Financial Engineering and Structured Products

Module 1 – Intro & Overview: Mortgages and Mortgage Backed Securities (MBS)

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    - Office Hours: 3:30 – 5:30 Wednesday, WH212

Schedule
- Lecture Encounters
  - Monday & Wednesday, 12:00 - 1:15, Ames 234
  - Friday 12:00 - 12:50, Hodson 213
  - “Section” as scheduled

Resources
- Textbooks
  - Keith Allman: Modeling Structured Finance Cash Flows w/Microsoft Excel, Wiley 2007 (Required)
  - Ann Rutledge & Sylvain Raynes: Elements of Structured Finance, Oxford 2010 (Strongly Recommended)
  - Williams Preinitz: Structured Finance: Modeling, Monitoring, and Valuation: Jump Start VBA, Wiley 2009 (Recommended for Some)
Resources
- Supplemental Material
  - As Directed
- Blackboard
- Course Home Page: AMS Website
  - http://jesse.ams.jhu.edu/~daudley/448
- Additional Subject Material
  - Class Resources & Lecture Slides
- Industry & Street “Research”
  - Consult at your leisure/risk; or as assigned
  - Interest can generate Special Topics sessions

Protocol
- Attendance
  - Lecture – Mandatory (default) for MSE Fin Math majors
  - Quizzes
- Section – Strongly Advised/Recommended
- Assignments
  - Due as Scheduled (for full credit)
  - Must be handed in to avoid “incomplete”
  - Exceptions must be requested in advance

Measures of Performance
- Mid Term Exams (2) (~4/9 of grade)
- Final Exam (~1/3 of grade)
- Homework as assigned and designated, “Pop” Quizzes, and Presentations (~2/9 of grade)
  - Includes Class Participation and Attendance
  - Un-excused Absence for any Quiz will result in zero credit toward that element of the HW/Quiz average – no exceptions
  - Late HW is accepted only with prior approval

Overview
550.448 Financial Engineering and Structured (Financial) Products: This course focuses on securitization, structured securities and the structuring of aggregates of financial instruments into engineered solutions to problems of capital/finance. Topics include:
- The fundamentals of creating asset-backed and structured securities – including:
  - mortgage and asset-backed securities (MBS/ABS),
  - collateralized mortgage obligations (CMOs),
  - other asset-backed collateralized debt/loan obligations (CDOs/CLOs)
  - Asset-backed commercial paper (ABCP)
- Introducing Collateral/Asset types and w/study of risk/modeling issues
- Structuring and allocating cash-flows, (re-)engineering risk and credit
- Problems in Asset-Liability Portfolio Management
### Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Module</th>
<th>Due</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/26/2015</td>
<td>Intro &amp; Overview</td>
<td>Mtg/MBS (M1)</td>
<td>R&amp;R(1-3), MBS, Allman(1-2), Preinitz(3)</td>
</tr>
<tr>
<td>1/28/2015</td>
<td>Intro &amp; Overview</td>
<td>Mtg/MBS (M1)</td>
<td></td>
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<td>1/30/2015</td>
<td>Intro &amp; Overview</td>
<td>Mtg/MBS (M1)</td>
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<td>2/2/2015</td>
<td>Intro &amp; Overview</td>
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<td>2/4/2015</td>
<td>Legal, Accounting, &amp; the SPE (M2)</td>
<td>R&amp;R(1-3), MBS, Allman(1-2)</td>
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<td>2/6/2015</td>
<td>Legal, Accounting, &amp; the SPE (M2)</td>
<td>Mtg/MBS (M1)</td>
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<td>2/9/2015</td>
<td>Static Valuation &amp; Credit (M6)</td>
<td>Assignment 1</td>
<td>R&amp;R(6), Allman(4-6)</td>
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<tr>
<td>2/11/2015</td>
<td>Asset Side Cash Flows (M4)</td>
<td>Assignment 2</td>
<td>R&amp;R(9)</td>
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<tr>
<td>2/13/2015</td>
<td>Asset Side Cash Flows (M4)</td>
<td>Midterm 1 Review</td>
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<tr>
<td>2/16/2015</td>
<td>Midterm 1 Review</td>
<td>All HW Resumed</td>
<td></td>
</tr>
<tr>
<td>2/18/2015</td>
<td>Midterm 1 Review</td>
<td>All HW Resumed</td>
<td></td>
</tr>
<tr>
<td>3/2/2015</td>
<td>Liability-Side Cash Flows (M5)</td>
<td>Assignment 3</td>
<td>R&amp;R(7), Allman(6-7)</td>
</tr>
<tr>
<td>3/6/2015</td>
<td>Liability-Side Cash Flows (M5A)</td>
<td>Assignment 3</td>
<td></td>
</tr>
<tr>
<td>3/9/2015</td>
<td>Dynamic Behavior (M8)</td>
<td>R&amp;R(12-13), Allman(9)</td>
<td></td>
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<tr>
<td>3/11/2015</td>
<td>Dynamic Behavior (M8)</td>
<td>Section - Mid Class</td>
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<tr>
<td>3/13/2015</td>
<td>Section - Mid Class</td>
<td>Spring Breaks</td>
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<td>3/18/2015</td>
<td>Spring Breaks</td>
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### Assignment

