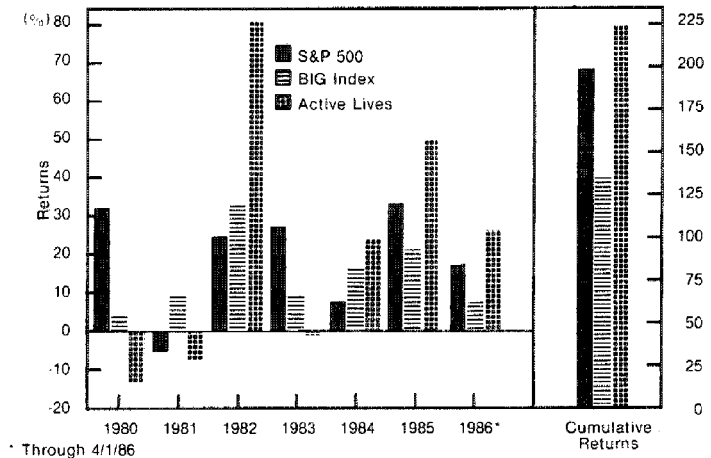


Figure 25. Active-Lives Liability Returns, 1980-1986

active-lives liability on January 1, 1980, had a theoretical duration of 12.59 years—considerably longer than the retired-lives liability of the BIG Index. This longer duration could be expected to lead to more

volatile liability returns, and, as Figure 25 indicates, this expectation is met. For example, in 1980 the active-lives liability return was -13.48 percent. Thus, an investor in the BIG Index with only a 1.90 percent return over this period would have enjoyed a 15.38 percent increase in surplus value, due primarily to the huge decline in the present value of the liabilities.

In contrast, during 1982 the decline in interest rates caused the present value of the active-lives schedule to soar by almost 80 percent, a multiple of the returns available in either the S&P 500 or the BIG Index. It would have been virtually impossible, therefore, for any fund with a large active-lives component to avoid serious surplus erosion in 1982. Some surplus erosion also was likely in 1984, 1985, and in the first three months of 1986. Thus, despite the great performance of both stocks and bonds in the first three months of 1986, the surplus of nearly every active-lives fund would have eroded because of the soaring costs of these liabilities.

For purposes of clarity, this analysis focused first on pure retired-lives liabilities, then on pure active-lives liabilities. In practice, a pension fund's liability structure will consist of a dynamic combination of both types of liabilities. In fact, the actual schedule may be complex and may change in ways that are unique to the individual fund. To gain insight into a more realistic pattern of liability returns, it is useful to explore the "performance" of an integrated benefits structure consisting of a well-defined combination of both retired and active lives (see Figure 26). The present value of this combined flow comprises 60 percent retirees and 40 percent actives, based on their respective present values under a discount rate of 8 percent. Apply-

**Integrated Liability
Returns**

ing the 10-year new A industrial rate as a discounting proxy to the integrated flow illustrated in Figure 26 produces the performance results shown in Figure 27.

To the extent that this archetype is at all represen-

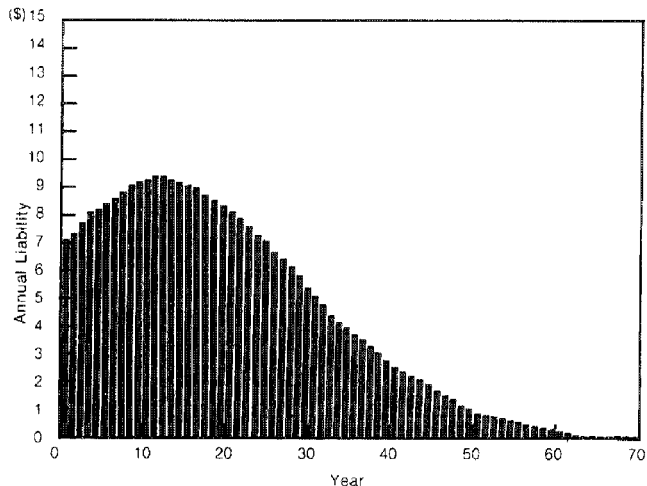


Figure 26. Integrated Liability Schedule, 60% Retired/40% Active (Dollars in Millions)

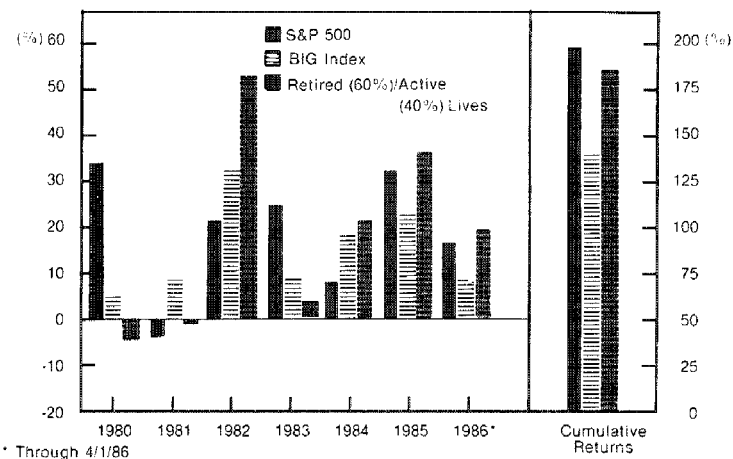


Figure 27. Integrated Liability Returns, 1980-1986

tative, these results are most intriguing. First, over the entire 75-month period, the performance of the bond market would have fallen significantly below the increased cost in this liability structure. The S&P 500 returns fared somewhat better than the combined liabilities. Nevertheless, in three of the four calendar years 1982-1985 (as well as in the first quarter of 1986), the integrated liability returns actually outdistanced the pure equity returns.

Few portfolios consist entirely of stocks or entirely of bonds. For more representative results, the integrated liability should be compared with a fund allocation that includes both stocks and bonds. Accordingly, a fund with 60 percent invested in the S&P 500 and 40 percent deployed in the BIG Index was formulated, producing the performance results depicted in Figure 28.

Comparison With
Stock/Bond Portfolios

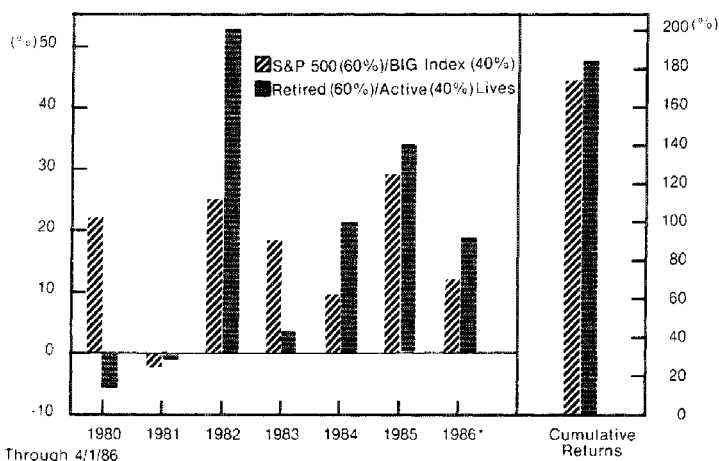


Figure 28. Portfolio and Integrated Liability Returns, 1980-1986

At no point in the entire period did the fund returns pull ahead of the liability performance. This shortfall

led to an enlarged deficit of about 11 percent over the 75-month period. A closer look at the period-by-period returns, however, suggests even greater cause for concern. In 1982 the liability return far exceeded the fund's asset performance, and in 1984 and 1985 the liability performance again outdistanced the asset performance. Perhaps more seriously, in the first three months of 1986 there was a sizable 6.6 percent shortfall between the asset performance and that of the combined liability schedule.

