BNY MELLON

Behavior Model for CMBS

Model ID #2402

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Validation Report:	Mengmeng Fu, Model Risk Management March 2, 2016

Purpose and Use

A. Purpose of Model:

BNY Mellon (ALM IRR) needs to measure the prepayment and credit risks of the commercial mortgage backed securities (CMBS) held in the Firm's investment securities portfolio.

B. Areas of Use:

The Commercial Hazard Rate Model (CHRM) applies to a number of risk processes (e.g. CCAR OCI, Economic Value of Equity (EVE) and Basel Economic Capital) and financial forecasting processes (e.g. Net Interest Income (NII) and planning). CHRM is used only for agency CMBS for the CCAR OCI forecast, while non-agency CMBS is modeled with the OTTI models.

C. Work Stream Category:

Securities

D. Limitations:

1) Although the CHRM model was estimated using data from non-agency CMBS deals, we are currently using it for both agency and non-agency CMBS for regulatory stress testing exercises. While the model does differentiate default forecast for agency and non-agency collaterals based on a number of measures of credit quality and different structures of securities are captured by QRM through Intex, the difference in behaviors between agency and non-agency CMBS could still exist.

   The IRR team is planning to conduct more performance monitoring for CMBS for CCAR 2017. Model error will be back-tested and studied at a more granular level. The team will also tune the model to calibrate the projection to actual performances if warranted by the back-testings.

2) Version 1 of the CHRM was developed in 2013. A new version of the CHRM model has been available since then. Although QRM modelers consider version 1 out-of-sample performance to be good, they have revised the model based on additional research and client feedback.

   As part of the remediation plan, the IRR team will upgrade the model to version 2 for CCAR 2017. As we implement the new model, we will upgrade the documentation for CHRM to clarify the new enhancements.

3) The unemployment rate and CPPI are not shocked for various CCAR scenarios. This may seem problematic. However, based on the model test section in this document, the behavioral assumptions have very low impact on the CMBS valuation. Therefore, there should be only a trial impact on the CCAR tests as a result of this limitation.

   For CCAR 2017, when the model is updated with new features, the IRR team will work with QRM to explore the way to shock unemployment and CPPI for stress testing as one of the enhancements.

Background

The ALM IRR group employs the QRM platform for balance sheet management. The modeling of the CMBS portfolio also utilizes CHRM and Intex, which are fully integrated into QRM. The former is used for prepayment and default forecasting and the latter is utilized for collateral data and cash flow modeling. CHRM addresses the need for dynamic prepayment and default modeling for CMBS securities.

CHRM will be used for all regulatory stress testing exercises (e.g., CCAR, DFAST, RRP).

CHRM will be part of a business as usual monthly process that will generate risk and income projections under different economic scenarios. These results are reviewed by the Treasury Risk Committee, ALCO, and the Board. Decisions on risk appetite and income targeting can be made based on the output.

As of December 2015, the CMBS section accounts for $5.6 billion (5%) of the investment securities portfolio. The model is currently implemented for both agency ($4.3 Bn) and non-agency ($1.3 Bn) CMBS in our portfolio for CCAR, DFAST and RRP. CHRM is used only for agency CMBS for the CCAR OCI forecast, while non-agency CMBS is modeled with the OTTI models.

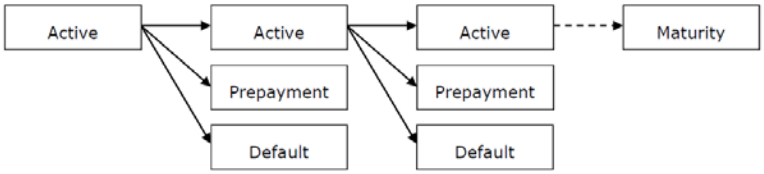
Model Specification

A. Methodology

Approach:

In CHRM, Prepayment and default are defined as mutually exclusive events. Only one can ever occur for a particular loan, though it is possible that neither may occur. CHRM describes the probability of these two events using a competing risk model of prepayment and default. In this idealization of

obligor behavior, the obligor's options at each point in time are to prepay, default, or continue making scheduled payments.



