Prepayment Model for Agency MBS, CMO and Whole Loan Mortgages (ADCo Prepayment)

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Purpose and Use

A. **Purpose of Model:** BNY Mellon (ALM-IRR) utilizes Andrew Davidson & Company (AD&Co) through the Quantitative Risk Management (QRM) platform to model prepayments for the mortgage-backed (MBS) securities held in Corporate Treasury's investment portfolio and the whole loan mortgage portfolio. The modeling impacts Economic Value of Equity (EVE), Net Interest Income (NII) projections, CCAR OCI, and Basel Interest Rate Economic Capital analytics.

B. **Areas of Use:** Andrew Davidson & Co (AD&Co) models are utilized for MBS, the whole loan mortgage portfolio and regulatory purposes for FR 14Q, 10Q/10K, CCAR and ICAAP reporting.

C. **Work Stream Category:** Securities

D. **Limitations:** The Model Risk Management Group (MRMG) 2014 review reported that non-agency subprime MBS and some non-agency Prime/Alt-a positions were not modeled using the AD&Co prepayment model, because AD&Co could not recognize some parameters provided for these positions and returned an error message. Constant CPR is used for these positions. This is an issue with model implementation and MRMG raised it as a model weakness in the 2014 validation [7].

IRR agreed with MRMG's assessment and stated that the introduction of the Loan Dynamics Model for the non-agency MBS should mitigate this issue. Also, MRMG indicated that AD&Co prepayment used for BNY Mellon's portfolio had the following limitations:

1. It was developed mainly based on Agency MBS Pool level data.

2. It used national HPI, instead of MSA or State HPI, in the prepayment projection.
3. The AD&Co Prepayment model does not use documentation type or loan size in prepayment projection.
4. Except for Agency Fixed, AD&Co does not use enhanced loan characteristics: Lien, FICO, State, Property Type, Occupancy or Loan Purpose. Further, for Agency ARM loans it does not use LTV either.

Such limitations have little impact on Agency MBS/CMO products, which contribute to 82% of the total portfolios covered by AD&Co. However, they make it less appropriate to model Non-Agency MBS and mortgages. AD&Co prepayment model 5.2h does not project default risk and non-agency MBS and mortgages will be subject to such risks.

Currently, non-agency MBS uses a constant CDR number, and mortgage loans use an additional discount spread to address the default risk. Last year this was raised as a model issue. Similar issues are also raised in QRM validation for Non-Agency MBS and mortgage loans.

ALM-IRR is currently testing QRM LDM. Use of LDM will enhance the modeling of non-agency MBS and the whole loan mortgage portfolio because QRM will be able to model defaults and severities. The focus of this document is on AD&Co's agency models which only model prepayments. LDM documentation will be completed separately.

Model Specification

A. Methodology

CCAR usage:

AD&Co's models drive prepayments and thus balance and income projections in the CCAR stress testing exercises. The inputs into the models are the same as discussed in the Input Data section further below. Additionally, HPI forecasts are input for each of the Federal Reserve scenarios.

Approach:

QRM is a vendor system developed and supported by Quantitative Risk Management (QRM). It is used by Corporate Treasury's Interest Rate Risk Group (ALM-IRR), to provide BNY Mellon with analytics for managing interest rate revenue, risk and market value of capital. ALM-IRR models the entire balance sheet of BNY Mellon in this platform.

Vendor options for prepayment modeling integrated within QRM were AD&Co and QRM's internal models. ALM-IRR chose AD&Co because of its more advanced modeling (e.g., Active-Passive Decomposition of the mortgage pool). Other models used within the Firm, such as BlackRock and Moody's, were not integrated with QRM.

The AD&Co Prepayment model consists of a series of prepayment models of different products. We separate them into Agency Fixed, Agency ARM and Non-Agency. Non-Agency is further divided into prime and subprime. The model is built mainly on pool level Agency MBS data[1]. It follows the industry standard methodology and models prepayment by factors of turnover, refinance, cash-out, and credit cure. Currently, it incorporates the following pool-level attributes:

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[1] According to communication with AD&Co, only $600MM (balance) Non-Agency is used in the model building.

- Weighted Average Loan Age (WALA)
- Weighted Average Gross Coupon (GWAC)
- Current Balance
- Origination Year
- Origination Quarter

It also considers these additional enhanced factors first released by Fannie Mae and Freddie Mac in 2003:

- Weighted Average Original LTV
- Weighted Average Original Credit Score (FICO)
- Loan Purpose (% of purchase/refinance loans in pool)
- Property Type (% of single-/multi-family loans in pool)
- Occupancy (% of owner/second homes/investment property loans in pool)
- Geographical composition by states in pool

Compared with other industry models, e.g. BlackRock Aladdin Prepayment, the AD&Co prepayment model employs an enhanced approach. This enhanced approach is, the Active-Passive Decomposition (APD) method to simulate path-dependent effects, e.g., burnout or "catch-up" for prepay-penalty pools. The main idea behind APD is to separate borrowers into two distinct groups: active and passive. Active borrowers are more sensitive to refinance opportunities and are more likely to prepay to take advantage of a lower interest rate, a more favorable loan type, or to cash out on the equity built up on their home. Passive borrowers are much less sensitive to refinance opportunities. It is further assumed that there is no migration between active and passive borrowers.

Stress Testing:

AD&Co, through QRM, is utilized for stress testing exercises (e.g., CCAR) as well as production efforts.