- **Reading**
  - Introduction and first 3 chapters of R&R (Securitization Law, Accounting and Corporate Structure)
  - Material on MBS – lecture slides and docs (CitiGroup, RBSCG, & JPM): focus on basics
  - Allman: Introduction and Chapters 1-2 (Excel, Dates, Day-Counts, & CF Generation)
  - Preinitz: Chapter 3 (Securitizing a Loan PF)

### Mortgages and Mortgage Backed Securities (MBS)

- A mortgage is a contract under which a borrower (the mortgagor) pledges a structure and/or a piece of property as collateral for a loan from a lender (mortgagee).
- The contract includes a loan amount, an interest rate, a frequency of payments and a loan term.
- This contract gives the lender the right to foreclose on the loan and seize the property in the event that the mortgagor fails to make the contractual payments. Such failure is called a default.
- The contract usually gives the borrower the right to prepay the principal amount (payoff amount) at any time.

- Typical mortgage originators (lenders) include commercial banks, thrifts, and mortgage bankers.
- Originators earn income by charging an origination fee (measured in percentage points, paid by the mortgagor at the closing), application fees and processing fees.
- Four types of properties that can be collateral for mortgages:
  - Residential real estate
    - Single family (one- to four- family) (houses, mobile homes)
    - Multi-family (more than four-family) (condominiums, cooperatives (co-ops))
  - Non-residential real estate
    - Commercial (office buildings, shopping centers, hospitals, industrial plants)
    - Farm properties
Mortgages and Mortgage Backed Securities (MBS)

**Mortgage Contract Characteristics**

**Amount**
- The amount of the loan is usually lower than the value of the property used as collateral.
- The ratio of the loan amount to the value of the property is called the loan-to-value ratio (LTV).
  - The lower this ratio, the more protection the mortgagee has, because the higher property value is backing a smaller loan. In the case of default, the mortgagee (lender) has a better chance of recovering the entire loan amount upon foreclosure and sale.

**Term**
- The term of a mortgage can vary; however, the most common mortgages have 15- or 30-year maturities.
- The term of the loan is critical in determining the amount of the periodic payments.
- All else being equal on a flat payment structure, the longer the loan term, the less each payment will be and the more total interest will be paid over the life of the loan.

**Frequency of Payment**
- Most mortgages have monthly payments; however, a payment schedule is determined at the origination of the mortgage and expressed explicitly in the mortgage contract.
- Generally, payments are remitted monthly.

**Rate**
- Mortgage rates are the borrowing cost to a mortgagor. The rate is referred to as the interest on the mortgage.
- Rates are quoted annually, but paid in installments determined in the contract (frequency), usually monthly.
- Rates can be fixed for the life of the loan, they can float based on an index and a spread, or they can be fixed for a set period and then begin to float.
- Floating rate mortgages typically have life caps as well as periodic caps (caps on the change in a specified period).
Mortgages and Mortgage Backed Securities (MBS)

- Mortgage Contract Characteristics (cont)
  - Rate
    - The main characteristics used in determining mortgage rates are:
      - Type (i.e., term, structure, fix/floating);
      - Loan amount (jumbo);
      - Prevailing rates (can vary by locale); and
      - Creditworthiness as measured by:
        - FICO score (300 to 850, higher is better) calculated by companies such as Experian, Trans Union, and Equifax;
        - Loan-to-value ratio (lower is better);
        - Debt-to-income ratio (lower is better);
        - Payment-to-income ratio (lower is better).

Mortgages and Mortgage Backed Securities (MBS)

- Mortgage Contract Characteristics (Example)
  - The most common single-family mortgage has the following characteristics:
    - 30-year maturity;
    - Monthly payments (total term of 12 months x 30 months = 360 months);
    - Fixed rate; and
    - Flat amortization.

Mortgages and Mortgage Backed Securities (MBS)

- Mortgage Contract Characteristics (Example)
  - In recent years, floating and hybrid mortgages had become common.
    - The yield curve had steepened, making these types of loans attractive (though long-term rates were low, short-term rates were even lower).
    - Borrowers were also thought to have become more sophisticated in understanding their interest rate risk and able to take advantage of the most economical debt instrument to finance their needs.