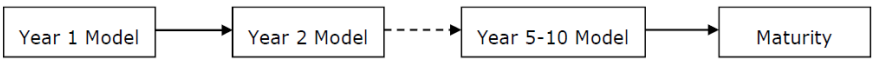
Since the performance data is provided at monthly intervals, modeling events as occurring monthly, and describing the probability of events in terms of monthly prepayment and default rates, would be natural. However, servicers only update financial statement ratios at annual intervals. To ensure consistency between the dependent variables (prepayment and default) and the independent variables (collateral characteristics and financial ratios), the performance data is collapsed to annual intervals.

More significantly, the current values but not the original values (data not available) for many of the financial ratios are used as inputs. Although this situation may hardly seem problematic—after all, today's debt service coverage ratio, for example, is surely more relevant to predicting future defaults than the debt service coverage ratio at origination—it poses a serious challenge to forecasting. The core of the problem is that linking prepayments, defaults, and recoveries to current values of financial ratios requires dynamical forecasts or simulations of those financial ratios, which are computationally and operationally intensive tasks.

In the case that dynamical forecasts or simulations of financial ratios are not available — in particular, if the financial ratios are assumed to be flat at the current levels going forward — the forecasts of defaults, prepayments, and recoveries could be seriously biased.

QRM's solution for this issues is to forecast future default and prepayment probabilities conditional not on the contemporaneous or original values of financial ratios, but rather on the values of financial ratios at the start of the forecast period. This model form is called as a "fully specified" model.

To estimate the fully specified model, one model was estimated using financial ratios and macroeconomic factors from the beginning of the first year. Then a second model was estimated with the same structure as the previous one but using financial ratios from the beginning of the first year and economic factors from the beginning of the second year. During the second step, only loans that survived the first year (i.e. a static pool) are included in the data points to ensure that the second model consistently estimates the probability of prepayment and default in the second year. After repeating this estimation approach to account for the first five years, QRM assumes the model parameters to stabilize in the following years. In application this means that a different set of parameters is used for each of the first five years of the forecast.



A simplified approach is to ignore the effect of financial ratios entirely as the data are not available in many cases. For this reason, QRM estimated an "abridged" model, following a conventional competing risk approach but excluding any property-level financial data and using only contractual

features and observed market factors. The abridged model is intended for institutions that either do not have all of the necessary data or do not require a detailed model.

The CHRM requires gross WAC, age, WAM, origination date, and first forecasting date, all of which are known for portfolio loans or assumed for CMBS. Using only these fields, the model will compute prepayment and default rates based on the abridged models. To run the fully specified models users will need to provide data for the original LTV (as a percentage), current debt service coverage ratio (DSCR), current occupancy percentage (as a percentage), current net cash flows (in dollars), original loan size (in dollars), state, and property type.

Currently, not all the data required are available for the full specified model. Hence, the abridged model is used for CCAR.

Assumptions:

Assumption 1:

Prepayments are defined as any full payoff observed prior to maturity. This definition necessarily excludes partial prepayments (curtailments), the effect of which is found to be more than an order of magnitude smaller than the effect of full prepayments.

Assumption 2:

Any Foreclosure, bankruptcy, REO, and loss events are considered as a default. Once a loan enters default the model assumes no risk of either prepayment or default in subsequent observations. Any observations after maturity are assumed to actually have occurred at maturity.

Assumption 3:

Modeling recoveries is relatively easy if recovery can be well-approximated as a single event that occurs simultaneously with default. Empirically this assumption is somewhat questionable—the foreclosure process often spans many months. However, comprehensively addressing this fact requires a delinquency transition model and is thus beyond the scope of the QRM's present analysis. Therefore, while the amounts of losses and recoveries should be correct, as should be the timing of losses, recoveries will tend to be premature.

