Moody's Research Labs

Decomposing Mortgage Portfolio Risk: Default, Prepayment, and Severity

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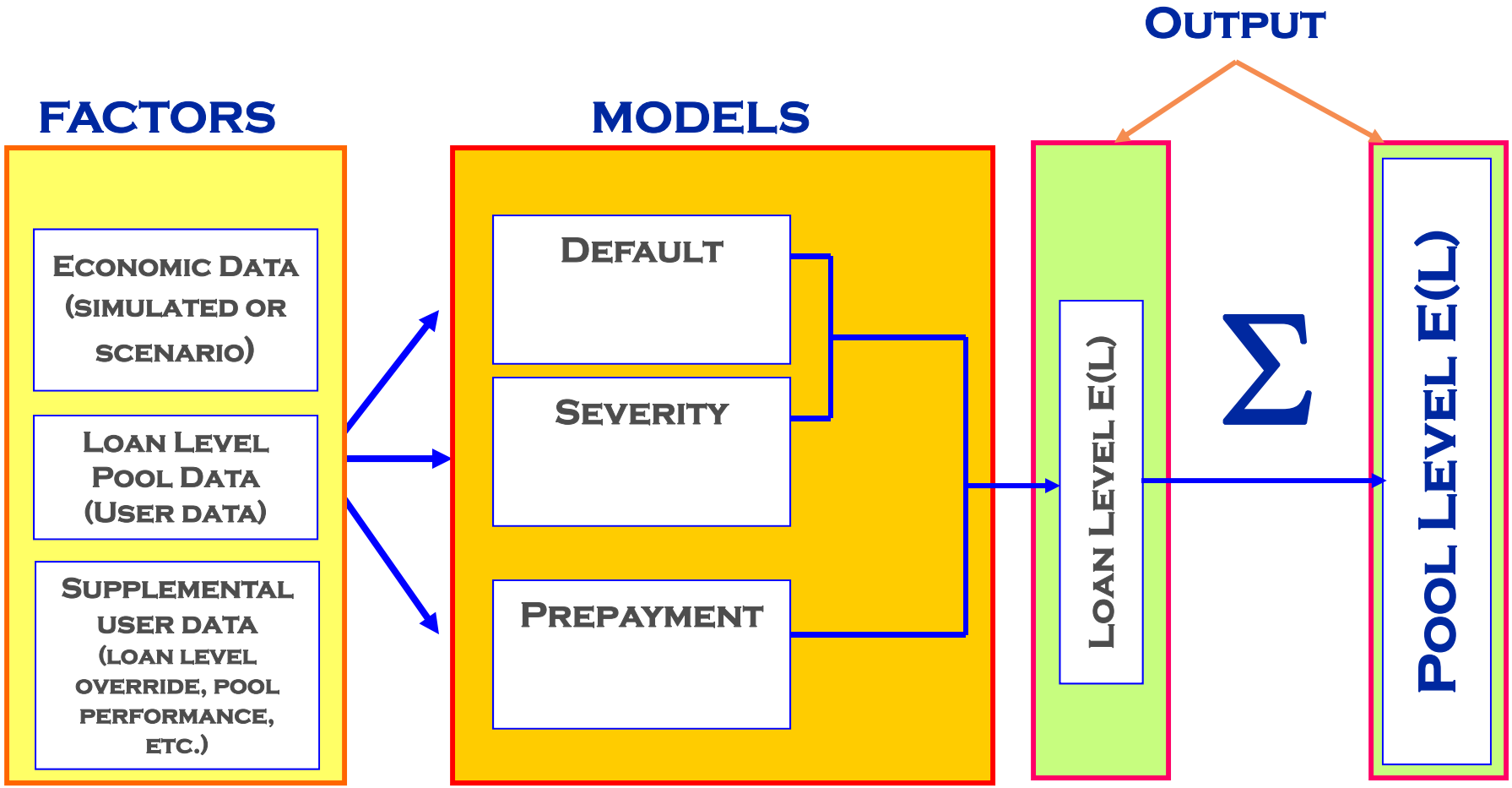
Overview

- The loss on a mortgage portfolio is an aggregate of the losses of the loans in the portfolio
- The loan behaviors that have direct impacts on loan losses:
  - A loss may occur if a loan **defaults.** The magnitude is determined by **severity**, or loss-given-default of the loan.
  - If a loan **prepays**, there will be no loss on this loan. Statistically, higher prepayment probability reduces the chance for a loan to default.
- Default, prepayment and severity are all affected by loan and borrower characteristics and macro economic factors. A factor may have an intuitive relationship with the individual behaviors, but not necessarily so with loan loss.
- MPA integrates the individual models through their dependence on common (especially economic) factors in a quasi-structural way to generate the loan level losses in a natural way. This correlates the loans in a natural way.
- Loan level losses are then aggregated to get the pool level losses.

Decomposition simplifies complicated processes. Re-integration gets it back to the complex real world.

Mortgage Modeling: Overview II



Agenda

1. Building the component models
    - » Default / Prepayment models
    - » Severity model
2. Simulating macro economic factors
3. Putting it altogether: Mortgage Portfolio Analyzer
4. Conclusion

1

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4. **Conclusion**

Default/Prepayment models: Cox regression

- Default/Prepayment: Cox Proportional Hazard Model is a natural choice.
  - Both default and prepayment are discrete events.
  - Both are affected by many factors (macro economic factors, loan characteristics and etc.).
  - Both are affected by seasoning (age) of the loan in a highly non-linear way.

