# MBS Index Returns:
# A Detailed Look

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## Summary

- We explain returns calculations for the Lehman Brothers MBS Index, including
  - aggregation of individual mortgage pass-through pools into generic MBS used in the index,
  - pricing of the MBS generics,
  - conventions used to calculate returns on these generics, and
  - aggregation of security returns into index returns.
- We discuss issues that arise in computing returns on portfolios of mortgage pools and in comparing them to index returns.
- The appendix offers a mathematical formulation of the conventions used to calculate index returns of MBS.

## INTRODUCTION

Lehman Brothers produces and publishes a family of rules-based indices that covers a broad universe of fixed-income securities. Producing any index involves four basic steps. First, the set of securities that will compose the index at any given time is identified according to a fixed set of rules. All securities in the index are then priced using an appropriate combination of trader quotes and matrix-pricing techniques. Returns of all securities in the index are computed based on beginning and end-of-period prices as well as interim cash flows. Finally, the index return is calculated as a market-weighted average of individual security returns.

Although the same basic methodology is used in the production of all Lehman Brothers indices, the specific trading practices and conventions prevalent in each market need to be reflected in the calculation of index returns. In the case of U.S. mortgage-backed securities (MBS), a number of issues pose challenges at each step in the process.

The decentralized origination of mortgage debt leads to an unmanageably large number of investable securities or "pools." For the purposes of building an index, Lehman Brothers combines groups of similar pools to form a more manageable set of "generic" aggregates. Such an aggregation, while solving the problems caused by a large number of securities, raises the related issue of how to price this securities universe since obtaining quotes even for every generic (let alone every pool) on a daily basis is not realistic. Computing returns for mortgage-backed securities is also complicated by such unique characteristics of the mortgage market as once-a-month settlement, payment delays, and delayed reporting of pool factors. The task of aggregating individual securities into an index is further complicated by the staggered settlement dates and factor reporting dates throughout the month for different classes of MBS.

To deal with these issues, Lehman Brothers has developed a set of conventions that leads to a well-behaved index, with meaningful index returns and statistics, that facilitates combining MBS securities with government and corporate bonds into aggregate indices. The conventions and assumptions used in computing MBS index prices and returns are explained in this report. Mathematical calculations are provided in the Appendix.

To calculate returns on mortgage portfolios, investors have to face all the above intricacies and more. Various portfolio accounting systems have their own ways of dealing with the special characteristics of MBS securities. These differences in convention can make comparing portfolio and index returns difficult. The final section of this report focuses on issues specific to portfolio returns, with the goal of helping investors to understand their portfolios' performance against our MBS Index.

## AGGREGATING POOLS INTO MBS GENERICS

Currently more than half a million mortgage pools exist in the United States, making this universe so big that creating a pool-based index is not feasible. The investment characteristics of fixed-rate mortgage pools are relatively homogenous along such dimensions as issuer, program, coupon, and loan origination year. In addition, MBS market participants view most mortgage pools belonging to categories defined along these dimensions as fungible. As a result, an index based on such aggregates would adequately represent the mortgage market. Using aggregates in the index is possible because most mortgage pass-throughs trade on a generic basis. Investors typically place orders to buy and sell "Ginnie Mae 30-year 7s of 1996" or "Fannie Mae 15-year 6s of 1997" without specifying actual pools.

To create generic aggregates, pools are grouped along the three most important dimensions: agency/program (sector), coupon, and origination year. This creates a universe of approximately 3,200 generics, or annual aggregates.[1] These generics are then treated as individual securities for purposes of pricing and computing returns and statistics. The amount outstanding for each generic is set to the sum of the included pools; statistics such as weighted average maturity (WAM) and weighted average coupon (WAC) are market-weighted averages of the individual pool data. The Lehman Brothers MBS Index is then built from the mortgage generics using the same rules-based criteria as all other Lehman indices.[2]

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[1] Over the last full five-year period (1993-1997), this number has fluctuated between 3,185 and 3,551.
[2] See the Lehman Brothers report, *A Guide to the Lehman Global Family of Fixed Income Indices*, January 1998.

Each generic must have a total outstanding balance of at least $100 million and a remaining term of at least 12 months to be included in the MBS Index. Certain less liquid sectors, such as GNMA manufactured housing, buy-down, and graduated payment mortgages, are excluded from the MBS Index. Figure 1 lists MBS sectors and indicates whether they are currently included in the MBS Index.

Within each sector, pools are grouped first by pool coupon in increments of 0.250%. Thus the maximum pool coupon variation within each generic is limited to ±0.125% around the generic's coupon. Each coupon group is then segregated by origination year. A pool is mapped to an origination year based on the weighted average origination year of the underlying loans, not the year the loans were securitized to create the pool. This approach creates generics that are more homogeneous in prepayment characteristics, which depend on the underlying mortgages. It is especially important for relatively new pools composed of seasoned loans.

The resulting aggregates are then assigned 8-character identifiers called "generic cusips." The naming convention reflects the three dimensions along which pools are aggregated. The first three letters represent sector (see "cusip code" column in Figure 1). The three digits following represent coupon: the first two show the whole part of the coupon; the third digit shows the number of eighths and may be 0, 2, 4, or 6. Finally, the last two digits of the 8-character cusip show the origination year. Thus, FNC07497 denotes a 15-year Fannie Mae with a coupon of 7.5% issued in 1997.

Figure 2 shows the current composition of a single most liquid generic in each sector of the MBS Index. This figure highlights the vast differences in liquidity among sectors of the mortgage market. A single generic may be composed of several thousand pools in the most liquid sectors or a handful in the least liquid. The pools that compose a given generic may also exhibit significant diversity due to demographic, geographic, and other effects. For example, the average pool factor (fraction of original pool balance outstanding) for FNMA 7s of 1993 (FNA07093) is 0.698, but the standard deviation is 0.111, indicating that the factor for a given pool from this group could easily be below 0.6 or above 0.8.

For purposes of computing returns and other analytics, each pool is mapped onto a generic security to which it contributes its outstanding balance. The mapping of a particular pool to a generic may occasionally change over time. This is because every pool is backed by a large number of individual mortgage loans. While these loans will typically be fairly homogeneous, their origination dates are not necessarily all in the same calendar year. As the underlying loans prepay, each at its own rate, the average origination date for a given pool may

Figure 1. **Index Participation of MBS Sectors**

| Sector Code | Cusip Code | Sector Description | In the Index |
| --- | --- | --- | --- |
| Gna | GNA | GNMA I Single Family 30-years | yes |
| GNb | GNB | GNMA II Single Family 30-years | yes |
| GNc | GNC | GNMA Buydown 30-years | no |
| GNd | GND | GNMA I Graduated Payment 30-years | no |
| GNe | GNE | GNMA II Graduated Payment 30-years | no |
| GNf | GNF | GNMA I Single Family "Midget" 15-years | yes |
| GNg | GNG | GNMA II Single Family "Midget" 15-years | no* |
| GNh | GNH | GNMA Manufactured Home Class B 15-years | no |
| FHa | FHA | FHLM Cash Single Family 30-years | yes |
| FHb | FHB/FGB (gold) | FHLM Guarantor and Gold Single Family 30-years | yes |
| FHc | FHC/FGC (gold) | FHLM Guarantor and Gold FHA/VA 30-years | no* |
| FHd | FHD/FGD (gold) | FHLM Guarantor and Gold Single Family 15-years | yes |
| FHe | FHE | FHLM Cash Single Family 15-years | yes |
| FHf | FGF | FHLM 5-years Balloon | yes |
| FHg | FGG | FHLM 7-years Balloon | yes |
| FNa | FNA | FNMA Conventional Long Term 30-years | yes |
| FNb | FNB | FNMA Government Long Term 30-years | yes |
| FNc | FNC | FNMA Conventional Intermediate 15-years | yes |
| FNd | FND | FNMA 7-years Balloon | yes |

* These sectors are not explicitly excluded from index participation. However, there are currently no generics in these sectors with outstanding balances above the $100 million index threshold.

