

Tradable Proxy Portfolios for the Lehman Brothers MBS Index

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SUMMARY

- We propose two strategies for the replication of the Lehman Brothers MBS Index. Both strategies invest in highly liquid MBS securities and are easy to implement and maintain. Neither strategy requires detailed knowledge of the U.S. mortgage market, yet they track the index very closely.
 - Unlike other bond indices, the MBS Index contains only non-traded *generics* or annual aggregates. A replicating proxy portfolio, on the other hand, contains only tradable MBS securities (pools or TBA contracts). The performance of these securities may differ from that of their respective annual aggregates, creating a potential for added tracking error in replication techniques that are formulated in terms of generics. The replication strategies we present minimize this added tracking error.
 - The TBAs-Only strategy constructs tradable proxy portfolios of TBA contracts. This strategy simplifies back-office processing because there is no physical delivery of pools. The historical simulation of this strategy from January 1994 through May 2001 invested, on average, in 11 TBA contracts and produced a realized tracking error of about 21 bp/year.
 - The Large Pools-Only strategy buys large pools of current mortgage production and allows some of them to season in the tradable proxy portfolio. Over time, the proxy matches the seasoning composition of the index increasingly well. The realized tracking error declines as the number of holdings grows steadily. On average, over the study period, the strategy invested in 44 pools and produced a realized tracking error of 15 bp/year. As the proxy portfolio seasons, the tracking error (measured over the last two years of the study period) goes down to 5 bp/year.
 - To investigate the relative importance of holding a larger number of issues versus having seasoned pools, we limit the number of issues in the Large Pools-Only strategy to twelve. This “Max12 Large Pools-Only” variant also produced a tracking error of 15 bp/year, proving that the key to improved tracking is matching the seasoned part of the index.
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INTRODUCTION

Mortgage securities constitute a significant portion of the Lehman Brothers Aggregate Index and the Lehman Global Aggregate Index (35.0% and 16.5%, respectively, as of May 31, 2001). To track these indices, one must take exposure to the U.S. mortgage market. To some 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 purpose of this study is to investigate how investors with limited MBS knowledge can replicate the MBS Index. We design and evaluate two relatively simple replication strategies that invest in highly tradable and liquid MBS securities and do not require detailed knowledge of the U.S. mortgage market.

Why would knowledge of the MBS market be necessary for index replication? After all, replication means tracking the index, not outperforming it. Investors who want to replicate an index can use sampling and optimization techniques to identify a set of index securities that will track the index with an expected tracking error. Such an exercise does not require detailed knowledge of the market. Investors simply buy the selected set with the expectation that its performance will track, with some degree of error, the performance of the overall index.

However, going from identifying a set of securities to actually buying it is not trivial in the case of the MBS Index. Unlike most other indices, the MBS Index contains only non-traded annual aggregates (their creation is discussed below). The first step in the replication process selects these index generics to form a tracking proxy portfolio. Then a second step is necessary: one or more tradable securities must be purchased for each generic to form the *tradable* proxy portfolio. Suppose the replication strategy selects the 1997 GNMA 8% index generic. There are many 1997 GNMA 8% pools to choose from, and there is no assurance that a particular pool selected for the tradable proxy portfolio will perform identically to the generic suggested by the replication technique. This additional layer of decision-making (*i.e.*, pool selection) and the potential for added tracking error from performance mismatch can make investors who are new to the MBS market uneasy about replicating the MBS Index.

We propose the following solution to this problem. First, we identify MBS securities that are likely to track their respective index generics. Next, we discuss which of these MBS securities are “tradable,” *i.e.*, bought and sold easily. Finally, we constrain the replication strategy to select only from among those generics for which tradable securities likely to track their performance exist. This approach improves the chances that the tradable proxy portfolio will track the performance of the generics proxy portfolio constructed by the replication technique. In this study, we measure the empirical success of this approach in replicating the MBS Index. We believe that the results should convince investors with little mortgage market knowledge that they can replicate the MBS Index without too much concern about pool selection.

We develop and evaluate two replication strategies that use this approach. The first strategy uses only TBA contracts. Holding only TBAs simplifies the back-office

operational aspects of investing in mortgages because it avoids taking physical delivery of MBS pools. However, the TBAs-Only strategy replicates only the recently originated part of the MBS market. The risk is that the seasoned portion of the MBS Index may behave differently, leading to tracking error. Better tracking of the index is achieved by the second replication strategy. This strategy uses only large MBS pools and, over time, represents the seasoned part of the index, as well as new issuance.

As we demonstrate below, both replication strategies use only MBS securities that are sufficiently liquid to make the replication feasible and practical. Both strategies are also easy to implement and maintain. Neither of the strategies presupposes that the investor has detailed knowledge of the MBS market. We show that both strategies deliver fairly low tracking errors relative to the index while reducing the risk of additional tracking error due to pool selection.

GENERICIS, POOLS, AND TBA CONTRACTS

Index generics are composites of tradable MBS securities (pools) defined by three characteristics: agency/program (*e.g.*, 30-year FNMA Conventional); origination year of the underlying mortgages (*e.g.*, 1996); and coupon (*e.g.*, 7.5%).¹ Pools are mapped to a generic according to these characteristics. For example, pool FN #512677 is a FNMA 7.5% passthrough security containing 30-year mortgage loans originated in 1999. This pool is mapped to the 1999 30-year FNMA 7.5% index generic. If an annual aggregate satisfies the liquidity constraint of Lehman's Global Family of Indices (currently at \$150 million remaining outstanding balance) it is included in the MBS Index. Currently, there are hundreds of thousands of pools, but only about 3200 annual aggregates. Out of these, 533 formed the Lehman MBS Index as of May 31, 2001.

To replicate the MBS Index, the investor must buy either specific pools or TBA (to-be-announced) contracts. The buyer of an MBS pool is entitled to the monthly interest and principal paydowns. The magnitude of these monthly payments depends on the prepayment behavior of the individual mortgages underlying the pool.

In lieu of buying a pool, an investor can buy a TBA 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 December 2000, an investor could agree to buy a 30-year FNMA 7.5% TBA for delivery and settlement on January 16, 2001.² On the trade date, the TBA buyer does not know the origination year, originator, WAM, or WAC³ (and many other attributes) of the pool(s) he will receive. The seller has an option to deliver any mortgage pool(s) to satisfy a TBA contract and usually delivers the least attractive pool(s) he can find.⁴

Generally, but not always, the seller will deliver pools containing recently originated mortgages, as these mortgages often have the worst prepayment characteristics. If mortgage rates fall, it is relatively easy and inexpensive for a homeowner to refinance a recently originated mortgage compared with a seasoned mortgage. On the other hand, if mortgage rates rise, a homeowner with a new mortgage might be less likely to move and prepay the loan compared with a homeowner with a seasoned mortgage who has lived in his house for some time. Also, because there is little prepayment history on new

¹ For a detailed discussion of the construction, pricing, and return calculations for Lehman Brothers MBS Index generics, refer to "MBS Index Returns: A Detailed Look," by L. Dynkin, J. Hyman, V. Konstantinovskiy, and N. Roth in *The Journal of Fixed Income*, Vol. 8, No. 4, March 1999.

² Delivery dates are specified at the time of purchase. Most follow dates set by the Bond Market Association (formerly called the PSA).

³ A pool may contain loans from a single originator or multiple originators. GNMA I pools contain loans from only a single originator. WAM is the weighted average of the remaining terms to maturity of the mortgage loans underlying the pool using the balance of each mortgage as the weighting factor. WAC is the weighted average of the gross interest rates of the loans underlying the pool. WAM and WAC are important determinants of a pool's proclivity to prepay in various interest rate environments.

⁴ This is why a mortgage pool of a given agency/program and coupon will not trade at a price less than the TBA price.

mortgages, market participants may discount them a bit more until their prepayment behavior is better understood. Because a TBA seller will likely deliver pools containing recently originated mortgages, TBA contracts and same-coupon pools of recently originated mortgages usually have the same price. Pools that trade at TBA prices are referred to as “TBA pools,” and pools that trade at a higher price are referred to as “seasoned” or “non-TBA pools.” As of April 1, 2001, the MBS Index was divided between TBA and seasoned issues (by percent market value) as shown in Figure 1.

A pool may trade at the TBA level for a period and then trade at a “pay-up” to the TBA price. For example, a 30-year FNMA 6.5% pool containing mortgages originated in 1999 currently trades at a pay-up of 7/32 to TBA 30-year FNMA 6.5%_s. A pool may trade back at the TBA level after trading at a pay-up for a period of time. Pools trade at a pay-up as they age, or if they have other valuable attributes that are different from the new pool production. Depending on the market environment, the percent of the MBS market that trades as TBA varies over time, as does the pay-up level for seasoned pools. Consequently, TBA contracts and TBA pools may not track the performance of many index generics, particularly seasoned ones.

