Total Return Management of Central Bank Reserves

Second Edition

January 2005

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- We discuss several developments in fixed-income markets that have led to changes in benchmark selection for central bank reserve management. The trend away from quick and massive currency interventions has shifted the balance reserve managers need to strike between maximizing liquidity and maximizing total return closer to total return objectives. The declining relative supply of U.S. Treasuries over much of the past decade, the relative attractiveness of spread product, the emergence of the euro credit market, and the gradual reduction in gold reserves have contributed to a consideration of including new asset classes in official reserves benchmarks.

- We develop a quantitative framework to address two main issues in redesigning a benchmark: what should be the benchmark's target duration and its allocation to spread assets.

- Lehman Brothers developed the No-View Treasury Portfolio Optimization strategy to meet the typical central bank constraints of liquidity and capital preservation. This strategy maximizes the expected return under an assumption of an unchanged yield curve (hence, "No-View"), subject to shortfall constraints.

- If invoked infrequently (e.g., once a year), No-View Optimization can be used to set benchmark duration targets. When used more frequently (e.g., monthly), it can help outperform benchmarks by dynamically allocating positions along the yield curve. This method consistently produces respectable information ratios and can be customized for a particular benchmark definition, risk tolerance, and required minimum return.

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- Given the size of a typical reserve portfolio, a strong argument can be made for inclusion of spread products, as event risk can be diversified. Including spread products provides a broader set of outperformance possibilities and risk diversification than a pure U.S. Treasury portfolio. We describe how to construct optimal credit portfolios for long-horizon investors using a quantitative framework developed by Lehman Brothers.

- Interest rate swaps earn a spread over Treasuries and have low idiosyncratic credit risk and high liquidity. Some institutions view swaps as a separate total return asset class, providing a portfolio with another type of spread sector exposure. We discuss the role swaps can play as a distinct asset class in central bank portfolios.

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INTRODUCTION TO THE SECOND EDITION

In the first edition of *Total Return Management of Central Bank Reserves*, published nearly three years ago, we discussed structural forces that were causing official institutions to re-examine their investment strategies and give greater consideration to managing their reserves with more of a total return and less of a liquidity objective. Since that time, while some of those forces have increased (e.g., the growth of the Euro credit markets) and others have diminished (e.g., worries about the shortage of U.S. Treasury debt securities), the movement toward a more total-return perspective has gained momentum. Some official institutions have even established investment subsidiaries to manage a portion of reserves on a strictly total return basis. While the parent organization usually sets custom benchmarks for its subsidiaries to reflect a desired duration profile and risk tolerance, the subsidiary portfolio managers have wider discretion to seek additional performance. This approach has offered several advantages to the parent organization: better use of portfolio management talent, improved risk management and performance attribution analytics and, most important, better and more diverse ideas for reserves management.

This second edition reflects several of the changes that occurred in quantitative portfolio management over the past three eventful years. As in the first edition, we devote a large part of the discussion to benchmark customization and the investment case for non-Treasury assets. However, in reaction to the stressful credit markets of 2001 and 2002 and reflecting the demand for better portfolio and risk management tools from long-horizon investors, we added two new sections describing our recent work in these areas.

First, since the credit events of 2001 and 2002 and the launch of the Lehman Brothers Swap Indices in 2002, investors have paid more attention to swaps as an asset class rather than a proxy for credit assets. We offer a quantitative analysis of the performance of swaps as a stand-alone investment instrument relative to other asset classes typically used by central banks. We show that swaps offer attractive relative returns with virtually no idiosyncratic “headline” risk and act as a good diversifier of portfolio risk.

Second, we introduce some new methods and tools specifically targeted to long-horizon investors. Some (especially Asian) central banks that recently experienced a rapid rise in the size of their reserves began separating their portfolios into two parts: the smaller managed on a total return basis and the larger on a buy-and-hold basis over a long horizon. Long- and short-horizon investors have different investment objectives and different perspectives on risk of spread (*i.e.,* non-Treasury) assets. Over a short horizon, spread returns are nearly symmetrical, because in the short run, spreads are more or less equally likely to either widen or tighten. Consequently, short-horizon investors typically try to maximize expected return while minimizing expected monthly tracking error (volatility of return deviation from the benchmark). Over a long horizon, however, credit returns are asymmetrical, as spread assets either earn a relatively narrow spread over Treasuries (with high probability) or lose a large fraction of their value (with low probability). Consequently, long-horizon investors typically try to maximize expected spread over Treasuries while minimizing the chance of large portfolio losses (sometimes referred to as "tail risk") commonly measured by value-at-risk or expected shortfall (total loss in the negative tail).

Long-horizon investors often approach spread asset investing as a two-step process. First, such investors typically make a "macro" decision regarding the portfolio allocation to various credit qualities (*e.g.,* Aa versus A). This is a decision that must balance the spread offered by various spread assets against the risk of defaults, including the risk of correlated defaults, over the investment horizon. Given the buy-and-hold nature of most reserve portfolios, this is a strategic decision that has a major effect on portfolio returns. Lehman Brothers has developed a method to determine the optimal allocation given the current level of spreads, expected recovery rates, and default correlations within each quality rating. In this edition, we outline this optimal allocation method and provide references to a more detailed description of the approach.

Once the strategic credit allocation decision has been made, the second decision is security selection for the long-horizon portfolio. Lehman Brothers has developed a portfolio tool, called COMPASS, for just this purpose. COMPASS performs two functions. It allows an investor to measure the expected shortfall of a portfolio given the investment horizon, default and recovery rates, and default correlations. COMPASS also includes an optimizer, so that the investor can specify a spread target, a set of eligible bonds, and various portfolio constraints (*e.g.*, an issuer cap of 1.5%) and have COMPASS determine the optimal positions in individual bonds that minimize the portfolio's expected shortfall, while satisfying the spread target and all the constraints. We believe that the quantitative discipline offered by these tools and methods can help central banks manage their reserve portfolios in an efficient and risk-controlled manner while contributing to enhanced portfolio performance.

For almost two decades, Lehman Brothers Quantitative Portfolio Strategies Group has worked with investors and official institutions to design custom benchmarks, evaluate risk and performance of various investment strategies, and develop portfolio management tools such as the Lehman Brothers Global Risk Model.[1] This has been a mutually productive relationship. On the one hand, we can help formulate and answer investor questions and concerns in a quantitatively rigorous fashion. On the other, the questions and concerns we hear from investors help shape our thoughts and research agenda. Working with central banks has been an integral part of this decades-long dialog, and we look forward to continuing this dialog in the years to come!

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[1] For details on Lehman Brothers' fixed-income risk models, please refer to "Multi-factor Risk Analysis of Bond Portfolios," by Lev Dynkin and Jay Hyman, in *Risk Management for Central Bank Foreign Reserves*, C. Bernadell, P. Cardon, J. Coche, F. Diebold, and S. Manganelli, editors, European Central Bank, May 2004.

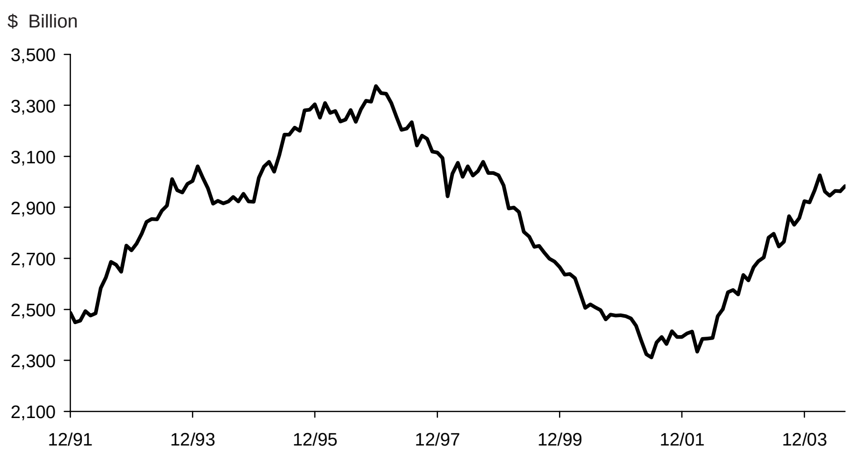
NEW DEVELOPMENTS IN THE MANAGEMENT OF FOREIGN CURRENCY RESERVES

Several events over the past decade have led central banks and other national wealth managers to re-examine their portfolio investment strategies. Perhaps the most important event has been the decline in the supply of U.S. Treasuries over much of the past decade. This asset class has historically comprised a substantial percentage of dollar reserves held by non-U.S. official institutions. As of September 2004, non-U.S. official institutions' holdings of marketable U.S. government debt comprised 29% of outstanding marketable supply.[2] Figure 1 portraits the dramatic decline in the supply of U.S. Treasuries between 1997 and early 2002. The drop in the supply of U.S. Treasuries was truly remarkable, in terms of both magnitude and suddenness. No one had anticipated such a dramatic turn of events. This down trend has reversed to some extent since the beginning of 2002, in response to the U.S. slowdown, tax cuts, and increased spending for national security. However, the supply of U.S. Treasuries currently available is still substantially lower than it was in the mid-1990s.

Figure 2 illustrates the effect of the change in the supply of U.S. Treasuries on the composition of the Lehman Brothers U.S. Aggregate Index. As of December 2001, Treasuries made up only 22% of the Lehman Brothers U.S. Aggregate Index, compared with 46% at the beginning of the 1990s. Despite the subsequent reversal in the supply of U.S. Treasuries since 2002, their share of the Aggregate

[2] Federal Reserve Board of Governors, *Flow of Funds Accounts of the United States*, Z.1 Release, Second Quarter 2004 and U.S. Treasury *Monthly Statement of the Public Debt of the United States*, August 31, 2004.

Figure 1. **Market Value of Outstanding Supply of U.S. Treasuries**
All Maturities, December 1991-August 2004



Index has increased only slightly. In contrast, the share of credit assets in the index increased from 19% in 1998 to 27% by early 2003. As of the beginning of September 2004, the market shares of Treasuries and credit were about even at 24% each, well behind the 36% share for mortgage-backed securities.

The large shift in the relative supply of Treasuries and spread product has contributed to the re-pricing of spread assets. Figure 3 shows the spread to off-the-run Treasuries of 10-year Aa-rated industrial corporate bonds since January 1994. Note that corporate spreads began to widen after it became apparent that absolute Treasury supply was declining. Corporate spreads continued to widen as the

Figure 2. **Market Value of Various Asset Classes**
Maturities of 1 Year and Longer; as a % of the Lehman Brothers U.S. Aggregate Index, December 1989-August 2004

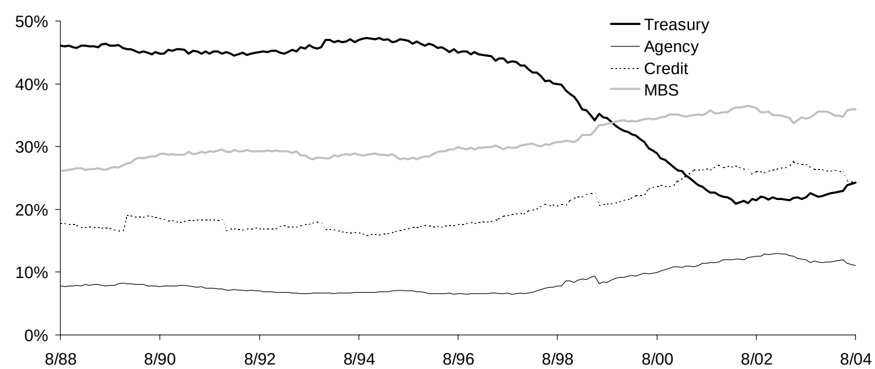
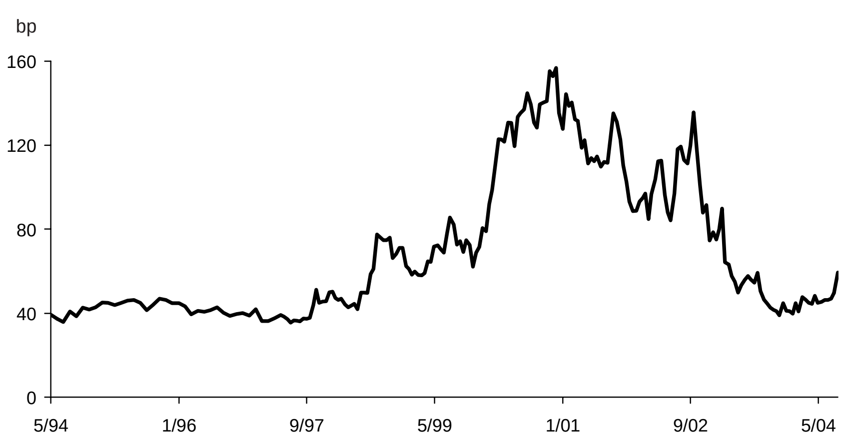


Figure 3. **10-Year Aa-Rated Industrial Corporate Spreads to Off-the-Run U.S. Treasuries**
January 1994-August 2004



economy cooled and investors' perceptions of default risk increased. Following the reversal in the supply of U.S. Treasuries in 2002, corporate spreads have tightened dramatically, reaching a level of 40-60 basis points.

National reserve managers responded in several ways to the reduction in Treasury supply and the increased relative attractiveness of spread product. First, many institutions expanded their investments in other asset classes that had long been acceptable, such as Aaa-rated sovereign and U.S. agency debt (including both debentures and, in rare instances, mortgage passthrough securities). Others began to explore new asset classes such as Aaa-rated asset-backed securities with stable cash flows. Over the years, official institutions have conducted research and have developed their back-office and trading capabilities in these asset classes. These particular assets have several attributes that make them a reasonable substitute for a portion of official U.S. Treasury holdings. First, they are all Aaa-rated, which allows institutions to add these assets without having to staff-up a large credit analysis operation. Second, these assets involve very little "headline," or "C-1," risk.[3] Official institutions have long been sensitive to the potential political problems of holding debt securities of an entity that is receiving unfavorable public scrutiny. Simply holding the entity's debt could give the appearance of endorsing its behavior.

Another response to reduced Treasury supply and the "headline" risk attached to specific credit assets has been consideration of interest rate swaps as a source of credit spread exposure. As the supply of swaps is potentially unlimited and does not depend on a single issuer, the swaps market avoids many of the idiosyncratic risks that accompany the U.S. Treasury and credit markets. Official institutions can invest cash in short-term bank and corporate assets and increase their spread duration by receiving the fixed-rate leg of an interest rate swap.[4]

The second major event of the past decade to influence reserve management practices was the emergence of the euro. The sharing of a single currency permits better reserves efficiency, allowing EMU member countries to pool their foreign currency reserves. Instead of each national central bank (NCB) holding significant reserves to buffer balance-of-payment and exchange rate fluctuations both within Euroland and with other countries, the ECB can meet the same requirements on behalf of all members with a much smaller amount of reserves overall. Consequently, the ECB has unshackled a significant amount of NCB reserves from the need to provide immediate liquidity. While it is still a possibility that NCBs may be called on to support the ECB in a major foreign exchange crisis, the ECB has given the NCBs the opportunity to manage their reserves with more of a total return objective. Instead of considering reserves solely as a liquidity

[3] "C-1" risk refers to an event that figures prominently on the front page of the *Money & Investing* section (*i.e.,* page C-1) of the *Wall Street Journal.*

[4] See "Swaps as a Total Return Instrument" *Global Relative Value*, Lehman Brothers, April 7, 2003.

reservoir, reserves (or some portion thereof) can be viewed as a national asset and maximizing its total risk-adjusted rate of return a national priority.

A related event during the 1990s was a reconsideration of the efficacy of foreign exchange intervention on a massive scale. Previously, central banks felt they needed vast amounts of dollars available at a moment's notice to challenge speculators whom they believed were destabilizing the currency. However, as massive intervention did not always accomplish its goal, central banks began to search for other ways to bolster their credibility to defend their currency. The increased use of joint intervention among several central banks and a willingness to intervene on a smaller, but much more sustained, scale have given central banks much-needed time when combating destabilizing currency movements. Central banks no longer have to manage their dollar reserves with the possibility that they would have to liquidate a substantial portion of reserves on short notice. Instead, they can credibly and effectively defend their currencies by demonstrating a commitment to liquidate dollar holdings as needed over time. This change in intervention thinking also allows central banks to manage their dollar reserves with more of a total return and less of a liquidity objective.

The emergence and deepening of the euro credit market has been another event over the decade that has caused central banks and other national wealth managers to re-examine their investment strategies. In the past, if an official institution wanted to invest in credit product, it could do so only in dollars. This limitation was a major disincentive for official investors to expend the time and resources to develop credit expertise. Today, there exists a thriving euro credit market that is expected to grow significantly in the future. The potential rewards of credit analysis are now much greater and can be applied to the management of all national financial assets.

Another recent event is the willingness of central banks gradually to sell portions of their gold holdings. While this activity will have little short-term impact, the long-run implications are substantial for reserve management. It is reasonable to expect that some proceeds from gold sales will be re-deployed in higher yielding fixed-income assets. Consequently, fixed-income assets are likely to grow from this activity, and there will be a need to find attractive ways to invest these assets.

All of these events have caused central banks to review the investment strategies for their reserve portfolios. In some cases, particularly for the NCBs in EMU member countries, the new circumstances may allow currency allocations to change significantly, possibly including a portion in the institution's domestic currency. Even when relieved of the burden of supporting the currency, however, central banks must consider many factors in setting their currency allocations besides total return maximization (*e.g.*, balance of trade and liability matching). This decision is a complex one, and the primary considerations vary from one country to the next. For these reasons, the details of the currency allocation decision are outside the scope of this report, which focuses on total return management.

Within each currency, due to the events discussed above, central banks and other official institutions are now thinking more like traditional portfolio managers in the private sector. As a result of this shift in investment strategy, institutions are encountering two questions commonly faced by traditional asset managers:

1) How to set the portfolio's duration target? and
2) How much of the portfolio (if any) should be allocated to the various non-Treasury asset classes?

We devote a separate section of this report to each of the two questions above and show how quantitative portfolio techniques can be used to address them. We first turn to the question of how to set a portfolio's duration target.

The goal of any asset manager is to achieve maximum return with minimum risk. There are several ways of formalizing this goal as an optimization problem. For example, one may seek the maximum return under a given risk constraint, or maximize a risk-versus-return ratio. In addition to specifying the objective function, managers are also confronted with choosing among different measures for both risk and return. Risk is usually measured in terms of historical return volatility, with some subtle distinctions: Volatility of total returns, excess returns over cash, or excess returns over Treasuries? Volatility of daily, monthly or quarterly returns? Volatility over what historical time period? For measuring returns, even more variations are possible. Many studies use *historical* returns. Analysis of historical data can provide useful insights into the risks of investing in different asset classes (or at different points along the yield curve) and the associated returns. However, determining the "best" trade-off between risk and return can be somewhat subjective and depends on the goals and constraints set for a given portfolio. Furthermore, every manager has had to confront the question: How well can historical returns serve as a proxy for future returns?

We discuss the traditional approach to duration setting, which uses historical Sharpe ratios. We also discuss some of the limitations of this approach. In particular, Sharpe ratio maximization ignores the "no loss" constraint under which reserve managers must operate.

An alternative to using historical data is to use *projected* expected returns based on analyst forecasts, but then the quantitative analysis is driven by the subjective recommendations of the analyst and cannot serve as an independent check.

A third possibility is to use a "No-View" forecast—that is, a return projection based on a neutral assumption. Each asset is assumed to earn a horizon return consistent with current market conditions remaining essentially unchanged. As discussed below, we make extensive use of this form of "No-View" optimization, both for setting benchmark duration and for managing a portfolio to outperform an established performance benchmark. Under No-View, the manager simply assumes that the current yield curve remains unchanged for his review period. The manager then specifies his risk constraint (*e.g.*, minimum allowable return), and the optimization produces a target portfolio duration that maximizes expected performance subject to the risk constraint. We also show how No-View can be used to outperform an established benchmark.

Next, we turn to the question of what fraction of a portfolio should be allocated to non-Treasury assets, given that many official institutions hold spread assets for relatively long periods of time. We discuss the main factors that determine the optimal credit allocation for long-horizon investors and how they are different from those considered by short-horizon investors. We also describe a method developed by Lehman Brothers that helps determine the strategic allocation across various credit qualities, conditional on the current level of spreads, expected recovery rates, and default correlations within each quality class.

Unlike many credit sectors, swaps offer tremendous liquidity benefits, as well as virtually no idiosyncratic event risk. We show that swaps have offered total returns comparable with other asset categories and provide useful portfolio diversification benefits because of their relatively low correlation with other spread assets. We discuss the role swaps can have as a distinct asset class in central bank portfolios.

METHODS FOR SETTING THE PORTFOLIO'S DURATION TARGET

If an institution manages its reserves to maximize "risk-adjusted" returns, what should be the duration target of its portfolio? Extending the duration, or the interest rate sensitivity, of a portfolio tends to increase the portfolio's expected returns but at the cost of increased market value volatility. Generally, portfolio managers have no incentive to extend the portfolio's duration unless they expect to be compensated sufficiently for the increase in risk. One traditional approach to duration target-setting is to select the duration value that historically has produced the best risk-adjusted performance, or the greatest return per unit of risk.

