Loan Level Mortgage Modeling

Modeling and Data Challenges
Agenda

1. The complexity of loan level modeling
2. Our approach for modeling mortgages
3. Data Challenges
4. Conclusion
The complexity of loan level modeling

» Modeling complexity

- Many (many) scenarios are required to capture the behavior of mortgages in different states of the world
- Different types of loans behave very differently
- Non-monotonic behavior with respect to several factors
- Interaction terms needed to explain borrower behavior
- Single period analysis cannot generally be used for path-dependent instruments like mortgages

» Data complexity

- A lot of data fields needed to fully describe the mortgage
- Mortgages do not amortize quickly, so need to deal with legacy data
- Need to incorporate future loan volume with loan level detail
Loan level modeling in different economies

Many scenarios are required to capture the behavior of mortgages in different states of the world.

Same loan in different economies exhibits different behavior and may be correlated differently.
Different baselines for different types of loans

Different types of loans behave very differently

- **2/28 ARM**
- **5/25 ARM**
- **3/27 ARM**
- **FRM-30y**
Non-monotonic behavior with respect to several factors

Prepayment

Prepayment incentive is different for borrowers in different updated LTV buckets
Interaction terms needed to explain borrower behavior

Default sensitivity is different for borrowers in different FICO buckets
Using Aggregate Pool Statistics

Consider two pools drawn from this population: one homogenous and one barbelled (but both with approximately the same mean CLTV and FICO).

<table>
<thead>
<tr>
<th>FICO SCORE</th>
<th>Low &lt; 710</th>
<th>Medium [710,750)</th>
<th>High [750,775)</th>
<th>Very High &gt;= 775</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low &lt; 710</td>
<td>2.4</td>
<td>4.9</td>
<td>5.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Medium [710,750)</td>
<td>1.0</td>
<td>3.2</td>
<td>3.5</td>
<td>7.0</td>
</tr>
<tr>
<td>High [750,775)</td>
<td>0.5</td>
<td>1.5</td>
<td>1.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Very High &gt;= 775</td>
<td>0.1</td>
<td>0.7</td>
<td>0.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FICO</th>
<th>CLTV</th>
<th>Def. rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous</td>
<td>746</td>
<td>75.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Barbell</td>
<td>737</td>
<td>77.5</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Aggregate pool statistics may mask risk behavior.
Multi-period Simulation and path dependence

- Home prices start at 100 and end, 10 years later, at 134.
  - Scenario 1: home price appreciation of 3% per year for 10 years
  - Scenario 2: home price depreciation of 20% over 3 years followed by a gain over the next 7 years

Multi-period simulation is valuable due to strong path dependency.
Why are Mortgages Complicated to Model?

- A single loan can behave very differently in different economic scenarios.
- Different loan types behave very differently in the same economic scenario.
- Drivers of mortgage performance, including prepayment and default, are strongly path dependent.
- Mortgages have many embedded options, including
  - the option to prepay (call)
  - the option to walk away from the loan (put).
- The terms of these options do not generally average out analytically.

Mortgages are one of the most difficult asset classes to model.
Our Approach

» Our model is an analytic tool for assessing the credit risk of a portfolio of residential mortgages (RMBS & whole loans)

» The model comprises loan-level econometric models for default, prepayment, and severity.

» These models are integrated through common dependence on local macro-economic factors, which are simulated at national and local (MSA) levels.

» This integration produces correlation in loan behaviors across the portfolio.

» Because we use a multi-step Monte Carlo approach, the model can be combined with an external cash flow waterfall tool and used for simulation of RMBS transactions.

» The models also use pool-level performance to update the output in real-time.
Our Approach

» Panel data – monthly observations for each loan through time

» Survival models – Different baselines or nominal hazard rates as a function of loan age for different types of mortgages

» Competing risk framework – Defaults and Prepayments are two types of loan exit.

» Explanatory variables are observable macro-economic variables and loan and borrower characteristics

» Implementation in a multi-period framework.
Applications

» Stress testing of whole loan portfolios
» Surveillance and monitoring of RMBS transactions
» Selecting loans for securitization based on credit risk
» Whole loan pricing and trading
» Risk management of loan portfolios
» Regulatory reporting for CCAR and DFAST submissions
» ALLL and CECL calculation
Mortgage Modeling Overview

FACTORS

» Economic Data (Simulated or Scenario)

» Loan Level Pool Data (User Data)

» Supplemental User data (Loan level Override, Pool Performance etc.)

MODELS

» Default

» Severity

» Prepayment

OUTPUT

Σ

Loan Level E(L)

Pool Level E(L)
Mortgage Modeling Framework – Economic Factors

» The key economic processes that are simulated in the model are:

- **Interest rates** (Yield curve & LIBOR rates)
- **Home Price Change** (national, state, and MSA level)
- **Unemployment rates** (national, state, and MSA level)
- **Loan market rates** (Freddie Mac mortgage rate)
Delinquent loan pipeline makes up a key part of future losses.
Modeling Seasoned Mortgage Pools: Delinquent loans

» We categorize delinquent loans into: 30 DPD and 60 DPD buckets

» Default and prepayment hazard rates differ substantially between delinquent loans and current loans.

