Replicating the Lehman Brothers Aggregate Bond Index with Liquid Instruments

(including TBAs & CDX)

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EXECUTIVE SUMMARY

- We replicate the returns of the Lehman Brothers Aggregate Index and sub-components of the Index with derivatives using several strategies in isolation and together in combination.
- We provide transparent methodologies for replications of indices using futures, interest-rate swaps, Mortgage TBAs, and portfolio credit-default swaps.
- A simple replication strategy using futures achieved a tracking error of 23 bp per month versus the Lehman Aggregate Index. More sophisticated replications brought tracking error as low as 9 bp per month.
- Portfolio credit default swaps reduced tracking error by 7 bp per month and increased return by 7 bp per month.
- We find that using a variety of replication methodologies achieves the lowest tracking error, benefiting from a diversification of uncorrelated sub-index tracking errors.
- We conclude that the choice of optimal replication strategy depends on other portfolio exposures: a strategy that is optimal in isolation may not be optimal as part of a larger portfolio.
- We contrast replication with derivative instruments to other replication approaches, including replication with cash instruments and total return index swaps.
- The performance of various replication strategies is measured using a full historical replication, supplemented by ex-ante risk forecasts from the Lehman Brothers Multi-Factor Risk Model.
- Transaction costs are estimated to be 0.3-1.0 bp per month. The performance difference between the "full" replicating strategy and the Aggregate Index was 1.6 bp per month.

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INTRODUCTION

Index replication is not just for passive managers of fixed-income portfolios. Active managers, managers of balanced fixed-income and equity portfolios, and plan sponsors all may wish to replicate the returns on the Lehman Brothers U.S. Aggregate Index[1] or its sub-components. While index replication has been of interest to a small group of managers for a number of years (our earliest published study of index replication dates back to 1997), we have witnessed a substantial increase in interest in replication strategies in recent months. Though a desire to achieve index returns is a perfectly reasonable goal of replication, we have found that demand for replication strategies has been driven primarily by two very different needs.

First, low yields in fixed income markets and concerns over the likely future performance of equity markets have spawned a "rush for alpha."[2] This trend has notably manifested itself in the surge of inflows to hedge funds, but another side effect of this trend has been a broadening interest in "portable alpha" strategies. Typically, a portable alpha strategy involves the transfer of alpha from one asset class to another. For example, an equity manager uses equity futures to eliminate the "beta" from stock market exposure, but preserves the alpha. The manager then uses non-cash instruments to achieve the desired bond market exposure (e.g., matching the Lehman Brothers Aggregate Index).

Second, the increasing use of the Global Aggregate Index, a broad index of investment grade multi-currency fixed-income securities, has caused many managers to look for strategies to replicate its sub-components. A European-based manager may be adept at managing European credit and government securities, but may have less resources or expertise in managing U.S. fixed income. In particular, we find some non-U.S. managers choosing to refrain from offering a Global Aggregate product because they doubt their ability to manage U.S. mortgage-backed securities effectively. Since the Global Aggregate Index is fast becoming the benchmark of choice for many sponsors, we believe that such managers will be forced to forgo the possibility of participating in much of the growth in global fixed-income assignments. Instead, a strategy of replicating segments of the U.S. Aggregate Index can allow such a manager to offer a Global Aggregate product. Indeed, derivatives can be used to create a "portable alpha" strategy for the Global Aggregate, in which the alpha from a 100% Euro fixed income portfolio is "transported" to a Global Aggregate Index.

There are additional reasons to replicate index returns. A U.S. fixed-income active manager who possesses skill in one aspect of fixed-income management (e.g., credit allocation) may wish to offer the return of the Lehman Brothers Aggregate Index by replicating the return on the mortgage sector. Alternatively, this manager may, at any particular time, wish to eliminate the active risk in a given sector, either because the outlook for a given sector is neutral or because of a low level of confidence in a given view.

Plan sponsors engaged in asset allocation shifts are increasingly using transition managers to minimize implementation shortfall. Such transitions can involve transactions in multiple asset classes spread across more than a week. If the target portfolio is fixed income, it may be

[1] An overview of the Lehman Brothers U.S. Aggregate Index is provided in Appendix I.

[2] Alpha, as strictly defined by the Capital Asset Pricing Model, is the part of the return that is not explained by exposure to the relevant asset class.

optimal to gain the desired exposure to fixed income at the beginning of the transition, before the liquidation of assets has even begun. If the legacy portfolio is fixed income, there may be a desire to retain fixed-income exposure throughout the transition. In both cases, a replicating portfolio of derivative instruments can achieve these objectives.

Similarly, asset managers may use replication strategies to manage portfolio inflows and outflows. For example, following an inflow, it may take days for new bonds to be purchased. A replicating portfolio of derivatives can maintain market exposure on uninvested cash. Similarly, a replicating portfolio can maintain market exposure in the period between the sale and settlement of securities liquidated to meet a portfolio outflow.

Replication Methods

Methods of replicating bond indices fall into three categories: replication with cash instruments (i.e., bonds, not derivative instruments), replication with derivatives, and total-return index swaps.

Replication with cash instruments is an appropriate strategy in two kinds of situations. First, passive managers will generally use cash instruments to achieve very low return deviations from benchmark. This strategy makes sense for large portfolios with hundreds of holdings, for which the goal is pure indexation and the portfolio is fully funded. Second, active managers may wish to replicate that part of the benchmark for which they do not possess skill. In this case, however, using derivative instruments may be preferable, to permit the managers to exercise skill in other sectors (thereby generating alpha from 100% of portfolio assets). Cash replications are typically done using a stratified sampling approach, in which the index is dissected into cells and bonds are selected to represent the characteristics of each cell.[3]

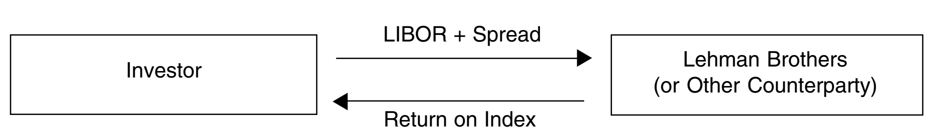
Managers who do not wish to use cash instruments, but also are not willing to manage a portfolio of derivative instruments, may choose to use total-return index swaps. Figure 1 shows an example of a total return swap.

Under a total return swap, the investor is guaranteed to receive the total return on the index selected, in return for paying the counterparty floating-rate LIBOR, plus a spread, to compensate the dealer for the risk in hedging the index exposure.[4] This approach is appropriate for investors with a high degree of risk aversion or those with relatively long (one year and longer) time horizons, owing to the limited liquidity and higher transaction costs associated with a swap.

[3] We discussed a stratified sampling method in *The Replication of the Lehman Global Aggregate Index with Cash Instruments*, August 2001.

[4] Under the swap, the basis risk between a given replicating strategy and the index is effectively borne by the dealer, who is compensated for it by the investor.

Figure 1. **Diagram of a Total Return Swap on the Lehman Brothers Aggregate Index**



In most other situations, replication with derivative instruments is likely to be preferable, and this method is the subject of the rest of this article. Derivative instruments are highly liquid, have low transaction costs, and are unfunded instruments. While there may be some basis risk between the derivative and underlying instruments, this is likely to be lower than the level of security-specific risk that a portfolio of actively managed cash instruments would typically possess.

In previous reports (please see references at the end of this article), we have examined various methods of index replication for both U.S. and global indices. These include replication of the U.S. Aggregate and sub-indices with futures alone, as well as futures and swaps, replication of the U.S. MBS Index with TBAs or large pools, and replication of the Global Aggregate with both derivatives and cash instruments. Here, we compare the performance of various replication approaches, in isolation and in combination. This includes strategies we have previously considered, as well as the new portfolio credit default swap instruments. In addition, we review some of the practical considerations that may affect the choice of replication method.

Sources of Risk in the Lehman Brothers Aggregate Index

In considering the merits of various replication strategies, we should examine the sources of volatility in the U.S. Aggregate Index. Figure 2 shows output from the Lehman Brothers Risk Model,[5] which breaks down the sources of risk for the Lehman Brothers Aggregate Index and various sub-components.