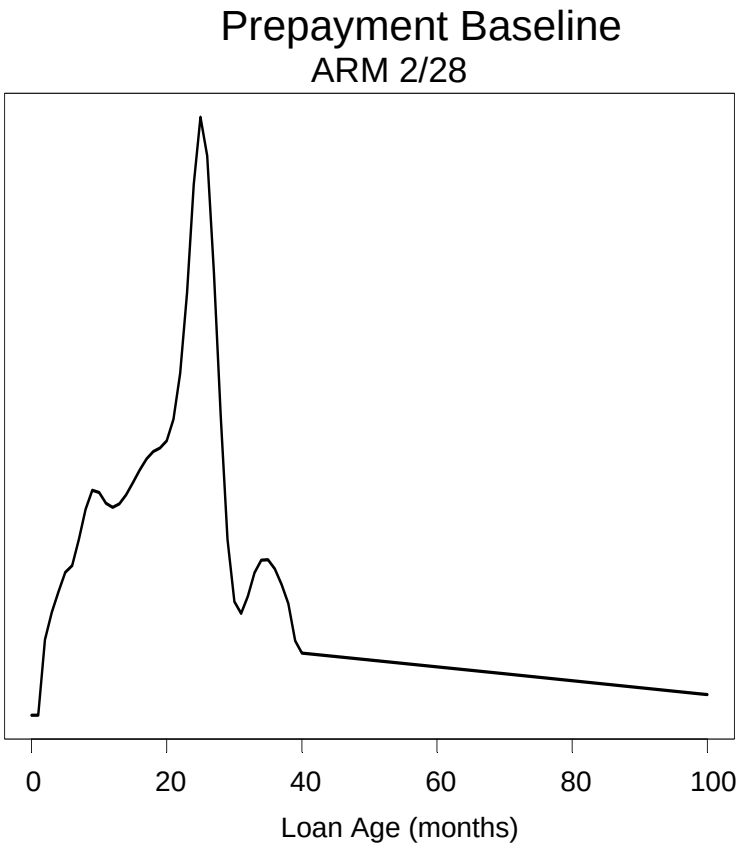
- Cox Proportional Hazard Model

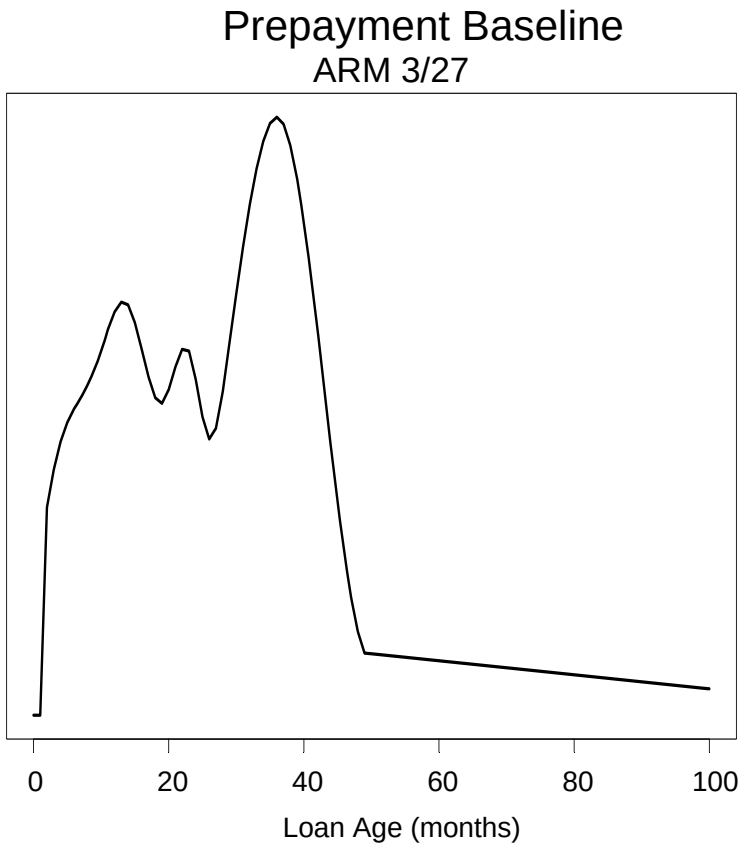
$$h_i(t) = h_0(t)\, e^{\beta' x}$$

  - In the equation, ***i*** indicates i^{th} loan. ***t*** indicates loan age.
  - $h_i(t)$ is the hazard rate we want to estimate. More specifically, it is the probability of i^{th} loan to default or prepay conditional on that it has survived till time t.
  - $h_0(t)$ is the baseline hazard of all loans (of the same type) on average. It is a non-parametric function of ***t*** and captures differences in loan behavior throughout a loan's life.
  - The $\beta' x_i$ in the exponential term is the regression component. It, as in any other regression, estimates the β coefficients for the factors.

Cox model offers both flexibility and interpretability.