The Duration of
Liabilities

Many of these results can be traced to the fundamental interest-rate sensitivity of the liability streams. The *pro forma* modified duration is quite long for the liabilities: 5.87 years for the retirees, 12.59 years for the actives, and 8.20 years for the integrated flows (all as of January 1, 1980). A more meaningful measure of interest-rate volatility, however, would be the effective duration relative to a consistent interest-rate benchmark. Since the 10-year Treasury rate has been used as a benchmark in computing the effective duration of the BIG Index and the S&P 500, it is natural to adopt it again in computing liabilities. In Figures 29, 30, and 31, the liability returns for each of the 75 months are plotted against corresponding changes in the 10-year Treasury. The regression line provides a measure of the effective duration values: 5.71 for retirees, 12.35 for actives, and 7.84 for the integrated schedule.

The effective durations are close to the *pro forma* duration values, which is hardly surprising. While there is a certain quality-spread variation between the discounting rate (10-year new A industrials) and the benchmark rate (10-year Treasuries), liability streams are free from some of the adverse convexity problems

that encumber corporate bonds, mortgage securities, agency issues and even certain Treasury issues, especially in times of low interest rates. In this sense, duration value tends to be a better gauge of a liability's

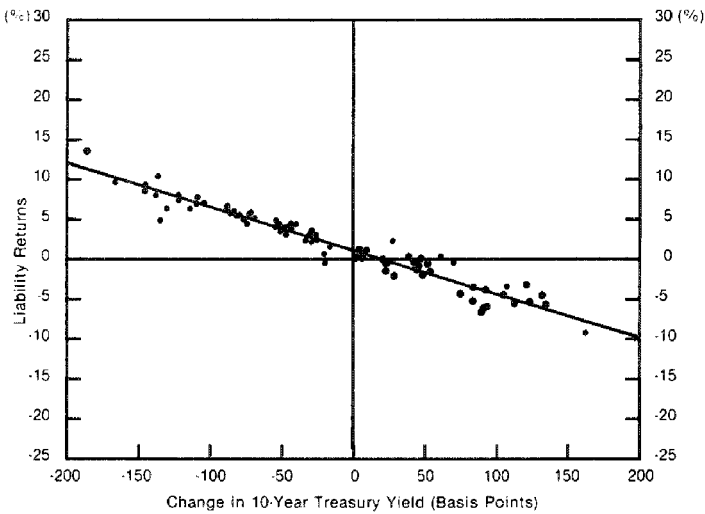


Figure 29. Effective Duration of Retired-Lives Liability

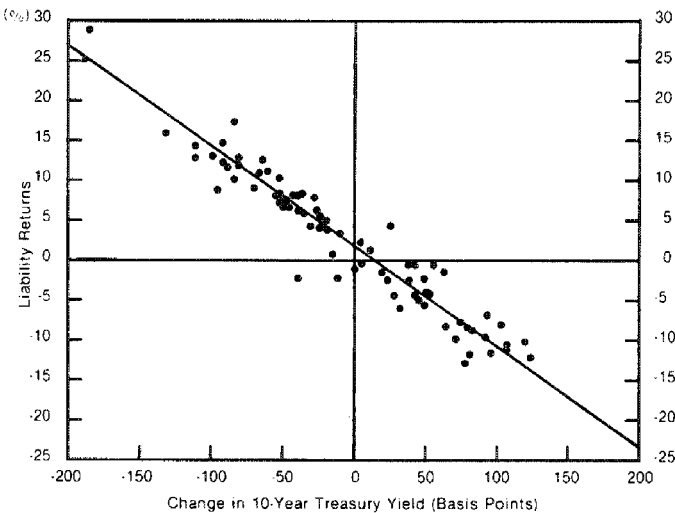


Figure 30. Effective Duration of Active-Lives Liability

volatility than of a bond portfolio's volatility.

The 7.84-year volatility of the integrated flows far exceeds the 4.27-year duration value for the BIG Index. The equity durations are lower yet. With the in-

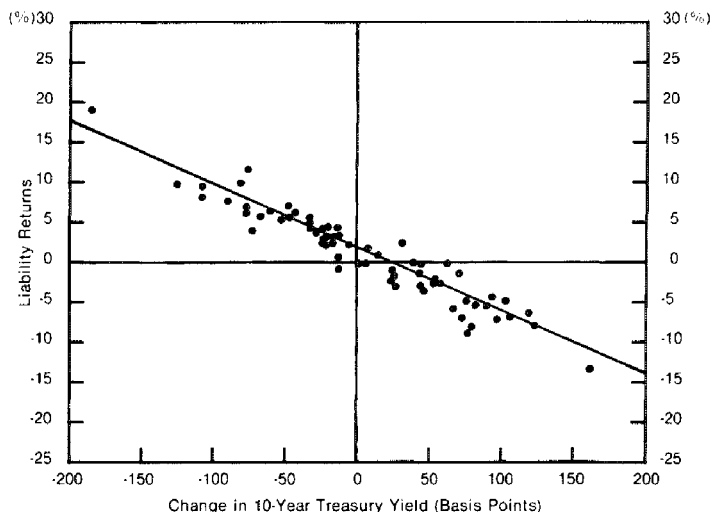


Figure 31. Effective Duration of Integrated Liability Schedule

creased correlation between bonds and stocks in late 1985 and early 1986, the S&P 500 duration may be greater than its historical average value, but a fund with typical allocations in stocks and bonds would still have a lower duration than these archetype liabilities. Such a duration gap naturally would make the fund surplus vulnerable to lower interest rates.

This vulnerability is corroborated by past performance results. When interest rates rose, as they did in 1980 and 1981, low liability returns often led to increases in the surplus. In contrast, when interest rates fell, the value of the liabilities rose and typically exceeded stock and bond market returns. The pattern shown in Figures 24, 25, and 27 is no coincidence, but may reflect a fundamental and dangerous liability trap.

Thus, in terms of surplus growth, the net performance of a pension fund may be most vulnerable precisely when fund sponsors and/or managers encounter the most favorable market returns and ample growth in the market value of their portfolios.

These performance results provide striking evidence of the vulnerability of the pension fund in today's markets. The high level of interest-rate volatility and the long duration of representative liability schedules create the potential for wide variations in liability returns. Although surplus is not the only determinant of pension fund allocations, it is becoming increasingly important in the accounting/actuarial environment.

Traditional asset allocation procedures generally do not address the question of surplus vulnerability. Stocks usually are ascribed both a higher expected return and a higher volatility than bonds. Thus, over longer horizon periods, equities are often regarded as the asset of choice. Too high an equity component, however, engenders unacceptably high levels of volatility in portfolio value. Therefore, the bond component is added to reduce portfolio variability to tolerable levels. In many procedures, the fixed-income component is defined as some benchmark bond or bond market index taken to have an essentially constant duration. With this static choice for fixed income, the bond component is valued as a predictably dull volatility-dilution agent. Thus, in traditional allocation procedures, the sole decision variable is the magnitude of the equity component; the bond component becomes a derived residual that follows from the equity decision.

This traditional approach fails to address three major facets of the current pension and market environment. First, it focuses solely on asset return, with no explicit treatment of liability return, liability risk, or the

Allocations Using Total
Portfolio Durations

resulting surplus vulnerability. Second, it fails to recognize the high level of interest-rate volatility that now appears endemic. Even within the traditional framework, this rate volatility erodes the role of bonds as risk-dampening agents. Third, it does not recognize a major development in capital markets over the past decade: the emergence of new instruments that allow the practical construction of fixed-income portfolios that span an extremely wide range of durations. This is true of conventional bonds and zero-coupon instruments, and the range expands even further when futures and options may be applied. For large funds the range of (duration) risk readily available for the fixed-income component may be much wider than the practical (beta) risk range available for the equity component.

