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TRENDS IN FIXED INCOME BENCHMARK SELECTION AND PORTFOLIO OPTIMIZATION

Introduction

The extraordinary recovery of the credit markets in 2003 has given investors much to celebrate this holiday season. Many managers have handily outperformed their credit benchmarks this year. It seems long ago when we peered into the abyss of the distressed credit markets of 2001 and 2002. Unlike several previous episodes of credit market turmoil, which involved smaller and lower-quality names, recent years witnessed the wounding of large and highly rated issuers whose bonds were widely held. The credit shocks were compounded by severe market illiquidity as many investors simultaneously attempted to reduce large exposures to troubled names. While many would just prefer to allow the years of credit market trauma to fade from memory, many valuable lessons were learned that have become standard investment management practice and will remain so for the foreseeable future.[1]

The stressful credit markets and the spike in security-specific risk forced a reconsideration of approaches to risk management, portfolio construction, and benchmark selection. This overview presents studies and methods that we have recently developed for investors to address the trend toward the diversification of both security-specific and systematic risk in their benchmark choices and portfolio solutions. Most of the topics discussed here are treated in detail in separate publications which we reference in this overview.

Benchmark Selection

We first briefly review the remarkably resilient trend of increased diversification of security-specific risk in benchmarks. This development began 2 years ago, as credit event risk became a dominant part of portfolio risk, and led to adaptation of issuer-capped benchmarks, as well as downgrade-tolerant and swap-based benchmarks.

While security-specific risk came to the fore in recent years, systematic risk remained in the background. In fact, many investors took advantage of the constantly expanding family of indices and improving index technology to adopt new benchmarks that permitted more effective diversification of the systematic risks of their investment portfolios. Specifically, we saw continued growth in the use of asset-swapped indices and yield-based indices as benchmarks.

In the global arena, we continued to witness a strong long-term trend from Global Treasury indices towards Global Aggregate indices. The primary advantage of the Global Aggregate Index is increased diversification of systematic risk exposures, adding credit spread and prepayment risk to the yield curve and FX risk. This index is also more evenly distributed across U.S., Eurozone, and Japanese bond markets.

Another interesting theme in benchmark selection that we observed last year is the self-imposition of "purchasable yield" indices that measure value added by the portfolio managers over long time horizons. Asset-liability managers (mostly insurance companies) continued to look for liability-based benchmarking solutions by tying their performance benchmarks both to their mix of assets and term structure profile of liabilities.

[1] These lessons are discussed at length in a forthcoming publication: *Portfolio and Index Strategies During Stressful Credit Markets*, Quantitative Portfolio Strategies Group, January 2004.

Portfolio Strategies

On the portfolio management side of the equation, diversification of security-specific risk was always a consideration, especially for credit portfolio managers. Clearly, the events of 2001-2002 brought this issue into even sharper focus for most asset managers. Our 2002 study of "Sufficient Diversification in Credit Portfolios" makes specific recommendations of optimal position size ratios in various segments of the credit market and the number of issues required to minimize the shortfall due to downgrades with a given confidence. It also offers a framework for avoiding excessive diversification, which takes into account credit analyst skill, cost of credit analysis, and portfolio size.

Managers benchmarked to Aggregate-type indices (whether domestic or global) have extended the traditional mix of core-plus strategies. In addition to high-yield and emerging markets debt, they now include inflation-linked securities; foreign treasury bonds on a fully or partially hedged basis (especially Euro-government bonds in U.S. Aggregate portfolios); and, in some instances, explicit investment positions in interest rate swaps and credit default swaps. Each of these additional core-plus strategies was included for a different reason, but together they provide powerful diversification of systematic risk in the portfolio.

In fact, if there is any common theme in the manager's choice of popular core-plus strategies, it is their low (near zero, not high negative) correlation to core asset classes in the Aggregate Indices.

In this overview, we discuss briefly the rationale for inclusion of these core-plus asset classes in the overall portfolio mix. We also point out how important it is to allocate the risk budget properly among all active core and core-plus views. To the extent that all core-plus allocations are to instruments outside of the benchmark, managers can reflect only bullish views by overweighting them relative to the index. We will show that this inability to reflect bearish views makes all core-plus strategies inferior to core if taken in isolation. Only in an optimal combination with core strategies do they provide the expected boost to performance and reduction in risk.

Risk Optimization

The increase in benchmark complexity and the broadening of core-plus choices leave the portfolio manager with a need to navigate through a very complex set of possible combinations of macro views. Tools are needed to help in this process and produce optimal allocations of the overall risk budget to individual strategies given the manager's views. Still more tools are needed to help form consistent views across a wide spectrum of market parameters. Optimal allocation to macro strategies must be complemented by security-level risk optimization.

In this overview, we briefly outline the powerful modeling and analytics capabilities Lehman has developed for both total return and buy-and-hold investors looking to optimize risk and return in their portfolios.

Our approach to optimal allocation of risk budget to macro strategies of total return investors is based on the concept of the investor's skill at each type of strategy. We define skill as the percentage of the time a directional view of a portfolio manager was correct over a pre-defined time horizon. Our approach allocates a given risk budget to active

macro strategies, based on the managers' directional views, demonstrated skill, and correlations among strategies. The optimal solution gives the most risk budget to strategies with the highest skill and lowest correlations to each other.

The Lehman Multi-factor Risk Model offers an analysis of the portfolio risk relative to a benchmark at the level of individual securities. It is a valuable tool for finding an optimal security-level composition of a portfolio structured to achieve a given risk budget, possibly with the help of the risk budgeting at the macro level. The Risk Model covers all securities in the Global Aggregate Index and High Yield Index, as well as many common derivatives.

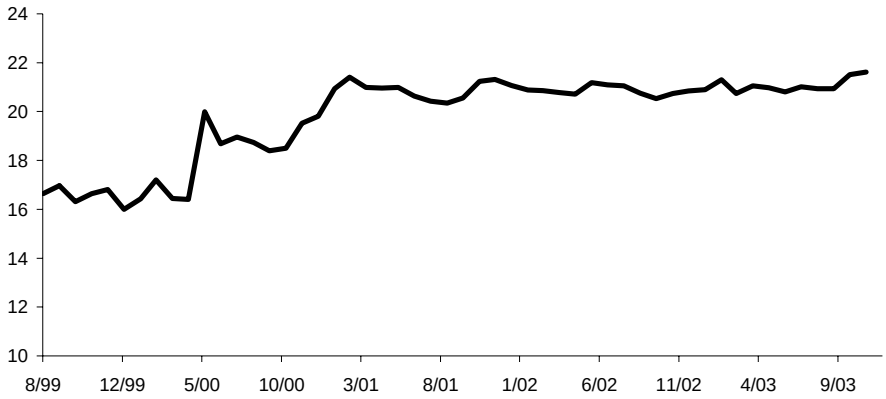
Buy-and-hold investors also engage in a two-step process of macro allocations and security-level implementation of this allocation. We discuss a framework for making macro allocation decisions to segments of the credit market for buy-and-hold investors with a long time horizon. We use a typical insurance company problem of a long-term allocation between single-A and Baa credits to illustrate our method. We follow it up with a discussion of a Lehman model and analytics that allow investors to find an optimal portfolio of specific credit issuers and maximize its expected return subject to a risk constraint.

I. RISK DIVERSIFICATION IN BENCHMARK SELECTION

Diversification of Security-Specific Risk in Benchmarks

The burst of security-specific risk prompted quick reconsideration of approaches to *portfolio* risk management and construction. This was not a surprising development. However, what was surprising was that managers and their plan sponsors increased their scrutiny of the security-specific risks imbedded in their *benchmarks*. Excessive exposure to individual issuers became a concern not just for portfolio managers. Plan sponsors re-examined benchmark design and closely examined their benchmarks for large single issuer concentrations. Sponsors asked: "Does it make sense for our organization to have a 2% exposure to name XYZ?" In fact, Figure 1 shows that as of November 2003, the top ten issuers in the U.S. Corporate Index as a group have a total market value weight of 21.6% in the index. For some plan sponsors, this is too much security-specific risk.

Figure 1. **% MV Weighting of Top Ten Issuers in the Corporate Index**
August 1999 – November 2003



Risk managers began to devote more of their attention not just to the risks in the portfolio, but to the risks in the benchmark, as well. The high level of absolute issuer name risk exposure in some commonly adopted benchmarks led to interest in issuer-capped benchmarks.

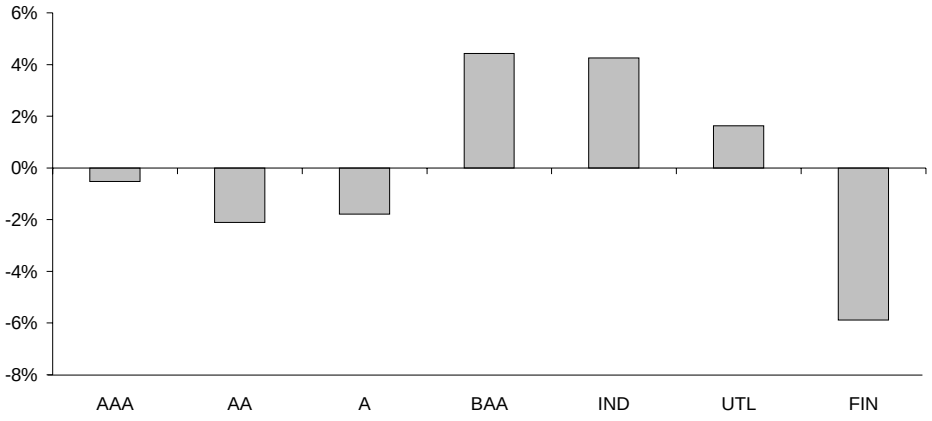
Issuer-Capped Benchmarks

An issuer-capped benchmark imposes a maximum on the market value weight that an issuer can have in the index. The motivation for capping an issuer's market value weight is to limit the exposure to the idiosyncratic risk of a large issuer. In the simplest case, a market-value cap (e.g., 1%) can be imposed, and every issuer capitalization is checked against this ceiling. The market value in excess of the cap is "shaved off" and distributed to all other issuers in the index in proportion to their market values. In some cases, the caps are chosen to be different for various credit ratings, reflecting the differences in issuer-specific risk between higher and lower credit qualities. While issuer-capped portfolios have long had a portfolio management role to play, issuer-capped indices are new and are a direct response to the high levels of security-specific risk of the past few years.

On the surface, issuer-capped indices seem very straightforward. However, in 2003 investors learned an important lesson: care must be taken when constructing issuer-capped benchmarks because the cap level and the redistribution rule can have significant effects on the risk and return performance of the benchmark.[2] We found that imposing a 1% cap would have improved the excess return performance over the past few years but that caps levels greater than 1% provided only a marginal excess return improvement. However, the magnitude of any improved performance is dependent on the redistribution rule of the excess market weight from large issuers to small ones. Some redistribution rules can limit the benefits of issuer capping by inadvertently introducing unfavorable sector-quality risk exposures relative to the uncapped index.

[2] "Issuer-Capped and Downgrade-Tolerant U.S. Corporate Indices," *Global Relative Value*, February 2003.

Figure 2. **Average Sector and Quality Exposures of 1%-Capped Index vs. Corp Index,** August 1999 - December 2002



For example, many investors initially use an "index-wide" redistribution rule that takes any "excess" market value and distributes it across all issues of non-capped issuers in the index in proportion to their weights in the index. However, such a redistribution rule can produce an index that has very different (and probably unintentional) sector and quality exposures than the uncapped index. Figure 2 shows that a 1% issuer-capped index with an index-wide redistribution rule has a significantly higher weighting in Baa-rated and industrial issues than the uncapped Corporate Index and a significant underweight to financials.

This inadvertent introduction of potentially unfavorable sector-quality risk exposures has led many investors to choose a "quality-sector neutral" redistribution rule that maintains the same sector-quality exposures in the capped index as in the uncapped Corporate Index.

In addition, depending on how the issuer-capped benchmark is constructed, the degree of "sloshing" can have an effect on the replicability of the index. Sloshing refers to the fact that a capped index causes the market value weight of smaller issuers to exceed their weight in the marketplace, sometimes dramatically so.[3] This raises a concern: is there enough supply in the marketplace to allow the manager to replicate (if he so chooses) the issuer-capped index?

Nevertheless, despite some of the subtleties involved that require sound judgment, issuer-capped indices are now a permanent part of the investment management landscape. Lehman Brothers has developed the index construction tools for investors to construct and back-test a wide variety of issuer-capped indices that meet their own risk management preferences for dealing with security-specific risk.

Swap-Based Benchmarks

Other plan sponsors and investors (e.g., insurance companies) have begun to address security-specific risk in their benchmark from a completely different angle: adopt a benchmark with zero security-specific risk. For example, Treasuries have little, if any, security-specific risk and have historically served as benchmarks for official institutions such as central banks. One advantage of Treasuries as benchmarks is that an investment manager is forced to justify any percentage holding of a credit asset. In stark contrast, a manager benchmarked against the U.S. Corporate Index who is neutral on Ford (or is too lazy to formulate a definite view) is forced to hold almost 3.5% market value in Ford in order to be neutral to the benchmark. While the manager has eliminated his relative performance risk, there remains a considerable absolute performance risk.

The trouble with adopting a Treasury benchmark to avoid security-specific risk is that it does not offer any long-run spread advantage[4] and does not challenge the investment manager to demonstrate skill in choosing credits that perform well and avoiding credits that perform poorly. The investment manager's relative performance is not penalized as a result of avoiding making any credit decisions.

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[3] For example, for a 1% issuer-capped index that follows a quality-sector neutral redistribution rule, the market value weight of Northern Trust is approximately five times its weight in the uncapped Corporate Index ($834 million versus $166 million).

[4] Please refer to *Total Return Management of Central Bank Reserves*, June 2002, for a discussion of the long-run advantage of moving to an Aggregate-type benchmark from a Treasury-only benchmark.