Development Data:

QRM estimated the CHRM using loan-level data from private CMBS deals. The data encompasses 6.8 million monthly observations of over 100 thousand commercial mortgages. With 10 years of history, beginning in January 2002 and extending through December 2011, the data covers a broad range of economic conditions, including a large portion of the boom and bust in the commercial property market—a condition necessary to achieve a robust model.

The data includes an extensive range of property-level fields, among them key financial statement ratios and collateral characteristics. Before analyzing the data, the modelers removed any observations that were missing critical information such as origination or maturity dates. All discussion, data summaries, and model results that follow are based on this scrubbed data.

The vast majority of the mortgages are 10-year fixed rate balloons with 30-year amortization terms and strict prepayment penalties. Most were originated between 2003 and 2007, when the securitization market was at its peak (Figure 1). During the financial crisis and subsequent recession in 2008 and 2009, mortgage originations declined sharply as investors became increasingly concerned about the future of the economy. However, as the economy has recovered, securitization activity has renewed, albeit at significantly lower levels than in the mid-2000s.

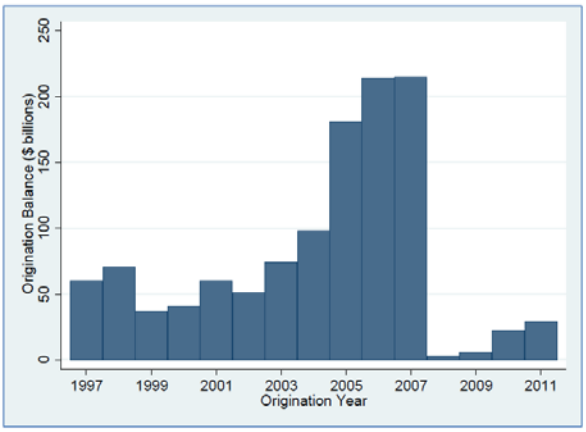


Figure 1: Historical CMBS Originations

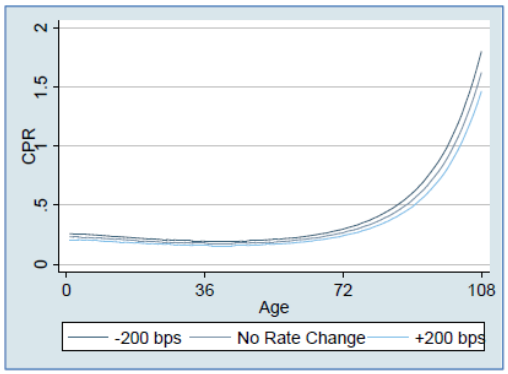
B. Input Data and Data Assumptions

Input Data:

Collateral information is passed to QRM from Intex via cusips. This process runs during the execution of a valuation or planning run in QRM.

1. Original Note Rate

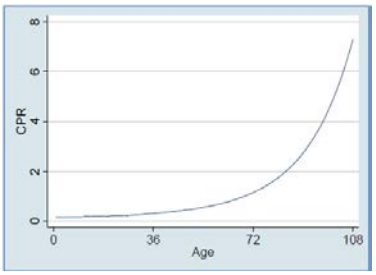
Both the original note rate and the spread-at origination (SATO) are potential proxies for otherwise unobserved credit risk that was underwritten via risk-based pricing. In the data, note rates range mostly between 4% and 10%, with a median of 6.45%. Since the vast majority of loans have 10-year terms and average lives of close to 10 years, SATO is measured as the difference between the note rate and the 10-year swap rate at origination.

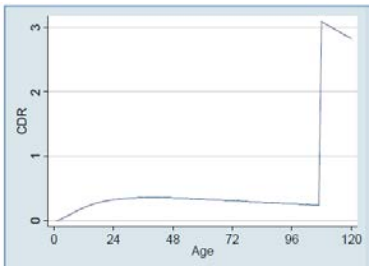


As showed above, the abridged prepayment model shows a mild negative relationship between interest rates and prepayment rates. However, even in the instance of a 200-bp decrease in the 10-year swap rate, the CPR only rises slightly.