Within the liability/surplus framework, these problems can be addressed only through a revised asset allocation process that explicitly models the interest-rate risk characteristics of all fund components, including bonds, equity, and liabilities. This makes the total portfolio duration an important risk measure for the asset side. Such a framework has implications for return enhancement as well as for risk control. Thus, for certain interest-rate scenarios within a tactical allocation, the liability return could become a significant positive contributor to surplus.

In any case, the total duration approach would begin to allow for measurement and control of interest-rate risk. Given the wide range of duration vehicles available in the market, this allows the fund the opportunity to adjust the duration of the bond component to achieve a desired level of overall fund exposure to rate movements. Thus, for a given equity weighting, the duration of the bond component may be selected to achieve vastly different target durations for the total portfolio.

Once the equity weighting is determined, the second decision may be stated in terms of either the bond component duration or the duration target for the total portfolio. For example, with 60 percent in equities, the 40 percent fixed-income portion may be invested either in cash equivalents for a total portfolio duration of under one year or in longer instruments to achieve a total duration of longer than six years. For the same fixed proportion invested in bonds, different bond portfolios may produce vastly different total portfolio durations for the overall fund.

Thus, there are compelling reasons to make some simple changes in the traditional asset allocation process without transforming it into a highly modeled form based on the surplus function. The range of choices in the bond component is so wide and so important that a simplistic stock-to-bond ratio no longer is appropriate. Rather, the fund sponsor should recognize two related but semi-independent choices, the equity weighting and the portfolio duration for the total fund, whereas in the traditional framework the equity weighting basically dictates all facets of the fund allocation. The portfolio duration may provide some risk compensation for the equity weighting. The vulnerability of both the portfolio value and the surplus ultimately will depend on the equity weight and the duration of the fixed-income component.

A comprehensive liability framework would form the most desirable basis for a more sophisticated asset allocation model. At the very least, the semantics of the allocation process should be revised so that decisions are framed in terms of equity weightings and total portfolio durations.

Surplus Management

The two preceding chapters suggested a statistical approach for extending the duration concept to other asset classes such as equities. Contrary to earlier literature and most preconceptions, this approach leads to equity duration values that are far lower than that of the typical pension liability. Hence, a greater allocation to equity creates a wider gap between the duration of assets and the duration of liabilities. Much of the surplus vulnerability arises because traditional asset allocations virtually always result in too short a duration.

One problem in surplus management is the traditional view that positive correlation is an evil to be avoided. The traditional efficient portfolio is constructed by seeking asset classes that have the lowest correlation, or, ideally, even negative correlations, with each other. In the new surplus framework, where there is a chronic shortage of duration on the asset side, there is a definite value to positive correlations with bond returns. Thus, any asset class having a high (negative) correlation with interest rates is far more desirable for a given prospective return and for a given level of residual risk. Clearly, domestic bonds can play a distinguished role in moderating this duration shortfall.

Moreover, the wide duration spectrum available in domestic bond markets may act as an important bridge to a new allocation procedure directed toward surplus management. In a traditional allocation, the asset class percentages are set at a macro level, then the composition of each class is determined at the micro level by the assigned managers or by the nature of the index selected as a core fund. This process leads to durations for the bond component and for the total portfolio that have been selected for various reasons, but probably with little concern for the control of surplus risk.

In the new surplus context, a more efficient portfolio would result from closer integration of the macro and micro decisions, especially with respect to the bond component. Thus, the bond duration could be derived from the macro decisions that set the percentage weightings among all other asset classes. For example, with this interactive approach, the total risk incurred by a greater equity ratio, and the tendency toward an even greater duration gap, might be counterbalanced by setting higher duration targets for the fixed-income portfolio.

A deeper problem for effective surplus management is the sponsors' tendency to view surplus value as short-term or *pro forma* in nature. This tendency is understandable in light of the new FASB standards. The concept of surplus function, however, unites both long-term and short-term considerations.

The long-term interpretation of surplus may be clarified through its relation to earnings rates. By definition, a fund with a zero surplus should be able to fulfill exactly its associated liabilities through the purchase of annuities or the construction of a dedicated bond portfolio at current market interest rates. A fund with a positive surplus should be able to fulfill some of

its liabilities, even if the long-term earnings rate falls somewhat below current annuity rates.

Thus, a fund with a positive surplus has a cushion that allows it to undertake market risks in searching for excess return. Even if these risks led to adverse outcomes and a long-term earnings rate below the current market rate, the fund could still have sufficient assets to meet its liabilities. On the other hand, a fund in a deficit position finds itself under the pressure of a long-term earnings rate shortfall, that is, a certain increment beyond current market rates must be earned over the long term for complete funding to be achieved with the assets in hand.

Therefore, the short-term measure of surplus status clearly has an important long-term implication in terms of the required earnings rate. The final section of this analysis illustrates how these earnings rate cushions may be computed and shows how they have changed under recent market movements.

The asset returns and correlation results presented earlier must first be updated. Figure 32 shows total returns from January 1, 1980, through July 1, 1986, for the S&P 500 Index and for the Salomon Brothers BIG Index as a proxy for the bond market, and also shows the combined returns from a portfolio invested 60 percent in the S&P 500 and 40 percent in the BIG Index.

The bond market and stock market returns suggest some degree of co-movement. In most allocation studies, the correlation between stock and bond returns is assumed to fall between 0.30 and 0.40. A correlation of 0.34 was found to represent the average value of monthly bond/stock returns for the period January 1980 through November 1985. Such a correlation of equities with bond market returns suggested

Asset Returns and Total
Portfolio Duration

that a similar correlation must exist between equities and interest-rate movements. Thus, a duration measure for stocks could be derived from any observed (or assumed) level of stock-bond correlations. Over the

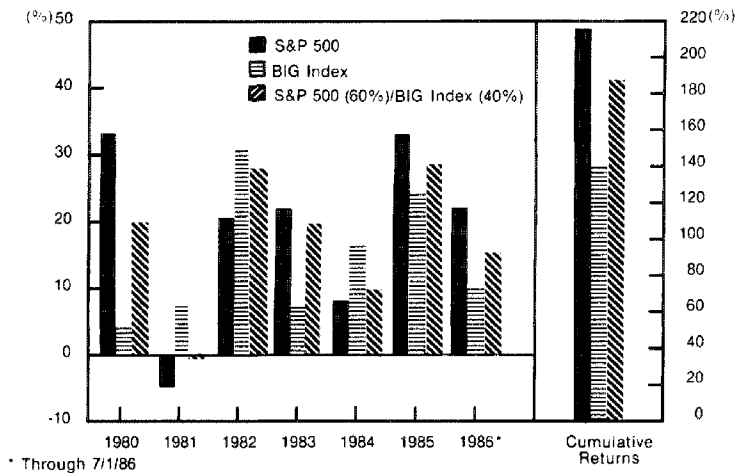


Figure 32. Equity and Fixed-Income Returns, 1980-1986

period cited, the average duration calculated for the S&P 500 was 2.19 years.

This finding contradicted two important preconceptions. First, for this period in particular, stock market behavior was frequently assumed to be driven largely by changes in interest rates. Second, prior academic work based on dividend discount models had concluded that stocks had very long duration—20, 30, 40, and even 50 years.¹ Subsequent work exploring the stock market durations associated with a wide range of sectors and time periods, using a variety of techniques for filtering interest-rate movements, produced a wide

¹This author is himself guilty of having reached an essentially similar conclusion in an earlier study. See *Bond Equivalents of Stock Returns*, Salomon Brothers Inc, June 1976.

range of duration values.

