Behavior Model for Non-Agency MBS (ADCo LDM)

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Model Owner:	Randhir Ahluwalia, ALM Interest Rate Risk
Model Developer:	QRM/AD&Co
Model User(s):	ALM Interest Rate Risk
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Purpose and Use

A. Purpose of Model: The Loan Dynamics Model (LDM) is a loan level model from Andrew Davidson & Co (AD&Co) which provides prepayment, default, and severity forecasts given collateral characteristics and economic factors (e.g., interest rates) for the non-agency mortgage-backed (MBS) securities held in the Firm's Treasury investment portfolio. LDM is integrated within the Quantitative Risk Management (QRM) platform which is used for Economic Value of Equity (EVE), Net Income Interest (NII) projection, CCAR OCI and Basel Interest Rate Economic Capital.

B. Scope: LDM will be utilized for non-agency MBS securities for business as usual practices and regulatory stress testing. ALM IRR will use LDM, as well as other BNYM groups (e.g. ALM Liquidity, Market Risk). Regulators are requiring BNY Mellon to better model cash flows for Non-Agency MBS, replacing the current methodology of Agency models and constant assumptions.

C. Work Stream Category: Securities

D. Limitations: LDM does not explicitly take unemployment as an input, which is required for the Federal Reserve's stress testing exercises. AD&Co, used for prepayment and default forecasting, suggested tuning adjustments that would mimic the desired unemployment levels. Details on unemployment tunings are included in [1]. QRM does not recommend such implementation of unemployment, thus unemployment will not be implemented within the LDM model.

LDM does not model loan modifications, such as principal forgiveness and rate modifications. Loans with such features may be securitized in Treasury's Non-Agency MBS book. Loan modifications are typically applied to loans in risk of default, where expected losses from default exceed expected

losses from modifying. Lack of this feature is thus a conservative assumption that would result in greater expected losses. Therefore, lack of this feature was deemed acceptable.

LDM is a loan level model that interacts with Intex and Quantitative Risk Management (QRM) platforms, and it takes a significant time to process. Given practical time constraints, longest running positions are placed into a non-Intex account and run without LDM, with constant collateral assumptions based on BlackRock's one year behavioral projections. The total market value for the mostly Prime non-Intex positions as of June 30, 2015 was $177 million and these represent about 6% of the Non-Agency MBS book.

Background

The ALM IRR group utilizes the QRM platform for balance sheet management. The modeling of the Treasury's investment portfolio also utilizes Andrew Davidson & Co (AD&Co) and Intex vendors, 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. To date, non-agency MBS have been modeled with a variant of Agency models with constant default rates. Recently QRM integrated the LDM model, which is a loan level model that dynamically models prepayments, defaults, and severities by transitioning the loans through different states (e.g., current, delinquent, default). LDM addresses the need for dynamic prepayment and default modeling for non-agency MBS securities.

- LDM will be used for all regulatory stress testing exercises (e.g., CCAR, DFAST, RRP).
- LDM will be part of a business-as-usual monthly process that will generate risk and income projections under different interest rate 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. Non-agencies account for $2.63 billion in book value as of June 30, 2015, which is less than 1% of BNY assets. Alt-A MBS book value is $1.3 billion, Prime MBS - $900 million, and Prime MBS - $430 million.

Model Specification

A. Methodology

Development data: According to [2], LDM was estimated from publicly available non-agency securities data collected from the corporate trust department of Wells Fargo Bank, N.A. The database (used to estimate the initial model) contained over 8 million loans from 144 different issuers covering the period from 1998 to 2006. The database contained a robust cross-section of non-agency loan types including jumbo prime, Alt-A, subprime loans and second liens. AD&Co updates the database monthly in order to monitor the accuracy of LDM forecasts and for current model development.

The composition of the database (when the model was developed) by credit sector and a list of top ten issuers (by # of loans) are shown in the following tables:

By Loan Type	Pct
Subprime	39%
Alt-A	22%
Jumbo Prime	21%
Conforming Prime	16%
Second Lien	1%

By Issuer
Wells Fargo Mortgage-Backed Securities Trust
Structured Asset Securities Corp (SASCO)
GE Capital Mortgage Services Inc.
Structured Asset Investment Loan Trust (SAIL)
Banc of America Mortgage Securities
ACE Securities
Merrill Lynch Mortgage Loans Inc. Park Place Securities
Norwest Asset Securities Corporation (NASCOR)

AD&Co uses Intex non-agency data to monitor model performance and to update the tuning recommendations, when needed.