Mortgages and Mortgage Backed Securities (MBS)

- Calculating Mortgage Payments
  - In a flat amortizing fixed mortgage, the monthly payment is determined at the beginning of the contract. Assume that \( A \) is the original balance, \( r \) is the interest rate, and \( N \) is the number of months in the contract. Then, the monthly payment is equal to:
    \[
    A \left[ \frac{r}{12} \left( \frac{r}{12} \right)^N \right] / \left[ \left( \frac{r}{12} \right)^N - 1 \right]
    \]
  - Homework: Derive this formula
Mortgages and Mortgage Backed Securities (MBS)

- Calculating Mortgage Payments
  - In a fixed amortizing mortgage, if the original balance is $250,000 and the rate is 6.0% for 30 years, each month the principal and interest payment is:

    \[
    \frac{250,000 \left( \frac{0.06}{12} \right)^{360}}{\left( 1 + \frac{0.06}{12} \right)^{360} - 1} = 1,498.88
    \]

Mortgages and Mortgage Backed Securities (MBS)

- Calculating Mortgage Payments
  - The previous calculation demonstrated how to find the total payment for a mortgage and develop a schedule for the life of the loan.
  
  In order to determine which portion of the payment is interest and which is principal in any given month, the following calculation can be completed.

  - For a mortgage with an N-month term, rate r, and initial balance A:
    - Interest in Month n:
      \[
      A \left( \frac{r}{12} \right) \left( 1 + \frac{r}{12} \right)^{n} - \left( 1 + \frac{r}{12} \right) ^{n-1} \left( 1 + \frac{r}{12} \right) - 1
      \]
    - Principal in Month n:
      \[
      A \left( \frac{r}{12} \right) \left( 1 + \frac{r}{12} \right)^{n} - \left( 1 + \frac{r}{12} \right) ^{n-1} \left( 1 + \frac{r}{12} \right) - 1
      \]

Mortgages and Mortgage Backed Securities (MBS)

- Calculating Mortgage Payments
  - Using the previous calculation (and example), a cash flow schedule can be created:

<table>
<thead>
<tr>
<th>Month</th>
<th>Starting Balance</th>
<th>Interest</th>
<th>Principal</th>
<th>Ending Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250,000</td>
<td>1,250.00</td>
<td>1,250.00</td>
<td>250,000</td>
</tr>
<tr>
<td>2</td>
<td>248,750</td>
<td>1,249.90</td>
<td>1,249.90</td>
<td>248,750</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>360</td>
<td>1,491.97</td>
<td>...</td>
<td>...</td>
<td>1,491.97</td>
</tr>
</tbody>
</table>

*Note that $1,498.88 - $1250.00 = $248.88

Mortgages and Mortgage Backed Securities (MBS)

- Calculating Mortgage Payments
  - Given the same example on the previous page, in month 130, the interest payment is: In order to determine which portion of the payment is interest and which is principal in any given month, the following calculation can be completed.

    \[
    \frac{250,000 \left( \frac{6.0}{12} \right)^{130} \left( 1 + \frac{6.0}{12} \right)^{-130} \left( 1 + \frac{6.0}{12} \right) - 1}{\left( 1 + \frac{6.0}{12} \right)^{130} - 1} = 1,025.28
    \]

  And the principal payment is equal to

    \[
    \frac{250,000 \left( \frac{6.0}{12} \right)^{130} \left( 1 + \frac{6.0}{12} \right)^{-130} \left( 1 + \frac{6.0}{12} \right) - 1}{\left( 1 + \frac{6.0}{12} \right)^{130} - 1} = 473.60
    \]

  Note that $1,025.28 + $473.60 = $1,498.88, the total payment determined on the previous page.
Mortgages and Mortgage Backed Securities (MBS)

- Calculating Mortgage Payments
  - The higher the mortgage rate, the greater the proportion of each monthly payment is devoted to interest. Hence, for the same amount and term, the higher the rate, the larger fraction of the original principal balance if left in any given month.

- Prepayment Option
  - Mortgagors have the right to reduce principal ahead of schedule, which is called the prepayment option.
  - Any payments made by the borrower in excess of scheduled payments are called prepayments. Cash ultimately obtained from a default and foreclosure sale of property constitute prepayments as well.
  - Prepayments may occur for one of several reasons:
    - Refinancing into a new mortgage with a lower interest rate;
    - Sale of property because of relocation or a move to a new house;
    - Defaults;
    - Partial prepayments (curellments); or
    - Homeowner motivations beyond rational economic (interest-rate related) considerations, which play an important role in assessing prepayment risk.

Mortgages and Mortgage Backed Securities (MBS)

- Summary
  - Of all the types of consumer loans originated each year, mortgages are the largest in total dollar volume.
  - To continue to originate mortgages at the pace consumers need, additional sources of funding are necessary.
  - The rest of this discussion explains how the capital markets act as an effective source.