Figure 33 shows the duration based on trailing 12-month returns for the S&P 500 for the period January 1980 through June 1986. The extraordinarily

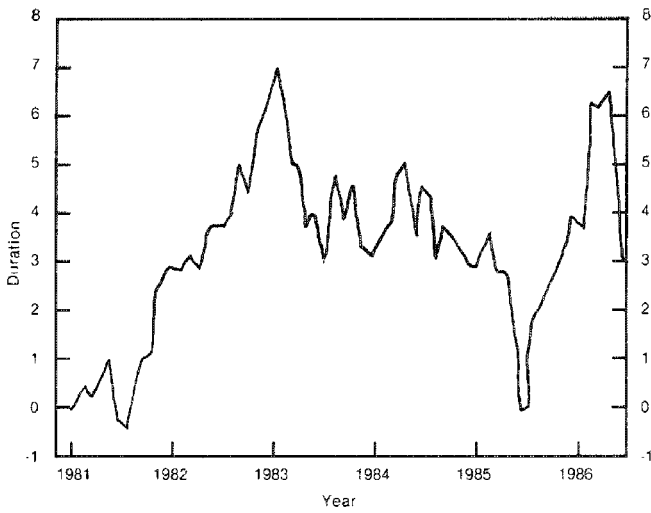


Figure 33. Rolling One-Year Empirical Duration for S&P 500

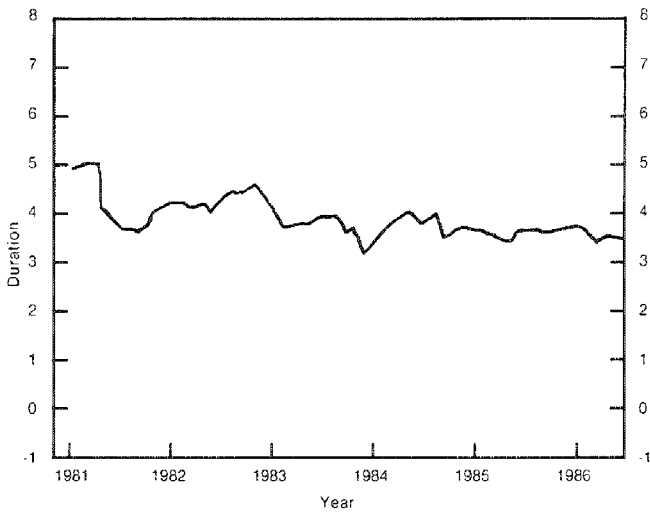


Figure 34. Rolling One-Year Empirical Duration for BIG Index

high duration of 6.18 reached as of March 1986 was short-lived, and the duration value declined rapidly to 2.90 years at the end of June 1986. Over the entire period, the empirical duration value averaged 2.29 years.

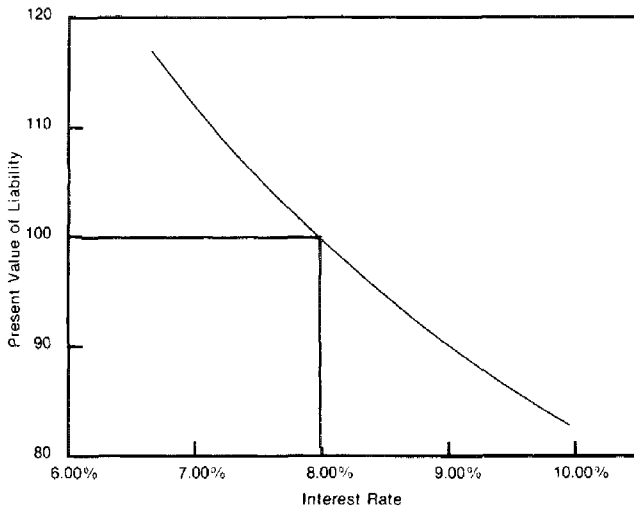
Moreover, the equation for transforming a given correlation into an empirical duration requires that only a high equity-to-bond volatility ratio—a rare occurrence—will produce equity durations as high as 6 years. Indeed, equity duration values of 2 to 5 years seem to dominate the *ex post* results shown in Figure 33. Computations based on the typical *ex ante* market assumptions used in asset allocation studies produce a similar range of values. Equity portfolios, then, have low empirical durations in terms of return sensitivity to nominal interest-rate movements. Put bluntly, results from dividend discount models that suggest the contrary are wrong.

Figure 34 provides a corresponding time chart of the empirical duration of the Salomon Brothers BIG Index against yield movements of 10-year Treasuries. This duration is far more stable, generally ranging between 3.5 and 4.7. Using mean values of 2.29 for the duration of the S&P 500 and 4.16 for the BIG Index, a 60/40 traditional stock/bond portfolio would have an asset duration of 3.04. If the correlation of the equity and bond markets is assumed to be particularly high—say 0.78—the 60/40 portfolio still would have a total duration of only 5.12. Clearly, it would be difficult for this 60 percent S&P 500/40 percent BIG Index portfolio to have a duration in excess of 5.12. Even this maximum duration value, however, falls far short of that needed to match the interest-rate sensitivity of pension liabilities.

Liability Returns

For simplicity and clarity, a single stable liability schedule was defined as a benchmark, as depicted previously in Figure 26. The present value of this

liability stream depends on the interest rate used as a discounting factor, as shown in Figure 35. This present value cost may be interpreted as the dollar amount of assets required to fund the liabilities fully



**Figure 35. Present Value of Liabilities
(Dollars in Millions)**

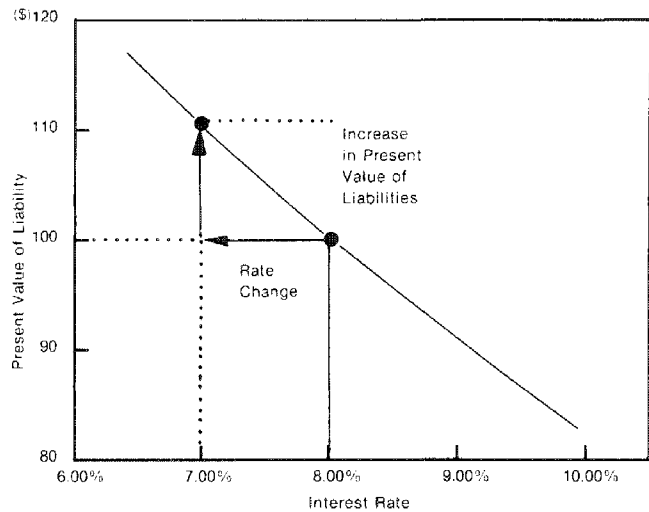
when invested at the specified interest rate.²

As interest rates change, so will the liabilities cost. Thus, as shown in Figure 36, an interest-rate change from 8 percent to 7 percent would lead to an \$11 million (11 percent) increase in the present value cost of these liabilities. Using terminology usually reserved for the asset side, this 11 percent cost increase has been referred to here as a liability return.

As shown previously, the liability return represents a threshold that the assets must match to maintain a

²It should be noted that both the liability schedules and the discount rates have been depicted in nominal terms. This general method may be extended to deal with the effects of inflation, but that discussion lies outside the scope of this paper.

given surplus level. In particular, if assets and liabilities are equal at the outset—that is, if the surplus is zero—then the asset return must equal this liability return for the asset and liability values to remain even.



**Figure 36. Liability Return
(Dollars in Millions)**

If the surplus is not zero—that is, if there is a surplus or a deficit—asset returns must equal liability returns, in dollars, to maintain a constant dollar surplus. Thus, for the surplus condition to be preserved, the asset return times the asset base must equal the liability return times the liability base.