Overview: LDM is AD&Co's loan level model which provides dynamic collateral CPR, CDR, Severity forecasts given collateral characteristics and economic factors (e.g., interest rates). Unlike many competing models, LDM utilizes transitions between states (Current, Delinquent, Seriously Delinquent, and Terminated) for each underlying loan. Transition probabilities between states are differentiated between loan types, issuers, and vintages. The model is implemented on a QRM platform and it interacts with Intex for collateral information. Please find more detail in [2].

Alternative models, such as those provided by BlackRock and Moody's, exist. However, these were not explored since they are not integrated within the QRM framework. Recently, QRM released the capability to input outside vectors of CPRs, CDRs, and Severities into the framework. However, this method is cusip specific and it is not dynamic to adjust to the many rate scenarios which ALM IRR analyzes. ALM IRR benchmarks to BlackRock, however, it is not feasible to implement the alternative models because they are not compatible with QRM and analysis that ALM IRR produces.

LDM was released by QRM as a part of a patch, which included other system updates. Furthermore, QRM recommended the use of updated dlls (dynamic link libraries) for AD&Co's behavioral models. Thus, prior to testing LDM, testing was performed for the patch and dlls to ensure that the differences were within acceptable norms.

The out-of-the-box LDM was first applied to all non-agency MBS and, given the resulting long processing times (e.g., 12 hours for valuation), the current approach of placing longest running cusips into a constant prepayment/default account was retained. QRM's valuation process was run for spot rates and parallel interest rate shocks, as well as, planning process with base interest rates and parallel shocks interest rate shocks. The results were compared to the valuation and planning processes output using the production mix (no LDM) of models used for non-agency MBS.

The CPR, CDR, Severity metrics were also compared to historical performance from BlackRock and Bloomberg. Out-of-the-box LDM metrics were deemed reasonable. Tuning tests [13] also showed that by moving different tuning parameters, the CPR, CDR, and Severity metrics were able to be changed and thus modified to any desirable level.

Given IRR's need for a non-agency MBS model with dynamic prepayment and default models, LDM results versus current models, and the capability of tuning LDM to historical performance, it was concluded that LDM was suitable for IRR's use in QRM.

Assumptions: LDM assumptions are documented by AD&Co in [2]. The model transitions the loans from different states. The tables below indicate which static and dynamic variables guide the model transitions, where C stands for Current, D – Delinquent, S – Seriously Delinquent, and T – Terminal.

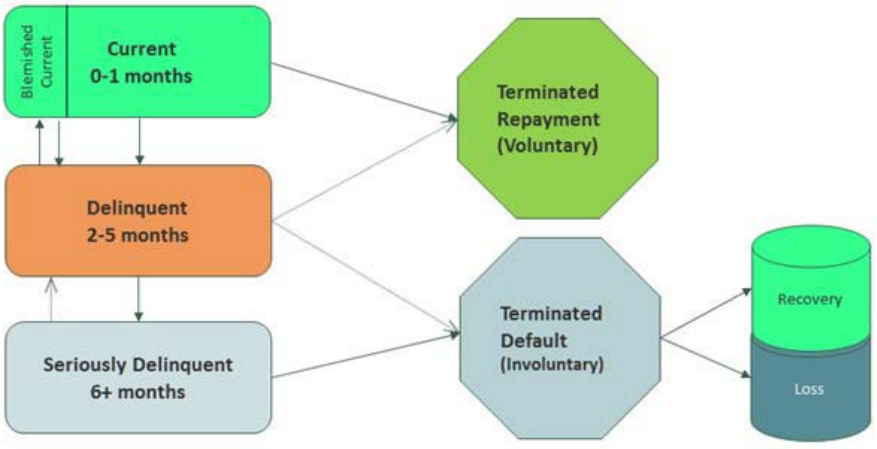
		CtoD	CtoT	DtoC	StoC	StoT	ProbLoss/Severity
STATIC VARIABLES							
Loan Type	Issuer	X	X				X
	Original Term	X	X				
	ARM	X	X	X			
	ARM Type	X	X				
	Original Balance	X	X		X	X	X
	Original Credit Score	X	X	X	X	X	X
LTV	Original LTV						X
	Original Combined LTV	X	X	X	X	X	
	Lien Position					X	X
	Documentation	X		X			
	Occupancy	X		X	X	X	X
	Loan Purpose	X		X			
	Property Type			X	X		
	NumUnits			X	X		
	Prepay Penalty		X	X			
	Interest Only		X				
	Option ARM						
State	Judicial Foreclosure						X
	Foreclosure Timelines					X	
	Housing Stock						X
	Sato						
	Sato Residual			X	X	X	
	Vintage	X	X				
	Mortgage Insurance						X