B. Input Data and Data Assumptions

Input Data:

For the models to function, collateral information, interest rate forecast, and macro-economic data are needed. All collateral information for MBS is obtained from the integrated and automated Intex interface within QRM; whole loan mortgage data comes from BNY Mellon's Almis3 datamart. QRM provides the interest rate paths for valuation and prepayment forecasting. AD&Co provides the data files with other necessary macro-economic files and tunings (e.g. HPI).

Assumptions:

The monthly prepayment speed Single Monthly Mortality (SMM) for the active piece is given by:

$$ActiveSMM = turnoverSMM + refiSMM + cashoutSMM + cureSMM \qquad (1)$$

The passive piece experiences some refinance, but not as much as the active counterparty (betas are typically 25% or less):

$$PassiveSMM = turnoverSMM + \beta_1 \times refiSMM + \beta_2 \times cashoutSMM + \beta_3 \times cureSMM \qquad (2)$$

Then the total SMM for the entire pool is:

$$TotalSMM = \Psi \times activeSMM + (1 - \Psi) \times passiveSMM \tag{3}$$

, where Ψ represents the percent of active borrower in the pool. As active borrowers refinance and leave the pool, Ψ changes over time:

$$\Psi_{t+1} = \Psi_t \times \frac{1 - ActiveSMM}{1 - TotalSMM} \tag{4}$$

AD&Co uses a non-linear regression procedure in the statistical software package SAS to estimate the prepayment model. For detailed information on this procedure, please refer to SAS User's Guide website PROC NLIN statement [6]. AD&Co begins by fitting the various pieces of the model (turnover, refi, etc.) individually, then using the optimizer to fit the initial mix of active and passive borrowers in a pool, which is the model parameter Ψ_0 in formula (4). This parameter varies by product type. For example, 15 year collateral tends to have a lower Ψ_0 than 30 year collateral since those pools are typically made up of borrowers who have refinanced into a shorter amortization term. The initial value usually falls between 0.8 and 0.65, or 80% active to 65% active.

The same procedure applies for fitting the different Betas that are used as multipliers in the active/passive formula (2). AD&Co usually begins parameter optimization with values for each beta around 0.20. Initially, AD&Co attempts to fit the Ψ_0 and Beta parameters in the same step; however, depending upon the size of the data set or time period covered, AD&Co may choose to fit them separately.

AD&Co does not look at borrowers to decide who is active or passive. The APD split (parameter Ψ_0) and the passivity scale are merely parameters of the model. To explain this in practical terms, setting Ψ_0 to 1 or to 0 makes the pool homogeneous and eliminates burnout altogether. On the other hand, setting Ψ_0 to 0.5 makes the fastest burnout, in some sense. By observing the actual empirical burnout pattern, one can find the best-fitting Ψ_0.

In addition, BNY Mellon does not have a mortgage rate model or HPI model. Therefore AD&Co models for the mortgage rate and HPI are used.

Formulation:

AD&Co Mortgage Rate Model [4]

The AD&Co primary mortgage rate is calculated by the following formula:

Primary Rates = CCY + internal spread + slide tuning (5)

Where,
a) CCY is the current coupon yield. It is calculated as:

$$CCY_t = a * 2YSwap_t + (1 - a) * 10YSwap_t + Spread_0$$
$$Spread_0 = CCY_0 - [a * 2YSwap_0 + (1 - a) * 10YSwap_0] \tag{6}$$

b) Parameter 'a' is from the linear regression;
c) Slide tuning is a tuning parameter which enables the models user to further add a spread to the projected primary mortgage rate;
d) Internal spread is the intercept from the linear regression.

For different mortgage rates, the parameters 'a', 'internal spread' and 'sliding tuning' will be different.

AD&Co provides 'a' and 'R-Squared' for some of the mortgage rate on its website[2]. The R-squared are all over 90%. We did a back-test for the mortgage rate in the test section B.2.
AD&Co HPI Model [5]

AD&Co HPI model projects the annualized Home Price Appreciation (HPA) rate. The HPI currently used by BNY Mellon AD&Co implementation is National HPI. The AD&Co HPI model is used in BNY Mellon's implementation. At default, the randomness is turned off in the AD&Co HPI model. So the volatilities are turned-off. Thus, the model is driven by the financing rate that determines housing affordability and income inflation.

The model used data from 1984 to 2009. It used HPA purchase-only data from FHFA, Current Coupon Rate (to reflect the effect of "affordable lending") and income data published by the Census.

$$HPA(t) = x_1(t) + i\inf(t) \tag{7}$$

Where

a) the first order derivative of $x_1(t)$ follow:
$$x_1' = x_2 + k_1 X_{eq}' \text{ Where } x_2' = -ax_2 - bx_1 + k_3 X_{eq}'$$

b) X_{eq}' is the first order of log-HPI equilibrium, which is measured via the mortgage payment rate.

c) iinf(t) is the income inflation at time t. It is assumed to have a 0.61 correlation with the interest rate in forecasting; (i.e. a 1% change in interest rate results in a 0.61% change in income).

The solution to (7) is solved using monthly time steps going forward. The following Figure 2 summarizes the AD&Co HPI model. Please note that the randomness of the model is turned-off; hence, there is zero 'jump' and zero volatility for the HPA diffusion term.