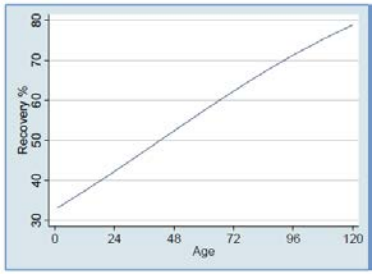
2. Age and Maturity

Prepayment, Default and recovery rates all vary systematically with loan age (see below). Within the first few years of origination, prepayments are close to 0% CPR and rise monotonically with loan age. Then one year before balloon maturity, prepayment rates exhibit a big jump to nearly 50% (omitted in the below chart to illustrate seasoning). Default rates ramp up in the first two years, slowly decline afterwards, then jump significantly just prior to and at balloon maturity, when large payments typically are due.





Over time, amortization decreases the outstanding balance, lowering the obligor's current LTV and thus raising the expected recovery rate. Model recovery rates begin at about 40%, just after origination, and they rise to nearly 80% as the loan nears balloon maturity. Hence CHRM forecasts recovery rates to rise with loan age.



Economic Factors are inputted into CHRM by QRM. QRM framework provides model for unemployment and commercial property price. Interest rate scenarios are assigned through QRM facilitating both implied forward rates and rate scenarios for stress testing.

1. 10-Year Swap Rate

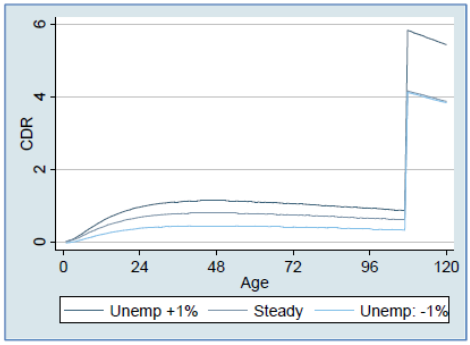
Dependence on interest rates is a critical feature of many prepayment models; if obligors have the option to refinance their loans when rates drop, then the market risk profile of those instruments changes significantly. Again, since most loans have 10-year terms, the incentive to refinance is measured as the lifetime change in the 10-year LIBOR swap rate, which is expected to be highly correlated with the lifetime change in the commercial mortgage rate available to the obligor.

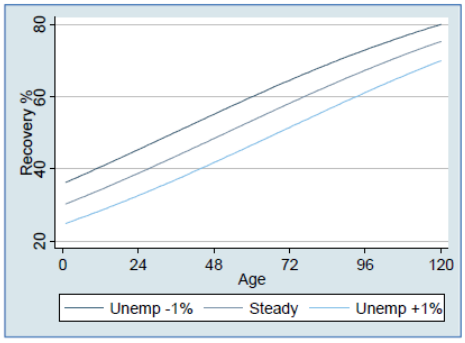
2. Unemployment Rate

Macroeconomic conditions have always had some effect on prepayments and defaults. The favorable conditions that existed until 2008 resulted in low default rates and a prevalence of refinancing opportunities. Since then, deteriorating economic conditions have prompted higher default rates and fewer refinancing options.

Default rates in the abridged version season over approximately two years, level out, and then spike near maturity. In this model the primary driver of default rates is the national unemployment rate, rather than the state unemployment rate.

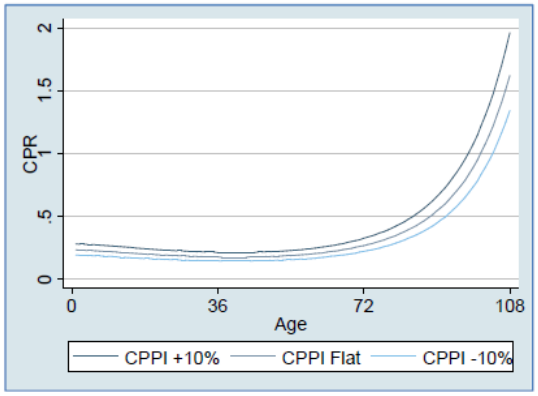
Recovery rates in the abridged model rise over time as loans amortize. The abridged default model uses national unemployment as the primary economic driver of recoveries.