The Lehman Brothers Multi-Factor Risk Model quantifies the ex-ante tracking error volatility (the expected volatility of the return deviation) of a portfolio versus its benchmark or the absolute volatility of a portfolio or index. The model is based on the historical returns of individual securities in the Lehman Brothers Bond Indices, in many instances dating back over more than a decade. The model derives historical magnitudes of different market risk factors and the relationships among them. It then measures current mismatches between the portfolio and benchmark sensitivities to these risks

[5] Available in our POINT analytics platform. An outline of the risk model is provided in "Introducing the Lehman Global Risk Model," *Global Relative Value*, December 8, 2003. A detailed description of Lehman's approach to the construction of the risk model is provided in *The Lehman Multi-Factor Risk Model*, 1999. Specifications of the MBS Risk Model and the Credit Risk Model are accessible from Lehman Live.

Figure 2. **Sources of Risk in Lehman Brothers Indices**, bp per month

Global Risk Factor	U.S. Aggregate	U.S. Treasury	U.S. MBS	U.S. Credit
Yield Curve	150.03	141.78	77.65	150.91
Swap Spreads	19.73	18.01	33.88	
Volatility	7.34	0.06	10.33	0.30
Investment-Grade Spreads	19.02	7.40	22.01	57.01
Treasury Spreads	0.79	7.40		
Credit and Agency Spreads	15.76	57.01		
MBS/Securitized	7.81	22.01		
CMBS/ABS	0.89			
Systematic Risk	146.79	139.36	80.43	145.75
Idiosyncratic Risk	2.74	0.61	2.83	7.89
Total Risk (bp per month)	146.81	139.36	80.48	145.96

Source: Lehman POINT.

and multiplies these mismatches by historical volatilities and correlations ("covariance matrix") to produce its output.

While tracking error volatility (TEV) is a measure of volatility, it can be used (with caution) to make forecasts of the likely distribution of future relative returns. For example, assuming returns are normally distributed, a portfolio with a TEV of 25 bp per month would be expected to have a return within +/- 25 bp per month around the expected return difference between the portfolio and benchmark approximately two-thirds of the time (and underperformance of worse than -25 bp relative to the expected return difference one-sixth of the time).

The total volatility of a given index reflects the risk due to exposure to various risk factors and correlations between risk factors. Accordingly, the volatilities are not additive. The expected volatility of a given index can be expressed as a function of its exposures to risk factors and the volatility of those factors. The credit index (or an individual credit security) will be exposed to term structure risk, swap spread risk, credit spread risk, (together, "systematic risk"), and idiosyncratic risk.

The risk characteristics of a given index determine which instruments can best replicate it. For all U.S. investment-grade fixed-income indices, term structure is by far the dominant source of risk. Therefore, a portfolio of treasury futures, matched as closely as possible to the duration characteristics of the relevant index, should be able to attain a reasonable replication "result." For mortgage-backed securities, swap spread risk is almost as important as MBS spread risk. Therefore, we would expect that receiving fixed-rate interest rate swaps would achieve a better replication result than using treasury futures. For credit, while swaps would also be expected to achieve improved replication, additional instruments would be needed to reduce credit spread risk to achieve replication results closer to those of other sectors.

FORMING A DERIVATIVES REPLICATION STRATEGY

Our examination of the sources of risk in various indices suggests that a replicating portfolio that matches the systematic exposure of these indices would achieve reasonable results in delivering acceptably low levels of tracking error. However, we have two categories of choices in building such a portfolio: a choice of instruments (pick any or all) and a choice replication technique (pick one), as shown in Figure 3.

Figure 3. **Decisions in Forming a Replication Strategy with Derivative Instruments**

Instruments
- Bond Futures
- Interest-Rate Futures
- Interest-Rate Swaps
- Mortgage TBAs
- Credit-Default Swaps

Replication Techniques
- Stratified Sampling (Cell Matching)
- Key-Rate Duration Matching
- Minimum Variance Hedge

Approaches to Replicating Exposures

There are three main approaches to replication:

- A **stratified sampling** approach divides the index into duration cells. A derivative instrument is selected for each cell in an amount to match the duration exposure of that cell.
- A **key-rate duration** (KRD) approach attempts to match the overall key-rate duration exposures of the index. Key-rate duration measures sensitivity to shifts at specific "key-rate" points along the yield curve (and can therefore measure the effect of non-parallel yield curve shifts), in comparison with "conventional duration," which measures sensitivity to parallel yield curve shifts.
- A **minimum-variance hedge** approach, with the help of a risk model, seeks to minimize the predicted tracking error of a replicating portfolio against its index. Therefore, the replicating portfolio will reflect the correlations between sectors and instruments in the portfolio and index—for example, between corporate and government bonds.

In the past, our replication studies have used a stratified sampling approach. Since 2001, we have been computing KRDs, and in a recent study,[6] we demonstrated that such an approach has delivered modestly lower tracking errors than the stratified sampling approach. The regression hedge approach is more model-driven and less transparent than the other two approaches. Furthermore, it is reliant on the relationships between different risk factors—for example, between term structure movements and credit spread changes, which change over time. Accordingly, in this article, we chose to examine the performance of various replication strategies using the KRD-matching approach.

In the Lehman Brothers Yield Curve Model, there are six key rates (Figure 4). In some cases, however, we have fewer than six instruments available for our replication (e.g., replication with Treasury futures, for which we have only four separate instruments). Accordingly, it is not possible to match all six key-rate durations.

Replication Strategies

Replication with Treasury Futures

The number of bond futures contracts available—the 2-year, 5-year, 10-year, and long contracts—is not sufficient to achieve a perfect match of the six KRDs in the Lehman Brothers Yield Curve Model. We consider two possible choices in dealing with this issue.

[6] "Replicating Index Returns with Treasury Futures: Duration Cells versus Key-Rate Durations," *Global Relative Value*, July 2004.

Figure 4. **Key-Rate Durations of Treasury Futures Contracts as of August 31, 2004**

	Key-Rate Duration					
Contract	**6-Mo**	**2-Yr**	**5-Yr**	**10-Yr**	**20-Yr**	**30-Yr**
2-Year	-0.07	1.97	0.06	0.00	0.00	0.00
5-Year	0.00	0.70	3.55	0.00	0.00	0.00
10-Year	0.01	0.05	3.41	2.85	0.00	0.00
Long Bond	0.01	0.05	0.23	2.65	8.16	0.61

First, an optimization can be established to minimize the sum of the squared differences between the respective index and the replicating portfolio KRDs. However, we choose a second method, reducing the number of key-rates to equal the number of available instruments in order to achieve a perfect match, by combining the 6-month and 2-year key-rate durations and the 20- and 30-year KRDs. As Figure 4 demonstrates, the key-rate duration exposure of the bond futures contracts is minimal for the 6-month rate, while only the long bond contract has any exposure to the 20- or 30-year rate. Nevertheless, there will still be an unavoidable mismatch between the duration exposure of the futures replicating portfolio and the Aggregate Index. We can match the sum of the KRDs of the 20- and 30-year vertices with a single instrument, but we cannot match the KRD exposure of both vertices separately.

Replication with Interest Rate Swaps

The fixed-rate leg of an interest-rate swap represents the average of forward rates, which reflect the credit quality of the panel of banks that set the LIBOR rates. Therefore, the pricing of interest-rate swaps reflects a credit risk premium, while their spread to treasuries will also reflect a liquidity premium. Accordingly, receiving the fixed component of an interest-rate swap would be expected to provide a better alternative to replicating the returns of non-Treasury components of the Aggregate Index. In addition, since the swap curve is effectively continuous, we can select six instruments to match exactly the key-rate duration profile of the Aggregate Index.