Previously, the 10-year single A industrial rate was used as a discounting proxy for the liability flows. Application of this rate on a monthly basis to the integrated liability schedule generates the sequence of returns shown in Figure 37. These returns are very volatile at the outset. In many months the liability returns reached significant positive levels of 5 percent or higher. Moreover, several periods produced significant runs of such high monthly returns, which is

hardly surprising during a period of declining interest rates. Figure 38 compares the liability returns with the asset returns from the 60 percent S&P 500/40 percent BIG Index portfolio. In many instances, the liability

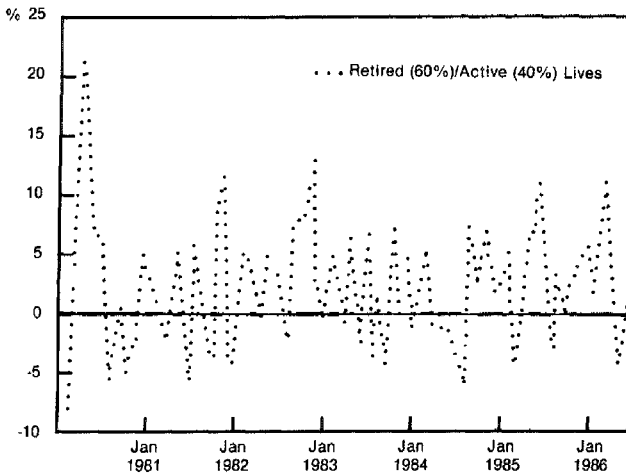


Figure 37. Integrated Liability Returns, January 1980-July 1986

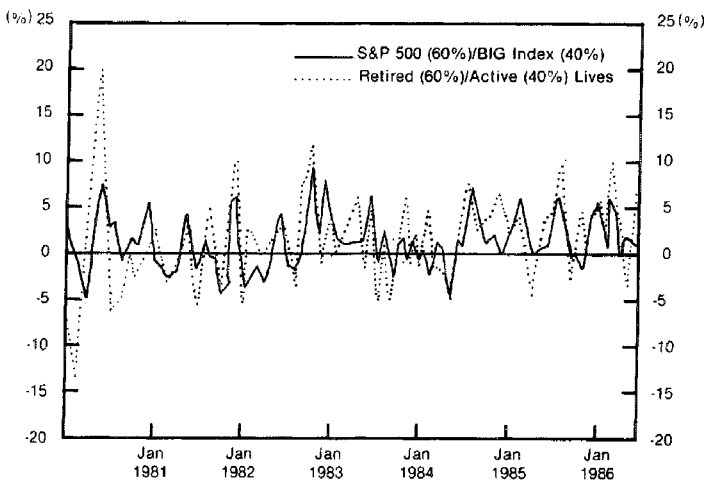


Figure 38. Asset Returns and Liability Returns, 60% S&P 500/40% BIG Index

returns exceeded the asset returns month by month, as well as over a span of several months.

The liability schedule used in these calculations has a duration of approximately eight years. Had a more realistic liability schedule been used—that is, one with a larger component of active lives—the resulting liability schedule would have had a significantly longer duration. Given the four-to-five-year durations associated with traditional asset mixes, the assets side tends to have a chronic shortfall in duration relative to the liabilities.

Historical Surplus Changes

A fund that begins the month in a net even position—that is, with a surplus of zero—will increase its surplus to the extent that asset returns exceed liability returns. Thus, the difference between the two series of monthly returns depicted in Figure 38 could be graphed to show surplus changes in a fund that started even at the beginning of each month. This difference series is shown in Figure 39. Almost all of the monthly surplus changes exceed 3 percent, either negatively or positively, and in several months they fluctuate by more than 5 percent. Clearly, on a monthly basis, even this conservative surplus function exhibits a high degree of volatility.

Cumulative surplus changes must be examined over periods of longer than one month, as depicted in Figures 40, 41, and 42. Figure 40 shows cumulative surplus changes over quarterly periods and shows seven quarters in this period during which the surplus declined (that is, the deficit increased) more than 5 percent.

The record of annual surplus changes, as shown in Figure 41, gives a somewhat more comforting result. With one exception, yearly surplus changes have been

relatively moderate—less than 10 percent. Most of them have been negative, which seems at first surprising in an era of extraordinary portfolio returns. The most severe surplus loss occurred in 1982, when the

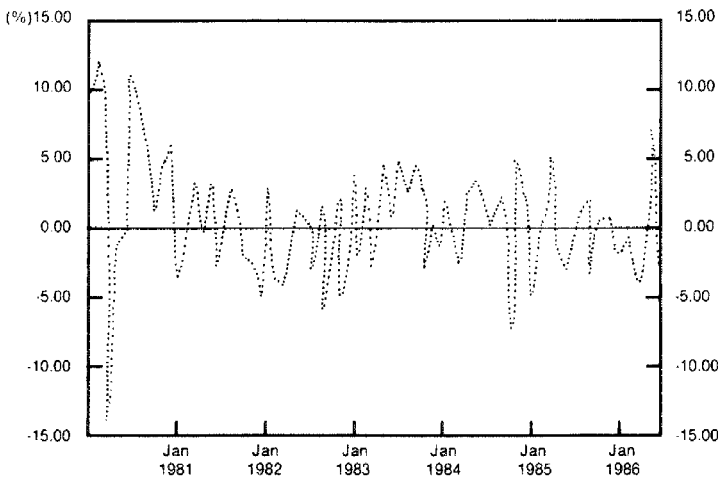


Figure 39. Monthly Surplus Changes (As % of Liability Value)

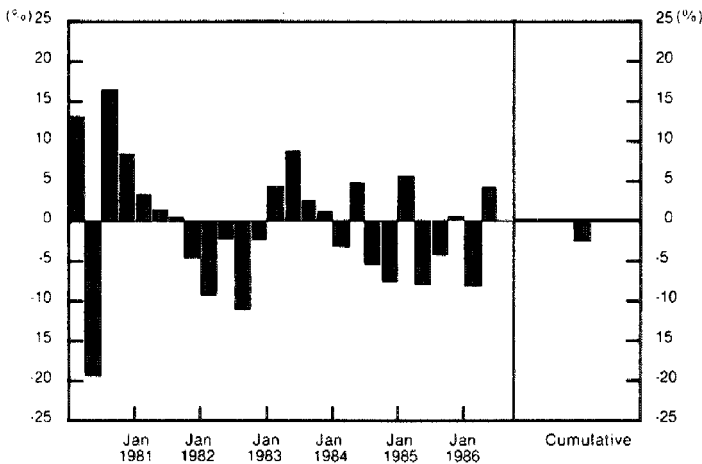


Figure 40. Quarterly Surplus Changes

liability return exceeded the asset return by almost 26 percent. Aside from this dramatic year, however, the liability returns and asset returns were relatively closely matched.