Mortgages and Mortgage Backed Securities (MBS)

- What is a Mortgage Backed Security (MBS)
  - An MBS is when a number of mortgages that are similar in amounts, terms, rates, and structure are combined into a single group.
  - Mortgage documents associated with this group are transmitted to a custodian, reviewed by a trustee, and are assigned an identification (pool) number by an issuing entity (described in greater detail later).
  - An MBS is issued with a face amount equal to the cumulative outstanding principal balance of the mortgages (original balance) and with certain characteristics such as bond coupon.
Mortgages and Mortgage Backed Securities (MBS)

- What is a Mortgage Backed Security (MBS)
  - The mortgages that have been pooled together serve as the collateral for the security.
  - Because loans underlying a pool are similar but not identical, properties of an MBS must be described using weighted averages by face value:
    - WAM - weighted average maturity;
    - WAC - weighted average coupon; and
    - WALA - weighted average loan age.
  - The principal amount of the pool/lot will decrease every month – the mortgage/pool factor.

- Benefits of Securitization
  - Benefits of securitization to mortgage lenders include:
    - More efficient use of capital;
    - Increased velocity of origination (origination fee and servicing fee);
    - Greater balance sheet liquidity;
    - Funding diversification;
    - Asset-liability management;
    - Ability to manage portfolio growth; and securitization provides
      - A business exit strategy.

- Benefits of Securitization
  - Benefits to investors include:
    - Access to an investable asset with a
    - Yield premium over Treasuries;
    - Limited/No credit risk (in many cases); and
    - Liquidity.
Mortgages and Mortgage Backed Securities (MBS)

- Prepayments
  - Mortgagors have the statutory right to re-finance at their discretion, notwithstanding prepayment penalty mortgages (PPMs). This is called the prepayment option.
  - Prepayments are usually the most important factor in valuing a large class of MBS.
  - Prepayments affect MBS through call risk and extension risk.

- Reinvestment risk aspect of prepayments
  - Invariably, MBS are priced with an assumption about future prepayments – the risk to investors is that their assumption was WRONG or is CHANGING.

- Call risk occurs when monthly cash flows are earlier than expected and hence the weighted average life of the bond is shortened. This is caused by higher-than-expected prepayments:
  - This benefits the holder of a discount MBS (i.e., the holder bought the MBS for less than face principal value - below par), as principal purchased below par is returned early at par.
  - This harms the holder of a premium MBS (i.e., the holder bought the MBS for more than face principal value - above par), as principal purchased above par is returned early at par.

- Extension risk occurs when monthly cash flows are slower than expected and hence the weighted average life of the bond is extended. This is caused by lower-than-expected prepayments:
  - This harms the holder of a discount MBS, as the lower prepayments prolong the period of below-market coupon payments.
  - This benefits the holder of a premium MBS, as the lower prepayments prolong the period of above-market coupon payments.

- Prepayments are greater when interest rates are low, causing cash from MBS to be returned faster from above market mortgages.
- This creates the problem of having unexpected cash to reinvest in securities with lower yields.
Mortgages and Mortgage Backed Securities (MBS)

- Measuring Prepayments (MBS)
  - The following are commonly used prepayment measurements:
    - SMM (single monthly mortality rate):
      - Percentage of mortgages outstanding at the beginning of the month that are prepaid during the month.
    - CPR (conditional prepayment rate):
      - SMM expressed at an annual rate: \[ 1 - CPR = (1 - SMM)^{1/12} \]
    - PSA (Public Securities Association) model:
      - Next

Mortgages and Mortgage Backed Securities (MBS)

- PSA (Public Securities Association) model:
  - A CPR ramp model that accounts for seasoning of the loans and is modeled off of prepayment relocation assumptions.
  - This ramp is made up of annualized prepayment rates of 0.2% CPR in the first month, 0.2% increases in every month thereafter until the 30th month, when the rate reaches 6% and stays at this level.
  - This model acknowledges that prepayment assumptions will change; hence PSA is thought of as a baseline and referenced with a % difference (i.e., 120% PSA assumes 20% higher prepayments than the baseline PSA alone).

- PSA (Public Securities Association) model:
  - This baseline can be estimated by the prepayment history of deep discount coupons, as prepayments on such coupons primarily reflect housing turnover.
  - At a lower-than-market coupon, home owners do not have an incentive to refinance.
  - % of PSA is used to reflect views on future changes in the refinancing incentive.
Mortgages and Mortgage Backed Securities (MBS)

1.41

- Measuring Prepayments (MBS)
  - PSA (Public Securities Association) model:
    - Based on this, PSA prepayments affect principal paydown:

- Prepayment Burnout in MBS
  - For the same refinancing incentive, more-seasoned pools show slower prepayment speeds. This is generally referred to as the effect of Burnout.
  - As seasoned premium mortgages accumulate more burnout and thus are less sensitive to declines in mortgage rates, prepayment risk is generally lower.
  - Because of the perceived lower optionality, investors usually are willing to pay more for vintage premiums than for new origination of the same coupon.

1.42

- Prepayment Burnout in MBS
  - Borrowers who are usually the first to refinance and drop out of a mortgage pool generally:
    - Are more sophisticated financially (optimally exercising their option to refinance);
    - Face lower refinancing costs;
    - Have more built-in equity in their homes;
    - Have higher incomes.