TBA contract buyers can postpone accepting pool delivery by “rolling” their TBA positions month-to-month. Rolling works as follows. Before the upcoming settlement, the TBA buyer contacts the seller and asks for the “drop” in price to delay settlement one month.⁵ If agreeable, the buyer and seller “offset” the upcoming sale and enter into a new purchase/sale contract for the next month at the (lower) price determined by the drop. The advantage of rolling is in simplifying the buyer’s operations requirements, because no monthly interest and principal payments from pools must be collected and reconciled. In addition, because no cash is required in the TBA purchase until settlement, some TBA buyers may invest cash in high-yielding short-term instruments to earn additional return.

⁵ Settlement can be delayed for more than one month, but usually not more than three. The drop is usually positive, as mortgage yields are generally greater than one-month rates. However, mortgage rolls can occur at negative drops.

Figure 1. **The Lehman Brothers MBS Index Composition by Market Value %, April 1, 2001**

	30-Yr Conv	30-Yr GNMA	15-Yr & Balloons	Total
Priced at TBA Level	25.6	10.5	4.8	41.0
Non-TBA or Seasoned	<u>33.5</u>	<u>12.3</u>	<u>13.2</u>	<u>59.0</u>
Total	59.2	22.8	18.0	100.0

IDENTIFYING TRADABLE MBS SECURITIES LIKELY TO TRACK INDEX GENERICS

Irrespective of the replication technique (*e.g.*, optimization or stratified sampling, discussed below), the investor must hold some combination of MBS pools and TBA contracts to track the MBS Index. Unfortunately, there is no guarantee that these tradable MBS instruments will track their respective index generics. Potential performance differences between pools and TBA contracts and their generics should be taken into account when evaluating the tracking error of any replication strategy.

As an example, consider how a specific pool can differ from its index generic. MBS pricing services generally price all MBS pools of a given agency/program, coupon, and origination year at the same level. However, the timing of their cash flows may be very different depending on the prepayments of the mortgage loans underlying each pool. Of course, even similar pools are unlikely to have identical prepayments. But the difference in prepayments due purely to random noise averages out over time. However, pools belonging to the same index generic can have materially different characteristics (*e.g.*, WAC, geography, originator, and average loan balance). Prepayment differences resulting from these could persist. Consider the following two 1997 30-year GNMA 8% pools that are mapped to the same 1997 30-year GNMA 8% index generic (Figure 2).

Because the pools are priced identically, the large difference in performance (60 bp) is due to differences in prepayments. For the twelve-month period shown, pool #435461 had faster prepayments than pool #436112. The difference was probably due to an originator's aggressive buyout activity.⁶ Because the latter pool is a premium security, faster prepayments were a drag on total returns. Even though buyouts may not persist, the potential for additional tracking error is clear.

⁶ Mortgage servicers have the option to purchase, at par, loans from a GNMA mortgage pool once the loans have become three months delinquent. These purchases tend to occur in pools trading above par and show up as prepayments. It is profitable for servicers to purchase these loans at par, cure the delinquencies, and then resell the re-performing loans as another pool at a higher price.

Figure 2. **Comparison of Two 30-Year 8% GNMA Pools Mapped to the Same Index Generic (GNA08097*), December 1, 2000**

	Pool GN #436112	Pool GN #435461	GNA08097
Coupon	8%	8%	8%
WAC	8.5%	8.5%	8.5%
WALA	37 months	35 months	41 month
3mo CPR	0.0%	60.5%	16.5%
6mo CPR	0.0%	48.6%	14.7%
12mo CPR	3.1%	31.2%	14.2%
Original Balance	\$2.53 million	\$2.02 million	\$12,830 million
Geography	44% OH; 11% FL	50% MI; 24% OH	N/A
Total Return (12/99-11/00)	8.73%	8.13%	8.58%

* GNA08097 refers to the 1997 30-year GNMA 8% index generic. For a complete description of MBS Index notation, refer to "MBS Index Returns: A Detailed Look" (see footnote 1).

Other reasons for noticeable prepayment differences among pools: geographic differences (one part of the country has faster housing turnover than another), loan size (smaller loans are less likely to be refinanced than larger loans because of the fixed costs involved in refinancing), and pool-level diversification (a small pool with fewer loans may be more prone to idiosyncratic prepayment behavior than a large pool).

As discussed above, an index generic is a composite of all its mapped tradable MBS pools. If similar pools can perform differently from each other, then a pool can perform differently from its generic.

Compare these two pools with their index generic. Prepayments (and total returns) for the generic were somewhere between those for the two pools. Not only can similar pools perform differently from each other; they can perform differently from their index generic. This fact makes MBS Index replication somewhat challenging because there is no assurance that a tradable MBS instrument will perform accordingly to its index generic. Nevertheless, might there be some tradable MBS instruments that are likely to track their index generics? If so, we can more confidently use replication techniques to form efficient tradable proxy portfolios.

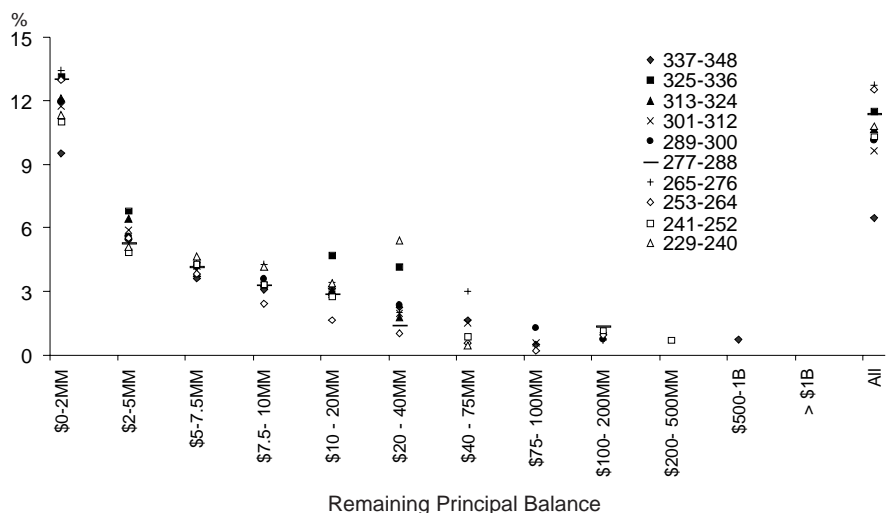
USING POOLS TO TRACK INDEX GENERICS

The GNMA 8% example above may give investors pause when assuming that their pools will perform identically to their index generic. Pools in the tradable proxy portfolio may not track the performance of the generic assumed by the replication technique. What pools might reasonably be expected to track their generic? Pricing is usually not the issue because pools of a given vintage are priced the same as the generic.⁷ The main issue is the timing of cash flows due to prepayments. If the pool size is large enough, will it behave like the “average?” Will a \$50 million pool track the performance of its generic more closely than a \$5 million pool? Because a pool contains a sample of mortgages drawn from the population of mortgages of a given coupon range, it seems reasonable to expect that increasing the pool (*i.e.*, sample) size increases the chance that the pool will track the generic (*i.e.*, population) closely.

How well do large pools track their generics? We examine the 1-year CPR across all 35,000+ 30-year FNMA 7.5% pools as of December 1, 2000. We present the standard deviations of 1-year CPR percentages across pools, sorted by WAM group and current pool balance. As Figure 3 shows, the standard deviation declines as pool size increases. Figure 4 demonstrates that the mean 1-year CPR is roughly constant for each WAM irrespective of the pool size. Finally, Figure 5 shows that the range of 1-year CPR declines as the pool size increases. For a given WAM group, the range shows the 1-year CPR difference between the pool with the greatest 1-year CPR and the pool with the smallest 1-year CPR.

⁷ This may not always remain so. The market does distinguish between low-WAC and high-WAC and low-loan-balance and high-loan-balance pools of a given vintage. Pricing services may follow.

Figure 3. **The Standard Deviation of 1-Year CPR for Different WAM Ranges, December 1, 2000**



If large pools (both seasoned and recently issued) tend to track closely the “average” (*i.e.*, generic) pool, then a strategy of buying pieces of large pools may be an effective way to build a tradable proxy portfolio. While large pools are a small percentage of the total number of pools, they are well represented by the percentage of remaining principal balance. As shown in Figure 6, for example, in the WAM range of 337-348 months, the \$500 million-\$1 billion bucket accounts for 14.2% of the total principal