		CtoD	CtoT	DtoC	DtoT	StoC	StoT	ProbLoss/Severity
DYNAMIC VARIABLES								
HPI	Age	X	X	X	X	X	X	X
	Month	X	X					
	Scheduled Balance							X
	Current Combined LTV	X	X					
	Delta_LTV			X	X	X	X	
	HPI_MSA							X
	HPA_MSA	X						
Burnout/Changing Loan State	Prior Delinquency	X	X					
	PSA		X					
Coupon	Current WAC		X					
	Expected WAC		X					
	Short-Term Payment Shock	X						
	Payment Shock from Origination	X						
	Near Reset Effect		X			X		
	Delta FNMA				X			
State of the Economy	HPA_USA	X						X
	Credit Spread		X					

LDM also utilized two economic drivers: home prices and interest rates. For the former, national and local HPI forecasts are used. For the latter, 2y and 10y rates drive the current coupon calculations and an index rate forecast is required for the Adjustable-Rate Mortgages (ARMs). QRM's market swap rates are used for the 2y and 10y term points in valuation and IRR's specific forecasts are used in planning scenarios. IRR references AD&Co's fcst_index.txt file for the index rate forecast.

Formulation: LDM models loan level state transitions, ranging from Current to Terminated. Transitions are binary events and are modeled using a logistic function in simpler cases to customized non-linear functions in more complex cases. The charts below outline the definitions and the transitions.

Name	State	Description
C	Current	0-1 Months Delinquent (0-59 Days)
D	Delinquent	2-5 Months Delinquent (60 - 179 Days)
S	Seriously Delinquent	6+ Months Delinquent (180+, FC, REO)
T	Terminated	No Current Balance



Among 16 possible transitions, there are six transitions that AD&Co considered is reasonable and not trivial.

Name	State Transition Description	Description
C to T	Current to Terminated	Prepayment
C to D	Current to Delinquent	Delinquency
D to C	Delinquent to Current	Cure
D to T	Delinquent to Terminated	Delinquent Prepayment / Short Sale
S to C	Seriously Delinquent to Current	Recovery
S to T	Seriously Delinquent to Terminated	Liquidation

AD&Co uses logistic regression to project each transition. The dynamic variable and static variable for modeling each transition was shown in the Assumption section. Tobit regression was used for loss severity. After calculating the probability of each transition, the model further calculates the behavior estimation of MRR (Monthly Repayment Rate), CRR (Conditional Repayment Rate), MDR (Monthly Default Rate), CDR (Conditional Default Rate), SMM (Single Montly Mortality), CPR (Consitional Prepayment Rate).