Traditional Approach to Portfolio Duration Setting: Sharpe Ratios

The Sharpe ratio is a commonly used measure of risk-adjusted performance that shows the average excess return (over the risk-free return) per unit of volatility in excess returns.[5] The Sharpe ratio is defined as:

$$SR_i = \frac{\text{mean}\,(d_i)}{\text{standard deviation}\,(d_i)},$$

where d_i is defined as the monthly total return on bond (or portfolio) i minus the monthly risk-free return for the same month. The mean and standard deviation of the excess returns are computed over many months.

Using data from October 1993 through August 2004, we calculate Sharpe ratios for U.S. Treasuries of the following maturity buckets: < 1.5 years, 1.5-3.5 years, 3.5 -7.5 years, 7.5-15 years, 15-25 years, and > 25 years. We use a risk-free return based on the one-month term repurchase rate backed by (general collateral) U.S. Treasuries. In a similar manner, we also calculate Sharpe ratios for the euro (German treasuries prior to December 1998, and the euro core curve thereafter) and the Japanese yen (JGB). The results are shown in Figure 4.

Figure 4 demonstrates that relatively short-duration U.S. Treasuries had the best risk-adjusted performance over the past thirteen years. In fact, the shortest maturity Treasury bucket had the best Sharpe ratio. The results for the euro and Japanese yen are very similar to those for U.S. Treasuries: short maturity bonds produced the best risk-adjusted performance. In both cases, the best Sharpe ratio was produced by the 2-year maturity Treasury (for the yen, the 5-year maturity had a similar Sharpe ratio).

For all three currencies, the conclusion is that shorter-maturity Treasuries generally produce the best risk-adjusted returns. This is one reason traditional central bank duration targets are in the six-month to two-year range.

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[5] For information on the Sharpe ratio, please refer to "Mutual Fund Performance," by William F. Sharpe, *Journal of Business,* January 1966.

Another Approach to Portfolio Duration Setting: No-View Optimization

One objection to using historical Sharpe ratios for portfolio duration targeting is that realized returns can vary widely from one year to the next. In contrast, volatilities are much less variable. Consequently, historical Sharpe ratios fluctuate significantly depending on the time period selected. The approach presented above used a long historical period in an effort to smooth out these fluctuations. However, if we repeat the analysis in the previous section using only data from the first part of the period (October 1993 to September 1999), the results for the U.S. Treasuries differ substantially. As Figure 5 shows, the Sharpe ratios were generally much lower than

Figure 4. **Sharpe Ratios by Maturity for Various Currencies**
October 1993 -August 2004

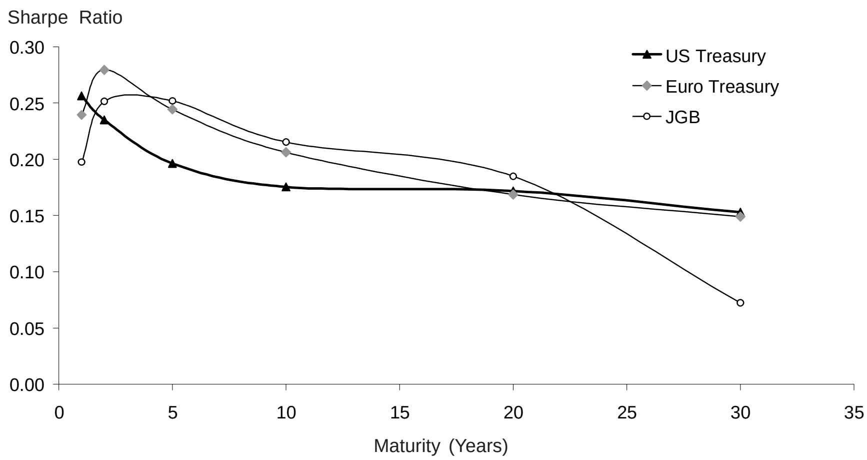
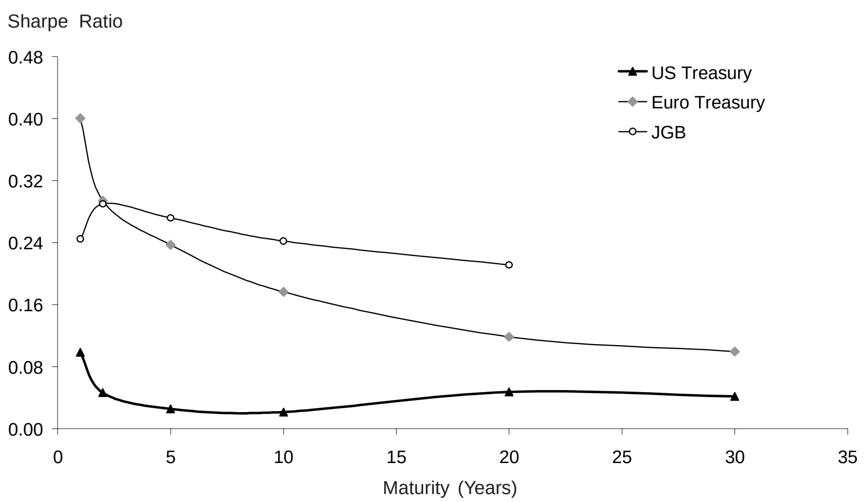


Figure 5. **Sharpe Ratios by Maturity for Various Currencies**
October 1993-September 1999



those in the second part of the period. One conclusion we can draw from this is that using the Sharpe ratio is most appropriate for an organization that plans to change its portfolio's duration target relatively infrequently.

The use of Sharpe ratios alone also does not accurately represent the approach to risk and reward typical of official institutions such as central banks. The implicit message of such a ratio is that any risk may be acceptable as long as it carries the promise of sufficient expected returns. This may be reasonable for a long-term total return manager, but does not reflect the constraints under which reserves managers must operate. In many cases, the prime directive given by a reserve board to its managers resembles the doctor's oath: "First, do no harm." In other words, the goal is to achieve the highest possible returns while maintaining liquidity and minimizing the probability of negative total returns over the course of a review period.

Limitations of the Sharpe ratio maximization approach became particularly apparent to managers of U.S. dollar-denominated reserves in 1994. This was a year of significant interest rate tightening by the Federal Open Market Committee of the U.S. Federal Reserve Board that saw 3-month Treasury bill yields rise from 3.08% to 5.69%. Returns for many fixed income assets were close to zero for the year, including assets in the 1- to 3-year maturity bucket traditionally preferred by central banks and often selected by the Sharpe ratio approach. Relying on short-duration assets, with their typical low yields, is no guarantee of positive total returns!

Investors in short-duration Treasuries faced a similar situation at the end of October 2004 when the yield on the Lehman 1-3 Year Treasury Index dropped to 2.48%, one of the lowest levels on record. This low yield level provided relatively thin protection against the prospect of a negative total return over the next twelve months. The small safety margin against negative returns was particularly troublesome given the steepness of the yield curve and its implications for future yield increases and negative price returns. Investors in this part of the curve might have been concerned that an unexpectedly strong and fast economic recovery could result in the first negative annual return for 1- to 3-year Treasuries.[6]

In light of these events, many institutions have sought a quantitative mechanism for setting the portfolio's duration under a "no loss" requirement. One response is to use historical data to answer the following question: What fixed combination of Treasury assets of various maturities would have maximized the long-term average total return subject to the constraint that the total return in every review period was positive? As one would expect, the answer differs depending on the portfolio review period. To guarantee no negative returns over any given monthly

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[6] Please refer to the Appendix for a thorough analysis of the likelihood of negative total returns for short-duration assets over an annual holding period.

review period requires an extremely conservative portfolio duration. Guaranteeing non-negative returns for longer review periods (*e.g.*, a quarter, half-year, or full year) allows for progressively longer durations.

There are other drawbacks to this type of analysis. Essentially, it assumes that an allocation based on historical data that never had a negative return over a given review period is unlikely to have one in the future. Yet this is not foolproof. An allocation having a constraint of no negative annual return based on data before 1994 would have had a negative return in 1994. (As a result, the same analysis repeated one year later would indicate a shorter duration—but only after the fact.) However, duration targets based on shorter review periods would have succeeded in avoiding negative returns for 1994.

Another drawback of this static approach is that it assumes a single target duration held constant over time. In fact, this decision is often reviewed periodically, based on the current level and slope of the yield curve. Higher yields mean that a larger rise in rates may be absorbed without experiencing a loss, so a steeper yield curve provides a bigger incentive to extend along the curve. Each time the target duration is revisited, the decision should therefore consider the current market environment, as well as the requirement to achieve a minimum return (*e.g.*, zero) over the review period.

To improve on the static approach and at the request of several central banks, we developed the Lehman Brothers No-View Treasury Optimization strategy. This dynamic strategy imposes a minimum return requirement (*e.g.*, zero) but allows the target duration to change periodically in response to market conditions. In this method, historical returns are used to determine the risk of various points on the yield curve, but not to project their expected returns. To estimate expected returns, the investment manager is assumed to have "no view" on the movement in interest rates. The manager simply assumes that the current yield curve will be the yield curve at the end of his review period. Given the current yield curve and the review period (say, one quarter), expected returns and standard deviations of returns can be calculated for various maturity points. The minimum return requirement, at a given level of confidence, specifies the allowable amount of risk. With expected returns and a minimum return requirement we can construct the portfolio with the highest expected return for this given amount of risk. The duration of this portfolio can then be considered to be the optimal target duration.

No-View Optimization is designed to boost portfolio performance while meeting institutional requirements for liquidity and capital preservation. It can be used for two important portfolio management applications. The first application is to determine the portfolio's target duration, as described above. While the optimization produces an optimal portfolio allocation to a given set of assets, the key output in this application is the target duration. This process is repeated on a fairly infrequent basis, perhaps annually. Below, we present an example of using No-View Optimization to determine a portfolio's target duration.

The second application of No-View Optimization uses the optimization as a portfolio strategy tool to help outperform a benchmark. In this case, the optimization is carried out on a frequent basis (*e.g.*, monthly), and the portfolio is rebalanced to match the optimal allocation along the yield curve. Later in this section, we discuss and present an example of this second application of No-View Optimization. Throughout this section, we provide illustrations of the strategy's behavior based on data through the end of 2001. Fully up-to-date data for specific parameter sets are, of course, available on a customized basis.

Application #1:
Using No-View Optimization to Determine a Portfolio's Target Duration

As mentioned above, the key feature underlying No-View Optimization is that there is no attempt to predict future interest rates. Instead, we assume that the current par yield curve remains unchanged over the review period. In essence, this is a naïve yield curve model that maintains the constant prediction of no change in the yield curve. In practice, weekly and monthly yield curve changes are extremely hard to predict. Few sophisticated yield curve forecasting models offer better forecasts than the naïve model. Rather than having portfolio allocations driven by imprecise estimates of yield curve changes, No-View Optimization sets the expected return for the upcoming period equal to current yield plus rolldown plus a convexity correction.[7] Using historical return volatilities (usually computed by taking the standard deviation of realized total returns over, say, the last sixty months), the procedure employs statistical optimization to select assets offering the highest expected return for a given amount of risk.

The No-View Optimization procedure chooses portfolio asset weights (and, hence, the portfolio's duration) to maximize expected return subject to risk constraints. The optimization has three basic parameters that can be adjusted to reflect the risk tolerance of a particular institution: the length of the review period, the minimum allowable return (r_{min}), and the size of the confidence level (n) in achieving the minimum return. The length of the review period is defined as the performance interval for the strategy. For example, if the strategy is required to produce a specific minimum return each quarter, then the length of the review period is three months. For very short review periods, the strategy is forced to select a very short duration portfolio, as a small rise in yields can easily offset the yield earned on the portfolio. However, lengthening the review period generally allows the strategy to take more

[7] For two assets of the same duration, the one with greater positive convexity will outperform in an extreme yield curve shift in either direction. The convexity term reflects this as an advantage in expected return. The convexity correction is (1/2) x convexity x $(\text{volatility})^2$. This correction increases the expected return of longer duration (*i.e.,* more convex) assets so that expected returns of all assets in the investment set can be compared on a convexity neutral basis.

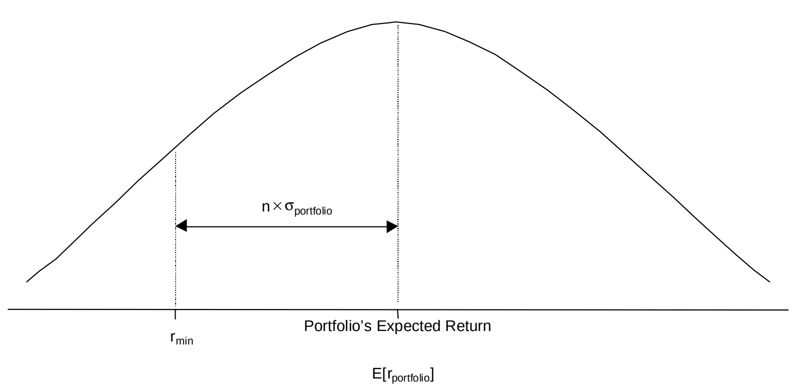
risk (*i.e.*, by increasing the portfolio's duration), as the portfolio has additional time to earn a yield to offset any adverse price movement.

The minimum return threshold specifies the minimum critical return value, which the portfolio is allowed to violate only a certain percentage of the time, depending on the confidence level (n). In other words, the expected return on the portfolio over the review period must be at least n standard deviations above the worst case return (r_{min}). Together, r_{min} and n determine the statistical frequency that the portfolio's return may fail to achieve a return equal to r_{min}. As explained more fully below, a given review period, minimum return threshold and confidence level determine the set of allowable portfolios, each with its own expected return ($E[r_{portfolio}]$) and risk ($\sigma_{portfolio}$). Figure 6, which shows a stylized distribution function of a portfolio's total return, presents a graphic description of a portfolio that satisfies the risk constraint. For example, if the review period is quarterly, the minimum return threshold is 1%, and the confidence level is one standard deviation, the optimization procedure looks for the portfolio with the highest expected return and whose expected return and standard deviation of returns satisfy the risk constraint. In this example, a portfolio whose standard deviation of returns ($\sigma_{portfolio}$) equals 50 basis points and whose quarterly expected return is at least 1.50% satisfies the risk constraint.

The amount of risk the strategy can take can be increased by lengthening the review period, by lowering the minimum return threshold, or by reducing the confidence level. Moving any parameter in the opposite direction will make the strategy more conservative.

It is important to note that a portfolio that satisfies the risk constraint may sometimes violate the minimum return threshold. There is always the possibility that some extraordinary event will cause yields to rise faster than ever before.

Figure 6. **No-View Optimization,** Risk Constraint Schematic



However, if the volatility of future yield changes is assumed to be similar to the historical volatility, then the probability of losses beyond the confidence interval is relatively small and is known in a statistical sense. If returns are normally distributed, then for $n = 1$, the probability that returns will violate the minimum return threshold is 15.9%.[8] If a higher level of confidence is required, a greater value of n should be used. If $n = 2$ standard deviations, the probability that returns will violate the minimum return threshold falls to 2.3%. As the value of n increases, the optimization selects a less volatile (*i.e.*, shorter duration) portfolio in order to reduce the chance that portfolio returns will violate the minimum return threshold.

In mathematical terms, No-View Optimization finds the asset weights, w_i, for all assets eligible to be included in the portfolio (*i.e.*, the investment set) that solve the following linear programming problem: [9]

$$\begin{aligned} &\text{maximize} && \Sigma_i w_i \mathrm{E}[r_i] \\ &\text{such that} && \Sigma_i w_i (\mathrm{E}[r_i] - n \times \sigma_i) = r_{min}\text{, and} \\ &&& w_i \geq 0 \text{ for all i (\textit{i.e.}, no short sales allowed),} \end{aligned} \qquad (1)$$

where

$\mathrm{E}[r_i]$ is the expected return of the ith security in the investable set;

n is the number of standard deviations used to determine the confidence level;

σ_i is the return volatility of the ith security in the investable set; and

r_{min} is the minimum return threshold for the review period.

The following example shows how No-View Optimization can be used to set a portfolio's target duration. Assume that the manager's review period is one quarter, the minimum return threshold is 25 basis points per quarter, and the confidence level is one standard deviation. Based on the yield curve as of 30 June 2001 and the historical volatilities of quarterly asset returns over the preceding five years, the inputs for the optimization are presented in Figure 7.

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[8] If portfolio returns are normally distributed, then the probability that returns are within one standard deviation from the mean is 68.3%. Consequently, the probability that returns are less than one standard deviation below the mean is 15.9% (= ½ ×(1 – 0.683)).

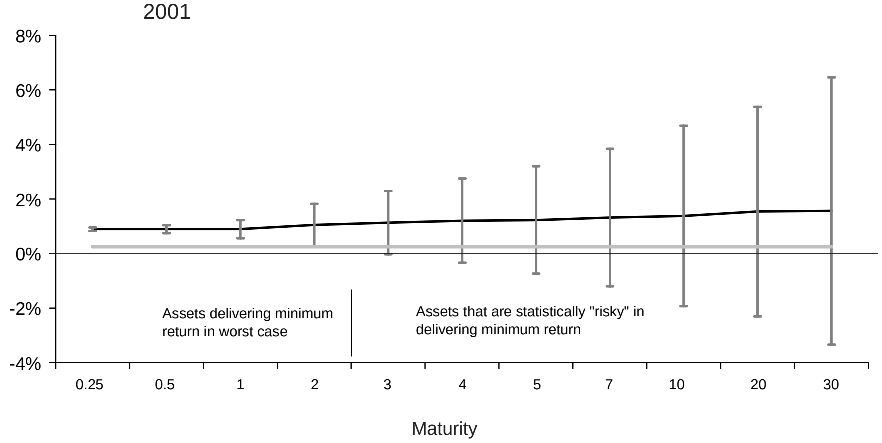
[9] Results are similar whether one uses a quadratic procedure to calculate portfolio risk or a linear procedure that simply assumes that all Treasury returns are perfectly correlated. To err on the side of conservatism, our procedure assumes that Treasury returns are perfectly correlated in the risk constraint, implying that all points on the yield curve experience their worst case returns simultaneously.

Figure 8 presents graphically the information in Figure 7. The solid black line shows the expected return as a function of the maturity of the Treasury security. The grey line represents the minimum return threshold of 25 basis points per quarter. For each maturity, quarterly expected return equals the current yield plus rolldown plus a convexity adjustment assuming that the yield curve remains unchanged over the review period. The vertical bars at each maturity represent one standard deviation around the expected return value. For example, for the 2-year Treasury, the quarterly expected return is 1.05%, and a one standard deviation interval around the expected return is given by 1.05% -0.77% to 1.05% + 0.77%, or 0.28% to 1.82%. Note that the 2-year Treasury delivers the required minimum return in the worst case but all longer maturity Treasuries do not.

Figure 7. **Portfolio Duration Targeting: No-View Optimization Inputs**
June 30, 2001**, %**

U.S. Treasury Maturity	6/30/01 Yield	Quarterly Expected Return	Standard Deviation of Quarterly Returns
3-month	3.65	0.89	0.07
6-month	3.63	0.89	0.15
1-year	3.63	0.89	0.33
2-year	4.26	1.05	0.77
3-year	4.60	1.13	1.16
4-year	4.89	1.21	1.54
5-year	4.95	1.32	2.53
7-year	5.27	1.32	2.53
10-year	5.40	1.38	3.31
20-year	5.91	1.54	3.85
30-year	5.81	1.56	4.90

Figure 8. **No-View Optimization: Expected Returns of U.S. Treasury Assets with 1 Standard Deviation Confidence Intervals,** June 30, 2001



No-View Optimization then finds the best combination of issues to maximize expected returns subject to the risk constraint. Figure 9 presents the portfolio produced by No-View Optimization. The portfolio contains a 33% weighting in the 3-month Treasury bill and a 67% weighting in the 3-year Treasury note. By buying some of the low-risk asset (*i.e.*, the 3-month Treasury bill) the optimization is able to buy some riskier assets (*i.e.*, the 3-year Treasury note) to obtain a higher expected return. The portfolio's target duration is given by the duration of the portfolio found by the optimization: 1.85 years. As will be shown later, concentration constraints can be imposed so that No-View Optimization will not recommend too high a concentration in a single position.

There are several ways to use the output of the optimization to form a performance benchmark. An investment manager can use the optimal portfolio (with its precise asset weights) as a performance benchmark. Alternatively, the duration of the optimal portfolio can be used strictly to determine the target duration for the portfolio. It is then possible to define a performance benchmark with this target duration but with asset weights determined using other methods that might better reflect a manager's investment restrictions. One example would be to subdivide the Lehman Treasury Index into a short-duration sub-index and a long-duration sub-index, and then weight the two sub-indices so that benchmark duration equals the No-View Optimization's target duration.

As discussed, No-View Optimization uses the current yield curve as of the analysis date to set the target duration. However, this target may become "stale" as the yield curve changes over time. If left unchanged for too long, it could drift away from the current optimal target duration. On the other hand, if the portfolio's target duration is recomputed too frequently, portfolio duration and risk properties may become highly variable. A reasonable compromise is to re-compute the target duration whenever the yield curve moves significantly. Perhaps the easiest way to determine staleness is to set re-computation triggers based on the cumulative change in the steepness and level of the Treasury curve.