Figure 4. **The Mean 1-Year CPR for Different WAM Ranges**
December 1, 2000

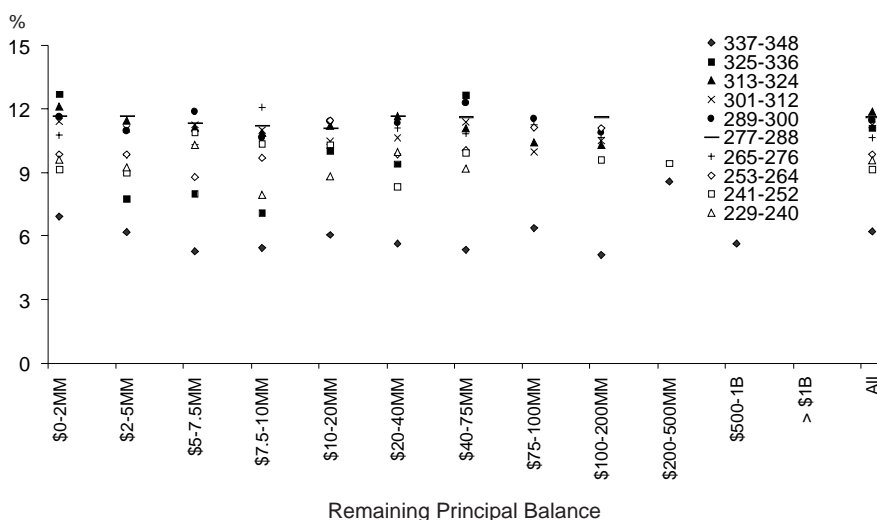


Figure 5. **The Range of 1-Year CPR for Different WAM Ranges**
December 1, 2000

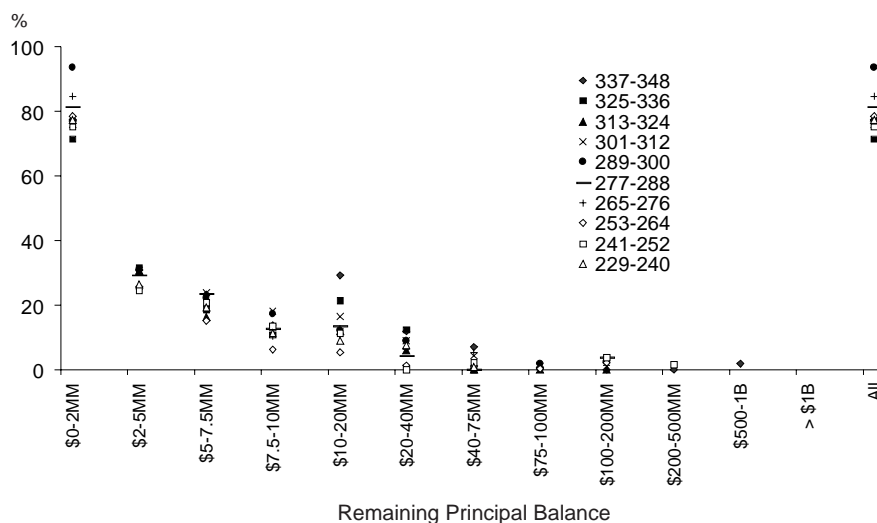
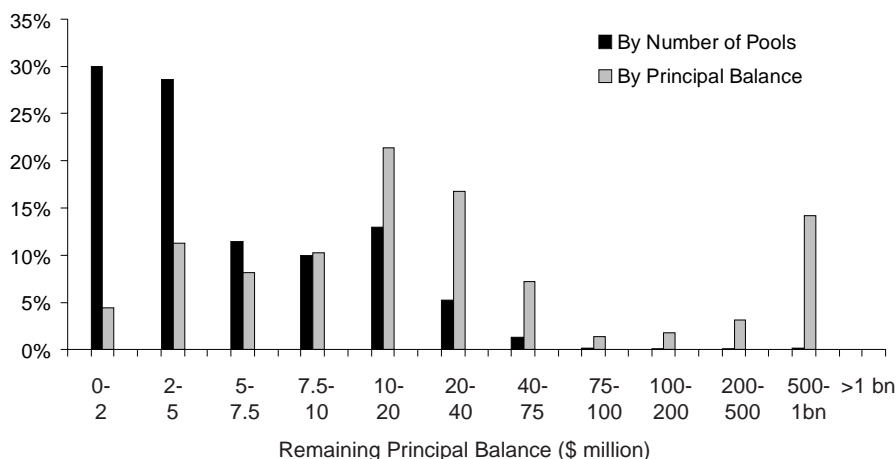


Figure 6. **Percentage of Total Pools and Total Remaining Principal Balance by Pool Size for the 337-348 WAM Range**
December 1, 2000



balance but is represented by just six pools, or 0.2% of the total number. Consequently, buying large pools to replicate index generics is a viable strategy.

Another advantage of this strategy is that a considerable portion of the index is composed of seasoned generics, as shown in Figure 1. In theory, large seasoned pools could be used to track the seasoned generic component of the index, which would help reduce the proxy portfolio's overall tracking error. In practice, however, large seasoned pools are often difficult to find in the marketplace. Consequently, buying pieces of large pools to replicate seasoned index generics is a difficult strategy to implement, and any proposed replication strategy using large pools must account for this difficulty.

USING TBA CONTRACTS TO TRACK INDEX GENERICS

Generally, buyers and sellers of TBA contracts on current production mortgage coupons implicitly assume average attributes (*e.g.*, WAC and average loan size) 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 generic. 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 generic.⁸

Although prices for current-coupon TBA contracts and recently originated index generics are usually identical, one potential source of performance difference between them is the TBA roll. At times, TBA holders are able to pick up additional return by rolling the settlement of TBA contracts at an “implied financing rate” from one month to the next and investing the unused cash in a higher-yielding short-term asset. The implied financing rate is essentially what the rolling TBA holder (also known as the roll “seller”) pays to entice someone else to use capital to take delivery this month and allow the roll seller to postpone delivery. One can derive the implied financing rate using an arbitrage argument. The holder of a TBA contract can either take delivery or roll the TBA position to the next month. If the holder takes delivery, they will use cash to settle the trade and will receive MBS pools and the monthly cash flows (coupon, principal prepayments, and any reinvestment income) from these pools. The monthly rate of return expected by the pool holder is determined by these cash flows and next month’s TBA price (which reflects the roll drop).

Alternatively, by rolling the TBA position to the next month, holders agree to settle the trade at the next month’s TBA price (including the drop) and will hold onto the cash. If the TBA buyer rolls, then someone else takes pool delivery. The monthly rate of return earned by the pool holder is the implied financing rate that the roller of the TBA position foregoes, or “pays,” for deferring settlement. This implied financing rate is essentially the no-arbitrage rate that must be earned on cash to make the TBA buyer indifferent between taking delivery and rolling the position. If the rate actually earned on cash is greater than the implied rate, then the roll offers a return advantage.

It is important to note that an investor using TBA contracts to replicate the MBS Index is affected by any change in the prepayment quality of the TBA deliverable even if the investor never takes delivery. As the market fluctuates, there may be a change in the assumed TBA deliverable. The new deliverable underlying the TBA in the proxy might have different convexity properties from the old deliverable. When the old TBA deliverable was a good tradable proxy security for recent production

⁸ It is still possible for TBAs to diverge from the current index generic. The TBA contract more accurately reflects what is likely to be delivered in the near future. Over the course of a year, some characteristics of the TBA deliverable might change (*e.g.*, WAC and average loan balance) as changes occur in mortgage originations. The current annual generic, on the other hand, reflects the year’s *cumulative* production. Nevertheless, buying a current-coupon TBA contract and rolling it from month to month is likely to track current production index generics quite well.

generics in the index, the new deliverable may not be. To the extent that the characteristics of the TBA deliverable depart from recent production generics used in the replication, the proxy portfolio's *ex post* (realized) tracking error may exceed the *ex ante* (expected) tracking error. In particular, this problem is most likely to arise with "off-market" TBA contracts.

The TBA roll offers the potential for additional returns that can enhance performance of a TBA mortgage portfolio. This advantage arises from imbalances in the current month's supply and demand for a particular mortgage coupon. Mortgage originators often sell their current production to broker/dealers a month or two in advance (which reflects the time between the mortgage commitment and the mortgage closing). Consequently, broker/dealers are usually long current production coupon MBS in the forward months. To entice MBS buyers to defer taking delivery until a forward month in which the broker/dealer has more supply, the level of the drop adjusts to offer a roll advantage. As a result of these supply and demand dynamics, a roll advantage often exists only for current production coupons. At other times, there is no roll advantage at all. Even if there appears to be a roll advantage, care must be taken to verify that the implied financing rate was correctly estimated and interpreted.

First, the implied financing rate may be less than the current short-term rates because the market is expecting rate reductions (*e.g.*, Federal Reserve actions). The implied financing rate of the mortgage roll applies for the period between two PSA settlement dates. Investors usually agree to roll well before this period begins. Consequently, to measure the roll advantage, investors must compare the implied rate with the proper forward short-term investment rate.

Second, in addition to the drop level, estimating the implied financing rate requires assumptions about prepayments, reinvestment rate, and the type of MBS pool likely to be delivered at the termination of the roll. As discussed above, it is typically assumed that the TBA deliverable is the same at the beginning and at the end of the roll. In other words, the MBS security in the hold strategy is comparable with the underlying TBA deliverable in the roll strategy. This last component of the implied financing rate calculation is sometimes overlooked. The underlying characteristics of pools likely to be delivered against a TBA contract change over time. For example, the FNMA 6% deliverable into the TBA contract in January 2001 may be very different from the FNMA 6% deliverable in April 2001 because there was much new production of FNMA 6% pools during the first calendar quarter of 2001. New production FNMA 6% pools have significantly higher WACs and WAMs (*i.e.*, worse convexity characteristics) that make them less valuable than older production. As the market fluctuates, the assumption as to what type of MBS pool will likely be delivered changes and is reflected in the dollar roll market. In fact, the original TBA seller may temporarily offer a particularly attractive roll level just to ensure that TBA holders continue rolling at least until the new (less desirable) supply becomes available. Consequently, any roll advantage needs to be adjusted, if appropriate, for the expected change in the quality of the pool deliverable. A reported roll advantage may just be fair compensation for rolling into a less valuable TBA deliverable.