3. Commercial Property Prices

CHRM considers the effect of property prices as measured using the NCREIF Property Index (NPI) at the national level. QRM found prepayments are positively correlated with changes in commercial property prices, increasing as prices rise and decreasing as they fall (see below).



Testing the Model

A. Analysis of the Model

Result accuracy:

For the fully specified model, QRM assessed the goodness of fit by calculating and summarizing the errors in predicted CPR, CDR, and recovery rates. The QRM modelers also visually examine plots of

in-sample fits, looking at patterns of actual and model rates along different dimensions. Because the modeling was performed on an annual basis, all performance statistics presented below are based on annual data and expressed as annual rates.

Both the prepayment and default model performance is strong by quantitative measures, as summarized in Table 1 below. The recovery model shows a slight positive bias over time, likely because the majority of defaults occur in 2009 through 2011 and the sample for the recovery model is approximately one hundredth the size of the sample we used to estimate prepayment and default models.

Table 1: Year-1 model performance summary

Aggregate monthly error in CPR, CDR, or recovery rate

	Abs. mean	*Mean*	*Std. dev.*	*Min*	*Max*
Prepayment	0.7%	0.2%	0.9%	-1.2% (2007)	1.2% (2003)
Default	0.2%	0.0%	0.2%	-0.4% (2002)	0.4% (2004)
Recovery	5.4%	3.2%	5.7%	-6.5% (2011)	9.7% (2005)

In the following figures, QRM showed the fit for the abridged prepayment, default and recovery models. These figures offer evidence that the model replicates actual behavior well, across the range of historical experience.

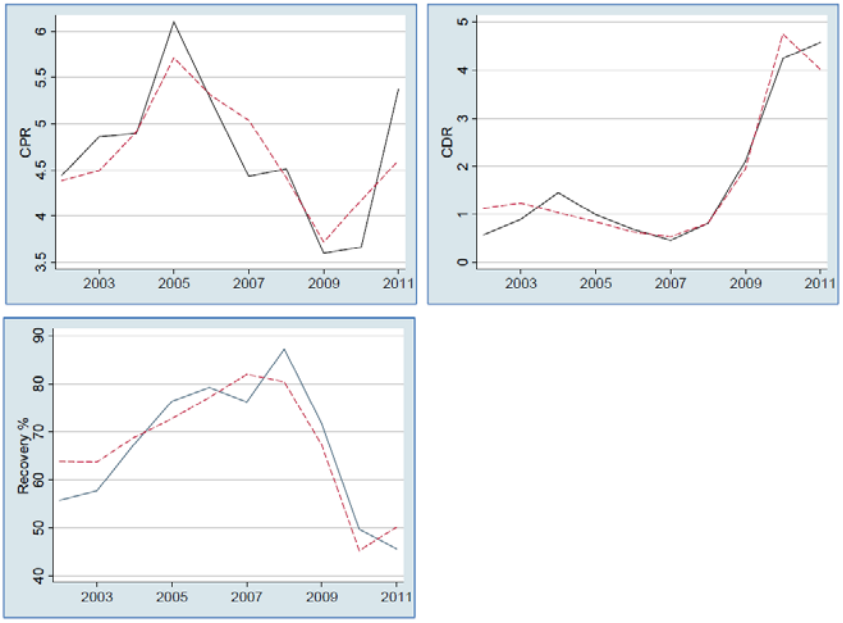


Figure 8: Actual vs. abridged model prepayment, default, and recovery rates

Below is a table that shows the default sensitivity of BNY's CMBS portfolio. Market value and interest income of the CMBS is not sensitive to default assumptions since our CMBS are primarily senior tranches, which is protected from the credit risk.