	CtoT	DtoT	StoT	ProbLoss/Severity
MRR	X	X	X	X
CRR	X	X	X	X

MDR	X	X	X	X
CDR	X	X	X	X
SMM	X	X	X	X
CPR	X	X	X	X

The LDM model is transition-based. The prepayment and default rates were developed using logistic regression. The severity model utilizes Tobit regression. Since AD&Co LDM is an AD&Co proprietary model, access to its code is not available. However, MRR, MDR, SMM, CRR, CDR, CPR consist of three transitions, including CtoT, DtoT and StoT, as well as probability of loss. The following formula was provided by AD&Co to calculate each of them:

$$MRR = \frac{C * CBAL * CT * (1 - PL\_TC) + D * DBAL * DT * (1 - PL\_DC) + S * SBAL * ST * (1 - PL\_TS)}{C * CBAL + D * DBAL + S * SBAL}$$

$$MDR = \frac{C * CBAL * CT * (PL\_TC) + D * DBAL * DT * (PL\_DC) + S * SBAL * ST * (PL\_TS)}{C * CBAL + D * DBAL + S * SBAL}$$

$$SMM = MRR + MDR$$

$$CRR = \left(1 - \left(1 - \frac{MRR}{100}\right)^{12}\right) * 100$$

$$CDR = \left(1 - \left(1 - \frac{MDR}{100}\right)^{12}\right) * 100$$

$$CPR = \left(1 - \left(1 - \frac{SMM}{100}\right)^{12}\right) * 100$$

$$Severity = \frac{C * CBAL * CT * (PL\_TC) * LM\_TC + D * DBAL * DT * (PL\_DC) * LM\_TD + S * SBAL * ST * (PL\_TS) * LM\_TS}{C * CBAL * CT * PL\_TC + D * DBAL * DT * PL\_TD + S * SBAL * ST * PL\_TS}$$

where C = Probability that a loan is current, D = Probability that a loan is delinquency

S = Probability that a loan is in Serious Delinquency

CBAL = Balance at Current State, DBAL = Balance at Delinquency State,

SBAL = Balance at Seriously Delinquency State

PL_TC = The probability of loss from C to T(0 for CT), PL_TD = The probability of loss from D to T

PL_TS = The probability of loss from S to T

LM_TC = Loss Magnitude from C to T, LM_TD = Loss Magnitude from D to T

LM_TS = Loss Magnitude from D to T

[4] details the transitions methodology in greater detail.

Other modeling with LDM includes home prices and interest rates. The home price model is a stochastic model linked to interest rates, where HPA is viewed as a random factor modeled as a stochastic process. HPI is projected at a national level and simulated down to the MSAs.

AD&Co Mortgage Rate Model: Mortgage market rates play a crucial role in the AD&Co's borrower behaviour modelling and economic factors modelling such as home prices. In prepayment and default models, it enters into a borrower's incentive to refinance. In home-rice modelling, it enters the

perception of HPI forecast. AD&Co uses the secondary-market rate, so-called current coupon, and adds a typical primary-secondary spread (PSS). The formula for calculating mortgage market rates is:

$$Primary\ Rates = CCY + PSS$$

CCY is the current coupon yield. It is modeled as

$$CCY_t = a * 2YSwap_t + (1-a) * 10YSwap_t + Spread_0$$
$$Spread_0 = CCY_0 - [a * 2YSwap_0 + (1-a) * 10YSwap_0]$$

where parameter a is from the linear regression, 2YSwap and 10YSwap are 2 years and 10 years swap rates.

For detailed methodology in CCY modeling, please refer to [3].

The primary-secondary spread (PSS) is modeled by a logistic function:

$$PSS_t = \frac{\beta(PSS_{min} - PSS_{max})}{\beta + \exp[-\delta * (CCY_t + T_t)]} + PSS_{max}$$

$$T_t = \gamma T_{t-1} + (1-\gamma)(CCY_t - CCY_{t-1})$$

where the trend term T_t is an AR(1) filter, β, δ, PSS_{min} and PSS_{max} can be optimized. PSS remains within between PSS_{min} and PSS_{max}.

For detailed PSS methodology, please refer to [5] and [6].

The period covered by the data used to initially calibrate the model is January 2000 to May 2012. The source of the secondary market rates are the Bloomberg indices (MTGExxxx) and the source for the primary rates are Freddie Mac's Primary Mortgage Market Survey (PMMS) rates.

The current AD&Co mortgage rate model is different from the previous version which is used in AD&Co prepayment model. In the old model, the PSS was fixed and adjusted through tunings. The formulas is

$$Primary\ Rates = CCY + internal\ spread + slide\ tuning$$

AD&Co established the model validation process for mortgage rate model including monthly monitoring for both CCY and PSS ([7]).