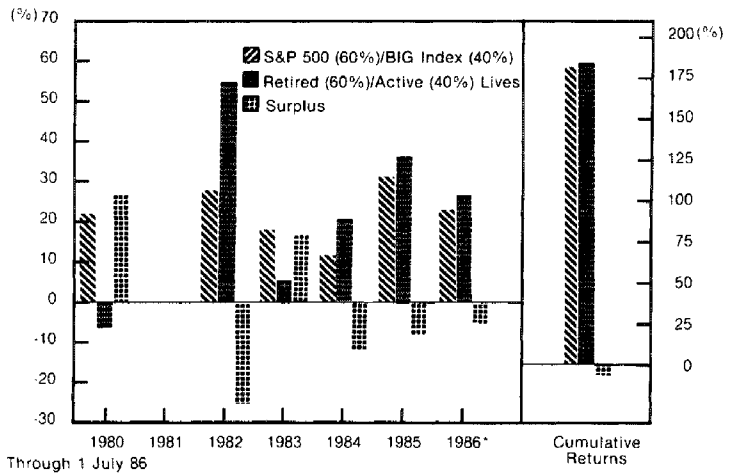


Figure 41. Annual Surplus Changes

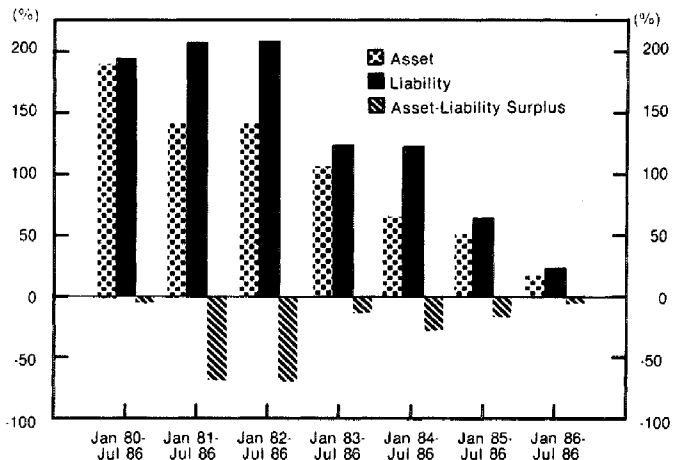


Figure 42. Cumulative Surplus Changes From Various Starting Dates

There is, however, a less comforting view. In Figure 42, cumulative asset and liability returns have been computed for periods beginning in successive years and all ending on June 30, 1986. Results for the period January 1, 1980, through June 30, 1986, coincide with the cumulative return results shown in Figure 41. Results for the period January 1, 1981, through June 30, 1986, show liability returns of 204 percent exceeding asset returns of 139 percent, resulting in a surplus decrease of 65 percent. A fund starting in January 1982 experienced an identical surplus loss of 65 percent. Similarly, for funds starting in January 1983, 1984, and 1985, subsequent years led to surplus losses of various magnitudes. Even for the first half of 1986—a period of truly exceptional asset returns—there was a net surplus loss. Though these results are for a closed system that does not take into consideration additional contributions or new structural liabilities, they are hardly reassuring to fund sponsors who are normally comfortable with any surplus of around 15 percent.

Figure 43 plots the monthly surplus changes from Figure 39 against interest-rate changes that occurred during the respective months and shows a strong regression, with a slope of 4.8 years. This slope represents a surplus duration, the value of which is related to the gap between total portfolio duration and liability duration. The total portfolio duration of the 60 percent S&P 500/40 percent BIG Index portfolio was found earlier to be 3.04 years, and the liability duration was 7.84 years. Thus, the duration gap is approximately -4.80 years, which accounts for the regression slope of 4.80 for the surplus changes.

Duration of Surplus
Changes

Control of this duration gap is a major challenge in surplus management. Figure 44 depicts surplus regres-

sion lines for portfolios with 100 percent weightings in the S&P 500 and in the BIG Index. Allocations consisting of mixtures of these two asset categories would lead to slopes between these two extremes. All such

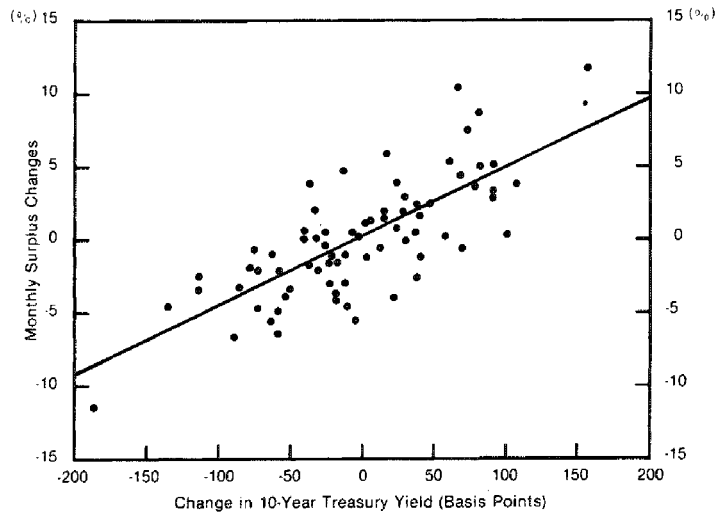


Figure 43. Monthly Surplus Changes and Interest-Rate Movements

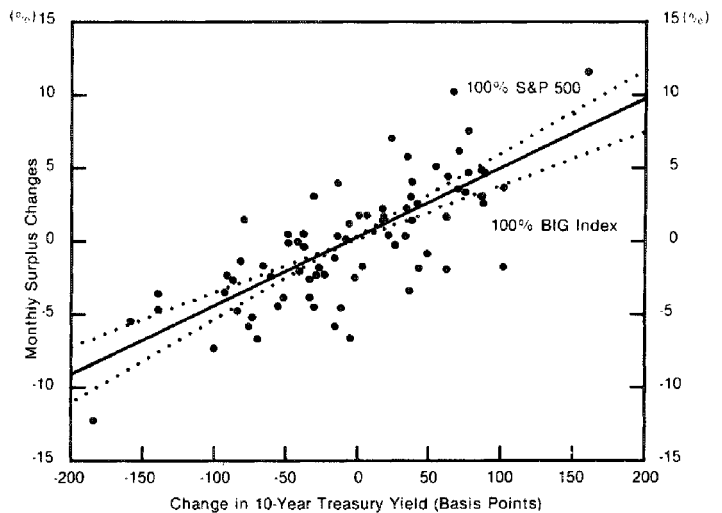


Figure 44. Surplus Changes Relative to Stock and Bond Index Portfolios

combinations produce surplus functions with considerable interest-rate sensitivity. Once again, it is clear that traditional asset allocations give rise to highly vulnerable surplus positions.

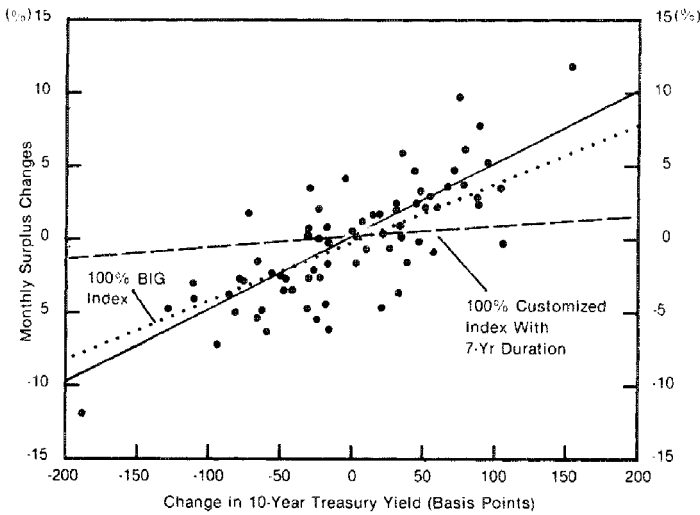


Figure 45. Surplus Changes Relative to Customized Index Portfolios

What can be done to reduce this surplus vulnerability? Figure 45 shows the regression slope for a customized bond index with a total portfolio duration of seven years. As would be expected, this move toward an immunized portfolio considerably reduces the interest-rate risk. This risk reduction, however, must be weighed against the loss of the *ex ante* return increment that is normally the motivation behind higher weighting in the S&P 500.