- Modeling Prepayments (MBS)
  - In characterizing prepayments, a large variety of mortgage and market data are available for study, including:
    - Loan types
    - Refinancing alternatives
    - Coupons
    - Prepayment costs
    - Vintages
    - Housing values
    - Dollar balances
    - Tax rates
    - Mortgage rates
    - Regulations
    - Shape of the yield curve
Mortgages and Mortgage Backed Securities (MBS)

Modeling Prepayments (MBS)

- A prepayment function is generally based on four sub-models of homeowner prepayment decisions:

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinancings</td>
<td>Relocations</td>
<td>Defaults</td>
<td>Curtailments</td>
</tr>
</tbody>
</table>

- Different types of mortgages (e.g. FNMA or GNMA) require different prepayment functions

Prepayment functions are generally estimated by fitting actual prepayment speeds to various key variables, including:
- Level of interest rates in various products;
- Shape of the yield curve;
- Mortgage spreads;
- Refinancing costs (fees, up-front points);
- Loan age, seasonal factors; and
- Macroeconomic factors such as housing prices, aggregate income, etc.

In practice, prepayment models are less than perfect. Hence, the MBS valuation is always subject to prepayment model risk (the risk that prepayment predictions are systematically biased).

- One known area of possible prepayment model risk is that mortgagors usually do not or cannot optimize their right to exercise their prepayment options.
1. Mortgages and Mortgage Backed Securities (MBS)

- **Modeling Prepayments – The Refi S – Curve**
  - Borrowers have various thresholds for refinancing under different incentives.
  - Refinancing speeds are determined by measuring the difference between a borrower's mortgage rate and the current market mortgage rate.
  - The following curve was developed as a general guideline as to when borrowers refinance; however, each different type of mortgage pool has its own curve.

2. Mortgages and Mortgage Backed Securities (MBS)

- **Modeling Prepayments – The Output**
  - To value an MBS, you must estimate the cash flows in future months; however, cash flows depend on future interest rates - both on their levels and on the paths they took to reach those levels.
  - One way to model these cash flows is to assume that future rates implied by the forward curve will be realized:
    - At each future payment date there will be a yield curve implied by forwards from today’s yield curve.
    - By using this yield curve in combination with a separate model of how mortgage rates respond to the yield curve, the future refinancing incentive can be calculated.
  - Problem: What if the forward rates aren't realized?
<table>
<thead>
<tr>
<th>Mortgages and Mortgage Backed Securities (MBS)</th>
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</tr>
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<tbody>
<tr>
<td>Model Prepayments – Option Adjusted Spread (OAS)</td>
<td>Model Prepayments – Option Adjusted Spread (OAS) (continued)</td>
</tr>
<tr>
<td>• In order to take the volatility and uncertainty of rates into account, a model to simulate future rate paths is used.</td>
<td>• These projected cash flows are then discounted at the spot rates along each interest rate path.</td>
</tr>
<tr>
<td>• Mortgage rates are generated as a function of these simulated rates, using a separate model of mortgage spreads with respect to interest rates.</td>
<td>• The average of the discounted cashflows over all scenarios should equal the price of the MBS.</td>
</tr>
<tr>
<td>• Prepayment rates, along each interest rate path, are calculated using the prepayment function, and mortgage cash flows (both scheduled and prepayments) are projected along each interest rate path.</td>
<td>• What if it does not? Then a new yield curve is fabricated by adding a parallel shift to the interest rates, rerunning the cashflows, discounting and determining the average present value with the new parallel shift assumption.</td>
</tr>
<tr>
<td>1.53</td>
<td>• This process is repeated until the average present value equals the price.</td>
</tr>
</tbody>
</table>

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<thead>
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<tbody>
<tr>
<td>Model Prepayments – Option Adjusted Spread (OAS) (continued)</td>
<td>Model Prepayments – Embedded Option</td>
</tr>
<tr>
<td>• The option-adjusted spread (OAS) is then the parallel shift calculated by equating the average present value of projected cash flows (over all the simulations) to the market price of the security.</td>
<td>• Owing to interest rate volatility, the prepayment characteristics of the underlying mortgages can create (or decrease) value.</td>
</tr>
<tr>
<td>• If two bonds are equal in many respects, then a high OAS implies relative cheapness and a low OAS implies relative richness.</td>
<td>• We can assume that interest rates have zero volatility and value an MBS along the base-case scenario: the forward (mortgage) rate curve.</td>
</tr>
<tr>
<td>• Note that every prepayment model is different; hence, OAS can be different (from different prepayment models) when based on these calculations.</td>
<td>1.57</td>
</tr>
</tbody>
</table>
Mortgages and Mortgage Backed Securities (MBS)