Figure 2 Flowchart of the AD&Co HPA Model
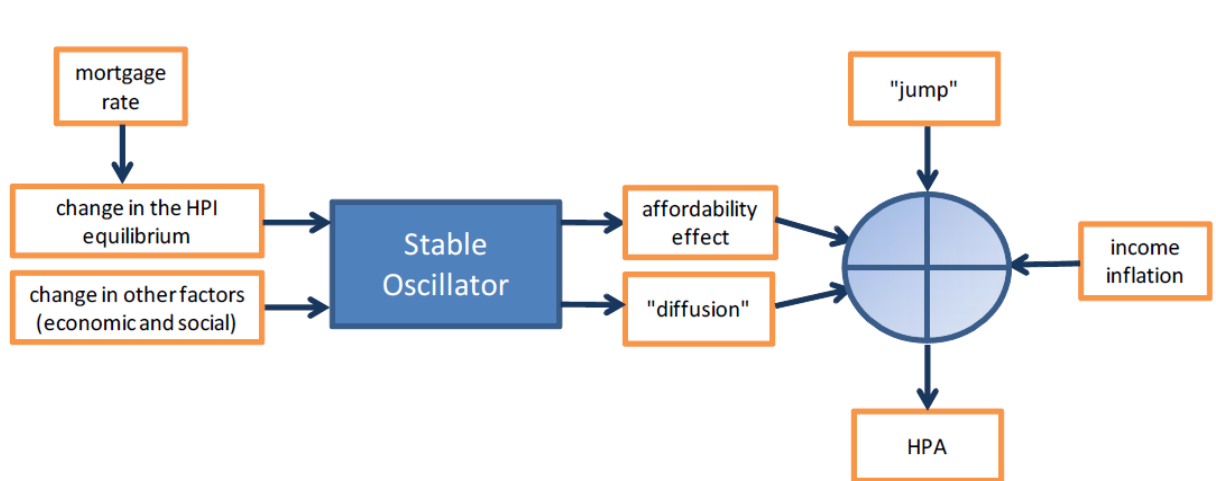
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[2] Andrew Davidson website

Assumptions Used as Inputs:

- Static CDR and loss severity are used for non-agency MBS.

- Agency pool-level data are also used for modeling CPR for non-agency MBS, where a model could be applied.

- National HPI is used as proxy for more granular level HPI.

- Enhanced loan characteristics don't affect the projected CPR.

- APD method assumed that borrowers can be separated into active and passive and there is no migration between two types of borrowers.

Future implementation of Loan Dynamics will dynamically model CPR, CDR, and loss severity, as well as, use non-agency loan level data for the behavioral modeling.

C. Calculations

Sample results below:

(in mm)	Book Value	Market Value	Economic Value	OAD	Convexity
Agency MBS Fixed Rate					
FHLMC	12,871	13,005	13,050	3.5	(0.39)
GNMA	1,476	1,486	1,499	3.0	(0.07)
FNMA	15,453	15,608	15,643	3.4	(0.47)
Agency MBS Float Rate					
FHLMC	190	200	203	1.1	(0.00)
GNMA	8	9	9	1.2	0.00
FNMA	278	292	297	1.0	0.00
Agency CMO Fixed Rate	4,487	4,509	4,532	3.6	(0.30)
Agency CMO Float Rate	10,160	10,192	10,243	0.4	(0.31)
Other MBS	4,543	4,508	4,562	5.3	(0.40)
Non-Agency MBS					
Alt-A MBS (Intex)	1,282	1,612	1,558	0.9	(0.09)
Prime MBS (Intex)	879	978	943	1.8	(0.02)
Subprime (Intex)	421	421	430	4.4	0.27
Total	**52,048**	**52,821**	**52,968**	**2.9**	**(2)**

Table 5 QRM Planning Report (sample CPR) July 2015

	15-Aug	15-Sep	15-Oct	15-Nov	15-Dec
Agency MBS Fixed Rate					
FHLMC	11.4	11.5	10.5	10.4	10.0
GNMA	19.0	20.2	19.6	19.4	18.5
FNMA	13.1	13.3	12.3	12.1	11.6
Agency MBS Float Rate					
FHLMC	8.8	9.4	9.1	9.9	9.5
GNMA	5.1	5.9	5.6	6.4	6.2
FNMA	5.3	5.9	5.8	6.4	6.3
Agency CMO Fixed Rate	17.1	19.9	19.6	19.2	18.3
Agency CMO Float Rate	23.5	26.1	26.2	26.3	25.8
Other MBS	8.9	11.7	12.9	13.9	13.4
Non-Agency MBS					
Alt-A MBS (Intex)	12.5	12.9	12.2	12.3	11.8
Prime MBS (Intex)	17.0	17.3	16.1	15.8	15.0
Subprime (Intex)	0.0	0.0	0.0	0.0	0.0

Testing the Model

A. Analysis of the Model

AD&Co In-Sample Back-Testing

AD&Co performed the in-sample back-testing for fixed rate and adjustable rate agency MBS. The latest trend report using 5.2h was published in September 2013. Since then, AD&Co uses 5.2i for trend reports which shows monthly actual and model prepayment trends.

The in-sample back-testing summary results of AD&Co 5.2h are in Table 2 and 3. Color is used to bucket measures AD&Co calculates and highlights the goodness of model and actual fit. While green and red indicate good and bad overall fits, respectively, the yellow and orange colors show deteriorating fits in order. For more detailed back-testing for each rate type, please refer to the Appendix B.