The historical relationships between yields on various indices and on portfolios of duration-matched interest rate swaps can be examined using the Lehman Brothers Mirror Swaps Indices.[7] In addition, for investors who do not wish to enter several interest-rate swaps, Lehman Brothers offers a total-return swap on various Mirror Swap Indices. This also eliminates the need to rebalance the portfolio to bring duration exposures back in line as the index changes from month to month and swap instruments age.

Replication with Futures and Interest Rate Swaps

An obvious extension of the futures and swaps replication is to use treasury futures to replicate the treasury sector and swaps to replicate the non-treasury sectors. For this strategy, we can also eliminate the term-structure replication error of the treasury component (see above) using swaps.

Replication of the MBS Index with TBAs

The Mortgage-backed securities (MBS) sector represents a large component of the Aggregate Index. The availability of liquid instruments to replicate the index and a straightforward method for doing so suggests that such an approach should not greatly increase the complexity relative to a futures-only or swaps-only replication. While futures and swaps can replicate the yield curve exposures of the MBS index, they leave exposure to MBS spread, prepayment, and volatility effects. Using a mortgage product can improve the replication considerably by hedging these exposures, as well. TBAs offer two key advantages over MBS pools in replication strategies: they are suitable for an unfunded strategy—since no cash outlay is required, prior to settlement a TBA is

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[7] The Mirror Swap Index is a portfolio of interest rate swaps (receiving fixed) constructed to match the key-rate duration profiles of various Lehman Brothers indices. For more details, see *The Lehman Brothers Swaps Indices*, January 2002.

simply rolled from month to month; and the back-office aspects of investing in mortgages are much simpler for TBAs than for pools, since monthly interest payments and principal paydowns are avoided. The remaining risk in a TBA replication is essentially due to the difference in risk characteristics between new and seasoned mortgages. See Appendix II for more details.

Replication of the Credit Index with CDS[8] and Interest Rate Swaps

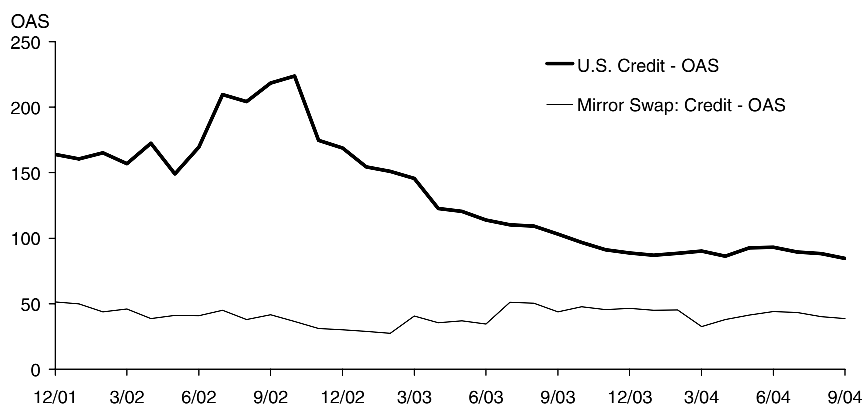
While interest-rate swap spreads are at times highly correlated with credit spreads, there have been extended periods during which this relationship has broken down. In such periods, LIBOR spreads have typically remained quite stable while credit spreads have been quite volatile. For example, Figure 5 shows that 2002 was a period of great volatility for credit spreads, while swap spreads, as measured by the Mirror Swap Credit Index, were relatively stable.

Portfolio credit default swap (CDS) baskets now provide a very liquid instrument that investors can use to take a long (or short) position in credit. Credit yields can be broken down into two constituents: the swap yield and a credit spread to swaps. Accordingly, we can match the exposure of credit to movements in swap yields using interest-rate swaps and the exposure to movements in LIBOR credit spreads by using CDS. The widely traded CDX.NA.IG products are baskets of 125 equally weighted CDS available in 5- and 10-year maturities. In our analysis, we combine 5- and 10-year CDX in proportions sufficient to match the spread duration and yield of the Credit Index.

Since these instruments have been available only since October 2003, a period of stable credit spreads, we cannot easily gauge the benefits of including them in a credit index replication strategy. Therefore, we supplemented the CDX data by valuing portfolios of CDS instruments constructed from the issuers that composed the CDX basket as of October 2003, for the period June 2002 to September 2003. We would caution that a look-forward bias is introduced by doing this. CDX-IG by construction comprises investment-grade-only issuers. In constructing a basket in October 2003 valued back to July 2002, we are certain to avoid some issuers that were downgraded over the period that may have been included in a basket actually constructed in 2002. The large number

[8] A review of credit-default swaps is provided in Appendix III

Figure 5. **Option-Adjusted Spreads for the U.S. Credit and Mirror Swap Credit Index**



of names in the basket (125) should mitigate this risk.[9] The period under review was admittedly one in which there were very few "fallen angels." We note that in addition to the basis risk that exists between CDS and credit, there is an additional basis that exists between CDX and the underlying CDS. This second basis is not modeled in our supplemental study, but we do not believe that its presence materially altered the outcome. The basis risk in CDS and CDX will be examined in a future study.

PERFORMANCE SUMMARY OF REPLICATION STRATEGIES

The key metric by which we measure the performance of various replication strategies is tracking error volatility (TEV). This is preferable to using average out (under) performance for several reasons. The volatility of returns tends to be much more persistent than the returns themselves, that is, history is a much better guide for predicting volatility than for predicting return. It is also not likely that a period of substantial underperformance of a given replication strategy will persist, since this would imply a secular cheapening in a group of highly liquid derivative instruments, or a secular trend in credit or MBS spreads. Finally, the objective of any replication strategy is to replicate the index, not outperform. Outperformance is what active managers are paid for. Neverthless, we report mean outperformance of each replicating strategy to give a flavor for the degrees of out (under) performance.

Figure 6 shows the results of replicating the Lehman Brothers Aggregate Index and selected sub-indices using the approaches outlined above. The replication of the Treasury Index with treasury futures achieves an acceptable TEV of 10.6 bp per month. We find that over this period, the futures portfolio outperformed the Treasury Index. Interestingly, this is consistent with prior studies that showed mean outperformance of 3.1 bp per month over three separate time periods.[10] This reflects two effects. We assume in our replication that cash is invested at LIBOR, which over the past two years has had a 1.8bp per month higher yield than treasury bills. The residual outperfomance suggests that the premium that long futures positions enjoy for being short the cash bond delivery option has been "too large" over these periods (see below for more discussion of the delivery option).

Treasury futures fare less well, as expected, as instruments to replicate MBS and Credit Indices. While term structure risk is reduced, spread risk remains. In prior studies, we found that interest-rate swaps delivered measurable reductions in tracking error compared with Treasury futures when replicating the MBS and Credit Indices. In the most recent period, however, we note that while swaps deliver lower TEV against the Credit Index, they have a higher TEV for replication of the MBS Index compared with using Treasury futures.

Figure 7 shows that there has been a close relationship between mortgage spreads and swap spreads, so it might seem that swaps should have performed better than futures. The replication results suggest, however, that other factors are responsible for this effect. In recent years, swaps have been a favored tool for the convexity hedging of MBS securities, and therefore swap spreads have tended to behave directionally, tightening

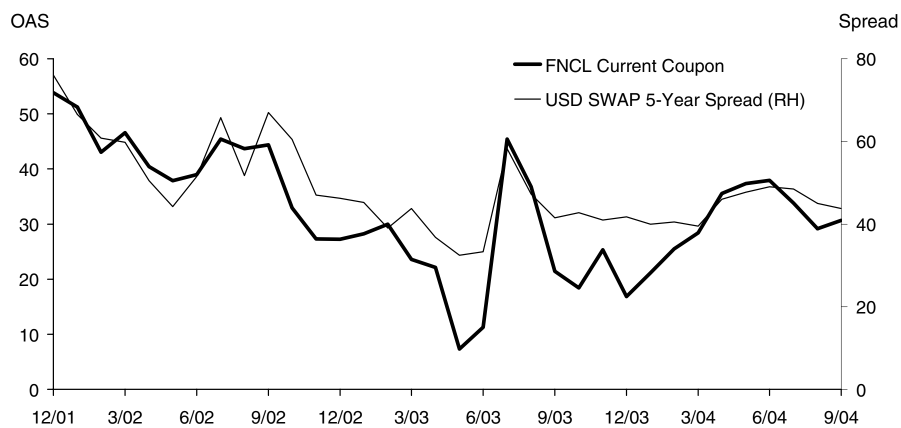
[9] During the period, EP and AHOLD were investment-grade issuers that were downgraded to high yield that might reasonably have been expected to have been included in a CDS basket. They represented 0.4% and 0.1% of the Credit Index, respectively, in the month prior to downgrade.