Is there an asset that can serve as a benchmark that has both little security-specific risk but would force the investment manger to demonstrate skill in choosing credits? "I've got one word for you … swaps."[5] Swaps offer tremendous liquidity, limited "headline" or idiosyncratic risk, and an opportunity for plan sponsors to capture some of the long-run spread advantage of investing in non-Treasury product.

As all investors know, swaps have become a key feature of the debt markets during the 1990s. In fact, in several ways, the swaps market is larger and more heavily traded than U.S. Treasury market.

Swap payments are based on LIBOR, and therefore the par swap rate curve can be viewed as a generic yield curve for large, highly-rated banks whose inter-bank lending rates comprise the LIBOR index.[6] Correspondingly, the swap spread is considered a general proxy for high-grade credit spreads.[7] Note that the swap spread does not reflect the counterparty risk of swaps, which is effectively eliminated through collateral management.

In January 2002, Lehman Brothers introduced a family of bellwether swap indices.[8] Fortuitously, these indices were introduced shortly before investors began to search for benchmarks with little security-specific risk. Swap indices have become particularly popular with insurance companies who manage credit portfolios internally. In addition, we know of numerous mandates that have been awarded to investment managers where the underlying benchmark is a swap index or a custom blend of bellwether swap indices to match a particular liability duration target.

A manager who has a swap index as a benchmark is completely free to hold only those credits that he thinks will outperform and avoid credits he thinks will underperform duration-matched swaps. For credits on which he is neutral or has no view, he can hold a zero market value weight. In contrast, if his benchmark were the U.S. Corporate Index, he would be under pressure to hold at least the benchmark's percentage holding of an issuer and leave the sponsor exposed to the security-specific risk. Even if the manager had a negative view on the largest issuer in the Corporate Index, he would be unlikely to hold a zero percent weight, as that would be an extremely large active bet against the benchmark.

Downgrade-Tolerant Benchmarks

The period of stressful credit markets also drew attention to another issue regarding the replicability of the Corporate Index. In particular, there was concern that its quality requirement made the index impossible for credit managers to replicate, especially in a high security-specific risk environment that produces a large number of fallen angels. The index quality requirement forces the removal from the index of fallen angels at the end of their downgrade month. These issues are removed at a price level that reflects where they can be

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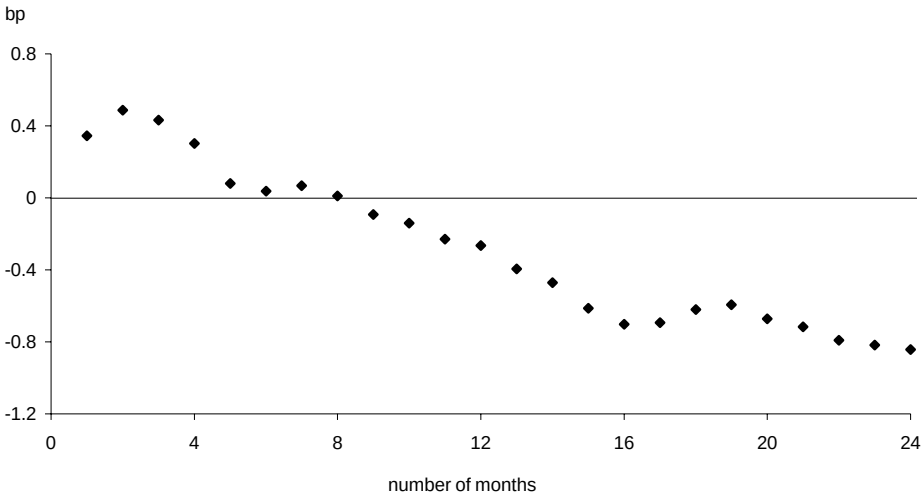
[5] Apologies to Calder Willingham and Buck Henry, screenwriters, *The Graduate*, 1967.
[6] A list of the banks that currently participate in the "LIBOR panel" for US dollar LIBOR and other currency deposit rates is available from the British Bankers Association website at bba.org.uk
[7] For a discussion of the correlation between swap spreads and credit spreads, please see "Weaker Swap-Credit Market Correlations: Temporary or Permanent?" Lehman Brothers, *Global Relative Value*, November 12, 2001.
[8] For more information on swaps and the Lehman Swap Indices please refer to The Lehman Brothers Swap Indices, Lehman Brothers, January 2002.

sold at the margin, not where all outstanding amounts of the bonds can be sold. In contrast, a portfolio manager must find willing buyers and often has little choice but to hold on the fallen angels for at least several months until buyers can be located and the price stabilizes. As a result, some investors believed that the index's quality requirement produces a "survivorship bias" that makes the index extremely difficult for credit managers to replicate during stressful markets. Does the index possess a performance advantage because it can immediately remove fallen angels whereas a manager needs time to sell?

In response to this issue some investors have expressed interest in downgrade tolerant indices that allow fallen angels to remain in the Credit Index for a period of time following downgrade. We measured the magnitude of the survivorship bias and found that it is typically small, but not negligible. However, the bias is volatile and can, at times, be positive or negative. The bias is generally a decreasing function of the tolerance period (Figure 3). For example, the bias is largest if the portfolio manager held onto fallen angels for three months or less. However, the bias disappears and turns negative at the six month tolerance period reflecting the general recovery of fallen angels. The most important lesson learned during the study of downgrade-tolerant indices is if plan sponsors are willing to give managers time to work out of downgraded issues, they should give managers at least six months to do so.[9]

[9] The performance of fallen angels subsequent to downgrade was a popular, if unpleasant, topic with many credit investors in 2003. In particular, since many investment-grade investors are required to eventually sell fallen angels, when was the best time to sell? We examined the optimal holding period and performance of fallen angel issues across many dimensions: issuer size, post-downgrade rating, post-downgrade price level and time since downgrade (i.e., the "seasoning" period). We found that the performance results vary greatly across fallen angel issues and that there were no clear decision rules as to which type of fallen angels to hold or sell, or the best time to sell. However, we did find an overall improvement in the risk-adjusted forward performance of fallen angel issues as seasoning increases.

Figure 3. **Average Survivorship Bias as a Function of the Tolerance Period**
bp/month, January 1990 – September 2003



Diversification of Systematic Risks in Benchmarks

The volatile fixed-income markets of recent years have given many investors another reason to appreciate the value of a performance benchmark. For senior management and plan sponsors, knowing that their manager is measured against a specific benchmark removes a great deal of uncertainty as to how the portfolio should be performing in absolute terms. In addition, of course, benchmarking allows objective evaluation of the investment manager. Benchmarking of performance continues to gain adherents. However, it is important that whatever benchmark is selected, it reflects the systematic risks that the plan sponsor or investor intends to assume.

As in years past, many plan sponsors and portfolio managers contacted us for help in identifying and justifying an appropriate benchmark. In many cases, if a standard Lehman index was not appropriate, we were able to construct a custom benchmark. Given the constantly improving index technology, benchmarking has been introduced into new areas that were not possible even a year ago. Three notable new areas are asset-swapped floating rate benchmarks, yield-based benchmarks, and liability-based benchmarks.

Asset-Swapped Indices

In the current environment of moderate credit spreads (and calls for tightening spreads) and low interest rate levels (with strong worries about rising rates), floating rate assets have become popular. Many sponsors and senior managers have asked their portfolio managers to keep their durations very short while allowing them to maintain an overweight to the spread sectors. These portfolio managers are free to exercise their credit skills by selecting assets likely to perform well but are not allowed to take any term structure risk.

Normally, this would restrict the portfolio manager to the floating rate market. However, this may unduly expose the portfolio to unintended concentrated systematic sector exposures or issuer idiosyncratic risk. Ideally, the sponsor may want the manager to take the same set of diversified systematic spread sector risks (i.e., credit quality and sector exposures) as embedded in the Corporate Index while simultaneously removing exposure to all systematic Treasury key rate risk factors except, perhaps, the 6-month key rate. The challenge is to design a benchmark with a short Treasury duration and one that also reflects the normal allocation to the overall credit sector with its diversified systematic credit spread sector risks.

To exercise their spread sector skills while minimizing interest rate exposure, these investors can buy fixed-rate spread assets contained in the various spread sectors of the Aggregate Index on an "asset swapped" basis. Asset swaps are a synthetic financial instrument which allows an investor to own a fixed-rate bond (and its credit exposure) and swap the fixed rate coupons for floating rate coupons.[10] In essence, an asset swap gives an investor an opportunity to take spread sector exposure with little term structure risk.

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[10] For an introduction to asset swaps, please refer to *Introduction to Asset Swaps*, Dominic O'Kane, Lehman Brothers, January 2000.

There is no formal index of asset swap performance. To benchmark an asset swapped portfolio effectively, the benchmark must represent a "neutral" spread sector portfolio so that a manager's deviations from neutral will have the potential to appear as outperforming the benchmark. Using 3-month LIBOR as a benchmark is inadequate because it reflects only a single credit (i.e., swap spreads) and does not represent the wide array of spread sector decisions available to the investment manager. An ideal benchmark design for asset-swapped managers is a floating-rate benchmark that reflects a diversified set of spread sector exposures.

For example, suppose an asset-swapped portfolio manager is normally 30% weighted in ABS, 30% in MBS, 10% in CMBS and 30% in A-rated corporates. In general, LIBOR is an inappropriate benchmark because the floating portfolios contain exposures to credit spread risk and prepayment risk. The idea is to create a custom floating index that reflects the manager's normal spread asset allocation. We have detailed a methodology for constructing floating-rate benchmarks for asset-swapped portfolios. Using the swap indices, we can construct "mirror" swap indices (on a key-rate duration matched basis) for each of the diversified fixed-rate asset classes the manager is allowed to purchase. We then use the mirror indices to construct asset-swap indices for each asset class. The various asset-swap indices are then combined into a composite index based on the client's "neutral" weightings for each of the asset classes.[11]

Liability-Based Benchmarks[12]

Liability benchmarks are custom indices, constructed using traded assets or published indices, designed to match the fair market value of a portfolio of liability cash flows. Since a liability benchmark matches the cash flows of the liability portfolio, a change in the benchmark's value due to market fluctuations will track changes in the present value of the liability portfolio. A liability benchmark is a "neutral" benchmark that gives the sponsor (e.g., a life insurance company) and manager a performance yardstick incorporating the term structure constraints imposed by the liability schedule. The sponsor can be confident that if he holds the positions underlying the liability benchmark then he will meet his liability schedule. This makes the liability benchmark a "neutral" benchmark.

A liability benchmark also retains many of the desirable attributes of a traditional fixed-income index: benchmark returns are calculated using market prices; the benchmark is replicable; and the benchmark is well-defined so that the sponsor and manager can actively monitor and evaluate its risk and performance and the performance of the manager's investment portfolio against the benchmark. Just like any other index, the manager can using standard portfolio analytics to estimate his portfolio's tracking error against the liability benchmark, perform scenario analysis and evaluate individual security swaps. Also, since the liability benchmark is a "neutral" benchmark, its performance can be compared directly to the manager's performance.

There are two different approaches to constructing liability benchmarks: constructing a portfolio of bonds to serve as a benchmark, or constructing a composite index of published indices. Figure 4 summarizes the different approaches in defining a liability benchmark.

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[11] Please see "Benchmarks for Asset-Swapped Portfolios," Lehman Brothers, *Global Relative Value*, February 2002.
[12] For an introduction to this issue please see "Liability-Based Benchmarks," Lehman Brothers, *Global Relative Value*, March 2001.

Figure 4. **Two Approaches to Constructing Liability-Based Benchmarks**

Liabilities	Portfolio benchmark	Composite benchmark
Static (Sinking Fund)	Cash flow matched based on a universe of bonds and/or interest rate swaps	Includes amortizing indices defined on the basis of the final maturity date of eligible securities
Dynamic (Open book)	Cash-matched based on a portfolio of constant maturity swap indices	Based on bond and/or swap indices Mirror swap indices allow inclusion of credit asset classes Swap indices allow precise cash flow matching as in a portfolio benchmark

The preferred approach depends on the nature of the liabilities and investor preferences. For example, liability cash flows can be either static or dynamic as new liabilities (e.g., life insurance policies) join the book. For static liabilities, one can select a portfolio of fixed maturity assets whose cash flows will match the liability flows. This can be done by assembling a portfolio benchmark with positions in individual bonds optimized to match closely the liability cash flows. If the liabilities remain unchanged and the portfolio does not experience any credit event, such a portfolio benchmark can effectively neutralize interest rate risk. A passive manager can buy that portfolio and then hold it to maturity, much like a sinking fund.

Static liabilities can also be approximated by a combination of "amortizing" bond indices with inclusion rules defined on the basis of the final maturity date of eligible index bonds. This second option for representing static liabilities does not neutralize risk as precisely as portfolio benchmarks, but offers the advantage of including new issues into the benchmark which provides a fairer representation of market liquidity.

For a dynamic liability portfolio, its risk profile will be better matched by a liability benchmark containing constant maturity assets, like constant maturity interest rate swaps.[13] Alternatively, one can use a blend of published bond indices to obtain the required duration and convexity, of the liability stream. Using a basket of published bond indices makes the liability benchmark a better representation of current investment opportunities and, therefore, may be more appropriate for active management mandates.

Depending on the sponsor's degree of risk aversion, the sponsor can also include spread assets in the liability benchmark to reflect the sponsor's investment preferences. The liability benchmark will still match the cash flows of the liability portfolio, but the benchmark will reflect the type of spread assets (e.g., corporate bonds) that the investment portfolio normally contains. However, the yield curve component of the liability benchmark does not have to be tied to the choice of spread assets.

For example, a 20-year liability in sterling can be represented by a liability benchmark containing a 20-year bellwether sterling swap index. However, if credit assets are acceptable for the investment portfolio, investors may want to consider selecting a liability benchmark containing 20-year investment-grade bonds. However, the credit sector has few bonds in this maturity sector and any liability benchmark containing the few available issues would exhibit high idiosyncratic risk.