Figure 2.　**Most Liquid Generics in Each Sector of the MBS Index,** May 1998

| Code | Cusip | Sector Description | Outstanding ($ million) | Pools | Factors Avg. | St. Dev. |
|------|-------|--------------------|-------------------------|-------|--------------|----------|
| FNA | FNA07093 | FNMA Conventional Long Term 30-years | 36,315 | 9369 | 0.698 | 0.111 |
| FGB | FGB07097 | FHLM Gold Single Family 30-years | 30,595 | 2586 | 0.951 | 0.053 |
| GNA | GNA07093 | GNMA I Single Family 30-years | 27,696 | 6830 | 0.704 | 0.095 |
| FNC | FNC06493 | FNMA Conventional Intermediate 15-years | 16,578 | 5843 | 0.568 | 0.095 |
| FGD | FGD06493 | FHLM Gold Single Family 15-years | 14,022 | 4368 | 0.558 | 0.098 |
| GNB | GNB07097 | GNMA II Single Family 30-years | 7,055 | 117 | 0.984 | 0.023 |
| GNF | GNF06493 | GNMA I Single Family 15-years | 3,031 | 1786 | 0.561 | 0.080 |
| FND | FND07096 | FNMA 7-years Balloon | 3,024 | 731 | 0.734 | 0.130 |
| FGG | FGG06093 | FHLM 7-years Balloon | 1,751 | 688 | 0.531 | 0.143 |
| FHB | FHB08487 | FHLM Guarantor Single Family 30-years | 1,015 | 4596 | 0.119 | 0.076 |
| FGF | FGF06496 | FHLM 5-years Balloon | 689 | 299 | 0.752 | 0.123 |
| FHA | FHA09489 | FHLM Cash Single Family 30-years | 346 | 15 | 0.073 | 0.012 |
| FNB | FNB08076 | FNMA Government Long Term 30-years | 268 | 29 | 0.361 | 0.235 |
| FHD | FHD08087 | FHLM Guarantor Single Family 15-years | 222 | 1867 | 0.079 | 0.041 |
| FHE | FHE08486 | FHLM Cash Single Family 15-years | 133 | 19 | 0.040 | 0.031 |

migrate from one year to another. Pool mappings are recalculated each month based on the weighted average loan age (WALA) reported for each pool by the agencies.[3] For example, a FHLM pool of 15-year single-family loans issued in March 1998 with a WALA of 5 months will be put into a generic with a 1997 origination year. By December 1999, though, uneven prepayments might bring the WALA of this pool to 22, in which case the pool would be mapped into 1998 origination. The WAC of a pool might similarly drift over time but would never cause a change in pool mapping since pools are mapped based on the pass-through (pool) coupon, which is set when the pool is created and never changes.

All three agencies have programs for the secondary aggregation of existing pools; platinum pools (Ginnie Mae), giant pools (Freddie Mac), and mega pools (Fannie Mae). These programs allow holders of multiple pools with small remaining balances to consolidate their holdings. Swapping many small and illiquid pools for one large pool improves liquidity, simplifies back-office operations, and reduces custodial costs. All the underlying pools are already part of generics, so these "pools of pools" do not participate in the creation of aggregates and are not included in the index in order to prevent double counting.

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[3] Subtracting WALA from the current date gives the weighted average origination date for the pool. FNMA does not report pool WALA. Because of loan curtailments (extra principal payments made by home owners) remaining WAM cannot be used to compute WALA. Instead, for FNMA pools, original (as of the pool issue date) WALA is calculated as the original maturity minus WAM at the pool issue date. The pool weighted average origination date is then determined by subtracting original WALA from the pool issue date.

## PRICING MBS GENERICS

### Collecting Quotes and Matrix Pricing

The Lehman Brothers mortgage trading desk selectively quotes prices for to-be-announced (TBA) issues and price spreads over TBA for seasoned issues.[4] Quotes are provided for the most liquid sectors and origination years within them on a per coupon basis. For nonquoted issues, mapping procedures have been established and are reviewed periodically to reflect the current trading patterns of particular mortgage sectors, coupons, or seasoning categories.

As shown in Figure 3, four levels of detail are used in quoting MBS prices. For the most liquid sectors (GNMA I 30-year, FNMA 30- and 15-year), the trading desk provides both TBA prices and explicit spread-over-TBA price quotes for certain origination years within the sectors. At the next level (GNMA II 30-year, FHML Gold 30- and 15-year), only TBA prices are quoted directly; the price spreads of the three most liquid sectors are used for seasoned issues. Pass-throughs with long payment delays (FHML Cash and Guarantor 30- and 15-year) are priced at a fixed spread (currently $16/32$) below the prices of similar issues in conventional sectors. The illiquid FNMA Government (FHA/VA) 30-year sector is wholly matrix-priced. Finally, all FNMA and FHMLC balloons and GNMA I 15-year use the TBA price quotes for all origination years.

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[4] For a detailed description of TBA trading, see the Lehman Brothers report, *Trading, Settlement, and Clearing Procedures for Agency MBS,* October 1992.

Figure 3. **Types of MBS Price Quotations**

| Code | Sector | TBA | Seasoned |
|------|--------|-----|----------|
| **Quoted TBA prices and selectively quoted over-TBA spreads for seasoned issues** | | | |
| GNA | GNMA I Single Family 30-years | Quoted | Quoted/mapped spreads |
| FNA | FNMA Conventional Long Term 30-years | Quoted | Quoted/mapped spreads |
| FNC | FNMA Conventional Intermediate 15-years | Quoted | Quoted/mapped spreads |
| **Quoted TBA prices and comparable sectors' over-TBA spreads for seasoned issues** | | | |
| GNB | GNMA II Single Family 30-years | Quoted | GNA over-TBA spreads |
| FGB | FHLM Gold Single Family 30-years | Quoted | FNA over-TBA spreads |
| FGD | FHLM Gold Single Family 15-years | Quoted | FNC over-TBA spreads |
| **Freddie Mac non-Gold** | | | |
| FHA | FHLM Cash Single Family 30-years | N/A | FNA price minus $16/32$ |
| FHB | FHLM Guarantor Single Family 30-years | N/A | FNA price minus $16/32$ |
| FHD | FHLM Guarantor Single Family 15-years | N/A | FNC price minus $16/32$ |
| FHE | FHLM Cash Single Family 15-years | N/A | FNC price minus $16/32$ |
| **A single price quoted for TBA and seasoned issues** | | | |
| GNF | GNMA I Single Family 15-years | | Quoted |
| FND | FNMA 7-years Balloon | | Quoted |
| FGF | FHLM 5-years Balloon | | Quoted |
| FGG | FHLM 7-years Balloon | | Quoted |

The set of origination years for which over-TBA price spreads are provided is chosen separately for each sector and coupon level to best represent the way the market trades. Typically, the years for which spreads are quoted for a particular coupon will correspond to those years in which it experienced significant issuance. Origination years that are not quoted directly in one way or another are normally mapped to the nearest quoted *later* year. Figure 4 illustrates how this mapping approach is used to price all 8% FNMA 30-year conventional single-family pass-throughs from a set of quotes for selected origination years (shown in bold).