» Each delinquency status has different default and prepayment behavior.

» Can determine extra risk in delinquent loans as compared to equivalent current loans.

Delinquent loans behave very differently from current loans.
Modeling Seasoned Loans: Incorporating pool-specific Realized Performance To-date

» Realized performance can, on occasion, be very different than predicted due to unobservable differences in underwriting, servicing, borrower characteristics, etc.

» It is important to incorporate individual components of the realized performance, namely default, prepayments, and severity, separately.

» If past performance is available, it can be very valuable.

» Need to back-test each individual component of the models against pool performance to calibrate the models.

Pool-level idiosyncratic behavior can be useful in future projection.
In addition to generating the full loss distribution, we can estimate losses under *Moody’s* or user-defined scenarios.
TRC is the contribution a loan makes to the tail risk of a portfolio.

<table>
<thead>
<tr>
<th></th>
<th>EL</th>
<th>99.5% VaR Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original portfolio</td>
<td>4.0%</td>
<td>12.6%</td>
</tr>
<tr>
<td>With 100 highest EL loans removed</td>
<td>2.9%</td>
<td>10.2%</td>
</tr>
<tr>
<td>With 100 highest contributors to VaR removed</td>
<td>3.1%</td>
<td>9.7%</td>
</tr>
</tbody>
</table>

Tail risk of a loan is often different than its stand-alone risk.
Custom Scenarios

» Custom scenarios are an integral part of stress testing

» User can provide a view for one or more macro-economic variables such as interest rates, GDP, HPI, and Unemployment rate

» Models can “fill-out” all the missing variables at the national, state, or MSA level and through time in a consistent manner

» Can “anchor” a simulation around a custom scenario. We can then obtain a full loss distribution, Value at Risk, Tail Risk Contribution, and loan level detail.
Validation and Testing

» How do we know that we have done a good job?

- Calendar time plots

  » Segments modeled separately (for example, first liens and second liens)

  » Segments not part of the model (for example, low FICO, high LTV)
Validation and Testing

» Univariate plots
  - Model variables
  - Variables not included in the model

» Avoid over-fitting

» Do not rely on statistical tests alone
Additional Calibration and Testing

Some other things to look for

» Do we need to extrapolate some functions? For example, unemployment rates outside the range of observable data.

» Forecasts under different stress and baseline scenarios. How do projections over time compare with historical losses?

» Sensitivities to key variables. Are the sensitivities in line with expectations?

» Overrides or calibration for things not considered. Have some policies changed?
Analyse portfolios of mortgages (and other asset classes) in a correlated fashion using an intuitive and consistent set of macro-economic variables.

- Generate losses for *Moody’s Analytics*, Fed CCAR, and user defined scenarios.
- Conduct **scenario analysis** using observable macro-economic factors.
- Conduct **validation** using realized economies to-date.
- Use the **same framework** to evaluate **seasoned** portfolios and **new originations**.
- Determine a loss distribution and calculate **VaR**.
- Calculate the **tail risk contribution** for each loan and manage the tail risk of a portfolio of mortgages.
- Provide collateral loss distribution and cash flows that **can be combined with a waterfall engine** to produce tranche-level loss distributions.
The Role of Data

Data correctness and completeness is fundamental to the entire modeling effort.
Data Challenges – Model Building

Lack of good historical training data

» Most banks do not have a long enough data history.
» Post crisis data is usually of better quality, but pre-crisis data can have gaps.
» Acquisitions and mergers create unique data problems.
» Acquisitions and mergers can result in data of different underlying risks.
» Policy decisions can result in unpredictable performance.

Techniques for handling data inadequacies

» Can use proxy data to derive relationships and calibrate to the bank’s data.
» Use segmentation to distinguish between different portfolios. For example, the portfolios of banks before and after an acquisition could be separately calibrated.
» Each policy decision has to be addressed individually and carefully.
Data Challenges – Model Execution

Model Execution

» Determine how a loan amortizes
» Determine interest rate changes for ARM loans
» Determine HELOC utilization
» Delinquency information

What information do we need

» Loan terms
» Underlying index, margin, caps, and floors for ARM loans
» Model for HELOC utilization
» May need to fill-in missing data since we may not be in a position to remove loans with bad data
Data Challenges – Future Volume

Future volume

» Not all portfolios are in a run-off mode
» Loans originated in the future will contribute to losses
» Future volume depends on balance attrition as well as growth policies
» Need to generate future originations with loan level detail
» The loan level data should have the desired average values, distributions, and correlations

How do we generate future volume with loan level detail?

» Generate future volume by segments – for example, first lien mortgages, second lien mortgages, fixed rate loans, ARM loans.
» Examine a reference portfolio for each segment and infer distributions and correlations from it.
» Allow override of any inferred distributions.
» Generate loan level data by sampling from these distributions.
Conclusion

» Modeling at the loan level offers significant detail in estimating losses.

» Modeling each loan behavior (default, prepayment, and severity) separately provides substantial flexibility in calibration and specification.

» The state of the local and national economy significantly impacts the performance of loans.

» A loan level approach can be challenging from a data as well as a modeling point of view.

» With good data collection and careful modeling, this approach can be used in different areas of the business.
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