[13] Constant maturity interest rate swaps can be represented by the Lehman bellwether swap indices. Please see *The Lehman Brothers Swap Indices*, Lehman Brothers, January 2002 for details.

To work around this situation, consider constructing the following composite benchmark. A diversified portfolio of credit assets can be added to the liability benchmark by taking the sterling ex-Gilt Aggregate Index and combining it with a short position in the corresponding "mirror" swap index.[14] This combination of indices essentially produces a index that has full spread duration exposure to the credit market but little term structure exposure. To match the term structure exposure of the 20-year liability, we then add the 20-year sterling swap index to the liability benchmark. This composite approach to liability benchmark construction allows a clear separation of interest rate and spread risks and enables the investor to adjust the benchmark composition to reflect a desired amount credit exposure.

Just as for domestic credit, international credit indices can be included in the liability benchmark as long as an overlay of swap indices ensures consistency with domestic liabilities. The liability benchmark can then include the following positions:

- Long the published foreign credit bond index;
- Short the foreign mirror swap index of that credit index;
- Long the domestic portfolio benchmark of individual swap indices that matches the liability cash flows; and
- Long a basis swap that converts foreign LIBOR into domestic LIBOR.

Various credit markets globally can be included in the benchmark universe to provide a diversified global credit exposure as well as a broad opportunity set for active strategies. Figure 5 provides example index allocations with respect to a 20-year sterling liability.

The Quantitative Portfolio Strategies group advises life insurers and pension plans on the selection and design of liability benchmarks. Active management with respect to such a benchmark is supported by the Lehman portfolio analytics toolkit and the Multi-Factor Risk Model.

Yield-Based Benchmarks

Traditional total return benchmark are not appropriate for every investor. Some investment managers operate under many more constraints than simply maximizing total return. For example, a manager may not be allowed to sell assets unless called upon to do so by the organization. For other managers, the performance of their portfolio may

[14] See the discussion of asset-swapped benchmarks above for information on mirror swap indices.

Figure 5. **Examples of Benchmarks for a 20-Year Sterling Liability**

Annualized returns and volatilities for hypothetical 20-year sterling liability benchmarks (Jul 2000-Nov 2003)	Return	Volatility	Tracking error with respect to 20-year sterling liability
20-year Bellwether Swap index	10.84	11.35	0.00
Non-Gilt Index - Mirror Index + 20-year Swap Index	11.12	12.02	2.47
US Corporate Index - US Mirror Swap Index + UK 20-year Swap Index	10.16	10.77	3.66
70% Non-Gilt and 30% US Corp Spread Return + UK 20-year Swap Index	10.83	11.52	2.26

be measured using book-value accounting, not market-value based total return. Consequently, for these managers, a total return benchmark is not relevant. In fact, a manager may outperform a benchmark on a total return basis but underperform on a book-value basis. As a result, some managers have asked us to design benchmarks custom tailored to their investment management objectives and constraints.

The goal of "buy-and-hold" investors is to add assets to the portfolio that have a high yield, but also meet a set of stringent credit criteria. The yield on the established Lehman indices may not be a reliable guide as to the yields available to the manager in the marketplace. The yield on the Lehman indices reflects the average yield of all bonds in the index including bonds issued long ago; bonds that are off limits to the manager (for credit or competitive reasons); bonds, which, if purchased, would violate internal issuer caps; or bonds that were issued in such small amounts that they are effectively unavailable to the manager.

How can an organization evaluate the performance of manager who must operate under such constraints? Ideally, a yield benchmark should be constructed to reflect the average yield available to the managers in the marketplace subject to the managers' constraints ("purchasable yield"). Fortunately, given the great improvement in index technology, such "non-standard" benchmarks are now possible and are one of the fastest growing set of custom benchmarks for clients. For example, we can now construct custom daily yield indices for clients that reflects their assessments of assets available for purchase (e.g., issue date within the past two years), issuer constraints (e.g., not allowed to buy more than q% of issuer XYZ), quality constraints (e.g., not allowed to buy more than z% of Baa-rated bonds), sector constraints (e.g., not allowed to buy defense-sector bonds), and trading level constraints (e.g., not allowed to buy bonds whose yield is w% greater than other bonds in its peer group). Furthermore, these constraints can be adjusted dynamically. Managers are then evaluated according to whether they can add assets with yields that exceed the daily yield index.

The obvious advantage of these custom indices is that it allows an impartial evaluation of the portfolio manager's performance while fully incorporating the constraints imposed on the manager. However, there are two other important benefits. First, the custom index can be analyzed using Lehman's suite of index analytics. This means that the systematic risk factor exposures of the custom index can be identified and quantified. Often, many portfolio constraints are imposed without fully understanding their cost in terms of systematic risk factor exposures. As we learned with issuer-capped indices, imposing constraints on a portfolio can have unintended effects of exacerbating systematic risk exposures. The portfolio constraint can now be more properly evaluated in the context of its contribution to the systematic risk of the overall portfolio.

Second, the custom index can serve as a useful guide to the portfolio manager. Managers without a benchmark can often find themselves grazing repeatedly in the same pasture. An index, however, forces the manager to consider sampling all available grazing fields in the marketplace. For example, if REITS are eligible for the index yet the manager does not hold any, then the benchmark process forces the manager to ask himself, "Why not?" This is a helpful portfolio management exercise when searching for relative value and also keeps the manager's attention on the systematic risk exposures of his portfolio versus the custom benchmark.

Such custom "non-market" benchmarks that reflect specialized management objectives are an area that received considerable attention in 2003 and will continue to do so in the following year as more investors realize that such indices are now possible.

Global Aggregate Benchmarks: Continued Migration from Global Treasury Indices

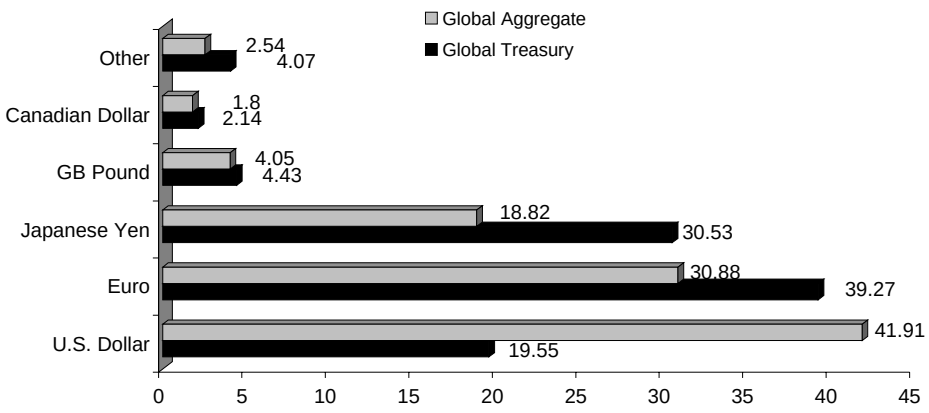
The migration of investors toward more inclusive global indices, such as the Lehman Global Aggregate and away from global government indices, gained momentum over the past two years. While a small minority of investors who desire government-only credit exposure in their portfolios may choose to retain Treasury benchmarks, we believe the vast majority, who has not already done so, will move to broader aggregates. A broader aggregate is more representative of the investible universe of fixed income securities. European Monetary Union encouraged the expansion of the European corporate markets, while at a stroke substantially reducing the opportunity for investors to add value through diversified cross-country and cross-currency trades.

Some investors are cautious about adopting broader mandates, concerned about the "dilution of skill" that they fear will arise as they invest in less familiar sectors of the Global Fixed Income markets. We believe, however, that this fear is unjustified for several reasons. Firstly, we have shown[15] that an optimal portfolio consists of a mix of diversified strategies with varying skill levels. Even if a manager is most skilled at a particular strategy, performance can be improved by allocating some of the risk budget to another strategy that offers significant diversification. Managers who nevertheless do not wish to take active risk in certain sectors can easily establish proxy portfolios to track those sectors. A study of proxy portfolios in the mortgage sector showed that a portfolio of twelve TBAs can track the index with low levels of tracking error.[16] In a global portfolio context, even this low level of tracking error is reduced, given its low correlation with other sources of portfolio risk.

Other investors believe that they can add value in non-government sectors, but that their greatest opportunity for doing so lies in opportunistic investment in a government bond-benchmarked

[15] "Value of Skill in Macro Strategies for Global Fixed Income Investing", Lehman Brothers, May 2003.
[16] "Tradable Proxy Portfolios for the Lehman Brothers MBS Index", Lehman Brothers, July 2001.

Figure 6. **Comparison of Global Aggregate and Global Treasury Index,** as of November 30, 2003



portfolio. As part of our work on manager skill, we also showed that while a core-plus strategy can be beneficial, it is much more beneficial in most cases to have those "plus sectors" in the benchmark. This is because a long-only constrained manager is unable to short the "plus sectors", which causes the manager to achieve a lower information ratio than in a long-short setting. A manager's information ratio, according to the "Fundamental Law of Active Management" defined by Grinold & Kahn,[17] is in part a function of the number of independent decisions taken each year (defined as "breadth"). A Global Aggregate index allows managers to exercise their skill with much more breadth than a global government index.

Some global investors have chosen the Global Aggregate to reduce the dependence of portfolio returns on one market, Japan, that represents 30.5% of the Global Treasury Index and only 18.8% of the Global Aggregate Index.

In recent years we have seen some U.S. domestic plan sponsors and managers choose hedged Global Aggregate benchmarks in preference not to global government benchmarks, but to U.S. aggregate benchmarks. This choice has generally been made for two reasons. Firstly, the Global Aggregate is a less volatile index, as U.S. interest rate and spread risk is diversified across global markets. Secondly, the duration of the Global Aggregate is longer (and therefore more attractive for pension funds and insurance companies) and more stable than the U.S. Aggregate (with its higher weighting in negatively convex MBS.)

The launch of the Lehman Brothers Global Risk Model should further accelerate the trend of investors moving toward broader benchmarks, as investors are now able to measure and manage risk in portfolios benchmarked against the Lehman Global Aggregate and its constituents.

[17] *Active Portfolio Management*, Richard C. Grinold and Ronald N. Kahn, McGraw-Hill, 1999.

Figure 7. **Sector Comparison of the Global Aggregate and U.S. Aggregate Index,** as of November 30, 2003

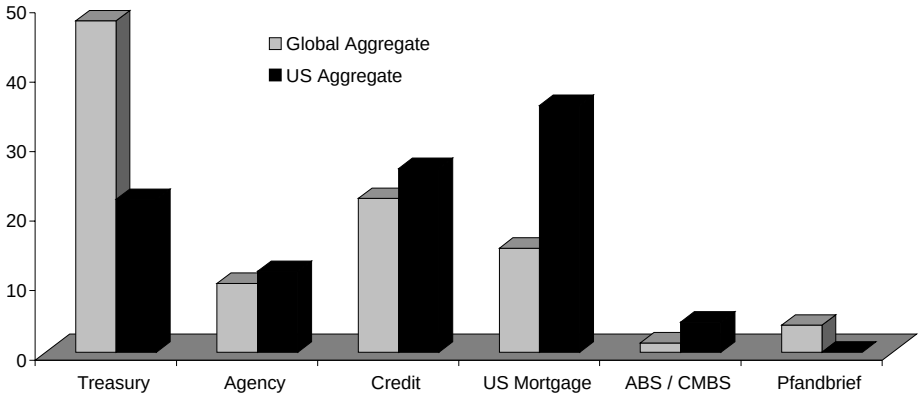


Figure 8. **Comparison of Global Aggregate to U.S. Aggregate Indices – Volatilities and Durations**

	Annual Standard Deviation of Return	Current Mod. Adj. Dur.	Minimum Mod. Adj. Dur.	Maximum Mod. Adj. Dur.
	1/90-11/03	1/03-11/03	1/03-11/03	1/03-11/03
US Aggregate	4.40%	4.50	3.77	4.70
Global Aggregate (hedged)	3.26%	5.01	4.63	5.09

II. RISK DIVERSIFICATION IN PORTFOLIO STRATEGIES AND RISK OPTIMIZATION

Diversification of Security-Specific Risk in Portfolios

In recent years, portfolio managers have adopted a more disciplined approach to diversifying portfolio risk. Regarding security-specific risk in a credit portfolio, managers have long known that event risk is higher in lower qualities. However, the optimal levels of diversification were not at all obvious. In addition, diversification cannot be pursued willy-nilly since thoughtless and uncontrolled diversification not only increases transaction costs but also increases the cost and dilutes the value of credit research. As many readers know, we have addressed this issue in recent years in our study of sufficient diversification in credit portfolios,[18] concentrating on the security-specific risk of downgrade in investment-grade portfolios. We developed a simple model of downgrade risk based on the observed historical underperformance of downgraded bonds and transition probabilities published by rating agencies. To minimize tracking error due to downgrade risk the model recommends uneven diversification in various credit ratings.

Sufficient Diversification in Credit Portfolios

In our 2003 update to our original study (to include 2002 experience), the recommended ratio of diversification levels was 10:3:1. In other words, the optimal position size in Baa-rated bonds was one-tenth the position size of Aaa/Aa-rated bonds, and one-third the position size of A-rated bonds. To arrive at more realistic position size ratios, we took in account the volatility of spreads not caused by rating transitions ("natural" volatility). Indeed, this type of volatility is significant in the high-quality segment of the market and tended to reduce the optimal diversification ratios. The recommended position size ratio including both natural volatility and downgrade volatility was found to be 5:3:1 in our 2003 update. While investors may not precisely follow these ratios, many have embraced the lessons of the study and follow a more disciplined diversification strategy in the lower credit qualities.