Still, the roll advantage can, at times, offer significant added return. However, in this study, we do not calculate and add a roll advantage to the TBA proxy portfolio returns. Our focus is on the tracking error of the proxy portfolio to the MBS Index. Any roll advantage will mostly produce an improved mean return for the proxy, not an improved tracking error. Furthermore, many investors try to enhance the roll advantage by assuming additional credit and option risk in their short-term cash investments. While this strategy often has merit, it deviates from the pure index replication strategies we focus on in this study.

To keep the replication strategy simple and less dependent on detailed MBS market knowledge, we assume that only current-coupon TBA contracts track the relevant recent origination index generic used by the replication technique. While off-market TBA contracts may also track their generics, we disqualify them from the tradable proxy portfolio because they require more detailed MBS market knowledge than assumed by these replication techniques. Consequently, a replication strategy using TBA contracts produces a tradable proxy portfolio containing only current-coupon TBAs.

Off-market TBA contracts occur when there have been large changes in mortgage interest rates. For example, suppose that several years ago, 9% coupon mortgages were current production. Subsequently, interest rates declined, and no new 9% coupon mortgages have been originated since. Today, an investor might still be able to buy a 9% TBA contract and expect the contract to track the respective 9% index annual aggregate for the most recent year of issuance. However, as we argue below, off-market TBA contracts have a greater potential than current-coupon TBA contracts for not tracking their respective index generic.

Off-market-coupon TBA contracts have their own price dynamics depending on expectations of future mortgage supply, the trading positions of the TBA seller, and technical conditions in the marketplace. By definition, there is little or no new pool production for off-market coupons. However, sellers of off-market TBA contracts must be prepared for the possibility that the TBA buyer who is currently rolling his contracts may decide to take delivery. Because there is no new pool production, the seller runs the risk of having difficulty finding pools to satisfy the TBA contract. The possibility of being caught short can make broker/dealers reluctant to continue rolling off-market TBA contracts. In fact, in response to this risk, there may come a time when the TBA seller may want to encourage the investor to take delivery by offering an unattractive drop level. The TBA seller may also do this because he has received or located some off-market pools that have unattractive prepayment characteristics that he would like to deliver. Given the availability of prepayment history and the likelihood that the more desirable pools may be locked up in other portfolios, the off-market coupon pools available for delivery will probably be those least attractive to hold, with potentially high idiosyncratic risk compared with the relevant index generic. If the TBA buyer takes delivery because the roll advantage is no longer positive, the pools he receives may not track the relevant index annual aggregate.

Another problem with off-market TBA contracts is that the underlying deliverable can change more dramatically. If the investor bought and rolled an off-market TBA contract and interest rates subsequently changed so that market participants began to anticipate future production of the coupon, the TBA contract would begin to track the characteristics of anticipated future production. Depending on how long ago the coupon was last produced and the structural changes in the mortgage market, the differences in the old and new production for the coupon could be substantial. In addition, depending on movements in mortgage rates, this change can happen relatively suddenly. Consequently, investors must monitor the characteristics of anticipated mortgage production and compare it with the assumptions underlying their off-market TBA contracts. Investors must also be prepared to re-examine the structure of the proxy portfolio, as the TBA position may no longer track the index generic assumed by their replication techniques.

TWO TRADABLE MBS REPLICATION STRATEGIES: DESIGN, CONSTRUCTION, AND EMPIRICAL PERFORMANCE

We have identified two tradable MBS instruments likely to track index generics: large pools and current-coupon TBA contracts. These instruments can be used in a tradable proxy portfolio to track the MBS Index. Unfortunately, there are limitations to this approach. First, large seasoned pools are often not available in the marketplace and, thus, cannot initially be part of a realistic tradable proxy portfolio. Second, current-coupon TBAs adequately track only recently originated generics. With these limitations in mind, we consider two strategies for constructing proxy portfolios. We then compare the historically simulated empirical performance of these strategies with the MBS Index.

While there are several key differences between both strategies, some of the mechanics of constructing proxy portfolios are the same. At the end of each calendar quarter, a mortgage proxy portfolio is constructed using the Lehman Brothers multi-factor risk model and its portfolio optimizer.⁹ (There are other ways to construct proxy portfolios. Stratified sampling can be applied to divide the index into orthogonal buckets, and securities can be selected using linear programming techniques so as to match the curve, convexity, and sector risk of the index.¹⁰ Another technique is to purchase total return swaps on the Lehman MBS Index.)

The optimization process begins with the creation of a “seed” portfolio that contains just one manually selected generic (while, theoretically, the seed may be anything, careful selection of the first security will make the optimization path more straightforward). Next, an investable set, *i.e.*, a set of securities acceptable for inclusion in the portfolio, is chosen. Once this set is selected, the optimizer begins an iterative process, known as gradient descent, searching for market value-neutral, one-for-one swap transactions that will minimize the expected tracking error. The securities in the swap pool are ranked in terms of reduction in tracking error per unit of each security purchased. The model indicates which bond, if purchased, will lead to the steepest decline in tracking error, but leaves the choice of the trade to the investor. Once a bond has been selected for purchase, the optimizer offers a list of recommended candidates to sell (with the optimal transaction size for each pair of bonds), sorted in order of achievable reduction in tracking error. Investors are free to adjust the model’s recommendations, either selecting different bonds to sell or adjusting recommended trade amounts.

As a result, at each rebalancing, the optimizer selects index generics from a specified available set to form a proxy portfolio with the minimum possible expected tracking

⁹ For a detailed description of the model, refer to *The Lehman Brothers Multi-Factor Risk Model*, Lehman Brothers, July 1999. The model uses historical variances and correlations of risk factors (covariance matrix) to translate structural differences between the proxy portfolio and index benchmark into an expected tracking error.

¹⁰ “Replicating the MBS Index Risk and Return Characteristics Using Proxy Portfolios,” Lehman Brothers, March 1997.

error versus the Lehman MBS Index. The resulting proxy portfolio is held for the next three months, and its monthly total returns are compared with the returns on the index. At the end of the next calendar quarter, the proxy portfolio is rebalanced (*i.e.*, “re-optimized”) by selling issues in the old proxy and buying new issues in the current available set to produce a new proxy that minimizes the expected tracking error. The optimizer uses risk sensitivities and historical variances and correlations of risk factors available at the time of rebalancing. The rebalancing process is constrained to allow additions to existing holdings only if they are included in the current available set. This constraint ensures that the two strategies are replicable by the investor.

“TBAs-Only” Strategy

The first strategy builds a proxy portfolio of current-coupon recently issued generics. The investor can then buy a tradable proxy portfolio of current coupon TBAs with the expectation that the TBAs will track the performance of the generics. As the composition of the new issue mortgage market changes over time, this strategy adjusts its holdings of TBA contracts so as always to reflect the most recent and active portion of the mortgage market. For example, if two years ago, high-coupon mortgages were predominantly issued, then at that time, the tradable proxy portfolio would contain TBAs on high coupons. If low-coupon issuance dominates today, the replication process will have gradually led to the replacement of high-coupon TBAs with low-coupon TBAs.

The basket of current-coupon recently issued generics is optimized to minimize the expected tracking error relative to the MBS Index. Specifically, the available set for the TBAs-Only strategy is defined as the set of index generics with at least \$2.5 billion outstanding and a WAM of at least 348 months (for the 15-year product, the constraints are \$1 billion outstanding and a WAM of at least 168 months). Motivation for these constraints is explained below. Every three months, at each rebalancing period, the optimizer considers recently originated index generics in the available set for the proxy portfolio. Index generics for coupons not recently issued in sufficient volume are ineligible. Under this replication strategy, the tradable proxy contains only actively traded TBA contracts. Once a year, the existing proxy portfolio is purged and an entirely new proxy portfolio of index generics is constructed. If, as is likely, some of the generics in the old proxy remain in the available set, then the new proxy may contain generics that had been purged. This annual purging simply ensures that the proxy portfolio contains only current-coupon generics. The corresponding tradable proxy portfolio will, therefore, contain TBA contracts that are likely to track the performance of the generics assumed by the optimizer.

“Large Pools-Only” Strategy

The second strategy builds a proxy portfolio of generics, both seasoned and recent origination. The investor then buys portions of large MBS pools for the tradable proxy portfolio with the expectation that large pools will track the performance of the generics. In practice, however, because tradable large seasoned pools are difficult to find, we assume that large pools can be bought initially only as new originations. Consequently, this strategy assumes that the proxy portfolio initially contains only recently issued generics and that a portion of these holdings remains in the portfolio and seasons over time.

