Modeling of Mortgage Prepayments and Defaults

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Topics

• An Overview of the Mortgage Market

• Challenges in Prepayment and Default Modeling

• Implications for Valuation of Mortgage-Backed Securities
The US Mortgage Market --
Colossus of the Bond World

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Mortgage Debt</td>
<td>$12.3 trillion</td>
</tr>
<tr>
<td>Single-Family Mortgage Debt</td>
<td>$9.5 trillion</td>
</tr>
<tr>
<td>Mortgage-Backed Securities</td>
<td>$6.2 trillion</td>
</tr>
<tr>
<td>Asset-Backed Securities</td>
<td>$2.0 trillion</td>
</tr>
<tr>
<td>US Treasuries</td>
<td>$4.2 trillion</td>
</tr>
<tr>
<td>Corporate Bonds</td>
<td>$5.2 trillion</td>
</tr>
<tr>
<td>Municipals</td>
<td>$2.3 trillion</td>
</tr>
</tbody>
</table>

What are Mortgage Securities?

- A number of mortgage loans - from a few dozen to more than 10,000 - are pooled;

- Each loan pays interest and principal until it matures, is prepaid, or goes into default;

- Cashflows from the loans are paid to investors, after subtraction of administrative (or *servicing*) fees;

- Cashflows are either simply passed on to investors (*pass-through securities*) or allocated according to specified rules (*structured securities*, such as *Collateralized Mortgage Obligations (CMOs)*).
Basic Security Features

• Cashflows are monthly, unlike Treasures or corporate bonds, which pay semi-annually;

• Amortizing assets => principal paid out over a period of time;

• For pass-throughs, each monthly payment will tend to include some principal;

• For structured MBS/ABS, principal paid out over a principal window

• Prepayment of principal by borrowers
  – call risk key property of many MBS/ABS
  – durations much shorter than similar maturity bullet security.
Basic MBS is the Pass-Through

• Issued by FHLMC, FNMA, GNMA and Private Entities

• Many mortgages with similar characteristics collected into a pool

• Investor receives pro-rata share of monthly payments

• Interest and principal payments are guaranteed by the issuing agency, or through credit enhancements (for private issuers)
Structure of a Pass-Through

Borrower pays 6.5% + principal payments

Investor receives coupon payments of 6% + principal payments

Fannie/Freddie/Ginnie receives a guarantee fee of 0.15%

Loan servicer receives servicing fee of 0.35%

Source: Citigroup. Actual numbers may vary from pool to pool
Valuation of Mortgage Securities

- MBSs are bonds with embedded options;
- More complex than standard callable bonds:
  - Each $1 is a separate option
  - Option-exercise is inefficient
  - High degree of path dependence
- Prepayment models key to valuation;
- Prepayment models combined with Term Structure Models to obtain “option-adjusted” spreads (OAS).
Basic Steps in Mortgage Valuation

- Generate a “large” number of interest rate paths, both for discounting and for cash flow generation;

- On each path, call a prepayment model/default model to calculate mortgage cash flows;

- Calculate average PV of cash flows, using benchmark rates plus a spread;

- Spread that equates average PV to market price is the option-adjusted spread (OAS).
Prepayment Rates Are Critical in Determining MBS Value

A. Cashflows Assuming No Prepayments

B. Cashflows Assuming a More Realistic Prepayment Rate

Source: Citigroup.
Some Difficulties in Developing Prepayment Models

- A large number of important variables
- Continual innovations in mortgage financing implies constantly changing regimes
- Diverse and changing range of mortgage loan types
- A high degree of path dependence
- Unpredictable and “inefficient” borrower behavior
- Limited historical prepayment data and incomplete information
A Large Number of Factors Impact Prepayment and Default Rates

- **Economic**: Mortgage Rates, Housing Inflation, Consumer Confidence, Unemployment, etc.

- **Loan**: Coupon rate, original term, remaining term, type (Fixed, ARM, Hybrid), loan size, geographical location, etc.

- **Borrower**: Credit, Socio-Economic Status, Personal Situation

- **Other**: Past exposure to refinancing opportunities, mortgage origination and servicing process, etc.
Changing Environment

• Key determinants change over time: closing costs, choice of loan types, mortgage lending industry, loan origination process, etc.