TRAINS®

Investors' demand for diversification of security-specific risk in their credit portfolios also generated a new type of credit instrument: a basket of liquid corporate bonds traded as *one security*. Lehman Brothers launched "targeted return index securities," or TRAINS®, in both the U.S. dollar and euro markets. The US$-TRAINS® contains about twenty-five corporate bonds having a minimum outstanding amount of $1 billion. TRAINS® are issued in several maturities, offering the possibility of combining several TRAINS® according to their index weights and reliably tracking the overall index with just a few transactions.[19]

Time Decay of Security-Specific Risk in the Multi-Factor Risk Model

In response to heightened security-specific event risk, investors have sought better quantitative credit analysis tools to measure portfolio risk. Many credit portfolios in 2001

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

[19] TRAINS® come in many flavors. Currently, there are five U.S. cash TRAINS®: 5-year, 10-year, and "long" maturities of the Lehman Credit Index; Baa TRAINS®; and a high-yield TRAINS® representing the B and higher rated component of the Lehman High Yield Index. There is also a Euro-TRAINS®, a 5-year bullet bond backed by a portfolio of fifty single name credit default swaps and an underlying Aaa-rated fixed coupon bond. The 50-name basket was assembled to approximate the spread performance of the Euro Corporate Index.

and 2002 experienced deviations from the benchmark that exceeded five times the standard deviation predicted by the Lehman multi-factor risk model. These deviations were driven almost entirely by security-specific events. The risk model's estimate of portfolio risk, based on the long-term historical volatility of residuals in the credit market, was an inadequate predictor in a marketplace with heightened issuer-specific risk.

In response to these events, the risk model was enhanced to include a user option to give recent observations more weight in the estimation of idiosyncratic risk. The weighting scheme is exponential time decay. This time decay option lets the risk model adjust to idiosyncratic shocks much faster. As a result, tracking errors predicted by the model for undiversified portfolios increased significantly. In the months following the change, the realized performance of most credit portfolios fell in line with predicted tracking errors.[20]

The introduction of time decay was part of the general overhaul of the Lehman multi-factor risk models that began in 2002.[21] Details on the new risk models, including the 2003 debut of the Global Risk Model and a high-yield credit risk model that includes a default risk module incorporating correlated movements in issuer asset values, are described later in this year-end review in greater detail.

Portfolio Strategies for Systematic Risk Diversification

Diversification of systematic risk can be achieved not only by switching to more diversified benchmarks, but also by using investment strategies that invest in asset classes outside the benchmark (so-called "core-plus" strategies). Below, we highlight several strategies that we have analyzed for clients.

TIPS as a Core-Plus Strategy [22]

Since their first issuance in February 1997, TIPS have steadily increased in importance in the marketplace. The market value of TIPS outstanding now equals 11.3% of the Treasury Index and 2.5% of the Aggregate Index. The total return performance of TIPS has also attracted attention. After the first 20 months of their existence, during which

[20] Users of the risk model should give careful consideration whether to use time decay. It is not necessarily always the best and "most conservative" option. Indeed, if a user had used time decay prior to the 1998 crisis, he would have severely underestimated his tracking error, as the experience of the 1990 recession would have been significantly underweighted. In general, one should not use time decay after a period of calm. When, at some point, the current high idiosyncratic volatility comes to an end, managers looking for conservative estimates of risk should switch back to the equal weighting scheme.

[21] "The New Lehman Brothers Credit Risk Model," May 14, 2002, *Quantitative Credit Research Quarterly,* 2002-Q2, Lehman Brothers.

[22] For details please refer to "TIPS in Total Return Portfolios," Lehman Brothers, Global Relative Value, July 2003.

Figure 9. **Annual and Cumulative Total Returns: TIPS vs. the Treasury and Aggregate Indices,** %

Year	Aggregate	Treasury	TIPS
1997	9.35	9.53	2.38
1998	8.69	10.03	3.95
1999	-0.82	-2.56	2.40
2000	11.63	13.52	13.17
2001	8.44	6.75	7.89
2002	10.26	11.79	16.57
2003 (to 11/03)	3.06	1.34	7.31
1/97- 11/03	62.12	61.22	66.44

TIPS substantially underperformed nominal bonds, TIPS have outperformed the Aggregate Index in all subsequent years (Figure 9). In 2002, the TIPS Index outperformed the Treasury Index by almost 5% in total return and the Aggregate by more than 6.4%. This outperformance continued into late 2003.

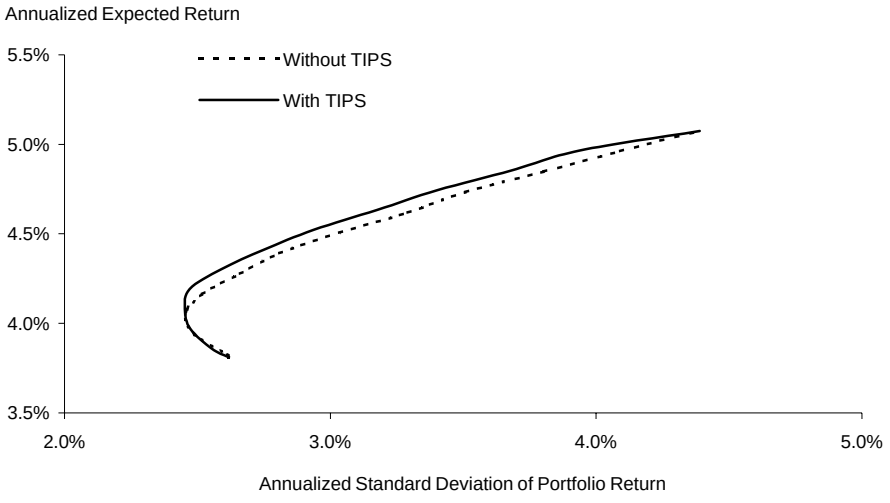
Following the strong performance of TIPS in recent years, do they still represent value for long-term investors? The relative value of holding same-maturity nominal versus inflation-linked securities until maturity is determined mostly by the magnitude of realized inflation versus the "breakeven rate" of inflation embedded in the relative values of the two bonds. If future realized inflation is in fact higher than the breakeven rate of inflation, TIPS will most likely outperform nominal bonds. The breakeven rate of inflation is the sum of three factors: expected future inflation, the risk premium, and the liquidity premium. Our own analysis suggests that the sum of the risk premium and liquidity premium has historically been a small negative, suggesting that for a given inflation rate, the investor is paid a small premium for owning TIPS compared with nominal Treasuries. This suggests that investors pay nothing for largely eliminating inflation uncertainty and, in fact, receive a premium for doing so.

How do TIPS compare with other asset classes? We conducted a mean-variance analysis of TIPS, together with other fixed-income asset classes: Treasuries, credit, MBS, and ABS. Figure 10 presents the correlations, volatilities, and expected returns used in the analysis. Figure 11 shows the resulting efficient frontier.

Figure 10. **Correlations, Volatilities, and Means of Expected Returns**

	Treasury	Credit	MBS	ABS	TIPS
Treasury	1				
Credit	0.803	1			
MBS	0.785	0.745	1		
ABS	0.898	0.813	0.888	1	
TIPS	0.714	0.643	0.486	0.645	1

Figure 11. **Efficient Frontier**



We find, therefore, that both from a traditional diversification analysis, as well as from a buy-and-hold perspective, TIPS represent a beneficial addition to any long-term core or core-plus fixed-income policy asset allocation.

Swaps as a Total Return Investment[23]

Fixed-for-floating swaps have been around for more than 20 years. Over that period, liquidity and market breadth of the swaps market have increased tremendously. While swaps have a distinguished history as a risk management tool, lately swaps (specifically, a combination of a receive-fixed swap and a cash investment in three-month LIBOR) have received attention as a total return investment.

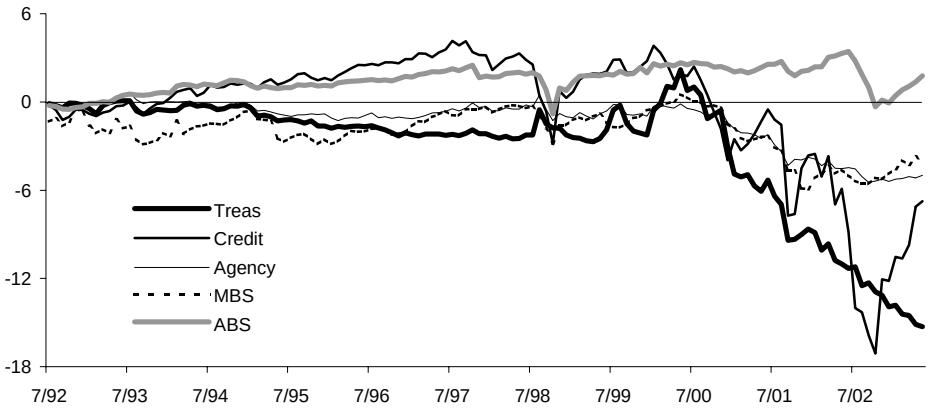
The rate paid on the fixed leg of a swap represents an average of forward LIBOR rates. Consequently, we can expect swaps rates to be subject to systemic risks similar to those that affect credit spreads. Changes in credit risk premium influence both swap and credit spreads. Expectations of significant changes in future Treasury supply, as well as "specialness" of individual Treasuries, are among the factors that affect the spreads over Treasuries of both swaps and other spread product. Given the close interaction of swap spreads with spreads on other assets, investors can track the returns on spread product more closely with swaps than with Treasuries. The Lehman Brothers Swap Indices, whose total return replicate a receive-fixed swap position and a cash investment in three-month LIBOR, provide market participants with a high quality source for swaps pricing, returns, and analytics.[24]

Figure 12 illustrates the cumulative excess returns of various components of the U.S. Aggregate over their respective swap mirror indices.[25] Swaps performed well on a relative return basis versus most cash instruments.

As shown in Figure 13, for July 1992-February 2003, 5-year swaps had a lower excess return correlation with the Aggregate Index than any of its five main components. The

[23] For details, please see "Swaps as a Total Return Investment," Lehman Brothers, Global Relative Value, April 2003.
[24] For details about the Lehman Brothers Swaps Indices, see *The Lehman Brothers Swap Indices*, Lehman Brothers, January 2002.
[25] These key-rate duration-matched swaps indices are known as mirror indices and are published as part of the Lehman Brothers Family of Indices.

Figure 12. **Cumulative Excess Returns over Swaps: Asset Class Components of U.S. Aggregate,** July 1992 - February 2003



low correlation between the excess returns of 5-year swaps and spread product implies that adding 5-year swaps to a diversified portfolio consisting of MBS, ABS, agencies, and credit can have risk-reducing benefits.

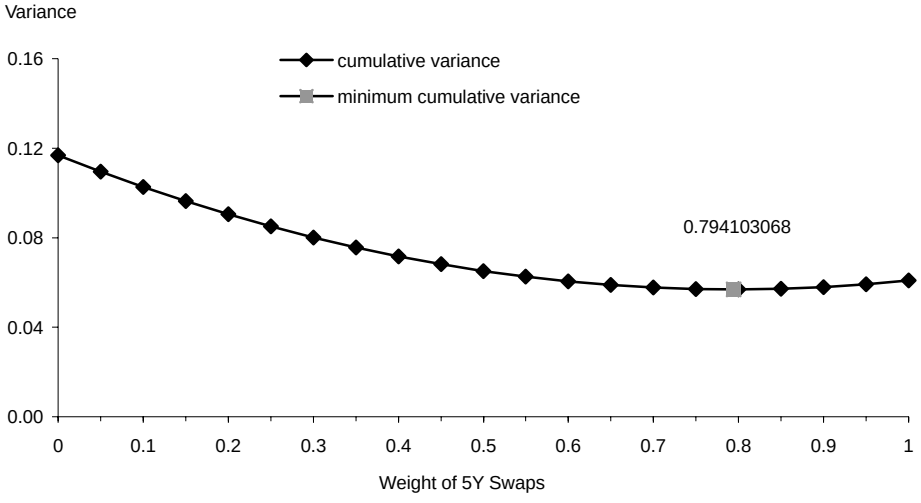
A simple way to test this claim is to construct a series of portfolios. Each portfolio in the series contains a specific percentage holding of the spread sector component of the Aggregate Index with the remaining percentage held in the 5-year swap index. We then search for the portfolio (and its percentage holding of swaps) that has the minimum excess return volatility. Figure 14 shows that for July 1992-February 2003, the optimal portfolio combination is 79.4% in swaps and 20.6% in the spread sector component of the Aggregate Index. This allocation achieves an excess return volatility of 23.9 bp/month. Clearly, this simple analysis is not meant to suggest allocating 79% of market share of swaps product to swaps. Rather, it is meant to show that swaps can play a valid part in fixed-income portfolios that are built with an eye on risk minimization.

The notion of swaps as a total return investment should be considered from both a tactical and a strategic asset allocation perspective. The outperformance that swaps exhibited over Treasuries, as well as over most other asset classes in the Lehman Aggregate Index, shows that even if they are not part of a benchmark, active managers should be given the option of investing in them. The outperformance on an excess return basis was accompanied by superior Sharpe and information ratios that confirmed swaps' performance on a risk-adjusted basis.

Figure 13. **Correlation Matrix: Excess Returns over Treasuries:**
July 1992 - February 2003

	Agg	Credit	Agency	MBS	ABS	5-Yr Swaps
Agg	1.00	0.89	0.59	0.74	0.63	0.51
Credit		1.00	0.42	0.37	0.59	0.40
Agency			1.00	0.49	0.54	0.73
MBS				1.00	0.41	0.35
ABS					1.00	0.42
5-Yr Swaps						1.00

Figure 14. **Variance of Excess Returns over Treasuries for Several Blends of 5-Year Swaps with the Aggregate Index ex-Treasuries**
July 1992 - February 2003



Swap spreads are held in line with the spreads on credit instruments largely via the arbitrage activity of important market participants. Yet certain factors, e.g. a steep yield curve that leads to substantial swapping activity by corporations, can cause significant dichotomy of swap and credit spreads. Although such factors diminish the value of swaps as hedging instruments, they improve the role of swaps as a means to diversify systematic risk in a total return portfolio.