[10] See "Hedging and Replication of Fixed Income Portfolios," Dynkin et al., *Journal of Portfolio Management*, March 2002.

Figure 6. **Index Replication Results**
August 2002-September 2004, bp per Month

Replication Method	Mean Outperformance	Tracking Error Volatility	R^2
a. **U.S. Treasury Index Replication**			
Treasury Futures	4.5	10.4	0.997
b. **U.S. MBS Index Replication**			
Treasury Futures	1.2	35.3	0.811
Interest-Rate Swaps	-1.8	38.5	0.775
TBAs	0.3	4.3	0.997
c. **U.S. Credit Index Replication**			
Treasury Futures	-25.1	62.7	0.878
Interest-rate Swaps	-26.9	57.8	0.896
Interest-rate Swaps + CDX	2.5	29.1	0.974
d. **U.S. Aggregate Index Replication**			
reasury Futures	-5.2	22.7	0.972
Interest-Rate Swaps	-7.4	17.5	0.983
Futures+Swaps	-7.1	17.3	0.983
Futures+Swaps+TBAs	-6.1	16.9	0.984
Futures+Swaps+CDX	0.7	10.9	0.994
Futures+Swaps+TBAs+CDX	1.6	9.4	0.995

Figure 7. **Option-Adjusted Spread of Current Coupon FNCL 30-Year MBS versus 5-Year Swap Spread**



as Treasury yields fall and widening as they rise. Therefore, using swaps in a replication in place of treasury futures may increase the effective duration mismatch of the replication strategy. An additional factor is the optionality of MBS and futures. A buyer of futures is short a delivery option.[11] The seller has the option to deliver one of a basket of cash securities to the buyer. Therefore, the futures buyer is short interest-rate volatility, as is the MBS buyer. A combination of swaps and swaptions would benefit from the correlation of swaps with MBS, as well as the exposure to interest-rate volatility, but is beyond the scope of this paper.

[11] There are actually several delivery options, the value of all of which is positively affected by interest-rate volatility. A detailed exposition of the various delivery options is beyond the scope of this paper.

Interest-rate swaps improve upon the replication of the Credit Index with futures given the credit exposure embedded in interest-rate swaps. Figure 5 shows that swap spreads have been relatively stable during a period of volatility in credit spreads. The sharp contraction in credit spreads caused futures and swaps replications to underperform the Credit Index significantly, in return terms. While swap spreads and credit spreads have been relatively stable since the fourth quarter of 2003, the period prior to that was far from stable.

The use of CDX in the replication, not surprisingly, improves upon the replication with swaps alone. As Figure 8 shows, CDS spreads tracked credit spreads closely over this period. We also see that the relative advantage of CDS, compared to swaps alone, was much greater during the earlier period of volatility.

Figure 9 demonstrates that the tracking error of the swaps-only strategy was more than twice as large that of the swaps+CDS strategy during the period of greater spread volatility. An additional benefit of CDS is the greater carry earned by the portfolio. In return for accepting default risk (which is reflected also in the credit index), the investor earns that incremental carry. As long as CDS spreads are sufficient to offset default losses, CDS will increase expected return and reduce risk.

Bringing together all of the various replication strategies in Figure 6d, we can see how the tracking error of the Aggregate Index improves as we add more replicating instruments. The most notable improvement would seem to be adding CDS, which reduced the volatility by 6.5-8.0 bp. Intriguingly, while TBAs are greatly superior to other methods in replicating the MBS Index by itself (4.1 bp TEV versus 36 bp for replication with futures), TBAs do not greatly improve the replication of the Aggregate Index. Figure 10 gives us some insight into this.

Comparing the first two lines in the correlation matrix, we find a substantial negative correlation between the MBS replication with swaps and the treasury replication with futures. There is a smaller, positive correlation between the MBS replication with TBAs and the futures replication. This reflects the volatility effect highlighted above. In an environment of rising interest-rate volatility, futures would be expected to underperform

Figure 8. **Relationship between Credit Spreads and CDS**

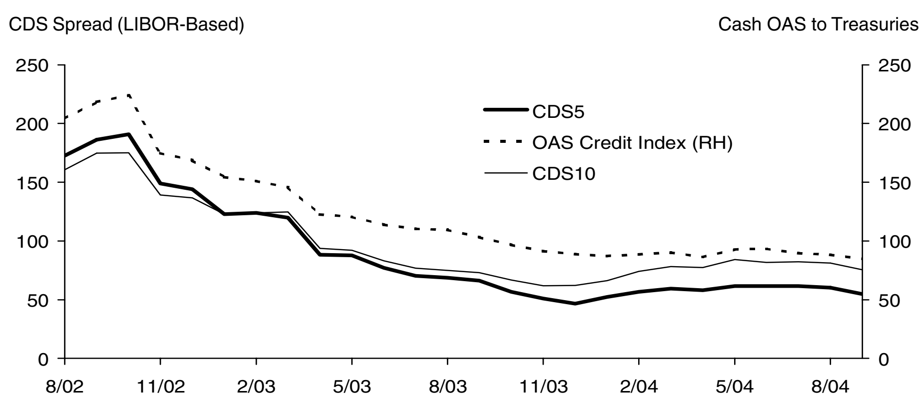


Figure 9. **Credit Replication Tracking Error (bp per month) in Two Different Sub-Periods**

	8/02-9/03	10/03-9/04	Total Period
Swaps only	75.9	22.6	57.8
Swaps + CDS	34.7	19.0	29.1

Figure 10. **Correlations of Realized Return Differentials of Replicating Strategies**

Correlation	Swaps for MBS	TBAs for MBS	Futures for UST	Swaps for Credit
Swaps for MBS	1.000	-0.533	-0.732	-0.268
TBAs for MBS	-0.533	1.000	0.343	0.156
Futures for UST	-0.732	0.343	1.000	0.364
Swaps for Credit	-0.268	0.156	0.364	1.000

cash treasuries, and swaps would outperform MBS (i.e., strong negative correlation). In that same environment, TBAs would tend to underperform the MBS Index (i.e., weak positive correlation) as TBAs tend to have higher volatility exposures than the more seasoned issues in the index. The correlation of the credit replication strategy with the two MBS replication strategies is also notably different. Rising interest-rate volatility causes swaps to outperform MBS, while convexity-hedging caused them to underperform credit, demonstrating a negative correlation between the MBS-with-swaps replication and the Credit-with-swaps replication. An example of this can be seen in Figure 11, which plots the return difference to benchmark of various replication strategies. In July 2003, the Aggregate Index fell by 3.36%, as yields rose 94 bp. Swap spreads widened, causing swaps to underperform duration-matched Treasuries, though they outperformed MBS. Replicating portfolios for both the credit index and the Aggregate index using swaps substantially underperformed, and so we see a negative correlation between these replication strategies, and the MBS replication-with-swaps strategy. During this same month, the TBA replication strategy also underperformed, a positive correlation with the non-MBS replication strategies. Therefore, a swaps replication strategy for MBS, while notably inferior for replicating mortgages in isolation, is little different from TBA replication as part of an Aggregate Index replication strategy.

Figure 11b demonstrates that the return differential of the full Aggregate replication strategy is driven by the the performance of the Credit Index replication. Indeed, 91% of the volatility of the Aggregate replication strategy over this period can be explained by the Credit Index replication (as measured by r-squared).