B. Input Data and Data Assumptions

Input Data: LDM's inputs include collateral characteristics, interest rates, potentially macro-economic forecasts (e.g., HPI), and development/calibration data used by AD&Co for model building/calibration.

Collateral information is passed to QRM from Intex via cusips. This process runs during the execution of a valuation or planning run in QRM. The inputs can be viewed via log files during a

single instrument analysis for a sample cusip. QRM does not produce an orderly report for model input, but a sizable log file can be produced at runtime showing all collateral information for all cusips. Substantial time is required to develop a robust parsing mechanism for useable data display. Interest rates in QRM's valuation are mostly QRM sourced and IRR-determined for planning. IRR's interest rates use is a well-defined process that has been validated and undergoes rigorous monthly verification.

The inputs and assumptions variables used in LDM are the same for ALM-IRR production process and stress testing exercises such as CCAR. In CCAR, a custom input can be used in place of the generic QRM or AD&Co provided field. For example, HPI forecast for CCAR is a custom input and not the series forecast provided by AD&Co.

Assumptions Used as Inputs:

When input data for a model parameter is unavailable from Intex, QRM returns an error during the valuation or planning run. In such a case, the cusip will be placed into a non-Intex account with a generic assumption, where behavioral assumptions of collateral are assumed constant. These constant assumptions are reviewed and updated quarterly. During LDM's implementation, no cusips lacked input assumptions. However, if in the future inputs are lacking, the above process will be followed.

There are no judgmental or qualitative assumptions input into the LDM model. For the positions in the non-Intex accounts, the behavioral assumptions are determined from BlackRock projections.

C. Calculations

Transitions From AC	From BC	From C	From D	From S	To T
AC to AC	BC to BC	C to C	D to C	S to C	T From C
AC to D	BC to D	C to D	D to D	S to D	T From AC
AC to S	BC to S	C to S	D to S	S toS	T From BC
AC to T	BC to T	C to T	D to T	S to T	T From D
					T From S

States	Preay and Loss	Preay and Loss	Assumptions	Cash Flows
Always Current	Index	Prob Loss TC	2 Yr	Scheduled Balance
Blemished Current	Date	Prob Loss TD	10 Yr	Scheduled Payment
Current	Arm WAC	Prob Loss TS	CCY	Scheduled Principal
Delinquent	Age	Loss Magnitude TC	Arm Index	Scheduled Interest
Seriously Delinquent	MRR	Loss Magnitude TD	Local HPI	Current LTV
Terminated	CRR	Loss Magnitude TS	National HPI	
Delinquent 60 Plus	MDR	Loss Severity		
Delinquent 180 Plus	CDR	Cumulative Loss		
	SMM	Cumulative Prepay		
	CPR	Cumulative Default		

Among these outputs, QRM only takes monthly CRR, CDR and Severity. QRM CPR output is actually CRR, therefore for the remainder of the document CPR will be analogous us CRR.

LDM allows users to choose from four definitions of default: Basic, Bank, Implied and Loss Termination. The choice of definition does not alter the cash flows, thus losses remain internally consistent across all definitions. The distinction lies in how defaults and prepayments are distributed across definitions. The following table summarizes the portion of terminated loans that are included in the calculation of prepayments, defaults and losses [8].

	Basic	*Bank*	*Implied*	*Loss Termination*
Prepayments	Terminations from C & D without losses	Terminations from C & D without losses	Terminations from C without losses	Terminations from C, D, & S without losses
Defaults	Terminations from C & D with a loss; Loans Terminated from S	Terminations from C & D with a loss All loans in S	Terminations from C with loss All terminations from D & S	All terminations from C , D, S with losses
Losses	Terminations from C, D, S with losses	Terminations from C, D, S with losses	Terminations from C, D, S with losses	Terminations from C, D, S with losses
Severity	Losses/Default	Losses/Default	Losses/Default	Losses/Default

ALM-IRR chose to use the Basic definition of default because the CDR series with this option was stable over time and in line with expectation for non-agency collateral in a stable interest rate environment. Bank default option was also explored, but the CDR series declined sharply over the initial 12 months in a stable interest rate environment. There is no intuitive explanation for this behavior.