Application #2: Using No-View Optimization to Outperform an Established Performance Benchmark

No-View Optimization is also helpful when trying to outperform a pre-specified benchmark. For this application, the risk parameters r_{min} and n can be set based on

Figure 9. **Portfolio Duration Targeting: No-View Optimization Results**
June 30, 2001

U.S. Treasury Issue	% Market Value in Portfolio	Duration
3-month	33%	0.24
3-year	67%	2.64
	100%	1.85 = target duration

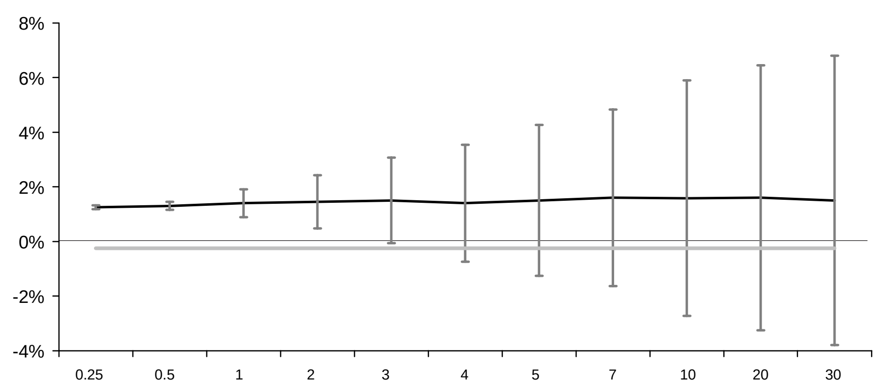
the institution's overall risk constraint or set to match the benchmark's risk profile. In addition to the main risk constraint, the procedure may also contain a concentration constraint (discussed below) that limits exposure to any single asset. Investors can then employ No-View Optimization to search for a portfolio that has higher expected return than the benchmark but that satisfies the risk constraint.

As an example, suppose an investor's performance benchmark is a 3-year maturity U.S. Treasury note. Assuming a quarterly performance horizon, we express expected returns, return volatility, and the minimum allowable return in terms of percent per quarter. Let's initially suppose the minimum allowable return is a fixed *negative* 25 basis points per quarter (r_{min} = -0.25) and the confidence level is set to one standard deviation (n = 1). The investment set consists of 3-month, 6-month, 12-month, 2-year, 3-year, 5-year, 7-year, 10-year, 20-year, and 30-year Treasuries. Figure 10 shows the expected returns and one standard deviation bands for each security in the investment set as well as the minimum return threshold.

No-View Optimization seeks to maximize expected return subject to the risk constraint. If the investment set contains only securities with maturities of 3-years and less, the procedure would choose a 100% investment in the 3-year note. This is because the 3-year note offers the highest expected return and does not violate the risk constraint. In this case, the portfolio's expected return would be 1.61% (per quarter).

However, with the actual investment set, the procedure improves on a 100% investment in the 3-year note by placing 60% of asset value in the 2-year note and 40% in the 7-year note. The very small decrease in expected return that comes from moving assets from the 3-year to the 2-year moves the portfolio further away from its risk constraint. The optimization procedure then finds that it can allocate this "unused" portion of the risk constraint to a position in the 7-year note and achieve

Figure 10. **No-View Optimization: Expected Return of U.S. Treasury Assets with 1 Standard Deviation Confidence Intervals, Minimum Allowable Return -25 bp/quarter,** June 30, 2001



a pickup in portfolio expected return of 6 basis points per quarter (= 1.67% - 1.61%) while still satisfying the risk constraint.

In the example above, the risk constraint had a static minimum return threshold. However, this threshold could be made variable and customized to reflect the performance benchmark. The next section illustrates some possible enhancements to the risk constraint.

Setting the Minimum Return Threshold

The minimum return threshold can be defined in a variety of ways. The simplest is to set the minimum return to be a fixed constant as was shown above (*e.g.*, $r_{\min}$ = -25 basis points per quarter). However, floating thresholds and relative thresholds are also possible. A *floating* minimum return threshold ties the minimum worst case return to the expected return of the benchmark portfolio. One example of a floating threshold would be to set the threshold to the expected return on the benchmark less 50 basis points (quarterly). In other words, the floating threshold would be:

$$r_{\min} = E[r_{bench}] - 50 \text{ basis points},$$

where

$E[r_{bench}]$ = expected return on the benchmark.

In this case, as interest rates and the expected return of the benchmark rise, the worst case return rises as well.

A *relative* minimum return threshold ties the minimum worst case return to the minimum worst case return of the benchmark. In other words, a relative minimum return threshold uses a formula of the form:

$$r_{\min} = E[r_{bench}] - n \times \sigma_{bench},$$

where

$E[r_{bench}]$ = expected return on the benchmark;

σ_{bench} = the benchmark's return volatility; and

n=the same number of standard deviations used in the risk constraint

(Equation (1)).

Figure 11 illustrates the relative minimum return threshold. In general, a relative threshold tends to produce a portfolio with a risk similar to that of the benchmark. How so? The risk constraint requires

$$E[r_{portfolio}] - r_{min} = n \times \sigma_{portfolio}.$$

Substituting $E[r_{bench}] - n \times \sigma_{bench}$ for r_{min} we have

$$E[r_{portfolio}] - E[r_{bench}] = n \times (\sigma_{portfolio} - \sigma_{bench}).$$

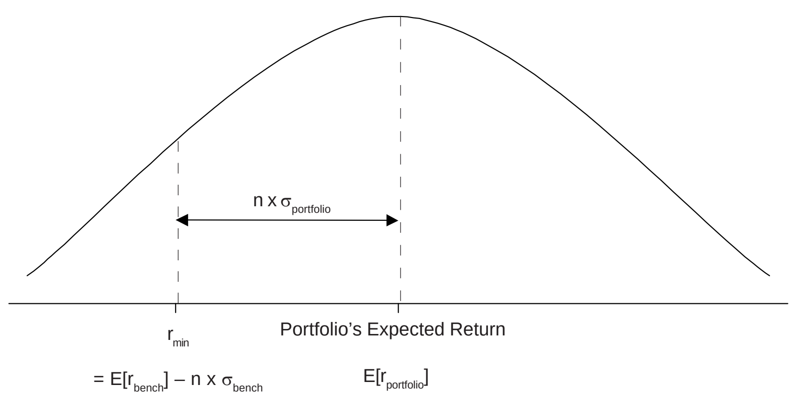
If the expected returns on the portfolio and the benchmark are close, then $\sigma_{portfolio}$ will be close to σ_{bench}.

In the case of a relative minimum return threshold, changes in the investor's value of *n* have little effect on the portfolio's volatility. To see this, step through the changes in the risk constraint as *n* increases. If the investor increases his value of *n*, the minimum return threshold (r_{min}) decreases. Holding everything else unchanged, the lower threshold permits selection of a portfolio with higher expected return and risk since the minimum return threshold is now further away from the portfolio's expected return. However, this effect is immediately offset because the increase in the confidence level implies that the investor wishes to reduce the probability that his portfolio's return violates the now-lower minimum return threshold. In other words, the effect on portfolio risk ($\sigma_{portfolio}$) of the reduction in r_{min} is offset by the demand for greater confidence that the portfolio's return does not fall short of r_{min}. Consequently, changes in the investor's value of *n* tends to have little effect on $\sigma_{portfolio}$.

The relative threshold tries to keep the worst case return for the portfolio close to the worst case return for the benchmark. This allows the optimization procedure to create a portfolio that is expected to outperform the benchmark at no additional risk.

We now turn to some advanced features of No-View Optimization.

Figure 11. **No-View Optimization: Relative Minimum Return Threshold**



Advanced Features of No-View Optimization: Inversion Detection and Dynamic Threshold Adjustment

Inversion Detection

No-View Optimization is based on the assumption of a positive risk-return trade-off. When the yield curve is inverted, the assumption of an unchanging yield curve is not tenable because it implies that short-maturity bonds have both lower risk and higher expected returns than long-maturity bonds. In order to avoid using the unchanging yield curve assumption during such periods, an inversion detection procedure can be invoked that requires buying the benchmark during inversions.

The criterion for detecting yield curve inversion is as follows:

1) Divide assets in the investment set into a short bloc (3-month to 2-year) and a long bloc (3-year to 10-year);
2) Calculate the average expected return for each bloc; and
3) If the expected return on the long bloc is less than the expected return on the short bloc, then the yield curve is inverted and inversion detection requires investment in the benchmark.

If the yield curve was inverted in the previous period, then the quarterly expected return on the long bloc this period needs to be at least 5 basis points higher than the short bloc for the procedure to declare that inversion has ended. This 5 basis point buffer provides stability during periods in which the yield curve is on the cusp of inversion.

Dynamic Adjustment of the Minimum Return Threshold

Investors can also implement No-View Optimization with a dynamic adjustment feature that automatically varies the risk constraint depending on year-to-date performance. Specifically, if the portfolio has underperformed the benchmark beyond a certain limit, then dynamic adjustment tightens the minimum return threshold (*i.e.,* increases r_{min}). Conversely, if the portfolio has outperformed, then the minimum return threshold is loosened. (We represent the change in the minimum return threshold due to the dynamic adjusted feature by the term Δ_{dyn}.)

The dynamic adjustment feature is very flexible. Dynamic adjustment can be used with different types of minimum return thresholds (*e.g.,* absolute and relative). The rule can also be uniform throughout the year, or it can change in ways most suitable for the investor. For example, some investors may choose to set dynamic adjustment (Δ_{dyn}) equal to zero in the fourth quarter irrespective of the level of year-to-date outperformance. This feature helps to protect earlier gains as the portfolio nears the end of its annual review period. We will use this feature in the example below.

To use dynamic adjustment, the investment manager specifies a maximum amount of *annual* underperformance to be tolerated *relative to the performance target*. If the manager is using an absolute minimum return threshold, then the minimum annual return is the performance target. If the manager is using a relative minimum return threshold, then the benchmark is the performance target. Once the manager specifies an annual underperformance limit, the following two quantities can be defined:

> *pro rata* limit = annual underperformance limit × (fraction of a year since January 1), and
>
> *excess* underperformance = MAX[realized year-to-date underperformance – *pro rata* limit, 0].

If year-to-date underperformance is less than the *pro rata* limit, then the risk constraint is left unchanged. However, if the year-to-date underperformance is greater than the *pro rata* limit, then the risk constraint is tightened by the amount of the excess underperformance. The risk constraint can be tightened until the portfolio is forced to hold cash (*i.e.*, duration = 0). In the case of year-to-date outperformance, dynamic adjustment loosens the risk constraint by the amount of realized year-to-date outperformance. In summary, dynamic adjustment equals

excess underperformance, or
year-to-date actual outperformance (or, = 0 in fourth quarter).

For example, if an absolute minimum return threshold is used and the portfolio underperforms this target, then dynamic adjustment tightens the risk constraint (raises r_{min}), which shortens the portfolio's duration. The shorter duration reduces the risk that the portfolio will further underperform its target and also gives the portfolio a chance to recover a portion of its absolute underperformance *via* earnings on its short duration assets.

Dynamic adjustment works in much the same way if the investor uses a relative minimum return threshold. The effect of dynamic adjustment on the relative minimum return threshold is as follows:

$$r_{min} = \mathrm{E}[\mathrm{r}_{bench}] - n \times \sigma_{bench} - \Delta_{dyn.}$$

To illustrate dynamic adjustment, consider the case in which the annual underperformance limit is set to 200 basis points, implying a quarterly *pro rata* limit of 50 basis points. At the start of the year, the amount of dynamic adjustment equals zero. If first-quarter realized underperformance exceeds 50 basis points, then the risk constraint will tighten by the amount of the underperformance in excess of 50 basis points. If the amount of underperformance is less than 50 basis points, then dynamic adjustment equals zero. Figure 12 illustrates the dynamic adjustment function at the end of the first quarter.

If, at the end of the second quarter, year-to-date underperformance exceeds 100 basis points, then the minimum return threshold is increased by the amount of the underperformance in excess of 100 basis points. If year-to-date underperformance at the end of the second quarter is less than 100 basis points, then the dynamic adjustment equals zero. Figure 13 illustrates the dynamic adjustment function at the end of the second quarter.

In each period, if the portfolio has year-to-date outperformance, then dynamic adjustment loosens the risk constraint by the full amount of year-to-date outperformance. However, in an effort to safeguard year-to-date gains going into the fourth quarter, the amount of dynamic adjustment equals zero at the start of the fourth quarter irrespective of the amount of year-to-date outperformance.

Figure 12. **Dynamic Adjustment Function at End of First Quarter**

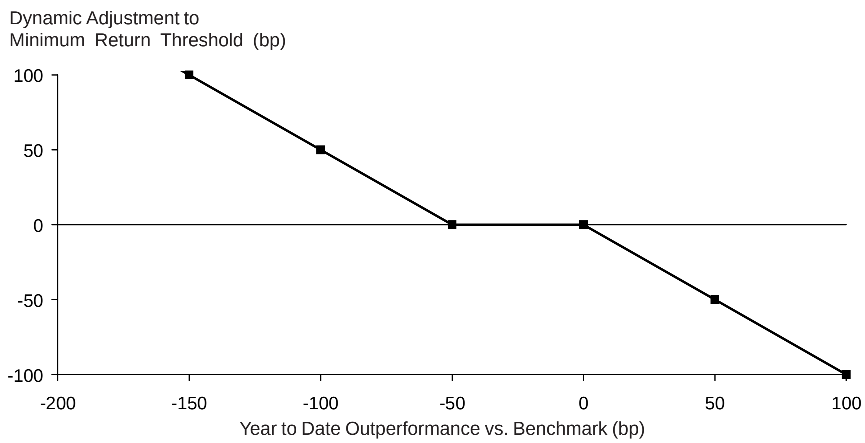
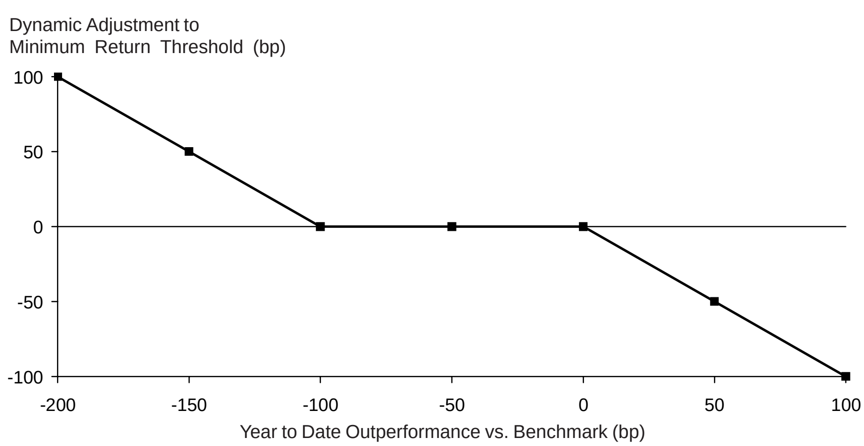


Figure 13. **Dynamic Adjustment Function at End of Second Quarter**



Depending on year-to-date performance, dynamic adjustment moderates the aggressiveness of No-View Optimization in its search for excess returns while still meeting the yearly risk constraint. Figure 14 shows how dynamic adjustment can alter the risk of the portfolio. In this example, the portfolio has outperformed, producing a positive dynamic adjustment value. In turn, the minimum return threshold is reduced by the dynamic adjustment value. Assuming that the investor leaves his confidence level (*n*) unchanged, the optimization will now select a riskier (*i.e.*, $\sigma'_{portfolio} > \sigma_{portfolio}$) portfolio if it will produce greater expected returns while still meeting the new risk constraint (r'_{min}).

Conversely, if the portfolio had underperformed, it would have produced a negative dynamic adjustment value equal to the excess underperformance. Consequently, the minimum return threshold is increased by the dynamic adjustment value (Figure 15). Assuming that the investor leaves his confidence level (*n*) unchanged, the optimization will now select a less risky (*i.e.*, $\sigma''_{portfolio} < \sigma_{portfolio}$) portfolio to maximize expected returns while meeting the new risk constraint (r''_{min}). It is important to note that the new portfolio is less risky in an absolute sense (*i.e.*, lower duration), not necessarily in a relative sense (*i.e.*, duration closer to that of the benchmark).

Other Advanced Features of No-View Optimization

No-View Optimization seeks to maximize expected return subject to the risk constraint. Depending on the shape of the yield curve and historical volatilities, No-View Optimization may select a portfolio with a duration very different from the benchmark duration. This may make some managers uncomfortable despite the fact that the portfolio should not violate the minimum return threshold at the stated confidence level.

Figure 14. **Effect of a Positive Dynamic Adjustment Value on Portfolio Risk**

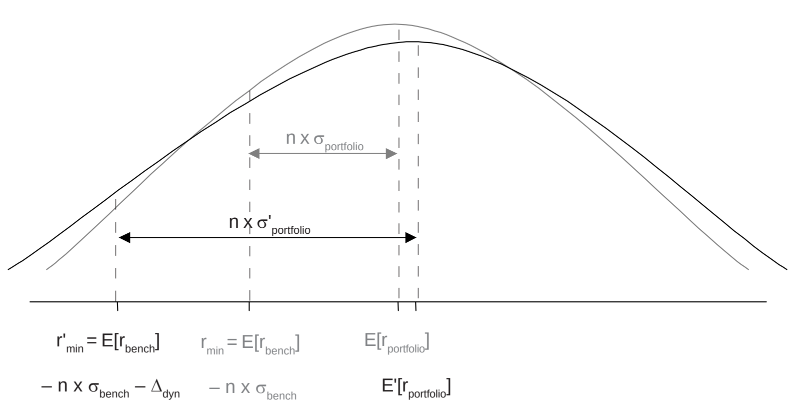
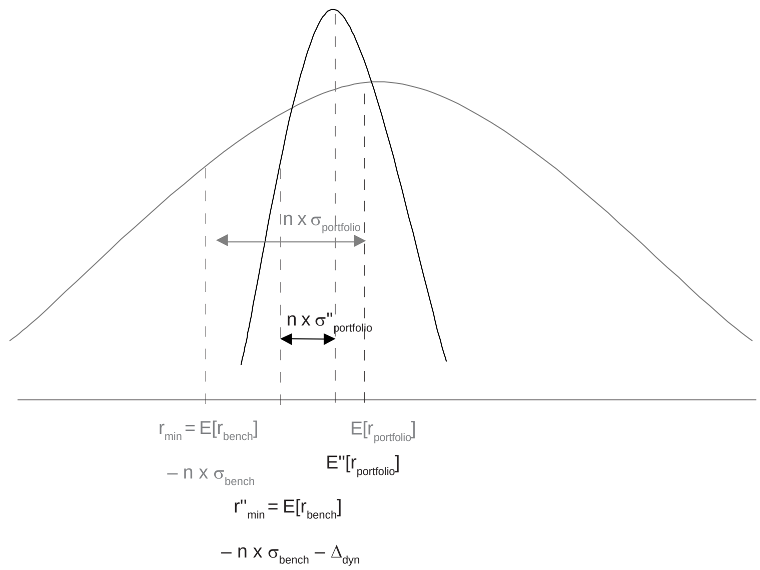


Figure 15. **Effect of a Negative Dynamic Adjustment Value on Portfolio Risk**



To further reduce the possibility of violating the minimum return threshold, No-View Optimization allows the user to specify constraints on the maximum and minimum portfolio duration (the *duration constraint*). Typically, duration constraints are set to keep portfolio duration within a symmetric band around the benchmark duration.

No-View Optimization also allows the user to set the maximum portfolio percentage allocation to any single security (the *concentration constraint*). This feature allows investors to reduce the potential for peculiar movements at points along the yield curve to affect relative performance.

Later in this section, we present data on the effects of these two constraints on the performance of the portfolio.

Evaluating the Performance of the No-View Optimization Strategy

It is instructive to examine in detail the performance of the No-View Optimization strategy. When is the strategy likely to outperform and underperform the benchmark?

To illustrate the ability of No-View Optimization to outperform a benchmark, we simulated the performance of the strategy over a fifteen year period. The investment set consisted of 3-month, 6-month, 12-month, 2-year, 3-year, 5-year, 7-year, 10-year, 20-year, and 30-year Treasuries. The performance benchmark was a 3-year duration Treasury index and the portfolio was rebalanced at the end of each month according to the optimization solution. The performance horizon was quarterly. We used a relative minimum return threshold, inversion detection, and set the confidence level equal to one. The concentration constraint was set to 60% and the dynamic adjustment mechanism allowed a 50 basis point shortfall per quarter (*i.e.,* a 200 basis point annual underperformance limit) before any tightening of the risk constraint.

Quarterly results for three different settings of the duration constraint are shown in Figure 16. The first set of columns contains results for a very loose duration constraint (zero to ten years). The second requires the portfolio's duration to be within one year of the benchmark's duration. The last set imposes a very tight duration constraint, forcing the portfolio's duration to be within half a year of the benchmark's duration. We will discuss in detail the results for the optimization with the widest duration constraint (*i.e.*, zero to ten years). The wide duration constraint helps to magnify the performance of the strategy and highlights those environments in which the strategy is likely to outperform or underperform.