## Adjusting Quotes to Obtain Index Prices

Once a price quote is obtained for a generic MBS, it must be adjusted for the difference between index and market settlement conventions. A single standard settlement day each month is designated by the Bond Market Association (formerly Public Securities Association, or PSA) for each sector of the MBS market. Quoted prices for MBS generics are always for this standard PSA settlement. The MBS Index, however, uses a same-day settlement convention to reflect the current market value of securities held by the index.[5] The discrepancy between the settlement convention used for quotes and for pricing the index necessitates price adjustments of

[5] This settlement convention for the MBS Index has been in place since October 1994 (see the Lehman Brothers report, *Revised Methodology for Calculating MBS Index Returns*, October 1994). Most other Lehman Brothers indices follow the next calendar day settlement convention.

two types. First, a pure adjustment of forward prices to spot prices reflects the cost of carry. More importantly, when the index and PSA settlement dates are in different months, the index price includes one more payment of principal and interest.

As an illustration, we will calculate the index price for FHLM 15-year 7s of 1997 (FGD07097) on April 3, 1998. As shown in Figure 5, the April PSA settlement date for this sector was the 16th. The quoted price for PSA settlement as of the 3rd was 102.19 (Figure 6).

Figure 4. **30-year Single-family FNMA 8%**
as of April 22, 1998

| Origination Year | PSA Settlement Price | Spread over TBA (32nds) | Outstanding Market Value ($ million) |
|------------------|----------------------|-------------------------|---------------------------------------|
| **1997** | **103.500** | **0** | **6,154** |
| 1996 | 103.500 | 0 | 11,544 |
| 1995 | 103.500 | 0 | 6,918 |
| **1994** | **103.531** | **1** | **7,146** |
| **1993** | **104.063** | **18** | **2,707** |
| **1992** | **104.188** | **22** | **14,703** |
| 1991 | 104.188 | 22 | 4,022 |
| 1990 | 104.188 | 22 | 468 |
| 1989 | 104.188 | 22 | 207 |
| 1988 | 104.188 | 22 | 168 |
| **1987** | **104.375** | **28** | **708** |
| 1986 | 104.375 | 28 | 399 |
| **1977** | **104.625** | **36** | **174** |
| 1976 | 104.625 | 36 | 235 |
| 1975 | 104.625 | 36 | 160 |
| 1974 | 104.625 | 36 | 156 |

With accrued interest of 0.29 as of the 16th, the settlement payment based on this quote would be 102.48. The present value of this payment as of the 3rd (discounting by a GNMA repo rate standard for all pass-throughs in the index) is 102.27. The index price for immediate settlement on the 3rd is backed out by subtracting the accrued interest of 0.04 from this present value and equals 102.23. The exact formula is shown in Case I in the Appendix.

In this example, calculation of the index price adjusts the PSA settlement quote for the cost of carry until settlement. This is sufficient because a purchase that settles on April 3 will entitle the buyer to the identical set of cash flows as a purchase that settles on April 16 since each monthly cash flow belongs to the owner of record at the end of the month. The situation at or near the end of the month is different. The trader quote on April 24 is for May PSA settlement. Such a purchase will entitle the buyer to receive cash flows from this security starting in June.

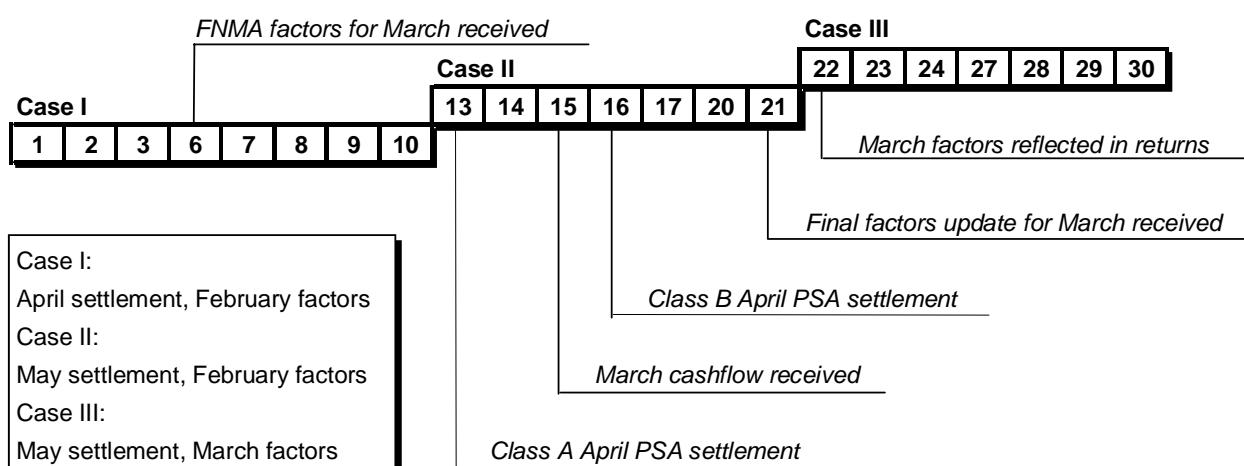Figure 5. **15-year MBS (PSA Class B),** April 1998