The replication "errors" of various strategies can be explained in some cases by the presence of a risk factor in the index, exposure to which cannot be reflected in the replicating portfolio. For example, the futures replication of the Aggregate Index attempts to replicate its term structure exposure, but cannot replicate its credit exposure. Not surprisingly, as Figure 12 shows, the realized return differential of the futures portfolio to the Aggregate index is highly correlated with changes in credit spreads. On the other hand, the return differential of the "full replication" strategy is not correlated with credit spreads.

Figure 11a. **Realized Return Differences of MBS Replication and Credit Replication**

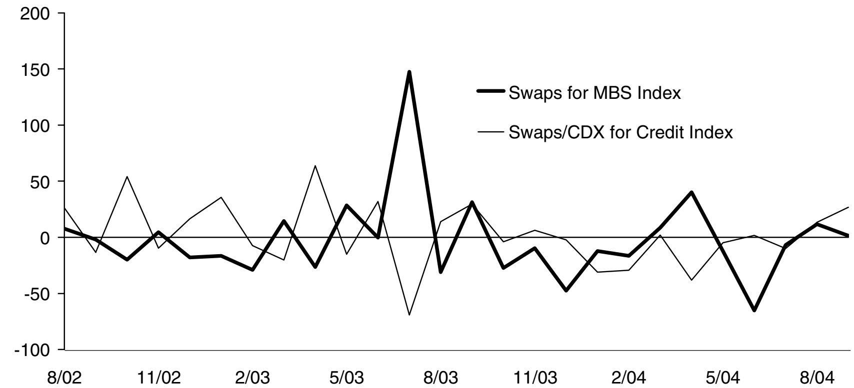
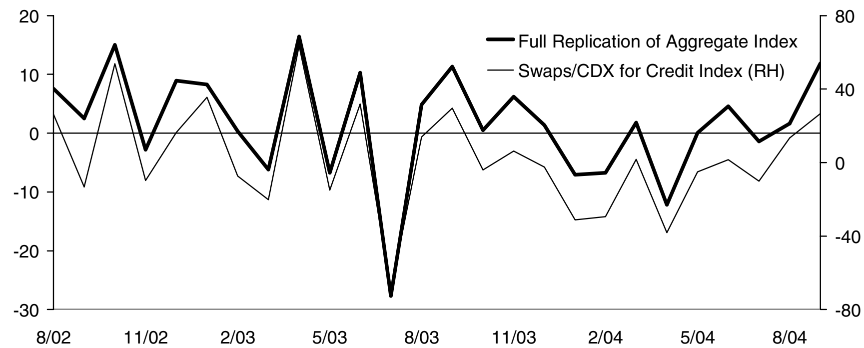


Figure 11b. **Realized Return Differences of "Full" Aggregate Replication Strategy**



These findings have important implications for the choice of replication strategy. Considered in isolation and given investor risk preferences, the choice of strategy may be clear. However, if this replication strategy is part of a larger portfolio, the relationship between the return difference of a given replication strategy and the returns of other portfolio assets must be considered. For example, an investor with sizeable equity exposure may prefer a fixed-income replication strategy using only futures, given the negative correlation with equity returns shown in Figure 12. Falling equity prices have been correlated with rising credit spreads and, therefore, with excess returns to a credit replication strategy with bond futures (and swaps).

USING A RISK MODEL TO FORECAST REPLICATION RISK

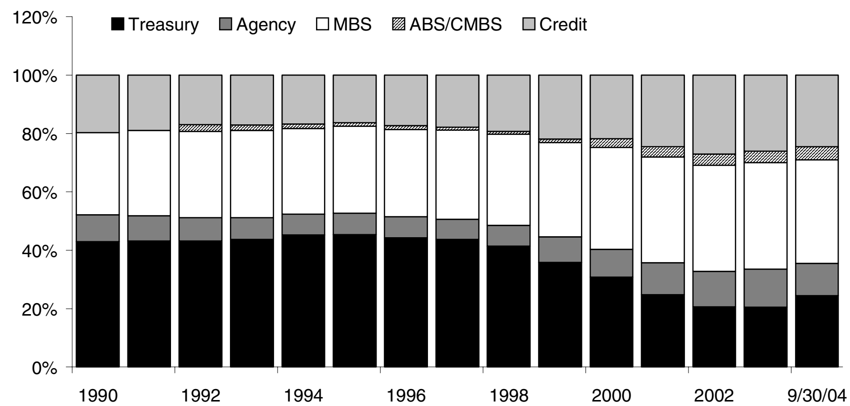
While an empirical analysis is valuable in forecasting the likely tracking errors of various replication strategies, there are some drawbacks to this approach. Most important, the weightings and characteristics of the sectors within the Lehman

Figure 12. **Correlations of Selected Aggregate Replication Strategies with Credit Spreads and Equities**

	Futures Replication	"Full" Replication*
Correl. w -ve change in OAS Credit Index	-0.847	0.065
Correl. w change in S&P 500 Index	-0.505	0.047

* Replication with Futures, Swaps, TBAs and CDX

Figure 13. **Changes in the Sectoral Distribution of the Lehman US Aggregate Index Over Time**



Aggregate index change over time, which will affect the relative success of each index replication strategy. Figure 13 shows that the sectoral distribution of the Aggregate Index has changed markedly over time. We have prevously seen that credit spreads are the dominant source of risk in replication strategies. Accordingly, we would expect that replication performance would change depending on the weight of credit instruments in the Aggregate. There may, therefore, be some bias introduced into forecasts of Aggregate replication TEVs, by differences in the characteristics of the index over time. The use of a risk model can eliminate such biases.

The Lehman Global Risk Model forecasts the volatility of the return difference (TEV) between a portfolio and its benchmark. The TEV uses the current index weights and the current relative exposures between portfolio and benchmark (e.g., key-rate durations) and the historic volatilities and correlations of risk factors (e.g., yield changes). Therefore, the Risk Model approach generates a TEV forecast that is independent of changes in index characteristics over time.

Figure 14 looks at three replicating portfolios created to track the Lehman Aggregate for August 2004, using only Treasury futures, futures, and swaps, and a combination of futures, swaps, and TBAs. In each case, the forecast TEV is within 1-2 bp of the

Figure 14. **Sources of Risk (Factor Volatilities) in the Lehman Aggregate and Replicating Strategies—Exponentially Weighted Co-variance Matrix**

Global Risk Factor	Lehman Aggregate	Treasury Futures	Futures+ Swaps	Futures+Swaps +TBAs
Yield Curve	150.0	3.2	6.0	2.7
Swap Spreads	19.7	19.7	1.8	0.8
Volatility	7.3	7.3	7.3	0.4
Investment-Grade Spreads	19.0	19.0	19.0	16.5
Treasury Spreads	0.8	0.8	0.8	0.8
Credit and Agency Spreads	15.8	15.8	15.8	15.8
MBS/Securitized	7.8	7.8	7.8	0.9
CMBS/ABS	0.9	0.9	0.9	0.9
Systematic risk	146.8	23.1	19.3	16.0
Idiosyncratic risk	2.7	6.4	3.1	3.3
Total risk (bp per month)	**146.8**	**24.0**	**19.6**	**16.3**
Empirically derived risk	**N/A**	**22.7**	**17.3**	**16.9**

Source: Lehman POINT

empirically achieved result. The risk model covariance matrix is constructed from many months of data, which greatly increases the confidence in the forecast TEV suggested by our empirical results, accumulated over 25 monthly observations.

The risk model output is also valuable for the insight into the risks that are reduced through various replication strategies, as well as quantifying the exposures and risk factor volatilities that remain. In Figure 14, we see the importance of yield curve risk as part of the overall volatility of the Lehman Aggregate. Each replication strategy largely eliminates this source of risk, leaving other risk exposures. The risk of the futures replication strategy is not surprisingly dominated by credit and agency spread risk, while MBS spread risk and volatility risk (which largely reflects the optionality of MBS) are also significant. Interestingly, using futures introduces idiosyncratic risk, reflecting the basis risk between cash and futures instruments. Spread risk factors are expressed relative to swaps, with the exception of Treasuries. Therefore, replicating credit or MBS using swaps reduces the forecast TEV attributable to swaps spreads, but leaves the TEV attributable to credit and MBS spreads unchanged.