In an effort to maximize expected returns, No-View Optimization has a tendency in a positive yield curve environment to produce a portfolio with a duration longer

Figure 16. **Performance of No-View Optimization**
Effect of the Duration Constraint
Performance Benchmark = 3-Year Duration UST Index, 1986–2000

		Duration Constraint								
	Benchmark	0–10 Years			2–4 Years			2.5–3.5 Years		
Year	Return	Return	Diff	Dur	Return	Diff	Dur	Return	Diff	Dur
1986	12.80%	12.10%	-0.68%	4.89	14.60%	1.80%	4.00	13.5%	0.68%	3.50
1987	2.32	2.88	0.56	3.06	2.88	0.56	3.06	2.88	0.56	3.06
1988	6.27	6.46	0.19	2.80	6.46	0.19	2.80	6.45	0.19	2.80
1989	12.80	13.50	0.69	3.17	13.50	0.71	3.14	13.50	0.74	3.10
1990	9.23	9.24	0.01	3.03	9.24	0.01	3.03	9.24	0.01	3.03
1991	12.90	16.10	3.28	3.44	14.70	1.88	3.26	14.30	1.42	3.14
1992	6.13	6.48	0.35	4.41	6.72	0.59	3.42	6.63	0.50	3.21
1993	7.54	13.50	5.95	7.71	9.00	1.46	3.89	8.36	0.83	3.46
1994	-0.80	-1.04	-0.25	3.03	-1.04	-0.25	3.03	-1.04	-0.25	3.03
1995	13.70	21.90	8.18	7.16	15.70	2.04	3.94	14.70	1.02	3.49
1996	3.83	3.65	-0.18	3.63	3.54	-0.29	3.44	3.48	-0.35	3.40
1997	7.82	8.31	0.49	3.89	9.06	1.24	3.75	8.44	0.63	3.46
1998	8.23	8.64	0.41	3.83	8.76	0.53	3.51	8.84	0.61	3.28
1999	0.43	0.27	-0.16	3.24	0.27	-0.16	3.24	0.27	-0.16	3.22
2000	9.96	8.75	-1.21	2.92	8.75	-1.21	2.92	9.30	-0.67	2.97
Average	7.54	8.72	1.18	4.01	8.15	0.61	3.36	7.93	0.38	3.21
Std. Dev.			2.61			0.93			0.57	
Info. Ratio			0.45			0.65			0.67	

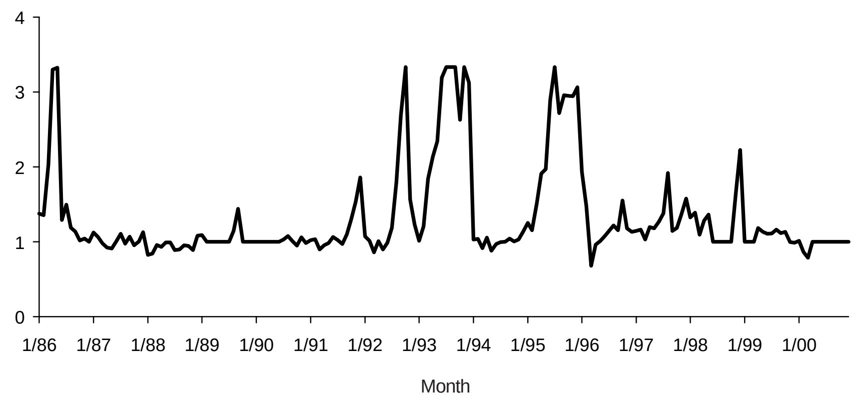
than the benchmark. Since a positively sloped yield curve is the usual situation, No-View Optimization is typically long its benchmark. Note that the relative duration of the portfolio is likely to be only loosely related to the degree of curve steepness. The optimization tries to maximize expected returns and will do so in all positively sloped curve environments. Even if the curve is only moderately steep, the optimization will try just as hard to add duration as it would if the curve were particularly steep. In contrast, the relative duration of the portfolio is likely to be more closely related to the looseness of the risk constraint. As the risk constraint is loosened, the optimization will maximize expected returns with more latitude to increase portfolio volatility (*i.e.*, duration).

Figure 17 shows the monthly relative duration of the optimized portfolio versus the benchmark since January 1986. Note that the relative duration is typically greater than 1.0, indicating that the portfolio generally has a longer duration than the benchmark.

Since the strategy usually begins with a relatively long duration, the strategy will initially outperform in a given year if rates decline. This outperformance, in turn, loosens the risk constraint (*via* dynamic adjustment), which allows the strategy to increase its relative duration for the next month. If the market continues to rally, the strategy's outperformance increases, which further loosens the risk constraint and permits further relative duration extension. Consequently, in a trending and rallying market, this strategy will likely perform well.

If, instead of continuing to rally, rates increase, the strategy will begin to underperform. Depending on the magnitude of the underperformance, the risk constraint is tightened which tends to reduce the portfolio's duration. If the market

Figure 17. **Ratio of No-View Optimization Portfolio Duration to Benchmark Duration**
3-Year Duration Benchmark; Relative Minimum Return Threshold; Quarterly Review Period; Monthly: January 1986-December 2000



continues to sell off, the portfolio's relative underperformance likely continues (although at a diminished rate), which produces a further tightening of the risk constraint (and duration reduction).

This duration reduction from the tightening risk constraint serves two purposes. First, if the portfolio's duration was initially greater than the benchmark's, it brings the portfolio's duration closer to that of the benchmark. This tends to slow down any further relative underperformance. Second, the duration reduction serves to protect the portfolio's absolute return. If the rising interest rate trend continues, the portfolio's absolute duration will decline further (*i.e.*, relative duration less than 1.0) and will tend to "lock in" the portfolio's absolute performance for the year. However, it is important to note that the portfolio's relative performance will not be "locked in." In fact, if rates continue to rise, the portfolio (whose duration has been shortened relative to the benchmark) may begin to outperform the benchmark.

In a "choppy" market, the strategy's performance will likely stay close to the benchmark's, depending on the monthly pattern of rate movements. If the market initially rallies, the strategy will outperform and its relative duration will extend as described above. If the market then sells off, the strategy gives up some (perhaps exceeding) its prior month's gain, producing a possible tightening of its risk constraint. Consequently, as the market bounces around, the strategy produces small gains and losses.

To better understand how No-View Optimization performs, let's examine actual annual performance of the strategy. Figure 18 shows the performance of the No-View strategy for the years 1990 through 2000. Note that in every year but one (1994), the strategy had positive absolute returns.

Figure 19 shows the slope (10-year versus 2-year) of the U.S. Treasury curve for the years 1990 through June 2004. Inversion detection occurred in early 1990, mid-1998, early 1999, and for most of 2000. Figure 19 also shows the yield of the 5-year Treasury note. As discussed above, we would expect the No-View strategy to perform well, both absolutely and relatively, in a trending and a rallying market. Based on Figure 19, Figure 20 lists the years in which the level of yields declined somewhat steadily throughout much of the year. How well did the strategy perform?

The strategy performed extremely well, both absolutely and relatively, in four of these five years. As the market rallied, the portfolio, with its relatively long duration position, outperformed the benchmark. As the portfolio outperformed, the risk constraint was loosened, allowing the portfolio to lengthen further, producing additional outperformance as the market steadily rallied.

It is informative to compare performance in years 1993 and 1995. Although yields declined in both years, yields fell only in the second half of 1993, whereas they fell continuously throughout 1995. In addition, rates fell more than twice as much in

Figure 18. **No-View Optimization Strategy Annual Performance: Absolute and Relative Returns,** 3-Year Duration Benchmark; Relative Minimum Return Threshold; Quarterly Review Period, 1990-2000

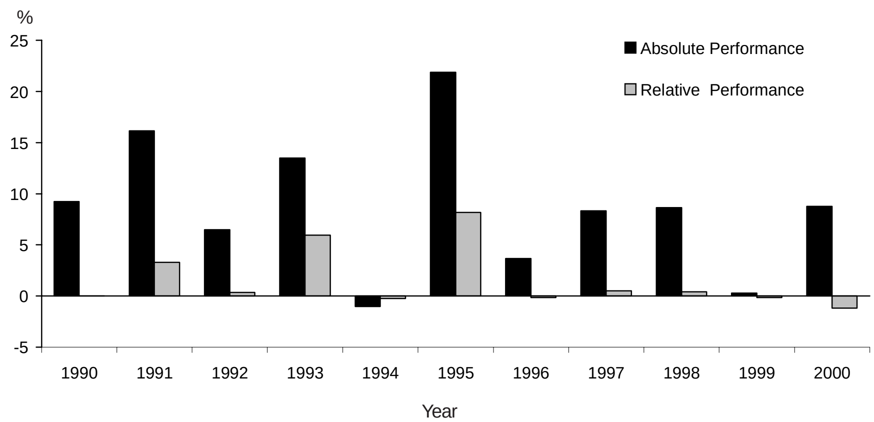


Figure 19. **2- to 10-Year Treasury Curve Slope and 5-Year Treasury Yield**
1990-2004

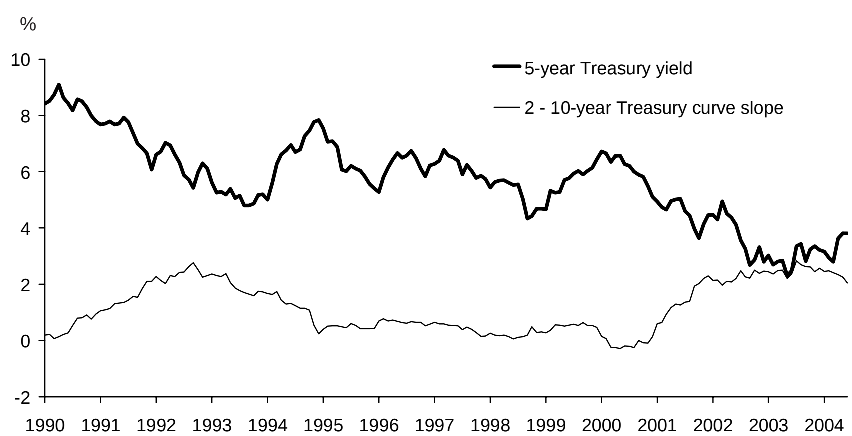


Figure 20. **No-View Optimization in Years When Yields Generally Fell**
3-Year Duration Benchmark; Relative Minimum Return Threshold; Quarterly Review Period, Absolute and Relative Performance in %

Year	Inversion Detection During Year?	Portfolio's Average Duration	Portfolio's Relative Performance	Portfolio's Absolute Performance
1991	No	3.44	3.28	16.14
1993	No	7.71	5.95	13.49
1995	No	7.16	8.18	21.87
1998	Yes	3.83	0.41	8.64
2000	Yes	2.92	-1.21	8.75

1995 than they did in 1993. As a result, 1995 was able to profit more from the relaxation of the risk constraint and achieve greater absolute and relative outperformance compared with 1993.

Note, however, the peculiarly poor performance in 2000. Rates rose early in the year, producing underperformance. Although rates fell sharply in the second half of the year, inversion detection kicked in which prevented the strategy from going long duration versus the benchmark as the market rallied. Instead, inversion detection required that the portfolio invest in the benchmark, locking in its relative losses from the first half of the year. However, the portfolio and the benchmark were able to enjoy some respectable absolute returns for the year.

As Figure 19 shows, interest rates increased steadily during most, if not all, of the following three years: 1994, 1996, and 1999. Figure 21 reveals that the strategy underperformed its benchmark in each of these three years. However, the underperformance was relatively small. As discussed above, the increase in yields caused the relatively long duration portfolio to underperform the benchmark. As rates continued to rise, the underperformance persisted, but was mitigated by the tightening of the risk constraint.

Note the performance in 1996: relative performance of -0.18%, but an absolute performance of 3.65%. In this year, rates rose in the first half but declined in the second, with a small overall increase for the year. As rates initially rose, the strategy underperformed relative to the benchmark causing its duration to drift toward that of the benchmark. As rates subsequently fell, the portfolio's absolute performance improved but its relative underperformance persisted.

The strategy managed to outperform in 1997 both absolutely (+8.31%) and relatively (+0.49%), despite the rise in yields in the first third of the year, because the strategy was able to maintain a long relative duration position as yields rallied for the remainder of the year.

1990 and 1992 were roughly neutral relative performance years. In 1990, rates rose initially, producing underperformance. However, rates rallied strongly in

Figure 21. **No-View Optimization in Years When Yields Generally Rose**
3-year Benchmark; Relative Minimum Return Threshold; Quarterly Review Period, Absolute and Relative Performance in %

Year	Inversion Detection During Year?	Portfolio's Average Duration	Portfolio's Relative Performance	Portfolio's Absolute Performance
1994	No	3.03	-0.25	-1.04
1996	No	3.63	-0.18	3.65
1999	Yes	3.24	-0.16	0.27

the second half of the year, allowing the strategy to perform in line with the benchmark. In 1992, rates rose initially, then rallied for most of the year allowing the portfolio to outperform and extend duration. Unfortunately, rates rose strongly in the last four months of the year and erased much of its earlier relative outperformance.

In general, the strategy produces good relative performance in years in which interest rates trend downward. However, the downward trend in rates must occur before any market sell-off causes the dynamic adjustment mechanism to constrain its relative and absolute duration position. The danger for the strategy is if interest rates rise sharply, causing underperformance and a tightening of the risk constraint that limits potential for relative and absolute market gains if rates were to fall subsequently. After a period of rising rates, investors may be tempted to remove the dynamic adjustment feature. However, this feature protected the portfolio nicely during some of the most difficult market environments in which rates continued rising. Overall, the strategy follows the successful trader’s maxim: “Let your profits run, but cut your losses early.”

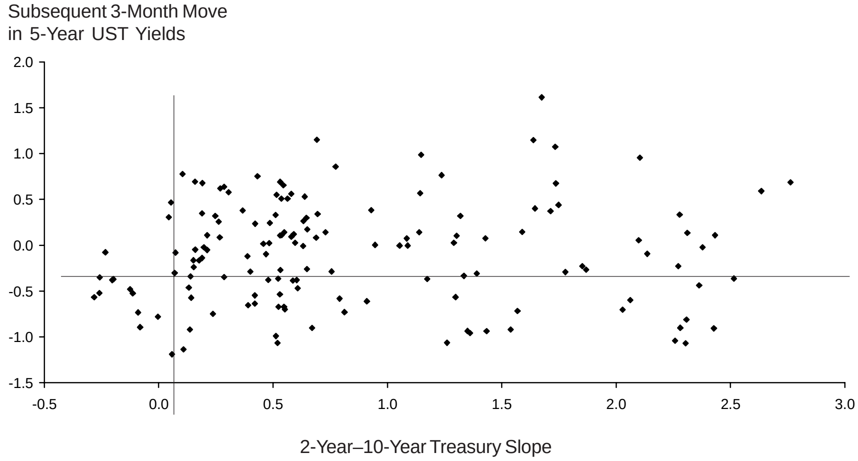
Is there a particularly good time to begin this strategy? As discussed, the strategy has a bias to be long duration versus the benchmark. Should investors implement the strategy when the curve is particularly flat (but, not inverted) or steep? Conventional wisdom suggests that when the curve is steep, this is a signal that economic recovery may begin soon, causing interest rates to rise. Conversely, when the curve is flat, this is a signal of an impending economic slowdown, leading to lower interest rates. If conventional wisdom holds, then it may be better to implement this strategy when the curve is relatively flat rather than when it is steep.

Conventional wisdom may not be a good guide. Figure 22 plots the 2-year to 10-year Treasury spread and the subsequent three-month move in 5-year Treasury yields. The figure shows that the current slope of the yield curve is not a clear indicator of subsequent moves in the 5-year Treasury.

Interestingly, Figure 22 shows that when the yield curve is inverted, the 5-year Treasury yield declines over the next three months. This empirical result may persuade some investors to go long duration versus the benchmark. However, the No-View Optimization strategy with inversion detection requires investing in the benchmark when the curve is inverted. If inversion detection were disabled, the inverted curve causes the optimization to produce a relatively short-duration portfolio. Consequently, some investors may decide not to implement No-View Optimization if the curve is inverted.

In general, there is no particularly good or bad time to implement the No-View Optimization strategy. Investors can rely on the dynamic adjustment feature to limit losses if they happen to begin the strategy at an inopportune time.

Figure 22. **2-Year–10-Year UST Slope versus Subsequent 3-Month Move in 5-Year UST Yields,** June 1989–June 2004



Evaluating Variants of No-View Optimization

Figure 16 presents simulation results for three different settings of the duration constraint and reveals the following pattern: As the duration constraint is tightened both average outperformance and the volatility of outperformance decrease. A tighter duration constraint forces the portfolio to replicate the benchmark more closely, diminishing the strategy's potential outperformance. However, Figure 16 also shows that tightening the duration constraint increases the strategy's information ratio.[10]

Which duration constraint to use? It is preferable to use a moderate duration constraint because it gives the portfolio a chance for greater absolute outperformance for roughly the same information ratio. Against a 3-year constant duration benchmark, this would point to the two- to four-year duration constraint. This strategy achieved an average outperformance of 61 basis points per year (Figure 16). The volatility of outperformance was 93 basis points per year, producing an information ratio of 0.65.

To examine the effect of the concentration constraint, Figure 23 compares the results from two optimizations, which are identical in every respect except for the concentration constraint. The first (called, "standard") has the concentration constraint

[10] Information ratio is average outperformance relative to the performance benchmark divided by the volatility of the outperformance. The information ratio and the Sharpe ratio discussed earlier are closely related. The Sharpe ratio measures an asset's risk and return versus cash, whereas the information ratio measures a portfolio's risk and return versus the portfolio's benchmark. If the benchmark is cash, then the Sharpe ratio and information ratio are identical.

set to 60%, whereas the second has no concentration constraint. Both have the duration constraint set to within one year of benchmark duration, as well as inversion detection and dynamic adjustment of the minimum return threshold.

The concentration constraint has a minor effect on realized performance, increasing average outperformance by 4 basis points (from 57 basis points to 61 basis points) but also increasing the volatility of outperformance by 10 basis points (from 83 basis points to 93 basis points). Overall, the concentration constraint slightly reduces the strategy's information ratio from 0.69 to 0.65. However, common sense notions of diversification argue for avoiding highly concentrated investments in a portfolio. In this case, the investor would want to weigh the analytical cost of the concentration constraint against its intuitive benefits.

Figure 24 compares the "standard" analysis to two variants of the strategy in order to investigate the effects of 1) dynamic adjustment and 2) inversion detection. The first variant does not use dynamic adjustment of the minimum return threshold. The second does not use inversion detection, so it does not invest in the benchmark during inversions. All other parameter settings are identical.

Figure 24 shows that dynamic adjustment allows the optimization to be more aggressive, returning 21 basis points of additional average outperformance (0.61 basis points versus 0.40 basis points) and 19 basis points of increased outperformance volatility. Overall, the inclusion of the dynamic threshold adjustment increased the information ratio from 0.54 to 0.65.

Figure 23. **Performance of No-View Optimization Impact of the Concentration Constraint,** 1986–2000

	Benchmark	"Standard" Case 60% Concentration Constraint			No Concentration Constraint		
Year	**Return**	**Return**	**Diff**	**Duration**	**Return**	**Diff**	**Duration**
1986	12.80%	14.60%	1.80%	4.00	14.50%	1.71%	4.00
1987	2.32	2.88	0.56	3.06	2.99	0.67	3.06
1988	6.27	6.46	0.19	2.80	6.87	0.60	2.93
1989	12.80	13.50	0.71	3.14	13.50	0.70	3.15
1990	9.23	9.24	0.01	3.03	9.18	-0.05	3.04
1991	12.90	14.70	1.88	3.26	14.40	1.57	3.25
1992	6.13	6.72	0.59	3.42	6.41	0.28	3.37
1993	7.54	9.00	1.46	3.89	9.00	1.46	3.88
1994	-0.80	-1.04	-0.25	3.03	-1.04	-0.24	3.02
1995	13.70	15.70	2.04	3.94	15.30	1.56	3.76
1996	3.83	3.54	-0.29	3.44	3.64	-0.19	3.37
1997	7.82	9.06	1.24	3.75	9.00	1.18	3.75
1998	8.23	8.76	0.53	3.51	8.79	0.56	3.54
1999	0.43	0.27	-0.16	3.24	0.28	-0.15	3.27
2000	9.96	8.75	-1.21	2.92	8.84	-1.12	2.93
Average	7.54	8.15	0.61	3.36	8.11	0.57	3.35
Std. Dev.			0.93			0.83	
Info. Ratio			0.65			0.69	

Inversion detection also improved average outperformance. Figure 24 shows that inversion detection increased average outperformance by 7 basis points (0.61 basis points versus 0.54 basis points) at a negligible two basis points increase in outperformance volatility. Inversion detection improved the strategy's information ratio from 0.60 to 0.65.

Overall, in this example, we find that the best No-View Optimization strategy is one with a moderate duration constraint (within one year of the benchmark), a 60% concentration constraint, inversion detection and dynamic adjustment of the minimum return threshold. This variant of the strategy produced an average annual outperformance of 61 basis points to the 3-year duration benchmark, with an information ratio of 0.65.