Figure 6. **15-year Single-family FHLM Gold 7s of 1997,** April 1998

| MBS Index Settlement | | | PSA Settlement | | | | MTD Returns (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Price | Accrued | Date | Price | PSA | SMM | Price | Coupon | Paydown | Total |
| 03/31/98 | 101.77 | 0.58 | 04/16/98 | 101.78 | 1,183 | 1.976 | -0.054 | 0.558 | -0.0368 | 0.467 |
| 04/01/98 | 101.93 | 0.00 | 04/16/98 | 101.88 | 1,183 | 1.976 | 0.146 | -0.001* | -0.0446 | 0.101 |
| 04/02/98 | 102.05 | 0.02 | 04/16/98 | 102.00 | 1,183 | 1.976 | 0.262 | 0.018 | -0.0442 | 0.235 |
| 04/03/98 | 102.23 | 0.04 | 04/16/98 | 102.19 | 1,183 | 1.976 | 0.437 | 0.036 | -0.0439 | 0.430 |
| 04/06/98 | 102.10 | 0.10 | 04/16/98 | 102.06 | 1,183 | 1.976 | 0.309 | 0.092 | -0.0428 | 0.358 |
| 04/07/98 | 102.03 | 0.12 | 04/16/98 | 102.00 | 1,183 | 1.976 | 0.246 | 0.111 | -0.0424 | 0.314 |
| 04/08/98 | 101.96 | 0.14 | 04/16/98 | 101.94 | 1,183 | 1.976 | 0.183 | 0.129 | -0.0421 | 0.271 |
| 04/09/98 | 101.93 | 0.16 | 04/16/98 | 101.91 | 1,183 | 1.976 | 0.150 | 0.148 | -0.0417 | 0.257 |
| 04/13/98 | 101.73 | 0.23 | 05/18/98 | 101.66 | 1,183 | 1.976 | -0.042 | 0.223 | -0.0403 | 0.141 |
| 04/14/98 | 101.82 | 0.25 | 05/18/98 | 101.75 | 1,183 | 1.976 | 0.042 | 0.241 | -0.0399 | 0.244 |
| 04/15/98 | 101.90 | 0.27 | 05/18/98 | 101.84 | 1,183 | 1.976 | 0.126 | 0.260 | -0.0399 | 0.346 |
| 04/16/98 | 101.99 | 0.29 | 05/18/98 | 101.94 | 1,183 | 1.976 | 0.210 | 0.278 | -0.0399 | 0.448 |
| 04/17/98 | 102.02 | 0.31 | 05/18/98 | 101.97 | 1,183 | 1.976 | 0.236 | 0.297 | -0.0399 | 0.493 |
| 04/20/98 | 101.92 | 0.37 | 05/18/98 | 101.88 | 1,183 | 1.976 | 0.139 | 0.353 | -0.0399 | 0.452 |
| 04/21/98 | 101.85 | 0.39 | 05/18/98 | 101.81 | 1,183 | 1.976 | 0.078 | 0.371 | -0.0399 | 0.409 |
| 04/22/98 | 101.85 | 0.41 | 05/18/98 | 101.81 | 1,104 | 1.829 | 0.078 | 0.390 | -0.0374 | 0.431 |
| 04/23/98 | 101.85 | 0.43 | 05/18/98 | 101.81 | 1,104 | 1.829 | 0.074 | 0.409 | -0.0374 | 0.446 |
| 04/24/98 | 101.88 | 0.45 | 05/18/98 | 101.84 | 1,104 | 1.829 | 0.100 | 0.428 | -0.0374 | 0.490 |
| 04/27/98 | 101.62 | 0.51 | 05/18/98 | 101.59 | 1,104 | 1.829 | -0.142 | 0.483 | -0.0374 | 0.304 |
| 04/28/98 | 101.62 | 0.53 | 05/18/98 | 101.59 | 1,104 | 1.829 | -0.146 | 0.502 | -0.0374 | 0.319 |
| 04/29/98 | 101.65 | 0.54 | 05/18/98 | 101.63 | 1,104 | 1.829 | -0.120 | 0.520 | -0.0374 | 0.364 |
| 04/30/98 | 101.99 | 0.58 | 05/18/98 | 102.00 | 1,104 | 1.829 | 0.208 | 0.558 | -0.0374 | 0.729 |

* See Case I in the Appendix for an explanation of the small negative coupon return on the first day of the month.

However, a purchase for immediate settlement (or an existing position) would entitle the owner to an additional payment of principal and interest in May. In this case, the index settlement price is backed out to match the sum of the present values of the following two quantities. The first principal and interest cash flow (which would be received in May) is discounted from the payment date back to the present. The position remaining after this paydown is valued by discounting the quoted price and the appropriate accrued interest from the PSA settlement date back to the present. This calculation is complicated by the May cash flow, which is the subject of this adjustment and is not yet known. Rather than projecting it using our proprietary (and subjective) prepayment model, we use the simple approximation that next month's single monthly mortality (SMM), or percentage of outstanding prepaid, will be equal to the most recently observed one. The formulas are given in Cases II and III in the Appendix. In Case II, we project the SMM for the May prepayment based on February, while in Case III we use the March SMM.

While all events that affect the MBS Index are essentially monthly in nature, they occur throughout the month. The PSA subdivides the market into five classes, A through E, of MBS securities, with a distinct settlement date for each. Similarly, the agencies issue monthly pool factor reports on different days for different types of pass-throughs. There may also be one or more updates following the initial factor release. To simplify index calculations, our convention is to address each of these monthly events *simultaneously for all securities* in the index. Thus, all securities in the index switch to their respective next month PSA settlement dates as soon as the earliest class (Class A) switches. As a result, the *month* of PSA settlement is always the same for all securities in the index. Similarly, pool factor updates are not applied to the index database in a piecemeal fashion as they come in. Instead, factors are updated all at once after the last factor update is received. Currently, the last factor update for the previous month is received on the 15th business day of each month. Starting on the next business day, the SMM computed from the previous month's factors begins to serve as the estimate for the current month's prepayment.

This convention ensures that all securities progress through the same sequence of calculations in the course of a month, regardless of their individual characteristics. Figure 5 helps to clarify this process. For the 15-year

FNMA shown, the Case I calculation (based on a quote for April settlement) could have been applied until the Class B settlement date of April 16. However, starting on the 13th of the month (the Class A settlement date), the entire index is quoted for May settlement. Similarly, the switch from Case II (based on February factors) to Case III (March factors) is delayed from the 6th, when factors were received for this particular security, until the 22nd, when all index pool factors are updated.

## COMPUTING RETURNS

### Returns on Individual Generics
Because mortgage pass-throughs are amortizing securities, their realized return always consists of two parts—the return on the portion of the initial investment that is still in securitized form and the return on the portion paid out as cash. Thus, all return calculations will be affected by the remaining balance and paid down amount numbers, which in turn depend on the current month prepayment estimate.

Advancement into a month determines which month's prepayment is used as an estimate in computing month-to-date returns. Figure 6 traces month-to-date returns for a particular Freddie Mac pass-through. At the beginning of April, the March factors are not yet available for some securities in the index, so the February prepayment (PSA of 1,183 for this particular pass-through) is used as an estimate for all securities in the index. When on the 16th business day (April 22, 1998), the factors are updated for the index, March prepayment (PSA of 1,104 for this security) begins to serve as an estimate in calculating month-to-date returns.

These switches in prepayment estimates may lead to discontinuities in the daily sequence of month-to-date returns. If prepayments change little from one month to the next, the effect is negligible. When there is a significant change in prepayments, this discontinuity can become noticeable (particularly in the paydown return). Investors who closely monitor month-to-date returns need to be aware of this potential discontinuity. As shown in Figure 6, on April 22 there was a small jump in paydown return.

The coupon return calculation for the MBS Index reflects the 30/360 day count convention and makes monthly coupon flows independent of the actual

number of days in a particular month. In the end-of-month return calculation, accrued interest is brought up to the full monthly coupon (30 days accrual) regardless of the actual number of days in the month. For end-of-month calculations, the MBS Index is assumed always to settle on the last day of the month, whether it is a business day or not. So if the last business day happens to be the 27th, the accrued interest on that day will jump from 26 days worth up to the full monthly coupon. For an 8% pass-through, for example, the accrued interest will go from 8x26/360 (+0.578%) directly to 8x30/360 (+0.667%) instead of to 8x27/360 (+0.600%).