Default/Prepayment models: Example of baselines

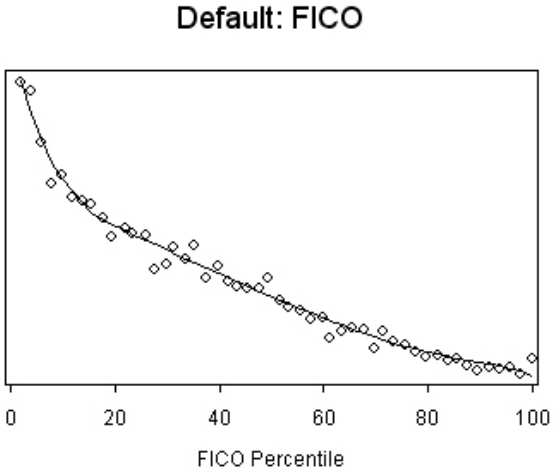


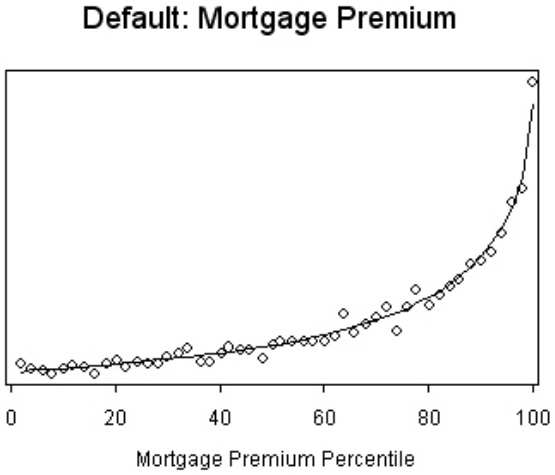


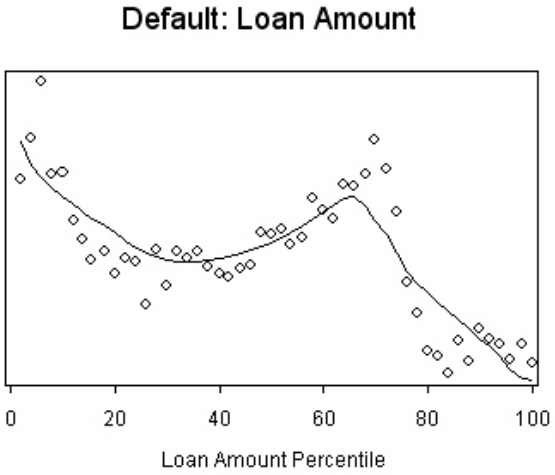
Default/Prepayment models: Variable selection

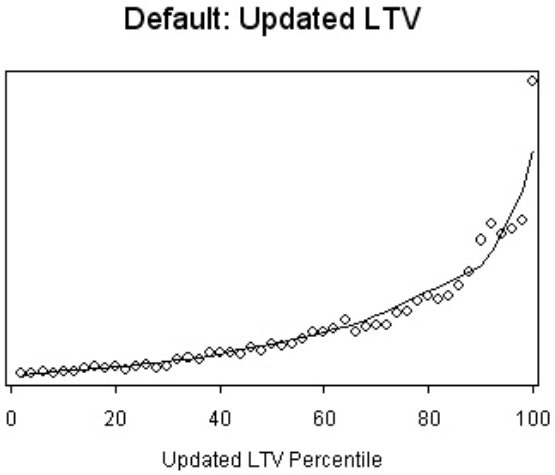
- Common sense/Economic theory
- Statistical robustness
  - The coefficient of a factor should reflect economic reasoning, with correct direction (sign) and magnitude.
  - A factor should not be highly correlated with other factors in the model.
- Practical implementation
  - A factor should be readily available.
  - A factor should be defined relatively unambiguously.
- Uni-variate / multi-variate analysis
  - This provides a direct view of the relationship between the factors and the hazard rate

Default/Prepayment models: Uni-variate analysis

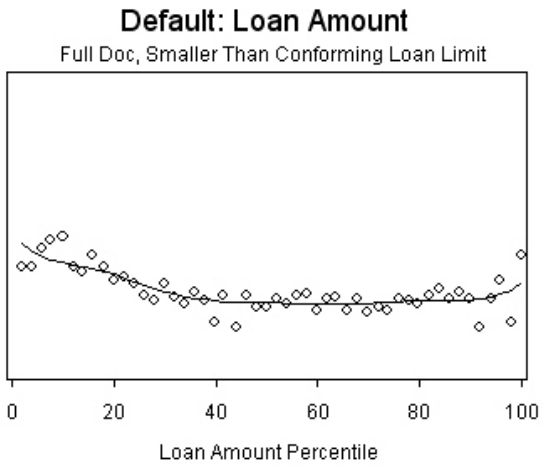


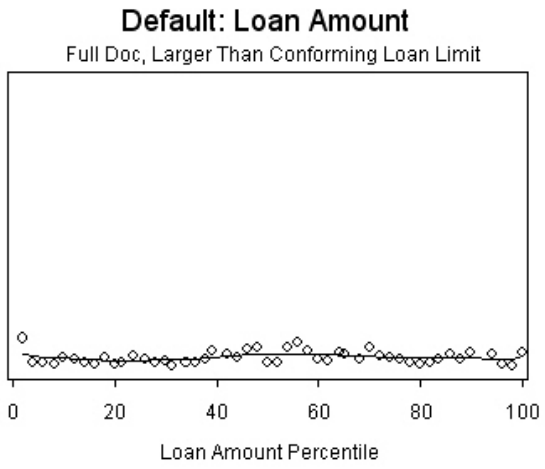


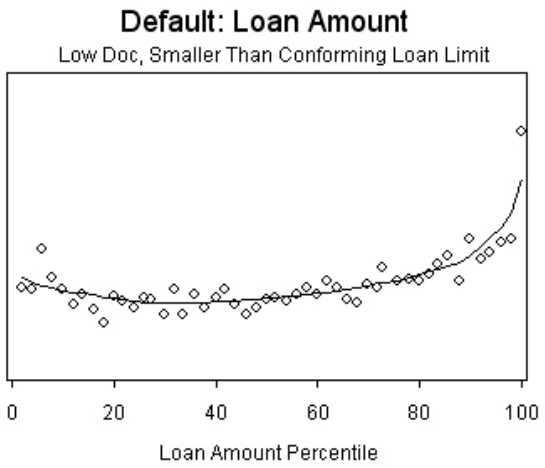


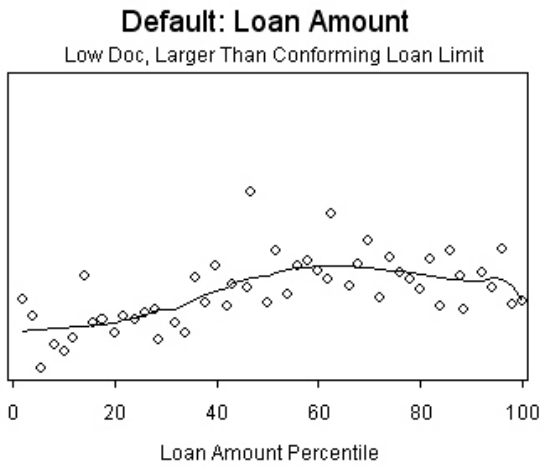


Default/Prepayment models: Multi-variate interactions









Model factors are carefully selected and tested.