Credit Default Swaps in Total Return Portfolios and the Lehman CDS Index

The past several years have witnessed rapid growth in the credit derivatives market, which now exceeds $2 trillion in size globally. The way in which default swaps are used and the types of market participants have changed significantly. Credit default swaps (CDS) have found a permanent place in the portfolios of asset managers and insurers, helping them either to hedge existing exposures or create new exposures that they could not otherwise create. A conventional corporate "cash" instrument bundles together interest rate risk, swap spread, and credit spread risk (and currency risk for a non-domestic security). CDS allow investors to separate these various exposures, to create exactly the desired portfolio of risk exposures. Some investors have begun to separate their credit view entirely from market views, with the help of CDS, and are structuring their credit teams accordingly. So, for example, Ford is analyzed by a single auto analyst, not by one analyst for Ford U.S. dollar issues and a different analyst for Ford euro issues.

Many investors had taken a cautious approach to the use of CDS in portfolios, awaiting a test of the new structures. In 2001 and 2002, we had many such tests, following the defaults of WorldCom and Enron among others. Accordingly, in 2003, and helped by improving credit trends, we have seen more investors begin to use CDS in their portfolios. Default swaps are now widely used in the following applications: [26]

- Hedging out the risk of default (the "classic use")
- Expressing a relative view between two credits (e.g., buy Company X bonds and receive protection on Company Y)
- Expressing a view between bonds and CDS of the same credit ("Default Swap basis")[27]
- Achieving, in some cases, more liquid exposure than available in the cash market
- Exotics, including first-to-default baskets and synthetic CDOs.[28]

Recognizing the need among total return investors for benchmarking and performance measurement tools consistent with those used to manage the rest of their credit portfolios, we have launched the Lehman Brothers Credit Default Swap Index. The Lehman Brothers CDS Index is designed to provide benchmarking, research, analytics, and trading capabilities for the wide range of market participants. Reflecting the market standards and the liquidity in traded CDS, our indices will be pegged to rolling 5-year maturity contracts.

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[26] For an introduction to Credit Default Swaps and their applications, see "Introduction to Default Swaps", Lehman Brothers European Fixed Income Research, January 2000

[27] For an explanation of factors that drive the Default Swap basis see "Explaining the Basis: Cash vs. Default Swaps", Lehman Structured Credit Research, May 2001

[28] Further details are in "The Lehman Brothers Guide to Exotic Credit Derivatives", Lehman Structured Credit Research, October 2003

Figure 15. **Comparison of the Lehman U.S. CDS Indices and U.S. Corporate Bond Index,** as at November 30, 2003

Characteristic	Corporate Index	CDS Mkt. Weight	CDS Equal Weight
Average credit quality	A3/Baa1	A3/Baa1	A3/Baa1
AAA	4.3%	6.5%	3.1%
AA	6.0%	6.8%	5.4%
A	43.6%	38.3%	37.2%
BBB	46.1%	48.5%	54.4%
# Issuers in index (by ticker)	607	250	250

Due to the decentralized nature of the CDS market, there is no clear way to measure the outstanding amount of CDS for a given issuer. Our indices are therefore published in two flavors, based on the same 250 issuers but with different weights. One method is to weight the issuers by their relative shares of market value in the Corporate Index, providing a link between our indices of the CDS and cash markets. The other is to assign equal weights to all issuers, reflecting the fact that CDS are often used specifically to obtain exposures to issuers with less liquidity in the cash market. Figure 15 compares the credit quality profiles of the two versions of the CDS index with that of the Corporate Index.

The Treasuries-to-Euros Trade as a Core-Plus Strategy

A popular, and rewarding trade (certainly for unhedged investors) in 2003, has been long Eurozone bonds versus U.S. bonds. This trade has been put on for a variety of reasons. For hedged investors, volatility of the Bund-Treasury spread has presented trading opportunities in this and other years. Unhedged investors have wished to express a view of Euro appreciation through a trade whose performance is dominated by the direction of the currency rather than relative bond market performance (as we shall see).

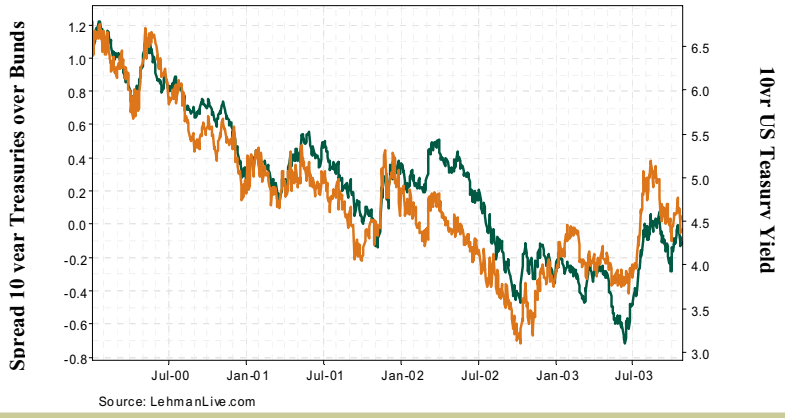
For U.S. managers putting on the trade opportunistically, or for Global managers establishing the trade strategically, the questions are the same: How risky is the trade and what is the correct hedge ratio? In a recent report,[29] we examined these questions using empirical data as well as data from our own Global Risk Model.

The most obvious way of executing the trade, for a hedged investor, is by dollar duration-matching, but that doesn't make it the right way. Duration is a measure of price sensitivity with respect to yield. The problem in this case, is that the duration of U.S. Treasuries measures the sensitivity with respect to U.S. yields, and the duration of Bunds, the sensitivity with respect to Bund yields. In our earlier piece we defined beta as a measure of the sensitivity of a change in Bund prices with respect to a change in U.S. yields.

The usefulness of beta as a measure can be seen in Figure 16, which demonstrates that, over the past four years, the movement of the Bund-Treasury spread has been highly correlated with absolute movements in U.S. Treasury yields. Over this period more than 60% of movements in the Bund-Treasury spread were explained by absolute movements in U.S. 10-year yields.

[29] "The Bund-Treasury Trade in Portfolios", Lehman Brothers, *Global Relative Value*, November 2003.

Figure 16. **Movements in the 10-Year Treasury-over-Bund Spread Relative to U.S. 10-Year**



Source: LehmanLive.com

Legend	Axis	03-Jan-00 to 27-Oct-03	Last	Minimum	Maximum	Mean	Std. Dev
	Right	U.S. 10-Year On-the-Run	4.263	3.103 13-Jun-03	6.788 21-Jan-00	4.936	0.849
	Left	Spread 10 yr Bunds to 10 yr U.S.T	-0.027	-0.718 09-Oct-02	1.222 03-Jan-00	0.180	0.439

Figure 17. **Proportion of the Volatility Due to Currency Exposure**

Weighting Scheme	FX Exposure	Volatility (bp/month)	% Volatility from currency
Duration	Hedged	160	0%
Beta	Hedged	109	0%
Duration	Un-hedged	335	69.5%
Beta	Un-hedged	289	83.6%

Historically, a manager who established a Bund-Treasury trade on a duration-weighted basis was essentially expressing a U.S. interest rate view. If U.S. yields declined, the U.S. yield spread to Bunds tended to narrow, while if U.S. yields rose, the yield spread widened. The chart suggests that the spread narrowed by around 5 bp for every 10 bp fall in U.S. yields (a beta of 0.5). Perhaps many times that managers have put on this trade, it has been out of a desire to express a view on U.S. yields alongside the direction of the spread. However, we believe that at least some managers would want to be able to establish the trade without having a view on U.S. bond yields. Beta-weighting the trade largely eliminates the effective U.S. interest-rate exposure, leaving the performance of the trade dependent upon the fundamentals (and technicals) of the Bund market. Alternatively, the trade could also be weighted in order that the risk of the position is equally dependent upon movements in Treasury and Bund yields.

Many times, managers will choose to express bond and currency trades separately. For example, they can use foreign exchange forwards to express a relative spread view on bond markets (by removing the currency component of the trade, leaving only the bond component), or short-term bonds or money-market securities to express a currency view. A manager who expresses both views together will be exposed to movements in the bond spread and to movements in the euro (and their co-movements). In Figure 17, using our risk model, we examine what proportion of the volatility of an unhedged 10 year Bund's return has been due to currency exposure. Compared to the hedged position, the

volatility is twice to nearly three times as great for an unhedged position, depending on the weighting method used. Overall, currency volatility comprises 70%-84% of the total position. The overall risk of the beta-weighted position is lower, given its lesser sensitivity to more volatile U.S. yields, and therefore the proportion of risk from currency volatility is proportionately greater.

It is not a trivial exercise to gauge the impact of a Bund-Treasury trade (particularly if it is unhedged) on portfolio risk. Exchange rate exposures are correlated with spread exposures, as well as with yield curve exposures. It is even harder for de-centralized Global Aggregate managers. For such managers, a view on the Bund-Treasury spread is likely to be expressed through a reallocation from the U.S. team to the European team. The trade then becomes a long position in the Euro-Aggregate and an effective short position in the U.S. Aggregate. How can this trade be correctly sized to take into account duration differences between the two regional indices? How do you allow for the correlations between the various sectors of the U.S. and Euro portions of the Global Aggregate? What is needed is a global risk model which can consider the effect of such a trade on total portfolio risk relative to benchmark, taking into account the correlations between all portfolio risk exposures. The Lehman Global Risk Model (discussed below) allows users to do just that.

Trends in Pension Portfolio Transitions

Numerous benchmark switches and additional core-plus strategies lead to increased importance of *Transition Management*: the sale and/or purchase of securities when a plan sponsor moves assets from the original manager, the so-called *legacy manager*, to a new manager, the *target manager*. Additional reasons for such movements include policy asset allocation shifts, manager underperformance, and consolidation of assets amongst fewer managers. Increasingly, however, benchmark changes are the main reason for the transitions.

Over the course of 2003 we have been involved in a number of transitions via an analysis of legacy portfolios pre-trade and input into the construction of target portfolios. Looking out into 2004, this experience allows us to reflect on the trends we see emerging from the plan sponsor space. We provide a summary of the most important trends as we perceive them for the year 2004, with the part of the plan sponsor space that is most affected by the topic listed in parenthesis.

1) TIPS (All funds): Increase allocation to TIPS out of Core-Plus Fixed Income for a) diversification reasons b) to fund COLA-dependent liabilities.
2) TIPS (Public Pensions): Increase in TIPS allocation to 5-10% of *total assets*. Take management of these funds in-house, on an indexed or enhanced-indexed basis. Benchmark to the Lehman TIPS Index, or a customized Long-TIPS-only benchmark.
3) Alternative Investments (All Funds): Increase allocation to alternative investments to at least 5-10% of total assets. In other words, the race to achieve outperformance is being taken to another level. Hedge funds of all stripes, LBO, venture capital, and vulture funds are at the front of the line. In terms of hedge fund investing, public funds are lagging, due to the more conservative structure of their investment policies. Again, most funds to finance these new investments come out of Core-Plus Fixed Income.

4) High Yield and Emerging Market Debt (All Funds): Increase allocation to high yield and emerging market debt to capture higher yields and expected returns, while at the same time improving diversification. Again, this will be mostly funded by a move out of Core-Plus Fixed Income.
5) Global Equities (All Funds): Increase exposure to global equities, where asset allocation studies by consultant show insufficient exposure to this asset class.
6) Movement to Longer-Duration Core Fixed Income Benchmark (All Funds): With corporate pensions leading the way, adoption of a Lehman Long Government/ Credit benchmark (average duration 15 years) can go a long way to aligning the duration of the fixed-income assets with the duration of the liabilities they are supposed to finance.
7) Derivatives (Private Funds): Benchmarks constituting of long-maturity swaps are being considered. Swaptions are sold, to get exposure to long-term swap rates at higher yields. Risky investments (equities, hedge funds), are hedged with puts or portfolio insurance.

Most of the shifts listed above are funded out of Core-Fixed-Income, with a shift towards increased risk of individual strategies but in a highly diversified mix of investments. How these investments, that carry increased amounts of credit risk, or are higher leverage, will perform in a protracted economic downturn, will probably be left unanswered for some time. Risk numbers for total portfolios, based on returns from "normal" periods might not provide the full picture. Nonetheless, the perceived need to increase returns in a diversified fashion, in a low expected return environment for the traditional asset classes—equities and core fixed income—will remain with us for the foreseeable future.

Portfolio Risk Optimization

The combination of more complex benchmarks and a broader palette of core-plus strategies increases the demand for risk optimization tools. Managers reflect many more views along multiple dimensions. Tools are needed to combine these views in an optimal way consistent with historical behavior or stress test the portfolio under historically extreme scenarios. We attempted to address this need in our risk budgeting methodology based on manager's skill. Optimal combinations of macro views of portfolio managers need to be implemented using securities with appropriate risk characteristics. The security selection is often a significant source of alpha. Security-level implementation of optimal macro allocations is the subject of the Lehman Multi-factor risk model. The risk model quantifies diversification risk.

Risk Budgeting for Macro Strategies with Limited Skill

Manager skill is a critical factor in determining portfolio performance. While this is apparent to everybody, the notion of skill is rarely used formally in any practical context, e.g. to allocate risk within a portfolio or to project the expected outperformance. Even more surprisingly, skill is almost never measured in any disciplined way. Yet, skill is the single most important factor in translating investment risk into investment return. In that, skill is similar to a machine's efficiency: the degree to which spent resources produce useful output.