All Lehman Brothers indices assume no reinvestment. In calculations of month-to-date coupon and paydown returns for the MBS Index, this assumption introduces an asymmetry. When the index settlement date is before the cash flow payment date (1 + agency delay), the value of the future cash flow is discounted. But after the payment date, the cash flow already received is not reinvested forward. This effect can be seen in Figure 6. Up to the cash flow payment date (through April 14th), the paydown return increases as the coming payment is discounted over fewer days (see the formulas in the Appendix). From that day on it stays constant (except for the one jump due to the prepayment estimate switch on the 22nd).

For purposes of the Lehman Brothers MBS Index, both interest and principal components of the received cash flow contribute to the paydown return while coupon return is based on only the surviving portion. Because the beginning or "base" value for all return calculations is the last day of the previous month, on the very first day of the current month the mortgage security "sheds" one cash flow. Thus, the full paydown return for the month is realized on the first day of the month (Figure 6).

Figure 7 traces the daily sequence of MBS Index returns for April 1998. Alongside the month-to-date returns, we show *daily* returns[6] that highlight the conventions described above. As this figure shows, the same return patterns demonstrated and explained above for an individual generic are also evident at the index level.

## Aggregating the Generics' Returns into the Index Return

Returns on the MBS Index are computed as market value-weighted averages of the individual generics' returns. As a result, index returns are determined not only by the price changes but also by the index composition. While this is true for all Lehman Brothers indices, the effect is more pronounced for the MBS Index due to mortgage prepayments and new issuance.

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[6] A *daily* return is defined as the difference between two consecutive month-to-date returns.

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Figure 7. **Daily MBS Index Returns for April 1998**

| | MTD Returns (%) | | | | Daily Returns (%) | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Price | Coupon | Paydown | Total | Price | Coupon | Paydown | Total |
| **03/31/98** | **-0.094** | **0.581** | **-0.064** | **0.423** | | | | |
| 04/01/98 | 0.208 | -0.002 | -0.068 | 0.138 | 0.208 | -0.002 | -0.068 | 0.138 |
| 04/02/98 | 0.343 | 0.018 | -0.068 | 0.293 | 0.135 | 0.019 | 0.000 | 0.154 |
| 04/03/98 | 0.506 | 0.037 | -0.067 | 0.476 | 0.163 | 0.019 | 0.000 | 0.183 |
| 04/06/98 | 0.366 | 0.096 | -0.066 | 0.395 | -0.140 | 0.058 | 0.001 | -0.081 |
| 04/07/98 | 0.348 | 0.115 | -0.066 | 0.397 | -0.018 | 0.019 | 0.000 | 0.002 |
| 04/08/98 | 0.258 | 0.134 | -0.066 | 0.327 | -0.090 | 0.019 | 0.000 | -0.070 |
| 04/09/98 | 0.251 | 0.154 | -0.065 | 0.340 | -0.007 | 0.019 | 0.000 | 0.013 |
| 04/13/98 | 0.006 | 0.232 | -0.064 | 0.173 | -0.246 | 0.078 | 0.001 | -0.167 |
| 04/14/98 | 0.121 | 0.251 | -0.064 | 0.308 | 0.115 | 0.019 | 0.000 | 0.135 |
| 04/15/98 | 0.205 | 0.270 | -0.063 | 0.412 | 0.084 | 0.019 | 0.000 | 0.103 |
| 04/16/98 | 0.262 | 0.290 | -0.063 | 0.489 | 0.058 | 0.019 | 0.000 | 0.077 |
| 04/17/98 | 0.257 | 0.309 | -0.063 | 0.504 | -0.005 | 0.019 | 0.000 | 0.015 |
| 04/20/98 | 0.138 | 0.367 | -0.063 | 0.443 | -0.119 | 0.058 | 0.000 | -0.060 |
| 04/21/98 | 0.050 | 0.387 | -0.062 | 0.374 | -0.089 | 0.019 | 0.000 | -0.069 |
| 04/22/98 | 0.045 | 0.404 | -0.078 | 0.371 | -0.005 | 0.017 | -0.016 | -0.003 |
| 04/23/98 | 0.041 | 0.423 | -0.078 | 0.386 | -0.004 | 0.019 | 0.000 | 0.016 |
| 04/24/98 | 0.058 | 0.443 | -0.078 | 0.423 | 0.017 | 0.019 | 0.000 | 0.037 |
| 04/27/98 | -0.243 | 0.500 | -0.078 | 0.180 | -0.301 | 0.058 | 0.000 | -0.244 |
| 04/28/98 | -0.245 | 0.520 | -0.078 | 0.197 | -0.002 | 0.019 | 0.000 | 0.017 |
| 04/29/98 | -0.251 | 0.539 | -0.078 | 0.210 | -0.007 | 0.019 | 0.000 | 0.013 |
| **04/30/98** | **0.068** | **0.577** | **-0.078** | **0.567** | 0.319 | 0.038 | 0.000 | 0.357 |

As Figure 8 shows, the relative weight of a particular generic may change significantly in the course of a single year. Because higher coupons prepay quickly and most new issuance is at market level, the MBS Index composition tends to gravitate toward current coupon. This effect is illustrated in Figure 9. The MBS Index price tends to stay closer to par than do those of the Lehman Brothers Treasury or Corporate Indices, as the MBS weighted average coupon follows the market yield more closely.

## MANAGING PORTFOLIOS AGAINST THE MBS INDEX

When comparing the performance of an MBS portfolio against the Lehman Brothers MBS Index, it is important to understand how and why return calculations differ.

An index measures value and changes in value of a particular market. There is no ownership of the component securities in an index (i.e., no buying and selling), yet ownership is a critical factor in the context of portfolio performance measurement, especially in the MBS sector. Portfolios that are benchmarked against an index are generally actively traded and are typically marked to market on a daily basis. Changes in these daily valuations are the basis of performance measurement.

In this section we describe a few of the more significant ways in which performance measurement for an actively traded MBS portfolio differs from the Lehman Brothers MBS Index return methodology. The list is not exhaustive in that it does not include some common trading practices such as dollar rolls, short positions, and hedging. However, issues that are of concern to most portfolio managers are discussed here:
- Pools versus aggregates
- Delivery variance
- Income accrual
- Reinvestment
- Transactions
- Profit and loss versus total return

### Pools versus Aggregates
As previously described, the Lehman Brothers MBS Index consists of a set of generic securities derived from the universe of agency-backed pools. Those generics have to satisfy the rules for index inclusion. Using aggregates rather than pools makes the task of producing an index feasible, but using aggregates as proxies for pools in a portfolio provides only approximations of actual performance.

From month to month, the set of pools that maps to a particular aggregate can change. This may be due to slight changes in average origination year of the loans underlying a pool, causing some pools to drift to an aggregate with an adjacent origination year. It may also be due to new issuance during the course of the year adding new pools to a particular aggregate. In this case, an aggregate may actually grow in size from one month to the next. Therefore, it is possible that over time the particular aggregate to which a pool is mapped may no longer closely approximate the pool's characteristics.