For fixed rate agency MBS, the AD&Co 5.2h prepayment model fits the historical data very well.

For adjustable rate agency MBS, the AD&Co 5.2h prepayment model has a bad fit for FH 10/1, FN 3/1, FN 5/1 and FN 7/1 in terms of coupon, and for FH 7/1, FH10/1 and FN 7/1. Overall, AD&Co 5.2h fits historical data for fixed rate MBS better than ARM MBS.

According to AD&Co, prior to every model release, AD&Co analyzes the extent of red (bad fits) and assesses the reasons for the difference observed in back-testing. If the difference is caused by a fundamental issue, AD&Co will revise its model and re-estimate model parameters. If it is a transient situation, the model is tuned, appropriately. Following a model release, AD&Co continues to monitor performance of our models every month and take corrective action, if needed, ranging from minor tuning to major re-modeling.

Table 2 AD&Co In-Sample Back-Testing for Fixed Rate Agency MBS

Weighted RMSE/STD for aggregated actual and model results

	Analysis Date	Age	Coupon	Vintage
FN30	0.5553	0.3176	0.5755	0.5702
FN15	0.5610	0.2610	0.4581	0.3647
FH30	0.6485	0.4752	0.8486	0.8022
FH15	0.5318	0.4294	0.7616	0.5053
GN30	0.5694	0.3151	0.3545	0.4195
GN15	0.6677	0.2599	0.4944	0.4044

Table 3 AD&Co In-Sample Back-Testing for Adjustable Rate Agency MBS

Weighted RMSE/STD for aggregated actual and model results

	Analysis Date	Age	Coupon	Vintage
FH 3/1	0.9228	0.9271	1.9792	1.5595
FH 5/1	0.9764	1.0433	1.9172	1.6859
FH 7/1	0.7402	0.5706	2.8552	3.0161
FH 10/1	0.8200	0.7805	3.2470	3.3444
FN 3/1	0.8736	0.9369	4.8474	2.5810
FN 5/1	1.0033	1.0412	3.0822	2.3065
FN 7/1	0.8878	0.9544	4.2186	4.2752
FN 10/1	0.8097	0.6995	2.4889	2.6066
GN 3/1	0.9634	0.9392	0.5525	0.6116
GN 5/1	0.9459	0.7915	0.6658	0.6398

Result Accuracy:

AD&Co models are benchmarked monthly to BlackRock models and results are reported to the Treasury Risk Committee and Asset and Liability Committee (ALCO). If large discrepancies arise, they are investigated. Below is the July 2015 report for the investment portfolio.

QRM & Blackrock Investment Portfolio Metric Benchmark

As of July 2015	Face Value			Market Value			OAD			Dollar Convexity			Convexity Measure			1M CPR		
	QRM	BLK	Diff	QRM	BLK	Diff	QRM	BLK	Diff	QRM	BLK	Diff	QRM	BLK	Diff	QRM	BLK	Diff
ABS	3,276	3,275	1	3,278	3,280	1	0.5	0.5	0.0	1	0	(1)	0.04	0.00	(0.03)	19.7	57.6	37.9
Agency CMO	14,527	14,525	(2)	14,701	14,712	11	1.4	1.6	0.3	(82)	20	102	(0.56)	0.14	0.69	20.8	15.1	(5.7)
Agency MBS 15y**	23,598	20,958	(2,640)	24,558	21,838	(2,720)	3.5	3.7	0.2	(135)	(41)	94	(0.55)	(0.19)	0.36	11.5	9.3	(2.2)
Agency MBS 20y	499	499	0	517	518	1	4.3	4.3	0.0	(3)	(3)	1	(0.62)	(0.50)	0.13	14.3	10.7	(3.6)
Agency MBS 30y	2,062	1,979	(83)	2,251	2,172	(79)	3.0	3.9	0.9	(21)	(26)	(5)	(0.92)	(1.17)	(0.26)	21.5	16.2	(5.2)
Agency MBS Other Fixed	2,723	2,723	(0)	2,820	2,826	7	2.9	2.4	(0.5)	(24)	(20)	4	(0.84)	(0.70)	0.14	16.7	18.5	1.7
International MBS	1,712	1,712	(0)	1,691	1,700	9	0.2	0.3	0.1	53	25	(27)	3.11	1.50	(1.61)	12.4	9.3	(3.1)
Non-Agency MBS	3,532	3,532	0	3,011	3,016	6	1.7	0.3	(1.4)	17	1	(16)	0.56	0.03	(0.53)	13.9	11.4	(2.5)
CDO/CLO	2,833	2,628	(205)	2,829	2,626	(203)	0.3	0.4	0.1	(0)	1	1	(0.00)	0.02	0.02	14.9	5.0	(9.9)
Corporate/Covered Bonds	4,333	4,195	(138)	4,477	4,372	(104)	3.1	3.0	(0.1)	7	7	0	0.15	0.16	0.01	0.0	0.0	0.0
Agency MBS Floats	471	471	(0)	501	502	1	1.0	0.9	(0.2)	(0)	2	2	(0.01)	0.33	0.34	12.9	15.9	3.0
CMBS	5,729	5,729	0	5,820	5,833	13	4.0	4.0	(0.1)	16	22	6	0.27	0.37	0.10	3.8	0.8	(3.0)
Municipal Bonds	4,009	4,007	(1)	4,433	4,482	49	3.5	3.1	(0.4)	4	6	2	0.09	0.13	0.04	0.0	0.0	0.0
Sovereign Debt	43,431	42,538	(893)	44,452	43,746	(705)	4.1	4.0	(0.1)	210	173	(36)	0.47	0.40	(0.08)	0.0	0.0	0.0
Total	112,733	108,769	(3,962)	115,338	111,625	(3,713)	3.2	3.2	(0.0)	42	168	126	0.04	0.15	0.11	14.0	10.7	(3.4)

* Face Value, Market Value and Dollar Convexity in million's
** TBA MBS are excluded from the BlackRock balances resulting in face and book value variance between BlackRock and QRM.