Practically, Forecast Audit or Detail Forecast Audit reports from QRM display monthly forecasts for CPR, CDR, and Recoveries:

Detailed Forecast Audit	
	07/31/2015
Balance Sheet	
Assets	
Investment Portfolio	
Non-Agency MBS	
AAM0102-COLLAT	
CPR	12.12
CDR	1.42
Recovery Rate	55.06

Testing was performed on the September 2014 portfolio ([9], [10]).

Patch: LDM release was packaged into a QRM patch, where other changes to the software were included. Testing was performed without LDM on current set of dlls to ensure that results do not show material changes simply due to the patch itself. The results can be viewed in the two attached files above.

Valuation results show the biggest variance in the Bull Flattner scenario of about ½ million dollars; non-agency models (utilizing AD&Co's FIXEDMBS) are responsible for most of the deviation. Since the results were run in two different environments (Patch in Development and current non-Patch in Production), QRM attributed this difference to the instability of AD&Co dlls. The magnitude of the market value variance is acceptable, given the total market value of non-agency MBS is about $3.6 billion.

Base and shocks planning comparisons show little variance in balances and income. The maximum average balance difference of $4 million, over 12 months, occurs in scenario where interest rates are shocked up in parallel by 300 basis points (up 300. All interest income variance is under $1 million. The movement in balances for central banks and fed funds purchased/repo is attributed to the balance change in the investment portfolio.

DLL: Following up on QRM's suggestion regarding switching to the more stable AD&Co dlls, testing was performed to compare the results with the two underlying dlls. The purpose of this test was *not* to examine stability, but to account for any other variance in results when switching the modeling to LDM. The results can be viewed in the pink-colored tabs in Appendix Patch, DLL, LDM.

The biggest variance in market value is observed in the Up 300 rate scenario $1.4 million, and again concentrated in non-agencies. The maximum average balance difference over 12 months occurs in the shock Up 300 scenario - $4 million. All interest income variance is under $1 million. Results were communicated to QRM and variances were deemed to be insignificant in magnitude.

Patch & DLL: The first Patch test was redone with the updated dlls. The results can be viewed in the two attached files above.

The biggest variance in valuation was observed in the Up 300 scenario– $2 million. The maximum average balance difference over 12 months occurs in shock Up 300 - $4 million. All interest income variance is under $1 million. Variances were deemed to be insignificant in magnitude.

LDM EVE and NII: Understanding the differences in valuation and planning for the patch and dlls, we commenced LDM testing. The results can be viewed in the two attached files above. Appendix LDM detail includes more granular analysis of the non-agencies. LDM results correspond to the out-of-the-box tuned model provided by AD&Co and the testing in this section aims to verify the functionality of the model without focusing on the variance in results. Details of implementing LDM can be found in [11] (password 'qrm'):

LDM was implemented by attaching the behavioral prepayment function to the non-agency MBS collateral in QRM. The current process for non-agency MBS analysis includes a handful of Prime MBS cusips being run with constant prepayment and default assumptions, necessary because of to the long processing time required between QRM and Intex. In the first step of LDM testing, all non-agency MBS collateral was switched to the LDM model. Valuation processing time was nearly 12 hours and a decision was made to continue using constant assumptions for the same set of Prime MBS cusips.

Upon further analysis, it was discovered that QRM outputs CPR and CDR at the tranche level. QRM is working on reporting collateral level CPR and CDR, since current output options do not allow for direct tuning of non-agency collateral. The next section discusses a work-around solution for tuning on the non-agency collateral.

After implementing LDM, all cusips processed in QRM without error in valuation and planning. The biggest variance in market value was observed in the Up 300 scenario - $97 million, and again

concentrated in non-agencies. The maximum average balance difference over 12 months occurred in the Base scenario - $128 million; the maximum income variance was $90 million in the Up 300 scenario. The results corresponded to the untuned LDM.

Testing the Model

A. Analysis of the Model

Assumption Validity: AD&Co performed extensive validation of the model and monitors its performance regularly. The following documents are relevant to validation: [4], [7], [14], [15], [16].