Also, cash flows for any pool and its associated aggregate will differ. Cash flows for pools are defined by the behavior of the underlying loans. Coupons and scheduled principal are based on standard mortgage

Figure 8. **Changes in Relative Weights of Selected Generics in the MBS Index**

| Date | MBS Index MV ($ bill.) | FNMA Convent. 30-year 8 of 1992 | | FNMA Convent. 30-year 7 of 1997 | |
|---|---|---|---|---|---|
| | | MV ($ bill.) | % Index MV | MV ($ bill.) | % Index MV |
| 1/31/97 | 1,401.2 | 19.4 | 1.38 | N/A | N/A |
| 2/28/97 | 1,405.3 | 19.2 | 1.37 | 0.5 | 0.04 |
| 3/31/97 | 1,394.4 | 18.8 | 1.35 | 2.5 | 0.18 |
| 4/30/97 | 1,411.7 | 18.8 | 1.33 | 4.0 | 0.28 |
| 5/31/97 | 1,421.1 | 18.7 | 1.31 | 5.5 | 0.39 |
| 6/30/97 | 1,432.6 | 18.6 | 1.30 | 6.7 | 0.47 |
| 7/31/97 | 1,456.5 | 18.5 | 1.27 | 7.5 | 0.51 |
| 8/31/97 | 1,446.4 | 18.2 | 1.26 | 8.3 | 0.57 |
| 9/30/97 | 1,463.8 | 18.1 | 1.24 | 11.2 | 0.76 |
| 10/31/97 | 1,482.8 | 17.9 | 1.21 | 14.8 | 1.00 |
| 11/30/97 | 1,489.1 | 17.7 | 1.19 | 19.4 | 1.31 |
| 12/31/97 | 1,504.2 | 17.3 | 1.15 | 24.5 | 1.63 |
| 1/31/98 | 1,521.4 | 17.1 | 1.12 | 29.2 | 1.92 |
| 2/28/98 | 1,527.1 | 16.8 | 1.10 | 33.0 | 2.16 |
| 3/31/98 | 1,523.3 | 16.2 | 1.06 | 35.0 | 2.29 |
| 4/30/98 | 1,529.3 | 15.4 | 1.01 | 35.4 | 2.32 |

Figure 9. **Price Deviation from Par for the MBS, Treasury, and Corporate Indices**, 1989-1997

| | MBS | Treasury | Corporate |
|---|---|---|---|
| Avg of absolute deviations of index price from par: | 2.72 | 6.23 | 3.80 |
| Avg of absolute values of differences between coupon and yield: | 0.64 | 1.24 | 0.79 |

formulas, and all prepayments are passed through to the investor. Since the composition of an aggregate can change, and in particular can actually grow in size, using the cash flows of the constituent pools could result in patterns that do not make sense, such as negative amortization. Therefore, cash flows for aggregates for a given performance period are calculated based on the average WAM and prepayment rate (CPR%) of the constituent pools for that month (and NOT aggregated from the underlying pools).

Furthermore, cash flows may differ because any pool or pools in a portfolio that map to a particular aggregate are likely to be a small subset of all the pools that make up the aggregate. By definition this subset will have a similar indicative profile (i.e., similar WAC, WAM, and WALA), but it may have a different demographic profile. For example, the subset of pools in a portfolio may be concentrated in a small geographic area whereas the pools that compose the aggregate are more geographically diverse. Demographics can play a large part in how mortgages prepay.

### Delivery Variance
When pass-throughs are traded on a TBA or generic basis, the exact pools and amounts that will be delivered are not known until two days before settlement. According to current PSA requirements, good delivery can be within 1% of the original face value of the TBA trade. This aspect of the pass-through market is well understood by most participants, and traders use their delivery option to take advantage of price movements. For example, if a trade was done at a price of 102 but the same bond is trading at 103 when the delivery is specified, a trader will seek to deliver the minimum amount allowed. Alternatively, if the price of the bond is lower when the delivery is specified than it was on the trade date, the trader will try to deliver the maximum. Similarly, a good back office takes advantage of the option to deliver the worst performing pools (such as fast prepaying premium coupon securities) as long as they constitute good delivery.

When mortgage pools are purchased for a portfolio in this fashion, the exact amount to be marked to market remains unknown until the allocation date two days before settlement. An estimate must then be used to calculate performance until the delivery amount is known. After delivery, calculations are done on the actual amount. This kind of estimation is not required in the MBS Index

because all amounts are known and fixed for the period of performance measurement.

### Income Accrual
In the MBS market, trades settle once a month according to the PSA schedule for the various classes of agency/coupons, typically around the middle of the month. Buying a mortgage pass-through results in immediate exposure of the portfolio to price risk, but there is no interest accrual until the trade settles. Between the trade date and the settlement date, the position is considered pending. After the settlement date, the position becomes an outright holding. Once an outright holding is sold, there is no more price risk associated with the position, but income continues to accrue until the settlement date of the sale. Thus, a portfolio is exposed to price risk from trade date to trade date, and accrues interest from settlement date to settlement date.[7]

In the MBS Index there are no pending positions. Once a security is included in the index, it contributes to performance similar to an outright holding in a portfolio. This is because in the MBS Index settlement dates by convention are the same as the "trade" or pricing dates. Therefore price changes and daily accrual are included in the return calculation for the entire holding period. When comparing performance of a portfolio against the MBS Index, it is important to understand these timing differences. For the period when a pending position is not earning interest, a portfolio may be at a disadvantage relative to the index.

It is difficult to impose the MBS Index date conventions on a portfolio. Active portfolio managers often execute transactions (buys or sells) and then unwind the position while it is still pending for the same settlement date.[8] As a result there is a realized price gain or loss for the portfolio, but there is no interest income at all. This type of trading must be taken into account by any system that calculates MBS portfolio performance but has no relevance in the context of the MBS Index.

### Reinvestment
If an MBS portfolio is at a disadvantage relative to the MBS Index for those times or situations when interest

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[7] Some systems account for all remaining accrual after a pending sale on the trade date rather than continuing to include it in daily mark-to-market reports.
[8] There is still delivery risk in this type of trading, especially if the trades are executed with different dealers.

is not accruing, it has an advantage over the index in reinvestment. Mortgage pass-throughs have monthly cash flows that consist of interest and principal (both scheduled and unscheduled). Therefore, reinvestment of cash flows plays a much larger role in managing a mortgage portfolio than it does for other fixed-income investments that have less frequent cash flows.

The return calculations for the MBS Index effectively assume a 0% reinvestment rate for cash flows from the payment date through the end of the performance period. At the end of the month, all the accumulated cash is assumed to be invested in the next month's index. This is equivalent to a delayed reinvestment into the market. Until the end of the month, though, the cash does not participate in valuations. The magnitude of the reinvestment return that the index would have achieved depends on the rate of prepayment and on prevailing short-term interest rates. At times of high prepayment, reinvestment return is typically moderated by low interest rates. In any event, the reinvestment return foregone by the index is modest. For example, for the MBS Index in June 1998, it would have been just 0.5 bp per month, assuming reinvestment at the Federal funds rate. In 1996, slower prepayments would have brought this down to 0.3 bp per month.