OAD Notes:
- Agency MBS 15Y & Agency MBS 30Y Blackrock durations are higher due to slower prepays.
- Agency MBS Other Fixed and Agency MBS floats Blackrock durations are lower than QRM due to lower durations of MBS ARM and Hybrid accounts.
- Non-agency MBS QRM duration is higher due to a few CUSIPs with very large durations.

CPR Notes:
- ABS, Blackrock CPR is very large because the projected CPRs of credit cards and floor plan are assumed to be either 99% or 100%.
- Non-agency MBS QRM CPR is higher due to a few CUSIPs with large CPRs.
- BlackRock's CDO/CLO computations use static CPRs and reported CPRs appear to be tranche level rather than collateral level.
- For CMBS, BNY Mellon is currently running BRS model CMBS v1.2, which assumes zero prepayment speeds. Blackrock CPRs for most CUSIPs are close to zero.
- The total weighted average CPR is calculated based on Agency CMO, Agency MBS 15y, Agency MBS 20y, Agency MBS 30y, Agency MBS Other Fixed, Agency MBS Floats, CMBS, International MBS, Non-Agency MBS and CDO/CLO.

AD&Co prepayment models are back-tested on a monthly basis and results are reported to Treasury Risk Committee and ALCO. If the CPR deviation from actuals is more the 20% over the trailing 3 months for a particular product, tuning should be considered. Exceptions can be made when the volume for a particular product is small, causing high volatility in reported CPR.

Please see [8] for Prepayment Tuning and Backtesting. Samples of the reported prepay and backtests for July 2015 are shown below:

Agency MBS Prepayment Back-testing

(In bb)	Book Value	July Tune CPR			June Tune CPR			May Tune CPR			Apr Tune CPR			Mar Tune CPR			Feb Tune CPR		
		ADCo 1m	BBG 1m	ADCo/BBG	ADCo 1m	BBG 1m	ADCo/BBG	ADCo 1m	BBG 1m	ADCo/BBG	ADCo 1m	BBG 1m	ADCo/BBG	ADCo 1m	BBG 1m	ADCo/BBG	ADCo 1m	BBG 1m	ADCo/ BBG
FHLMC																			
Fixed																			
15 YR FIXED	11.8	11.0	10.8	1.0	11.2	11.0	1.0	10.1	9.8	1.0	9.4	9.5	1.0	9.0	9.3	1.0	7.6	7.2	1.1
20 YR FIXED	0.0	13.1	11.9	1.1	13.2	11.4	1.2	12.3	7.9	1.6	12.0	8.1	1.5	6.1	7.5	0.8	5.0	4.9	1.0
30 YR FIXED	2.0	8.5	8.2	1.0	10.2	10.6	1.0	9.0	10.0	0.9	8.0	8.4	1.0	5.1	7.3	0.7	5.5	5.9	0.9
Floating/Hybrid																			
Hybrid ARM 3/1	0.0	15.7	21.7	0.7	10.1	7.6	1.3	9.8	1.5	6.6	9.2	6.0	1.5	9.0	20.4	0.4	7.3	0.6	11.3
Hybrid ARM 5/1	0.1	8.7	20.8	0.4	14.7	10.8	1.4	14.6	16.9	0.9	14.3	15.8	0.9	14.5	11.1	1.3	12.6	15.8	0.8
Hybrid ARM 7/1	0.3	14.0	17.3	0.8	15.2	10.5	1.4	14.7	14.5	1.0	13.9	17.0	0.8	15.1	15.8	1.0	13.0	12.0	1.1
Hybrid ARM 10/1	0.5	13.2	14.3	0.9	19.3	21.3	0.9	19.1	20.8	0.9	18.8	19.1	1.0	16.1	17.0	1.0	11.9	14.9	0.8
FNMA																			
Fixed																			
15 YR FIXED	12.4	12.1	11.6	1.0	11.4	11.3	1.0	10.4	10.4	1.0	9.5	9.8	1.0	9.1	9.4	1.0	7.7	7.0	1.1
20 YR FIXED	0.4	14.6	10.1	1.4	10.7	10.8	1.0	10.2	10.4	1.0	10.1	12.1	0.8	10.9	9.5	1.2	9.7	8.5	1.1
30 YR FIXED	2.1	15.6	13.2	1.2	13.8	14.7	0.9	13.3	12.4	1.1	12.9	13.6	0.9	16.0	13.2	1.2	12.0	9.6	1.3
Floating/Hybrid																			
Hybrid ARM 1/1	0.0	0.4	0.3	1.1	0.9	0.4	2.2	0.8	0.4	2.0	0.8	29.6	0.0	0.6	0.3	2.0	0.4	29.5	0.0
Hybrid ARM 3/1	0.0	10.8	1.1	10.2	11.4	27.9	0.4	11.0	26.7	0.4	10.3	6.4	1.6	9.9	2.1	4.6	8.0	0.3	24.0
Hybrid ARM 5/1	0.4	10.2	18.9	0.5	15.9	18.8	0.8	15.8	21.2	0.7	15.5	15.0	1.0	12.6	18.8	0.7	11.3	11.5	1.0
Hybrid ARM 7/1	0.5	12.3	28.5	0.4	21.0	23.2	0.9	20.8	25.6	0.8	19.2	25.2	0.8	16.6	22.7	0.7	14.5	13.5	1.1
Hybrid ARM 10/1	0.5	16.5	20.1	0.8	22.2	18.4	1.2	22.1	19.2	1.1	21.6	19.1	1.1	20.0	23.3	0.9	15.6	12.8	1.2
Other	0.1	8.4	11.7	0.7	8.5	11.5	0.7	7.6	8.3	0.9	-			-			-		
GNMA																			
Fixed																			
15 YR FIXED	0.1	13.0	15.6	0.8	11.4	10.7	1.1	10.6	10.0	1.1	10.9	10.6	1.0	7.8	7.0	1.1	6.5	6.7	1.0
30 YR FIXED	1.5	19.1	17.6	1.1	16.2	19.3	0.8	15.6	15.5	1.0	13.5	13.1	1.0	12.3	15.6	0.8	7.7	9.6	0.8
Floating/Hybrid																			
Hybrid ARM 1/1	0.0	4.7	6.4	0.7	4.9	8.5	0.6	4.8	7.8	0.6	4.3	7.4	0.6	4.0	6.5	0.6	2.9	6.5	0.4
OTHER	-																		
Other	0.0	1.5	7.3	0.2	2.2	4.7	0.5	2.1	0.3	6.9	2.0	3.8	0.5	1.3	8.1	0.2	1.9	2.3	0.8
CMO	15.9	20.7	17.6	1.2	20.3	18.4	1.1	19.5	17.2	1.1	19.0	17.4	1.1	19.4	17.6	1.1	16.9	13.9	1.2
Total	49	14.9	13.9	1.1	14.8	14.2	1.0	13.9	13.2	1.1	13.2	12.8	1.0	13.0	12.7	1.0	11.0	9.7	1.1