Surplus risk from low rates may be reduced by extending the duration of the bond component beyond the four years associated with portfolios that reflect overall bond market characteristics. As the portfolio's equity component becomes proportionately larger, further extensions of the bond component's duration can

help increase total portfolio duration. Without such counterbalancing, increasing equity weights results in far greater risk levels than might be expected from standard volatility studies. Equities contribute to surplus risk along two dimensions: (1) interest-rate risk derived from their low duration, and (2) residual volatility from other causes. By using the bond component to counterbalance the duration shortfall resulting from significant equity weightings, control of the portfolio's total surplus risk may be improved.

Any such extensions of duration, however, should be evaluated against the potential for future interest-rate movements. When only limited declines of interest rates are anticipated, the sponsor may utilize the portfolio's liability component opportunistically. That is, the sponsor may maintain a relatively low asset duration to remain poised for significant cost reductions from rising rates.

The Surplus as an Earnings Cushion

The short-term surplus measure may be interpreted in a long-term context that provides a valuable insight into the nature of the funding process. Figure 46 depicts a fund with a positive surplus under current market rates of 8 percent. If the asset value remained unchanged, the discounting rate could fall to 6.5 percent and the surplus would still be great enough to fund the liabilities. In other words, the surplus is sufficient to allow the existing fund to achieve a long-term earnings rate of 6.5 percent—150 basis points below the current market rate—and still fulfill its liabilities. Thus, the surplus acts as an earnings cushion, providing a margin of 150 basis points below the current market rate to cover contingencies in future returns and the dangers associated with riskier asset classes.

Similarly, a negative surplus (a deficit) may be

viewed as a negative earnings rate cushion, a hurdle spread that the fund must earn above market rates to fulfill its liabilities without additional cash injections. For example, in an 8 percent market a pension fund

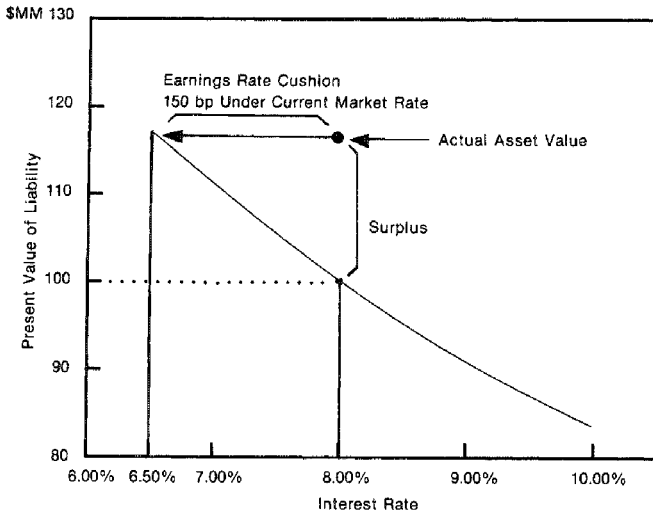


Figure 46. Surplus as an Earnings Rate Cushion (Dollars in Millions)

with a deficit corresponding to a required earnings rate of 9.5 percent would have to earn 150 basis points more than the current market rate in order to provide adequate funding. Obviously, when the surplus is zero, the assets are just sufficient to fund the liabilities at the presumed market discounting rate, with neither cushion nor hurdle.

Surplus changes may be viewed as changes in these cushion/hurdle spreads. Figure 47 shows cushion/hurdle spreads for annual periods beginning in 1980. This figure translates the annual surplus changes from Figure 41 into the terms of an earnings rate cushion. For example, the -26 percent surplus change over 1982 becomes a 260-basis-point deficit in the long-term earnings rate. Thus, with the A industrial rate standing at

11.63 percent at the end of 1982, a fund that started in 1982 with a zero surplus would have to earn 14.23 percent—11.63 percent + 2.60 percent—to fulfill its liabilities without additional cash injections.

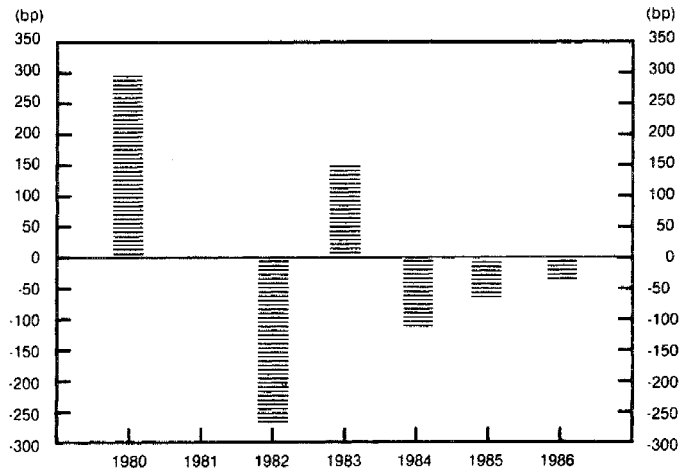


Figure 47. Earnings Cushions Developed Over Annual Periods

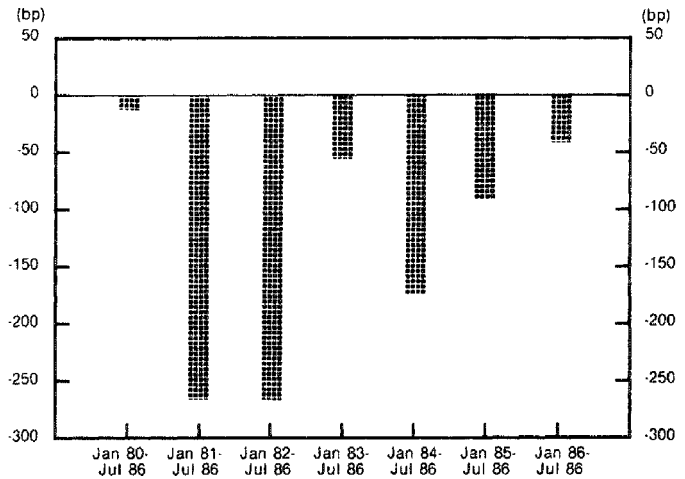


Figure 48. Cumulative Earnings Cushions Developed From Various Starting Dates

Figure 48 shows earnings cushions for periods ending June 30, 1986, but with different start dates—a translation of Figure 42 into earnings cushion terms. Significant hurdle spreads are associated with the surplus losses incurred over this period.

A fund with a high hurdle spread above market rates is in a difficult position, assuming that no further injections of funds are planned. It must achieve earnings rates that exceed market rates by at least the hurdle spread. Such a fund might be tempted to undertake risky positions in the hope of achieving excess returns above those available in a risk-neutral or immunizing portfolio. On the other hand, the fund has no room for return shortfalls that would further exacerbate the deficit and hurdle-spread situation.

The earnings cushion approach also is consistent with the common practice of evaluating various asset classes in terms of their expected return increments over current market rates.

This earnings view of the deficit and surplus, and of their associated changes, shows that the surplus clearly does represent an economically significant long-term variable. Thus, surplus management is relevant not only for pension sponsors concerned with near-term accounting results or with potential early terminations, but also for those sponsors seeking a well-controlled investment procedure for the long-term funding of their liabilities.

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Appendix

We first express the co-movement of equity market returns \tilde{R}_E with bond market returns, \tilde{R}_B , through the equation:

$$(1) \quad \tilde{R}_E - R_F = A_1 + B(\tilde{R}_B - R_F) + \tilde{e}_1$$

where R_F is the risk-free rate, and \tilde{e}_1 represents all market factors other than the bond market that may affect equity returns. We may place the following requirements upon \tilde{e}_1 :

$$(2) \quad E(\tilde{e}_1) = 0 \text{ and } E(\tilde{e}_1 \cdot \tilde{R}_B) = 0$$

The regression coefficient, B , may be expressed as:

$$(3) \quad B = \left(\frac{\sigma_E}{\sigma_B} \right) \rho(E, B)$$

where σ_E is the standard deviation of \tilde{R}_E , σ_B is the standard deviation of \tilde{R}_B and $\rho(E, B)$ is the correlation coefficient of \tilde{R}_E and \tilde{R}_B .