The risk model forecasts a reduction in TEV of 3.3 bp by using TBAs to replicate the MBS portion of the Aggregate, compared to using swaps. Our empirical analysis showed only a reduction of 0.4 bp, however. This demonstrates the closer correlation between swaps and MBS during the past two years, than over longer periods during which the Risk Model was calibrated. This increased correlation therefore caused swaps to “perform” almost as well as TBAs over the period of our empirical study. Using both empirical analysis and a risk model to forecast replication tracking errors can therefore allow investors to view the effect of changes in correlations between instruments.[12]

The replication with futures, swaps, and TBAs is dominated by credit spread risk. Therefore, we would expect that CDS should improve the replication, as our empirical results show. We look forward to analyzing the impact of CDS on forecast risk when this instrument is incorporated into the Risk Model in the near future.

[12] Using an exponentially weighted, or a simple-weighted covariance matrix for ex-ante tracking errors, a choice that is available within POINT, can also allow for the impact of changing correlations on TEV.

REPLICATION DETAILS

A sample U.S. Aggregate replication portfolio is provided in Appendix 4, for a portfolio of notional size US$1billion as at July 31, 2004.

Rebalancing, Re-investment, and Transaction Costs

In our empirical studies, we assume that all positions are rebalanced monthly. In practice, most investors will make small adjustments monthly to positions to allow for the changing characteristics of the index and the aging of derivative positions. On a quarterly basis, futures will be rolled to prevent the exercise of the delivery option and swaps will be rolled into the "on-the-run" maturities. TBAs are rolled monthly to avoid pool delivery. New CDX instruments are created semi-annually, and we assume in our studies that a roll into the new instrument is executed with that same frequency.

During the period between the creation of new CDX instruments, it is possible that an issuer will be downgraded, causing it to fall out of the Credit Index (but remain in CDX). During this period, the investor may be subject to tracking error, as the performance of the "fallen angel" may not match that of the investment-grade credits. Based on an analysis of the historic performance of fallen angels, in the months following a fall below investment grade and the credit ratings of CDX, we estimate this risk to be 7 bp per month for the credit index.[13] However, this risk can be largely eliminated if the investor buys single-name default protection for the downgraded issuer.

An all-derivatives portfolio, by definition, does not require cash, outside of that needed to meet variation margin for futures or mark-to-market collateral calls for swaps. We assume in our study that cash is invested in 1-month LIBOR. In practice, investors will be required to deposit initial margin with the clearing firm,[14] which, for an Aggregate Index replicating portfolio, currently averages 1.3% of the notional portfolio amount. However, both this and any variation margin can be posted in the form of T-bills. As a result, only a small portion of funds will be invested below LIBOR in practice.

Transaction costs will depend upon the choice of strategy and the frequency of rebalancing. Figure 15 displays estimated transaction costs, assuming monthly rebalancing.

REPLICATING THE GLOBAL AGGREGATE (OR JUST THE U.S. PORTION)

This paper suggests that using a combination of strategies can achieve the lowest tracking error for replicating the U.S. Aggregate Index. Is this true for the Global Aggregate also?

[13] We discuss the performance of fallen angels and distressed bonds in *Portfolio and Index Strategies During Stressful Credit Markets*, January 2004

[14] Current CBOT initial margin requirements for 2-year, 5-year, 10-year, and long bond futures are $743, $810, $1,350, and $2,025 per contract, respectively

Figure 15. **Transaction Costs of Various Replication Strategies**

Replication Strategy	Cost (bp per month)
Futures	0.5
Swaps	0.3
Futures + Swaps	0.3
Futures + Swaps + TBAs	0.9
Futures + Swaps + TBAs + CDX	1.0

The answer to this question depends upon the choices of strategies in the various currency "blocks," and whether these are active or passive replication strategies.

Figure 16 suggests that the choice of replicating strategy in the U.S. may be correlated with the strategy used for managing the Euro Aggregate component (of the Global Aggregate). In Figure 16, we show the correlations between the return differences of two replicating strategies (versus benchmark) and returns on Euro credit (excess return) and Euro governments (price return). The return differences of the futures replication strategy turn out to be strongly negatively correlated with excess return to Euro credit. This is not surprising, since the risk from a futures-only replication strategy of the U.S. Aggregate is largely coming from credit (Figure 14); the short U.S. credit exposure is negatively correlated with long Euro credit. This may be attractive for an active European-based investor if the value-added generated is positively correlated with European credit excess returns (and therefore negatively correlated with the U.S. replication strategy). However, for many investors, a low correlation will be preferred, since the overall risk of the portfolio will be reduced, whether the investor is short or long Euro credit.

We have demonstrated that there is a modest improvement in tracking error contributed by replicating the U.S. MBS index with TBAs. It is likely that this improvement would be reduced further in a Global Aggregate-benchmarked portfolio, since the weighting of the MBS index is much smaller, and the higher tracking error associated with replicating the index with swaps is diversified away.

Different replicating strategies for the non-U.S. portions of the Global Aggregate will have different correlations with the U.S. replication. Figure 16 suggests that if Futures replication is used for the U.S. portion, there will be a significant positive correlation with a Euro replication strategy that is effectively short Euro credit (e.g., a Euro-futures replication strategy). Fortunately, there are replication strategies that a Global Aggregate manager can use to replicate the Euro-Aggregate that mirror the techniques we have discussed for replicating the U.S. Aggregate. In particular, portfolio CDS products such as iTRAXX can be used, together with interest-rate swaps, to replicate the Euro-credit index. A preliminary study by our European colleagues suggests that the use of iTRAXX, together with a portfolio of interest rate swaps, can reduce the tracking error associated with replicating the Euro-credit index, and they look forward to publishing a completed study shortly.

CHOICES AND CONCLUSIONS

There are various considerations in choosing the appropriate replication strategy. Portfolio constraints may ultimately determine the choice of strategy, perhaps restricting the investor to a futures-only strategy or a combination not considered herein (e.g.,

Figure 16. **Aggregate Replication Error (bp per month) in Two Different Sub-periods**

	Futures Replication	Full Replication
Correlation with Euro Credit Excess Return	-0.69	-0.02
Correlation with Euro Government Price Return	0.07	0.29

futures + TBAs). In the absence of client constraints, the investor's risk "utility function" (i.e., cost per unit of risk reduction) will determine the choice of strategy. If the degree of risk aversion is high, a total return swap may prove to be a desirable choice. However, for large replicating portfolios (e.g., above $300 million), sufficient liquidity may not exist to permit the use of an index swap for the entire portfolio.

The choice of replication method should not be considered in isolation but rather in combination with the overall strategy. It is not necessarily the case that the lowest TEV strategy is always preferable. For example, if the replication is part of a portable alpha strategy, the relationship of the expected return deviations from benchmark of various replication strategies should be considered relative to the expected alpha of the strategy. A replication strategy for the Aggregate Index using treasury futures will outperform during times of widening spreads and underperform in the opposite environment. The correlation of this performance pattern to the alpha strategy may actually make this a more attractive option than a replication strategy that, by itself, has a lower tracking error. The choice of replication strategy to be used for the MBS Index will depend upon whether the entire Aggregate index is being replicated or just the mortgage component.

The data we possess for credit default swaps limit the period over which we have been able to conduct this study. Nevertheless, the sample size (25 monthly observations) is large enough to give statistical significance to the key findings of this article. We look forward to further investigation of replication strategies as more data are made available.

This article has considered various replication strategies and noted the diversification benefits from combining replication techniques. We welcome inquiry from investors with specific index replication questions.