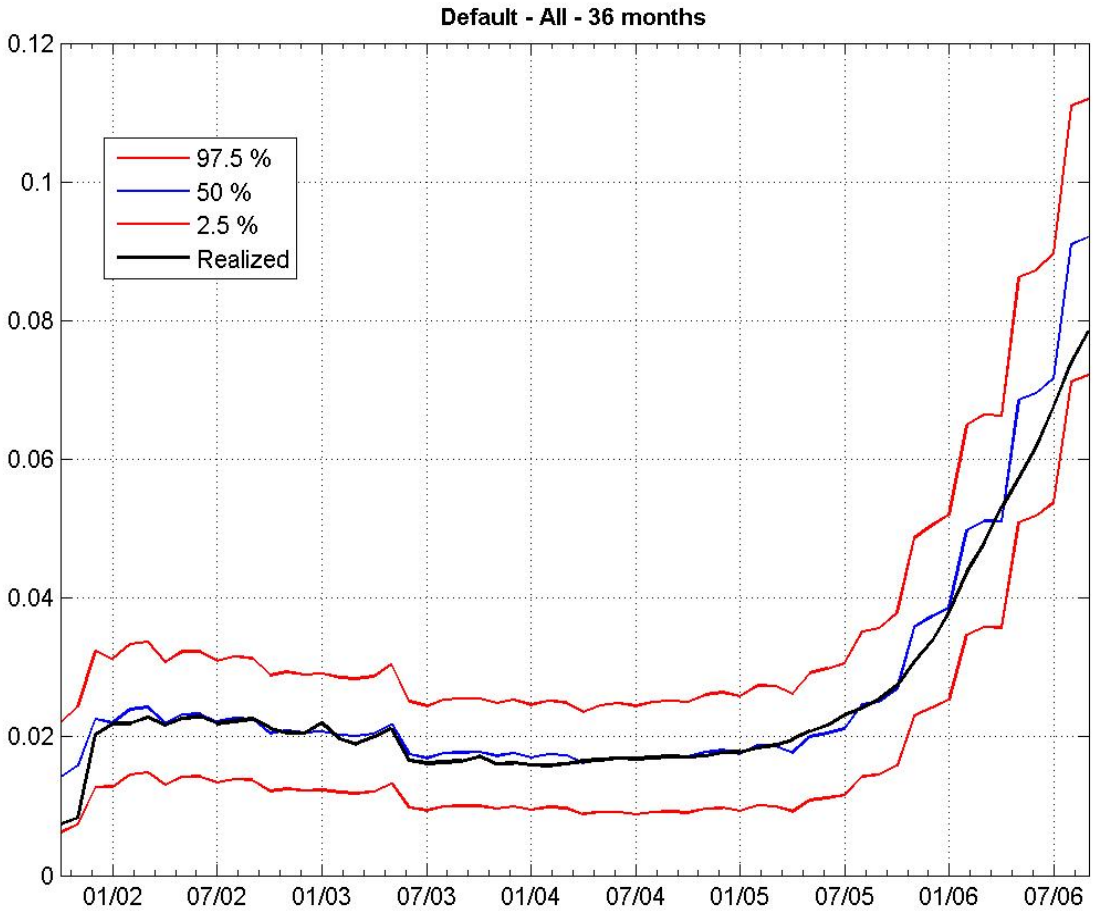
Default model: Key factors

(see Whitepaper for the complete list and more detailed discussions)

- **FICO:** The higher the FICO, the better the borrower quality and the lower the default rate
- **Mortgage Premium at Origination:** The higher the mortgage premium at origination, the lower the borrower quality and the higher the default rate
- **Change in Mortgage Premium:** As mortgage premium gets higher, a borrower becomes worse off and thus the default rate gets higher.
- **Updated Loan-to-Value:** Higher values of the updated LTV imply lower equity in the home and thus reduced aversion to defaulting, i.e. higher default rate.
- **Loan Type:** ARM loans may be exposed to rate/payment shock and thus suffer a higher default rate.