In several recent studies, we made skill central in the historical simulation of various investment strategies whose merits we were trying to compare. In this so-called "imperfect foresight" approach, the working definition of skill was the difference between the

Figure 18. **Probability of the Right Choice as a Function of Skill Level**

	Two-Choice Strategy		Ten-Choice Strategy	
Skill Level	**Right**	**Wrong**	**Right**	**Wrong**
0%	50.0%	50.0%	10.0%	10.0%
5%	52.5%	47.5%	10.5%	9.5%
10%	55.0%	45.0%	11.0%	9.0%
15%	57.5%	42.5%	11.5%	8.5%
20%	60.0%	40.0%	12.0%	8.0%
40%	70.0%	30.0%	14.0%	6.0%
60%	80.0%	20.0%	16.0%	4.0%
80%	90.0%	10.0%	18.0%	2.0%
100%	100.0%	0.0%	20.0%	0.0%

likelihood of making the right and the wrong decisions. For example, in a situation of binary choice, a person without any skill (0% skill level) would be equally likely to make each of the two selections (50% probability). Skill of 10% would mean making the right choice 55% of the time and the wrong choice 45% of the time. A manager with "perfect foresight" (100% skill level) would of course make the right choice with 100% probability. This definition allows for convenient modeling of any desired skill level by simple linear interpolation between the two extremes. In strategies in which there are more than two options, the probabilities will have to be scaled appropriately. Figure 18 illustrates this approach for a binary choice strategy and for a multiple choice strategy that requires the selection of one out of ten available decisions. Every possible decision is categorized as right or wrong based on the ultimate outcome; we assume here a certain symmetry (e.g., long or short a particular trade) that ensures that half of the possible strategies are winning strategies and half will be losers. This definition also facilitates measurement of the actual (realized) skill in making investment decisions. The skill is simply the difference between the probability of the correct decisions and wrong ones over a particular period.

In the most recent study utilizing the imperfect foresight approach,[30] we compared the historical performance of a diverse set of macro strategies ranging from global and single-market duration timing to currency overlays to core spread assets to such core-plus investments as emerging markets and high yield. Every month over the study period we modeled each strategy using our hindsight knowledge of what decisions would have been right then. The set of positions each strategy took was simulated based on the assumed level of skill. At the end of each month, performance of all strategies was measured. The resulting time series of returns allowed us to compute and compare the information ratios (risk-adjusted benchmark outperformance) for this very heterogeneous set of strategies.

This and similar studies produced a number of interesting insights. Figure 19 shows the historical performance summary for two sets of strategies, core and core-plus. The essential difference between them is that a core strategy can go both long and short an asset (short meaning underweight vs. the benchmark). Core-plus strategies can either buy an asset (go long) or do nothing. This obviously limits the extent to which a manager's skill may be utilized, because there is no way to act on (correct) predictions of an asset's underperformance. The effect is very much visible in the presented results. The core-plus information ratios are roughly half of those for the core strategies.

[30] *Value of Skill in Macro Strategies for Global Fixed Income Investing*, Lehman Brothers, June 2003.

While the disadvantage of long-only strategies was to be expected, this and other foresight studies revealed another interesting fact. As Figure 19 shows clearly, the information ratios of completely unrelated strategies are very similar for a given skill level. Apparently, the particular nature of an investment strategy plays a minor role. Performance is essentially determined by the skill and dimensionality (number of independent decisions) of a strategy. Though this may seem counterintuitive, our empirical results confirm the idea proposed by Grinold and Kahn[2] as the "fundamental law of active management."

Instead of "skill", Grinold and Kahn used a slightly different notion of "information coefficient" (*IC*) based on the correlation between predictions and realizations. It can be shown however, that our probability-based definition of skill is closely related to the *IC*. The risk-adjusted benchmark outperformance, or information ratio (*IR*), was shown to be:

$$IR = IC \cdot \sqrt{BR}$$

where *BR* stands for the strategy's "breadth" or the number of independent decisions.

[31] *Active Portfolio Management*, Richard C. Grinold and Ronald N. Kahn, McGraw-Hill, 1999.

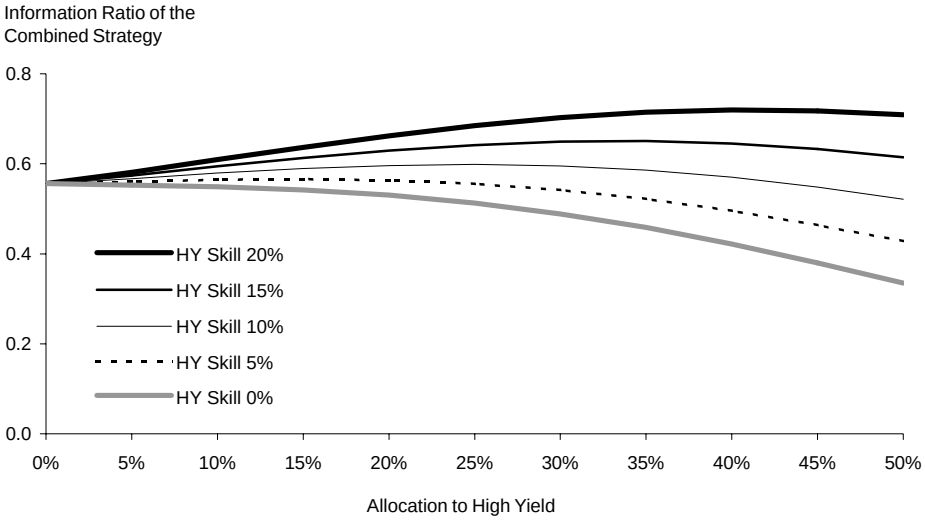
Figure 19. **Performance of Core (Long/Short) and Core-Plus (Long Only) Strategies**

Core Strategies	Global Duration Jan 1990 - Dec 2002			Market Duration Jan 1990 - Dec 2002			FX Overlay in G3 Currencies Jan 1990 - Dec 2002		
Skill Levels	Mean Outperform (bp/yr)	Volatility (bp/yr)	Information Ratio	Mean Outperform (bp/yr)	Volatility (bp/yr)	Information Ratio	Mean Outperform (bp/yr)	Volatility (bp/yr)	Information Ratio
0%	0.0	44.9	0.00	0.0	44.7	0.00	0.0	52.5	0.00
5%	6.2	44.8	0.14	6.0	44.7	0.13	6.8	52.5	0.13
10%	12.3	44.7	0.28	12.0	44.6	0.27	13.6	52.3	0.26
15%	18.5	44.6	0.41	18.0	44.4	0.41	20.4	52.2	0.39
20%	24.6	44.3	0.56	24.0	44.2	0.54	27.2	51.9	0.52
40%	49.3	42.6	1.16	48.0	42.5	1.13	54.4	50.1	1.09
60%	73.9	39.5	1.87	72.0	39.6	1.82	81.6	46.9	1.74
80%	98.5	34.8	2.83	96.0	35.1	2.73	108.9	42.1	2.59
100%	123.2	27.5	4.48	120.0	28.3	4.23	136.1	34.9	3.90

Core Strategies*	U.S. Credit Aug 1988 - Dec 2002			Emerging Markets Jan 1993 - Dec 2002			U.S. High Yield Aug 1988 - Dec 2002		
Skill Levels	Mean Outperform (bp/yr)	Volatility (bp/yr)	Information Ratio	Mean Outperform (bp/yr)	Volatility (bp/yr)	Information Ratio	Mean Outperform (bp/yr)	Volatility (bp/yr)	Information Ratio
0%	0.0	7.0	0.00	0.0	53.4	0.00	0.0	25.4	0.00
5%	0.5	7.0	0.08	4.7	53.1	0.09	2.2	25.4	0.09
10%	1.0	6.9	0.15	9.5	52.8	0.18	4.4	25.3	0.17
15%	1.6	6.9	0.23	14.2	52.4	0.27	6.6	25.2	0.26
20%	2.1	6.9	0.31	18.9	51.9	0.36	8.7	25.1	0.35
40%	4.2	6.7	0.63	37.9	49.7	0.76	17.5	24.5	0.71
60%	6.3	6.4	0.98	56.8	46.8	1.21	26.2	23.7	1.11
80%	8.4	6.1	1.38	75.7	43.1	1.76	35.0	22.5	1.55
100%	10.5	5.7	1.84	94.7	38.2	2.48	43.7	20.9	2.09

* De-meaned results

Figure 20. **Performance of Core (Long/Short) and Core-Plus (Long Only) Strategies**



Another insight that the study provided pertains to strategy diversification. What we demonstrated in our study, however, was that even strategies with relatively low potential (e.g., because of inferior skill levels and/or limitations on short positions) have their place in the investment mix. Figure 20 shows plots of information ratio for a combination strategy vs. the Lehman Global Aggregate index. The strategy reflects a global duration view at the 20% skill level, and a high yield view at a range of skills from 0% to 20%. One has to bear in mind that the high yield strategy is core-plus in this context and so inherently inferior to the global duration strategy. Yet as Figure 20 shows, even with the high yield skill levels below 20%, the combination strategy outperforms the pure global duration (information ratio of 0.56). For example, at the 20% skill level in high yield, a combination strategy with 40% allocation to high yield produces the information ratio of 0.72.

Realizing the merits of combining strategies with different skill levels led us to develop a framework for the optimal allocation of total risk budget among investment strategies. If we rewrite the above formula for information ratio as

$$IR = \frac{\alpha}{TE} \Rightarrow \alpha = TE \cdot SKILL \cdot \sqrt{BREADTH}$$

we see that a strategy's alpha (outperformance) is proportional to the tracking error allocated to the strategy, to the skill level, and to the square root of strategy breadth. Using this relationship to estimate alpha, we can find the allocation of total tracking error among the different strategies such that alpha is maximized. Once each strategy is assigned an isolated tracking error, we can determine the size of active position that produces this tracking error. An important difference between this approach and traditional asset allocation is that expected returns are based only on skill and allocated risk. We feel that this is preferable to such alternatives as historical returns or direct return forecasts. It is well accepted that historical returns are poor predictors of future returns. Projecting alpha based on subjective views, presents its own set of problems. Managers usually have directional views on particular assets, but no reliable way of determining the magnitude of the expected movements. Explicit forecasts of basis point moves in yields

and spreads are notoriously difficult to generate with any accuracy. For example, a manager is much more likely to be right in predicting credit spread tightening than in predicting by how many basis points spreads will tighten. In multi-asset portfolios managed by a team of specialists, deciding on the magnitude of single-asset exposure is even more problematic. Clearly, most strategies and asset classes are correlated to some extent, and optimal positions in multiple assets can only be determined at the overall portfolio level. Our skill-based framework allows managers to express directional views only, without forcing them to specify these views in basis points of projected movement in market parameters.

At the core of the risk budgeting framework is a covariance matrix of returns for all asset classes underlying all considered strategies. A combination of the active positions created by all participating strategies creates the portfolio's vector of exposures against the benchmark. Multiplying this vector by the covariance matrix, we can compute the overall portfolio tracking error (and constrain it to be within the stated limit, or risk budget).

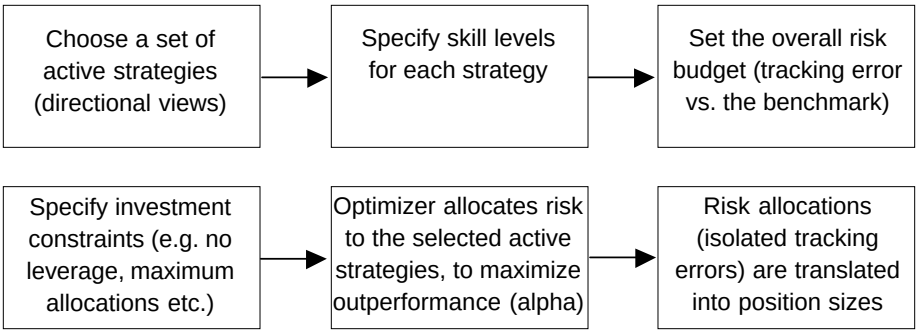
This framework is extremely flexible and is easily customized for different sets of strategies as well as different investment constraints. The optimal allocation of risk is a function of skill assigned to specific strategies, correlations between them and optimization constraints. For example, in the cash-only portfolios (no leverage), short positions in core assets are limited by their weights in the benchmark, and short positions in core-plus assets are not achievable at all. Similarly, long positions may be limited by the available funding, e.g. Treasuries or cash. Obviously, the use of derivative instruments greatly expands the menu of strategy combinations at the manager's disposal. Use of Treasury futures, for instance, allows curve-neutral duration extension. On the other hand, in a cash-only portfolio, duration extension can be done only by reallocating assets along the curve (selling shorter bonds and buying longer ones). Such reallocation creates an

Figure 21. **Examples of Macro Strategies in a Risk Budgeting Framework**

Active Strategies	**Example Positions**	**Example Implementation**	**Relevant Factors in Cov. Matrix**
Duration	Curve-neutral short and long; Cash-neutral reallocation along the yield curve	Treasury futures; selling or buying Treasury bonds against cash	Total returns of Treasury maturity buckets over cash
Yield curve twists	Duration-neutral reallocation along the yield curve	Treasury futures; selling or buying Treasury bonds against cash	Total returns of Treasury maturity buckets over cash
Core spread assets	Overweight or underweight vs. the benchmark	Buying or selling the spread assets vs. Treasuries	Excess returns of the spread assets over curve-neutral Treasuries
Swap spreads exposure	Receive or pay fixed on the interest rate swaps	Entering a swap and hedging the interest rate exposure by buying or selling Treasuries	Excess returns of swaps vs. curve-neutral Treasuries
Asset spreads over swaps	Going long (short) a particular asset class and short (long) swaps spread	Buying or selling assets vs. cash, and entering into curve-hedged swaps	Excess returns of assets vs. curve-neutral swaps
Core-plus assets	Going long out-of-the-benchmark assets	Buying core-plus assets for cash or by selling Treasuries	Excess returns of core-plus assets vs. curve-neutral Treasuries or cash
Foreign-exchange exposure	Going long one currency vs. another	Currency forwards or futures	Currency returns in excess of base currency cash returns

Optimization Output
Active positions ("bet sizes") in all asset classes underlying the macro strategies chosen by the portfolio manager

Figure 22. **Examples of Macro Strategies in a Risk Budgeting Framework**



unintended curve bet as well. Figure 21 shows a sample of active strategies handled in several real-life applications of our risk budgeting framework. For each strategy, the figure shows how the pertinent exposures are created, and how their risk is represented in the covariance matrix.