Specifically, the available set for the Large Pools-Only strategy is defined as the set of index generics with at least \$5 billion outstanding and a WAM of at least 336 months (for the 15-year product, a WAM of at least 156 months). The large amount outstanding and recent WAM requirements ensure that an investor will be able to obtain large pools for the proxy portfolio.¹¹

Initially, the Large Pools-Only proxy portfolio contains generics selected from among all agency/programs and coupons of recent origination. This is similar to the TBAs-Only strategy. By the next rebalancing, the proxy generics will have aged, but because the tradable proxy pools are large and will track their generics as they both season, the seasoned generics remain eligible for the rebalanced proxy portfolio. This is in contrast to the TBAs-Only strategy, which purges its proxy portfolio once a year. The new Large Pools-Only proxy is chosen from among the existing generics, as well as recent originations (as was done initially). However, *additions* to an already-held issue are still allowed, but only if that issue is in the current available set. This strategy allows large, diverse, and seasoned pools to remain in the proxy portfolio while minimizing pool-specific risk. At each rebalancing, new large pools are added to keep up with new additions to the index. A drawback of this approach is that the proxy portfolio initially tracks the index only as well as the TBAs-Only strategy presented above. It takes time for positions in large seasoned pools to reduce tracking error further.

The Available Sets

A key difference between the two replication strategies is the definition of their available sets. The criteria for the respective available sets differ so that each strategy's tradable proxy portfolio contains securities likely to track generic performance assumed by the replication technique.

The available set for the TBAs-Only replication strategy consists of index annual aggregates with a WAM of 348 or higher and an amount outstanding of at least \$2.5 billion.¹² The magnitudes of these constraints guide the replication technique to select only those index generics for which there are current coupon TBA contracts. The \$2.5 billion amount outstanding restriction prevents the replication technique from selecting an index annual aggregate for which there is very little new tradable

¹¹ How can investors obtain large current production pools? There are many ways. First, investors can ask broker/dealers for their inventory of pools and then select pools (or a portfolio of pools) that are likely to behave close to the "average" pool. For example, each month, there is usually a FNMA "major" pool (or the FHLMC "auction" pool) that is the largest FNMA pool for a given coupon created that month. Broker/dealers may have a piece of this pool in inventory. Second, investors could combine many small pools into a single large pool (sometimes called a "mega" or "giant" pool). This is a straightforward process that occurs regularly as firms try to reduce operations costs. Third, when buying TBA contracts with the intention to take delivery, buyers can make "stipulations." For example, when buying 30FN7.5%, buyers could stipulate that they wish to receive pools that have a remaining principal balance of \$20 million or more. Fourth, investors could stipulate that they wish to receive no fewer than x pools in an effort to get overall pool diversification. One drawback of this approach is the increased operations effort compared with receiving a portion of a single very large pool. Not surprisingly, such "stips" often require a modest pay-up to TBA. It is not always the case, though, especially not for recent origination, to which we constrained the optimization.

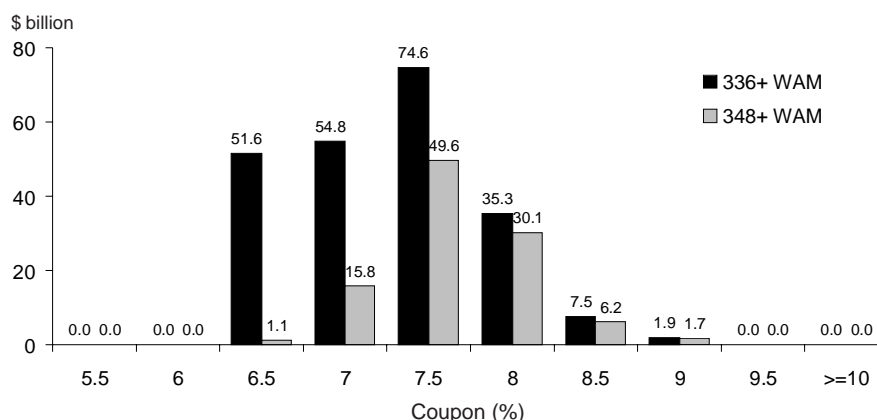
¹² For brevity, we discuss in detail only the constraints on 30-year FNMA generics.

production. Figure 7 shows that as of December 31, 2000, the 6.5% and 9.0% 30-year FNMA index generics with a WAM of 348 or higher had small amounts outstanding. While TBA contracts on FNMA 6.5% and 9.0% coupons were available in the market, the TBAs-Only strategy considers them off-market coupons and less likely to track their index generic. The \$2.5 billion restriction keeps the optimizer from selecting such off-market generics for the proxy portfolio. If, during the quarter, production increases in these two coupons, then they may become part of the available set the following quarter. As Figure 7 shows, given the magnitude of new production by coupon, the \$2.5 billion constraint is not very restrictive.

The TBAs-Only strategy also has a WAM restriction of 348 or higher. As with the \$2.5 billion liquidity constraint, the WAM restriction ensures that the replication technique selects only current-production index generics so that the TBA contracts in the tradable proxy portfolio will track their performance. In reality, the TBA market may track shorter WAM generics from time to time, so the 348+ WAM constraint in the replication might be too conservative. However, over the past few years, the mortgage market seems to treat even moderately seasoned product differently from TBAs.

The available set for the Large Pools-Only strategy differs from the TBAs-Only strategy's in both WAM and amount outstanding. For the Large Pools-Only strategy, the goal is to have the optimizer select only those index generics for which it is possible to obtain large pools. While large pools of seasoned product are hard but not impossible to find, the Large Pools-Only strategy conservatively assumes that an investor can consistently find only large pools with a WAM of 336 or higher. The Large Pools-Only strategy could have used the higher WAM constraint in the TBAs-Only strategy with little impact on the overall results. As the Large Pools-Only strategy allows pools to season in the proxy portfolio, initially buying pools with a 348+ WAM rather than a 336+ WAM would make little difference in the

Figure 7. **Distribution of Amount Outstanding by Coupon**
December 31, 2000



tracking error performance of the strategy over time. The larger amount outstanding constraint of \$5 billion is imposed so that there is sufficient production of the 336+ WAM generics to make it likely that large pools are available. As Figure 7 shows, the 9.0% 30-year FNMA index generic with a 336+ WAM had an amount outstanding of less than \$5 billion. To be conservative, the Large Pools-Only strategy assumes that an investor would be unlikely to find large pools for this coupon. Overall, the WAM and amount outstanding constraints ensure that the tradable MBS proxy portfolio contains securities likely to track generic performance. Of course, whenever an investor is able to find large pools of shorter WAMs, the tracking error of the Large Pools-Only strategy will improve faster.

Construction of Proxy Portfolios

To develop a clearer understanding of these two strategies, let us examine them in action. Beginning with the identification of the available set for each strategy, we then describe the construction of their generic proxy portfolios at the study's beginning point of December 31, 1993. Finally, we show how the portfolios are rebalanced three months later, on March 31, 1994.

It is useful to start by discussing the interest rate environment at the time at which we begin the historical examination of the two strategies. Figure 8 shows the time series of the 30-year current-coupon mortgage yield from 1992 through 2000. By the end of 1993, current coupon mortgage yields reached a cyclical low having declined roughly 400 bp, more or less steadily, over the prior five years.

As Figure 9 shows, by December 1993, the MBS Index had a fairly even distribution of coupons. The higher coupons (*e.g.*, 8%, 8.5%, 9%, and 9.5%) were originated many years earlier, which is reflected in the shorter average WAM for these coupons. As of December 1993, these higher-coupon mortgages were rapidly being refinanced into lower-coupon mortgages (*e.g.*, 6%, 6.5%, 7%, and 7.5%) which is reflected in the higher average WAM for these coupons.

Figure 8. **30-Year FNMA Current-Coupon Mortgage Yield, 1992-2000**



For the TBAs-Only strategy, Figure 10 shows the distribution of amounts outstanding by coupon, as of December 31, 1993, for the FNMA index annual aggregates with a 348+ WAM. The bulk of new production was in the 6.5%, 7%, and 7.5% coupons, with amounts outstanding of \$20 billion, \$43.3 billion, and \$16.9 billion, respectively. Consequently, the December 31, 1993, available set for the TBAs-Only strategy contained FNMA 1993 6.5%*s*, 7.0%*s*, and 7.5%*s*. Overall, FNMA index generics with a 348+ WAM constituted 31.9% of all 30-year FNMA*s* in the MBS Index.