Mortgage Loans Prepayment

		Portfolio Details July ME									Historical CPRs						
Type	QRM Account	QRM Product	#Loans	Beg Balance	Current Balance	Loan Size	WAC	WALA	WAM	Jan	Feb	Mar	Apr	May	Jun	Jul
ARM	Treasury	3/1 Hybrid ARM CorpTsy	128	40.7 M	35.5 M	277 K	3.5	116	275	13.0	20.1	21.5	0.5	25.3	7.0	40.2
ARM	Treasury	5/1 Hybrid ARM CorpTsy	908	334.6 M	307.0 M	338 K	3.1	113	251	7.4	15.8	7.9	13.0	10.2	15.8	13.3
ARM	Wealth Bank	1ML ARM IO WMB	393	361.6 M	363.6 M	925 K	2.1	56	303	10.9	4.8	10.2	29.0	14.1	20.7	32.3
ARM	Wealth Bank	3/1 Hybrid ARM IO WMB	158	144.8 M	135.1 M	855 K	2.8	91	266	2.2	18.2	10.6	4.2	16.2	18.0	24.3
ARM	Wealth Bank	5/1 Hybrid ARM IO WMB	1,830	1,558.7 M	1,456.3 M	796 K	2.7	53	306	19.3	21.6	17.2	22.5	24.9	21.9	30.9
ARM	Wealth Bank	7/1 Hybrid ARM IO WMB	2,117	1,904.5 M	2,104.7 M	994 K	2.8	30	330	15.2	11.4	19.0	17.4	10.6	24.6	20.4
ARM	Wealth Bank	10/1 Hybrid ARM IO WMB	1,082	886.7 M	1,088.4 M	1,006 K	3.4	25	335	21.6	10.8	9.4	20.4	11.6	16.6	20.4
Fixed	CRA	30Yr FRM CRA	1,368	245.5 M	227.6 M	166 K	4.9	110	260	10.8	5.5	7.5	16.6	16.1	16.7	18.2
Fixed	Employee	15Yr FRM Empl	442	53.0 M	46.6 M	105 K	3.3	71	110	8.2	10.0	2.6	15.1	10.4	8.1	14.1
Fixed	Employee	30Yr FRM Empl	1,085	265.8 M	247.6 M	228 K	3.9	90	269	5.3	2.5	12.9	9.4	10.1	13.5
Fixed	Former Employee	15Yr FRM FmrEmpl	346	29.3 M	24.1 M	70 K	3.9	92	100	20.6	7.3	23.0	27.6	22.6	3.4	7.7
Fixed	Former Employee	30Yr FRM FmrEmpl	904	191.7 M	174.3 M	193 K	4.6	108	258	18.6	15.4	12.3	14.0	12.6	16.8	18.7
Fixed	Wealth Bank	30yr FRM AM WMB	403	239.3 M	330.6 M	820 K	4.0	18	342	0.6	3.4	11.3	9.2	48.8	1.9	5.7
NotTuned	NotTuned_ARM	NotTuned_ARM	744	239.5 M	333.6 M	448 K	2.9	50	327	15.2	8.0	27.3	10.0	2.4	12.3	10.1
NotTuned	NotTuned_Fixed	NotTuned_Fixed	710	164.4 M	213.8 M	301 K	3.8	42	203	17.5	22.7	8.9	13.6	28.4	31.4	30.3
Grand Total			12,618	6,660.1 M	7,088.7 M	562 K	3.1	48	308	15.3	13.3	14.8	18.2	16.7	19.8	22.3