- **Modeling Prepayments – Embedded Option**
  - The spread that results between valuing the MBS along the forward (mortgage) rate curve and valuing the MBS along a LIBOR-swaps curve is called a zero volatility option adjusted spread (ZVO).
  - This is the excess return over swaps that an MBS investor would earn if interest rates were non-random and the embedded option had no value.
  - OAS, on the other hand, reflects the expected return when interest rates are volatile and the embedded option has value.
- The implied cost of the option embedded in an MBS is the difference between the ZVO and OAS:
  \[ ZVO = OAS + \text{option cost} \]

Mortgages and Mortgage Backed Securities (MBS)

- **Convexity and Duration**
  - Duration, \( d \), is the percentage change in the price of an MBS due to a 100 basis point change in yield. For example, the value of an MBS with a duration of 3 will decline about 3 points for each 100 basis point increase in interest rates.
  - Convexity, \( c \), measures the sensitivity of a bond's price to larger changes in yield.
  - Therefore, convexity is the sensitivity of a bond's duration to changes in yield:
  \[ \Delta d = -c \times \Delta y \]
  - When looking at the price function of an MBS changing across small variations in yield, remember that prepayments will also vary.

- **Convexity and Duration (continued)**
  - Given \( P \) = price, and \( \Delta y \) = change in yield, then:
    - Duration:
      \[ d = \frac{P(\Delta y) - P(+\Delta y)}{2P(0)\Delta y} \]
    - Convexity:
      \[ c = \frac{P(\Delta y) + P(+\Delta y) - 2P(0)}{2P(0)(\Delta y)^2} \]

As yields fall, mortgage rates fall and prepayments rise (due to the refinancing incentive), which causes cash flows to increase in the near term and "shortens" the MBS. This will reduce duration.

Conversely, as yields rise, mortgage rates rise and prepayments decrease, which decreases cash flows in the near term and "extends" the bond. This will increase duration.
Mortgages and Mortgage Backed Securities (MBS)

- **Convexity and Duration (continued)**
  - This "reverse" relationship is what causes "negative" convexity:
    - Holders of MBS generally do not want to be exposed to interest rate risk. They can hedge their MBS with another security such that as MBS prices fall (when yields rise), the hedged security’s price rises, and vice versa.
    - The hedge has a duration opposite to that of the MBS.
    - Typically, the hedge is a short position in 10-year Treasuries or swaps.
    - Because of negative convexity, this type of technique has shortcomings and must be actively managed.
    - Even worse, if prepayment assumptions change hedging strategies can compound losses.

Mortgages and Mortgage Backed Securities (MBS)

- **Agency vs. Non-Agency MBS**
  - The primary bifurcation in MBS is between "agency" and "non-agency" collateral.
  - Agency securities have underlying collateral that is guaranteed or insured by one of three government or government-sponsored enterprises (GSE):
    - Federal National Mortgage Association or "Fannie Mae" (FNMA);
    - Federal Home Loan Mortgage Corporation or "Freddie Mac" (FHLMC); or
    - Government National Mortgage Association or "Ginnie Mae" (GNMA).

Mortgages and Mortgage Backed Securities (MBS)

- **Agency vs. Non-Agency MBS**
  - Non-agency securities are excluded from these guarantees / insurance if they have certain characteristics, such as:
    - "Jumbo" loans - Fannie Mae and Freddie Mac cannot buy loans with balances exceeding a limit set annually by the US government (currently $417,000; with some exceptions up to $729,750 in "high cost areas")
    - Loans on second properties - vacation homes, investment properties;
    - Loans with insufficient documentation; or
    - Loans where the borrowers have credit history problems.

Mortgages and Mortgage Backed Securities (MBS)

- **Bond Market Breakdown**

```
Mortgage Related
  - Residential (single and multi)
  - Non-Agency
  - Commercial

Asset Backed
  - Mortgage Related
    - HEL (>80% of ABS in '06)
    - Non-Mortgage Related
      - Credit Card Receivables
      - Auto Loans
      - Student Loans

Federal Agency Debt
  - FHLB
  - FNMA, FHLMC, GNMA

Municipal Debt
```

Dec 31, 2006
($Trillions)
Mortgages and Mortgage Backed Securities (MBS)

- **Mortgage Market Breakdown**

  **Dec 31, 2006**

  ($Billions)

  Agency $3,899B
  Non-Agency $1,834B

  FNMA $2,022B
  FHLMC $1,463B
  GNMA $414B

  **KEY ATTRIBUTES**

  **AGENCY vs NON-AGENCY**

  **Agency Backed**
  - Considered AAA Credit – Guaranteed by Government Sponsored Enterprise (GSE)
  - Mortgages used as collateral for security must conform to GSE requirements
  - Securities issued as pass-throughs

  **Non-Agency Backed**
  - Credit rated by S&P, Moody’s, etc.
  - Mortgages may not conform to GSEs
  - Jumbo (Prime)
  - Limited Documentation (Alt-A)
  - Subprime (credit and cashout)
  - Securities issued as credit delineated structures – not as pass-throughs