$ millions *As of Jan 31, 2016*

CDR Sensitivity	Market Value				$ Value Sensitivity to CDR				% Value Sensitivity to CDR			
	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200
-30%	$ 5,814	$ 5,708	$ 5,605	$ 5,409	$ 0	$ (0)	$ (0)	$ (1)	0.00%	0.00%	-0.01%	-0.01%
-20%	$ 5,814	$ 5,708	$ 5,605	$ 5,409	$ 0	$ (0)	$ (0)	$ (0)	0.00%	0.00%	0.00%	-0.01%
-10%	$ 5,814	$ 5,708	$ 5,605	$ 5,409	$ 0	$ (0)	$ (0)	$ (0)	0.00%	0.00%	0.00%	0.00%
Base	$ 5,814	$ 5,708	$ 5,605	$ 5,409								
10%	$ 5,814	$ 5,708	$ 5,605	$ 5,409	$ (0)	$ 0	$ 0	$ 0	0.00%	0.00%	0.00%	0.00%
20%	$ 5,814	$ 5,708	$ 5,606	$ 5,410	$ (0)	$ 0	$ 0	$ 0	0.00%	0.00%	0.00%	0.01%
30%	$ 5,814	$ 5,708	$ 5,606	$ 5,410	$ (0)	$ 0	$ 0	$ 1	0.00%	0.00%	0.01%	0.01%

CDR Sensitivity	12 month Interest Income				$ Interest Sensitivity to CDR				% Interest Sensitivity to CDR			
	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200
-30%	$ 133	$ 145	$ 154	$ 173	$ (0.3)	$ (0.2)	$ (0.1)	$ (0.0)	0.0%	0.0%	0.0%	0.0%
-20%	$ 133	$ 145	$ 154	$ 173	$ (0.2)	$ (0.1)	$ (0.1)	$ (0.0)	0.0%	0.0%	0.0%	0.0%
-10%	$ 133	$ 145	$ 154	$ 173	$ (0.1)	$ (0.1)	$ (0.0)	$ (0.0)	0.0%	0.0%	0.0%	0.0%
Base	$ 133	$ 144	$ 154	$ 173								
10%	$ 133	$ 144	$ 154	$ 173	$ 0.1	$ 0.0	$ 0.0	$ (0.0)	0.0%	0.0%	0.0%	0.0%
20%	$ 133	$ 144	$ 154	$ 173	$ 0.1	$ 0.1	$ 0.0	$ (0.1)	0.0%	0.0%	0.0%	0.0%
30%	$ 133	$ 144	$ 154	$ 173	$ 0.3	$ 0.3	$ 0.2	$ 0.1	0.0%	0.0%	0.0%	0.0%

The following table shows the low prepayment model risk of the CMBS portfolio market value. Prepayment risks are largely muted by the prepayment penalty clause stipulated in most of the loan contracts. As showed in the actual prepayment graph (Model Specification-section B), CPR is close to 0% during the lock-out period and then spikes right before balloon maturity. Unlike consumer mortgages, age rather than the interest rate move is the dominating driver for commercial loan prepays. Therefore, the uncertainties in prepay are relatively low. The bullet nature of cash flow persists across the prepayment shocks.

Compared to the market value sensitivity, interest sensitivity to CPR is slightly higher due to a more direct impact by higher voluntary runoff, but it is still at a low level. Due to the aforementioned reason, interest income uncertainty due to voluntary prepay is largely muted. In a nutshell, prepayments on our CMBS have minimal impact on interest rate risk because of the strict prepayment penalties tied to them.

$ millions *As of Dec 31, 2015*

CPR Sensitivity	Market Value				$ Value Sensitivity to CPR				% Value Sensitivity to CPR			
	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200
-30%	$ 5,658	$ 5,552	$ 5,450	$ 5,256	$ (0)	$ (1)	$ (2)	$ (4)	0.00%	-0.02%	-0.04%	-0.07%
-20%	$ 5,658	$ 5,553	$ 5,451	$ 5,257	$ (0)	$ (1)	$ (1)	$ (2)	0.00%	-0.01%	-0.03%	-0.04%
-10%	$ 5,658	$ 5,553	$ 5,452	$ 5,259	$ (0)	$ (0)	$ (1)	$ (1)	0.00%	-0.01%	-0.01%	-0.02%
Base	$ 5,658	$ 5,554	$ 5,452	$ 5,260								
10%	$ 5,658	$ 5,554	$ 5,453	$ 5,261	$ 0	$ 0	$ 1	$ 1	0.00%	0.01%	0.01%	0.02%
20%	$ 5,658	$ 5,554	$ 5,454	$ 5,262	$ 0	$ 1	$ 1	$ 2	0.00%	0.01%	0.02%	0.04%
30%	$ 5,658	$ 5,555	$ 5,454	$ 5,263	$ 0	$ 1	$ 2	$ 3	0.01%	0.02%	0.03%	0.06%