• Borrowers have become more savvy over the years

• Borrower sentiment (or psychology) plays an important role
Changes in the Mortgage Market over Time

Sources: Fannie Mae, Freddie Mac and Citigroup..
The Media Effect Measures Psychological Impact of Multi-Year Lows in Rates

Rates drop 100bp from April to Year End’97, but nothing happens

Rates hit multi-year low

Rates back to early 1998 lows but nothing happens

Rates fall significantly below early 1998 lows

Source: Mortgage Bankers Association, Freddie Mac, Citigroup

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Loan Type Variation: Term

- **30-Year**: Most common type in the US;
- **15-Year**: Higher monthly payments, so few 1st time home buyers => slower turnover and seasoning ramp. Also common refi vehicle for 30-year mortgages;
- **20-Year**: Attracts borrowers who want a 15-year loan, but cannot afford the higher monthly payments;
- **10-Year**: Mostly people refinancing out of a 15-year loan;
- **40-Year**: A newer product, popular with borrowers stretching to buy a house and who want to minimize the monthly payment.

**Notes:**

1. For a given difference between the coupons on the current and a new mortgage, the shorter the term, the lower the refinancing incentive;
2. Regardless of the shape of the yield curve, the shorter the term, the lower the mortgage rate.
Loan Type Variation: Coupon

• **Fixed Rate.** Basic mortgage in the US;

• **Adjustable Rate.** Coupon resets periodically at a stated margin over a specified index (typically 1-year Treasury or 6-month LIBOR). Initial coupon often “teased” and much lower than on a fixed-rate loan, so ARMs attract lot of 1st time buyers or other people with short time horizons;

• **Hybrid.** Coupon fixed for the first 3, 5, 7 or 10 years, then adjusts like a standard ARM. The shorter the fixed rate period, the shorter the typical borrower horizon, and the faster the speeds.
Loan Type Variation: Credit

- **Jumbo.** Prime quality loans that are too large for agency pools;

- **Fannie May/Freddie Mac.** Generally prime quality loans that fall below the “conforming limit”;

- **Ginnie Mae.** Loans insured by the FHA or the VA. Relative to FN/FH, poorer credit and lower loan balances.

- **Alternative (Alt) A.** Borrowers are generally moderate to good credit (hence the “A”), but lack “full documentation”

- **Sub-Prime.** Borrowers with poor credit histories.
Loan Type Variation: Other Features

• **Loan Size.** Has a big impact on speeds.

• **Geographical Location.** Ditto.

• **Prepayment Penalties.** Uncommon in prime loans, but prevalent for sub-primes.

• **Amortization Schedule.** Traditional mortgages in the US have been fully amortizing. However, strong growth in recent years in loans which pay interest only for a number of years (eg 10/20), or can even have negative amortization (ie. loan balance can increase), such as *Option ARMs.*
Prepayment Speeds on Prime and Subprime Loans

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Effect of Loan Balance

Loan Loan Balance (LLB) pools are less reactive to refinancing opportunities, but little difference in turnover speeds

Source: Citigroup.
Significant Differences in Speeds by State

Factors include loan size, closing costs, taxes, home price appreciation, and local economic conditions.

Source: Citigroup.
High Degree of Path Dependence

• Borrowers will differ in their propensity and ability to refinance

• As a pool of borrowers experiences refinancings, most able borrowers leave the pool at higher rates

• Remaining borrowers less responsive (burnout)

• Hence prepayment rates depend on complete history of interest rates
Sources: Freddie Mac and Citigroup.
Inefficient Exercise of the Prepayment Option

Burnout and Media Effect

CPR (%)

WAC — "No Point" Mtg Rate (bp)

Speeds on 2001 Coupons in Jan 2004

Speeds on 2001 Coupons in Jul 2003
History of Prepayment Modeling

• First Generation Models (Salomon, 1985)
  - Standard Multiple Regression Models
  - Many Variables → good historical fit, but not robust over time

• Diversity of Collateral and Borrowers and Continuing Changes in Prepayment Environment Suggests More Fundamental Approach (Salomon, 1995)
  - Sources of Prepayments (Modular Approach)
  - Flexible and Dynamic Inputs and Relationships
Why are Mortgages Prepaid?

- **Housing Turnover** - the sale of a home triggers a prepayment
- **Refinancings** - the loan is refinanced
- **Defaults** - foreclosure on the house leads to the loan being paid off
- **Curtailments** (or partial prepayments) - borrowers make more than their scheduled payment
- **Full Payoffs** - the loan is paid off: for example, due to a natural disaster

This is true for all loans, regardless of type of loan, country/region etc. However, the magnitude of each component will depend on *cultural*, *demographic*, *collateral* and *economic* factors.
Structure and Key Features of the Model

Modular Approach:

Projected Speed = Sum of speeds due to

1. Housing Turnover
2. Refinancings - Rate, Cash-Outs and Credit Driven
3. Curtailments
4. Defaults
Overall Housing Turnover Rate

Source: National Association of Realtors, US Census Bureau, Citigroup
Housing Turnover-Related Speeds

- Dominant in high-interest-rate environment
- Strong seasonal component
- Seasoning: brand-new pools tend to prepay more slowly
- Lock-in: higher coupons typically have higher turnover rates
Seasoning Depends on Loan Age and Home Price Appreciation

Age-related Seasoning is a critical dimension of Turnover

However, Seasoning is Modulated by Appreciation in Home Prices
Actual and Projected Home Price Appreciation

Source: Fannie Mae, Freddie Mac, Citigroup

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We assume that there are several classes of borrowers, ranging from slowest to fastest, each class having its own refi curve.