In actual portfolios, cash flows are normally reinvested into the market immediately upon receipt. But even when funds are temporarily kept as cash (or more likely, as low risk, low yielding cash equivalents such as U.S. Treasury bills), they remain part of the portfolio and continue to have an impact on performance.

## Transactions

For return calculations, membership in the MBS Index is fixed once a month (on the last business day of the previous month). Returns are calculated on this fixed set of securities (either daily or for the whole month) and are linked across month boundaries via compounding to provide performance results for longer historical time frames. For actively traded portfolios, however, membership can change daily. Furthermore, positions, either pending or outright, may be traded in their entirety or in multiple lots at (potentially) different prices. These issues need to be considered when calculating portfolio returns.

If the set of securities is fixed (i.e., no transactions) for a given period of time, then performance is calculated

from the starting and ending market values of the security and any intervening cash flow. If the mix of securities changes, the performance period must first be broken into subperiods defined by those days on which transactions occur.[9] Then, depending on how much detail must be captured, some algorithm is used to look at all the opening values (i.e., existing positions plus any new purchases) and closing values (i.e., remaining positions plus any sales) of the securities to arrive at a set of returns.

For example, the simplest algorithm would be to calculate an average starting value or cost from all the opening positions and an average ending value from all the closing positions. If it is necessary to keep track of both realized and unrealized returns, then some algorithm for pairing positions and trades must be employed.

## Profit and Loss versus Total Return

When reviewing portfolio performance, investors typically measure how much each market sector within their holdings contributes to the total. When segregating performance in this fashion, it is sometimes useful to look at results in terms of dollars (profit and loss) rather than percentages (total return). This is true any time the basis, or the beginning market value upon which return is calculated, is either not well defined or changes. With static portfolios, the basis is well defined and fixed, and portfolio total return can be defined as the market weighted average of the returns of the component securities. This is equivalent to dividing the sum of the profit or loss in dollars of each security in the portfolio by the portfolio basis. When the portfolio changes over the holding period, however, this relationship breaks down.

Figure 10 illustrates the performance of a hypothetical mortgage portfolio over a three-year period. The initial investment of $100 million was allocated 30% to discounts, 60% to current coupons, and 10% to premiums. Each year the allocation changes, and to arrive at the cumulative return for each sector, the periodic returns are compounded. The cumulative return for the portfolio is then no longer a weighted average of the cumulative returns of its component sectors. But the cumulative

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[9] In the 1997 AIMR (Association for Investment Management and Research) *Performance Presentation Standards Handbook*, daily performance periods are recommended. AIMR also requires, as part of compliance, that time-weighted rates of return be used.

Figure 10. **Performance of a Hypothetical Mortgage Portfolio**

| | Year 1 | Year 2 | Year 3 | Cumulative |
|---|---|---|---|---|
| MBS Discounts | | | | |
| Allocation | 30% | 30% | 35% | |
| Total Return | 5.00 | 5.50 | 4.00 | 15.21 |
| Profit ($ million) | 1.50 | 1.74 | 1.57 | 4.81 |
| MBS Current Coupons | | | | |
| Allocation | 60% | 40% | 35% | |
| Total Return | 6.00 | 6.50 | 6.50 | 20.23 |
| Profit ($ million) | 3.60 | 2.75 | 2.56 | 8.91 |
| MBS Premiums | | | | |
| Allocation | 10% | 30% | 30% | |
| Total Return | 6.50 | 7.00 | 6.50 | 21.36 |
| Profit ($ million) | 0.65 | 2.22 | 2.19 | 5.06 |
| Portfolio | | | | |
| Allocation | 100% | 100% | 100% | |
| Total Return | 5.75 | 6.35 | 5.63 | 18.79 |
| Profit ($ million) | 5.75 | 6.72 | 6.32 | 18.79 |

profit is still a sum of the cumulative parts. If the goal is to understand performance of the whole in terms of performance of the parts of the portfolio, it helps to use P&L units that are additive.

Lehman Brothers recently introduced a model for analyzing and explaining portfolio performance relative to an index. For an in-depth description of this model, see the Lehman Brothers report, *Attribution of Portfolio Performance Relative to an Index*, March 1998. Briefly, performance attribution involves partitioning a portfolio into those market sectors where allocation decisions were made relative to an index, and calculating the excess performance associated with each of these decisions, as well as that due to the actual securities chosen within each sector.

Profit and loss, therefore, is a reasonable framework for analyzing performance of an actively traded portfolio, either in addition to or instead of percentage return. It is used in the Lehman Brothers implementation of the performance attribution model[10] currently under development. The main disadvantage of using profit and loss is that it is difficult to rank portfolios of different sizes based on excess profit; for this, percentage return is a more appropriate measure.

## CONCLUSION

The Lehman Brothers MBS Index serves as a basis for performance evaluation and risk measurement for a large number of MBS portfolios and mortgage components of diversified portfolios. Its published returns are based on a number of sensible and common conventions that allow aggregation of results for different MBS securities and across a variety of other asset classes in the Lehman indices. This report summarizes those conventions and provides guidance for comparisons between portfolio returns and benchmark returns. Disparate settlements, the timing of pool factor updates, cash flow delays, and evolution of outstanding balances all make the MBS return computations particularly dependent on index conventions.

The Lehman MBS Index assumes a "buy and hold" strategy intra-month and changes its composition only on the last business day of each month. This is the general rule for all Lehman indices. The dynamic nature of most portfolios makes comparisons and especially attribution of performance differences challenging. We are working to develop the appropriate analytics and hope that this report clarifies some of the issues involved in this process.

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[10] Since the market value of an index is usually orders of magnitude larger than a portfolio, it is necessary to normalize the size of the index to the size of the portfolio before meaningful comparisons can be made.

## APPENDIX

For the purposes of index return calculations there are three important days within each month:

- $t_{cf}$ - the day on which the cash payment of interest and principal is received by the bondholders of record (1 + agency delay).
- $t_{psa}$ - the current month PSA settlement date for Class A, on which all mortgage securities in the index switch to the next month settlement.
- $t_f$ - the next business day after the day of the last factor update (from that day on previous month SMM are used as the current month prepayment estimates). Currently, it is the 16th business day of the month (so the switch to the next month PSA settlement always happens earlier, i.e. $t_{psa}$ is always before $t_f$).

We present end-of-month return calculations as well as three cases of daily month-to-date returns calculations depending on where the index settlement date is relative to the three dates above (see Figure 5). In each case, we show how the PSA price is converted into the index price and how all returns are computed.

To make notation more intuitive, we label calculation components with actual calendar months, rather than abstract subscripts, such as *i* and *i+1.* In all formulas, we assume that calculations take place as we progress through the month of April.