Figure 9. **30-Year FNMA: Distribution of Amount Outstanding and WAM by Coupon, December 31, 1993**

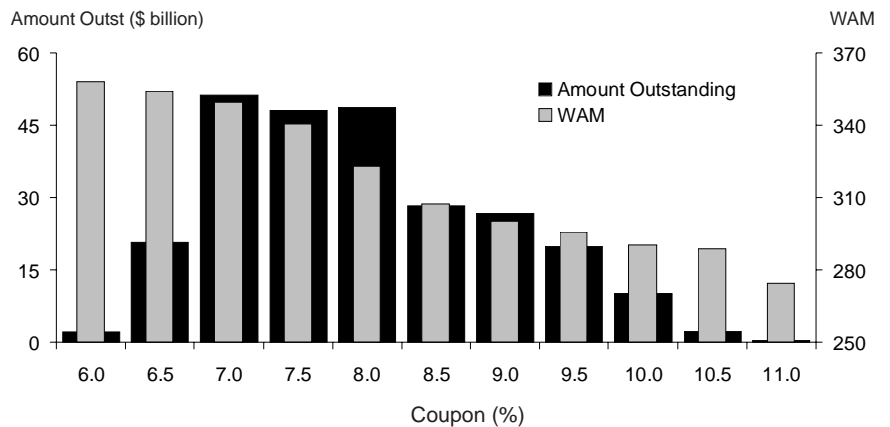
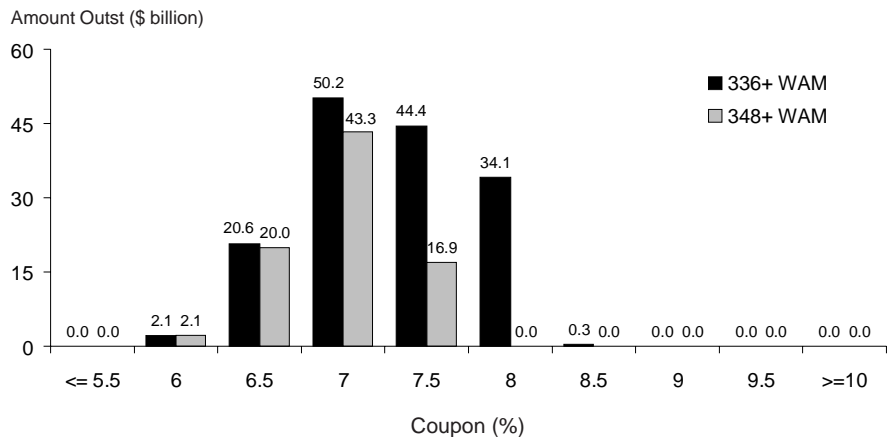


Figure 10. **30-Year FNMA (336+ and 348+ WAM): Distribution of Amount Outstanding by Coupon, December 31, 1993**



For the Large Pools-Only strategy, Figure 10 also shows the coupon distribution, as of December 31, 1993, for FNMA annual aggregates with a WAM of 336 or higher. The lower WAM constraint allows the higher coupons issued in 1992 to be included in the available set. Because these higher coupons were issued relatively recently, the Large Pools-Only strategy assumes that an investor could obtain portions of large pools for these WAMs. Consequently, the 336+ WAM coupon distribution is skewed more to the right than the 348+ WAM coupon distribution. For the Large Pools-Only strategy, the available set as of December 31, 1993, contained FNMA 1993 6.5%s, 7.0%s, and 7.5%s (same as the TBAs-Only strategy above), plus 1992 7.0%s, 7.5%s, and 8.0%s. Overall, annual aggregates with a WAM of 336 or higher contributed 57.8% of all 30-year FNMAs in the MBS Index.

The complete available set for the TBAs-Only strategy on that date consists of eleven generics. Four of these generics were selected for the proxy portfolio. Both the available set and proxy portfolio are shown in Figure 11. Tradable TBA contracts were easily available for each of these four generics.

The available set for the Large Pools-Only strategy consists of nineteen generics. The risk model selected ten of these generics for the proxy portfolio. Both the available set and proxy portfolio are shown in Figure 12. Tradable large pools were available for each of these ten recent production generics.

For the historical evaluation of both strategies, we hold the proxy portfolios unchanged for the next three months. At the end of the following quarter, on March 31, 1994, we rebalance both proxies. In practice, the proxy portfolio can be rebalanced more frequently (*e.g.*, once a month). Monthly rebalancing would likely improve tracking, especially in such tumultuous periods as early 1994. When the proxy portfolio is rebalanced, issues in the old proxy are sold and new issues in the current available set are purchased to generate a new proxy that minimizes expected tracking error.

Figure 11. **Available Set and Proxy Portfolio for the TBAs-Only Strategy**
December 31, 1993

1993	6.5%	FNMA	30yr	
1993	7.0%	FNMA	30yr	
1993	7.5%	FNMA	30yr	
1993	6.0%	FNMA	15yr	
1993	6.5%	FNMA	15yr	Selected (14%)
1993	7.0%	FNMA	15yr	Selected (17%)
1993	7.5%	FNMA	15yr	Selected (37%)
1993	6.5%	GNMA	30yr	
1993	7.0%	GNMA	30yr	
1993	7.5%	GNMA	30yr	
1993	8.0%	GNMA	30yr	Selected (32%)

Figure 12. **Available Set and Proxy Portfolio for the Large Pools-Only Strategy**, December 31, 1993

1993	6.5%	FNMA	30yr	Selected (3%)
1992	7.0%	FNMA	30yr	Selected (4%)
1993	7.0%	FNMA	30yr	
1992	7.5%	FNMA	30yr	
1993	7.5%	FNMA	30yr	
1992	8.0%	FNMA	30yr	Selected (16%)
1993	6.0%	FNMA	15yr	Selected (9%)
1993	6.5%	FNMA	15yr	Selected (8%)
1992	7.0%	FNMA	15yr	
1993	7.0%	FNMA	15yr	
1992	7.5%	FNMA	15yr	
1992	8.0%	FNMA	15yr	Selected (28%)
1993	6.5%	GNMA	30yr	Selected (1%)
1993	7.0%	GNMA	30yr	Selected (3%)
1992	7.5%	GNMA	30yr	Selected (2%)
1993	7.5%	GNMA	30yr	
1992	8.0%	GNMA	30yr	
1993	8.0%	GNMA	30yr	
1992	8.5%	GNMA	30yr	Selected (26%)

As mentioned earlier, there is a difference in the rebalancing process between the two strategies. The Large Pools-Only strategy rebalances once a quarter, as described. For the TBAs-Only strategy, however, in addition to quarterly rebalancing, once a year (at the end of March) the proxy portfolio is purged and a completely new proxy portfolio is selected from the current available set. Many of the generics selected for the new proxy may be the same as those that were purged. The purpose of purging the TBAs-Only proxy is to prevent the accumulation of seasoned generics, because there are no TBA contracts that will track their performance.

Let's now move the clock ahead one calendar quarter to March 31, 1994. Note from Figure 8 that mortgage yields increased sharply since December 1993. As a result, the generics in the available set now include some higher coupons. Figure 13 shows that the new available set for the TBAs-Only strategy contains sixteen generics. Because this is the March quarter-end, the TBAs-Only proxy begins as an empty portfolio. The risk model selects four of these generics for the proxy portfolio (there are two new generics and two deleted generics).

On March 31, 1994, a new proxy portfolio is also generated for the Large Pools-Only strategy. Unlike the TBAs-Only strategy, the generics in the proxy are allowed to remain in the proxy portfolio. However, no new amounts can be added to the proxy portfolio unless those generics are in the available set. As of March 31, 1994, the available set for the Large Pools-Only strategy consists of twenty generics (four generics dropped from last quarter's available set and five new generics added). The risk model selects fourteen of these generics for the proxy portfolio (there are five new generics and one deleted generic). In this case, none of the new generics in the available set is selected for the proxy portfolio. Instead, the risk model takes advantage of the availability of slightly seasoned higher-coupon generics for the proxy portfolio. Both the available set and proxy portfolio are shown in Figure 14.

Figure 13. **Changes in the Available Set and Portfolio for the TBAs-Only Strategy, March 31, 1994**

Index Generics				Available Set		Portfolio		
				New	Drop	New	Drop	Keep
1993	6.00%	FNMA	30yr	√				
1993	6.50%	FNMA	30yr					
1994	6.50%	FNMA	30yr	√				
1993	7.00%	FNMA	30yr			√		
1994	7.00%	FNMA	30yr	√				
1993	7.50%	FNMA	30yr		√			
1993	5.50%	FNMA	15yr	√				
1993	6.00%	FNMA	15yr					
1994	6.00%	FNMA	15yr	√				
1993	6.50%	FNMA	15yr					√
1994	6.50%	FNMA	15yr	√				
1993	7.00%	FNMA	15yr					√
1993	7.50%	FNMA	15yr		√		√	
1993	6.50%	GNMA	30yr					
1994	6.50%	GNMA	30yr	√				
1993	7.00%	GNMA	30yr					
1994	7.00%	GNMA	30yr	√				
1993	7.50%	GNMA	30yr		√			
1994	7.50%	GNMA	30yr	√		√		
1993	8.00%	GNMA	30yr		√		√	

Figure 14. **Changes in the Available Set and Portfolio for the Large Pools-Only Strategy, March 31, 1994**

Index Generics				Available Set		Portfolio		
				New	Drop	New	Drop	Keep
1993	6.00%	FNMA	30yr	√				
1993	6.50%	FNMA	30yr					√
1994	6.50%	FNMA	30yr	√				
1992	7.00%	FNMA	30yr					√
1993	7.00%	FNMA	30yr			√		
1992	7.50%	FNMA	30yr			√		
1993	7.50%	FNMA	30yr					
1992	8.00%	FNMA	30yr		√			√
1993	6.00%	FNMA	15yr					√
1993	6.50%	FNMA	15yr					√
1992	7.00%	FNMA	15yr			√		
1993	7.00%	FNMA	15yr					
1992	7.50%	FNMA	15yr			√		
1992	8.00%	FNMA	15yr		√			√
1993	6.50%	GNMA	30yr		√		√	
1994	6.50%	GNMA	30yr	√				
1992	7.00%	GNMA	30yr	√				
1993	7.00%	GNMA	30yr					√
1994	7.00%	GNMA	30yr	√				
1992	7.50%	GNMA	30yr					√
1993	7.50%	GNMA	30yr					
1992	8.00%	GNMA	30yr		√			
1993	8.00%	GNMA	30yr			√		
1992	8.50%	GNMA	30yr		√			√

This rebalancing process occurs each quarter. The rebalancing example above shows that the TBAs-Only proxy portfolio will always contain a limited number of issues because it is designed to hold only current-production generics, enforced by the annual purging. Over the period from December 1993 to December 2000, the TBAs-Only proxy held an average of eleven generics. The number of generics in the proxy will fluctuate as new current-coupon generics emerge that mirror fluctuations in current-coupon mortgage yields.