Mortgages and Mortgage Backed Securities (MBS)

- **Agency vs. Non-Agency MBS - Comparison**

<table>
<thead>
<tr>
<th>Agency</th>
<th>Non-Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNMA and FHLMC</td>
<td>GNMA</td>
</tr>
<tr>
<td>Status</td>
<td>Wholly-owned entity of the Department of Housing and Urban Development (HUD).</td>
</tr>
<tr>
<td></td>
<td>Backed by the full faith and credit of the US government.</td>
</tr>
<tr>
<td>Security Parameters</td>
<td></td>
</tr>
<tr>
<td>Conventional insured (see FNMA/FHLMC guaranteed)</td>
<td>FIA insured (VAM) (guaranteed mortgages)</td>
</tr>
<tr>
<td>- 94% max LTV</td>
<td>- Certain property types</td>
</tr>
<tr>
<td>- 90% max LTV</td>
<td></td>
</tr>
<tr>
<td>- 80% max LTV</td>
<td></td>
</tr>
<tr>
<td>- 75% max LTV</td>
<td></td>
</tr>
</tbody>
</table>

Mortgages and Mortgage Backed Securities (MBS)

- **Agency vs. Non-Agency MBS - Non-Agency**

  - Non-agency MBS are not guaranteed / insured by the federal government.
  - In order to achieve a triple-A rating, the bonds must have sufficient levels of credit enhancement. This can be achieved through:
    - Several structuring methods, which will be described later (one of which is subordination)
    - Senior/subordinate structures create “levels” of bonds such that the lowest rated tranches absorb credit losses first and the most senior tranches only experience credit losses if all the subordinate bonds are completely written down.
Mortgages and Mortgage Backed Securities (MBS)

- **Agency vs. Non-Agency MBS - Non-Agency**
  - Third party guarantees, which are letters of credit from financial institutions and bond insurance that guarantee timely payment of principal and interest against losses up to some specified level for a fee.
  - Cash reserves, where underwriting profits or a servicing spread is set aside to cover default losses. If this is not used, then the underwriter receives the fees at the maturity of the security.
  - Over-collateralization, where extra collateral is placed in the deal (e.g., $110 million of mortgages backs $100 million in bonds). Any extra collateral that remains at maturity is usually returned to the originator.

Mortgages and Mortgage Backed Securities (MBS)

- **MBS Collateral**
  - Mortgage loans may have many different characteristics, as described in the first section of this presentation.
  - Loans that do not have the characteristics needed to qualify for agency guarantee / insurance, are often used as collateral for non-agency MBS.
    - Each pool of loans has similar characteristics, but pools are structured differently, and have different features and performance.

Mortgages and Mortgage Backed Securities (MBS)

- **MBS Collateral**
  - The main types of non-agency-eligible collateral are:
    - Jumbo (prime and hybrid): Loans that are not qualified for agency guarantee / insurance because of loan size.
    - Subprime: Loans further down the credit spectrum.
    - Alternative A (Alt-A): Loans in the middle-of-the-credit spectrum, missing documentation on prime borrowers and other characteristics that exclude these loans from being Prime.
    - FHA/VA Re-performing: Loans backed by GNMA that have been delinquent, bought out of the pool, and made to perform again, yet still do not qualify for securitization through FNMA or FHLMC.
    - Scratch and Dent: Exceptions to underwriting guidelines have been made in order to fulfill the loan (e.g., lower-than-acceptable FICO, impaired borrowers, etc.).

Mortgages and Mortgage Backed Securities (MBS)

- **Jumbo – Characteristics**
  - Jumbo loans have balances exceeding the limit for agency conforming insurance.
  - Fixed and floating loans with this characteristic are called jumbo prime loans; hybrid rate loans are called jumbo hybrid ARMs.
  - Characteristics typical of Jumbo loans are:
    - FICO: 700+
    - Documentation: full conforming
    - Past delinquencies: 0
    - LTV: 80%
    - Mortgage insurance: Over 80%
Mortgages and Mortgage Backed Securities (MBS)

- Jumbo Hybrid ARM – Performance
  - In a refinancing environment, prepays are generally faster because large monthly payments create a bigger refinancing incentive.
  - Prepayment speeds are comparable or typically slower than agency collateral in a non-refinancing environment.
    - This creates a negative convexity worse than agency MBS.
  - Banks like these types of loans because of their high credit quality, short duration, and wider spread than agency MBS.

- Agencies see these assets as fundamentally cheap, with wide OAS.
- Hybrid ARM MBS prepayments have closely tracked those of balloon loans (loans with an amortization schedule longer than the life of the loan, forcing a large payment at maturity).