For all cases we use the following:

$t_{psa}^{Apr}, t_{psa}^{May}$     PSA settlement dates for a particular MBS in April and May

$t_{end}^{Mar}, t_{end}^{Apr}$     the last calendar days of March and April

$C$     monthly coupon (annual coupon in percent/12)

$r$     daily repo rate (annualized 1-month GNMA repo/360)

$P(t,s)$     price at time $t$ for settlement on $s$

$A(s)$     accrued interest at settlement on $s$

$BV = P(t_{end}^{Mar}, t_{end}^{Mar}) + C$     base value for all returns calculations during April

$F^{Jan}, F^{Feb}, F^{Mar}$     factors at the end of January, February, and March, respectively

$S^{Feb} = \dfrac{F^{Feb}}{F^{Jan}}$     monthly survival rate for February

$S^{Mar} = \dfrac{F^{Mar}}{F^{Feb}}$     monthly survival rate for March

| Case I. | **Month-to-date[a] Returns Calculation before $t_{psa}$** |
|---|---|
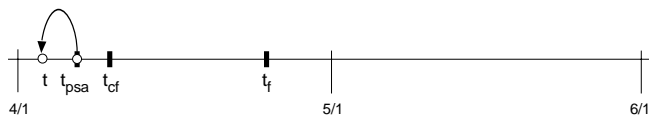


April settlement, February factors.

This is the simplest case for index price calculation because all that is required is discounting from the PSA settlement date back to the index settlement date.

$$\text{Index price } (P(t,t)) = \frac{P(t,t_{psa}^{Apr}) + A(t_{psa}^{Apr})}{(1+r)^{(t_{psa}^{Apr} - t)}} - A(t) \tag{1}$$

$$\text{Price return} = \frac{1}{BV} \times \left[ S^{Feb} \times \left( P(t,t) - P(t_{end}^{Mar}, t_{end}^{Mar}) \right) \right] \tag{2}$$

$$\text{Coupon return[b]} = \frac{1}{BV} \times \left[ S^{Feb} \times \left( \frac{C}{(1+r)^{(t_{cf} - t)}} + A(t) - C \right) \right] \tag{3}$$

$$\text{Paydown return} = \frac{1}{BV} \times \left[ (1 - S^{Feb}) \times \left( \frac{100}{(1+r)^{(t_{cf} - t)}} - P(t_{end}^{Mar}, t_{end}^{Mar}) + \frac{C}{(1+r)^{(t_{cf} - t)}} - C \right) \right] \tag{4}$$

Or, after the current month cash flow has been received:

$$\text{Coupon return} = \frac{S^{Feb} \times A(t)}{BV} \tag{5}$$

$$\text{Paydown return} = \frac{1}{BV} \times \left[ (1 - S^{Feb}) \times \left( 100 - P(t_{end}^{Mar}, t_{end}^{Mar}) \right) \right] \tag{6}$$

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[a] Calculations on any particular day use the previous business day's close, so the reported returns are for the period from the beginning of the month through the previous business day.
[b] On the first day of the month, when accrued interest is zero, coupon return will be a small negative number as the present value of $C$ is less than $C$ itself (see Figure 6).

| Case II. | **Month-to-date Returns Calculation between $t_{psa}$ and $t_f$** |
|---|---|
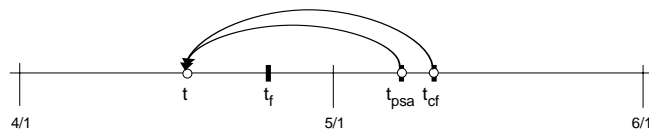


May settlement, February factors.

This and the following cases differ from Case I in that the index price must be adjusted for the unknown future cash flow, which needs to be "reinstated."

$$\text{Index price } (P(t,t)) = \frac{S^{Feb} \times (P(t,t_{psa}^{May}) + A(t_{psa}^{May}))}{(1+r)^{(t_{psa}^{May} - t)}}$$

$$+ \frac{(1 - S^{Feb}) \times 100 + C}{(1+r)^{(t_{cf} - t)}} - A(t) \tag{7}$$

All the formulas for returns calculations are the same as in Case I.

Case III.    **Month-to-date Returns Calculation after $t_f$**
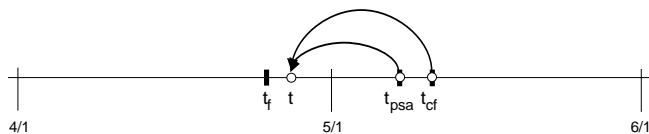


May settlement, March factors.

This case differs from Case II in that the March prepayment is used to compute both the index price and returns.

Index price $(P(t,t)) = \dfrac{S^{Mar} \times (P(t,t_{psa}^{May}) + A(t_{psa}^{May}))}{(1+r)^{(t_{psa}^{May} - t)}}$

$$+ \frac{(1 - S^{Mar}) \times 100 + C}{(1+r)^{(t_{cf} - t)}} - A(t) \qquad (8)$$

Price return $= \dfrac{1}{BV} \times \Big[ S^{Mar} \times \big( P(t,t)$

$$- P(t_{end}^{Mar}, t_{end}^{Mar}) \big) \Big] \qquad (9)$$

Coupon return $= \dfrac{1}{BV} \times \Bigg[ S^{Mar} \times \bigg( \dfrac{C}{(1+r)^{(t_{cf} - t)}} \cdot$

$$+ A(t) - C \bigg) \Bigg] \qquad (10)$$

Paydown return $= \dfrac{1}{BV} \times \Bigg[ (1 - S^{Mar})$

$$\times \bigg( \frac{100}{(1+r)^{(t_{cf} - t)}} - P(t_{end}^{Mar}, t_{end}^{Mar})$$

$$+ \frac{C}{(1+r)^{(t_{cf} - t)}} - C \bigg) \Bigg] \qquad (11)$$

Or, after the current month cash flow has been received:

Coupon return $= \dfrac{S^{Mar} \times A(t)}{BV}$

$$\qquad (12)$$

Paydown return $= \dfrac{1}{BV} \times \Big[ (1 - S^{Mar})$

$$\times \big( 100 - P(t_{end}^{Mar}, t_{end}^{Mar}) \big) \Big] \qquad (13)$$

Case IV.    **End-of-month Returns Calculation**

The only difference from Case III is that the accrued interest equals the full monthly coupon.

Index price $( P(t_{end}^{Apr}, t_{end}^{Apr}) )$

$$= \frac{S^{Mar} \times (P(t_{end}^{Apr}, t_{psa}^{May}) + A(t_{psa}^{May}))}{(1+r)^{(t_{psa}^{May} - t_{end}^{Apr})}}$$

$$+ \frac{(1 - S^{Mar}) \times 100 + C}{(1+r)^{(t_{cf} - t_{end}^{Apr})}} - C \qquad (14)$$

Price return $= \dfrac{1}{BV} \times \Big[ S^{Mar} \times \big( P(t_{end}^{Apr}, t_{end}^{Apr})$

$$- P(t_{end}^{Mar}, t_{end}^{Mar}) \big) \Big] \qquad (15)$$

Coupon return $= \dfrac{S^{Mar} \times C}{BV}$ $\qquad (16)$

Paydown return $= \dfrac{1}{BV} \times \Big[ (1 - S^{Mar}) \times \big( 100$

$$- P(t_{end}^{Mar}, t_{end}^{Mar}) \big) \Big] \qquad (17)$$

Total return is always the sum of price, coupon, and paydown returns.