Figure 22 summarizes the risk budgeting process in a diagram. We have implemented Excel-based risk budgeting tools for several active managers in the U.S. and overseas, and all these implementations follow the same algorithm. The portfolio manager specifies the overall risk budget, sets up the desired directional exposures from a menu of strategies (e.g., short duration, long high yield, etc.), and provides the assumed skill levels for each of them. The optimizer then determines alpha-maximizing *isolated* tracking errors for each strategy and computes the corresponding position sizes. The overall tracking error is computed for the whole portfolio and constrained to stay within the specified risk budget.

Multi-Factor Risk Model for Domestic and Global Investors

While risk-budgeting applications help optimize risk at the level of macro decisions in a portfolio, a more detailed risk model is required to measure risk at the security level. As many managers learned in 2001 and 2002, security or issuer-specific risk can be a significant source of alpha (and not necessarily positive alpha). Prior to 2001, many investors were comfortable with perhaps 2-2 ½% positions for A and Aa-rated credit, with perhaps 1-1½% positions in Baas. We have previously examined the appropriate ratio between the various credit rating categories.[32]

While some investors may desire to limit security-specific risk, other groups of investors possess superior skill in security or issue selection, and seek to add most of their alpha by taking specific risk. These investors will typically wish to limit their exposure to market, or systematic risk. A risk model is the only way in which investors can measure both systematic and idiosyncratic risks.

Lehman Brothers has, for more than a decade, provided risk modeling tools allowing investors to measure and manage its risk against U.S. and more recently euro indices.

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

With the release of the Global Risk Model, we add comprehensive risk models for the sterling and Japanese yen bond markets. The need for a Global Risk Model has become clear as markets (and investment management mandates) have become increasingly globalized. Additionally, domestic managers are often looking to add value through opportunistic allocations to non-domestic bond markets.

Global and domestic portfolio managers may have exposures to international yield curve movements, currency risk, swap spread risk, sector risk, industry risk, credit risk, prepayment risk, volatility risk, basis risk through futures, and security specific risk. With the Lehman Global Risk Model, managers are able to compute total portfolio risk against their chosen benchmark, and disaggregate that risk. Investors can compute how much of that risk is coming from market factors (systematic risk) and security-specific risk factors (idiosyncratic risk). Managers can also understand how each individual exposure or group of exposures contributes to total portfolio risk.

Exposures to different risk factors are expressed in different units. For example, interest rate risk is measured using (key-rate) duration, currency risk by percentage of market value, and credit/industry/sector risk by spread duration. Additional metrics are needed for volatility risk and prepayment risk. How can risk factors expressed in different units be combined to obtain an overall measure of portfolio risk? Even where risk exposures are measured in the same units, large differences in volatilities can render such comparisons less than meaningful. For example, a 1% overweight in U.S. agencies versus U.S. Treasuries is many times less risky than 1% overweight 10 year Bunds (unhedged) versus U.S. Treasuries.

The Global Risk Model addresses this issue by measuring all risks in terms of a single metric. Tracking Error Volatility (TEV) measures risk in common units across different kinds of exposures, and reflects differences in volatility between exposures and their correlations. TEV is defined as the standard deviation of the difference between portfolio and benchmark returns. In the latest release of Lehman POINT (Portfolio and Index Tool), portfolio managers are able to measure total portfolio TEV, and to disaggregate it, to understand precisely which exposures are contributing to TEV, from global exposures down to issue-specific exposures.

Risk Model Applications

Risk budgeting, as described above, enables managers to decide how they would like to allocate risk across different kinds of portfolio exposures, while capping the overall level of portfolio risk.[33] The Global Risk Model can help managers implement the desired macro exposures. It measures the precise exposures of a portfolio relative to its benchmark, and isolates the amount of risk taken in each of various dimensions (e.g.. currency, sector, credit). Taking into account the degree to which those exposures are correlated, it can then show how much each dimension contributes to total portfolio risk.

As an indexation tool, a risk model is indispensable. A common approach to indexation divides the index into buckets (stratified sampling). However, this approach does not allow for differences in the relative importance of each bucket, and assumes that any bond is as

[33] For a full discussion of a risk budgeting approach to Fixed Income investing, see *Value of Skill in Macro Strategies for Global Fixed Income Investing*, Lehman Brothers, May 2003.

representative of its bucket as any other bond, potentially leading to unintended risk exposures. The risk model approach quantifies the risks contributed by mismatches at the cell level, taking account of the correlations between securities, and their idiosyncratic risk.

Many global managers have a competitive advantage in a particular sector or region, compared to other sectors. These managers may desire to limit Tracking Error Volatility in certain sectors, while taking the bulk of their TEV elsewhere. A variety of managers have taken this approach, building proxy portfolios to track a portion of the Global Aggregate. This approach has been particularly successful in the U.S. MBS market, one sector of the Global Aggregate which many non-U.S. managers have found particularly challenging to outperform.[34]

We often hear that many managers "intuitively know" how much risk they are taking in their portfolios and that risk models are not a necessary tool. Our contention (unsurprisingly) would be that even managers with excellent intuition will find such models valuable for two reasons. Firstly, intuition is often colored by recent experience, leading managers to under-estimate risk following a period of low volatility (as some credit managers did in 2001-2002). Our Risk Model utilizes many years of data, but allows managers to specify whether to give more weight to recent data (using exponential weighting), or use equally weighted data. Secondly, the quantity of idiosyncratic risk in a portfolio is not something that can be approximated with intuition. We know that Ford has higher idiosyncratic risk than GE, but how much more? How much idiosyncratic risk is there in a portfolio with 30 credits, compared to 50 or 100 credits? These are questions that can only be answered by a risk model that is based on proven financial theory and estimated using long, high-quality time series data for individual bonds. Finally, risk models can ensure that the only risk taken in portfolios is that which is desired, rather than un-intended.

The Scope of the Global Risk Model

The Global Risk Model attributes ex-ante risk to the key decisions taken by portfolio managers. This includes currency allocation, interest rate management (disaggregated by currency, if applicable), swap spreads, interest rate volatility, sector allocation, intra-sector risk (e.g., rating/industry for credit), issuer and security selection. Every country, currency and sector in the Global Aggregate Index is covered by the Global Risk Model. Additionally, U.S. high yield, interest-rate swaps, cross-currency swaps, caps and floors, and selected bond futures are also covered.

The U.S., euro, sterling and Japanese markets each have currency, curve, volatility (not Japan), swap spread and investment grade spread factors. These four regional models accordingly have the same degree of "granularity" as the existing U.S. and euro risk models. Other markets are modeled via currency, curve and swap spread risk factors. Portfolio managers that manage core or "core-plus" mandates in any part of the World can now use the risk model to measure risk in single country portfolios or in portfolios benchmarked to domestic indices, with allocations to non-base currency bond markets.[35]

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[34] See "Tradable Proxy Portfolios for the Lehman Brothers MBS Index", Lehman Brothers, July 2001. We have also explored the replication of the Global Aggregate in "Replication with Derivatives", Global Relative Value, March 2001, and "Replication of the Global Aggregate with Cash Instruments", Global Relative Value, August 2001

[35] For more details of the Global Risk Model and its applications, see "Introducing the Lehman Brothers Global Risk Model", December 2003 and "A Portfolio Manager's Guide to Risk Management", forthcoming.

History-Based Scenario Definitions

Investors often make explicit forecasts on specific, observable market dimensions: a benchmark interest rate or swap spread, credit spread for an entire market sector, or a particular exchange rate for example. Rarely however is a fund manager able to formulate a scenario consistently, in terms of both direction and magnitude, across many different market sectors.

Our scenario model builds on our multi-factor risk model, where systematic risk factors are inter-related through a covariance matrix. Covariances are typically estimated from historical observations with or without a time-weighting scheme that attach more importance to recent observations. Maximum likelihood analysis allows investors to make an explicit forecast on only one or a few arbitrarily selected factors and then infer consistent realizations for all other factors. Expected factor realizations, typically expressed in terms of basis point yield or spread changes, and sensitivities available at the individual bond level ultimately translate into expected returns for individual securities.

It may happen that one or more explicit forecasts represent unlikely scenarios. For example, anticipating a 50 bp yield change on a one-month horizon when historical yield volatility is only 25 bp/month is, assuming a normal distribution, a 2% probability event. Similarly, it may be somewhat inconsistent according to historical covariances to anticipate a spread widening at the same time as an increase in yield, when yield and spread changes are typically negatively correlated. Our scenario model provides an assessment of the likelihood of an explicit forecast in the light of the covariances that underlie the analysis, and allows a rescaling of forecasts to meet pre-specified likelihood targets.

Figure 23 provides a simplified example of explicit interest rate scenario in the U.S. market, and associated implicit realizations across the entire yield curve and selected spread sectors.

The model also allows the input of relative as well as absolute views. For example, an investor may forecast that the 2-10 year yield curve slope will tighten by 5 bp, without any explicit views on the overall direction of interest rates. It is also possible to include varying degrees of confidence in individual forecast. For example, views on credit spreads may be moderate but expressed with high confidence, while currency and interest rate views may be expressed with a lower confidence.

Figure 23. **Scenario Projections in bp Yield or Spread Changes on a One-Year Horizon**

	Explicit Forecast	Implied Realization	Implied realization rescaled to achieved a one standard deviation likelihood
Tsy 6m par yield		57.2	47.1
Tsy 2y par yield		97.6	80.7
Tsy 5y par yield		107.4	88.9
Tsy 10y par yield	100	100.0	82.7
Tsy 20y par yield		84.8	70.1
Tsy 30y par yield		81.5	67.3
Banking AA spread		0.3	-0.3
Banking A spread		3.8	2.3
Banking BBB spread	20	20.0	14.3
Likelihood (in StdDev)		1.1	1.0

By performing scenario analysis on the risk systematic factors that underlie our risk model, we leverage on the risk model analysis and its robust covariance matrix estimation methodology. We also base our analysis on observable and intuitive risk factors that directly explain the return of almost any investment-grade security globally.

Portfolio Risk Optimization for Buy-and-Hold Investors

Just like their marked-to-market counterparts, buy-and-hold investors consider risk/return tradeoffs at both the top-down and bottom-up levels. However, the key measures of risk and return are expressed in different terms. Instead of optimizing an expected short-term return against a return volatility, long-term investors trade off yield to maturity against the risk of default losses. This difference of perspective means that the short-term views of total return investors may create superior long-term investment opportunities for buy-and-hold investors. In addition, this trade-off of yield vs. default risk will be the key issue when facing questions of asset allocation as well as when analyzing a portfolio in terms of exposures to individual issuers. In both cases, assumptions about the correlations between events at different issuers can have a profound impact on the assessment of overall portfolio credit risk.

A typical example of a buy-and-hold setting may be found in the insurance industry. Some insurance products have investment characteristics very much like fixed income liabilities issued by the company. The funds paid in as premiums are invested in credit portfolios, whose goal is to earn greater long-term returns than the company is paying out on their liabilities. For a Aa-rated insurer, this would typically mean investing in a blend of A and Baa-rated bonds. The higher spreads in these qualities should allow the asset portfolio to outperform the liabilities on average; but if default losses are extreme, the portfolio could easily underperform the liabilities. The biggest single question confronting the manager of such a portfolio is often, "How much of my portfolio should be in BBB's?"

We address this type of question using a macro-level model of credit asset classes, with a small set of assumptions about the spread, expected default rate, and correlations that typify the issuers within a given asset class.[36] This offers an easy way to visualize the effect of macro decisions such as the percentage of the portfolio to be placed in a given sector, or the number of bonds to be used to fill a certain macro allocation. We can also see how the optimal asset class composition reacts to changes in these assumptions or to the specification of the risk limit (VAR or expected shortfall at a given confidence level).

While this analysis can be very useful for top-level decisions, it does not help in measuring the credit risk of a specific portfolio of issuers. Lehman's COMPASS tool (described below) applies similar models at a much more detailed level to optimize the issuer-level composition of the portfolio.

Optimal Credit Allocation for Buy-and-Hold Investors

In a series of articles throughout the past year,[37] we have analyzed the risk of default in a credit portfolio according to a small set of assumptions about the spread, expected default

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[36] This analysis, summarized here, will be described more fully in a forthcoming publication, "Optimal Credit Allocation for Buy-and-Hold Investors", January 2004.

[37] Please see "A Case for Credit Investing in Buy-and-Hold Portfolios," Lehman Brothers, Global Relative Value, December 2002, and "Credit Investing in Buy-and-Hold Portfolios, Part II: The Effect of Correlations," Lehman Brothers, Global Relative Value, January 2003.

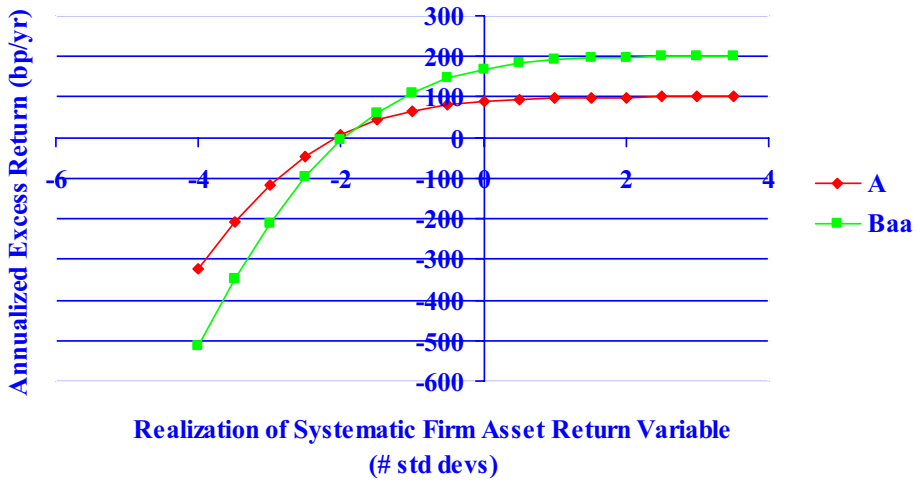
rate, and correlations that typify the issuers within a given asset class. We use a simple approximation for the long-term return of a credit portfolio in which a bond either survives to maturity, earning its yield over the holding period, or defaults and earns nothing but a recovery value. We analyzed the tail of the portfolio's return profile under different assumptions about the distribution of the number of defaults. We tried two different methods for estimating the worst case realized portfolio default rates, at a given confidence level, for a given number of bonds of a given quality. In the first, we used a binomial model for the number of defaults (no correlations), but assumed a very pessimistic value for the expected default probability, setting it equal to that of Moody's worst observed annual cohort over the last 30 years (e.g., nearly 10% probability of default over a 10-year horizon for Baa bonds). In the second, we set the expected default probability equal to the Moody's historical average (about 5% for Baa), but assumed an issuer asset correlation of 20%. We found that at a 95% confidence level, the two approaches produced very similar results, but that at 99% confidence some fundamental differences emerge. The model that incorporates correlations shows that diversification among different issuers is not as effective as we might have thought at reducing the risk of very large losses in the tails.