The next step is to express bond market returns as a linear function of δ , the change in a benchmark long-term yield:

$$(4) \quad \tilde{R}_B - R_F = A_2 - D_B \tilde{\delta} + \tilde{e}_2$$

The coefficient, D_B , is the effective duration of the bond market relative to shifts in the benchmark yield (taken as 10-year Treasuries for the example in the text). The random variable, \tilde{e}_2 , accounts for all other market effects from yield curve reshaping, spread changes, and so forth. Once again, we assume that:

$$(5) \quad E(\tilde{e}_2) = 0 \text{ and } E(\tilde{\delta} \cdot \tilde{e}_2) = 0$$

We then combine (1) and (4) to relate equity market returns to yield changes:

$$(6) \quad \tilde{R}_E - R_F = A_3 - D_E \tilde{\delta} + \tilde{e}_3$$

where

$$(7) \quad D_E = D_B B$$

and

$$(8) \quad \tilde{e}_3 = B\tilde{e}_2 + \tilde{e}_1$$

Here, we make the assumption that nonparallel shift effects are independent of stock market behavior, so that:

$$(9) \quad E(\tilde{e}_2 \bullet \tilde{e}_1) = 0$$

and so that all parallel shift effects upon the stock market are sufficiently represented through bond market returns, that is:

$$(10) \quad E(\tilde{d} \bullet \tilde{e}_1) = 0$$

The latter assumption enables us to conclude that:

$$(11) \quad E(\tilde{d} \bullet \tilde{e}_3) = 0$$

(It should be noted that the above assumptions are non-trivial; for example, certain nonparallel yield curve effects such as changing short- to long-term rate spreads could have a direct impact on stock market behavior.)

With this result in (11), one can demonstrate that:

$$(12) \quad \rho(E, \tilde{d}) = \rho(E, B) \rho(B, \tilde{d})$$

and that

$$(13) \quad D_E = D_B \left(\frac{\sigma_E}{\sigma_B} \right) \rho(B, E)$$

has the statistical property of being an equity market duration.

Moreover, since from (4), one has:

$$(14) \quad D_B = - \left(\frac{\sigma_B}{\sigma_{\tilde{d}}} \right) \rho(B, \tilde{d})$$

one may express the equity/yield change correlation (12) as:

$$(15) \quad \rho(E, \tilde{d}) = - \rho(E, B) \left(\frac{\sigma_{\tilde{d}}}{\sigma_B} \right) D_B$$

For a portfolio of bonds and stocks, the total return \tilde{R}_T becomes

$$(16) \quad \tilde{R}_T = W_{BP} \tilde{R}_{BP} + W_{EP} \tilde{R}_{EP}$$

where W_{BP} and W_{EP} are the fractional allocations to the bond and stock portfolios, and \tilde{R}_{BP} and \tilde{R}_{EP} are the respective component returns.

Suppose the bond portfolio has a duration of D_{BP} and that its returns are related to parallel yield shifts through:

$$(17) \tilde{R}_{BP} - R_F = A_4 - D_{BP} \tilde{\delta} + \tilde{e}_4$$

where once again:

$$(18) E(\tilde{e}_4) = 0 \text{ and } E(\tilde{\delta} \bullet \tilde{e}_4) = 0$$

Also suppose that the equity portfolio has a beta value of β_{EP} and that its return is related to the equity market return by:

$$(19) \tilde{R}_{EP} - R_F = A_5 + \beta_{EP} (\tilde{R}_E - R_F) + \tilde{e}_5$$

By carrying out the same type of combination of (18), (1), and (4), as in the earlier derivation, one obtains:

$$(20) \tilde{R}_{EP} - R_F = A_6 - \beta_{EP} D_E \tilde{\delta} + \tilde{e}_6$$

Using similar assumptions as before, \tilde{e}_6 is assumed to be independent of $\tilde{\delta}$. (The assumption that \tilde{e}_5 is uncorrelated with $\tilde{\delta}$ implies that the equity portfolio was constructed to achieve a pure β_{EP} magnification of the volatility of the market as a whole; that is, all "yield tilt" and/or interest rate factors retain the same proportional weight as in the equity market index.) With these assumptions, one obtains:

$$(21) D_{EP} = \beta_{EP} D_E \\ = \beta_{EP} D_B \left(\frac{\sigma_E}{\sigma_B} \right) \varrho(B, E)$$

which is a duration measure for the equity portfolio.

The objective is to be able to express the total portfolio return in terms of a parallel rate shift term and an "all other market factors" term:

$$(22) \tilde{R}_{TP} - R_F = A_7 - D_{TP} \tilde{\delta} + \tilde{e}_7$$

This follows directly from (16) and (19) together with the assumptions that have been made regarding the independence of the \tilde{e} residuals. Moreover, the total portfolio duration D_{TP} may be written as:

$$(23) D_{TP} = W_{BP} D_{BP} + W_{EP} \beta_{EP} D_B \left(\frac{\sigma_E}{\sigma_B} \right) \varrho(B, E)$$

The effective allocation to the fixed-income market could now be expressed as the equivalent interest rate sensitivity of the total portfolio. This could be articulated in a number of ways. For example, for a given portfolio allocation where a given correlation $\rho(B, E)$ is assumed, one might ask what the corresponding bond allocations W_B^* would be in a traditional environment (where $\rho = 0$) to achieve the same total rate sensitivity:

$$(24) \quad D_B W_B^* = D_{TP} \cdot 1$$

or

$$(25) \quad W_B^* = \frac{D_{TP}}{D_B} \\ = W_{BP} \frac{D_{BP}}{D_B} + W_{EP} \beta_{EP} \left(\frac{\sigma_E}{\sigma_B} \right) \rho(B, E)$$

More generally, one might gauge the allocation against a benchmark bond portfolio having any target duration, D_{TGT} :

$$(26) \quad W_B^* = \frac{D_{TP}}{D_{TGT}}$$

In particular, if one chose the liability duration, D_L , as the target, then the surplus function would be immunized (to the first order) when $W_B^{**} = 100$ percent, and at risk with higher or lower W_B^{**} values.

The surplus function, S , is simply the difference in the total portfolio value, V_{TP} , and the present value, V_L , of the liabilities,

$$(27) \quad S = V_{TP} - V_L$$

If D_L is the duration of the liabilities, then the first-order linear effect of interest changes upon the surplus function becomes:

$$(28) \quad \Delta S = \left[\frac{\partial V_{TP}}{\partial \delta} - \frac{\partial V_L}{\partial \delta} \right] \tilde{\delta} + \tilde{e}_s$$

But

$$(29) \quad \frac{\partial V_{TP}}{\partial \delta} = -D_{TP} V_{TP}^{\circ}$$

and

$$(30) \quad \frac{\partial V_L}{\partial \delta} = -D_L V_L^{\circ}$$

so that

$$(31) \quad \Delta S = - \left[D_{TP} V_{TP}^{\circ} - D_L V_L^{\circ} \right] \tilde{\delta} + \tilde{e}_8$$

$$= -V_L^{\circ} \left[D_{TP} \left(\frac{V_{TP}^{\circ}}{V_L^{\circ}} \right) - D_L \right] \tilde{\delta} + \tilde{e}_8$$

Thus, relative to the initial value of the liabilities as a base, the expression D_S ,

$$(32) \quad D_S = D_{TP} \left(\frac{V_{TP}^{\circ}}{V_L^{\circ}} \right) - D_L$$

is a first-order approximation for the parallel rate shift sensitivity of the surplus function.