AD&Co provides an online module ([17]), where the user can use various inputs (e.g., HPI, rates) to test the performance of the LDM model.

Back-testing and tuning: ALM-IRR views back-testing and tuning of prepayment/default models as parts of the same process. That is, a model's performance is assessed by performing historical back-testing on the behavioral outputs (e.g., CPR, CDR) and if a particular collateral segment is out of acceptable range of accuracy, it is then tuned. Back-testing is performed monthly and tuning is performed, at least, on a quarterly frequency.

LDM was back-tested and tuned using the same process that is currently used for Agency MBS. Bloomberg one month CPR, CDR, Severity was extracted for each security for trailing three months. One-month planning cycle was run in QRM for the same time periods and the same behavioral metrics were obtained. Results were grouped by types of collateral (e.g., Alt-A 15 year fixed) and for each month QRM/Bloomberg behavioral metric (e.g., CPR from QRM divided by CPR from Bloomberg) was computed. An average over the three months was taken. If for a particular collateral group, this ratio is .8, for example, it implies that AD&Co is too slow in that particular collateral behavior metric. Tuning files were then used to speed up or slow down collateral behavior. The final results for back-testing and tuning can be found in [26].

On a technical note, QRM's outputting of only tranche level CPR, CDR, and Severity for tranche products is problematic for tuning. QRM is working on addressing this issue. As a solution, two methodologies were explored. First, the user can activate logs generated between QRM and Intex, showing collateral attributes (e.g., LTV, origination date, FICO). Then the logs can be parsed and each collateral item can be set up in a proxy portfolio with those attributes; tuning would follow on the proxy portfolio. Alternatively, QRM suggested setting up the collateral by concatenating the deal name and "-COLLAT" into the cusip field of a proxy portfolio. Deal name mapping for non-agency MBS cusips is available through a reporting option. This setup will enable QRM to directly pull collateral attributes from Intex. Both methodologies were explored, but the latter was chosen because of its straight-forward data sourcing from Intex, rather than the parsing and entry process of the former.

Collateral was grouped using the Breakdown field from QRM's balance sheet data source, ALMIS, into groups that resemble the shelves used for tuning.

Benchmarking: QRM results were compared against BlackRock for security valuations and risk measures ([24], [25]). Two observations were driving most of the differences. First, BlackRock computes risk measures using 50 basis points parallel shocks, whereas QRM uses 10 basis points. In a low-rate environment, with flooring of rates at zero, bigger shocks cause asymmetric risk

computations. Second, BlackRock zeroes out rate risk for deeper discounted bonds, assuming all risk is credit related.

Result accuracy: LDM has no history of performance to complete any back-testing. The Back-testing and tuning section of Calculations includes a comparison of AD&Co's out-of-the-box CPR, CDR, and Severity output to the same BlackRock historical and modeled metrics, as well as Bloomberg historical. AD&C0's output appears reasonable, given AD&Co's tunings correspond to the whole population on non-agencies. Documents [24], [25], and [26] detail the back-testing and benchmarking results.

Back-testing and benchmarking for LDM will be monthly and tuning – quarterly, unless some product type exhibits substantial change in collateral behavior.

Model fidelity (stability and behavior):

QRM directly interfaces with Intex to obtain all the necessary collateral information. Other necessary inputs are gathered by QRM from AD&Co's historical/forecasting file (provided monthly). The only current market input that IRR controls is the level of interest rates. Interest rates mainly drive the speed of the prepayments, through the 2y and 10y rate levels used in current coupon computations.

The testing in the Calculations section included valuation and planning with parallel shocks in the interest rate. The files in that section contain sensitivity results for the non-agencies to shocks in the interest rates. As discussed previously, only the non-agency MBS part of the investment portfolio is changing in the LDM analysis.

In valuation, the market value of non-agency securities decreases in upward shocks of the interest rates. This is the expected relationship between price and interest rates. Prepayment behavior is muted because these non-agencies are legacy securities originated in mid-2000, experiencing burnout. In planning, CPRs slightly decrease and average balances slightly increase, but overall negligible. CDRs slightly increase. NII increases with higher rates as floaters re-price. Because non-agencies are priced at a discount (~85), accretion is a large portion of income. Accretion output (Amortization of Premium), looks stable in all scenarios; weighted average life is not materially affected (little CPR, CDR changes). The details of the result are found in [18].