The number of generics in the Large Pools-Only proxy tends to increase steadily as portions of seasoned generics are permitted to remain while new generics are added. By December 2000, the Large Pools-Only proxy contained 77 generics, having started with ten in December 1993. (Below, we discuss a variation on the Large Pools-Only strategy to limit the number of generics in the proxy portfolio.)

Empirical Performance of Replication Strategies

For both strategies, we examine the realized tracking errors from January 1994 through May 2001. We calculate the actual monthly returns for the proxy portfolio and compare them with the returns on the MBS Index. The results for both strategies are summarized in Figure 15. We chose to begin the historical simulation on December 31, 1993, which marked the beginning of a major directional change in interest rates and stress in the mortgage market. Including this period allows readers to examine the performance of the two strategies in a wider range of market environments.

Not surprisingly, the Large Pools-Only strategy had a lower annualized tracking error than the TBAs-Only strategy (15 bp vs. 21 bp). Graphs of the monthly performance differences versus the MBS Index for each strategy are presented in Figures 16 and 17. Both strategies experienced relatively large tracking errors in the first few months of the period, from January 1994 through March 1994. This was a period of tumult in the mortgage market, as the Federal Reserve reversed course and began a dramatic tightening of short-term interest rates. Once this period passed, the tracking error for both strategies improved. In addition, as of December 1993, the MBS part of the covariance matrix underlying the Lehman risk model was calibrated with only three months of historical data, which was too short a period to prepare the model for the sudden market shift in early 1994. This probably explains the relatively large performance differences between the proxy portfolios and the index during that period.

Figure 15. **Performance Summary (bp) for the MBS Index Replication Strategies, January 1994-May 2001**

	TBAs-Only	Large Pools-Only
Monthly Return Difference (Portfolio vs. the Index)		
Average	-1.2	0.2
Standard Deviation (Realized Tracking Error)	6.0	4.4
Minimum	-18.7	-9.2
Maximum	17.6	23.6
Realized Tracking Error (Annualized):	20.9	15.2

Now the risk model has almost a hundred months of history, covering a variety of market environments. Investors using the model today to construct replicating portfolios are unlikely to experience this phenomenon.

The variability in the monthly return differences for the Large Pools-Only strategy tends to dampen over time. This is not surprising because this proxy portfolio looks more and more like the underlying index as the proxy holdings season. In addition, the initial return deviation for the Large Pools-Only strategy is probably the worst-case result. Tracking could be improved if large seasoned pools were purchased at the outset of the replication strategy, as opposed to waiting for proxy securities to season. For example, if an investor commenced the Large Pools-Only strategy today and if a large pool of 1993 30-year GNMA 7%*s* became available, it could immediately be added to the proxy portfolio to improve tracking error. However, to be conservative, we measured historical performance assuming that seasoned large pools are not available at the commencement of the strategy.

Figure 16. **Monthly Return Difference (bp), TBAs-Only Strategy versus the MBS Index, January 1994-May 2001**

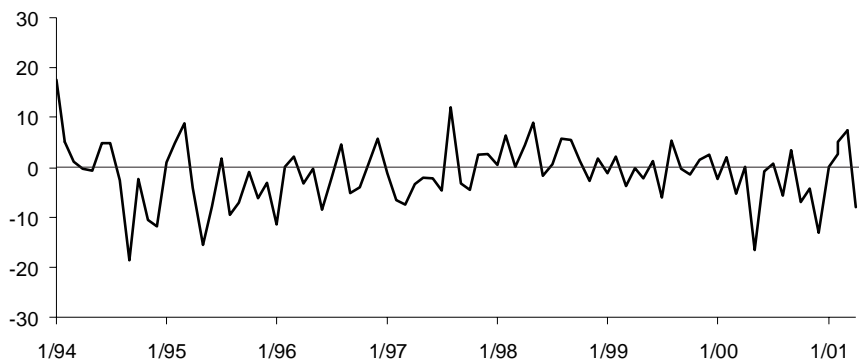
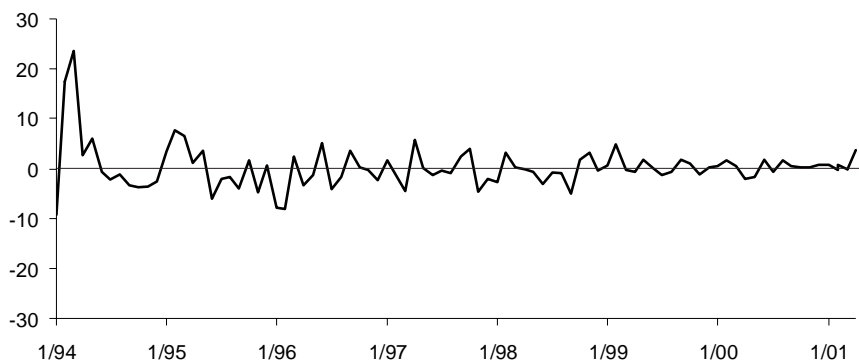


Figure 17. **Monthly Return Difference (bp), Large Pools-Only Strategy versus the MBS Index, January 1994-May 2001**



Over all, the Large Pools-Only strategy has annual realized tracking error that is 6 bp lower than that of the TBAs-Only strategy. This difference in tracking error is not surprising, as the two proxies gradually become very different. The Large Pools-Only proxy can hold large seasoned pools, and the number of bonds in the portfolio increases over time (Figure 18).

In contrast, the number of bonds in the TBAs-Only proxy remains relatively constant. It contains twelve bonds by May 2001. The number of issues in the TBAs-Only proxy tends to drop each March as the TBAs-Only proxy portfolio begins from scratch. The number of issues tends to increase as the mortgage current coupon changes and new actively traded TBA coupons become available. However, because the TBAs-Only strategy periodically culls off-market coupons, the number of issues in the proxy portfolio remains limited.

A more significant performance difference between the two strategies becomes apparent when the sample period is divided into two-year overlapping windows. Figure 19 presents these results.

Figure 18. **Number of Holdings in the Proxy Portfolio, TBAs-Only Strategy versus Large Pools-Only, December 1993-May 2001**

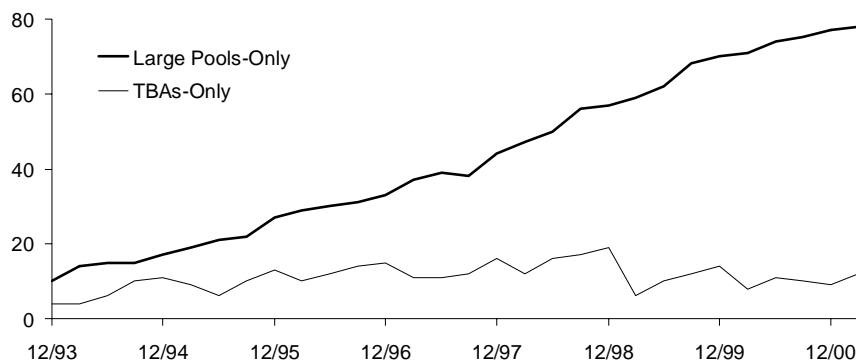


Figure 19. **Realized Tracking Error (Annualized) versus the Lehman MBS Index (bp)**
Two-Year Overlapping Intervals, January 1994-May 2001

Period	TBAs-Only		Large Pools-Only	
	Tracking Error	Avg # of Holdings	Tracking Error	Avg # of Holdings
Jan 94-Dec 95	28.0	8	25.1	17
Jan 95-Dec 96	20.2	11	14.7	25
Jan 96-Dec 97	17.4	12	12.5	33
Jan 97-Dec 98	16.8	14	9.5	43
Jan 98-Dec 99	12.2	14	7.3	55
Jan 99-May 01	18.3	11	5.1	69

Upon closer inspection, the relative performance of the two strategies becomes clearer. For the first two-year period, the realized tracking errors for the two strategies were comparable. This result is reasonable because the Large Pools-Only strategy has had relatively little time to add seasoned generics to the proxy portfolio. Thereafter, however, the realized tracking error of the Large Pools-Only strategy steadily improves relative to the TBAs-Only strategy, as the Large Pools-Only proxy becomes more and more similar to the index. The performance of the TBAs-Only strategy remains relatively constant as it tracks the recently issued portion of the index. For the final period, from January 1999 to May 2001, the Large Pools-Only strategy had a realized tracking error of only 5.1 bp, compared with 18.3 bp for the TBAs-Only strategy.