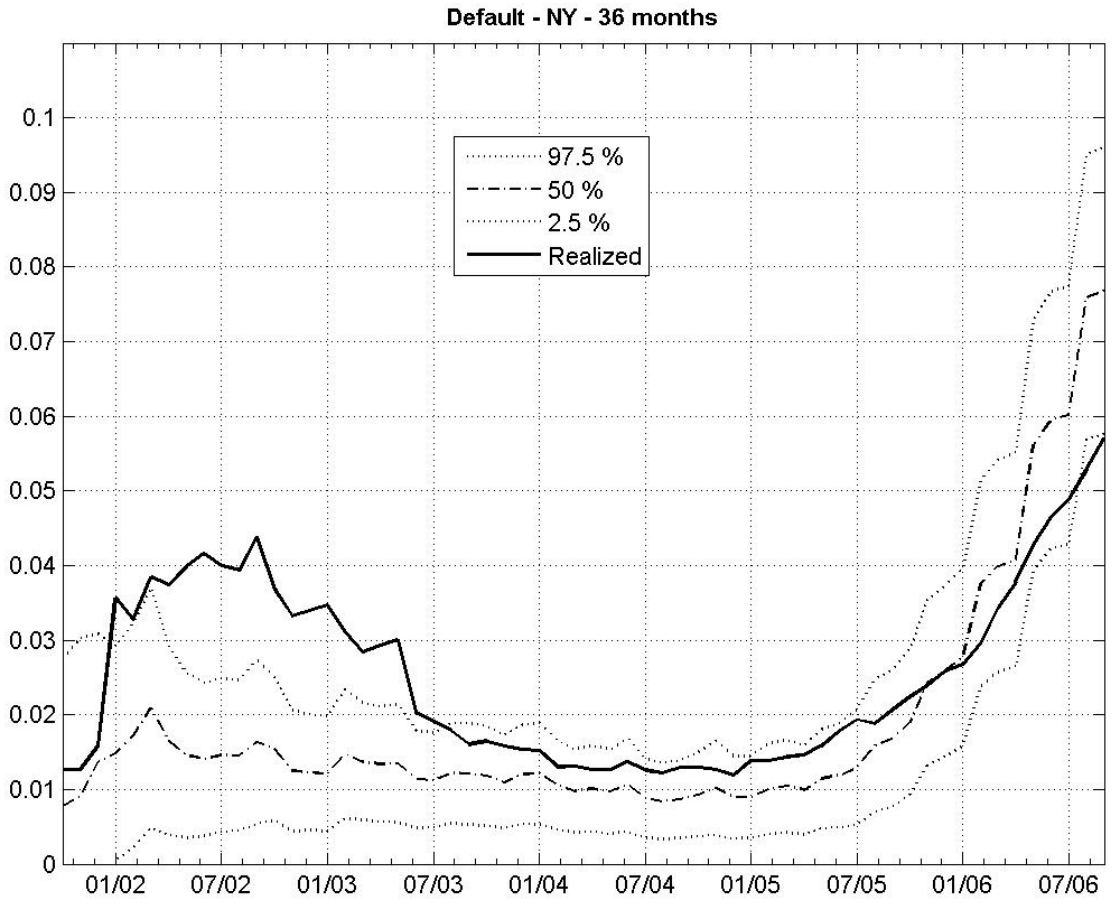
Many factors are explicitly related to macro economic factors.

Default model: Validation with real economy I



Observable economic factors facilitate detailed validation.

Default model: Validation with real economy II



Caveat: Not all extreme events are captured in the model.

Prepayment model: Key factors

(see Whitepaper for the complete list and more detailed discussions)

- **FICO:** Higher FICO borrowers are more likely to find a more attractive refinancing terms and thus are more likely to prepay.
- **Loan-to-Value:** The higher the LTV, the less equity a borrower has in the house and the less flexibility he has in refinancing or selling the property.
- **Home Price Change:** Home price is positively related to the borrower's equity and thus positively related to the prepayment rate.
- **Mortgage Premium at Origination:** Higher mortgage premium means high incentive for the borrower to prepay. Credit curing may be another reason.
- **Change in Mortgage Premium:** A positive change means either a drop in the market rate or an increase in the loan rate, both lead to higher propensity to prepay.
- **Prepayment Penalty Clauses:** This increases the cost to refinance and thus reduces the prepayment rate.
- **Burnout Effect:** A borrower who missed past opportunities is more likely to miss future opportunities as well.

Many factors are macro economy related and common to the ones in default model.

1

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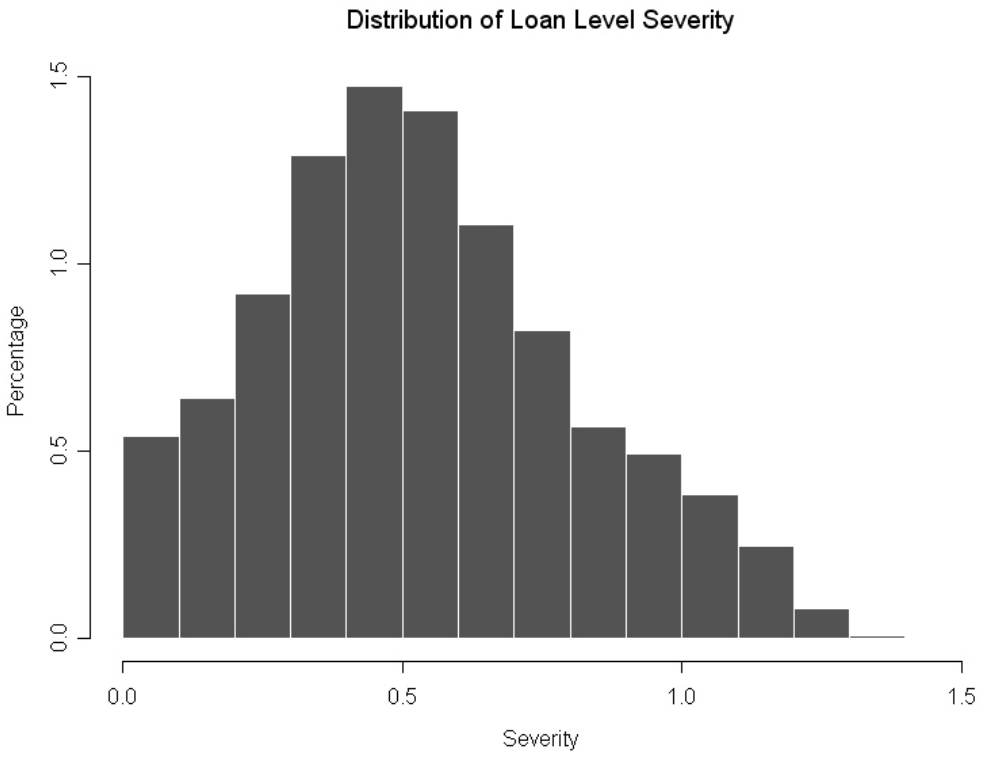
Severity model: Beta distribution

- Distribution of loan severity: Beta distribution by observation
  - Bounded
  - Skewed



Severity model: Methodology and key factors

- Two step approach
  - Beta distributed severities are first transformed into a standard normal distribution
  - A regression model is built in the Gaussian space
  - Predicted values in the Gaussian space are then transformed back into the severity space

- Some key factors (see Whitepaper for a more detailed discussions
  - **Judicial Regulation:** Many states have regulations that make it harder to liquidate a property and thus severity tend to be higher in these states.
  - **Forward Loan-to-Value:** The recovery is only made when a property is liquidated. As liquidation takes time, recovery usually happens months after default.
  - **Loan Amount:** Smaller loans tend to suffer higher percentage losses as fixed costs constitute a bigger percentage of total cost and thus less incentive for the lender to pursue recover.
  - **Mortgage Premium:** Higher mortgage premium leads to lower principle payment and also indicates a lower borrower quality. Both lead to higher severity.