Bibliography of Relevant Lehman Research Publications

1. *Replicating Index Returns with Treasury Futures*, November 1997
2. *The Global Aggregate: Return Replication with Derivatives*, September 2000
3. *Replication with Derivatives: The Global Aggregate Index and the Japanese Aggregate Index*, March 2001
4. *Tradable Proxy Portfolios for the Lehman Brothers MBS Index*, July 2001
5. *The Replication of the Lehman Global Aggregate Index with Cash Instruments*, August 2001
6. "*Hedging and Replication of Fixed Income Portfolios*," March 2002, *Journal of Portfolio Management*
7. *Replicating Index Returns with Treasury Futures: Duration Cells versus Key-rate Durations*, July 2004
8. *The Lehman Brothers Swap Indices*, January 2002
9. *Swaps as a Total Return Investment*, April 2003
10. *Simulating Portable Credit Strategies with CDS and Mirror Swap Indices*, October 2003
11. *Credit Derivatives Explained,* March 2001

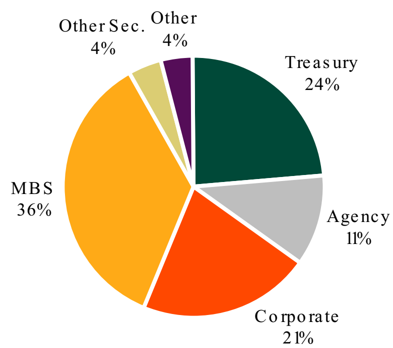
All publications quoted may be accessed from the Quantitative Portfolio Strategy site under Global Strategy on Lehman*Live,* except 6 (*Journal of Portfolio Management*) and 10,11 (Lehman Quantitative Credit Research).

APPENDIX I THE LEHMAN U.S. AGGREGATE INDEX

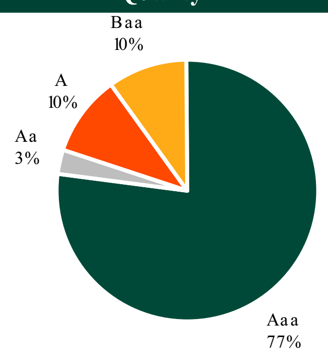
Overview

The U.S. Aggregate Index contains U.S. dollar-denominated securities that qualify under the index's rules for inclusion (see below). Inclusion is based on the currency of the issue, and not the domicile of the issuer. The principal asset classes in the index are Government, Credit (including corporate issues), and Securitised bonds. Securities in the index roll up to the US Universal and Global Aggregate Indices. The U.S. Aggregate Index was launched on January 1, 1976.

Sector



Quality



Access to the Index

Index Client Website **www.lehmanlive.com** **KEY FEATURES**	◆ Index and constituent-level data ◆ Performance time series ◆ Index turnover reports ◆ Fully customisable views ◆ Standardised market structure reports ◆ Guides to indices and portfolio strategies
Bloomberg Page LEHM **Tickers for Key Data Series**	◆ Total Return Index Value: LBUSTRUU ◆ Market Value: LBUSMVU ◆ Yield to Worst: LBUSYW ◆ Mod. Adj. Dur. (Returns Universe): LBUSRMD ◆ Average OAS: LBUSOAS ◆ Maturity: LBUSMAT
POINT (Portfolio and Index Tool) **Accessible for selected clients via** **www.lehmanlive.com** **KEY FEATURES**	◆ Performance attribution ◆ Market structure reports ◆ Index constituents ◆ Portfolio upload/analysis ◆ Multi-factor global risk model ◆ Tracking error optimiser ◆ Automated batch processing ◆ Fully customisable

Pricing and Related Issues

Frequency	Daily, on a T+1 basis. If the last business day of the month is a holiday in the U.S. market, then prices from the previous business day are used.
Timing	3:00 pm New York time.
Bid or Offer Side	Outstanding issues are priced on the bid side. New issues enter the index on the offer side.
Sources	Lehman trading desks
Methodology	Multi-contributor verification: The Lehman price for each security is checked against a blend of alternative valuations by our quality control group. Variations are analyzed and corrected, as necessary.
Reinvestment of Cashflows	Index cashflows are reinvested at the start of the month following their receipt. There is no return on cash held intra-month.

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Rules for Inclusion

Amount Outstanding	$250 million as of July 1, 2004
Quality	A minimum bond level rating of Baa3 from Moody's Investors Service or BBB- from Standard & Poor's Ratings Group.
	◆ The lower of the two agencies' ratings is applied for qualification purposes ◆ Where a rating from only one agency is available, that rating is used to determine the bond's index rating ◆ Unrated securities are included if an issuer rating is applicable ◆ Unrated subordinated securities are included if a subordinated issuer rating is applicable
Maturity	◆ One year minimum to final maturity on dated bonds, regardless of put or call features ◆ Undated securities are included in the index provided their coupons switch from fixed to variable rate. These are included until one year before their first call dates, providing they meet all other index criteria
Seniority of Debt	Senior and subordinated issues are included. Undated securities are included provided their coupons switch from fixed to variable rate.
	The following types of fixed to variable-rate security structures will also qualify for the index ◆ If the holder has the option to force the issuer to issue preference shares post the call date ◆ If there are other economic incentives for the issuer to call the issue, such as the removal of tax benefits after the first call date
	Fixed rate perpetual capital securities which remain fixed rate following their first call dates, and which provide no economic incentives to call the bonds, are excluded.
Currency of Issue	US dollars
Market of Issue	US public debt market
Security Types	**Included:** ◆ Fixed rate bullet, puttable and callable ◆ Soft bullets **Excluded:** ◆ Bonds with equity-type features (e.g., warrants, convertibility to equity) ◆ Private placements are excluded ◆ Floating rate issues

Rebalancing Rules

Frequency	Statistic (projected) Universe: Daily. Returns Universe: Monthly, on the last business day of the month.
Methodology	During the month, all indicative changes to securities are reflected in both the statistics (projected) universe and returns universe on a daily basis. This would include changes to ratings, amounts outstanding, or sector. These changes affect the qualification of securities in the statistics (projected) universe on a daily basis, but only affect the qualification of bonds for the returns universe at the end of the month.
Timing	Qualifying securities issued, but not necessarily settled, on or before the month-end rebalancing date qualify for inclusion in the following month's returns universe.

APPENDIX II REPLICATING THE LEHMAN MBS INDEX[15]

Mortgage securities constitute a significant portion of the Lehman Brothers Aggregate Index and the Lehman Global Aggregate Index (35.5% and 14.2% of market value, respectively, as of September 30, 2004). To track these indices, it is desirable to take exposure to the U.S. mortgage market. To some global investors, the U.S. mortgage market is enigmatic and intimidating because of its arcane terminology and highly variable cash flows. However, while achieving outperformance in this market indeed requires considerable knowledge and experience, the MBS Index is surprisingly easy *to track*.

The Lehman MBS Index consists of tradable fixed-rate mortgage pass-through securities, and is limited to conforming pools guaranteed by the U.S. government (Ginnie Mae) or by government-sponsored enterprises (Fannie Mae and Freddie Mac). In lieu of buying a pool, an investor can buy a TBA (to-be-announced) contract that is a forward contract to buy MBS pools of a given agency/program and coupon. The specific pools that the investor is buying are unknown until two days before settlement. Because it is a forward contract, no cash outlay is required until settlement. For example, in October 2004, an investor could agree to buy a 30-year FNMA 5.5% TBA for delivery and settlement on November 15, 2004. The investor could choose to take delivery of the security, or roll the TBA, by selling the same TBA prior to settlement date, and purchasing a TBA for December delivery. By purchasing a portfolio of TBAs, an investor can maintain exposure to the MBS market without ever taking delivery of any pools.

Generally, buyers and sellers of TBA contracts on current production mortgage coupons implicitly assume average attributes of the pools likely to be delivered. In other words, a TBA contract corresponds to a large pool of recently issued loans or a current production index composite. Because there is ample supply of new production to deliver against the TBA contract and little prepayment history to help identify pools with potentially highly idiosyncratic prepayment behavior, it is likely that a current coupon TBA contract will closely track the current production index composite.