CPR Sensitivity	12 month Interest Income				$ Interest Sensitivity to CPR				% Interest Sensitivity to CPR			
	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200	Base	Up 50	Up 100	Up 200
-30%	$ 135	$ 146	$ 155	$ 175	$ 6.4	$ 2.8	$ (0.1)	$ (9.3)	0.2%	0.1%	0.0%	-0.3%
-20%	$ 134	$ 145	$ 155	$ 175	$ 4.3	$ 1.9	$ (0.0)	$ (6.2)	0.1%	0.1%	0.0%	-0.2%
-10%	$ 134	$ 145	$ 155	$ 175	$ 2.1	$ 0.9	$ 0.0	$ (3.1)	0.1%	0.0%	0.0%	-0.1%
Base	$ 134	$ 145	$ 154	$ 175								
10%	$ 134	$ 145	$ 154	$ 175	$ (2.1)	$ (0.9)	$ 0.0	$ 3.1	-0.1%	0.0%	0.0%	0.1%
20%	$ 133	$ 145	$ 154	$ 175	$ (4.1)	$ (1.7)	$ 0.1	$ 6.3	-0.1%	-0.1%	0.0%	0.2%
30%	$ 133	$ 144	$ 154	$ 175	$ (6.1)	$ (2.6)	$ 0.1	$ 9.4	-0.2%	-0.1%	0.0%	0.3%

<u>Parameter sensitivity:</u>

For input variable sensitivities, refer to section B of model specification. The tests show projections are stable for age ranging from 0 to 120. For note rate, the prepayment sensitivity to refinance incentives is low, therefore, mitigating the chance of producing unrealistic results. Similarly, for unemployment rate and CPPI, low sensitivity of variables has lowered the risk of getting drastic forecasts.

CHRM is a proprietary model owned by QRM. The parameter stability tests are not provided in their documentation. This kind of model risk can be mitigated by regularly calibrating the model, which is included in IRR's plan to enhance the model in 2016.

B. Analysis of Implementation

CHRM is a model built by QRM, it is hence smoothly integrated with QRM framework. The QRM white paper outlines the process of implementation.

C. Ongoing Performance Monitoring Plan

BNY conducts a benchmark test monthly between CHRM forecast and Blackrock Forecast to test the reasonability of model results (see below). Our Dec 2015 benchmark test shows the estimated duration and market value match up with the Blackrock forecast.

This report is included in the monthly Interest Rate Risk Profile deck, which is review the by the senior management.

QRM and Blackrock Benchmark Test (CMBS)

	Face Value			OAD		
Period	QRM	BLK	Diff	QRM	BLK	Diff
Jan-16	5,732	5,732	1	3.7	3.8	0.1
Dec-15	5,626	5,626	(0)	3.7	3.7	(0.0)
Nov-15	5,758	5,758	(0)	3.7	3.7	0.0
Oct-15	5,891	5,891	0	3.9	3.9	0.0
Sep-15	5,702	5,696	(6)	4.0	4.0	(0.0)
Aug-15	5,787	5,787	(0)	4.0	3.9	(0.1)

References for Model Documentation:

Commercial Hazard Rate Model, July 2014 (PowerPoint Document)

Change Log

Please see below.

Revision History of Model

Date	Section	Description of Change	Validation of Change	Validation Date
September 2013	All	Start using the model on QRM platform	Full Scope Validation	7/31/2014
February	All	Model Documentation in		

25, 2016		new template		

Access Controls

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