QRM Projections					3month Average			
QRM Account	QRM Product	Apr	May	Jun	CPR Average within +-20%	QRM	Actual	Delta
Treasury	3/1 Hybrid ARM CorpTsy	19.2	19.5	19.6	24%	19.4	24.1	-4.7
Treasury	5/1 Hybrid ARM CorpTsy	13.3	13.5	14.2	-4%	13.7	13.1	0.6
Wealth Bank	1ML ARM IO WMB	16.5	17.8	21.4	18%	18.6	22.4	-3.8
Wealth Bank	3/1 Hybrid ARM IO WMB	17.2	18.3	20.1	4%	18.5	19.5	-0.9
Wealth Bank	5/1 Hybrid ARM IO WMB	24.1	25.4	27.0	1%	25.5	25.9	-0.4
Wealth Bank	7/1 Hybrid ARM IO WMB	16.5	18.0	17.7	5%	17.4	18.5	-1.1
Wealth Bank	10/1 Hybrid ARM IO WMB	13.6	14.3	14.5	14%	14.1	16.2	-2.0
CRA	30Yr FRM CRA	14.5	15.5	17.9	7%	16.0	17.0	-1.0
Employee	15Yr FRM Empl	11.4	11.8	13.1	-11%	12.1	10.9	1.2
Employee	30Yr FRM Empl	9.5	10.3	12.1	3%	10.6	11.0	-0.4
Former Employee	15Yr FRM FmrEmpl	25.8	26.5	27.7	-72%	27.7	7.7	20.0
Former Employee	30Yr FRM FmrEmpl	15.4	16.5	18.7	-5%	16.8	16.0	0.8
Wealth Bank	30yr FRM AM WMB	10.5	10.6	12.0	367%	10.5	48.8	-38.4
NotTuned_ARM	NotTuned_ARM	16.1	17.4	18.4	-37%	17.9	11.2	6.7
NotTuned_Fixed	NotTuned_Fixed	12.3	12.5	13.2	137%	12.7	30.1	-17.4

CPR Comparison
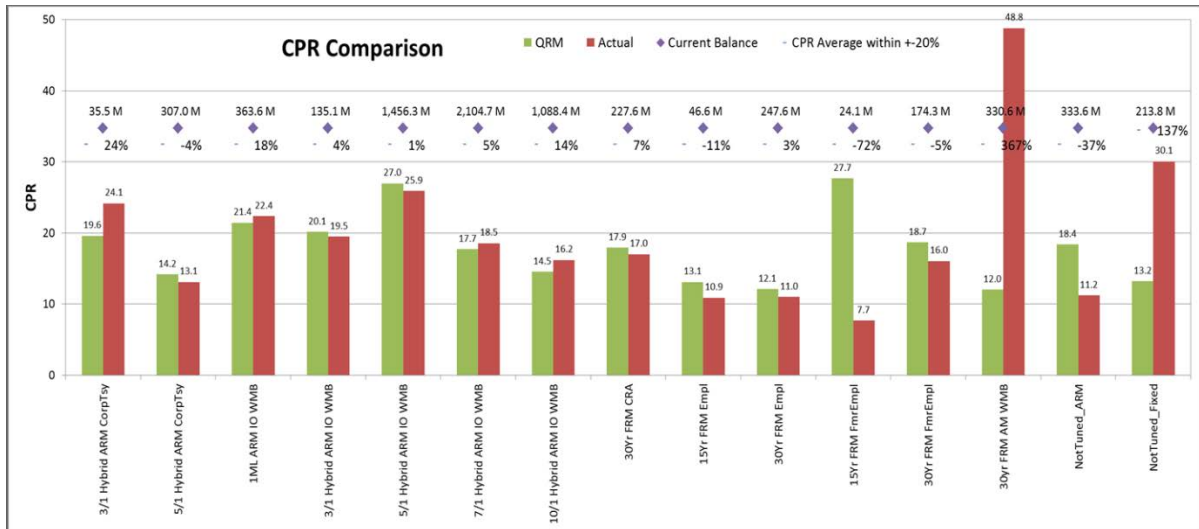
Parameter sensitivity:

Assumption sensitivity is performed and reported quarterly for the investment portfolio and whole loan mortgages. CPR sensitivity is tested by shocking the prepayments up and down. The analysis is done for the valuation of the positions as well as base case forecasting. Any differences are vetted and either resolved or noted. The June 2015 report is below:

Assumption Sensitivity – CPR

- Shocking Conditional Prepayment Rate primarily impacts the Mortgage Loans and Mortgage Backed Securities portfolio.
- EVE shows positive sensitivity to shocking up CPR, mostly driven by securities with prepayment optionality being priced at discount in the current rate environment. Loans and securities are sensitive to prepayment speed and increasing the prepayment speed pulls those closer to par.
- NII sensitivity to CPR is highly dependent on the investment strategy.