Mortgages and Mortgage Backed Securities (MBS)

- Subprime – Characteristics
  - The borrowers in these pools typically have credit problems, prior late payments on their mortgages, prior bankruptcies, or general problems with their bill paying histories.
  - Typical characteristics of Subprime MBS are:
    - FICO: 500 - 640
    - Documentation: Full or Limited
    - Past delinquencies: Up to 120 days
    - LTV: 80%
    - Mortgage insurance: rarely over 80%

- Note that 80% of these loans are hybrid fixed / floating, with two to three year fixed periods.
- Many of these loans are interest only.
Mortgages and Mortgage Backed Securities (MBS)

- Subprime – Performance
  - Subprime loans are typically less rate sensitive than agency MBS. Prepayments are typically dependent on increases in collateral value (where borrowers then can take cash out by refinancing) and credit curing.
  - Subprime MBS typically have less negative convexity than agency MBS.
  - Subprime loans create an opportunity to increase margins and returns since they have higher coupons; however, these loans do have riskier borrower credit performance than prime asset classes.

Mortgages and Mortgage Backed Securities (MBS)

- Subprime – Performance
  - There has been increasing regulatory pressure on sub-prime asset classes related to consumer protection laws, as well as increasing credit enhancement due to rating agencies revisiting their models.
    - Moody's changed their standard requirements in May of 2004,
    - S&P revised their standards in November 2004, and
    - Revisions from Fitch in 2005.

Mortgages and Mortgage Backed Securities (MBS)

- Alt-A – Characteristics
  - Alt-A pools consist of mortgages that are between prime and subprime credit quality, or have other features that disqualify them from being classified as Prime.
  - One way to look at Alt-A securities is by dividing them by:
    - Prime Alt-A: borrowers who are prime but missing documentation (self-employed, no employer references, etc.)
    - Non-prime Alt-A: strong subprime borrowers, sometimes called Alt-B
Mortgages and Mortgage Backed Securities (MBS)

- Alt-A – Characteristics
  - Characteristics typical of Alt-A collateral are
    - FICO: 640 - 720
    - Documentation: limited
    - Past delinquencies: once in the past twelve months
    - LTV: 70% - 95%
    - Mortgage insurance: sometimes

Mortgages and Mortgage Backed Securities (MBS)

- Alt-A – Performance
  - Alt-A securities typically have slower CPR than MBS of jumbo prime collateral.
    - For Prime Alt-A, prepayments are typically slower than those of prime pools in the first year and mimic prime prepayments in later years.
    - Non-Prime Alt-A usually have prepayments similar to those of subprime initially, or slightly faster (since they do have better credit quality); then they speed up if their credit quality improves and the borrower can refinance at a prime rate.
  - The Alt-A market usually has lower prepayment risk than a prime pool, and lower default risk than a subprime pool.

Mortgages and Mortgage Backed Securities (MBS)

- Alt-A – Performance
  - In addition, the convexity of Alt-A securities is typically less negative than that of agency MBS because:
    - When yields are low, fewer borrowers refinance;
    - When yields are high, there is little refinancing incentive; and
    - While defaults are higher than Jumbo collateral, they are not near those of subprime collateral.
  - Origination of Alt-A product has historically been counter-cyclical to movements in rates.
### Mortgages and Mortgage Backed Securities (MBS)

#### MBS Structures – Basic MBS Pass-Throughs
- Securities are traded in either a To Be Announced (TBA) format or by specifying a particular characteristic or pool number.
  - TBA securities are the most liquid in the market, and are traded by coupon. The actual security that is delivered is determined by the seller on the settle date, hence the To Be Announced acronym.
  - A specific pool vintage, or issuance, of a security can also be traded, and usually trades at a premium to a TBA security of the same coupon.

#### MBS Structures – Collateralized Mortgage Obligations (CMOs)
- CMOs are created by pooling mortgage pass-throughs or whole loans and by splitting their cash flows into tranches.
- A CMO is self-supporting, i.e. the collateral cash flow is able to meet the tranches’ cash flow requirement.
- Tranches vary by:
  - Average life;
  - Coupon;
  - Stability;
  - Prepayment risk; and
  - Credit Rating/Risk.
Mortgages and Mortgage Backed Securities (MBS)

- CMO Characteristics
  - There are agency and non-agency CMOs, just as there are agency and non-agency MBS.
    - Agency CMOs carry the same guarantee / insurance as agency MBS.
    - There is no need for credit enhancement in these structures owing to the agency guarantee / insurance; so tranching is used to create bonds of different average lives or interest-rate performance characteristics.
    - CMOs created out of whole loans do not carry the agency guarantee / insurance and are structured to create credit enhancement in addition to different average lives and performance characteristics.

Some examples of CMO tranche classes are:
- Sequential pay classes;
- Planned amortization classes (PAC);
- Targeted amortization classes;
- Support Classes;
- Z bonds;
- Accretion-direct classes;
- Floaters and inverse floaters; and
- Interest only / principal only (IO/PO)

- We will explicitly consider CMO and other liability structures later