No-View Treasury Optimization has demonstrated an ability to outperform a short Treasury performance benchmark while meeting a central bank's need for safety and liquidity. In addition, No-View Optimization can be used to set a portfolio's duration target. We have extensive experience in customizing these strategies to meet the specific requirements of various central banks and regard it to be an important tool for central bank asset management.

Figure 24. **Performance of No-View Optimization**
Impact of Dynamic Adjustment and Inversion Detection, 1986–2000

	Benchmark	"Standard" Case Dyn. Adj. + Inv. Det.			No Dynamic Adjustment			No Inversion Detect		
Year	**Return**	**Return**	**Diff**	**Dur**	**Return**	**Diff**	**Dur**	**Return**	**Diff**	**Dur**
1986	12.80%	14.60%	1.80%	4.00	14.40%	1.60%	3.55	14.60%	1.80%	4.00
1987	2.32	2.88	0.56	3.06	3.06	0.74	2.77	2.88	0.56	3.06
1988	6.27	6.46	0.19	2.80	6.52	0.25	2.79	6.46	0.19	2.80
1989	12.80	13.50	0.71	3.14	13.70	0.86	3.05	12.80	-0.01	3.41
1990	9.23	9.24	0.01	3.03	9.22	-0.02	3.02	8.83	-0.41	3.07
1991	12.90	14.70	1.88	3.26	13.50	0.63	2.93	14.70	1.88	3.26
1992	6.13	6.72	0.59	3.42	6.59	0.47	3.10	6.72	0.59	3.42
1993	7.54	9.00	1.46	3.89	8.12	0.58	3.23	9.00	1.46	3.89
1994	-0.80	-1.04	-0.25	3.03	-0.93	-0.13	3.00	-1.04	-0.25	3.03
1995	13.70	15.70	2.04	3.94	15.50	1.78	3.91	15.70	2.04	3.94
1996	3.83	3.54	-0.29	3.44	2.99	-0.84	3.59	3.54	-0.29	3.44
1997	7.82	9.06	1.24	3.75	8.32	0.51	3.40	9.06	1.24	3.75
1998	8.23	8.76	0.53	3.51	8.76	0.53	3.51	8.29	0.06	3.93
1999	0.43	0.27	-0.16	3.24	0.39	-0.04	3.14	0.22	-0.21	3.39
2000	9.96	8.75	-1.21	2.92	9.09	-0.87	3.00	9.44	-0.52	3.00
Average	7.54	8.15	0.61	3.36	7.94	0.40	3.20	8.08	0.54	3.43
Std. Dev.			0.93			0.74			0.91	
Info. Ratio			0.65			0.54			0.60	

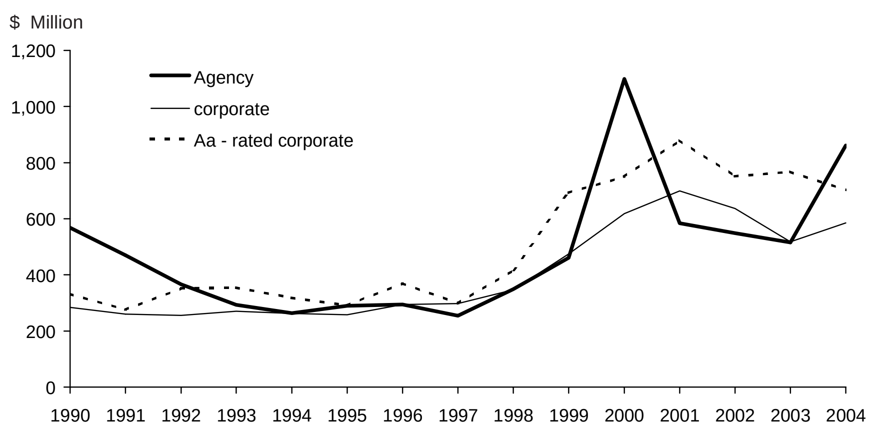
METHODS FOR DETERMINING THE PORTFOLIO'S ALLOCATION TO NON-TREASURY ASSETS

The Investment Case for Non-Treasury Assets

As discussed earlier, some central banks are considering managing their dollar reserves with more emphasis on liquidity. Consequently, some central banks are contemplating the possibility of adding non-treasury securities to their dollar portfolios. Naturally, a relevant question is whether the non-Treasury market is liquid enough for participation by official institutions. Most portfolio managers, especially since the various traumatic economic events of the late 1990s, desire liquidity. Issuers, acting in their own self-interest, have responded by issuing debt in larger and larger issue sizes. For example, in response to the Treasury buyback announcement in 2000, Fannie Mae and Freddie Mac expanded their Benchmark and Reference note programs with their large issue sizes and regular issuance intervals.[11] The intention of these programs is to reduce debt cost by directly satisfying the liquidity demands of investment managers. Other issuers have responded similarly, dramatically increasing the average issue size over the decade, as shown in Figure 25. The net effect is that the growth in average issue size has increased the liquidity of credit issues, allowing official institutions to participate effectively.

[11] Average agency new issue size also spiked in 2000 because the inverted yield curve discouraged issuance of callable agency debt which is typically smaller in size. Once the yield curve became positively sloped, callable issuance resumed and the average new issue size dropped from the high 2000 level.

Figure 25. **Average New Issue Size in the U.S. Agency and Credit Markets**
All Issues with at Least $150 Million Outstanding, 1990–2004



Source: Lehman Brothers *Family of Indices.*

Adding non-Treasury assets to a portfolio may still raise questions regarding liquidity. While many highly-rated non-Treasury assets are relatively liquid, they are not as liquid as U.S. Treasuries. It is useful to note, however, that a very strict liquidity requirement for a portfolio containing non-Treasury assets can be satisfied by the use of derivatives. For example, suppose a central bank wishes to have a relatively high exposure to the credit sector but is worried about liquidity. Instead of constraining the benchmark to hold a smaller-than-desired percentage in credit assets, the central bank can allow the use of futures, swaps, and structured products to replicate a portion of the desired credit exposure. As these derivatives are liquid instruments (more so than many individual corporate names), a central bank can accomplish a higher benchmark weighting to the credit sector while satisfying its liquidity requirement.[12] Later in this section, we discuss in detail the potential of swaps to serve as a proxy for credit exposure.

Another relevant question when considering non-Treasury assets is whether there is a solid economic argument for investing in these asset classes. To address this question we analyze the historical risk-adjusted performance (*i.e.*, Sharpe ratios) of various asset classes. Figure 26 presents the Sharpe ratios for five different asset classes for the period from August 1988 through June 2004. The five asset classes considered are U.S. Treasuries, Aaa-rated agencies, A-rated or better sovereigns, Aa-rated or better supranationals, and A-rated or better U.S. corporates.

Figure 26 shows that all asset classes produced higher mean total returns than U.S. Treasuries over the sixteen-year period. In addition, agencies, supranationals, and corporates produced higher risk-adjusted returns. Sovereigns had an Sharpe ratio equal to that of Treasuries (0.61). As most central banks and other official institutions usually have long investment horizons, these long-term results support the investment case for adding non-Treasury securities to official dollar portfolios.

[12] See *Replicating the Lehman Brothers Global Aggregate Bond Index with Liquid Instruments (Including TBAs and CDX)*, Lehman Brothers, October 28, 2004. For example, a portfolio of swaps and CDX replicates the U.S. Credit Index with a tracking error volatility of 29 basis points per month during August 2002-September 2004.

Figure 26. **Mean Annual Total Returns and Sharpe Ratios by Asset Class**
August 1988 - June 2004, %

Asset Class	Mean Total Return	Return over Riskless Rate	Volatility of Excess Return over Riskless Rate	Annualized Sharpe Ratio	Average Duration
Treasuries	7.73	2.80	4.62	0.61	5.17
Agencies	8.22	3.35	4.95	0.68	5.62
Sovereigns	8.41	3.54	5.79	0.61	6.03
Supranationals	8.60	3.73	5.17	0.72	5.50
Corporates	8.34	3.47	4.54	0.77	5.04

While Figure 26 shows the annualized Sharpe ratio calculated over the entire period, Figure 27 presents cumulative Sharpe ratios since July 1992 using data since August 1988. This figure shows how Sharpe ratios have evolved over time as new months are added to the data set.

Figure 27 shows that the Sharpe ratios for all five asset classes have tended to rise and fall together. Most notable is that the Sharpe ratio for corporates has consistently been greater than that for U.S. Treasuries.

Figure 28 shows the Sharpe ratios for the same five asset classes over 48-month rolling windows beginning in July 1992. The figure highlights that Sharpe ratios are much more volatile over shorter time windows (due to short-term variability in excess returns) and that U.S. Treasuries can, at times, outperform the other asset classes. The performance of sovereigns, in particular, is marked by the volatility spike due to the

Figure 27. **Cumulative Sharpe Ratios for Various Asset Classes**
July 1992–June 2004, Using Data since August 1988

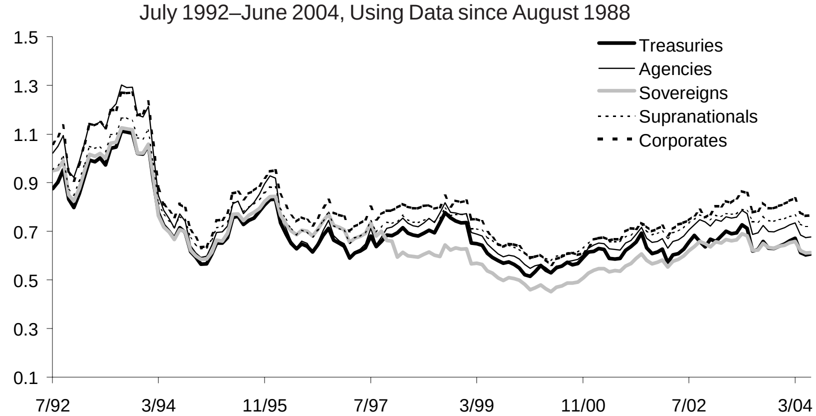
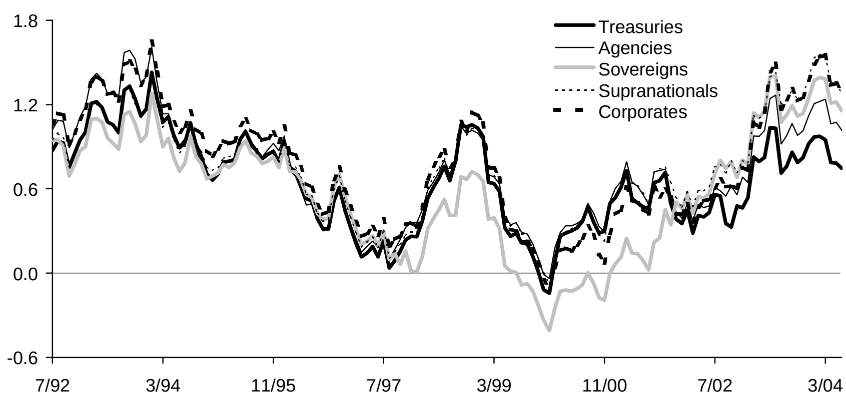


Figure 28. **Rolling Sharpe Ratios for Various Asset Classes**
48-Month Windows, July 1992–June 2004, Using Data since August 1988



"Asian contagion" of 1997, which remained within the rolling window until 2001; in more recent history, sovereigns outperform Treasuries handily, with Sharpe ratios similar to those of other spread assets.

Another way to measure the investment potential of non-Treasury assets is to examine their historical duration-matched performance versus Treasuries. Figure 29 presents mean excess returns over duration-matched Treasuries for the four spread asset classes for the period from August 1988 through June 2004. The figure also shows the volatility of these excess returns as well as the information ratio, which is defined as the mean excess return divided by the standard deviation.

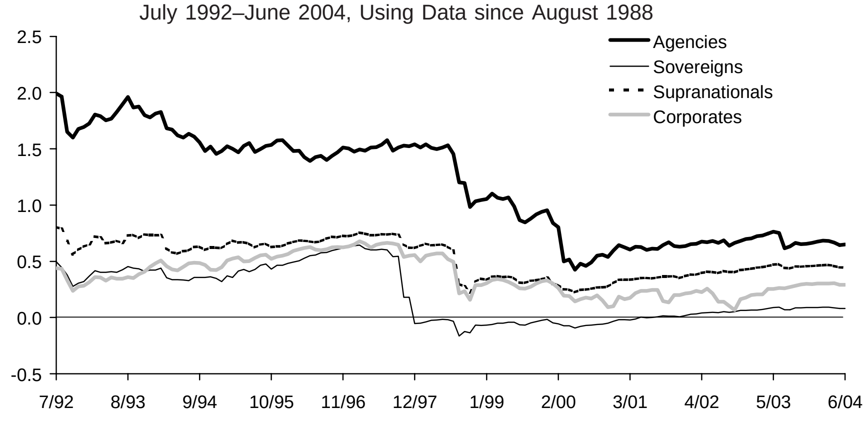
For the period, agencies had the highest information ratio—a result of having both the highest average excess return and the lowest standard deviation of excess returns. Supranationals had the next highest information ratio, followed by corporates and sovereigns.

Figure 30 displays the cumulative time series of annualized information ratios for the four asset classes. Figure 31 offers historical information ratios over 48-month

Figure 29. **Monthly Excess Returns over Duration Matched Treasuries**
August 1988–June 2004, bp

	Average	**Standard Deviation**	**Annualized Information Ratio**
Agencies	3.5	18.8	0.65
Sovereigns	1.3	55.2	0.08
Supranationals	3.3	25.8	0.45
Corporates	4.0	47.6	0.29

Figure 30. **Cumulative Information Ratios versus Treasuries for Various Asset Classes**
July 1992–June 2004, Using Data since August 1988



rolling windows. The cumulative time series show that information ratios were relatively steady until 1997 (for sovereigns) and 1998 (for agencies, supranationals and corporates), when credit concerns hurt spread product. The 48-month rolling window information ratios again clearly demonstrate the short-term variability in excess returns.

For the period from August 1988 to June 2004, Figure 32 offers correlations among the asset classes for both total returns and excess returns over duration-matched Treasuries. Correlations of total returns are relatively high, reflecting the exposure to the term structure of interest rates shared by all five asset classes. Correlations of

Figure 31. **Rolling Information Ratios versus Treasuries for Various Asset Classes**
48-Month Windows, July 1992–June 2004, Using Data since August 1988

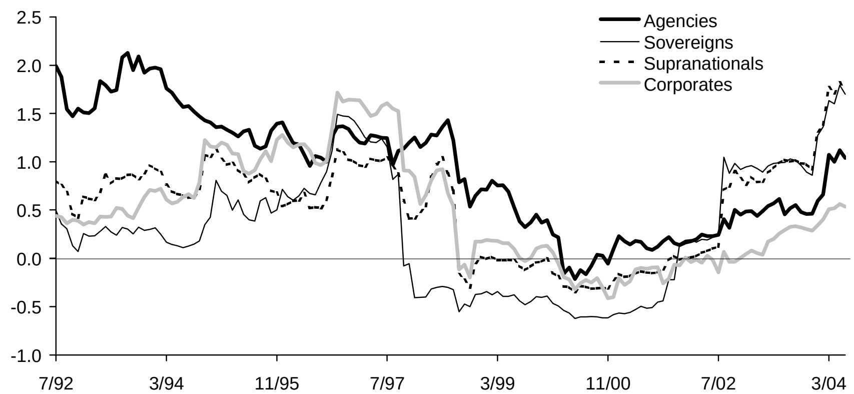


Figure 32. **Correlations of Total Returns and Excess Returns for Various Asset Classes,** August 1988–June 2004

a. **Total Returns**

	Treasuries	Agencies	Sovereigns	Supranationals	Corporates
Treasuries	1.00				
Agencies	0.97	1.00			
Sovereigns	0.92	0.91	1.00		
Supranationals	0.94	0.95	0.96	1.00	
Corporates	0.93	0.94	0.92	0.94	1.00

b. **Excess Returns,** over Duration-Matched Treasuries

	Agencies	Sovereigns	Supranationals	Corporates
Agencies	1.00			
Sovereigns	0.34	1.00		
Supranationals	0.54	0.62	1.00	
Corporates	0.38	0.43	0.56	1.00

excess returns (which strip out the common influence of Treasury returns) highlight the potential for the four spread asset classes to move independently of each other.

We have shown that spread assets offer long-term investment advantages over similar duration Treasuries. However, over short holding periods, investing in spread product involves the risk of underperforming similar duration Treasuries. Since August 1988, what has been the magnitude of this "shortfall" risk? For each of the four spread asset classes, Figure 33 presents the *worst* excess return for various holding periods since 1988. For example, Figure 33 shows that the worst one-year excess return for agencies was -1.94%, whereas for sovereigns, it was -10.68%.

Another way to examine the shortfall potential of investing in spread assets is to ask what was the worst total return for various holding periods as a function of the percentage of spread assets in a Treasury portfolio. For example, Figure 34 illustrates that the worst one-year total return for a portfolio containing 40% agencies and 60% Treasuries was -5.17%. This compares to the worst 1-year total return of -4.46% for a portfolio of 100% Treasuries. For a portfolio containing 20% sovereigns, the worst 1.5-year period total return (non-annualized) was -1.19%. Noticeably, for a two-year holding period, no portfolio had a worst-case total return that was negative, irrespective of the percentage of spread assets.

Determining the Proper Weighting

While the possibility of adding highly-rated non-Treasury asset classes is appealing, how much weight should non-Treasury assets have in the portfolio? As a first step, it is useful to look at the market value percentage of available supply. For example, as of August 2004, the Lehman U.S. Aggregate Index has a 24% market value weight in the credit sector. Is this market weighting appropriate for the portfolio of an official institution? An advantage of using the percentage of available supply as the portfolio weight is that the exposure to the sector will gradually change over time along with the market, allowing the portfolio to track the overall sector availability in the marketplace. However, using the percentage of available supply does not address the level of risk introduced to the portfolio and whether this level of risk is appropriate.

Figure 33. **Shortfall Risk, Worst Excess Return over Duration-Matched Treasuries by Holding Period (Non-Annualized),** August 1988 - June 2004,%

	Holding Period						
	1 Month	**3 Months**	**6 Months**	**1 Year**	**5 Years**	**10 Years**	**Full Period**
Agencies	-1.04	-1.60	-1.84	-1.94	-0.57	4.11	22.92
Sovereigns	-3.88	-7.26	-8.09	-10.68	-9.72	-11.29	8.39
Supranationals	-1.71	-2.45	-2.81	-2.84	-1.84	3.82	23.13
Corporates	-2.09	-2.75	-3.37	-3.43	-4.17	0.90	27.53

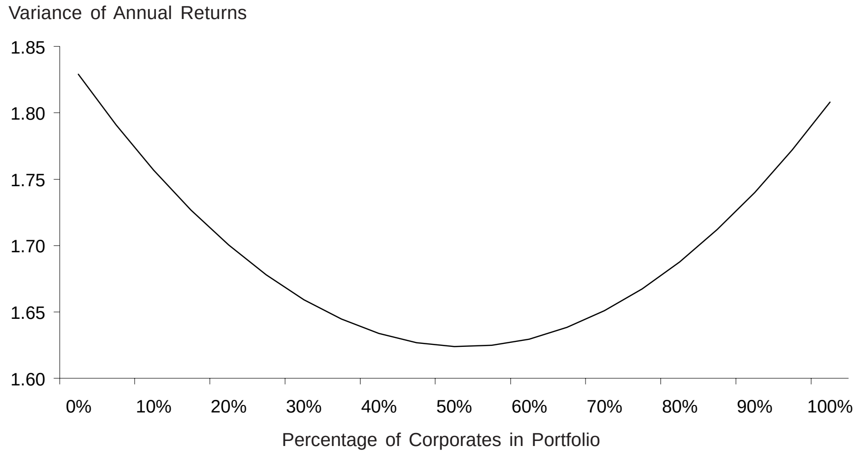
Figure 34. **Shortfall Risk, Worst Holding Period Total Returns (Non Annualized) by Percentage of Spread Asset in Portfolio,** August 1988-June 2004, %

	Holding Period			
	6 Months	**1 Year**	**1.5 Years**	**2 Years**
100% Treasuries	-4.47	-4.46	-0.60	5.18
Agencies				
20%	-4.69	-4.82	-0.71	4.79
40%	-4.90	-5.17	-0.82	4.39
100%	-5.55	-6.23	-1.76	3.21
Sovereigns				
20%	-5.12	-5.25	-1.19	5.14
40%	-5.77	-6.03	-1.77	5.09
100%	-7.69	-8.34	-3.52	2.91
Supranationals				
20%	-4.87	-4.94	-0.86	5.14
40%	-5.27	-5.42	-1.12	5.09
100%	-6.48	-6.83	-1.91	4.95
Corporates				
20%	-4.58	-4.55	-0.64	5.09
40%	-4.69	-4.63	-0.67	5.00
100%	-5.01	-4.87	-1.35	4.28

The advantage of adding non-Treasury asset classes to a portfolio is that their returns may not be perfectly correlated with returns on traditional Treasury securities. Consequently, adding a new asset class may reduce overall portfolio risk for a given level of expected return. One way to show the benefit of diversification is to plot the total return variance for various portfolios containing different combinations of U.S. Treasuries and the new asset class. For example, Figure 35 shows the total return variance for portfolios with different combinations of U.S. Treasuries and U.S. corporate bonds (represented by the U.S. Credit Index) for the period from March 1989 to June 2004.