Again, many factors are macro economy related and common to the ones in default and prepayment models.

2

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Simulating macro economic factors

- The key economic processes that are simulated in the model are:
  - ✓**Interest rates** (10-year CMT & 6-month LIBOR)
  - ✓**Home Price Change** (national, state, and MSA level)
  - ✓**Unemployment rates** (national, state, and MSA level)
  - ✓**Loan market rates** (Freddie Mac (FHLMC) mortgage rate or subprime market rate)

Explanation of modeling process - Auto Regressive processes are used to model changes in the unemployment rate and the log of the home price index at the national level. Subsequently the unemployment rate and home price index at the state and MSA level are modeled using the results at the national level, plus their own lags. These macro factors are correlated through common dependence on interest rates and, in the case of the local economic factors, on the national levels of unemployment and home prices, respectively.

3

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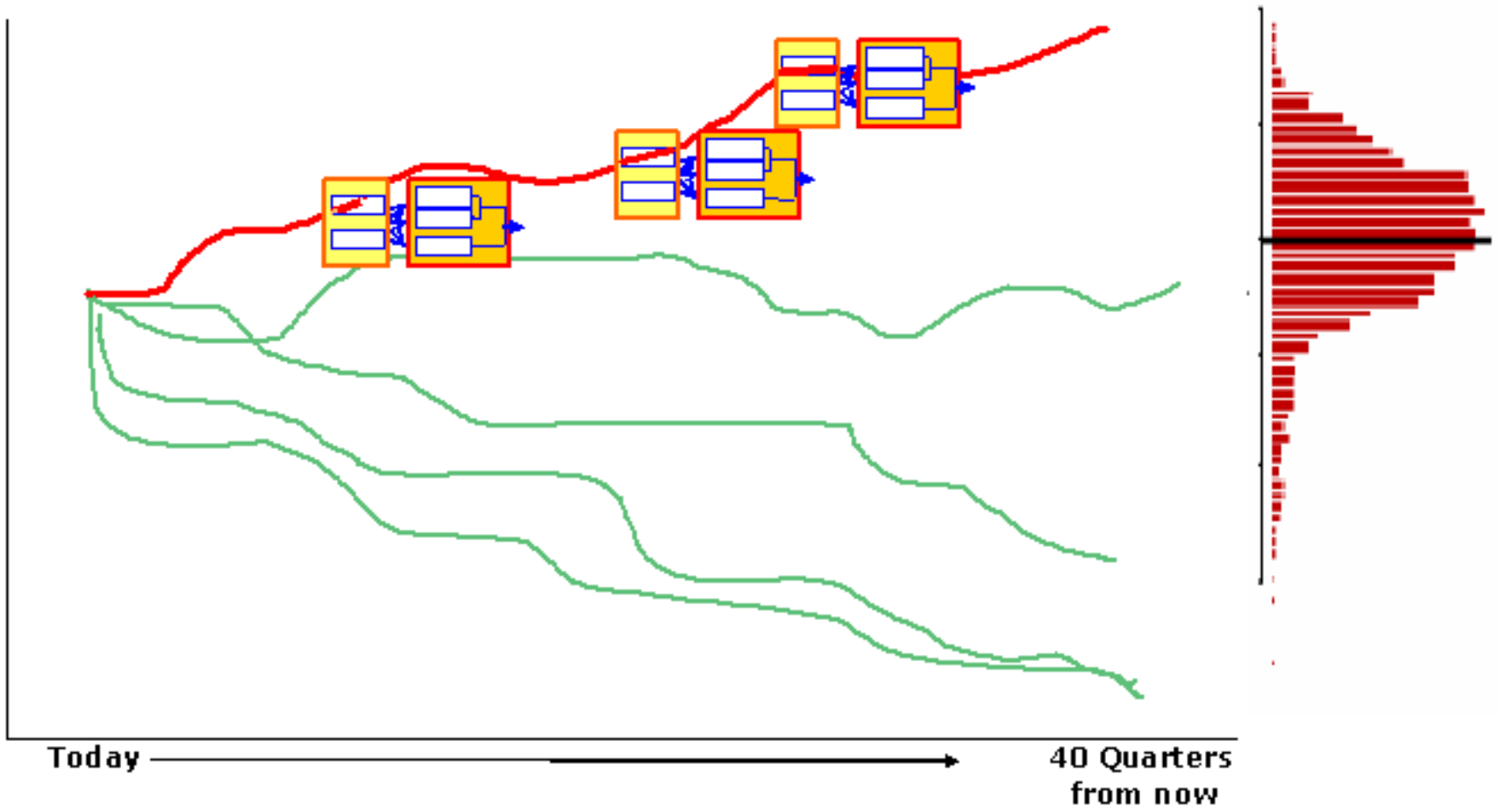
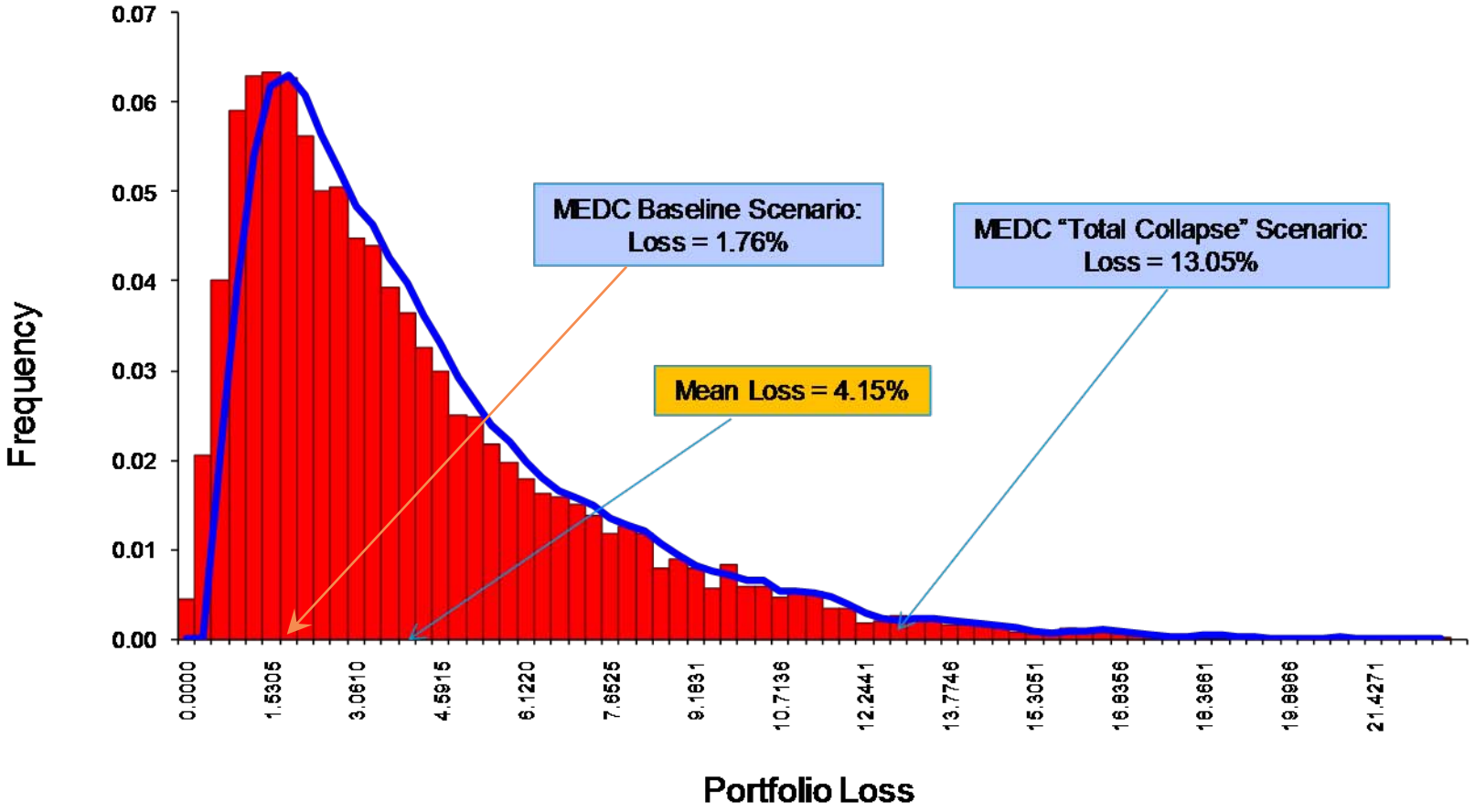
Putting it altogether: Mortgage Portfolio Analyzer