In the historical simulation of the two replication strategies, we chose not to limit portfolio turnover. Yet even in the absence of any restrictions, the Large Pools-Only strategy required, on average, a modest 7.5% turnover per quarter. The TBAs-Only strategy assumes rolling the whole position each month without ever taking delivery of pools, so there is really no comparable turnover measure.

Strategy Refinements (“Max12 Large Pools-Only” Strategy)

The number of issues in the Large Pools-Only proxy portfolio increases over time, whereas the number of issues in the TBAs-Only proxy is relatively static. For the period from January 1994 through May 2001, the Large Pools-Only proxy held, on average, 44 issues, whereas the TBAs-Only proxy held only eleven. Is the better tracking error performance of the Large Pools-Only strategy due mostly to the larger number of issues in the proxy portfolio, or is it due to the inclusion of seasoned pools in the proxy that better track the seasoned generics in the index?

To investigate the relative importance of having a larger number of issues versus including seasoned issues, we re-examined the Large Pools-Only strategy and limited the number of issues in the proxy to twelve. This strategy is labeled “Max12 Large Pools-Only.” The proxy construction methodology and the available set of generics from which the optimizer selects are unchanged.

Performance results for the Max12 Large Pools-Only strategy are presented in Figure 20 (and compared with the initial unconstrained variant).

Figure 20. **Performance Summary (bp) for Large Pools-Only Replication Strategies**, January 1994-May 2001

	Max12 Large Pools-Only	Large Pools-Only
Monthly Return Difference (Portfolio vs. the Index)		
Average	0.6	0.2
Standard Deviation (Realized Tracking Error)	4.4	4.4
Minimum	-9.2	-9.2
Maximum	24.4	23.6
Realized Tracking Error (Annualized):	15.2	15.2

Realized tracking error for the Max12 Large Pools-Only strategy is remarkably similar to that of the unrestricted Large Pools-Only strategy. This indicates that the better relative tracking error performance of the Large Pools-Only strategy over the TBAs-Only strategy is predominantly due to the presence of seasoned issues in the proxy portfolio and not to the much larger number of issues.

The two proxies have similar tracking errors for the entire period. However, there is a modest difference between the two strategies when the sample period is divided into two-year overlapping windows. These results are presented in Figure 21. As mentioned earlier, realized tracking errors for the Large Pools-Only strategy steadily decrease as the strategy ages. This pattern was expected because the portfolio begins to look more like the MBS Index over time. In contrast, while the realized tracking errors for the Max12 Large Pools-Only strategy also decline, they do so more unevenly and do not decline as far as the unconstrained strategy. Limiting the number of issues in the proxy portfolio seems to limit how low realized tracking error can go. While both strategies get the early and sustained benefit from the presence of seasoned issues in the proxy compared with the TBAs-Only strategy, the unconstrained Large Pools-Only strategy continues to benefit as the number of issues increases.

Figure 21. **Realized Tracking Error (Annualized)
versus the Lehman MBS Index (bp)**
Two-Year Overlapping Intervals, January 1994-May 2001

Period	Max12 Large Pools-Only		Large Pools-Only	
	Tracking Error	Avg # of Holdings	Tracking Error	Avg # of Holdings
Jan 94-Dec 95	26.2	12	25.1	17
Jan 95-Dec 96	13.8	12	14.7	25
Jan 96-Dec 97	9.5	12	12.5	33
Jan 97-Dec 98	7.2	12	9.5	43
Jan 98-Dec 99	8.6	12	7.3	55
Jan 99-May 01	7.7	12	5.1	69

MBS INDEX REPLICATION: CHALLENGES FOR THE FUTURE

As discussed above, an investor replicating the MBS Index faces the added difficulty of finding tradable MBS securities that track their respective index generic securities. This report argues that TBAs and large pools are likely to track their respective index generics and presents several replication strategies that historically would have offered low tracking errors versus the MBS Index. However, as with all financial markets, the behavior and structure of the MBS market continually evolves, and replication strategies must constantly be re-evaluated.

As an example, consider the following potential pattern emerging in the MBS market. As more loan-level detail and historical performance become available, investors have begun to examine mortgage loans more closely, looking for characteristics that may make them more valuable. For example, the data may show that mortgage loans with particularly low average loan balances are relatively slow to refinance when the opportunity arises compared with loans with high average loan balances. As investors begin to identify those mortgage loan characteristics (*e.g.*, WAC, geography, originator, and average loan balance) that make some loans less susceptible to prepayments, investors will seek out these loans for their portfolios.

How can investors obtain these loans? One way is to stipulate those desirable characteristics when buying pools from a broker/dealer. Another way is for investors to approach mortgage originators directly for loans having desirable attributes. Having purchased the loans for their portfolios, these investors may subsequently securitize the loans into agency pools, either for liquidity or for regulatory capital reasons. As a result of this securitization activity, these pools may become part of index generics. However, because these pools are locked up in portfolios, they are not available to other investors.

If this “skimming and securitization” activity picks up, the performance of many pools available in the market may diverge increasingly from their respective index generic. This divergence may take the form of systematic prepayment differences, and certain current production pools will likely trade at a pay-up to TBA. This would complicate the replication process, especially for the TBAs-Only strategy, because the underlying characteristics of the TBA deliverable will diverge from the current production index generics. In particular, the TBA position may be priced at an increasing discount to the respective index generic. In addition, the TBA position may become more negatively convex than assumed by the replication techniques that use generics. Both of these outcomes could cause a long-term TBAs-Only strategy to underperform the index and to have greater realized tracking error than what was expected from the replication technique.

The efficacy of the Large Pools-Only strategy will also be affected because large pools will be delivered from a reduced supply of available pools. Consequently, the large pools’ characteristics will also diverge from their generics. However, the situation may be less problematic for the Large Pools-Only strategy compared with the TBAs-Only strategy. The large pool size will continue to offer diversification advantages, especially if the large pool contains loans from multiple originators. The idiosyncratic risk

of a small pool could be greater than before if the available supply of pools has less desirable characteristics than the index generics. Another mitigating effect is that the Large Pools-Only strategy allows pools to season. To the extent that the prevalence of skimming gradually increases, the Large Pools-Only strategy will have the advantage of retaining seasoned pools acquired at the time when the skimming effect was less pronounced.

This potential change in the structure of the MBS market, as well as others that we may not foresee today, means that replication strategies cannot remain static but must continually adjust to remain relevant.

CONCLUSION

Replicating the Lehman MBS Index requires not only identifying the subset of generics that will track the index closely, but also choosing tradable MBS securities for the proxy portfolio that will, in turn, track their generics closely. This additional layer of decision-making and required market knowledge has a potential for creating additional tracking error and has deterred some investors from replicating the index on their own.

We present two strategies for the MBS Index replication: TBAs-Only and Large Pools-Only. The genesis for both strategies was the search for MBS securities likely to track their generics so as to reduce the contribution of pool selection to tracking error. TBAs track recently originated generics almost by definition, because a TBA implicitly assumes average attributes of pools likely to be delivered. Unfortunately, the TBA market is limited to recently issued coupons. Consequently, while TBAs track current coupons well, they will exhibit some tracking error when used to track the seasoned portion of the MBS Index. Yet, over all, the TBAs-Only strategy (that also has limited back-office requirements) produces relatively low realized tracking error of less than 21 bp per year.

The other strategy uses large-sized pools that tend to track their generics. While large pools for recent coupons are relatively easy to obtain, large seasoned pools are hard to find. Consequently, buying both large current- and seasoned-coupon pools is infeasible at the outset of a replication program. Instead, the Large Pools-Only strategy uses large pools for current coupons initially to replicate the index (similar to the TBAs-Only strategy). However, these pools are allowed to remain in the proxy and season, leading to increasingly closer tracking of the seasoned component of the index. Over time, this strategy tracks the index with less and less tracking error.

One potential drawback of the Large Pools-Only strategy is the steadily increasing number of pools in the proxy portfolio. However, the Max12 Large Pools-Only strategy demonstrates that the improved tracking performance of the Large Pools strategy is due primarily to the presence of seasoned issues in the proxy and not to a larger number of issues compared with the TBA strategy. Consequently, the Max12 strategy can be used if limiting the number of issues in the proxy portfolio is desired.

The chief merit of both strategies is that investors can effectively replicate the MBS Index without having detailed pool-level knowledge of the mortgage market. The relative simplicity of the two strategies may encourage some investors to attempt MBS Index replication on their own, rather than use an external manager.

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