Figure 35 is constructed as follows. For a given U.S. Treasury portfolio, we substitute a duration-matched corporate portfolio for a portion of the U.S. Treasury portfolio. That portion is shown as a percentage along the horizontal axis. As a result of this substitution, what would have been the variance in total returns for the Treasury plus corporate portfolio for the entire period? This exercise is repeated for various degrees of substitution: from 0% to 100%. As the percentage of corporates rises above zero, the overall variance of the portfolio decreases. This is the result of the less-than-perfect correlation in total returns between Treasuries and corporates. The decline in portfolio volatility continues up to a point and then begins to increase as the higher volatility of the corporate component of the portfolio begins to outweigh the diversification effect. The results show that a portfolio composed of roughly equal

Figure 35. **Variance of Portfolio Returns of Various Combinations of Treasuries and Duration-Matched Corporates**
March 1989–June 2004



shares of corporates and U.S. Treasuries would have produced the minimum variance portfolio over the entire fifteen-year period.

Finding the minimum variance portfolio allocation is one way to determine the proper weighting of non-government assets in the portfolio. A similar method is to calculate the Sharpe ratio (*i.e.*, mean excess return over riskless rate divided by excess return volatility) for various allocations. An advantage of the minimum variance method is that variances are less volatile than mean excess returns over time, which may produce results more suitable for organizations that plan to change their allocations infrequently.

Managing Non-Treasury Assets: Replication and Sufficient Diversification

Once the decision has been made to invest in non-Treasury assets and the proper portfolio allocation has been determined, the official institution must now deal with the very practical problem of managing these assets. The institution must be prepared to answer many difficult questions. For example, if the institution decides to invest in U.S. credit, how are the individual credits to be chosen? There are more than 580 issuers in the U.S. Credit Index; must the institution own most of them? How many credit analysts must it hire? If the institution owns only a small subset of bonds, will this expose the portfolio to undue event risk? How can the institution be sure that its investment portfolio is sufficiently diversified so that an event that overwhelms a single issuer will not dominate the performance of the investment portfolio? Finally, how are the credit issues going to be monitored over time?

Fortunately, it is quite possible to match closely the returns on an index without holding each individual issue within the index. For example, as of November 2004, the U.S. Credit Index contained approximately 2,830 issues from 589 issuers. However, to replicate the performance of the index with a low level of tracking error, it is necessary to hold only 50 to 60 issues. In other words, although an index may contain a large number of issues, it is highly replicable with relatively few issues.

Figure 36 shows that various indices can be replicated with a proxy portfolio containing a small number of bonds. The number of bonds in the proxy portfolio was obtained through the use of the Lehman Brothers Multi-Factor Global Risk Model. This model uses historical variances and correlations of risk factors to construct a proxy portfolio that has minimum expected tracking error with the index.[13]

The Risk Model can be used to construct proxy portfolios that, for a given number of bonds, will minimize expected tracking error due to exposure to systematic risk factors and the normal variation around those risk factors. The proxy portfolio remains vulnerable, however, to any extreme event risk. For example, a credit event such as a downgrade could affect a bond that has a much higher market value weight in the proxy portfolio than it does in the index. This fact wreaked havoc with investor portfolios in 2000 and 2001.

Nevertheless, it is possible to structure a replicating proxy portfolio to minimize the tracking error impact due to the possibility of downgrades. To minimize the risk of portfolio losses due to downgrades, a portfolio should use more stringent position size limits on the lower-rated sectors. In a recent study[14] of the U.S. Credit

[13] The Lehman Brothers Global Risk Model is available *via* the Lehman Brothers portfolio management system, POINT. The Global Risk Model covers all instruments in the Global Aggregate Index, including global investment-grade credit. For details, see *The Lehman Brothers Multi-Factor Risk Model*, July 1999, and *Lehman Brothers Global Risk Model: A Portfolio Manager's Guide*, forthcoming.

[14] *Sufficient Diversification in Credit Portfolios*, Lehman Brothers, June 2002.

Figure 36. **Effective Replication of Broad Indices with a Small Number of Bonds,** as of April 2002

Index	Number of Bonds in Proxy	Number of Bonds in Index	Tracking Error (bp/year)
Treasury	7	112	19
Treasury/Agency	41	930	10
Credit	59	3,971	24
Mortgage	19	538	13
Aggregate	118	6,879	9

Source: *The Lehman Brothers Multi-factor Risk Model,* Lehman Brothers, July 1999.

Index, we found the optimal ratio of position sizes in Aa, A, and Baa bonds to be approximately 9:4:1. For example, a proxy portfolio containing 50 bonds, distributed optimally (*i.e.*, 9:4:1, or 3 Aaa-Aa, 11A and 36 Baa) across various quality sectors, will have an expected tracking error of only 42 basis points due to downgrades and a 95% probability that underperformance due to downgrades will not exceed 69 basis points. As Figure 37 shows, the potential tracking error due to downgrades can be reduced further as the number of issues in the proxy portfolio, properly distributed, increases.

In practice, we find that investors do not use the 9:4:1 ratio. In fact, investors are interested in total idiosyncratic risk, not just the risk of downgrades. When we take into account the "natural" volatility, defined as the spread risk of issuer selection within a rating category, we find that while downgrade risk dominates in Baa, natural spread volatility is significant in the higher qualities. When both downgrade risk and "natural" volatility are considered, the optimal ratio of position limits for Aaa/Aa, A, and Baa securities, which is 4:3:1, is significantly less skewed.

These results show that a replicating proxy portfolio can be constructed with relatively few bonds to reduce both systematic and downgrade risk to very reasonable levels. This is a comforting result. Official institutions wishing simply to add exposure to credit assets can do so with a modest infrastructure of credit analysts.

Managing Non-Treasury Assets: Portfolio Tools for Central Banks as Long-Horizon Investors

Many official institutions intend to hold spread assets (*e.g.*, credit bonds) for relatively long periods of time, perhaps until maturity. This investment horizon is often driven by the institution's organizational structure, as well as a desire to avoid imparting an official view on corporate names via buying and selling activity. A long investment horizon can also offer investment benefits. To the extent that the marginal investor in the credit marketplace has a shorter investment horizon, market credit spreads will reflect some compensation for short-term spread volatility. Because long-horizon investors, by definition, can ride out any short-term volatility, they can capture any spread volatility premium.

Figure 37. **Structure of Optimally Structured Credit Index Proxies for Different Numbers of Bonds**

Number of Bonds	**50**	**100**	**150**	**200**	**500**
Number of Aaa - Aa Bonds	3	6	10	13	34
Number of A Bonds	11	21	32	43	114
Number Baa Bonds	36	73	108	144	352
Tracking Error Due to Downgrades (bp/year)	42	29	23	19	10
Worst Case Underperformance (95% confidence)	-0.69%	-0.48%	-0.38%	-0.31%	-0.16%

Source: *Sufficient Diversification in Credit Portfolios,* Lehman Brothers, June 2002.

Risk for long-horizon institutions is not monthly tracking volatility versus a benchmark or the volatility of monthly absolute portfolio returns. Instead, the risk is that assets will fail to produce their promised spread over Treasuries at the purchase date. In other words, will a portfolio of corporate bonds produce a return over Treasuries equal to their spread adjusted by the expected default and recovery rates at time of purchase? Or will actual defaults over the holding period exceed the anticipated rate, producing a lower than expected spread over Treasuries? Not only must the long-horizon investor worry whether overall default rates are greater than expected, but also whether issuer defaults in the portfolio are correlated. While the realized overall default rate in the market may equal the expected rate, the portfolio's default rate may exceed the market default rate if particular names in the portfolio default together.

Long-horizon and short-horizon investors have different investment objectives arising from the different return profiles of credit assets over long and short horizons. Over a short horizon credit returns are roughly symmetrical as credit spreads can either widen or tighten. Consequently, short-horizon investors typically try to maximize expected return while minimizing expected monthly tracking error. Over a long horizon, however, credit returns are asymmetrical as credit assets either earn a narrow spread over Treasuries with high probability or lose a large fraction of their value with low probability. Consequently, long-horizon investors typically try to maximize expected spread over Treasuries while minimizing the probability of large portfolio losses sometimes referred to as "tail risk."

In a recent paper we examine how the return profile of credit assets changes as the investment horizon changes.[15] Specifically, we show that tail risk increases even for relatively modest increases in the investor's holding period. To demonstrate this we gather the monthly and quarterly excess returns for a set of Lehman Brothers credit indices. For each index, we sort the excess returns and identify the worst 5% of both monthly and quarterly excess returns as well as the best 5% of returns. We measure the negative tail of each distribution by calculating the average excess return for both the worst and best 5% of excess returns. For example, for the corporate Energy Index, the average monthly excess return from 1994 - 2003 was -1.89% in the negative tail and +1.67% in the positive tail. However, for the same period, the average quarterly excess return was -3.66% and 2.10%, respectively, suggesting that the excess return distribution is more negatively skewed for the longer holding-period.

To more directly compare quarterly and monthly numbers, for each set of excess returns we construct "normalized" tail returns by subtracting the mean and dividing by the standard deviation of the relevant excess return distribution. Then, we divide each normalized tail return by 2.063 which would be the normalized tail return if excess returns had a standard normal distribution. Consequently, a normalized positive tail ratio greater than 1 indicates that the excess return

[15] "A Quick Look at Index Tails," *Global Relative Value*, Lehman Brothers, February 9, 2004.

distribution for a given index has a fatter-than-normal positive tail. The same reasoning applies for the negative tail.

To examine whether the distribution of credit excess returns becomes more asymmetric as the holding period lengthens, we compare the ratio of normalized negative tail returns with the ratio of positive tail returns. The degree of negative skewness (i.e., asymmetry) is measured by how much the negative ratio exceeds the positive ratio. Results for the various credit indices are presented in Figure 38 (using monthly excess returns) and in Figure 39 (using quarterly returns).

Figure 38. **Symmetry of Standardized Positive and Negative Tails using Monthly Excess Returns 1994–2003**

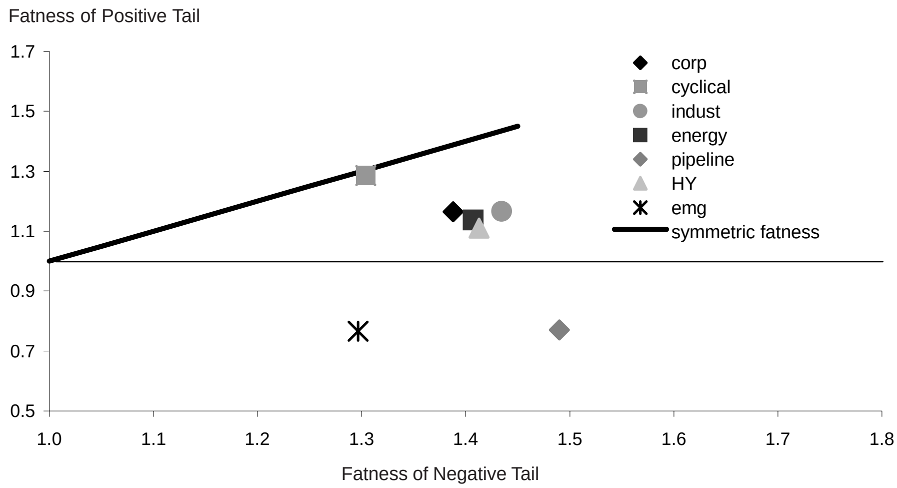


Figure 39. **Symmetry of Standardized Positive and Negative Tails using Quarterly Excess Returns 1994–2003**

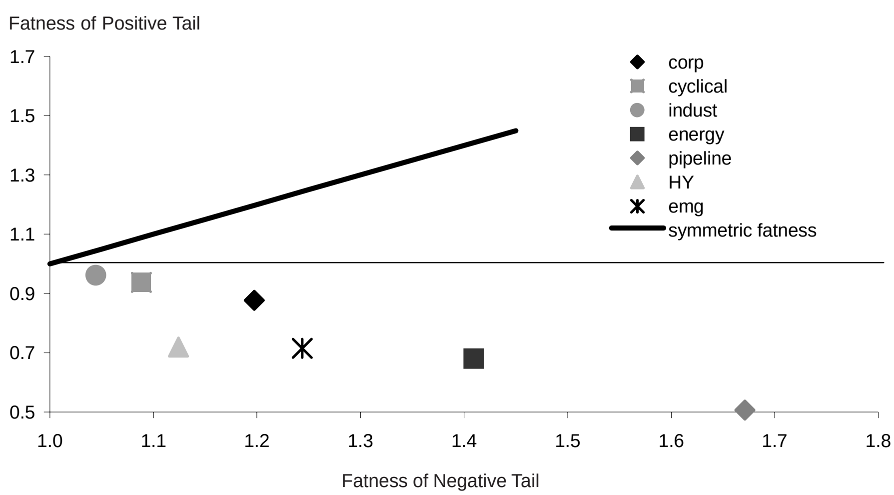


Figure 38 shows that monthly excess returns tend to have fat tails (i.e., normalized ratios greater than one) and a somewhat asymmetric distribution as the ratio of negative tail returns exceeds the corresponding ratio for positive tail returns (i.e., observations lie below the 45° ray. The large degree of asymmetry for the Emerging Market and Pipeline indices reflect the influence of the Russian crisis in 1998 and Enron in 2001, respectively.

In contrast, as shown in Figure 39, quarterly returns show less evidence of fat tails presumably because averaging returns over three months helps to smooth out extreme monthly returns. However, as anticipated, quarterly returns show evidence of more asymmetric excess returns as the observations lie further below the 45° ray compared to Figure 38. This increased asymmetric risk profile, or tail risk, is the risk faced by investors as they increase their investment horizon.

Tail risk embedded in a portfolio can be measured in several ways. One popular measure is "value-at-risk," or VaR, which is a level of losses expected to occur less than a specified percentage of time. For example, a 1% VaR of 50 basis points over a 5-year holding period means that there is a 1% probability that cumulative losses over the horizon in the portfolio will exceed 50 basis points. Another measure of tail risk is "expected shortfall" which is the average of all losses in the tail beyond the specified VaR level.[16]

Given a default rate, the possibility of correlated defaults can exacerbate a portfolio's tail risk. To see this suppose the probability of any issuer defaulting over a 5-year horizon is 5%. Further, for now, suppose that defaults are uncorrelated (*i.e.,* correlation = 0.0) and the probability distribution for the number of defaults in a portfolio is binomial. In a 50-bond portfolio, the expected number of defaults will be 2.5 (= 50 × 0.05) and the distribution will show a peak at 2.5 with a large amount of the distribution concentrated at 0, 1 and 2 defaults and little of the distribution exceeding six defaults (see Figure 40).

However, note what happens to the default distribution as the correlation increases from 0.0 to 0.2. The default rate remains at 5% so the mean of the default distribution remains at 2.5 defaults in this 50 bond portfolio. However, given the positive default correlation, there is a greater likelihood that when a bond does not default, other bonds will not default. Similarly, there is a greater likelihood that when a bond defaults, other bonds will tend to default as well. Consequently, probability in the center of the distribution has moved such that there is a greater likelihood of tail events (i.e. of very few or very many defaults). With a correlation of 0.2, the probability of six or more defaults is much greater (12.9%) than the case of uncorrelated defaults (3.8%). This is why long-horizon investors must incorporate the possibility of correlated defaults when estimating their tail risk.

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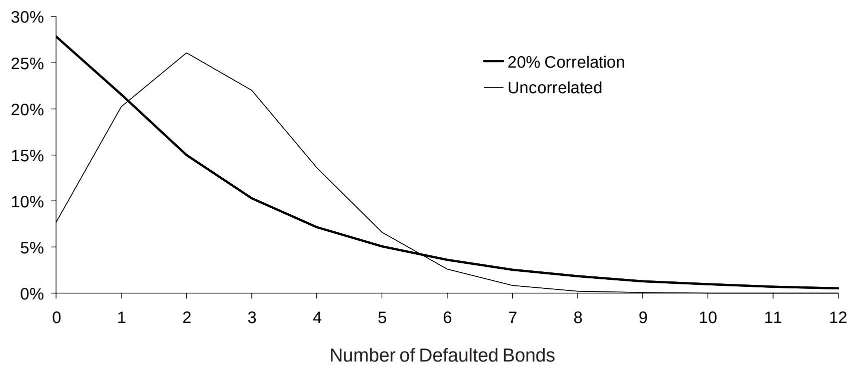
[16] To encourage diversification in portfolios, investors typically try to minimize expected shortfall, rather than VaR, for a given level of spread. The advantages of minimizing expected shortfall as opposed to VaR is explained in "Coherent Risk Measures Applied to the Default Risk of Credit Portfolios and CDO Tranches," *Fixed Income Quantitative Credit Research,* Lehman Brothers, January 31, 2002.

Figure 40. **Effect of Correlated Defaults on the Distribution of Defaults in a Portfolio**
Default Rate = 5%; Number of Bonds in the Portfolio = 50



The difference in investment objective between short and long-horizon investors leads to a difference in demand for portfolio management tools. Short-horizon credit investors often divide their investment process into two stages: first determine an optimal mix of macro strategies depending on short-term views and forecasting skill, and then construct bond portfolios using security selection skill and a risk model to control risk exposures. The shorter-horizon investor will use risk budgeting tools to help make macro allocations across various trading strategies to maximize the portfolio's information ratio for a given level of expected monthly tracking error. The use of tracking error as the risk measure implies the need for a risk model to produce estimates of the monthly tracking error and to help construct actual bond portfolios given the optimal macro allocation across strategies.[17]

Long-horizon investors may also approach credit investing as a two step process. First, long-horizon investors typically make a "macro" decision regarding the portfolio's allocation to various credit qualities (*e.g.*, Aa vs. A). This is a decision that must balance the spread offered by various credit qualities against their risk of default over the investment horizon. Given the buy-and-hold nature of the portfolio, this is a strategic decision that will have a major impact on portfolio returns. Once the strategic credit allocation decision has been made, the second decision is security selection to select particular issues for the portfolio.

[17] For an introduction to Lehman's risk budgeting methodology and tools (ORBS), please refer to "Effect of Security Selection Skill on Optimal Sector Allocation," *Global Relative Value*, August 9, 2004.

Determining the Optimal Long-Horizon Credit Allocation

For the strategic allocation across various credit qualities Lehman has developed a methodology to determine the optimal allocation given the current level of spreads, expected recovery rates and default correlations within each quality class.[18] The methodology can be described as follows. Each credit quality class (*e.g.*, A-rated bonds) is assumed to contain homogeneous issuers that have the same expected default rate over the investment horizon (say, ten years). To introduce the possibility of correlated defaults, the credit performance of issuers is assumed to be correlated to some systematic random market variable. This systematic market variable is unspecified but, for discussion purposes, could be thought of as the GDP growth rate. If GDP growth slows and hurts economy-wide asset performance, then all issuers will have a greater default probability. Conversely, if GDP growth accelerates then all issuers will have a lower default probability. Since the default rate for all issuers of a given quality class depends on realizations of the systematic market variable, defaults in the credit portfolio will tend to be positively correlated. Once a distribution for the systematic market variable is specified, along with an assumed recovery rate, it is possible to generate the distribution of portfolio losses due to defaults for the quality class.

Each credit quality class is then modeled in a similar way. We specify a cumulative default probability over the investment horizon, a degree of default correlation depending on the quality class's degree of correlation to the underlying systematic market variable, and a recovery rate to produce a portfolio loss distribution. Once all the loss distributions are known, and given the level of spreads available in the marketplace, the investor can maximize expected spread subject to a given level of tail risk of the overall portfolio loss distribution.

As an illustration suppose an investor with a ten-year investment horizon wishes to determine the portfolio's optimal allocation across A and Baa-rated issuers. Although the methodology allows a wide range of parameter estimates, for simplicity let's assume that A-rated issuers offer 100 basis points of spread over Treasuries, Baa-rated issuers offer 200 basis points, and that both A and Baa-rated issuers each have a default correlation of 0.20 and recovery rates of 20%. With this information it is possible to construct (see Figure 41) a table showing the expected return over Treasuries and expected shortfall (for the 1% tail) for various allocations to the two credit quality classes.[19]

For example, a portfolio of 70% A-rated credits and 30% Baa-rated credits has an expected annual excess return over Treasuries of 102 basis points with a standard deviation of 34 basis points. This allocation also has an expected shortfall (in the

[18] "Optimal Credit Allocation for Buy-and-Hold Investors," L. Dynkin, J. Hyman, and B. Phelps, *Journal of Portfolio Management*, Summer 2004.

[19] Details of the calculations to produce this table can be found in "Optimal Credit Allocation for Buy-and-Hold Investors," *Journal of Portfolio Management*, Summer 2004.

Figure 41. **Optimal Credit Allocations: 10-Year Investment Horizon**
Spreads: A-100 bp, Baa-200 bp; Default Probability over Horizon: A-2%, Baa-5%; Correlation = 0.2; Recovery = 20%

A Weight	**Baa Weight**	**Avg. Annual ExRet**	**StdDev Annual ExRet**	**ExShort** (1%)
100%	0%	81 bp	26 bp	-70 bp
90	10	88	29	-76
80	20	95	31	-83
70	30	102	34	-89
60	40	109	37	-96
50	50	116	40	-103
40	60	123	43	-109
30	70	130	46	-116
20	80	137	49	-123
10	90	144	52	-129
0	100	151	55	-136

1% tail) of -89 basis points. In other words, in the worst 1% of portfolio losses due to default, the average loss is 89 basis points.