Source: Citigroup.
Evolution of Population of Mortgagors

The mix of borrowers changes each month, as faster refinancers leave the pool at a faster rate.

Refi Rate = Fraction of pool in class 1 * Refi rate for class 1 + ... 
... + Fraction of pool in class k * Refi rate for class k

Source: Citigroup.
Other Aspects of the Refinancing Model

• No consensus on how to calculate the *refinancing incentive*
  
  - A common approach is to compare PVs of new and old mortgages
  
  - Another approach: # of months to recoup costs of refinancing

• Mortgage rates used to calculate refi incentive need to depend on loan type eg sub-prime rates much higher than prime rates

• Loan balance is an important factor in determining incentive

• A seasoning curve can be introduced using transient costs of refinancing;

• Reactivity to refinancing opportunities depends on FICO, LTV and other loan features.
A Simple Default Model – Multiple of the SDA Curve

The Standard Default Assumption (SDA Curve)
A Default Model Framework

• Probability of Default = Probability(LTV > Threshold) *Probability (Trigger Event)

• Likelihood of Trigger Events depends on FICO, Debt-to-Income ratio, unemployment rates, payment shock, etc.

![Graph of Default Probability vs Age (years)]
# Key Determinants of Trigger Events

<table>
<thead>
<tr>
<th>Source: Freddie Mac.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment or Curtailment of Income</td>
</tr>
<tr>
<td>Illness or Death of Mortgagor</td>
</tr>
<tr>
<td>Excessive Obligation</td>
</tr>
<tr>
<td>Marital Difficulties</td>
</tr>
<tr>
<td>Illness or Death in Family</td>
</tr>
<tr>
<td>Extreme Hardship</td>
</tr>
<tr>
<td>Business Failure</td>
</tr>
<tr>
<td>Property Problem or Casualty Loss</td>
</tr>
<tr>
<td>Inability to Sell or Rent Properties</td>
</tr>
<tr>
<td>Employment Transfer or Military Service</td>
</tr>
<tr>
<td>All other Reasons</td>
</tr>
</tbody>
</table>

Source: Freddie Mac.
## Historical Monthly Transition Rates for Sub-Prime Loans

### Fixed-Rate Loans

<table>
<thead>
<tr>
<th>From</th>
<th>Non-delinq (%)</th>
<th>Delinquent (%)</th>
<th>Foreclosure (%)</th>
<th>REO (%)</th>
<th>Payoff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-delinq</td>
<td>97.2</td>
<td>1.0</td>
<td>0.1</td>
<td>0.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Delinquent</td>
<td>10.8</td>
<td>73.5</td>
<td>14.4</td>
<td>0.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Foreclosure</td>
<td>2.9</td>
<td>1.7</td>
<td>88.2</td>
<td>5.2</td>
<td>2.0</td>
</tr>
<tr>
<td>REO</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>84.9</td>
<td>14.7</td>
</tr>
</tbody>
</table>

### 2/28 Hybrids

<table>
<thead>
<tr>
<th>From</th>
<th>Non-delinq (%)</th>
<th>Delinquent (%)</th>
<th>Foreclosure (%)</th>
<th>REO (%)</th>
<th>Payoff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-delinq</td>
<td>96.6</td>
<td>1.2</td>
<td>0.1</td>
<td>0.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Delinquent</td>
<td>10.0</td>
<td>72.5</td>
<td>16.0</td>
<td>0.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Foreclosure</td>
<td>3.3</td>
<td>1.8</td>
<td>87.8</td>
<td>4.8</td>
<td>2.3</td>
</tr>
<tr>
<td>REO</td>
<td>0.1</td>
<td>0.0</td>
<td>0.2</td>
<td>83.7</td>
<td>16.0</td>
</tr>
</tbody>
</table>

Source: Citigroup.
Subprime Collateral Default Rates by LTV
Summary and Implications for MBS Valuation

• Modeling of prepayments and defaults as much art as science;

• MBS cashflow generation depends on these models;

• Hence little consensus on valuations, especially for complex MBS derivatives;

• Work by non-practitioners of little value in deciding, say, how much more to pay for a $60,000 average balance Texas pool vs. a $80,000 Illinois pool;

• On a positive note, great employment opportunities for good prepayment modeler;