The model used to represent the correlation of issuer defaults builds on the work of Merton and Vasicek. If the asset returns of a given issuer over the holding period are sufficiently negative, that issuer will default. The asset returns of each issuer, in turn, are all assumed to be correlated with a single market return variable. If this market return variable is very negative, it will increase the probability of default for every issuer simultaneously. This common dependence on a single factor generates a systematic component to default risk that cannot be captured by a simple binomial model analysis. In Figure 24, we plot the expected excess returns over Treasuries of diversified portfolios of A and Baa bonds as a function of the outcome of this (normalized) market return variable. Based on historical data, we have assumed expected 10-year cumulative default probabilities of 2% for A and 5% for Baa, with correlations of 20% for both. The figure assumes a 10-year Treasury yield of 4%, and spreads of 100 bp for A and 200 bp for Baa. Recovery rates of 20% are assumed for both credit qualities.

When the market returns are positive, defaults are minimal for both of these investment-grade asset classes, and excess returns over Treasuries essentially converge to the limit of simply earning the spread. When market returns are negative, default rates increase for both asset classes, and in extreme cases can lead to severe underperformance. We see that for both credit qualities, a diversified credit portfolio will underperform Treasuries when the systematic variable takes a value of about –2.0 standard deviations or worse, which we expect to happen with a probability of about 2%. The crossover point between the performance curves of the two qualities occurs at a slightly higher level, between -1.5 and -2.0 standard deviations. In these times of credit distress, Baa investments will underperform their single-A counterparts; at all other times, they will outperform. Yet it is not at all clear how to choose which of these return distributions is better – this will depend on a particular investor's goals and risk appetite.

Once we have plotted the complete return distributions, as illustrated in Figure 24 (but, of course, at a much finer resolution), we can calculate various types of summary statistics that could drive investment decisions. While Figure 24 shows excess returns over Treasuries, we could just as clearly carry out a similar analysis using excess returns over Aa liabilities, to represent the viewpoint of the prototypical insurance company portfolio described above.

Figure 24. **Annualized Excess Returns Realized by Bonds of Different Qualities, Conditioned on the Market Variable**



In Figure 25, we compare the distributions of excess returns over Aa liabilities obtained for various blends of A and Baa securities. The analysis is carried out using the following assumptions: Treasury yield 4%; spreads of 60, 80, and 130 bp for Aa, A and Baa, respectively; single-A expected default probability 2% with 20% issuer correlation; Baa default probability 5% with correlation 25%; and 40% recovery rates throughout.

In addition to the expected excess return over Treasuries, we report its standard deviation, as well as several measures of tail risk. Two types of statistics are reported on tail risk for a given confidence level. The interpretation of the value at risk (VAR) is: you can be 95% confident that the result you will obtain will be the VAR or better. The interpretation of the expected shortfall (ES) is the average of all the possible outcomes that go beyond the VAR. (One could imagine two different distributions with the same VAR but with one having a much worse ES than the other.)

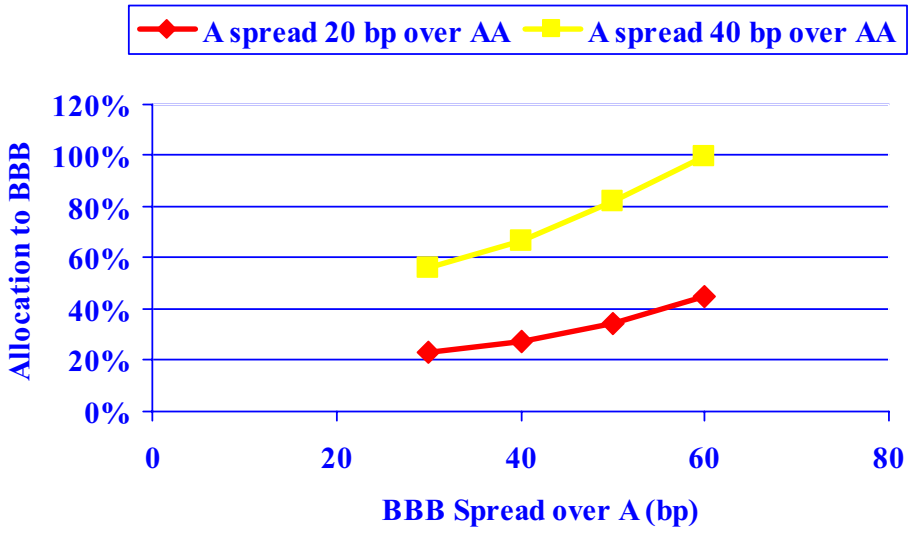
We see that due to the small spread differential, A-rated securities offer an expected return advantage over the Aa liabilities of only 4 bp/year, with a standard deviation of 22 bp. The breakeven probability is only 75%. For Baa securities, the larger spread cushion more than makes up for the higher expected default rate, and thus we obtain a higher expected return as well as a greater probability of breakeven. However, the Baa distribution has more risk in the tails. Assuming that the portfolio is composed of a linear blend of the two qualities gives a linear blend of the results for all of the performance measures shown (except IR).

One way to use this analysis to set the allocation is to seek to maximize the expected return subject to a specified risk limit. For example, using the data shown in Figure 25, an investor who requires 95% confidence that the portfolio will underperform the liabilities by no more than 50 bp/year would choose an allocation of between 30% and 40% to Baa. As long as the maximum amount of risk that can be tolerated is known, then this method can be used to back out the blend of A and Baa bonds that will achieve that level of risk, whether specified by VAR or expected shortfall, at any confidence level.

Figure 25. **Risk and Return of Blends of A and Baa Assets vs. Aa-Rated Liabilities.**
Assumed spreads over Treasuries: Aa 60 bp, A 80 bp, Baa 130 bp.

A Weight	Baa Weight	Mean Ann ExcRet	Stdev Ann ExcRet	95% VAR	95% ES	99% VAR	99% ES	Breakeven Prob	IR
100%	0%	4	22	-37	-68	-86	-123	75.1%	0.18
90%	10%	6	25	-40	-76	-96	-137	77.0%	0.26
80%	20%	9	28	-44	-83	-106	-151	78.2%	0.31
70%	30%	11	31	-48	-91	-117	-166	79.1%	0.36
60%	40%	14	34	-52	-99	-127	-180	79.8%	0.39
50%	50%	16	38	-56	-107	-137	-194	80.2%	0.43
40%	60%	18	41	-60	-115	-147	-208	80.8%	0.45
30%	70%	21	44	-64	-123	-158	-222	81.0%	0.47
20%	80%	23	47	-68	-130	-168	-237	81.4%	0.49
10%	90%	26	50	-72	-138	-178	-251	81.7%	0.51
0%	100%	28	54	-76	-146	-189	-265	81.8%	0.52

Figure 26. **Optimal Allocation to Baa as a Function of Spread Differentials**



These results are very sensitive to the spread assumptions, and in particular the spread differentials from Aa to A and from A to Baa. We assumed that A spreads were 20 bp over Aa, and that Baa spreads were 50 bp wider still; our loss constraint of 95% VAR = -50 bp led to a Baa allocation of 34%. Figure 26 shows how this optimal allocation would change as we vary these two spread differentials. Naturally, an increase in the spread advantage of Baa over A (without any adjustment of the expected default rates) increases the optimal allocation to Baa. When this advantage goes below a certain level (here shown to be about 30 bp) the expected return is higher for A, and there is no longer any incentive to take on Baa risk.

An even larger effect can be seen as we increase the spread differential between A and Aa. This increases the spread cushion on which the strategy rests, improving the mean excess return and the breakeven probabilities for both A and Baa assets. This allows us to take much more risk before challenging the VAR limit, and hence permits much larger contributions to Baa.

The analysis can be modified in various ways to fit various types of long-term investment objectives. At many institutions, for example, formal risk constraints are defined in terms of VAR limits on realized portfolio defaults, not in terms of excess returns as illustrated above. In this case, the risk limit will dictate a maximum exposure to Baa that will not change with fluctuating spreads. This can give rise to a two-tiered approach. First, we can use the distribution of excess returns to compute an optimal allocation to Baa that will tend to increase when spreads have widened enough to justify the additional risk. The limit on default losses can then be used to place a fixed upper bound on how high this allocation should be allowed to go.

Credit Portfolio Construction Using COMPASS

Many investors are familiar with the portfolio optimizer that is part of the Lehman Multi-Factor Risk Model toolkit. The optimizer allows the investor to identify sells and buys for his portfolio that will reduce expected tracking error versus his benchmark arising from normal market fluctuations. Based on client testimonials, this is a very useful tool for total return investors to manage the market risk of their portfolio.

As described above, buy-and-hold credit investors have a different world-view. These investors are less concerned with normal market fluctuations and daily or monthly tracking error versus a benchmark. Instead, these investors are concerned with defaults and recoveries. In particular, the buy-and-hold manager wants to know: Will a credit asset purchased for the portfolio perform as promised up until maturity? and, if the asset defaults, is it likely to default along with other assets in the portfolio? The latter is a key risk faced by buy-and-hold investors: I know that each asset in my portfolio has a probability of defaulting, but what is the chance that many assets in my portfolio will default simultaneously?

COMPASS (Credit OptiMized Portfolio Asset Selection System) is Lehman's portfolio optimization tool for buy-and-hold credit investors[38] developed by our European Credit Modeling team. An investor can use COMPASS to construct an optimized credit portfolio that maximizes expected portfolio return measure while minimizing a specified portfolio risk measure subject to various constraints. In addition, COMPASS can take an existing credit portfolio and suggest trades to improve the risk-adjusted return efficiency of the portfolio.

COMPASS works roughly as follows. Individual asset default rates are mapped to historical default rates based on the asset's credit rating. (Alternatively, the investor can use his own default rate assumptions.) Using equity returns, COMPASS models the default correlations of various assets in a credit portfolio. This correlation matrix is updated monthly using market data. Using this information, COMPASS simulates (using Monte Carlo simulation techniques) the correlated defaults for assets (including structured credit assets) in a portfolio. With this information and applying a model of recovery rates (which may, in turn, be correlated with default rates), COMPASS can generate a loss distribution for a portfolio.[39]

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[38] For details on COMPASS please refer to the *COMPASS User's Guide*, Lehman Brothers, October 2003.
[39] Please refer to *Modeling Credit: Theory and Practice*, by Dominic O'Kane and L. Schlögel, Lehman Brothers, February 2001 for an extensive discussion of modeling correlated defaults.

For a given level of expected return, COMPASS can generate the various possible portfolio loss distributions using as inputs a given set of available assets as identified by the investor. COMPASS then identifies the single portfolio with the lowest coherent risk measure (e.g., expected shortfall) given the level of expected return. This optimal portfolio can then either be purchased outright or can be used to determine buys and sells for an existing credit portfolio. COMPASS can also generate an "efficient frontier" and show the investor how his optimal portfolio risk exposure changes as the investor strives for different levels of expected portfolio return.

COMPASS is an extremely useful optimization tool for buy-and-hold investors, just as the Multi-Factor Risk Model optimizer is a useful tool for total return investors. Until COMPASS was available, buy-and-hold investors had little way of knowing whether they were minimizing their portfolio risk for a given level of expected return. Using COMPASS, investors can now objectively improve the performance efficiency of their credit portfolios.

CONCLUSION

The Quantitative Portfolio Strategies Group works with investors on a wide spectrum of issues ranging from benchmark selection and customization to portfolio construction. Included in this advisory activity are studies in support of asset class composition, proxy portfolio construction for replication of various indices, index replication with liquid derivatives for alpha transfer strategies, portfolio risk optimization and other strategies.

All research published by the Quantitative Portfolio Strategies Group, including everything referenced above, is available on the LehmanLive website under Global Strategy. We strongly encourage readers who would like a more detailed treatment of the topics covered here, to access the relevant research on our website.

For total return investors we customize our skill-based risk budgeting framework to a specific set of strategies and constraints. We use the Lehman Multi-factor Risk Model implemented on our POINT (Portfolio INdex Tools) analytics platform to convert optimal risk budget allocations into specific security holdings in portfolios with given risk characteristics.

We put our Risk Model to more uses than portfolio construction alone. An investor in the planning phase of macro strategies and constraints may be interested in comparing risk entailed in some pure views relative to his benchmark (e.g., the risk of a 1 year duration extension vs. the risk of a 1% concentration in a Baa issuer). The Risk Model translates the risk associated with diverse views into common units of expected return deviation from the benchmark. In stress testing a portfolio under different scenario assumptions, an investor may want to provide expected changes in some market parameters on which he holds a strong view and leave the rest to be determined from their historical relationships to these parameters.

The analysis we provide for buy-and-hold investors addresses both the top-down allocation decisions facing a portfolio manager and the bottom-up issuer selection using COMPASS.

The increased complexity of benchmarks and core-plus strategies employed in portfolios has made the risk optimization process essential to achieving the alpha and information ratio objectives of portfolio managers.

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