Which allocation the investor chooses depends on the investor's risk tolerance. If the investor wishes to keep the expected shortfall in the 1% tail to a loss of less than 100 basis points, then the investor must choose from among those portfolios with at least a 60% allocation to A-rated bonds.

The results in Figure 41 are dependent on the inputs, especially the spread differential between the two quality classes. For example if the spread differential between A and Baa-rated bonds increases with no change in the expected default rate, then the optimal portfolio (for a given level of expected shortfall) will include a greater allocation to Baa-rated bonds. Similarly, if the spread differential between A and Baa-rated bonds remains constant, but both spread levels over Treasury increases, then the optimal portfolio (for a given level of expected shortfall) will include a greater allocation to Baa-rated bonds. This is because the higher spread earned on all assets provides a cushion to accept greater risk from a higher allocation to Baa-rated bonds.

Constructing Optimal Long-Horizon Credit Portfolios

After making the macro decision regarding the portfolio's allocation to various credit qualities, the investor must now construct a portfolio by making security selection decisions. Unlike the assumptions underlying the macro credit allocation methodology discussed above, assets of a given quality can no longer be assumed homogenous with uniform default rates and correlations. For example, within the A-quality sector there are bonds with ratings ranging from A1 to A3 and from a wide range of industries and countries. The expected degree of default correlation will likely vary depending on the particular pair of issuers. For example, two A-rated banks from the United States may have a higher default correlation compared to the default correlation between an A-rated bank and an A-rated telecommunications company. In addition, issuers may be located in different countries which would also likely affect default correlations as issuers in different countries may have exposures to different systematic market variables that influence default rates.

The goal of the portfolio construction process is to build a portfolio of bonds (or, restructure an existing portfolio of bonds) which minimizes the expected shortfall (given the investor's tail parameter (*e.g.*, 1%)) for any given target spread level. Lehman has developed a portfolio tool, called "COMPASS," just for this purpose.[20] COMPASS performs two functions. First, COMPASS allows an investor to measure the expected shortfall of a portfolio given the investor's horizon, tail parameter (*e.g.*, 1%), default and recovery rates and default correlations. Second, COMPASS includes an optimizer. Consequently, the investor can specify a spread target, a set of eligible bonds, various portfolio constraints (*e.g.*, an issuer cap of 1.5%) and COMPASS will then optimize the portfolio by rebalancing bond positions, subject to the constraints, to minimize the portfolio's expected shortfall while satisfying the spread target.

COMPASS works as follows. The investor supplies a list of credit bonds in the portfolio (*e.g.*, CUSIPs and par weights) and specifies an investment horizon (*e.g.*, 5 years). Each issue in the portfolio is then mapped to its issuer. Each issuer, in turn, is assigned to a market sector (*e.g.*, industrial or consumer cyclical) and to a country (*e.g.*, Japan or United States). Each issuer is also assigned a default rate depending on the issuer's credit rating. This default rate could be a historical cumulative default rate for the investment horizon, given the rating, as periodically published by the rating agencies, or it could be independently specified by the investor. If the issuers were assumed to default independently of each other, then COMPASS would have enough information to simulate the default loss distribution for the portfolio. However, as discussed earlier, not only does the investor run the risk that defaults rates may be greater than anticipated, but that issuers may default in a correlated fashion. If so, then the possibility of large losses increases compared to the case where the default rate is the same, but defaults are uncorrelated. A key feature of COMPASS is the explicit incorporation of the possibility of correlated defaults in the simulation of portfolio losses.

COMPASS uses historical equity market return correlations for the various sector-country pairs as estimators for default correlations between issuers from various sectors and countries.[21] Using default rates, estimated default correlations and

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[20] For details on the COMPASS portfolio tool see "COMPASS User Guide," July 2004, Lehman Brothers. For details on the theory and methodology underlying COMPASS please refer to "Modeling Credit: Theory and Practice," by Dominic O'Kane and Lutz Schlögl, February 2001, Lehman Brothers. Investors have used COMPASS to analyze portfolios containing not just credit but also ABS and CMBS assets.

[21] Empirical evidence suggests that asset market returns (as well as other financial market returns) demonstrate "fat joint tails." In other words, the possibility of joint extreme realizations is empirically more likely than the probability implied by a joint normal distribution. The implication of "fat joint tails" is that if defaults were assumed to be joint normally distributed then the tail risk for the portfolio loss distribution would be understated. COMPASS includes a feature that allows the investor to specify a student-t distribution (with user-specified degrees of freedom) when simulating the portfolio loss distribution to better fit the observed empirical pattern of "fat joint tails."

assumed recovery rates, COMPASS uses Monte Carlo simulation techniques to generate an expected loss distribution for the portfolio. Figure 42 shows an example of a loss distribution generated by COMPASS.

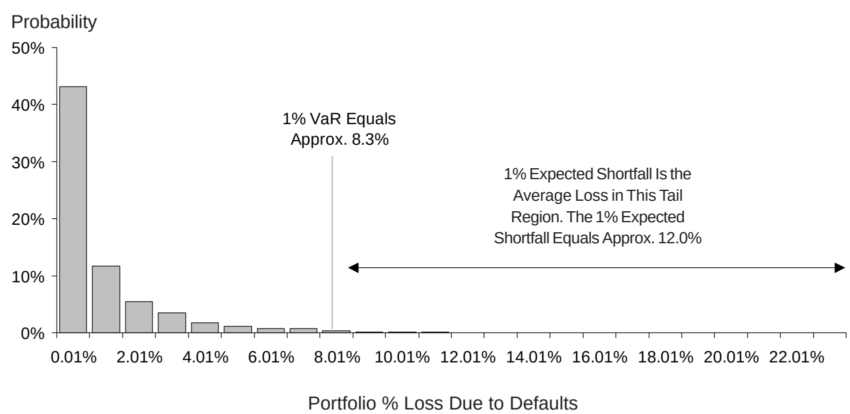
Figure 42 shows the simulated distribution of losses due to defaults for an investment-grade portfolio (expected annual spread of 108 basis points over U. S. Treasuries) over a five year horizon. This portfolio contains approximately 660 issues from 223 issuers. The assumed default rates are based on Moody's five-year cumulative corporate default rates over 1983-2002[22] and the assumed recovery rate is fixed at 35%. The bulk of the portfolio's loss distribution lies between 0.01% and 2%, indicating that this is a relatively high quality investment-grade portfolio. 42% of the time the portfolio will experience a loss due to defaults over the horizon totaling 1% or less. The 1% VaR is approximately 8.3% which indicates that 1% of the time the portfolio will experience losses due to defaults that will exceed 8.3% of the portfolio's par value. The expected shortfall is the average of the losses that occur beyond this 1% VaR value of 8.3%. For this portfolio, the expected shortfall is approximately 12.0%.[23]

Not only can COMPASS measure a credit portfolio's tail risk but it is also useful as a portfolio structuring tool. COMPASS contains a built-in optimizer which a long-horizon investor can use to structure (or rebalance) a credit portfolio to

[22] See *Default and Recovery Rates of Corporate Bond Issuers, 1920 – 2002*, Moody's Investors Service, February 2003.

[23] In other words, this is the average loss conditional on the portfolio experiencing a loss in the 1% tail region.

Figure 42. **Example of Portfolio Loss Distribution from Defaults**
COMPASS Simulation**;** Expected Annual Spread = 108 Basis Points



achieve a specified spread target while minimizing shortfall risk.[24] Given a spread target (and any other constraints such as issuer or sector exposure caps), the investor can invoke the COMPASS optimizer to construct a credit portfolio that minimizes the portfolio's expected shortfall subject to the investor's constraints.

To demonstrate the optimizer in COMPASS consider the portfolio whose loss profile was presented above in Figure 42. This portfolio had an expected annual spread over Treasuries of 108 basis points, a 1% VaR of 8.3% and an expected shortfall (1% tail) of 12.0%. We invoke the optimizer and ask COMPASS to rebalance the portfolio so as to minimize the expected shortfall while maintaining the expected spread level of 108 basis points. We also impose various issue and issuer caps to avoid unrealistic solutions.[25] The COMPASS optimizer then examines the level of spread offered by various issues, the corresponding default rates of the underlying issuers and default correlations across various issuers, and considers various portfolio weighting schemes which satisfy the investor-specified constraints. COMPASS then identifies the optimal constrained portfolio weighting scheme which achieves the expected spread target with the lowest expected shortfall. To help build some intuition on how the optimizer works, consider the following. COMPASS may identify two issues from different issuers with similar quality ratings offering approximately the same spread. However, one issuer may have lower default correlation with the other bonds in the portfolio. COMPASS will select this issuer over the other as a way of preserving spread while reducing expected shortfall.

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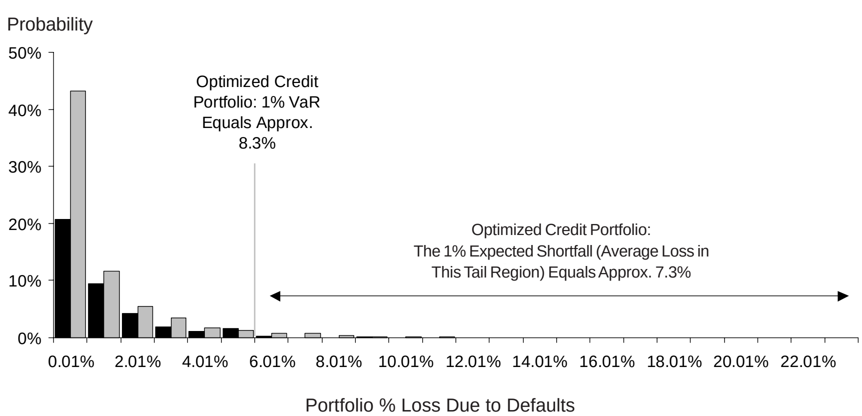
[24] This statement should be familiar to users of the Lehman Global Risk Model. Portfolio managers have long used the Risk Model not only to measure their portfolio's estimated monthly tracking error but also, via the built-in optimizer, to re-structure an existing portfolio to achieve a desired risk exposure. For details on the new Lehman Global Risk Model see "The Lehman Brothers Global Risk Model: A Portfolio Manager's Guide," Lehman Brothers, forthcoming 2005.

[25] COMPASS permits a wide range of user defined constraints. For example, an investor can specify a minimum book yield, a maximum level of transactions, a minimum/maximum exposure to various sectors, a minimum/maximum portfolio duration, etc.

Figure 43. **Example of COMPASS Optimized Portfolio Loss Distribution from Defaults**
Expected Annual Spread = 108 Basis Points



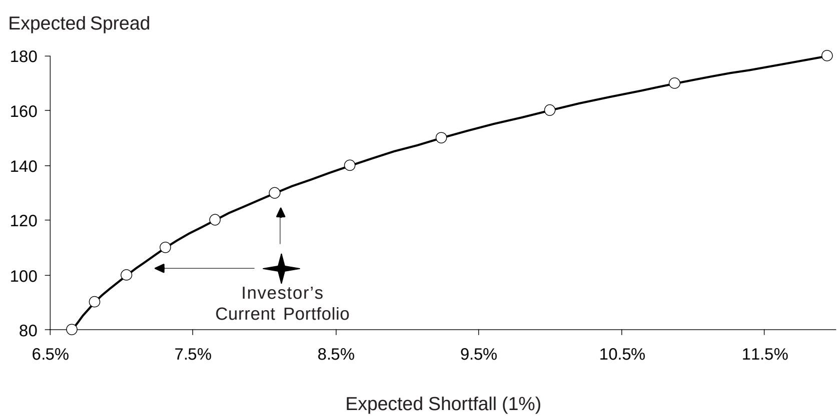
For our example portfolio, COMPASS identifies an optimized portfolio solution of 127 issues from 108 separate issuers that achieved the annual spread target of 108 basis points. The expected shortfall of the optimized portfolio is 7.3% with a VaR of 5.7%—a substantial improvement over the initial portfolio.[26] Figure 43 compares the loss distributions for both the original portfolio (shown in dark color bars—a repeat from Figure 42) and the optimized portfolio (shown in light color bars).

The optimization above was constructed to preserve the portfolio's annual expected spread level of 108 basis points. However, the investor can also use COMPASS to examine the tradeoff between risk and return that is available to the investor with the investor's current portfolio, constraints and investable set of bonds (if any). COMPASS automatically generates an efficient frontier by varying the spread target, while preserving all the other investor supplied constraints, and constructing optimal portfolios that minimize the expected shortfall. An example of such an efficient frontier is presented in Figure 44.

Figure 44 shows the COMPASS-generated efficient frontier assuming the investor can only rebalance the portfolio without adding issues not currently in the portfolio. This is the curve produced by connecting the various spread target points and the associated minimized expected shortfall value. Figure 44 also shows the location of the investor's current portfolio which is well inside the efficient frontier. Consequently, the investor has a range of portfolio choices depending on his risk preferences. The investor can maintain the same spread target while reducing the expected shortfall of the portfolio (the solution presented in Figure 43) or, alternatively, the investor can maintain his current level of expected shortfall (*i.e.*, 8.3%) and increase his annual spread (to approximately 135 basis points).

[26] COMPASS users can also use the Lehman Risk Model as an additional check to see if any unintended risk exposures have crept into the portfolio as a result of the rebalancing. This is particularly useful for long-horizon investors who nevertheless worry about any short-term tracking error versus a benchmark.

Figure 44. **Example of Efficient Frontier from COMPASS**
Minimized Expected Shortfall Associated with Spread Target Levels



Official institutions exploring adding credit assets to their portfolios generally do so from the perspective of holding the assets until maturity. However, managing such a credit portfolio requires portfolio tools specifically designed to analyze the asymmetric return profile of credit assets and the possibility of correlated defaults over the holding period. Lehman's optimal credit allocation methodology can help the long-horizon investor make the strategic "macro" decision regarding the portfolio's allocation to various credit qualities. For portfolio construction and optimization, Lehman's COMPASS portfolio tool can help investors build portfolio's that achieve a certain annual spread target while minimizing the portfolio's expected shortfall risk. The quantitative discipline offered by these tools and methodologies can help the long-horizon credit investor manage the portfolio in an efficient and risk-controlled manner while contributing to the enhanced return performance of the portfolio.

Swaps as a Total Return Investment

Official institutions are often sensitive to the "headline" risk of an issuer even if there is no impact on the issuer's credit quality. Simply holding the issuer's debt sometimes gives the appearance of endorsing an issuer's activities, even if the holding is less than a fraction of a percent of an institution's overall holdings. One way for institutions to avoid the potential for "headline" risk is to invest in interest rate swaps instead of credit. Swaps have become a key feature of the debt markets. In fact, in several ways, the swaps market is larger and more heavily traded than the U.S. Treasury market.

The rate paid on the fixed-leg of an interest rate swap represents an average of forward LIBOR rates. LIBOR, in turn, is a key funding rate for financial institutions (*e.g.*, banks) who issue substantial amounts of their own debt securities and who purchase significant amounts of other spread assets (*e.g.*, ABS and MBS). Consequently, swap rates (or, swap spreads to the corresponding government curve) are influenced by market factors that move spreads such as changes in credit risk premia and relative supply and demand for spread assets. However, swaps have two important advantages over other spread assets. First, in contrast to individual spread assets, swaps have little idiosyncratic default risk because the LIBOR setting is tied to the credit performance of a *group* of banks and not to a single issuer name. Second, swaps trade with remarkable liquidity compared to other spread markets.

While swaps have long been used for tactical (*e.g.*, hedging) purposes by banks and other portfolio investors, swaps have begun to receive attention as an *asset class* from a strategic perspective.[27] What has been the performance of swaps as an asset class?

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[27] "Swaps as a Total Return Investment," *Global Relative Value,* Lehman Brothers, April 7, 2003. In this analysis, we treat swaps as a cash investment by constructing a portfolio of a 3-month LIBID investment with a receive-fixed interest rate swap (i.e., received term LIBOR fixed and pay 3-month LIBOR). Except for a bid-ask adjustment, the 3-month LIBID deposit cancels the 3-month LIBOR obligation, leaving the investor with a net receive-fixed LIBOR position which can be treated as a fixed-coupon bond investment with the same maturity as the term of the swap. This is the approach taken in the construction of the Lehman Brothers Swap Indices. For details, please refer to *The Lehman Brothers Swap Indices,* January 2002.

Figure 45 presents cumulative excess returns for various component indices of the U. S. Aggregate Index against their corresponding key-rate duration matched portfolio of six swaps.[28] As Figure 2 shows, since 1992 swaps have outperformed Treasuries, MBS and Agencies and have modestly underperformed Credit and ABS. In regard to the relative performance versus Credit, note how well swaps performed versus credit during the stressful credit period of 2001-2002 as the large credit-event idiosyncratic shocks caused the sharp underperformance of credit versus swaps. Only ABS have performed consistently well versus swaps which is attributable to the asset class trading at comparable spreads to Treasuries as do swaps and also because the bankruptcy-remote nature of many ABS bonds helps insulate the asset class from issuer-event risk.

[28] The six swaps are: 6 months, 2-year, 5-year, 10-year, 20-year and 30-year.

Figure 45. **Cumulative Excess Return of U. S. Aggregate Index Components over a Corresponding Duration-Matched Swap Portfolio**
July 1992-November 2004, Outperformance (%)

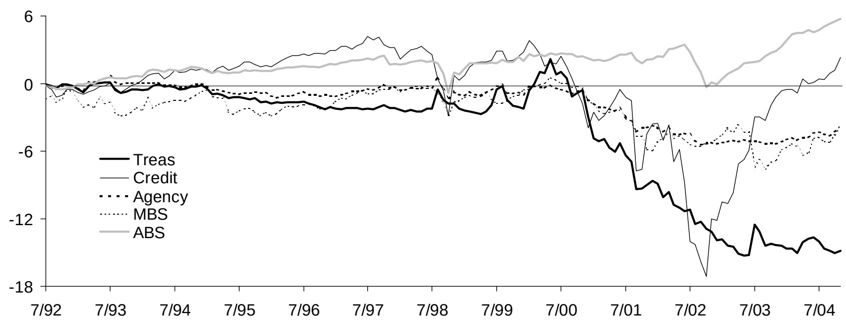


Figure 46. **Mean and Standard Deviation of Monthly Returns over 1-Month LIBOR and Sharpe Ratio for Component Indices of U. S. Aggregate and Corresponding Mirror Swap Indices**
July 1992-November 2004

	Aggregate		Treasury		Credit		Agency		MBS		ABS	
	Index	Mirror Swap	Index	Mirror Swap	Index	Mirror Swap	Index	Mirror Swap	Index	Mirror Swap	Index	Mirror Swap
1992-2004												
Mean (bp/Mo)	21.9	23.5	20.9	25.3	27.3	26.9	21.2	22.4	19.3	20.5	18.1	16.4
Stdev (bp/Mo)	111.6	124.5	134.3	145.8	143.0	159.7	117.1	121.5	83.7	92.4	76.5	81.8
Sharpe Ratio (Ann)	0.68	0.65	0.54	0.60	0.66	0.58	0.63	0.64	0.80	0.77	0.82	0.70
July 1992-July 1998												
Mean (bp/Mo)	20.6	21.4	20.6	22.7	27.5	25.5	20.6	21.0	17.2	17.6	13.3	11.5
Stdev (bp/Mo)	112.3	123.2	120.9	128.9	143.7	152.5	116.2	119.0	89.0	103.7	68.7	72.1
Sharpe Ratio (Ann)	0.64	0.60	0.59	0.61	0.66	0.58	0.62	0.61	0.67	0.59	0.67	0.55
August 1998-November 2004												
Mean (bp/Mo)	23.2	25.6	21.1	27.8	27.1	28.4	21.7	23.7	21.3	23.2	22.8	21.1
Stdev (bp/Mo)	111.7	126.5	146.8	161.2	143.3	167.4	118.7	124.6	78.8	80.7	83.5	90.3
Sharpe Ratio (Ann)	0.72	0.70	0.50	0.60	0.66	0.59	0.63	0.66	0.94	1.00	0.94	0.81

Swaps have also performed relatively well on a risk-adjusted basis. For the period from July 1992 through November 2004, Figure 46 presents the mean and volatility of monthly returns over 1-month LIBOR for the Aggregate Index, the various spread sectors (Agency, MBS, Credit and ABS) of the Aggregate Index, and each sector's corresponding duration-matched portfolio of swaps (so-called "mirror swap index"). For all asset classes except credit and ABS, swaps had a higher mean excess return over LIBOR. After adjusting for the volatility of the monthly excess returns, Figure 46 shows that swaps had comparable Sharpe Ratios. So, from a risk-adjusted perspective, swaps are comparable to other asset classes under consideration by official reserve managers.

We partition the 1992-2004 period into two sub-periods, July 1992-July 1998 and August 1998-November 2004, to highlight the period of high spread volatility beginning in mid-1998. We see that swaps performed better in the second period compared to the first as swaps avoided some of the credit and prepayment shocks experienced by other asset classes in the 1998-2004 sub-period.