TBAs offer two key advantages to investors. First, they are suitable for an all-derivative mortgage-replication strategy, since no cash outlay is required. Second, the TBA-strategy greatly simplifies back-office processing because there is no physical delivery of pools, and there are therefore no monthly interest and principal payments. There are some disadvantages also. A change in the prepayment quality of TBA deliverables versus the rest of the MBS market can lead to underperformance of TBAs, even if the investor rolls their TBAs from month-to-month. Since the seller of a TBA has the option to deliver any mortgage pool, he will generally deliver the least attractive pool, which is reflected in the pricing of TBAs. The investor can also at times earn significant return from rolling TBAs due to imbalances in the current month's supply and demand for a particular mortgage coupon.

A detailed description of the construction of TBA portfolios to replicate the MBS Index is provided in the paper on "Tradable Proxy Portfolios for the Lehman MBS Index," listed under the bibliography. We currently supply index-replicating TBA portfolios to a number of investors on a monthly basis.

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[15] This appendix is based on the paper "Tradable Proxy Portfolios for the Lehman MBS Index" (see bibliography)

APPENDIX III CREDIT DEFAULT SWAPS[16]

The primary purpose of credit derivatives is to enable the efficient transfer and repackaging of credit risk. Our definition of credit risk encompasses all credit related events ranging from a spread widening, through a ratings downgrade, all the way to default. In their simplest form, credit derivatives provide a more efficient way to replicate in a derivative form the credit risks that would otherwise exist in a standard cash instrument. For example, a standard credit default swap can be replicated using a cash bond and the repo market. Alternatively, a cash credit instrument can be replicated by combining a credit default swap with the fixed receipt of an interest-rate swap.

A default swap is a bilateral contract that enables an investor to buy protection against the risk of default of an asset issued by a specified **reference entity**. Following a defined **credit event**, the buyer of protection receives a payment intended to compensate against the loss on the investment. This is shown in Figure 17. In return, the protection buyer pays a fee. Usually, the fee is paid over the life of the transaction in the form of a regular accruing cash flow. The contract is typically specified using the confirmation document and legal definitions produced by the International Swap and Derivatives Association (ISDA).

Some default swaps define the triggering of a credit event using a **reference asset**. The main purpose of the reference asset is to specify exactly the capital structure seniority of the debt that is covered. The reference asset is also important in the determination of the recovery value should the default swap be cash settled. In many cases, following a default, the protection buyer will deliver a defaulted security for which they will receive par from the protection seller. Additionally, the maturity of the default swap need not be the same as the maturity of the reference asset. It is common to specify a reference asset with a longer maturity than the default swap.

CDX.NA.IG is a static portfolio of 125 equally weighted credit default swaps on 125 North American reference entities, that are rated investment grade, and is available in a range of maturities. Every six months a new set of CDX instruments is created, though existing instruments will continue to trade. Like individual CDS, they are unfunded instruments. A credit event triggered by a reference asset will be settled by the physical delivery of a deliverable defaulted security in exchange for par. By combining CDX with a portfolio of interest rates swaps (receiving fixed), it is possible to replicate, in unfunded form, the exposures of a portfolio of cash credit instruments

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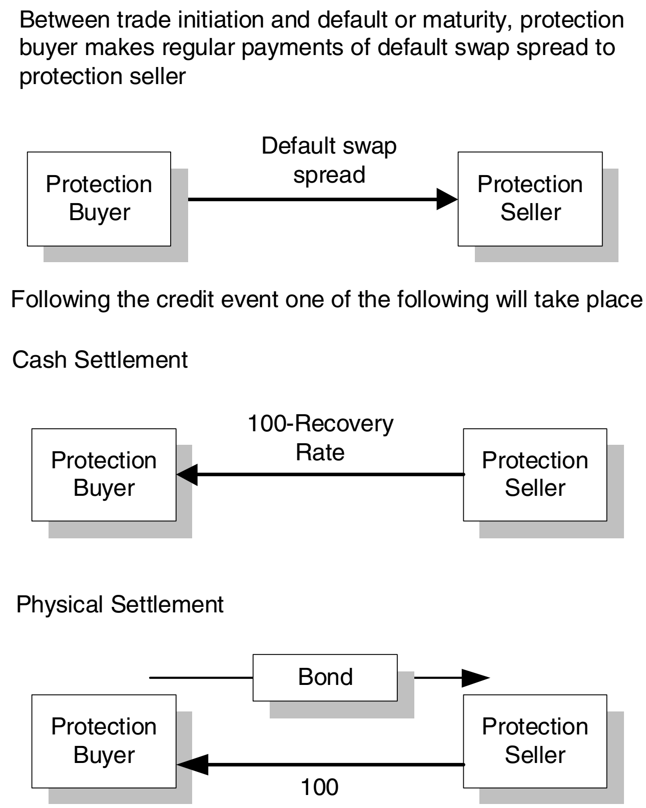
[16] This appendix draws on material from the Lehman publication "Credit Derivatives Explained"

Figure 17. **Mechanics of a Default Swap**



APPENDIX IV REPLICATING PORTFOLIO AS AT JUL-31ST 2004

Sector Cash	Identifier	Position Amount	Description	Coupon	Maturity Date
	USD	$1,000,000,000	CASH - U.S. Dollar		
Sector: FUTURES (4 positions)					
	TUU4:CBT	$98,800,000	2 year Treasury Notes		
	FVU4:CBT	-$1,800,000	5 year Treasury Notes		
	TYU4:CBT	$75,800,000	10 year Treasury Notes		
	USU4:CBT	$42,700,000	30 year US Treasury Bonds		
Sector: INTEREST_RATE_SWAP (6 positions)					
	IRD_9327	$72,227,000	IRSwap USD 1.965 LIBOR 6M		1/31/2005
	IRD_9332	$144,781,000	IRSwap USD 3.087 LIBOR 2Y		7/31/2006
	IRD_9335	$135,037,000	IRSwap USD 4.199 LIBOR 5Y		7/30/2009
	IRD_9338	$67,731,000	IRSwap USD 4.99 LIBOR 10Y		7/30/2014
	IRD_9341	$21,536,000	IRSwap USD 5.535 LIBOR 20Y		7/30/2024
	IRD_9344	$16,971,000	IRSwap USD 3.0 LIBOR 30Y		7/30/2034
Sector: MORTGAGES (2 positions)					
	FNC044QG	$43,608,833	FNMA Conventional Interm. 15yr	4.5	
	FNC050QG	$39,688,972	FNMA Conventional Interm. 15yr	5.0	
	FNC054QG	$13,946,931	FNMA Conventional Interm. 15yr	5.5	
	FNC060QG	$18,488,638	FNMA Conventional Interm. 15yr	6.0	
	FNA054QG	$42,630,967	FNMA Conventional Long T. 30yr	5.5	
	FNA060QG	$38,007,295	FNMA Conventional Long T. 30yr	6.0	
	FNA064QG	$54,389,948	FNMA Conventional Long T. 30yr	6.5	
	FGB050QG	$31,962,198	FHLM Gold Guar Single F.30yr	5.0	
	FGB054QG	$27,945,910	FHLM Gold Guar Single F.30yr	5.5	
	GNA064QG	$22,404,484	GNMA ISingle Family 30yr	6.5	
	GNA060QG	$13,129,784	GNMA ISingle Family 30yr	6.0	
	GNA054QG	$1,961,961	GNMA ISingle Family 30yr	5.5	
	GNA050QG	$10,934,080	GNMA ISingle Family 30yr	5.0	
Sector: CREDIT DEFAULT SWAPS (2 positions)					
	CDX.IG 2/09	$167,429,000	CDX Investment Grade 5yr #2		9/20/2009
	CDX.IG 2/14	$76,671,000	CDx Investment Grade 10yr #2		9/20/2014

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Publications-L. Pindyck, B. Davenport, W. Lee, D. Kramer, R. Madison, A. Acevedo, T. Wan, M. Graham, V. Monchi, K. Banham, G. Garnham, Z. Talbot