$ millions   As of Jun 30, 2015

CPR Sensitivity	Economic Value of Equity				$ EVE Sensitivity to CPR				% EVE 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%	$ 21,708	$ 21,100	$ 20,498	$ 19,197	$ (66)	$ (259)	$ (374)	$ (572)	-0.30%	-1.21%	-1.79%	-2.89%
-20%	$ 21,725	$ 21,180	$ 20,620	$ 19,390	$ (49)	$ (179)	$ (252)	$ (379)	-0.22%	-0.84%	-1.21%	-1.92%
-10%	$ 21,747	$ 21,267	$ 20,744	$ 19,580	$ (27)	$ (92)	$ (127)	$ (189)	-0.12%	-0.43%	-0.61%	-0.96%
Base	$ 21,774	$ 21,359	$ 20,872	$ 19,769								
10%	$ 21,798	$ 21,439	$ 20,984	$ 19,940	$ 24	$ 80	$ 113	$ 171	0.11%	0.37%	0.54%	0.86%
20%	$ 21,837	$ 21,540	$ 21,113	$ 20,122	$ 63	$ 181	$ 242	$ 353	0.29%	0.85%	1.16%	1.78%
30%	$ 21,892	$ 21,667	$ 21,263	$ 20,320	$ 119	$ 308	$ 392	$ 552	0.54%	1.44%	1.88%	2.79%

CPR Sensitivity	12 month Net Interest Income				$ NII Sensitivity to CPR				% NII 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%	$ 3,192	$ 3,488	$ 3,581	$ 3,509	$ 5.9	$ 1.4	$ (1.4)	$ (8.5)	0.2%	0.0%	0.0%	-0.2%
-20%	$ 3,190	$ 3,487	$ 3,582	$ 3,512	$ 3.9	$ 1.0	$ (0.9)	$ (5.6)	0.1%	0.0%	0.0%	-0.2%
-10%	$ 3,188	$ 3,487	$ 3,582	$ 3,515	$ 1.9	$ 0.5	$ (0.5)	$ (2.8)	0.1%	0.0%	0.0%	-0.1%
Base	$ 3,186	$ 3,486	$ 3,583	$ 3,517								
10%	$ 3,184	$ 3,486	$ 3,583	$ 3,520	$ (1.9)	$ (0.5)	$ 0.4	$ 2.8	-0.1%	0.0%	0.0%	0.1%
20%	$ 3,182	$ 3,485	$ 3,584	$ 3,523	$ (3.8)	$ (0.9)	$ 0.9	$ 5.5	-0.1%	0.0%	0.0%	0.2%
30%	$ 3,180	$ 3,485	$ 3,584	$ 3,526	$ (5.6)	$ (1.4)	$ 1.3	$ 8.2	-0.2%	0.0%	0.0%	0.2%

EVE sensitivity to CPR | NII sensitivity to CPR
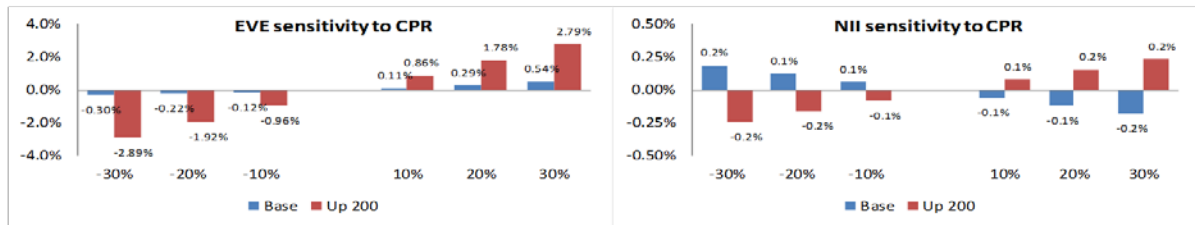
B. Analysis of Implementation

AD&Co models are integrated within QRM and are available for use "out-of-the-box". AD&Co is not incorporated into BNY Mellon systems.

C. Ongoing Performance Monitoring Plan

Prepayment back-testing will be performed on a monthly basis. The results will be reported to the head of IRR or his/her designee, Treasury Market Risk, and ALCO.

Tuning will be performed quarterly, keeping track of the starting levels of CPR, ending levels, and change in the tuning parameters. Tuning results will be reported to the Head of IRR or his/her designee, Treasury Market Risk, and ALCO.

References for Model Documentation:

[1]. *AD&Co Prepayment Model Validation 2013 (Word Document),* Model Risk Management Group, October 2013.
[2]. *Divide and conquer: exploring new OAS horizons*, Alex Levin, Andrew Davidson &Co., Inc. 2003, 2004
[3]. *Validation of Agency prepay models: Version 5.2h*, Eknath Belbase, Andrew Davidson &Co., Inc. September 2012
[4]. ADCo Mortgage Rate Model, Andrew Davidson & Co. website..
[5]. *Home price derivatives and Modeling*, Alex Levin, Andrew Davidson &Co., Inc. October 2009

[6]. PROC NLIN statement, SAS User's Guide website

[7]. 2433 – ADCo Prepayment Model, Model Documentation (Word Document)

[8]. ADCo Prepayment Tuning & Backtesting (Word Document)

Change Log

Please see below.

Revision History of Model

Date	Section	Description of Change	Validation of Change	Validation Date
9/10/15	All	Created		
12/29/15	Most	Addressing Validation Team's comments		
2/9/2016	All	Creating a new model document	The scope of the validation will be ongoing monitoring since there is no model change except tuning. Shiying (Brad) Si is the validator.	2/10/2016

Access Controls

Randhir Ahluwalia