Figures 45 and 46 show that the relative return and volatility of swaps versus other spread asset classes varies over time. For example, in the 1992-1998 sub-period swaps underperformed credit and slightly outperformed Agencies and MBS with somewhat more volatility. However, in the 1998-2004 sub-period, swaps outperformed credit, Agencies and MBS by a meaningful margin with an increase in volatility relative to credit and Agencies but with a decrease in volatility relative to MBS. This raises the enticing possibility that adding swaps to a portfolio containing other asset classes may produce some meaningful diversification benefits.

As many central banks currently invest in Agencies, MBS and, perhaps, ABS, it would be informative to examine the correlation of excess returns (versus Treasuries) between 5-year swaps and these asset classes.[29] Figure 47 presents the correlation of excess returns for these asset classes, and for Credit, for the period from July 1992 through November 2004. The correlation matrix shows that 5-year swaps had the

[29] We use the 5-year swap in this analysis because it represents a liquid point on the swaps curve and its duration is close to index durations.

Figure 47. **Correlation of Monthly Excess Returns (versus U. S. Treasuries)**
July 1992-November 2004

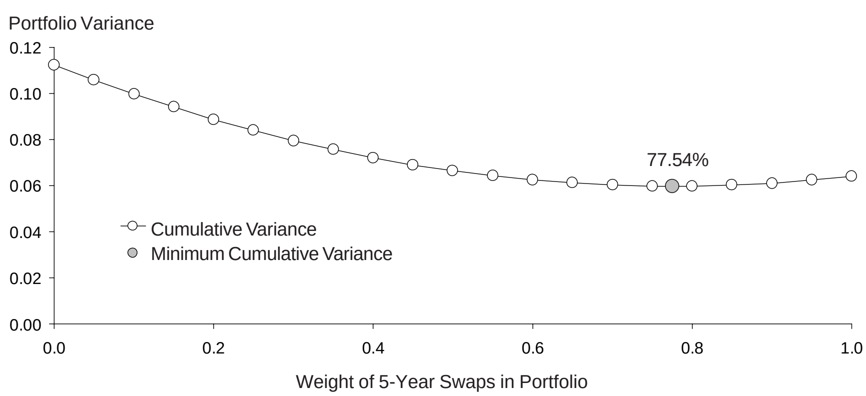
	Agg	Credit	Agency	MBS	ABS	5-Year Swaps
Aggregate	1.00	0.86	0.62	0.76	0.63	0.55
Credit		1.00	0.39	0.34	0.58	0.38
Agency			1.00	0.55	0.55	0.76
MBS				1.00	0.41	0.43
ABS					1.00	0.45
5-Year Swaps						1.00

lowest correlation with the Aggregate Index than any of its five main components. While this is not too surprising as the components are part of the Aggregate Index itself, the relatively low correlation of swap excess returns with those for other asset classes held by central banks indicate that swaps may have a role to play in reducing portfolio risk.

To illustrate the potential efficiency benefits of adding swaps to a portfolio, we construct a composite index consisting of the Agency, MBS and ABS spread sectors of the U. S. Aggregate Index. This is a predominantly Aaa-rated portfolio of spread assets commonly held by official institutions. For the period from July 1992 through November 2004 we calculate the variance of the monthly excess returns of this composite spread index (0.112). We then take this composite index and combine it, in varying proportions, with 5-year swaps. We begin with a portfolio of 100% in the composite spread index and 0% in 5-year swaps. This point is represented by the far left point in Figure 48. We then slowly increase the percentage weighting of swaps. So, for example, the next point to the right represents a portfolio with a 95% market value weight in the Agency/MBS/ABS composite index and a 5% weight in 5-year swaps. Figure 48 shows that by adding 5-year swaps to the portfolio, the variance of the portfolio's excess returns declines from 0.112 to 0.105. We continue in this fashion until we reach the other end of the spectrum with 0% in the composite spread index and 100% in the 5-year swap which produces a composite portfolio excess return variance of 0.064.

Figure 48 also shows the point at which the variance of the portfolio is at a minimum. This occurs when the weight of 5-years swaps in the portfolio equals approximately 78% which produces a variance of 0.0597 (or a monthly volatility of 24.4 basis points). This analysis is not meant to suggest that a spread portfolio should contain such a high weighting to swaps. Rather, it supports the argument

Figure 48. **Variance of Monthly Excess Returns over Treasuries as a Function of the Portfolio's Weight in 5-Year Swaps**
July 1992-November 2004



that swaps, as an asset class, can be a useful part of any fixed-income portfolio where risk management is a very important consideration.

Central banks should consider swaps as a distinct spread asset class with potential return and diversification benefits for their official portfolios. Unlike many credit sectors, swaps offer tremendous liquidity benefits as well as virtualy no idiosyncratic event risk.[30] More importantly, swaps have offered total returns comparable with other asset categories and can provide useful portfolio diversification benefits as well. While there is counterparty risk with swaps, which must be monitored, this risk can be significantly mitigated by the use of collateral and third-party arrangements.

[30] Another potential way to obtain credit spread exposure with limited idiosyncratic and headline risk is to invest in portfolios of credit default swaps (along with a cash investment in LIBOR). The additional expected return over swaps is mitigated by the additional event (and possible headline) risk of investing in a portfolio of credit names. There are standardized portfolios of CDS (e.g., CDX) which contain a relatively large number of credit names and which enjoy very strong market liquidity. For more details, see *Replicating the Lehman Brothers Aggregate Bond Index with Liquid Instruments (including TBAs & CDX),* Lehman Brothers, October 28, 2004.

CONCLUSION

We are in the midst of an exciting transformation in reserve management of central banks, from the traditional "liquidity first" focus to a more balanced objective that includes total return maximization and risk diversification considerations. The long-term forces driving this transformation, which we tried to summarize in this report, may well be permanent. Even if some of the original motivations have lost their urgency (for example, the demise of the U.S. Treasury asset class no longer looms on the horizon), the momentum has shifted. Almost every member of the global official institution community is revising benchmarks (or put differently—long-term asset allocation decisions). Institutions managing the national wealth of countries are leading the way, with central bank reserve managers following closely behind.

To be sure, the considerations driving such revisions are different for central banks than for pure institutional asset managers, with principal preservation, liquidity preference, and "headline" credit risk remaining major concerns. However, this process, once started, will inevitably lead to a significant broadening of the investment opportunity set and the resulting improvement in long-term risk-adjusted returns.

This paper addressed two of the important portfolio management issues currently facing many official institutions: how to set the portfolio's duration target and how much of the portfolio (if any) should be allocated to the various non-Treasury asset classes. We offered several quantitative techniques that can be used to help answer these questions. For duration targeting, we reviewed the use of Sharpe ratios, which are based on historical returns, and No-View Optimization, which is based on an agnostic assessment of the current market environment. We also demonstrated how No-View Optimization can be used to outperform an established benchmark. Finally, we presented evidence supporting the case for non-Treasury assets in a portfolio based on risk-adjusted returns and diversification benefits. We also specifically offered quantitative approaches for dealing with "headline" risk (*e.g.,* swaps) and idiosyncratic credit risk (*e.g.,* "sufficient diversification").

With a broader set of asset classes to consider, reserve managers will get an opportunity for diversification of portfolio management style. Instead of only timing duration or curve movements, they will be able to engage in the top-down style of sector rotation, or bottom-up style of security selection, especially in credit products. Duration and curve timing, in turn, may be achieved by combining subjective views of investment committees and portfolio managers with a model-driven approaches (such as No-View Optimization) offering a disciplined objective alternative.

Asset classes to enter the traditional mix of reserve portfolios will probably expand over time from Aaa-rated fixed cash flow instruments such as U.S. agency bullet debentures, supranational and sovereign debt, and ABS to the high-grade credit securities. In time, there may even be interest in achieving additional return by assuming the prepayment risk of U.S. MBS securities, which represent a very liquid and deep market (about 36% and 14% of the market value of the Lehman U.S. Aggregate and Global Aggregate Indices, respectively, as of August 2004). The highly technical nature of this market creates unavoidable complexities in any attempt to outperform it, but it is fairly easy to replicate with minimal back-office requirements.[31] The day may even come when a small part of the reserves may be invested in high-yield securities, as it is often the case for "core-plus" strategies of institutional investment managers.

Swaps may also emerge as an important total return instrument in central banks' reserve portfolios. Unlike many credit sectors, swaps offer tremendous liquidity benefits, as well as virtually no idiosyncratic event risk. Swaps have offered total returns that are comparable with other spread assets and can provide useful portfolio diversification benefits because of their relatively low correlation with other asset classes.

The shift in asset allocation of reserve portfolios that we started to witness in the late 1990s, from short-dated Treasury securities to a more diversified mix of assets, may, in fact, be one of the most interesting developments in the world of fixed income securities over the next decade.

[31] *Tradable Proxy Portfolios for the Lehman Brothers MBS Index*, Lehman Brothers, July 2001.

APPENDIX: THE PROSPECTS OF NEGATIVE ANNUAL TOTAL RETURNS FOR SHORT-DURATION TREASURY BENCHMARKS[32]

The 1- to 3-year Treasury Index has never experienced a negative 12-month total return in the Lehman data history. Many users of the 1- to 3-year Treasury Index seek capital preservation and have found comfort in the index's unbroken streak of positive annual returns. However, short-duration assets are no guarantee of positive total returns, especially in an environment of low yields and a very steep yield curve. The purpose of this appendix is to present a framework for analyzing the magnitude, likelihood, and timing of a Treasury curve backup that may cause negative annual returns for the 1- to 3-year Treasury Index and the 2-year on-the-run Treasury note.

One might be tempted to use the following standard duration-based approximation for returns

$$\text{index return} \approx (y \times \Delta t) - (D \times \Delta y) \qquad \text{(A1)}$$

to assess the yield increase required for the index to experience negative returns. At the end of September 2001, index duration was 1.70 years. With this number and a yield of 2.79%, Equation (A1) finds that a 164 basis point increase in index yield would be sufficient to push twelve returns to zero, and any increase in yields beyond this level would result in negative cumulative returns.

Equation A1 is accurate only for short holding periods in which both yield changes (Δy) and time changes (Δt) are small. Moreover, it assumes that time return is unaffected by the yield change. Suppose the increase in yield occurred halfway into the twelve-month investment period. Then, in six months, the index would suffer a similar negative price return of roughly $[-(1.7) \times (1.64)] = -2.79\%$ at the moment of the yield increase.[33] However, index yield would rise to 4.43% for the second six months of the investment horizon. The resulting increase in time return would boost the index's twelve-month cumulative return by roughly 82 basis points and result in a positive total twelve-month return of roughly 0.82%.

Timing is crucial. If the increase in yields occurs immediately, then the index will benefit from the higher time return for the entire twelve months. On the other hand, if the yield change occurs at the end of the investment period, the increase in index yield will cause the index to have an adverse price return with no accompanying increase in time return over the twelve-month horizon. Figure A1 reports the yield increases required for the 1- to 3-year Treasury Index to experience negative

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[32] This appendix was written in September 2001, and the numerical examples have not been updated. Nevertheless, the ideas discussed here will be relevant whenever short-term yields are particularly low.

[33] Due to monthly rebalancing, one would expect index duration in 6 months to remain close to unchanged.

12-month total returns under three scenarios: 1) all increases in yield occur immediately, 2) yield increases occur at a constant rate over time, and 3) all yield increases occur at the end of the investment period.

Rolldown and Expected Future Yield Curve Shifts

The shape of the yield curve may provide important information about likely yield changes. One important factor influencing future index yield is the change in index yield that comes from rolling down the current yield curve. Rolldown effects were approximated from the shape of the off-the-run spline. The current yield curve is quite steep and offers a 5.2 basis point decrease in yield at each month's rebalancing. Over six months, this translates into a decline of 31 basis points. Over a year, it comes to a 62 basis point drop.

These rolldown yield changes must be combined with the numbers from Figure A1 to obtain the yield curve shift that would result in a negative realized return.

Figure A2 shows that the short end of the yield curve would have to shift up by more than 125 basis points to result in a negative six-month total return. A negative twelve-month holding period return would require the short end of the curve to shift up by more than 287 basis points. Both of the numbers are under the "constant rate increase" scenario.

Yield Curve Steepness

Yield curve steepness tends to be mean reverting. Abnormally steep yield curves eventually revert to normal steepness. Similarly, abnormally flat or inverted yield

Figure A1. **Yield Increase Required for Negative Total Return**
October 1, 2001 (bp)

Yield Increases Occur	6-Month Holding Period	12-Month Holding Period
Immediately	109	356
At A Constant Rate	94	225
At the End	82	164

Figure A2. **Rolldown Effects and Curve Shift Required for Negative Returns**
October 1, 2001 (bp)

	6-Month Holding Period			12-Month Holding Period		
Increases Occur	Breakeven Index Yield Increase	Rolldown	Breakeven Curve Increase	Breakeven Index Yield Change	Rolldown	Breakeven Curve Increase
Immediately	109	31	140	356	62	418
At A Constant Rate	94	31	125	225	62	287
At the End	82	31	113	164	62	226

curves can also be expected to revert to normal steepness. As one moves down the end of September yield curve from the point that matches current index duration to the point 12 months farther out on the spline, yields increase by 59 basis points. Typically, the point 12 months farther out on the Treasury spline from the spot that matches the duration of 1- to 3-year Treasuries has 20 basis points of additional yield. It would be reasonable to expect this 38 basis points of abnormal slope to be erased over some future time horizon.

Of course, it isn't clear how much of this 38 basis point move, if any, will occur over the next twelve months. Additionally, it isn't clear how much of the movement will result in an increase in 1- to 3-year yields, rather than a decrease in 2- to 4-year yields. However, once the economy hits bottom, one can be confident that interest rate movements will be uniformly in the upward direction.

Regardless of how one allocates the 38 basis points of abnormal steepness in this part of the curve, it clearly cannot be more than a minor factor relative to the 287 basis point yield shift required to put 1- to 3-year Treasuries into negative annual return territory. For six-month returns, the abnormal steepness is 20 basis points, once again falling far short of what would be required to generate negative six-month holding period returns.

Figure A3 incorporates rolldown and yield curve steepness effects to estimate the unanticipated shift in the Treasury curve required to push total returns negative. If yield increases occur at a constant rate, the Treasury curve must increase by 287 basis points (Figure A2) to result in negative total returns. Current yield curve steepness suggests that the market anticipates a 38 basis point increase, implying that 249 basis points of unanticipated yield curve increases will lead to breakeven total returns for the year. The analysis estimates that anything more than this will lead to negative total returns over the upcoming twelve-month holding period.

Figure A3. **Steepness Effects and Curve Shift Required for Negative Returns** October 1, 2001 (bp)

	6-Month Holding Period			12-Month Holding Period		
Increases Occur	**At Start**	**Constant Rate**	**At the End**	**At Start**	**Constant Rate**	**At the End**
Breakeven Index Yield Increase	109	94	82	356	225	164
Roll-down	31	31	31	62	62	62
Abnormal Steepness	20	20	20	38	38	38
Breakeven Unanticipated Curve Increase	120	105	93	380	249	188

2-Year On-the-Run

As noted earlier, the 2-year on-the-run Treasury Note has rewarded investors with positive total returns over every 12-month interval in our data history dating back to 1985. At the end of September, the 2-year on-the-run had a yield of 2.82% and a 1.84-year duration. If we were to pursue breakeven analysis by applying these numbers to the standard duration-based approximation (Equation (A1)), the prediction obtained is that a 153 basis point increase in yield would be sufficient to cause negative twelve month returns.

However, we have already seen that the standard duration-based approximation for returns can be misleading. This is particularly the case for the 2-year on-the-run. Lehman's *PC Product*, for instance, reports that a 365 basis point shift in the Treasury curve is required to send 12-month returns on the 2-year note to zero. For holding periods with nontrivial length, it is important to apply the complete quadratic approximation for realized return:

$$\text{index return} \approx$$

$$(y \times \Delta t) - (D \times \Delta y) + ½ \times C \times (\Delta y)^2 + ½ \times y^2 \times (\Delta t)^2 + (1 - y \times D) \times \Delta t \times \Delta y, \quad (A2)$$

where D is duration and C is convexity. For short maturity indices such as the 1- to 3-year Treasury Index, convexity will be quite small, allowing us to ignore the third term. Similarly, y^2 is a very small number $(0.0282)^2$, implying that the fourth term in Equation (A2) can also be safely ignored. However, the last term in Equation (A2) will be significant. $(1 - yD)$ is close to one, and Δt equals one for an annual investment horizon.[34] Therefore, the last term will be on the order of Δy and is important in determining the breakeven yield change.

Applying the end of September index numbers to Equation (A2) estimates the breakeven yield change required for a negative twelve month total return on the 2-year on-the-run to be 316 basis points. Adding rolldown effects brings the estimated yield curve increase required for negative twelve-month returns to be 378 basis points, reasonably close to the more accurate *PC Product* number, which is based on complete re-pricing.

The Hold-to-Maturity Effect

The 1- to 3-year Treasury Index and the 2-year on-the-run offer comparable yields (2.79% for the 1- to 3-year index, 2.82% for the 2-year note), and the 2-year note has a slightly longer duration: 1.84 years versus 1.70 years for the index. Yet the 2-year note provides more protection against a negative 12-month return. The key

[34] The last term in Equation (A2) can be safely ignored for investment strategies like the 1 – 3 Year Treasury index that rebalance monthly. The proper way to apply Equation (A2) to assess annual returns with monthly rebalancing is to set Δt to (1/12) and then compound the results. Setting Δt to ($^1/_{12}$) reduces the importance of the last term in Equation (A2) by a factor of 12 relative to the importance of the standard duration term.

factor behind this is that the index rebalances each month to maintain an approximately constant duration of 1.7 years while the duration of the 2-year note gradually declines from 1.84 years to 0.90 years. The time-averaged duration of the 1- to 3-year index is roughly 1.63 years, compared with 1.37 for the 2-year note. While the current duration of the 2-year note is longer than the current duration of the 1- to 3-year index, the time-averaged duration of the 1- to 3-year index is much longer than the time-averaged duration of the 2-year note over the following 12-month period (1.63 versus 1.37).

Alternatively, this can be thought of as a "hold-until-maturity" effect. The 2-year note will certainly return its 2.82% yield if held for two years, regardless of any interim yield changes. A twelve-month holding period for a 2-year note is sufficiently close to the security's total life that a partial "hold-until-maturity" effect, represented by the last term in Equation (A2), greatly increases the yield change required for negative cumulative returns.

Yield Curve Volatility

While the current abnormally steep yield curve may not have much impact on expected interest rate movements, one may be concerned that they are an indicator of an abnormally volatile interest rate environment. Swaption volatilities can be used to assess current volatility. Swaption volatilities are typically quoted in terms of "yield volatilities," which are at an all-time high for short-tenor, short-maturity swaptions. For instance a 1-month option on a 2-year swap has a record implied yield volatility of 35.1%, more than twice its historical average of 17.25%.

However, the volatilities relevant for our analysis are basis point volatilities. Basis point volatility is yield volatility multiplied by yield level. Currently, the combination of extremely low yield levels and extremely high yield volatilities has caused basis point volatilities to be near their average levels. Basis point volatility on the 1-month, 2-year swaption mentioned above is 121 basis points, slightly above its typical level (101 bp). On the basis of this implied swaption volatility, an unanticipated 249 basis point increase in rates would be slightly more than a 2 sigma event for a 1-year horizon and clearly cannot be dismissed.

What to Do?

Investors who cannot tolerate negative annual returns may wish to shorten portfolio duration. 12-month bills always provide 100% safety against negative annual returns. Of course, it is not necessary to go that far. Our analysis of a buy-and-hold position on a 2-year note showed that a position with a time-averaged duration of 1.37 requires the yield curve to increase by more than 365 basis points for negative twelve-month returns to be realized. The current duration of the 1- to 3-year Treasury Index is 1.70. Moving portfolio duration from this range down to the vicinity of 1.3 years should provide solid protection. Currently, the 1-year part of the Treasury curve is rich, offering yields below both the 6-month and 2-year regions. Thus, moving to 1-year maturity assets will adversely affect yield. An alternative would be to invest in 3-month and 6-month bills, but this approach is likely to cause investors to reinvest at lower rates should the Fed continue to ease.

In addition to shortening duration, investors may wish to consider shifting to high grade spread product. At the end of September, the yield of the 1- to 3-year Agency Index was 3.13%, offering investors a somewhat larger cushion against the prospect of negative annual returns. One- to 3-year agencies also had a slightly shorter duration (1.67 versus 1.70). Figure A4 reports the yield increase required for negative twelve-month returns for 1- to 3-year U.S. Treasuries, 1- to 3-year agencies, and investment in the 2-year swap (rebalanced monthly). All numbers assume a gradual rise in yields. Compared to Treasuries, 1- to 3-year agencies required an additional 33 basis point increase in rates before suffering negative 12-month returns.

Figure A4. **Yield Increase Required for Negative Total Return Constant Increase Scenario**

	6-Month Holding Period	**12-Month Holding Period**
1-3 Year UST	94	225
1-3 Year USA	105	258
2-Year Swap (rebalanced monthly)	97	230

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