Integrating the component models along each simulated economic path

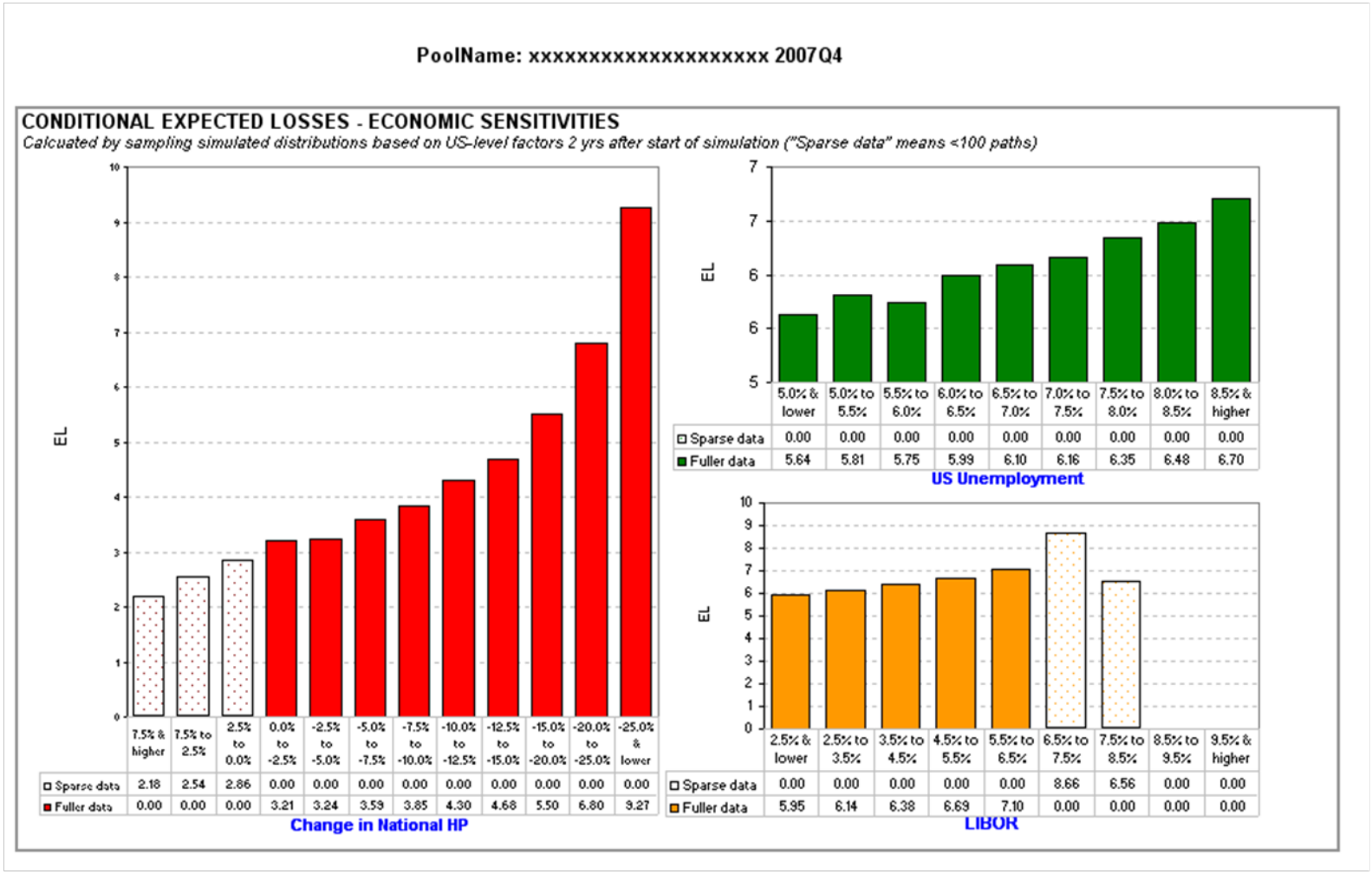


The result: Loss distribution – an example



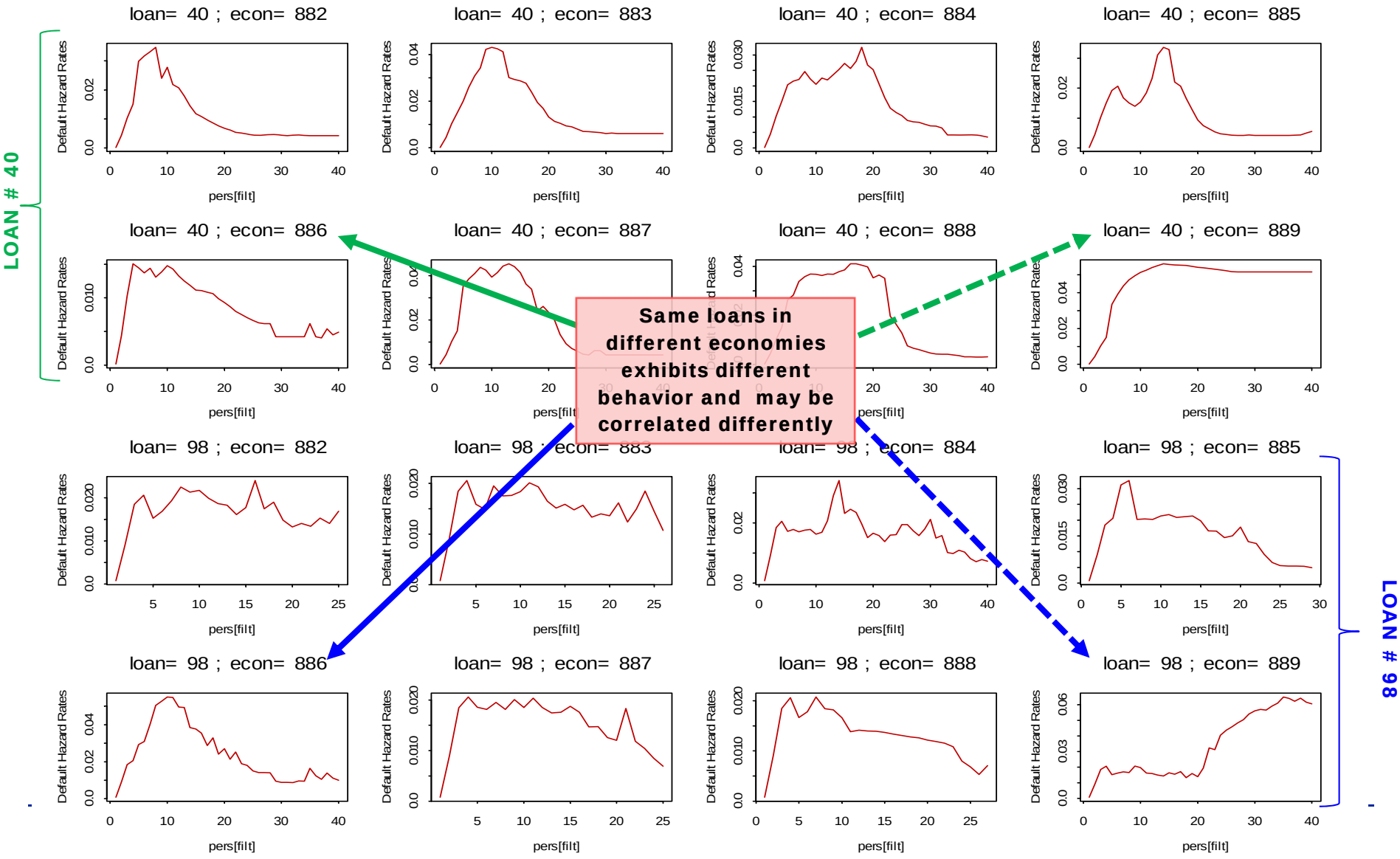
In addition to generating the full loss distribution, it is possible to estimate losses under *MEDC or user-defined scenarios*.

The result: Losses – economic sensitivities



Observable macro-economic factors facilitate insightful what-ifs.

The result: Impact of economies on individual loans



4

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Conclusion

- Decomposing the mortgage portfolio risk into separate models helps to break down complicated processes into more tractable pieces.
- The component models offer both flexibility and interpretability.
- The explicit use of the macro factors facilitates validation, calibration, scenario analysis and sensitivity analysis.
- The integration of the component models, through their dependence on common factors, reproduces the complexity in real world.