Extended sensitivity testing was also performed with respect to shifts in CPR, CDR, Severity, rates, and HPI. Results ([23]) were intuitive.

LDM stability and behavior will be reviewed on the on-going basis. Model validation performs annual model reviews, during which IRR can review/test modeling concerns in tandem.

B. Analysis of Implementation

LDM is a vendor model which is integrated within QRM. It is not incorporated into BNY Mellon systems [11].

Implementation test was performed for fixed rate mortgages and an arm product, showing that AD&Co's outputs flow into QRM's output ([20],[21],[22]). The tests successfully replicated the QRM's output for CPR, CDR, and recovery for the sample loans. AD&Co's log files were utilized to extract the SMM, MDR, and Loss Severity which QRM receives from AD&Co at runtime. These were converted to annual CPR, CDR and Recovery. This computation matched QRM's output for the selected loans.

C. Ongoing Performance Monitoring Plan

Prepayment, default, and severity back-testing will be performed on a monthly basis. The results will be reported to the head of IRR, Treasury Market Risk, and ALCO.

Tuning will be performed quarterly, keeping track of the starting levels of CPR, CDR, Severity, ending levels, and change in the tuning parameters. Tuning results will be reported to the head of IRR, Treasury Market Risk, and ALCO.

AD&Co's HPI forecasting will be back-tested periodically to insure the vendor's sound modeling of the macroeconomic factor.

ALM-IRR will investigate the feasibility of back-testing the mortgage rate, given AD&Co's model inputs.

References for Model Documentation:

[1] "LDM_Unemployment_TuningDoc_2014", AD&Co. (PDF document)

[2] "TechnicalPerspectives_NonAgencyLDM_February2015", AD&Co. (PDF document)

[3] "EBelbase_CurrentCoupon_QP_2013", AD&Co. (PDF document)

[4] "EBelbase_QP_Model_Validation", AD&Co., June 2012 (PDF document)

[5] "PSS model 2012", AD&Co., January 2012, (PDF document)

[6] "ALevin_20thAnnual_06_2012", AD&Co., June 2012, (PDF document),

[7] "EBelbase_ValidationPSS_QP_2014", AD&Co., June 2014, (PDF document),

[8] "LoanDynamics QP Oct08", AD&Co., October 2008, (PDF document)

[9] "Appendix Patch, DLL, LDM" (Excel spreadsheet)

[10] "Appendix LDM detail" (Excel spreadsheet)

[11] "Implementing ADCo LDM20 – May 2014", QRM, May 2014 (PDF document)

[12] "NonAgency Collateral" (Excel spreadsheet),

[13] "Summary of Collateral Tuning Test" (Excel spreadsheet)

[14] "LDMValidation_Tuning_Aug2012", AD&Co., August 2012 (PDF document)

[15] "EBelbase_ValidationAgencyLDM_QP_2014", AD&Co., April 2014, (PDF document)

[16] “EBelbase_ValidationAgencyLDMPart2_QP_2014”, AD&Co., April 2014 (PDF document)

[17] AD&Co module, AD&Co. website

[18] “Sensitivities” (Excel spreadsheet)

[20] “Detailed Forecast Audit 15 FRM” (Excel spreadsheet)

[21] “Detailed Forecast Audit 30 FRM” (Excel spreadsheet)

[22] “Detailed Forecast Audit ARM” (Excel spreadsheet)

[23] “LDM Sensitivities extended testing” (Excel spreadsheet)

[24] “Benchmarking May Results” (Excel spreadsheet)

[25] “Benchmarking April Results” (Excel spreadsheet)

[26] “LDM Tuning Results” (Excel spreadsheet)

Change Log

Model Validation’s commentary incorporated on 11/6/15.
Additional Model Validation commentary addressed and included other testing results on 2/16/16

Revision History of Model

Date	Section	Description of Change	Validation of Change	Validation Date
2/25/16	All	Document being created (Taras Smetaniouk)		